İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

A CONCEPTUAL DESIGN FOR THE DEVELOPMENT OF A CUSTOMIZABLE FRAMEWORK FOR THE CULTURAL HERITAGE DOMAIN

Ph.D. Thesis by
Caner GÜNEY, M.Sc.

Department : **Geodesy and Photogrammetry Engineering**
Programme: **Geomatics Engineering**

DECEMBER 2006

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(501022300)

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Supervisor (Chairman): **Assoc. Prof. Dr. Rahmi N. ÇELİK**

Members of the Examining Committee **Assoc. Prof. Dr. Necla ULUĞTEKİN (İTÜ)**

Assist. Prof. Dr. Lucienne T. ŞENOCAK (KÜ)

Prof. Dr. Tevfik AYAN (İTÜ)

Prof. Dr. Julian D. RICHARDS (UOY)

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

KÜLTÜREL MİRASLAR İÇİN UYARLANABİLİR BİR ÇATKININ GELİŞTİRİLMESİNE YÖNELİK KAVRAMSAL BİR TASARIM

DOKTORA TEZİ

Y. Müh. Caner GÜNEY
(501022300)

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Tez Danışmanı :	**Doç. Dr. Rahmi N. ÇELİK**
Diğer Jüri Üyeleri	**Doç. Dr. Necla ULUĞTEKİN (İTÜ)**
	Yard. Doç. Dr. Lucienne Thys-ŞENOCAK (KÜ)
	Prof. Dr. Tevfik AYAN (İTÜ)
	Prof. Dr. Julian D. Richards (UOY)

ARALIK 2006

PREFACE

I have always been interested in technology, information systems, and management of these systems.

My fundamental purpose was to present "whole picture" of the cultural heritage activity with a top-down approach, in particular in terms of technology, rather than exploring only specific topics with a bottom-up approach. In this dissertation, I therefore decided to study conceptually the holistic design of the business and the information&communication technologies concepts and how these could be implemented for a better future in the cultural heritage field. Moreover, I had a head start due to my master thesis that was entitled "*Multimedia Supported Geographic Information System Applications over the Internet and Geodetic Infrastructure (Application: The Documentation of Cultural Heritage Resources)*".

Here I attempted to touch on evolving business and technical concepts in order to deliver an innovative road map for the cultural heritage community. Therefore, since the beginning of the dissertation, a great deal of attention has been dedicated to researching technical issues, gaining experience with innovative technologies, their philosophies and methods, and the integration of such technologies.

I set up an overall geoenterprise architecture framework for the management, analysis and decision-making process in the cultural heritage sector. The ideas proposed in the dissertation are largely hypothetical. However, it provides an opportunity for the cultural heritage domain to share rethinking on the direction of the cultural heritage resource management and research, and on future cultural heritage strategies for improving and evaluating the impact of these on the cultural heritage sector.

Although this dissertation presents the conceptual design from a technical perspective, it is not intended exclusively for technologists. Any specialist or provider or stakeholder from the cultural heritage community familiar with databases, application servers and the basic Internet standards will find the dissertation accessible and informative.

It aims to have a transforming impact by enabling research practitioners and lecturers to embed the advanced use of information and communication technologies in their research and teaching strategies, in their creation and use of digital information, and in facilitating collaboration across traditional subject and discipline boundaries.

I know I can not boil the ocean. But I hope to draw attention to exploring new technologies, sharing my experiences and ultimately expanding our knowledge to improve the way the cultural heritage sector is developing.

NOVEMBER, 2006 Caner GÜNEY

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Very special thanks must go to Assis. Prof. Dr. Lucienne Thys-Şenocak (the Department of History, Koç University), for her unflinching support, invaluable practical and theoretical advice throughout this project. Whilst my focus of study diverged form her own she had a keen interest that was appreciated.

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I would like to extend my thanks to Prof. Dr. Julian Richards (the Department of Archaeology, the University of York) for his measured criticisms. He was and is, completely honest and told me exactly what he thought: I think I listened.

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A profound recognition must be made to my colleagues in the Division of Geodesy at Istanbul Technical University, whose support, assistance, patience and encouragement over many years, made all things possible. In the first place, I acknowledge with gratitude Prof. Dr. Tevfik Ayan (the head of the Geodesy Division, ITU) for providing the productive working environment in the Division and having brilliant suggestions and discussions.

I am also grateful to the “Kaletakimi”, all members of the “*Seddülbahir-Kumkale*” project team, for their assistance and moral support.

PhD students Holly Wright (the Department of Archaeology, the University of York) and Nicholas Lowell Stapp (the Department of Landscape Architecture, the University of Pennsylvania) provided extremely useful discussions on the papers related to this work. Their appreciation of my work proved highly motivating, and their comments were at all times well received, being both clear and accurate. They will make great professors, should they choose to.

I wish to acknowledge the intellectual contributions made by colleagues in the King's Manor and G65 (University of York) and the School of Design (University of Pennsylvania).

My gratitude must also go to my parents, Şahsene and İsmet Güney, and my brother, Önder Güney, who deserve more than just a mention at the bottom of an acknowledgments page. They are proud of me and everything I do. Any words of thanks are insufficient when weighed against the help they have given. They have always encouraged my academic adventure and tolerated my abstraction with understanding. Endless thanks and appreciation for their support, generosity and everything they have given me.

Finally, and most importantly of all, I would like also to thank the love of my life and gorgeous wife Ceren Bilgin Güney for making my life worth living and being both tolerant and remarkably patient on numerous occasions when my priorities did not coincide with hers. Without her encouraging words, stimulating discussions and astute criticisms this thesis would never have been written. Now it is your turn to do what you want.

ISTANBUL, 2006 Caner GÜNEY

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LIST OF ABBREVATIONS

2D	: Two Dimensional
3D	: Three Dimensional
3NF	: Third Normal Form
A2A	: Application to Application
ADML	**:** Architecture Description Markup Language
AJAX	: Asyncrohronous JavaScript and XML
AOP	: Aspect Oriented Programming
API	: Application Programming Interface
ASP	: Active Server Pages
ArcXML	: Arc Extensible Markup Language
AVR	: Automatic Voltage Regulator
B2B	: Business to Business
B2C	: Business to Computer
BI	: Business Intelligence
BSD	: Berkley Software Distribution
C2C	: Computer to Computer
C2H	: Computer to Human
CAD	: Computer Aided Design
CBD	: Component Based Development
CFML	: ColdFusion markup Language
CGI	: Common Gateway Interface
CH	: Cultural Heritage
CIDOC	: International Committee for Documentation
CLR	: Common Language Runtime
CMS	: Content Management System
CRM	: Conceptual Reference Model
COM	: Common Object Model
CORBA	: Common Object Request Broker Architecture
CSS	: Cascade Style Sheets
CSV	: Comma Separated Value
DB	: Database
DBMS	: Database Management System
DC	: Dublin Core
DCE	: Distributed Computing Environment
DCMI	: Dublin Core Metadata Initiative
DCOM	: Distributed Component Object Model
DHTML	: Dynamic Hypertext markup Language
DOM	: Document Object Model
DTD	: Document Type Definition
DTM	: Digital Terrain Model
EA	: Enterprise Architecture
EAI	: Enterprise Application Integration

EAI	: External Authoring Interface
EJB	: Enterprise JavaBeans
EIS	: Enterprise Information System
ESB	: Enterprise Service Bus
ER	: Entity Relationship
ETL	: Extraction Transforming and Loading
FGDC	: Federal Geographic Data Committee
FISH	: Forum on Information Standards in Heritage
FO	: Formatting Object
FOA	: Formatting Object Authoring
FSF	: Free Software Foundation
GeoCHEAF	: Geo-enable Cultural Heritage Enterprise Architecture Framework
GIOP	: Generic Inter-ORB Protocol
GIS	: Geospatial Information System
GNU	: GNU's Not Unix
GML	: Geographic Markup Language
GPL	: General Public License
GPS	: Global Positioning System
GPU	: Graphic Processing Unit
GSM	: Global System for Mobile Communications
GUI	: Graphical User Interface
H2A	: Human to Application
H2H	: Human to Human
HDBMS	: Hierarchical Database Management System
HM	: Hierarchical Model
HOLAP	: Hybrid OLAP
HPC	: High Performance Computing
HQL	: Hibernate Query Language
HTML	: Hypertext Markup Language
HTTP	: Hypertext Transfer Protocol
ICOM	: International Council of Museums
ICT	: Information and Communication Technology
IDE	: Integrated Development Environment
IDL	: Interface Definition Language
IEEE	: Institute of Electrical and Electronics Engineering
IIOP	: Internet Inter-ORB Protocol
IIS	: Internet Information Server
IPS	: Inter Portlet Communication
IS	: Information System
ISAPI	: Internet Server Application Programming Interface
ISO	: International Organization for Standardization
IT	: Information Technology
J2ME	: Java 2 Micro Edition
J2EE	: Java 2 Enterprise Edition
J2SE	: Java 2 Standard Edition
JAAS	: Java Authentication and Authorization Service
JavaEE	: Java Enterprise Edition
JAXM	: Java API for XML Messaging
JAXR	: Java API for XML Registiry
JAX-RPC	: Java API for XML-based RPC

JDBC : Java Database Connectivity
JDK : Java Development Kit
JDO : Java Data Objects
JFC : Java Foundation Class
JIT : Just In Time
JNI : Java Native Interface
JMS : Java Message Service
JRE : Java Runtime Environment
JSP : JavaServer Faces
JSP : JavaServer Pages
JSSE : Java Secure Socket Extension
JVM : Java Virtual Machine
JWSDL : Java API for WSDL
MS : Microsoft
LAMP : Linux - Apache - MySQL - PHP/Perl/Python
LDAP : Lightweight Directory Access Protocol
LGPL : Lesser General Public License
LOD : Level of Details
MathML : Mathematical Markup Language
MBD : Model Based Development
MDBMS : Multidimensional Database Management System
MIT : Massachusetts Institute of Technology
MDA : Model Driven Architecture
MOLAP : Multidimensional OLAP
MOM : Message Oriented Middleware
MRDB : Multiple Representation Database
MSIL : Microsoft Intermediate Language
MVC : Model View Controller
N/A : Not Available
NDBMS : Network Database Management System
NSAPI : Netscape Server Application Programming Interface
NXD : native XML DBMS
OAI : Open Archives Initiative
OAI-PMH : Open Archives Initiative Protocol for Metadata Harvesting
OAIS : Open Archival Information System
OASIS : Organization for the Advancement of Structured Information Standards
ODBC : Open Database Connectivity
ODBMS : Object Database Management System
ODS : Operational Data Source
OGC : Open Geospatial Consortium
OLAP : Online Analytical Processing
OLTP : Online Transactional Processing
OO : Object Oriented
OpenGL : Open Graphics Library
OpenSG : Open Scene Graph
ORDBMS : Object Relational Database Management System
ORM : Open Geospatial Consortium Reference Model
ORM : Object Relational Mapping
OS : Operating System

OSI	: Open Source Initiative
OMG	: Object Management Group
OOGQL	: Object Oriented Geo Query Language
OQL	: Object Query Language
OSI	: Open Systems Interconnection
OWL	: Web Ontology Language
PHP	: Hypertext Preprocessor
PIM	: Platform Independent Model
POJO	: Plain Old Java Objects
PPU	: Physics Processing Unit
QTVR	: Quicktime Virtual Reality
RDBMS	: Relational Database Management System
RDF	: Resource Description Framework
REST	: Representational State Transfer
RHEL	: Red Hat Enterprise Linux
RIA	: Rich Internet Applications
RM	: Relational Model
RMI	: Remote Method Invocation
ROLAP	: Relational OLAP
RPC	: Remote Procedure Call
SAAJ	: SOAP with Attachments API
SAI	: Script Authoring Interface
SAI	: Scene Access Interface
SAX	: Simple API for XML
SDBMS	: Spatial Database Management System
SDI	: Spatial Data Infrastructure
SGML	: Standard Generalized Markup Language
SHTTP	: Secure Hypertext Transport Protocol
SI	: Spatial Information
SIS	: Spatial Information System
SLES	: Suse Linux Enterprise Server
SMIL	: Synchronized Multimedia Integration Language
SOA	: Service Oriented Architecture
SOC	: Service Oriented Computing
SOAP	: Simple Object Access Protocol
SOX	: Schema for Object-oriented XML
SSL	: Secure Socket Layer
SSO	: Single Sign-On
SSJS	: Server Side JavaScript
SSI	: Server Side Includes
SSL	: Secure Sockets Layer
SQL	: Structured Query Language
SVG	: Scalable Vector Graphics
SWT	: Standard Widget Toolkit
TLS	: Transport Layer Security
TPS	: Total Positioning System
UDDI	: Universal Description Discovery and Integration
UI	: User Interface
UML	: Unified Modeling Language
UPS	: Uninterruptible Power Supply

URI	: Uniform Resource Identifier
URL	: Uniform Resource Locator
VML	: Vector Markup Language
VRML	: Virtual Reality Modeling Language
VSIS	: Virtual Spatial Information System
W3C	: World Wide Web Consortium
WAMP	: Windows - Apache - MySQL - PHP/Perl/Python
WCM	: Web Content Management
WCS	: Web Coverage Service
WFS	: Web Feature Service
Wi-Fi	: Wireless Fidelity
WiMAX	: Worldwide Interoperability for Microwave Access)
WML	: Wireless Markup Language
WMS	: Web Map Service
WORA	: Write Once Run Anywhere
WS-I	: Web Services Interoperability Organization
WSA	: Web Services Architecture
WSDL	: Web Service Description Language
WSDL	: Web Service Developer Pack
WSRP	: Web Service for Remote Portlets
WYSIWYG	: What You See Is What You Get
X3D	: Extensible 3 Dimension
XAML	: Extensible Application Markup Language
XDBMS	: XML Database Management System
XHTML	: Extensible Hypertext Markup Language
XInclude	: XML Inclusions
XLink	: XML Linking Language
XLiP	: XLink Processor
XML	: Extensible Markup Language
XMI	: XML Metadata Interchange
XPath	: XML Path Language
XPointer	: XML Pointer Language
XQuery	: XML Query Language
XSD	: XML Schema Definition
XSL	: XML Stylesheet Language
XSLT	: XML Stylesheet Language Transformation
XSSI	: Extended Server Side Includes
XUL	: XML User Interface Language
XUpdate	: XML Update Language

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A CONCEPTUAL DESIGN FOR THE DEVELOPMENT OF A CUSTOMIZABLE FRAMEWORK FOR THE CULTURAL HERITAGE DOMAIN

SUMMARY

In recent years there has been a surge of popular interest in the cultural heritage domain and a phenomenal growth in the use of the web to undertake management and research at all levels. Hence, organizations from across the cultural heritage sector have been able to take advantage of ICT to offer to their users new forms of access to their resources. However, users are still faced with the perennial problem of finding those resources that will be most relevant to any particular research project. To conclude this, "GeoCHEAF" develops business processes and strategies focusing on the review, implementation, management and dissemination of CH information. "GeoCHEAF" is the result of rigorous analysis of the CH domain operations and data sharing requirements and consideration of the ways in which modern internet technologies can support the CH projects workflows.

"GeoCHEAF" is a spatially-enabled open enterprise architecture framework that explores and captures the business and technical requirements of the cultural heritage domain *(challenge*) and elaborate design principles for the requirements (*objective*). These principles are intended to provide decision-making activities.

The goal of "GeoCHEAF" is to deliver enterprise solutions. For complex solutions, a modeling and design approach is needed. Therefore, in this dissertation, first a conceptual enterprise architecture design is mentioned to provide "GeoCHEAF" as an enterprise architecture framework for all present and future needs of the CH community. Then, the conceptual design process of the comprehensive and sophisticated framework "GeoCHEAF" is explained as a development and customization framework for the cultural heritage projects.

"GeoCHEAF" demonstrates how a cultural heritage enterprise works within a geo-enable enterprise architecture and the relationship between the parts (*systems*) of the whole by capturing the structure and the behavior of the systems in the enterprise.

"GeoCHEAF" benefits from the natural cohesion of Business&Technology in order to achieve business goals of the CH domain. It includes the IS/IT strategy, the solution blueprints and associated roadmaps, the supporting standards, and the design/governance processes to reach the mainstream in order to see the big picture in the complex technological environment. "GeoCHEAF" increases the operational capacity and efficiencies of any CH enterprise through adoption of modern interoperability approaches that are compatible with web and Internet technologies.

The conceptual framework "GeoCHEAF" is comprised of many other sub-frameworks, such as an enterprise-wide business framework, web computing framework, geoprocessing framework, run-time framework for visualization.

“GeoCHEAF” uses service-oriented architecture for the overall enterprise by organizing business systems as reusable components, not fixed processes. It aims to turn platform-based data processing into value-based services. The fact that XML is more than a data storage, retrieval and preservation mechanism holds enormous promise for the understanding, promotion, and preservation of cultural heritage.

Effective seamless integration of technology based upon the open standards and semantic technologies provides an interoperable architecture which expands communication and dissemination of the cultural heritage data and information to the public.

The configurations of global data sharing through the Internet, reusable component-based development and design, scalable web application topology, building loosely-coupled dynamic web applications are critical issues in the design of “GeoCHEAF”. Choosing and assessing the right technologies for the design is another critical issue. The effort to integrate the technology of “GeoCHEAF” brings together and organizes best-of-breed open source technologies to combine and apply to key issues in cultural heritage.

“GeoCHEAF” uses this approach not only to create a better modularity for user and functional requirements of the enterprise, but also to create the most productive enterprise computing architecture for the cultural heritage domain and cultural heritage informatics.

KÜLTÜREL MİRASLAR İÇİN UYARLANABİLİR BİR ÇATKININ GELİŞTİRİLMESİNE YÖNELİK KAVRAMSAL BİR TASARIM

ÖZET

Son yıllarda kültürel miraslar alanında internet uygulamalarının kültürel mirasların araştırılmasında ve yönetiminde kullanılmasına büyük bir ilgi vardır. Bunun sonucunda kültürel miraslar ile ilgili projelerin her aşamasında bilişim ve iletişim teknolojilerinden yararlanılmakta ve proje ürünleri ya da kaynakları kullanıcılara bu yolla sunulmaktadır. Bu ürünlerin ve kaynakların kullanıcılara sunulmasında ve sunulan bu kaynaklara ulaşılmasında gerek kullanıcı gerekse sunan organizasyon yıllardır süre gelen sorunlarla karşılaşmaktadır. "GeoCHEAF" bu sorunları ortadan kaldırmak için kültürel miras bilgisinin incelenmesine, uygulamasına, yönetimine ve yayınlanmasına odaklanarak yöntem ve stratejiler geliştirmektedir. "GeoCHEAF" kültürel miraslar alanındaki çalışmaların ve veri/bilgi paylaşımının gereksinimleri ile kültürel miraslarla ilgili projelerde gelişkin internet teknolojilerinin nasıl kullanıldığına yönelik gerçekleştirilen titiz bir analizin sonucunda ortaya çıkmıştır.

"GeoCHEAF" mekansal özelliği olan açık yapıdaki bir kuruluşa ait mimari bir çatkıdır. Kültürel miraslara yönelik kuruluşun işleyişine ve teknik boyutuna yönelik gereksinimlerini araştırır ve özümser, bunlara yönelik tasarım ilkelerini, bu ilkelerin karar verme süreçlerinde kullanılacağını öngörerek özenle detaylandırır.

"GeoCHEAF"in amacı kuruşa yönelik çözümler sunmaktadır. Karmaşık çözümler sunabilmek modelleme ve tasarım yaklaşımını gerektirir. Bunun için bu tez kapsamında ilk olarak kültürel miraslarla ilgilenen grupların mevcut ve gelecekteki gereksinimlerini karşılamak için geliştirilen kuruluş mimari çatkısının kavramsal tasarımı sonrasında da karmaşık ve kapsamlı bir mimari çatkı olan ve kültürel miraslarla ilgili projelerin geliştirilmesinde ve özelleştirilmesinde kullanılan "GeoCHEAF"in bu tasarıma uyarlama süreci açıklanmıştır.

"GeoCHEAF" mekansal özelliği olan kültürel miraslarla ilgili bir kuruluşun kendisine ait mimari bir çatkıda nasıl işleyeceğini ve kuruluşun bileşenlerinin (*sistemlerinin*) birbiri ve bütün ile olan ilişkilerini kuruşta bulanan sistemlerin yapılarını ve davranışlarını özümsemiş bir şekilde ifade eder.

"GeoCHEAF" kültürel miraslarla ilgili amaçları gerçekleştirebilmek için iş ve teknolojinin doğal uyumundan yararlanır. "GeoCHEAF" teknoloji karmaşıklığını yansıtan büyük resmi görebilecek ana görüşe ulaşabilmek için bilgi sistemi/teknolojisi, kültürel miraslar alanındaki çözüm taslakları ve ilgili yol haritaları, destekleyici standartları, tasarım ve yönetim süreçleri konularını içerir. "GeoCHEAF" kültürel miraslarla ilgili kuruluşun kullanılmaya hazır kapasitesini ve etkinliğini internet teknolojileri ile uyumlu birlikte işlerlik yaklaşımları üzerinden arttırır.

Kavramsal bir çatkı olan "GeoCHEAF" kuruluşun tamamını kapsayan iş çatkısı, internet üzerinden hesaplama çatkısı, mekansal veri işleme çatkısı, görselleştirme çatkısı gibi diğer bir çok alt çatkıdan oluşur.

"GeoCHEAF" tüm kuruluş için servise yönelik bir mimari kullanır. Bu mimari iş sistemlerini yeniden kullanabilen bileşenler şeklinde düzenler. Sözü edilen mimarinin amacı altyapıya bağımlı veri işlemeyi değer tabanlı servislere çevirmektir. Ayrıca XML teknolojisinin veri depolama, erişim ve korumasından daha ileri bir araç olduğu gerçeği kültürel mirasların anlaşılması ve korunması için büyük potansiyel içerir.

Açık standartlara ve semantik teknolojilere dayalı etkin kusursuz teknoloji bütünleşmesi birlikte işlenebilir bir mimariyi ortaya çıkarır. Bu mimari kültürel miraslara yönelik veri ve bilgilerin kullanıcılarla iletiminde ve yayılmasında kullanılır.

Küresel ölçekte internet üzerinden veri paylaşımı, yeniden kullanılabilir bileşenlere dayalı gelişim ve tasarım, ölçeklenebilir internet uygulama topolojisi, gevşek bir biçimde bağlı dinamik yapıdaki internet uygulamalarının geliştirilmesi konularının yapılandırılması "GeoCHEAF"in tasarımındaki kritik noktalardır. Tasarım için doğru teknolojilerin tayini ve seçimi diğer bir önemli konudur. "GeoCHEAF"in teknoloji birleştirme gayreti açık kod türündeki en etkin teknolojileri bir araya getirir ve bunları kültürel miraslar alanına uygular.

"GeoCHEAF"in yukarıda belirtilen yönleri gerek kullanıcılar ve kuruluşun işlevsel gereksinimleri için daha iyi bir modülerlik oluşturmak gerekse kültürel miraslar alanı ve kültürel miras bilişimi için en üretken kuruluş hesaplama mimarisini oluşturmakta kullanılır.

1. INTRODUCTION

1.1 Overview

Cultural heritage is the most important evidence regarding the past society and each object of this heritage has valuable information about the past. Unfortunately each valuable element of the cultural heritage resources has been vanishing day by day through time, vandals and the elements. The combination of natural disasters such as earthquakes and erosion along with the destruction brought by man-made processes such as military conflicts and urbanization dramatically accelerate the rate at inevitable ravages of the cultural heritage resources. Hence, some precautions are needed for protecting these valuable examples of cultural heritage from further deterioration and eventual extinction. (Guney et al., 2002; Guney and Celik, 2003a)

Among the examples of cultural heritage, there are two 17th century Ottoman fortresses, called "*Seddülbahir*" and "*Kumkale*", located at the southern tip of the Dardanelles in Turkey. A series of projects have been undertaken to save these endangered structures and the historical environment of the fortresses. This dissertation proposed that the fortresses can be restored and protected only when they have been fully measured, documented and stored in a proper information and management system. (Guney et al., 2002)

Information and Communication Technology (ICT) plays an increasingly critical role in almost everything these days including the work of the heritage sector, which acts to understand, promote, present, preserve, and improve access to humanity's cultural and natural heritage. Many of today's cultural heritage (CH) organizations rely on digital information and communication technology to gather, organize, interpret, and disseminate data relating to their various projects. In many cases, this involves applications and services that were created at different times and designed for different computing platforms. The challenge now faced by these organizations is to provide efficient and effective methods by which these disparate technologies can work together to achieve academic and/or commercial objectives that are constantly evolving. The Geo-enable Cultural Heritage Enterprise Architecture Framework (GeoCHEAF), a spatially-enabled open enterprise architecture framework for the cultural heritage domain, has been developed in the the dissertation in response to this challenge. (Guney et al., 2006)

Enterprise Architecture (EA) is a concept from the business world which involves identifying the main components of an organization or project and clearly articulating how these components function together to achieve defined objectives. (McGovern et al., 2003; Schekkerman, 2004; Stevenson, 1997) To achieve this, enterprise architecture requires a framework for focused business-ICT alignment, change management, technology selection & fusion, organizational agility and excellence in execution. “GeoCHEAF”, as an enterprise architecture framework, applies this approach to the cultural heritage domain through the use of spatial informatics and cultural heritage informatics. (Guney et al., 2006)

“GeoCHEAF” faces the challenge of designing, building, deploying, implementing, validating, monitoring, evaluating, and maintaining an enterprise architecture framework modeled specifically for the cultural heritage domain. In the context of this dissertation, the focus will be mainly on the design process which describes its design rationale in attempting to achieve maximum openness, interoperability, flexibility, interactivity, maintainability and scalability for projects of cultural significance.

This comprehensive approach is demonstrated using a real-world case: the documentation, survey, restitution, restoration and re-usage project of *Seddülbahir* and *Kumkale*, and its goal is to realize the project’s motto: 'sharing the life history of two Ottoman fortresses' with a broad range of enterprise constituents and public users. In that sense, the 'life history of the fortresses' is modeled within a Spatial Information System (SIS) to determine more accurately and efficiently the architectural changes from 17th century to the present day and to explore the natural, economical, social and political events, which have caused structural changes to the fortresses and surrounding buildings and environs. (Guney and Celik, 2003a; Guney and Celik, 2004a; Ozludemir et al., 2004)

Finally, this dissertation examines not only how a modern-day spatially-enabled open enterprise architecture framework can be configured to embrace cultural heritage projects, but also addresses how the cultural heritage strategy proposed can drive positive change within the cultural heritage domain by simply adopting elements of the enterprise architecture process.

1.2 Location and Brief Information about Historical Background of the Fortresses

The location of the fortresses is approximately 26°.199 E_{ITRF} and 41°.006 N_{ITRF} and the distance between the two fortresses is approximately 4150 meters. As shown in figure 1.1, they stand opposite each other on either shore of the Dardanelles, in north western Turkey. *Seddülbahir* is located on the European side of the straits, at the southern end of the Gallipoli Peninsula. The fortress of *Kumkale* is on the opposite Asian shore, approximately five kilometers from Troy. (Guney et al., 2002)

The cultural heritage of a region such as Dardanelles is of extreme importance to understanding of the many civilizations and peoples who inhabited and controlled these ancient straits. As the site of cities such *Dardanos* and *Homerös Troy*, much attention has been devoted to the documentation and preservation of the very ancient cultural heritage sites in the Dardanelles. However, comparatively little attention has focused upon the more recent Ottoman past and the architectural sites which remain from the seventeenth centuries of the Ottoman presence in this region. (Thys-Senocak, 1999)

The fortresses of *Seddülbahir* and *Kumkale* were built in the mid-seventeenth century (1658-1659) at the entrance to the Aegean, on either side of the Straits by *Hatice Turhan* Sultan, the mother of the Ottoman sultan, *Mehmed IV*. Initially the fortresses were constructed as part of the Ottoman defense against Venetian naval invasions into the Dardanelles during the long war over Crete; since that time they have served the Ottoman and later Turkish defense against a variety of enemies who have coveted either the strategic outlet to the Aegean or a convenient sea access to the Bosphorus and the capital of Istanbul. Both fortresses were instrumental in the Gallipoli campaign of World War I and severely damaged by artillery fire. After World War I and the withdrawal of French and British troops from the Gallipoli region, *Seddülbahir* and *Kumkale* were returned to the Ottoman government. Until the spring of 1997, *Seddülbahir* was maintained as a Turkish naval outpost. *Kumkale* is still operating as a naval base and is under the jurisdiction of the Ministry of Defense of Turkish Republic. (Thys-Senocak, 1999)

Figure 1.1: The location of the fortresses, *Seddülbahir* and *Kumkale*.

1.3 Evolution of the Project

Due to the fact that each valuable element of the historical remains from this Ottoman era is vanishing as a result of the deleterious effects of natural and human interventions, the first step in the preservation of these historical remains was a thorough documentation of existing structures and site characteristics. It is with this larger, long-term goal that the team of land surveyors, architects, historians and archaeologists began in 1997 to work on the Documentation Project of *Seddülbahir* and *Kumkale* Ottoman Fortresses. Apart from very simple drawings by the Ottoman military and European the Ottoman fortresses of *Seddülbahir* and *Kumkale* had not been documented or surveyed until this project began. (Guney et al., 2002)

The aim of the project was twofold: first to document the existing remains of the fortresses by generating the maps of the sites and architectural drawings of the structures on these sites; second, to bring together a vast array of both spatial and non-spatial data such as repair records from the Ottoman archives, European and Ottoman historical chronicles, historical maps, drawings, engravings and archival photographs from various libraries' collections in order to assess the development of the fortresses and adjoining structures. (Ozsavasci et al., 2003)

An additional facet of the project that developed in the 1999-2001 seasons at *Seddülbahir* and *Kumkale* was the oral history of the villages whose locations were within the parameters of the historical research and survey project work. (Ozsavasci et al., 2003) Another part of the project that the epigraphic-morphological-demographic documentation of the remaining 287 Ottoman tombstones of the *Kumkale* cemetery which was completed using a Geospatial Information System (GIS) application. (Guney et al., 2002)

Although there are several consecutive projects regarding the fortresses *Seddülbahir* and *Kumkale*, they are basically a joint project undertaken at the Division of Geodesy, İstanbul Technical University (Turkey) and the Department of History, Koç University (Turkey) for the preservation of the fortresses.

The projects regarding the fortresses are the following:

- the Documentation Project of *Seddülbahir* and *Kumkale* Ottoman Fortresses (1997-2003)
  - the Oral History Project of two Villages of *Seddülbahir* and *Kumkale*
  - the Epigraphic-Morphological-Demographic Documentation Project of *Kumkale* Cemetery
- *Seddülbahir* Fortress Site Survey-Restitution-Restoration-Reusage Project (2004-2006)
- the Museum Project of *Seddülbahir* Fortress (*in the planning phase*)

1.4 Scope and Contents of the Dissertation

The design of "GeoCHEAF" will be examined in this dissertation, followed by an explanation of the process through which the appropriate methods, technologies, standards and tools were chosen to fulfill the requirements of the cultural heritage domain.

The scope includes every phase of CH informatics: initial data capture/digitization, information/data processing and analyzing, reconstruction, visualization and documentation as well as the dissemination of results to the scientific and CH communities and to the general public.

There is a growing movement toward developing enterprise architectures. Chapter 2 first introduces enterprise and enterprise architecture concepts and terms, emphasizing the importance of these architectures in reaching business goals. Then, it analyzes the challenges of application in the CH domain and illustrates a high-level approach for building "GeoCHEAF". This chapter intends to convey the message that this architecture is a business tool and attempts to take a holistic view of the business architecture while aligning with the technical architecture.

In the following chapters, the technical sub-architectures of "GeoCHEAF" are expanded. A summary and classification of the relevant technologies and techniques are presented in these chapters, providing a roadmap for technology selection & fusion and pointing out the strengths and weaknesses of each.

The first section of chapter 3 will describe the impact of open source strategy in the CH sector and illustrate these with open source solutions. Section 2 explains semantics architecture of “GeoCHEAF”. In the another section of this chapter, an overview of what the Unified Modeling Language (UML) stands for and the thirteen diagrams that make up UML will be discussed. This section will help the reader understand what features are required when selecting a UML tool. At the end of the section, a figure and a UML diagram for the project will be built. In the last section, the reader will be introduced to the role of Extensible Markup Language (XML) and how XML and its offshoots, such as GML and X3D, can be used in the CH projects and SIS applications will be explored and defined. Additionally, this chapter will focus upon the potential impact of GML on the SIS.

Chapter 4 takes the reader through the web application world, explaining the road to dynamic content as a sequential narrative, starting with a brief review of the architectural foundations of the web and design points for web applications. The goal of this chapter is to derive order from the chaos by describing the foundations of the web and classifying the related technologies and programming techniques that are used to create dynamic web applications. In this chapter, the reader will be introduced the Java Enterprise Edition (Java EE) application environment as well as the concept of Service Oriented Architecture (SOA). It examines the qualities of a good middle-tier architecture so that an assessment can be drawn of these architectures. In addition, this chapter looks beyond Java at standards and implementations that provide for broad interoperability across heterogeneous application environments. Finally, this chapter presents a picture of web services and provides a look at how emerging web services standards will address the next generation of reliable information systems. The vision of this chapter is to enable CH enterprises to quickly deploy complex web applications and services for their projects.

The goal of chapter 5 is to form a comprehensive framework for data encoding, data exchanging among different systems of “GeoCHEAF”, and data/information storing. The process towards integration is going to be achieved by developing a dynamic data model capable of understanding complex realities, as the opposite of a static model of only information retrieving and query, and constructing an enterprise level database able to manipulate these data sets. This chapter also discusses the process of extracting, transporting, transforming, and loading data in a data warehousing environment.

The main goal of chapter 6 is to provide the reader with an overview and basic understanding of the key ideas and principles in data visualization. In this chapter how to apply the visualization framework to build a web-based visualization tool for geospatial data and how graphical methods can increase the understanding of complex data will be examined. Specifically, an interactive web-based CH data visualization architecture is going to be aimed to design. It explores various possibilities and ways to represent CH data in a virtual environment with a goal to help both expert and non-expert users to understand CH data more intuitively.

Chapter 7 addresses the topic of content networking exclusively and comprehensively. It emphasizes why and how content delivery works today, and applies that knowledge in the future. The first section of the chapter summarizes the content management architecture by presenting a classification of technologies that are relevant to dynamic content generation for the web. This section also demonstrates how to develop the successful use of a web portal to manage a multi-participant SIS project. Here, what would otherwise serve primarily as a data source has been expanded into a communication hub and a collaborative analysis tool for enterprise constituents, project members and the general public alike. The following sections presents security and physical infrastructure issues.

The main aim of chapter 8 is to develop strategies, which would allow for a universal method of mapping the spatial dimensions of CH resources. It describes spatial informatics technology and mostly demonstrates how a SIS project can be designed and managed for the CH domain. It presents the development of a web-based SIS system as a component of the technical architecture framework of "GeoCHEAF" and, discusses and critiques the performance of an interactive geo-query tool. The chapter also examines the past, current, and future of SIS within an enterprise architecture context, and applies the experience, discipline, and future direction of the Information Systems (IS) profession to GIS.

Finally, chapter 9 draws the conclusions and recommendations of the dissertation.

Appendix A focuses on the languages. It first explains what a markup language is, the brief history of markup languages and some of the people involved their creation, the value of using markup languages, a comparison of them and why XML was chosen in this dissertation. Afterwards, it investigates programming languages. Appendix B provides the overall figure of "GeoCHEAF".

2. AN ENTERPRISE ARCHITECTURE FRAMEWORK: “GeoCHEAF”

2.1 Defining Enterprise and Enterprise Architecture

This section provides a conceptual overview of the field of Enterprise Architecture (EA) and its associated disciplines. EA is still relatively immature from both a research and practical perspective and there is not a widespread consensus on the terminology. The terms 'Enterprise Architecture' and 'Enterprise' are interpreted and defined in many different ways and there is no single universally accepted definition yet.

An Enterprise is any collection of organizations that has a common set of goals/principles and/or single bottom line. In that sense, an enterprise can be a whole corporation, a division of a corporation, a government organization, a single department, or a network of geographically distant organizations linked together by common objectives. (Schekkerman, 2004)

From the viewpoint of this study, the definition of an enterprise is an open networked organization together with its systems (nodes) and their relationships (links) for which **knowledge** is the primary resource, **information** is the main asset, **data and data sharing** is the main business concern, and **ICT** is the underlying tool.

In this context, the “KaleTakimi”, which is a small scale enterprise, is comprised of systems (*internal entities including Archaeology, History, Architecture, Land Information/Management Systems*) that interact with each other and which also have external constituencies (*external entities including other academic, governmental and private-sector organizations*). The internal and external business processes often share common characteristics when managing the enterprise’s functional areas. Those systems developed by different groups in different times are operating as one system with a wide vision: This is what is defined as enterprise in the course of developing this dissertation. Figure 2.1 outlines this design philosophy of "KaleTakimi" as an enterprise.

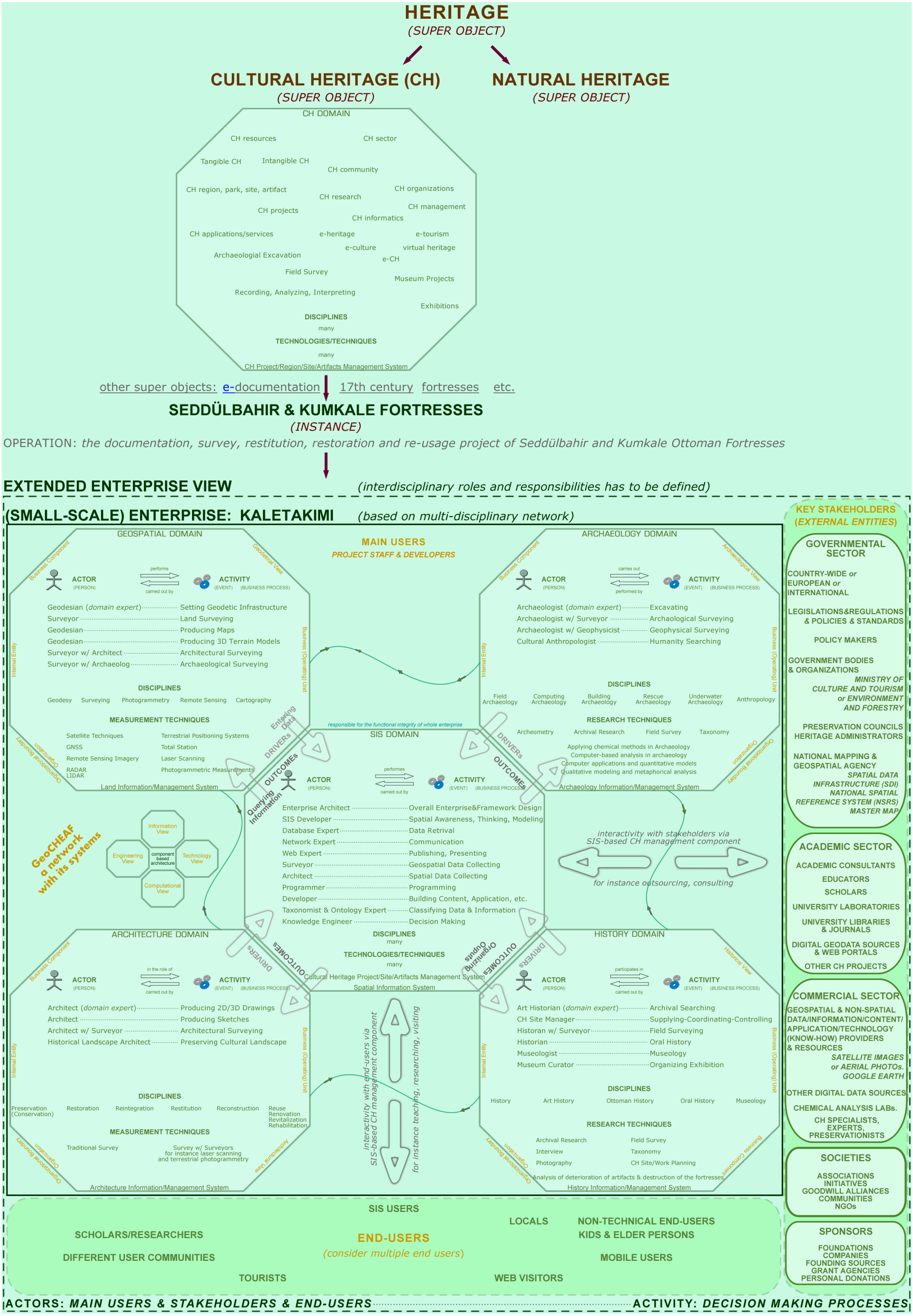

Figure 2.1: A schematic view of the "KaleTakimi"

It includes the full breadth of the organization, as well as the full depth of systems. Different teams in different systems bring their own special set of demands to the business processes. More demands require secure and fast interactions which are electronic, common standards for information and communication technology. The role-based process in this entity-driven architecture applied to the “KaleTakimi” is innovative and disciplined, while ensuring consistent, reliable and adaptive business operations. As shown in figure2.1, each system in the “KaleTakimi” generally takes a set of drivers and produces a well thought-out and co-ordinated set of outcomes to understand the enterprise environment and to explore solution opportunities. In other words, these systems in the “KaleTakimi” now need to extend into the central system, that is a spatially-enabled CH Management System, which is not under their control and yet integrates effectively by blurring the organizational boundaries.

EA is the key facilitating ingredient providing a holistic view and a mechanism for enabling the design and development as well as the communication and understanding of the enterprise.

EA refers to the top level architecture of an enterprise, identifies the main components of an organization and how the components in the organization’s nervous system function together to provide the capability for an enterprise to achieve defined business goals in its wide vision. The components in this context include categories like people, processes, business and technology for instance, goals, strategies, financial information, governance, domains, stakeholders, services, information, communications, applications, technological infrastructure, databases, networks etc. (McGovern et al., 2003; Schekkerman, 2004; Stevenson, 1997)

In the context of this dissertation, EA describes these systems in terms of their behaviors, method of communications, and constraints. It holds the organization together as it grows and evolves into the future and works across organizational boundaries and disciplines.

It is worthwhile noting that EA is an evolving discipline and, in its relatively short life, has already changed considerably in its scope. In the beginning, EA was regarded as a tool for Information Technologies (IT) rationalization. Its work was focused on issues involving enterprise application integration and the formulation and the implementation of technological standards across the enterprise. While this delivers real value, the potential is far greater. Over the last decade, the EA concept is still evolving and moving from the technology spectrum to the overall business spectrum. Increasingly EA is being seen as a uniquely powerful knowledge base and route map to guide business and ICT decision-making and innovation. EA has broadened to become a critical connection between high level business vision and its effective expression through strategy, human process and automation. If well executed, it will enable the design of more efficient, flexible organizations, create more agile loosely coupled processes, and identify new forms of value to be gained from ICT. As a discipline, it is an umbrella, over business, technology, application and information architecture. (Slusanchi, 2005)

EA is a term that is understood differently by technology and business professionals. Technology professionals have a wide-ranging view of EA -starting from a structured family of technical guidelines including concepts, principles, rules, patterns and interfaces, and the relationships among them, to use when building a new ICT capability. In contrast, business professionals tend to ignore the term as an ICT-only issue. Rather, they talk in terms of business models, business processes and, sometimes, the business architecture. The technical architecture refers to how the ICT components fit together, just as a business architecture describes how the business is put together. In reality, they are opposite sides of the same coin -joined completely within the EA because these two activities can be synchronized.

An EA is, in some sense, a statement of philosophy. Like all philosophies, it must begin with assumptions about the present state and the desired future state. (Dillon, 2004) After documenting the present state architecture (*current state of the enterprise*), understanding the reason for change and designing the future state architecture (*its future state*), a transformation (or migration) strategy is developed by identifying the gaps between the as-is state (*current as-is architecture*) and the to-be state (*target to-be architecture*), which enables an enterprise to evolve from the legacy systems of disparate stovepipe applications towards the to-be set of modernized, agile, and integrated business processes.

When creating an architecture it is useful to have a framework to identify and categorize the parts of the architecture. (Stevenson, 1997) Since there is no single universally correct or widely agreed-upon standard enterprise architecture framework model, organizations can either create their own framework based on their vision or use an existing one of which there are several well-known reference frameworks available like The Open Group Architecture Framework (TOGAF), Integrated Architecture Framework (IAF), Federal Enterprise Architecture Framework (FEAF), Zachman Framework, Joint Technical Architecture (JTA). (Stevenson, 1997; Dillon, 2004)

Many organizations borrow/select one or more of existing proven EA frameworks and adapt/customize them to their needs rather than starting from scratch. On the other hand, with such a broad array of goals, it can be very difficult to determine which framework is right for an organization. After reviewing several different schemes for defining enterprise architecture structure, “GeoCHEAF”, multi-tiered conceptual framework, was developed from scratch with its own interpretation of the CH domain, including a detailed meta-model in the form of an entity-relationship model rather than adhering to one of the high-level industry-accepted frameworks.

Object Management Group (OMG)’s Model Driven Architecture (MDA) and Unified Modeling Language (UML) modeling techniques were used to design “GeoCHEAF” and to make it an executable model for the CH domain.

Enterprise models must be composed of rich semantic descriptions of organizations. (Stevenson, 1997) Semantic web technologies (in particular, Resource Description Framework (RDF) and Web Ontology Language (OWL)) were used to represent a conceptual EA reference model of “GeoCHEAF” by benefiting from exiting reference models, like International Committee for Documentation-Conceptual Reference Model (CIDOC-CRM) by the International Committee for Documentation (CIDOC) of the International Council of Museums (ICOM), Open Archival Information System (OAIS) by the International Organization for Standardization (ISO), Open Geospatial Consortium Reference Model (ORM) by Open Geospatial Consortium (OGC), Open Systems Interconnection (OSI) etc.

As intended in its design, semantic interoperability capability of “GeoCHEAF” allows it to behave in a modular fashion, allowing additional functionality and uses to be customized as different uses for other CH projects or organizations within the CH domain.

2.2 Business Architecture of “GeoCHEAF”

Business architecture of “GeoCHEAF” is a functional representation of a CH activity which is meaningful to the various levels of users and encapsulated in the business concepts that constitute well-defined structure to operate the activity properly. The goal of the business architecture is to specify the behavior of a “system of systems” in the context of the business for which it is implemented in terms of collaborating and coordinating chunks of business functionality represented as business components.

Although, at first, the term “business” seems to define a profit-generating activity, in the context of this dissertation, the term “business” is intended to define a concept of an organization which is directed towards maintaining collective productivity and realizing creative goals regardless of involving commercial aspects, like profit or trade. Rather the term “business” as it is used here, relies on sharing know-how and know-why through the exchange of expertise and information to generate new ideas. The reason to use the term “business” in this context is to transcend the limitations imposed by the post modern definition of the term “business”. By expanding the definition of this term the promotion of a common approach to the tasks of e-documentation, preservation, management and communication of CH resources can be better realized.

As a robust EA framework, the business architecture scope of “GeoCHEAF” typically includes user requirements, high-level vision, missions, business goals, objectives, strategies, solutions, and design/governance processes under its business architecture. This scope focuses on functional and technical aspects of the enterprise from the perspective of the users of the systems within the enterprise. This is built up from a gap analysis of the existing environment and of the future state user requirements, constraints and opportunities affecting the enterprise. After that, the formulation of solutions, generation of alternatives, modeling and simulation are designed. Lastly, alternative selection, decision-making, and implementation would be realized. Figure 2.2 shows the business architecture framework of "GeoCHEAF".

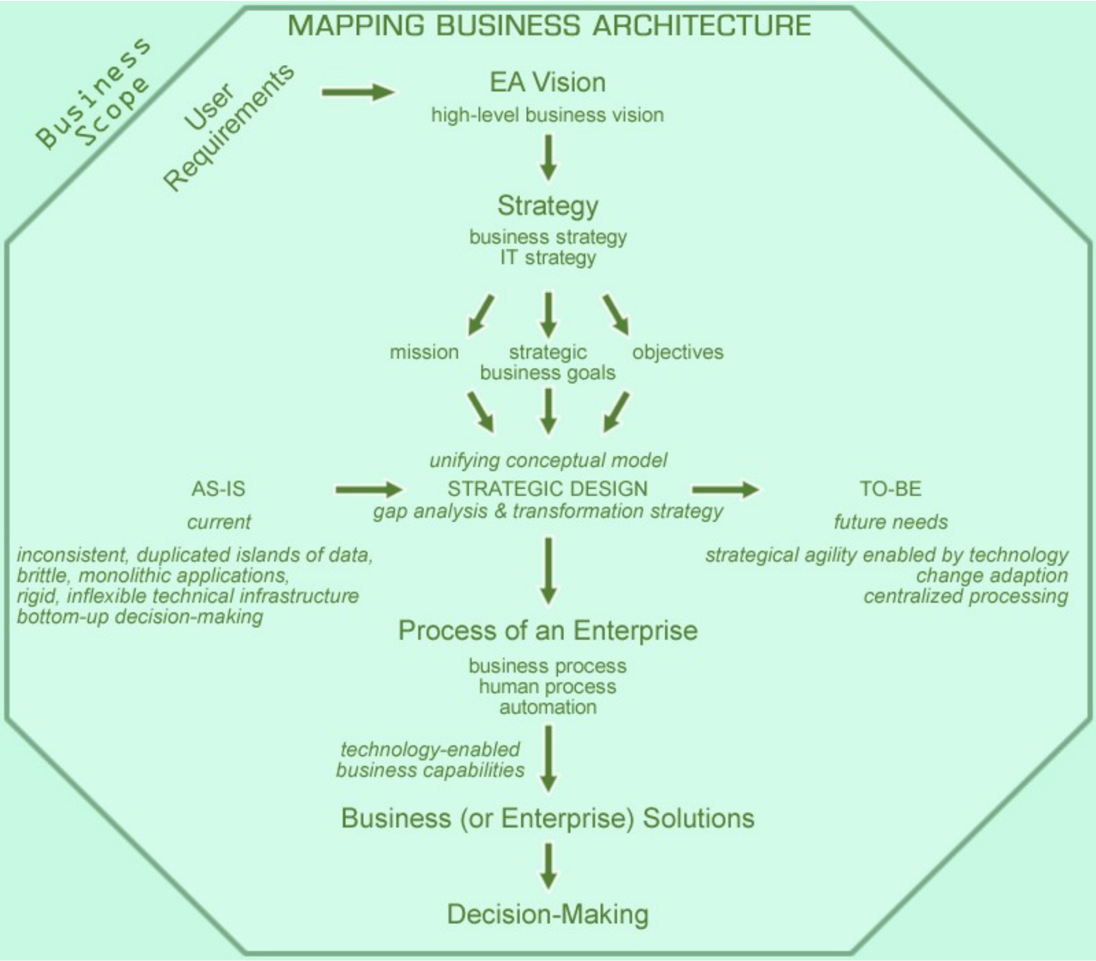

Figure 2.2: The business architecture scope of "GeoCHEAF"

The business architecture of "GeoCHEAF" was modeled and designed for the following target users or user groups:

- Primary users group: Project members, fellows, providers, CH specialists, partners
- Secondary users group: Decision makers, other stakeholders
- End users group: Visitors, tourists or anyone else who is interested in CH resources

In terms of “KaleTakimi”, after the project team understood the context of the project and “KaleTakimi” as an enterprise, identified the various user groups, formulated the questions concerning the project with rich pictures and root definition, and determined the expectations from the project. The vision and mission of the project was created, and the development strategy of the project was produced due to the user requirements matrix and the gap analysis. Prioritization of those requirements, flow chart of the stages and timings were constituted upon that strategy. Roles and responsibilities were defined and rationalization of ICT investment were realized due to these user requirements.

2.2.1 User requirements

In cultural heritage research, having an idea, acquiring data, and processing it is not enough for the CH community. With regard to ICT, there are many scientific and technological challenges facing those working in the CH domain. These challenges below address the problems encountered at the user level by CH community, which will be endeavored to solve in the course of the dissertation.

The initial challenge for CH organizations is to better understand the past, achieve sustainable and successful management of cultural heritage resources and facilitate effective decision-making on these resources by reducing project costs and time.

Recent developments in computing –the growth of web applications, advances in data management and visualization technology, object-oriented programming, mobile computing, and global GIS adaption- have led to an evolving vision and role of the CH domain. CH organizations demand the application of best-of-breed ICTs in their projects in order to promote their research and teaching practice while enabling significant scientific research of cultural heritage which would not be possible without them. Furthermore, these state-of-the-art technologies make it possible to access the data in a virtual state, as cultural heritage objects, simulating intact artifacts, while preserving them untouched for future research.

On the other hand, most of these organizations claim that using these dizzying cutting-edge technologies is difficult due to the high cost of software and/or data processing, complexity, and the high degree of training. In other words, researchers would prefer to focus on the science of CH instead of computer science.

The CH community needs more versatile communication among all relevant disciplines, stakeholders and users of a cultural heritage project, primarily, between **CH data/information/content/application providers**, who are aware of that their expertise has strategic potential for CH projects, such as surveyors, photogrammetrists, cartographers, mathematicians, statisticians, computer scientists, data management specialists, graphic designers, and **CH specialists or professionals**, who are sensitive to the importance of cultural heritage resources, such as archaeologists, historians, art historian, architects, conservation experts, museologists, curators and other related disciplines.

The field of CH is now a very data and information abundant sector because of the exponential growth of data volume, complexity and quality driven by the exponential surveying (involving laser scanning, Global Positioning System (GPS), photogrammetry, satellite imagery, geophysics, chemical analysis) and computing technology. One of the challenges for many organizations is to unlock existing data held in the research team's own silos and to make it available across the CH organization to perform strategic and operational decisions.

There is also a need within the CH community to deliver more innovative, accurate and better content/data/information/applications/services since better service delivery enables the exchange and sharing of spatial and non-spatial digital CH resources easily and effectively.

As indicated at the beginning of this section, in cultural heritage research, having an idea, acquiring data, and processing it is not enough for the CH community. CH research requires exploration of terabytes of data and the transformation of qualitative observations into quantitative results by placing management, process, computation, presentation and dissemination of vast volumes of data at the heart of modern cultural heritage research.

2.2.2 Vision and mission statements

The high-level vision of "GeoCHEAF" is to engineer a spatially-enabled enterprise architecture framework pattern for the CH domain which employs science-oriented, user(or domain)-driven, technology-enabled, business sensitive approach.

The fundamental mission of "GeoCHEAF" is to propose innovative, interoperable, scalable, and flexible enterprise solutions in a holistic way in order to fulfill the CH community's specific user requirements indicated above in achievable strategic goals indicated below.

"GeoCHEAF" highlights an enterprise architecture approach, such that all data and services associated with CH resources can be accessed and manipulated through the Internet in an open, seamless framework to ensure accurate and effective enterprise scale decision-making on sustainable and successful cultural heritage management process by maximizing the use of (geo)data, (geo)semantics and (geo)visualization.

To achieve this, the key issue is 'technology choice and fusion' based on an open architecture. "GeoCHEAF" uses the integration of technology that brings together different open source state-of-the-art technologies and open standards, including UML, XML, SOAP and Java, and extends their functionality with Internet, object-oriented concepts, business logic and GIS features to create a highly scalable ICT infrastructure by initiating a dialog between key technologies and CH professionals. This strategy makes it possible for "GeoCHEAF" to have a broad interoperability across heterogeneous data silos and application environments. It closely follows emerging standards and technologies and also validates new technological approaches to develop the best of breed cultural heritage applications and services.

"GeoCHEAF" contains a set of functional tools and provides a common vocabulary. It also includes a list of recommended standards and products that can be used to implement the CH projects.

A Communication Tool: Members of a CH project who comes from a variety of disciplines including archaeology, art and architectural history, cultural history, oral history, anthropology etc., need to work closely with other project members on generating the conceptual model, structure and other more pragmatic aspects of the desired project. The dialogue between project members must be able to move beyond the project itself and present the results in an accessible and comprehensible format to the extended enterprise constituencies such as heritage administrators, experts, grant agencies, preservationists, and educators via a project web portal transmitted over the web. “GeoCHEAF” provides a communication tool that first addresses and then bridges the gaps among CH specialists, data/information providers, content/application developers, management specialists and users including project members, academia, researchers, scholars, end-users, stakeholders, decision-makers for further collaboration to participate in the process. Finally, it initiates a dialogue between technologies and CH professionals. Hence, it encourages collaboration among all the components of the enterprise.

A Business Tool: “GeoCHEAF” fills the EA knowing-doing void among the all components within the enterprise. It manages the complexity of the enterprise, align business strategies and implementations, and facilitate rapid change in order to maintain business and technical advantages. It integrates business processes among the systems of the enterprise.

A Seamless Computing Tool: “GeoCHEAF” provides a streaming tool to integrate all EA components, promote integration of technologies, and improve the availability of needed data by providing distributed computing services.

2.2.3 Business goals

The business goals of “GeoCHEAF” were extrapolated at a conceptual level below based on the future state functional and technical user requirements of CH domain:

1. Gather the knowledge and experience of how best to bring technology, processes and people together and address the impact they can have on each other in order to describe a specific way in which to model CH research, projects, organizations as an enterprise, and explore spatial, temporal, social, cultural, and economic interactions.

2. Perform adaptable design of “GeoCHEAF” in order to position the enterprise to respond rapidly to changing needs, emerging opportunities and threats of the CH domain in terms of business strategies, governance, and technologies by aligning business and ICT strategies. Propose a service-oriented, model-driven, component-based modeling and design approach organized around the concepts of services and components in the Service-Oriented Architecture (SOA). Make all the business processes web-based as part of the e-business that is e-heritage solutions for the CH domain by ensuring adequate security & authentication.

3. Transcend the traditional hierarchical boundaries among different systems within an inherently interdisciplinary enterprise that has a broad range of constituents and interfaces. Provide better understanding, productivity, decision-making and science by supplying interdisciplinary collaboration, exchange of knowledge and expertise in a multi-participant working environment.

4. Share consistently deliverables internally and externally. Join up data, meta-data, information, knowledge, contents, web applications, services, resources, and systems in one unified environment, which is web portal, in order to enable every member of a research team and/or other users to globally interact with the deliverables, thus releasing the research team from a location specific dependency. Build a rich virtual research environment and a web based resource for edutainment and e-tourism.

5. Reduce data silos with higher levels of integrity and accuracy. User works against one integrated system of systems that provides dynamic and changeable views of same information and eliminates duplication of data or data silos.

6. Set up technology enabled platform fundamentally based on a rapidly developing technology. Provide CH professionals with an understanding of some of the complex technology and specific technical management issues that must be addressed when carrying out CH projects.

7. Deploy high-level technologies. Provide seamless integration of information, communication and geospatial technologies and their functionalities to improve the acquisition, distribution and use of data and information. Facilitate interpretation, exploration and analysis of large data sets by providing 'data exploration and discovery tools', 'state-of-the-art visualization', 'interaction and computing technology', 'analytical tool kit'.

8. Extrapolate at a conceptual level the future state functional and technical requirements and compare current technologies to those future state needs to identify gaps.

9. Formulate affordable and interoperable solutions. Assemble “GeoCHEAF” based on open architecture involving open computing standards, such as UML, XML, SOAP and Java to formulate and implement technology standards across the enterprise and to ensure interoperability with third-party tools.

10. Examine geospatial information technologies, like SIS, within both enterprise architecture and cultural heritage domain. Integrate various information systems (CH Site Management System, Architectural or Archaeological Information System, Monument Information System, Tourist Information System, (Geo)Spatial Information System, etc.) in one coherent architecture. This is done to facilitate integration of enterprise data/contents/services, further information sharing, increase usability, reduce ICT maintenance costs and promote effective management.

11. Document the entire architecture from requirements to implementation and define the shortcomings in business and technological considerations which need to be addressed.

2.2.4 Business strategy

"GeoCHEAF" life cycle is divided into seven parts:

1. Analysis (Preparation)
2. Design and Assess (Modeling)
3. Build
4. Deploy and Implement
5. Validate
6. Monitor and Evaluate (Operational experience, user feedbacks)
7. Maintain (Projected further developments)

2.2.4.1 Design strategy

"GeoCHEAF" presents an innovative, adaptive and holistic unified framework design for EA that breaks the overall architecture into its major component areas. Afterwards for each component area, a sub-architecture framework is defined. Together, all architecture frameworks define a vision for successfully implementing EA in CH projects through openness, interoperability, semantics and enterprise integration.

The design of "GeoCHEAF" is defined as a four-phase development process consisting of requirement analysis, overall EA framework and its sub-frameworks design, the components design within the frameworks and seamless integration of the components steps.

Requirement analysis step includes organizational structure and roles within it, target users, exploring users' and stakeholders' requirements, business goals, cost & schedule estimation, etc. Requirements comprise the contract between a developer and all level of users that specifies what the enterprise going to be built will do to support its vision.

The overall framework is a multi-tiered structure to maximize flexibility, adaptability and stability. In a multi-tiered model, "GeoCHEAF" consists of several distinct but highly interrelated frameworks, each of which can be conceptualized as having its own distinct architecture.

“GeoCHEAF” is an integrating framework which incorporates the following architectures:

1. Business Architecture: The EA describes the business but is also a part of the business. Therefore the architecture can be described within the architecture in terms of its models, processes, etc.

2. Technical Architecture: The technical architecture within EA is the design required in order to 'build a responsive IT infrastructure', 'develop and manage distributed systems', 'plan and manage communication networks', and 'define how the business will operate in the next generation of enterprise technology'.

3. Data Architecture: A major design objective of the data architecture within EA is to enable 'effective use of the data resources'.

4. Information Architecture: Information Architecture within EA is defined as 'a high-level map of the information requirements of an organization'. It shows how major classes of information are related to major functions of the organization.

5. Application Architecture: The form and structure of the application architecture within EA is specifically designed to 'improve the effectiveness of application development'.

In the context of this dissertation, as displayed in figure 2.3, the focus is mainly on technical attributes. Data, information, and application aspects are expanded as sub-architectures of the technical architecture to be able to maintain wholeness and harmony in the scope of the dissertation.

EA is about understanding all of the different components that go to make up the enterprise and how those components interrelate. Components in this context are all the components that enclose the areas of people, processes, business and technology. In that sense, examples of components are: strategies, business drivers, governance principles, stakeholders, units, locations, budgets, domains, functions, processes, services, information, communications, applications, systems, infrastructure, databases, networks etc. (Schekkerman, 2004)

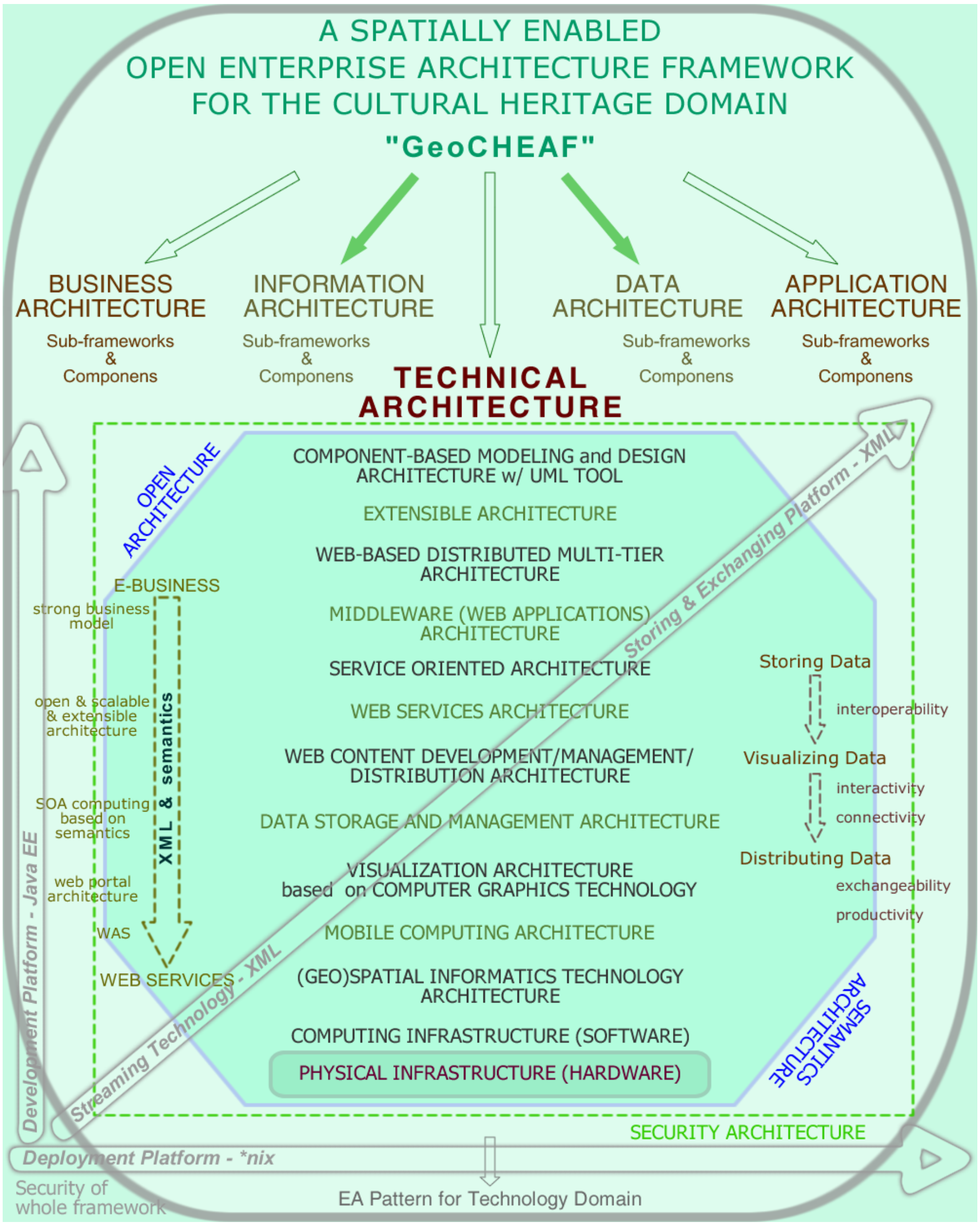

Figure 2.3: Frameworks and components of "GeoCHEAF"

A component does not exist in isolation; it fulfills a particular role in a given context and actively communicates with it. A component participates in a composition with other components to form a higher-level component. At the same time every component can be represented as a composition of lower-level components. A component must collaborate and coordinate its activities with other components in a composition to achieve a higher-level goal. Well-defined behavioral dependencies and the coordination in time between components are of great importance in achieving the goal.

A component is a module designed for a specific function, which can be independently added, removed or replaced/updated with a more appropriate component in the course of an enterprise's growth and as technology changes without affecting the rest of the architecture. This loose-coupling allows that changes can be confined to particular components or areas with minimal disruption to the system as a whole.

The component-based design approach works very well in many ways, in particular, how all parts of an enterprise work together to provide the capability of an enterprise to achieve its vision. Seamless EA integration shows how the components fit together through relationships among the components in the EA framework as a component network. UML was selected as the primary enterprise modeling and design tool for advanced modeling using a top-down approach when designing "GeoCHEAF". First, the processes was turned into components. Second, an architecture was created for linking those components that will permit them to integrate rapidly in the best combination or sequence required to tailor products or services.

The main goal of the design strategy is to specify the behavior of the system in the context of the business for which it is implemented in terms of collaborating and coordinating chunks of business functionality represented as business service components.

Figure 2.4 simply demonstrates the component-based modeling and design approach of "GeoCHEAF", which is basically model-driven and is used as a basis for modeling a SOA. This service-oriented component modeling and design approach provides a paradigm shift from components as objects to components as services that makes component concepts capable for modeling the architecture of collaborating and coordinating loose-coupled business services. It is because objects are not best way to tie together the programs in a distributed solution. However, service orientation is a complement to object orientation, not a replacement for it. Object orientation remains very important in software development. The approach is flexible and agile, providing the way of balancing business and ICT concerns, like effectively aligning business and ICT resources and processes, and adopting changes from both sides. (Stojanovic et al., 2005)

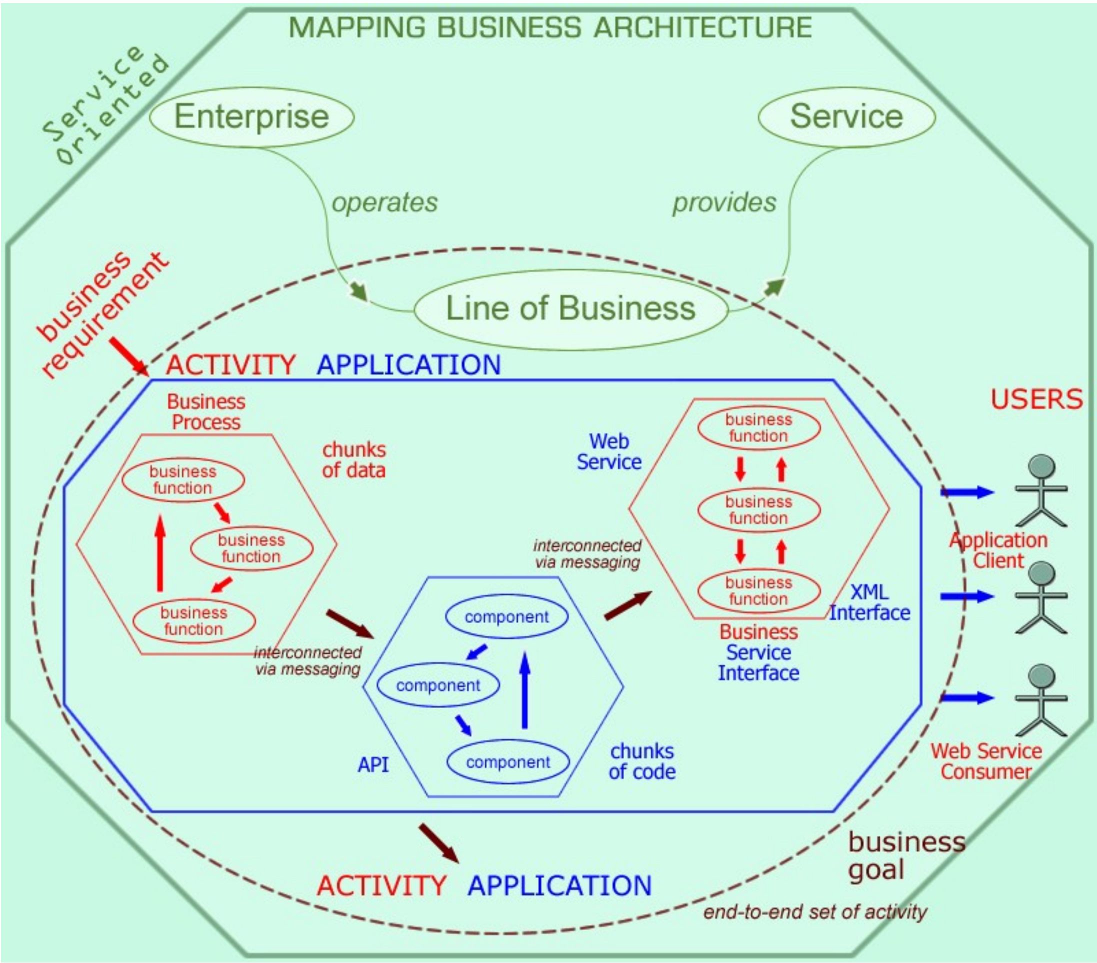

Figure 2.4: Component-based modeling and design approach of "GeoCHEAF"

SOA is an approach for building distributed systems that deliver application functionality as services to either end-user applications or other services. A basis of SOA is the concept of a service as a functional representation of a real-world business activity meaningful to the end user and encapsulated in a software solution. Using the analogy between the concept of service and a business process, SOA ensures that loosely coupled services are orchestrated into business processes that support the organization's business goals. (Stojanovic et al., 2005)

In the SOA modeling and design approach, components and services that are identified based on user requirements and goals modeled in implementation-independent way represent an abstraction layer between business and technology. Business goals, rules, concepts and processes are captured by components and services at the specification level that are further mapped to technology artifacts. This approach provides effective bi-directional traceability between business concepts and technology artifacts. This is the main idea behind the current OMG's MDA. MDA aims to bridge the gap between models and code and specifies a way of generating executable code for multiple platforms from one single Platform Independent Model (PIM). It crosses levels of abstraction with model-to-model and model-to-code transformations. (URL OMG)

Although component-based development (CBD) represents a bottom-up approach whereas model-based development (MBD) is more top-down in nature, it turns out that the concepts have much in common. "GeoCHEAF" can benefit from cross-fertilization by first designing EA frameworks as conceptual models with top-down approach through MBD and then, designing components within the models as bottom-up approach via CBD. "GeoCHEAF" is a set of integrated models covering all major aspects of the enterprise. Defining a model makes it easier to break up the enterprise into simple, discrete components that can be individually studied.

The classical objects in object orientation are at too low level of granularity (finer-grained) to be considered as a basis for defining services whilst loosely coupled larger-grained (coarse-grained) service-based business components represent a perfect mechanism for designing services in a SOA.

On the other hand, classical CBD methods do not provide thorough support for business-level concepts and services within the SOA (D'Souza and Wills, 1999). Their focus is mainly on finer-grained components that closely map the underlying entities like each function of a business process, rather than on larger-grained, like the business process itself as required by SOA. Therefore a SOA modeling and design approach should be naturally based on standard practices of component-based and object-oriented (OO) paradigms integrated with business process and workflow design concept and techniques. (Stojanovic et al., 2005)

2.3 Technical Architecture of "GeoCHEAF"

The technical architecture is an underlying architecture that plays a significant role in the success of the e-heritage solutions for the CH domain. Its scope includes every phase of CH information and communication technology: initial data capture/digitization, information/data processing, reconstruction, visualization and documentation as well as dissemination of results to the scientific and cultural heritage communities and to the general public.

"GeoCHEAF" has a comprehensive and sophisticated ICT strategy to fulfill CH enterprises' technical requirements by deploying, customizing and optimizing high-level innovative technologies. The major challenge is seamless integration of multiple disparate technologies to distribute the standards-based, interoperable and interactive services through an open, secure, scalable, distributed and loosely-coupled technical architecture and infrastructure that meets the demands of those enterprises' growth.

In the course of designing technical architecture, to suit the needs of the CH domain, a comprehensive overview of ICT and their integration problem was realized. There are not only a vast number of both open source and proprietary technologies available in the tremendous ICT market, but there are also rapidly evolving new technologies. To survive within such an enormous market, the enterprise needs a strong technical architecture, which is possible only when the architecture is flexible enough to accommodate the integration of existing legacy applications, scalable enough to accommodate the new innovative technologies and adaptable enough to future changes in technology. In the market today, CH communities should be naturally cautious about any swiftly evolving technology hype when they choose the right technology which supports their technical architecture of their studies or projects, especially in terms of cost, time and labor efficiency. In the ICT design strategy of “GeoCHEAF”, there is a need to understand the technical aspects of the projects in order to pick and chose the correct technology within the technology chaos.

Today 'being online' means 'being global', since the Internet is geographically an independent virtual world. People browse and data moves between geographically separate databases through the web which is the new geographic space that enables information, application and resource to travel at a global scale. In this design, the web is used as both a development platform and a web browser-based graphical user interface (GUI) to build and distribute data sets, contents, applications and services to the users.

Mapping the technical architecture of “GeoCHEAF” covers thirteen main architectures and two sub-infrastructures:

1. Open Architecture
2. Semantic Architecture
3. Modeling Architecture
4. Extensible Architecture
5. Web-based Distributed Multi-Tier Architecture
6. Service Oriented Architecture
7. Web Services Architecture
8. Data Storage and Management Architecture
9. Visualization Architecture
10. Web Content Management Architecture
11. Mobile Computing Architecture
12. Spatial Informatics Technology Architecture
13. Security Architecture
14. Infrastructure
    1. Computing Infrastructure (Enterprise Software)
    2. Physical Infrastructure (Enterprise Hardware)

Technical Architecture design pressures are composed of fundamental abilities:

- standards-based and semantic interoperability
- openness
- integrity & flexibility
- scalability
- extensibility
- interactivity
- modularity
- granularity
- global distribution & connectivity
- easy accessibility & re-usability
- reliability & security
- cost, time & labor-efficiency

3. INITIAL STRUCTURAL ARCHITECTURES

3.1 Open Architecture

Before, open source software was disliked. The preconceived opinion was that a product free of charge can not be worth as much as one which has a cost. In certain cases, this opinion was correct, since many open source projects were not developed well enough. But with the success of several open source projects, public interest has been awakened. Moreover, high-end systems in many sectors were custom-built, monolithic proprietary software systems that were expensive to develop and maintain. With the arrival of object- and service-oriented technology, systems integrators and software developers have realized the benefits of open, component-based software solutions and have adopted this technology. Today, the use of open source software has become increasingly prevalent in many areas of ICT. For example, the majority of web sites run on open source web server software e.g. Apache, Tomcat etc; operating systems such as Linux, BSD etc. have an increasing share of the market; open source web browsers are also increasing in popularity e.g. Firefox, Galeon etc. However, open source solutions might not always be better or more advantageous than proprietary software for an enterprise. This decision is based upon the business objectives, timeframes and the quality of the open source product. An open architecture can help to define these decisions for an enterprise.

The open architecture of “GeoCHEAF” is not just about source code. But, it covers the following strategic considerations together:

- Adopting and using appropriate open standards like XML, HTML, GML, and technologies/software like Java, Linux
- Obtaining more favorable open source licensing
- Selecting the appropriate open source software

- Getting support from multiple communities and/or vendors
- Ensuring interoperability with third-party tools and integrating with new technologies later in the process

The architecture based on these strategic considerations maximizes interoperable information and knowledge sharing via standards-based open source solutions/technology/software/products. Additionally, it investigates what the business benefits and pitfalls would be for open source technology for the CH community.

The architecture was to be based on mainstream ICT developments, including open standards such as those of the International Organization for Standardization (ISO), the Open Geospatial Consortium Inc (OGC), the World Wide Web Consortium (W3C) and the Organization for the Advancement of Structured Information Standards (OASIS).

Benefits of open source solutions/technology/software/products are:

- Lower cost of ownership & reduced start up cost (*Open source does not always mean free. Free and open source concepts are different. There are also commercial open source products in market. However, property solutions are still more expensive.*)
- Independence and control over the final product
- More frequent software releases
- Faster innovation
- Support for standards
- Open source community, user groups, discussion forums and good support
- Open code
- Good functionality
- Well tested software
- Availability of alpha releases
- Maximizing the client rights

Pitfalls of open source solutions/technology/software/products are:

- Hacking
- Often poorly documented
- Support from original developers sometimes slow
- No liability, responsibility is on the user

Pitfalls of closed source/proprietary software/commercial products/vendor products are:

- Higher cost
- Closed source
- Vendor perspective
- Support generally available at a price

As the industry moves more toward open standard technologies, more vendors support them. For example XML, GML, SVG, all major software vendors like Autodesk, ESRI, are supporting these standards in their own products like Autodesk Map Guide Open Source, ArcGIS.

On the other side, it is a tough challenge to choose the right open source solution because presently there is too much fragmentation in the market. For instance, there are over 100,000 open source Linux projects, or more than 50 open source web application development frameworks. Not all of them will be successful or get noticed in the realm of the Enterprise. "GeoCHEAF"s open architecture identified each of the technology domains needed in the enterprise and matched open source products to them as shown in table 3.1 briefly.

The open source technologies chosen tightly dovetailed as the components of the technical architecture of "GeoCHEAF" to create an affordable and effective open source computing platform for the CH domain.

Open source starts with licenses. Open source software is distributed under a variety of different types of open source licenses -GNU General Public License (GPL), GNU Lesser GPL (*formerly Library GPL*) (LGPL), Berkley Software Distribution (BSD), Massachusetts Institute of Technology (MIT), mixed/dual licensing, e.g. MySQL- all with the intent of guaranteeing that the code remains open. By definition, these licenses must not be specific to certain software distributions, and cannot restrict any product that is distributed alongside the open source software. Open source foundations such as Open Source Initiative (OSI), Free Software Foundation (FSF), GNU (that is a recursive acronym for 'GNU's Not Unix'), are non-profit organizations dedicated to managing and promoting open source definition.

Table 3.1: The appropriate open source software selection of "GeoCHEAF"

Technology Domain	***Open Source Software (Product)***	***License***
Modeling and Designing Tool	ArgoUML & PoseidonCE	BSD
Operating System (OS)	Solaris 10	Distro License for Java (DLJ)
Development Platform	Java EE	Java Research License (JRL)
Integrated Development Environment (IDE)	Eclipse	Eclipse Public License
Web Server	Apache + Tomcat	GNU GPL
Application Server	JBoss	GNU LGPL
Database Server	MySQL & PostgreSQL	GNU GPL & BSD
XML Database	eXist	GNU LGPL
Database Tool	phpMyAdmin / phpPgAdmin	GNU GPL
Map Server	UMN MapServer	MapServer License
Data Persistence Tool	Hibernate	GNU LGPL
Programming & Scripting	Java, PHP, Python	PHP License, Python License
Web Content Management	Typo3	GNU GPL
Productivity	OpenOffice.org	GNU LGPL
Security	OpenSSH	BSD
Web Browser	Mozilla Firefox & Opera	Mozilla Public License (MPL) & Opera License
Directory	OpenLDAP	OpenLDAP Public License

Linux is written and distributed under the GNU GPL which means that its source code is open, freely-distributed and available to the general public. So, even one can modify source code, and recompile and make one's own Linux version.

3.2 Semantic Architecture

The meaning of information is referred to as semantics and meaning is always in the relationships between things. The semantics architecture of “GeoCHEAF” provides semantic representation for the enterprise and its architecture including systems, data, adaptive information, declarative knowledge, applications and services in order to improve e-heritage solutions for the CH domain through semantic standards and technologies, semantic and enterprise integration, ontology driven semantic interoperability, and semantic web ontologies. In such an architecture, distributed repositories can be searched and relevant information according to user specified criteria are found and merged by means of an intelligent web agent or web services through the semantic web. For instance, a sort of specific artifact in the fortresses belongs to 17th century can be searched in different CH projects’ databases and portals, digital archives, museum collections and old antiquarian reports.

Ontologies play a critical role in associating meaning with data such that computers can understand enough to meaningfully process data automatically. Compared to syntactic means, a semantic approach leads to high quality and more relevant information for improved decision-making. Equally important is the use of ontologies to achieve shared understanding. Ontologies are also evolving as the basis for improving data usage, achieving semantic interoperability, developing advanced methods for representing and using complex metadata, correlating information, knowledge sharing and discovery. Ultimately, ontologies can be an important tool in expediting the advancement of related sciences, and they can reduce the cost by improving sharing of information and knowledge.

Figure 3.1 demonstrates interoperability spectrum from weak semantics to strong semantics. Ontologies provide vocabulary control just as taxonomies and thesauri do, but there are important differences. In general, ontologies aim to represent knowledge rather than describe content. This is why they require such rich descriptions of relationships among terms, rather than relationships that are merely equivalent, hierarchical, and associative. There are additional features that allow them to be processed effectively by computers. (Lombardi, 2002) The capability of Resource Description Framework (RDF) provides distribution of structured information to allow the reference model to be extended whilst the capability of Web Ontology Language (OWL) provides maintenance the consistency of those extensions. OWL represents the meanings of terms in vocabularies and the relationships between those terms in a way that is suitable for processing by software. OWL specification, written in XML, is a web standard for processing web information and maintained by World Wide Web Consortium (W3C) since February 2004. OWL is the current de facto standard for representing ontologies on the semantic web. (URL W3C)

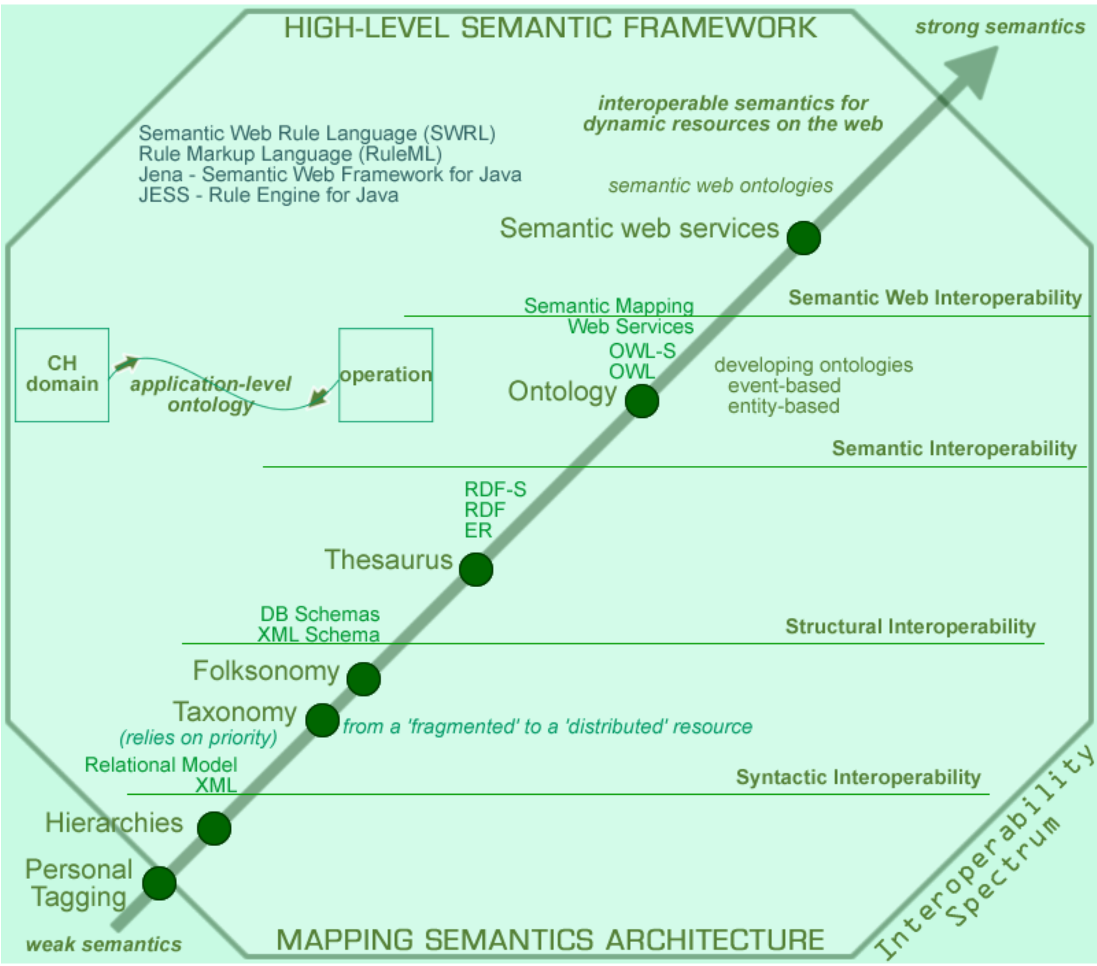

Figure 3.1: Semantic categorization types

The semantic web is a new form of web content that is meaningful to computers and in particular, connects web services. The emerging idea of the semantic web is based on the maximum automation of the complete knowledge life-cycle processes: knowledge representation, acquisition, adaptation, reasoning, sharing and use.

RDF is a metadata-based mechanism for helping to identify interoperability that is maintained by the W3C . In its syntax, 'a subject makes an assertion (a predicate) about an object' with an RDF triplet that includes a subject, pedicate and an object. (URL W3C) Metadata means 'data about data' or 'information about information' (or the information needed to communicate sensibly about information). (Wise and Miller, 1997). A metadata record is a file of information, usually presented as an XML document, which captures the basic characteristics of a data or information resource. It represents the who, what, when, where, why and how of the resource. In case of cartography, it could be the scale, the year of the publication or the datum and projection of the map.

In the digital age with ever-increasing quantities of CH data being collected, stored, and distributed in computer-readable forms, interconnection of information is becoming essential. In other words, a coherent and standardized metadata schema is necessary for the CH domain. There is a variety of metadata approaches which exist, such as MidasXML schema, Dublin Core (DC) element set, Federal Geographic Data Committee (FGDC)'s digital geospatial metadata system, and Global Change Master Directory (GCMD)'s Directory Interchange Format (DIF), and Open Achieves Initiative Protocol for Metadata Harvesting (OAI-PMH).

MidasXML is proposed as a historic environment-specific XML schema by the Forum on Information Standards in Heritage (FISH), further information available at http://www.heritage-standards.org/.

The Dublin Core Metadata Initiative (DCMI) is an organization dedicated to promoting the widespread adoption of interoperable metadata standards that support a broad range of purposes and business models, and is developing specialized metadata vocabularies for describing resources that enable more intelligent information discovery systems. The Dublin Core is a metadata element set that provides an easy and concise 15 element core designed to describe any type of information. It includes all DCMI terms (that is, refinements, encoding schemes, and controlled vocabulary terms) intended to facilitate discovery of resources. Implementations of Dublin Core typically make use of XML and RDF-based. (URL DCMI)

Geospatial metadata are used to document geospatial digital resources such as GIS files, geospatial databases, and earth imagery. A geospatial metadata record includes core library catalog elements such as Title, Abstract, and Publication Data; geographic elements such as Geographic Extent and Projection Information; and database elements such as Attribute Label Definitions and Attribute Domain Values. (URL FGDC)

Metadata has three main purposes (metadata allows one to do). First, it allows the nature of a body of information to be assessed without having to access the data themselves. The second purpose of metadata is that it allows a user to locate a piece of information. The third use of metadata is that it allows similar bodies of information to be grouped or linked together. Thus, the information about information communicated through metadata is generally: (Wise and Miller, 1997)

- the nature of information
- the location of information
- existence of similar information

In an archaeological context, examples of each of these might be: (Wise and Miller, 1997)

- that a dataset contains information on stone tools
- that the dataset may be viewed online through the Archaeology Data Service homepage
- that the British Museum holds a similar data set.

Since, of these metadata systems, the DC seems the most useful and the most widely applicable metadata system, and its concise 15 element core designed to describe any type of information including images, electronic texts, HTML pages, geospatial surveys, etc., both the DC and RDF were used in the design of semantic architecture of “GeoCHEAF” as a standard grammar for describing the content of information resources and exchanging them across different applications and subjects.

3.3 Modeling Architecture

It is a fact that architecture framework modeling and designing process takes longer than the development of it. However, that development time can be drastically reduced by proper architecture framework modeling and designing.

UML is a graphical open modeling standard language defined and maintained by the OMG. UML 2.0 is the current official version which released in 2004. (URL OMG; URL UML) UML was devised to satisfy the need to model OO systems and to enable CBD. In an OO system, generally several components are tied together using 'interfaces'. To understand how those different components interact, it is quite useful to build a model. (Maksimchuk and Nailburg, 2004)

In the design of “GeoCHEAF”, UML was selected as the primary modeling and design tool for a CH enterprise and its systems, applications and data architectures even though other EA and system modeling techniques and tools such as XML-based Architecture Description Markup Language (ADML) were considered. UML-based design of “GeoCHEAF” is matured from use cases to pattern-based EA as a conceptual model of the CH domain.

The reason why UML was chosen for modeling and designing is **standardization**. Different languages have been used for depicting systems using OO methodology. The prominent among these were the Rumbaugh methodology, the Booch methodology, and the Jacobson methodology. The problem was that, although each methodology had its advantages, they were essentially disparate. UML 'unifies' the design principles of each of these methodologies into a single, standard, language that can be easily applied across the board for all OO systems. But, unlike the different methodologies that tended more to the design and detailed design of systems, UML spans the realm of requirements, analysis, and design and, uniquely, implementation as well. (Chitnis et al., 2004a) The other reasons are:

- Vendor-neutral standard and authoritative source
- Best of breed solution based on natural selection
- Visual representation of executable architecture
- Reduce cost through round trip engineering
- Traceability across levels of abstraction
- Extensible semantics through profiles

Designing EA framework is a complicated task requiring the coordinated efforts of different user groups performing various functions involving capturing the needs of the systems and their business, bringing software components together, constructing databases, assembling hardware to support the systems. Fortunately, the UML enables one to model many different facets of their business, from the actual business and its processes to ICT functions such as database design, application architectures, hardware designs, and much more. (Maksimchuk and Nailburg, 2004)

UML provides a common graphical language for "GeoCHEAF" to bring together all the actors of the extended enterprise, such as historians, archaeologists, architects, surveyors, developers, users, so that they can understand the enterprise, its requirements, and how EA framework will be created for the enterprise in a collaborative modeling environment. By using UML, development teams of the enterprise gained significant benefits, including easier communication between team members, easy integration to repositories due to this language based on meta-models, use of a standardized input/output format (XML Metadata Interchange (XMI)), universal use for application and data modeling, unified representation from analysis to implementation to deployment.

UML-based design of "GeoCHEAF" features an underlying meta-model which is a model of a model. The UML meta-model expresses the proper semantics and structure for "GeoCHEAF". In this way, "GeoCHEAF" is flexible and adaptable enough to be customized to the specific needs of any other CH projects or enterprises.

UML is based on OO paradigm (OO modeling and design), and has some limitation regarding ontology development (ontology modeling). These limitations can be overcome using UML's extensions, like UML profiles, as well as other OMG's standards, like MDA. Currently, there is an initiative (i.e. RFP) within the OMG aiming to define a suitable language for modeling semantic web ontology languages in the context of the MDA. (URL OMG; URL UML)

3.3.1 UML diagrams

A model is an abstraction that contains all the elements needed to describe the intention of the thing being modeled. A diagram is a specific view into what one is trying to understand in a specific context at all or some part of the model. Each UML diagram is used for a specific purpose, typically to visualize a certain aspect of the thing being modeled and each diagram uses specific UML symbols to achieve its purpose. (Maksimchuk and Nailburg, 2004)

UML provides the ability to capture the characteristics of a system by using notations. UML provides a wide array of simple, easy to understand notations for documenting systems based on the OO design principles. These notations are called the thirteen diagrams of UML 2.0. The beauty of UML lies in the fact that any of the thirteen diagrams of UML can be used on an incremental basis as the need arises. For example, if there is a need to model requirements for a given system, only the use case diagrams can be used without using the other diagrams in UML. (Chitnis et al., 2004a)

To understand the thirteen diagrams of UML 2.0, they were categorized hierarchically, as shown in figure 3.2, and the ones most common used are explained briefly as following:

1. **Use case diagram:** The use case diagram is used to identify the primary elements and processes that form the system. The primary elements are termed as "actors" and the processes are called "use cases". The use case diagram shows which actors interact with each use case. (Chitnis et al., 2004a)

2. **Class diagram:** The class diagram is used to refine the use case diagram and defines a detailed design of the system. The class diagram classifies the actors defined in the use case diagram into a set of interrelated classes. The relationship or association between the classes can be either an "is-a" or "has-a" relationship. Each class in the class diagram may be capable of providing certain functionalities. These functionalities provided by the class are termed "methods" of the class. Apart from this, each class may have certain "attributes" that uniquely identify the class. (Chitnis et al., 2004a)

3. **Object diagram:** The object diagram is a special kind of class diagram. An object is an instance of a class. This essentially means that an object represents the state of a class at a given point of time while the system is running. The object diagram captures the state of different classes in the system and their relationships or associations at a given point of time. (Chitnis et al., 2004a)

4. **State diagram:** A state diagram, as the name suggests, represents the different states that objects in the system undergo during their life cycle. Objects in the system change states in response to events. In addition to this, a state diagram also captures the transition of the object's state from an initial state to a final state in response to events affecting the system. (Chitnis et al., 2004a)

5. **Activity diagram:** The process flows in the system are captured in the activity diagram. Similar to a state diagram, an activity diagram also consists of activities, actions, transitions, initial and final states, and guard conditions. (Chitnis et al., 2004a)

6. **Sequence diagram:** A sequence diagram represents the interaction between different objects in the system. The important aspect of a sequence diagram is that it is time-ordered. This means that the exact sequence of the interactions between the objects is represented step by step (in time order). Different objects in the sequence diagram interact with each other by passing "messages". (Chitnis et al., 2004a)

7. **Collaboration diagram:** A collaboration diagram groups together the interactions between different objects. The interactions are listed as numbered interactions that help to trace the sequence of the interactions. The collaboration diagram helps to identify all the possible interactions that each object has with other objects. (Chitnis et al., 2004a)

8. **Component diagram:** The component diagram represents the high-level parts that make up the system. This diagram depicts, at a high level, what components form part of the system and how they are interrelated. A component diagram depicts the components culled after the system has undergone the development or construction phase. (Chitnis et al., 2004a)

9. **Deployment diagram:** The deployment diagram captures the configuration of the runtime elements of the application. This diagram is by far most useful when a system is built and ready to be deployed. (Chitnis et al., 2004a)

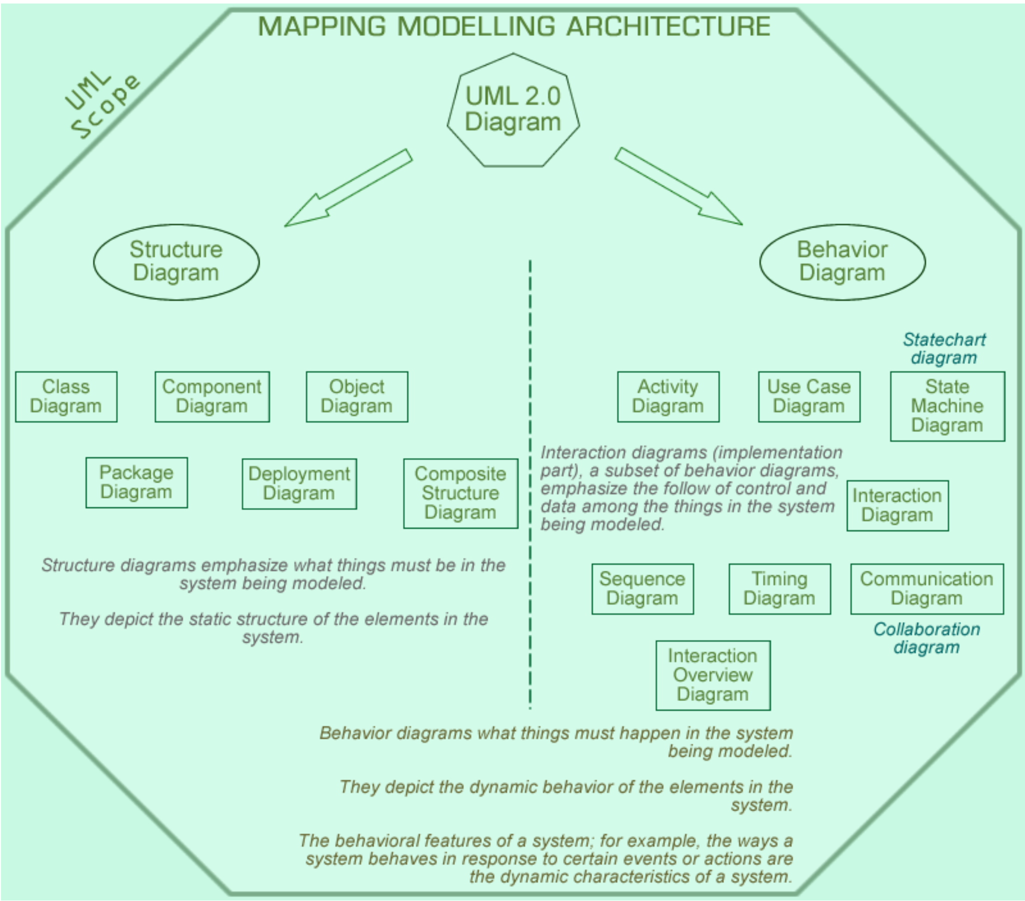

Figure 3.2: The hierarchy chart of UML 2.0 diagrams (URL Wikipedia)

3.3.2 UML tools

UML does not have any dependencies with respect to any technologies or languages. This implies that UML can be used to model systems and applications based on either of the current hot technologies; for example, Java 2 Enterprise Edition (J2EE) and .NET. Every effort has been made to keep UML as a clear and concise modeling language without being tied down to any technologies.

A number of modeling tools are available on the market, ranging in price from free to tens of thousands of dollars per seat license. Choosing the right modeling tool to design the architecture framework of an enterprise depends on the needs, the preferences and the budget of the enterprise. In general, the desirable features that would definitely be noticed whether that UML tool has them:

- **UML 2.0 diagram support:** The UML tool should support UML 2.0 and its all the thirteen diagrams that make up UML. (Chitnis et al., 2004b)

- **Forward engineering:** A UML tool should not have its use limited to just a pictorial depiction of diagrams. Because the structure of the system defined by the diagram is translated by a developer into actual source code (classes), the UML tool should bridge this step by generating the source code of the classes with the methods stubbed out. Developers can take up this stub code and fill in with the actual code. This characteristic of automating the generation of source code is called forward engineering. Forward engineering support by a UML tool is normally for a specific language or a set of languages like Java. (Chitnis et al., 2004b)

- **Reverse engineering:** Reverse engineering is exactly the opposite of forward engineering. In reverse engineering, the UML tool loads all the files of the application/system, identifies dependencies between the various classes, and essentially reconstructs the entire application structure along with all the relationships between the classes. Reverse engineering is a feature normally provided by sophisticated and high-end UML tools. (Chitnis et al., 2004b)

- **Round-trip engineering:** Another useful feature apart from forward and reverse engineering is round-trip engineering. Forward and reverse engineering are essentially one-off activities that take input and generate the required output. Round-trip engineering extends these features. An important rule in software design is that no design remains unchanged. This is as true for small systems as it is for large systems. During development, the design structure defined in the UML model does undergo changes to incorporate physical differences in implementation that may not have been envisaged during design. It becomes very difficult to keep the design of the system updated with the changes in the source code. The round-trip engineering feature enables the UML tool to synchronize the model with the changes in the application code. (Chitnis et al., 2004b)
- **Documentation:** Documentation is an integral aspect of a UML tool. Software designing, by nature, is an abstract process. Apart from a few syntax and semantic ground rules, there are no other rules. The thought process of a software architect who designs applications using UML can be lost if the reasons behind certain design decisions are not captured and well documented. This becomes painfully clear when large systems are maintained and no one has a clue to why a subsystem was designed in a certain way. Hence, a UML tool must necessarily provide some way for the designer to document design decisions in the diagrams by using simple things such as annotations or comments. In addition to this, the UML tool should support the generation of reports/listings of the different design elements of the diagram. (Chitnis et al., 2004b)
- **Version control:** A very important feature to have in the UML tool is either an integrated version control mechanism or connectivity to a standard version control system. Configuration management is an integral part in the building of software systems. Considering that the design of a system is a very important artifact of the software lifecycle, maintaining versions and baselines of the system design is a desirable feature to have in UML tools. In the absence of direct support for version control, it is the responsibility of the designer to maintain versions of the design. (Chitnis et al., 2004b)

- **Collaborative modeling environment:** Enterprise systems are huge and their designs are quite complex. While designing complex systems, there may be different teams involved and may carry out design work on different subsystems in parallel. This collaborative design effort needs to be properly synchronized by the UML tool. The UML tool should provide support for a collaborative modeling environment with capability to compare different versions designs for differences or even merge different versions of a design. Collaborative modeling is always a nice feature to have in UML tools. (Chitnis et al., 2004b)

- **Integration with popular Integrated Development Environments (IDE):** With the increasing use of iterative methodologies for building software systems, it becomes very difficult to keep the design of the system in sync with the developed code. Hence, it would be useful if the UML tool provides integration with an IDE. This integration of a UML tool with the IDE will help developers to really benefit from round-trip engineering. Any changes in the application code that developers make in the IDE are immediately reflected in the model in the UML tool and vice versa. (Chitnis et al., 2004b)

- **Test script generation:** The system or subsystem designed in a UML tool may represent a set of functional aspects as well. Hence, it would be really useful if, in addition to generating stub code, the tool also generates test scripts that can be used for testing how the generated class functions. (Chitnis et al., 2004b)

- **Model View Controller (MVC) modeling:** Enterprise application architectures have increasingly begun to standardize and are based on the MCV architecture. Hence, if an n-tier web-enabled enterprise applications are designed, a UML tool that supports designing applications based on the MVC architecture should be used. Support for MVC modeling makes it easier to organize and clearly distinguish the design elements along the lines of the MVC layers. This will help in the long run in improving the readability of the model. (Chitnis et al., 2004b)

The feature of publishing the UML diagrams as a set of web pages and images enables enterprises to share and distribute their application design where the UML tool used is not installed.

Both modeling tools 'ArgoUML', which is open source and a free-of-charge UML modeling tool under the BSD Open Source License, and 'Poseidon for UML *community edition*' from Gentleware, Inc., which has its roots in the ArgoUML open source project, were selected to design “GeoCHEAF” in this dissertation.

Java-based ArgoUML is the leading open source UML modeling tool and includes support for all standard UML 1.4 diagrams. It runs on any Java platform and is available in ten languages. It also has the ability to reverse engineer compiling Java code and generate UML diagrams for it. (URL ArgoUML)

Gentleware has taken ArgoUML a step further and turned it into a good modeling tool. Poseidon comes in different flavors suited to different requirements. Poseidon supports forward and reverse engineering and documentation generation by using special-purpose plug-ins. Gentleware has not forgotten its open source moorings and offers the Poseidon for UML Community Edition free for individual software developers. (URL Poseidon)

It supports the UML 2.0 specification, which describes a visual language by which maps or models of a project can be defined. It is a progressive tool that covers all aspects of the development cycle, providing full traceability from initial design phase through to deployment and maintenance. It also provides support for testing, maintenance and change control. High quality documentation can be quickly exported from their models in industry standard .RTF format and imported into Word for final customization and presentation. (URL Poseidon)

Poseidon contains the following features: (URL Poseidon)

- UML 2.0-compliant state diagrams
- Complete copy/cut/paste of diagrams and semantic model elements
- Customizable UMLdoc for HTML
- Concurrent license server as a Windows service

Community Edition: (URL Poseidon)

- Fully implemented in Java, platform independent
- Forward engineering for Java
- Supports all 9 diagrams of the UML
- Saving format compliant to the UML 2.0 Diagram Interchange Standard
- Supports XMI 1.2 as the standard saving format. XMI 1.0, 1.1 and 1.2 can be loaded
- Advanced printing options
- Exports as GIF, JPG, PNG, PS, EPS, SVG
- Undo/Redo
- Copy/Cut/Paste
- Internationalization and localization for English, German, Russian, French, Spanish, and Chinese

'Apollo for Eclipse' from Gentleware is the first UML modeling tool that is based on open source technology developed by the Eclipse Graphical Modeling Framework (GMF) project and is tightly integrated into the Eclipse IDE . The fully synchronized roundtrip engineering employs the latest releases of UML 2.1 and Java 5 to provide an instant visualization of any existing Java code through UML class diagrams, and likewise propagate changes to the UML model throughout the code. The tool fully integrates into the Eclipse environment, which makes it easy for developers to view code as models, and vice versa. (URL Poseidon)

eUML for Eclipse is a plugin for UML modeling in Eclipse. eUML Free Edition comes with most useful diagrams: class diagram, sequence diagram, use-case diagram. The class diagram includes real-time synchronization with the java code inside Eclipse.

'Poseidon Community Edition' and 'Apollo for Eclipse' were used as a comprehensive UML-based analysis and design tools that aid in “GeoCHEAF” development from the requirements gathering stage through to analysis, design models, testing and maintenance.

3.3.3 Modeling approach

A business model shows the enterprise's function in the world, what it does, how and when. The model should emphasize the architecture, that is, the static structures in the enterprise, besides explaining the various flows of events, that is, the dynamic behavior of the elements in the architecture. (Maksimchuk and Nailburg, 2004)

A use case simply describes the actions that user takes on a system. A use case diagram includes users, use cases, and the many relationships between the two within a system and possibly one or more subsystems. A use case diagram identifies the actors in a system and the operations they may perform. These system use cases will capture the scenarios of how the various actors will use the system being built. (Roff, 2002) Use case diagrams address the business processes that the system will implement while the use cases describe ways the system will work and who will interact with it. (Maksimchuk and Nailburg, 2004)

Use case diagrams (context diagrams) are starting pointing for designing a system or sometimes, to describing an existing system. A use case diagram is the highest form of detail about a system (a high-level view of a system). It is an excellent way to communicate to management, users, and other non-development people what a system will do when it is completed. A use case diagram does not go into detail about how a system will do something. A use case diagram does, however, illustrate who will use the system and what they will able to do with it. (Roff, 2002)

Actors within an enterprise -all people, businesses, and systems- play a role in dealing with the business. Bringing these elements (business actors and business use cases) together, the business use case model for the business are created. (Maksimchuk and Nailburg, 2004)

Use cases approach serves as a bridge between what the business wants to be (which is expressed in the business models) and what the system design will be (which is expressed in the future architecture and application design models). This approach also keeps the developer focused on the user. (Maksimchuk and Nailburg, 2004)

During this inception phase of the design of “GeoCHEAF”, “who will use the system” and “what they will do it” were determined as shown in appendix B. Once this information has been gathered, it was turned into use case diagrams and continued on to design so that an enterprise was built that effectively meets the needs of newly identified users and requirements. The behavioral requirements of systems and business processes of the enterprise were also captured by writing use cases.

A business analysis model establishes what is done inside the business to fulfill its purpose. The business object model shows which people use which things to complete their functions. Together these provide the internal view of how the business responds to requests from the outside world. The business use case model and business analysis model depict how business can be described in terms of processes that achieve goals by collaborating with different types of resource objects. (Maksimchuk and Nailburg, 2004)

3.4 Extensible Architecture

3.4.1 HTML limitations and XML benefits

The real job of a markup language is to define information in a document. eXtensible Markup Language (XML) is an open web standard developed by the W3C (*the original recommendation was released in December, 1997*) making information passed across the Internet 'self describing (data format)', which is independent of platform, infrastructure, language or tool. XML transports structured text between client and server by using pairs of human-readable text-based tags. The tags may be nested in hierarchical tree structures upon texts. Like HyperText Markup Language (HTML), XML is an easy markup language to understand and use. It is platform independent and supports internationalization and localization. While HTML defines how to display content in browsers by mixing content and presentation together, XML is a semi-structured document, which has a custom element set that defines and holds the content to be displayed by strictly separating the two. XML, the encoding standard deals only with data structure. This simple fact that XML holds data liberates it from mere document description to become a general tool for data description. The motto of HTML is: “I know how it looks,” whereas the motto of XML is: “I know what it means, and you tell me how it should look.” (Lake 2001; Waters 1999; URL 2002; URL W3C)

Although XML and HTML look similar in coding style, XML differs from HTML in that programmers define the rules. HTML is not extensible; it is a fixed format markup language that is limiting. For example, in HTML one can only create one type of document -a web page. Unlike HTML which uses a limited number of “known” tags agreed upon W3C specifications as a fixed element set, XML allows definition of user-defined markup elements as custom tags. Thus XML is eXtensible that is the source of the “X” in XML. In addition, XML describe those user-defined tags in a meta language known as the Document Type Definition (DTD). However, DTD is difficult to write because its syntax is different from XML, so it has recently been supplemented by XML schema, which is a meta language defined in terms of XML itself. The XML Stylesheet Language (XSL) is more powerful than Cascade Style Sheets (CSS), with both transformation (XSLT) and formatting object (FO) components. (Tworkowski 2001; URL Wikipedia; Cameron 2003; Schutzberg 1999)

Though similar to HTML, XML is far more descriptive, in two ways. First, while HTML is primarily a 'syntactic (or presentation)' language, used to specify how things should look in a browser, XML is primarily a 'semantic” (or logical)' language, used to specify what things mean. Second, while HTML is a single language, XML is a meta-language –a language used as the foundation for the creation of any number of other languages. (White Paper, 2003a)

The problem with HTML was that people wanted a system that would understand the nature of the information it carried. The Internet’s native language, HTML, was not designed for these tasks like re-routing vehicles, running shortest-path algorithms and re-directing results to a variety of output devices, including full graphics for a dispatch office’s computer, a text-based list for a hand-held organizer and audible speech for a courier’s cell phone. HTML is a WYSIWYG language: “What You See Is What You Get”. But the problem with that is, “What You See Is All You've Got”, and that is not enough for Internet-based business purposes. HTML certainly is not enough to automate spatial processing via the Internet either. A set of 'tags' are needed to describe the information's nature. A new language is required to encode rules that describe different data types. (Waters, 1999)

HTML has been defined as 'very loose'. This means that browsers and other web tools have been instructed to ignore minor errors or inconsistencies within the markup up page. If one forgets to close a tag by only including the first tag (i.e. one type<bold> but forget </bold>) this will not negatively effect the document as a whole. In contrast, XML is very rigid, in that its guidelines prescribe that one wrong markup tag should render the document inoperable. (Tworkowski, 2001) One consequence of permitting authors to invent their own tags is that XML coding must be strictly correct and contain no broken or missing tags. (Brooks, 2004)

HTML provides a simple form of linking one web page to another. This linking mechanism, a coarse grained mechanism that only allows one to point to complete web pages and only to single points in those web pages, is one of the key foundations of the web. The link is established through an anchor or bookmark embedded in the target page and a link reference embedded in the source page. Note that such a link associates only two resources (the source and target pages) and it does so in a unidirectional manner (source to target). XML goes much further. XML provides a mechanism for linking multiple resources into a complex association. XML links also can be traversed in both directions. XML further enables fine-grained associations to be constructed. Where HTML linking only supports the linking or association of web pages, XML linking can associate single XML elements or even element fragments. In particular, this has profound implications for Geographic Markup Language (GML)'s ability to build associations between spatial features. (Lake, 2001)

3.4.2 Towards e(X)tensible HTML: XHTML

XML, unlike Standard Generalized Markup Language (SGML) is widely spread. (Courtaud, 2002) XML is similar to the concept of SGML, and in fact, in general terms, XML is a *subset* of SGML and a *superset* of HTML. The main purpose of XML as opposed to using SGML is to keep the system simpler by focusing on a particular problem -documents on the Internet. By doing so it is hoped to avoid the feature-creep that complicated SGML. The newest incarnation of HTML is eXtensible Hypertext Markup Language (XHTML), a more rigorous and robust version that is in fact XML, and requires documents to be 'well-formed' as does XML, but which uses mostly the familiar HTML tags. The main difference between HTML and XHTML from the standpoint of coding the language is that all tags must be closed, including the so-called 'empty' tags such as
 which, not being a 'container tag', must be 'closed' in every instance like:
. (URL Wikipedia) Further information pertaining to markup languages is available in the Appendix A of the dissertation.

XHTML is not merely an expansion of previous HTML versions as HTML 4.x was to HTML3.x, and so forth. It, although seemingly a direct descendant of the HTML lineage, is for all intensive purposes, a new markup language. It is an XML application that recognizes HTML 4.x and its predecessors (due to the backwards compatibility of HTML). Its documents can still be read by HTML browsers. XHTML is a reformation of HTML 4.x as an XML application so that HTML can access the advantages of XML. (Tworkowski, 2001)

The problems with HTML are the followings: (Abrams, 1997)

- HTML syntax is not XML-compliant, so HTML will not work with the new generation of web tools.
- HTML has many complex tags. It is not easy to implement all of them on portable computing devices, cars, kiosks, etc. Additionally, HTML needs more specialized tags for specific devices, like televisions.

XHTML characteristics are:

- Extensibility: It extends HTML by making it XML compliant.
- Modularity: It defines different groups of tags, and a device can indicate what group(s) it implements.
- Interoperability: It permits embedding of markup tags specific to vector graphics, multimedia, math, e-commerce, etc.
- Accessibility: It could be accessed by a wide-range of devices.

The e(X)tensible part of XHTML is the real key. Because it is XML-based, XHTML allows users to create their own document types. XHTML can be extended to do whatever the enterprise needs. To create a valid XHTML document two lines at the top of each page must be placed: (URL W3C)

- The first line selects the XHTML Doctype (strict, transitional, frameset). DTD (or DOCTYPE)
- The second line identifies the namespace being used.

HTML documents contain text interspersed with formatting elements. CSS allow formatting elements to be separated into reusable style sheets. Uneven CSS implementations in browsers and ingrained practices resulted in an extended acceptance period for style sheets. Promotion of web standards and improved browser implementations of the standards have recently resulted in a steadily increasing use of CSS to separate presentation attributes from content. Client-side scripts can be embedded in HTML documents to add interactivity to web pages and further process a document before it is rendered by a browser. The Document Object Model (DOM) interface allows embedded scripts to modify the structure, content, and presentation of documents. The combination of HTML, client-side scripting, and DOM is informally known as Dynamic HTML (DHTML). The most popular client-side scripting language is JavaScript. It is also possible to reference Java applets, Flash presentations, and other kinds of precompiled programs within HTML documents, but the approach has compatibility, latency, and security issues that limit its effectiveness. (Doyle and Lopes, 2005; URL W3C)

3.4.3 XML Family

XML is the basis of many key technologies on the web and many growing areas of software development. XML was first designed to take into account the needs of semantics on the web. But XML is now seen as a standardized and easy way to make web data understandable and processable automatically with computers by making up the meaning of the web data as the core of the web services through XML-based web. (Courtaud, 2002) XML-based web components have proved to be the critical technology that makes the web services application model possible. (White Paper, 2003a) Configurations for web applications and services are now commonly maintained within XML files. The extensive availability of XML parsers makes it more convenient for programmers to work with XML files rather than develop parsers for proprietary file formats. (Doyle and Lopes, 2005) On such a semantic web, everything -from web documents to technologies for their visualization- tends to be presented using XML.

XML describes a family, or more correctly a class of data objects called XML documents which are stored on computers, and partially describes the behavior of programs that process these objects. (Tworkowski, 2001)

XML family has an extensive set of associated languages or a large set of XML-related processing technologies:

- XML Base
- XML Inclusions (XInclude)
- XML Fragment Interchange
- DTD
- XML Schema and XSD
- Extensible Stylesheet Language (XSL)
    - XSL Formating Objects (XSL-FO)
    - Extensible Stylesheet Language Transformations (XSLT)
- XML Path Language (XPath)
- XML Linking Language (XLink)
- XML Pointer Language (XPointer)
- XML Query (XQuery)
- The Document Object Model (DOM)
- XForm
- XML Update Language (XUpdate)
- Simple API for XML (SAX)

and specialized languages

- Scalable Vector Graphic (SVG)
- Extensible 3D (X3D)

- Synchronized Multimedia Integration Language (SMIL)
- Geography Markup Language (GML)
- Resource Description Framework (RDF)
- Mathematical Markup Language (MathML)
- and the hundreds dedicated to specific applications

XML documents have a basic structure defined by the base XML specification, but this is very generic. There are two main standards for defining the structure of document formats using XML. The earlier standard is called a DTD, which allows the description of the overall structure of a document, but does not provide much control in terms of data typing or validation of those documents. (White Paper, 2003c) DTDs proved to be inadequate for the needs of users of XML due to a number of reasons. The main reasons behind the criticisms of DTDs were the fact that they used a different syntax than XML -SGML syntax- and their non-existent support for datatypes. (Obasanjo, 2001) The more recent standard is XML Schema, which provides very detailed control over the structure and content of XML documents. As XML Schemas include type information, it is possible to validate documents to ensure that they are in conformance with the schema, in terms of both their structure and the data they contain. DTDs, on the other hand, can be used only to verify the structure of a document. (White Paper, 2003c)

Unlike C, C++ and even Java, XML is not a binary language. With a simple text editor, anyone can open any component based on any XML language and look at what is inside. This is important in a number of respects. Any XML component can be 'validated', i.e. read and checked for conformity with public standards. While this would be tedious work for the human eye, validation programs can easily parse and validate non-binary files. Also, organizations can develop more finely tuned validators, to make sure all components conform to internal standards or industry specific schemas. (White Paper, 2003a)

XML Schema Definitions (XSDs) can draw on a comprehensive set of predefined data types, as well as create new user-defined types. W3C XML Schema is a schema-definition language expressed in XML syntax.

An XML based schema definition language called 'Schema for Object-oriented XML (SOX)' is for defining the structure, content and semantics of XML documents to enable XML validation and higher levels of automated content checking. SOX provides an alternative to XML DTDs for modeling markup relationships to enable more efficient software development processes for distributed applications. SOX also provides basic intrinsic datatypes, an extensible datatyping mechanism, content model and attribute interface inheritance, a powerful namespace mechanism, and embedded documentation. As compared to XML DTDs, SOX dramatically decreases the complexity of supporting interoperation among heterogenous applications by facilitating software mapping of XML data structures, expressing domain abstractions and common relationships directly and explicitly, enabling reuse at the document design and the application programming levels, and supporting the generation of common application components. (URL W3C)

XML's popularity has resulted in a proliferation of schemas and related Internet standards. Enterprises are creating these XML dialects to suit their particular business needs. These standards vary not only from sector to sector, but even among individual systems within the enterprise. Integrating these different XML formats can quickly become a nightmare. XSLT, which is a native XML transformation mechanism, provides a mechanism to map one to another. XSLT is a language (defined in XML itself) that allows developers to define rules for programmatically transforming the structure of XML documents, such as transforming XML to XML, XML to other XML-compatible languages (e.g., XHTML). XSLT does not contain just mechanisms for mapping XML documents from one form to another, but it can also be used to convert common document formats such as Comma-Separated Values (CSVs), HTML, DTDs, XSDs and so on. XSLT mappings can be applied dynamically at runtime, thus automating one of the more tedious aspects of integration –data transformation. (White Paper, 2003c) For the beginner, although XSLT provides an extremely powerful XML mapping and transformation capability, it also has a considerable technical learning curve since XSLT mapping definitions can quickly become very complex. (URL Cocoon) XSLT is designed to be used with XML documents to transform data into a form appropriate for presentation in a particular context or into an alternate XML structure. The output from an XSLT transformation can be another XML format. XSLT is ideally suited to creating HTML documents from XML server-side with the HTML produced being processed by a user's web browser in the normally way.

Apache Cocoon, a well-known XML transformation framework, supports dynamic content generation to multiple client types (channels) through its XSLT-based eXtensible Server Page (XSP) templating language. (Doyle and Lopes, 2005)

XSLT is usually used in conjunction with another standard XML technology-XPath. XPath is an expression language used by XSLT to address a part of an XML document. XPath makes it easy for developers to select, group, sort, or compare data in XML documents. In XPath, an XML document is treated as a logical structure and is viewed as a hierarchy of nodes. The combination of XSLT and XPath enables developers to build very sophisticated mappings. For example, it is possible to construct conditional mappings, where the transformations depend on the actual dynamic data in the document being processed. This flexibility and power make the XSLT/XPath combination a fantastic tool for systems integrators, who often have to integrate data from many incompatible sources. (White Paper, 2003c; Obasanjo, 2001)

Smallx is a library and set of tools that is being developed to process XML infosets. It has two distinct features in that the infoset implementation allows streaming of documents and that processing of infosets can be accomplished using a concept called pipelines. The library contains a full compliment of technologies including XPath and XSLT. All of the sources for smallx are organized into a set of Netbeans projects. (https://smallx.dev.java.net/)

XLink and its associated XPointer specification are intended to provide linking functionality on the web. This will provide XML-based linking functionality equivalent to HTML, but with significant enhancements (more sophisticated form of hyperlink). Relevant parts of XLink and XPointer have already been implemented in SVG and probably will be implemented in at least some other XML applications.

XML query languages like XPath and XQuery address the problem of accessing specific information inside the tree structure of XML data.

XQuery is an attempt to provide a query language that provides the same breadth of functionality and underlying formalism as SQL does for relational databases. XQuery is a functional language where each query is an expression. XQuery expressions fall into seven broad types; path expressions, element constructors, FLWR expressions, expressions involving operators and functions, conditional expressions, quantified expressions or expressions that test or modify datatypes. The syntax and semantics of the different kinds of XQuery expressions vary significantly which is a testament to the numerous influences in the design of XQuery. XQuery has a sophisticated type system based on XML schema datatypes and supports the manipulation of the document nodes unlike XPath. Also the data model of XQuery is not only designed to operate on a single XML document but also a well-formed fragment of a document, a sequence of documents, or a sequence of document fragments. (Obasanjo, 2001)

XML appears to have the potential to make a significant impact on database applications, and XML is already being used in several database applications. One of the main reasons for this is that the “superiority” of XML schemas for data modeling -recursion and union types are easily specified using XML schemas. In order to do data modeling effectively, it should be studied systematically. A data model has three constituents to it -structural specification, constraint specification, and operators for manipulating and retrieving the data. Regular tree grammar theory has established itself as the basis for structural specification for XML schemas. Constraint specification is still being studied, and there are some approaches such as 'path-based constraint specification' and 'type-based constraint specification', with strong indications of type-based constraint specification as a very suitable candidate. Operators are available as part of XPath, XSLT, XQuery etc.

Many applications need to access both XML and relational data. This is often done by representing relational data as XML or by using an XML view of relational data. The ISO SQL/XML specification provides a mapping from relational data to XML. Given that, XQuery can be useful both for XML and XML views of relational sources (XML queries on relational sources), but mapping XQuery to SQL is complicated by the lack of nested structures in the relational model and the difference in expressive power between XQuery and SQL. XQuery facilities to access XML documents like databases for pattern matching and manipulation.

W3C has released XML Syntax for XQuery (XQueryX), in June 2001, that has the same semantics but uses XML based syntax instead called XQueryX. XQueryX is designed to be machine-readable to enable standard XML tools to create, read and modify queries. Expected uses of XQueryX include: automatic generation of queries, queries on queries (where queries are queried, and may be transformed into new queries), parser reuse (where one parser may generate XQueryX for multiple systems) and embedding of queries in XML documents. (URL W3C)

The XML DOM, a series of W3C specifications, defines a standard way for accessing and manipulating XML documents. The DOM presents an XML document as a tree-structure (a node tree, XML document trees), with the elements, attributes, and text defined as nodes. (URL W3C) Simple API for XML (SAX) is a serial access parser for XML. It provides a mechanism for reading data from an XML document. It is a popular alternative to the DOM. (URL Wikipedia)

GML is an XML-based encoding standard (or an XML grammar written in XML Schema) for the modeling, transport and storage of geospatial data and information, including both the spatial and non-spatial attributes of geographic features. (URL, 2003a) It has been developed by the the OGC as medium of uniform geospatial data storage and exchange among diverse applications, especially in a wide-area Internet context allowing web browsers the ability to view web based mapping without additional components or viewers. (URL, 2002) Since spatial databases are also used to store geospatial information, the concepts of GML can be used for the storage and exchange of spatial databases. GML is a uniform format to store geospatial data. GML representation of geospatial data and information is unique but the use of information can be different and meaning can vary depending on the context. This makes the data very flexible and portable. (Ying et al., 2006) The key concepts used by GML to model the world are drawn from the OGC Abstract Specification that provides a variety of kinds of objects for describing geospatial content including features, coordinate reference systems, geometry, topology, time, units of measure and generalized values. (URL, 2003a) GML must be styled for presentation. Presentation may mean being styled to a graphical form such as a map, but equally it could mean being styled to text or even to a sequence of voice instructions. (Lake, 2001) The weakness of a GML file is its large size because it is a single ASCII file.

The difference between XML and GML is that GML provides support for the geometric elements corresponding to the Point, LineString, LinearRing, Polygon, MultiPoint, MultiLineString, MultiPolygon and GeometryCollection. (URL, 2003a)

GML 1.0, published 1.0 in May 2000, was based on a combination of XML DTDs and RDF. This was an awkward but useful combination. DTDs were in widespread use, but lacked the ability to support type inheritance, had no underlying semantic model, and did not support namespaces. RDF on the other hand was less accepted but did offer namespace support, distributed schema integration, type hierarchies and a simple semantic model. While it was possible to more or less use all of these features it was at best an awkward combination. On February 20, 2001, the OGC published Version 2.0 of the GML, thus laying the foundations for the development of a geospatial web. GML 2.0 is based entirely on XML Schema and the adoption of XSD is a major advance. XML Schema incorporates support for type inheritance, distributed schema integration, and namespaces. Moreover there are now a great variety of tools and parsers that support XML Schema and more are anticipated in the near future. GML 2.0 makes use of the XLink and XPointer specifications to express relationships between geospatial entities. This means that such relationships can be expressed between features in the same database or between features across the Internet. Furthermore, GML 2.0 allows relationships to be constructed between GML feature elements in different databases without requiring any modification of the participating databases. No more than read access is required to establish a relationship. With GML 2.0, GML has reached a stage of maturity that enables the construction of real spatial datasets, the interchange of spatial information and the construction of distributed spatial relationships. (Lake, 2001)

Current version GML 3.0 has been extended to represent geospatial phenomena in addition to simple 2D linear features, including features with complex, non-linear, 3D geometries, spatial and temporal reference systems, topology, units of measure, metadata, gridded data, features with 2D topology, features with temporal properties, dynamic features, observations, and coverage visualization. GML 3.0 is almost entirely backwards compatible with GML 2. Like GML 2, GML 3 will play a key role in both spatial data encoding and transport, and in the description of geographic objects for geospatial web services. (URL, 2003a)

GML 3.0 is modular, meaning that users can select out only the parts necessary for use, which simplifies and minimizes the size of implementations. Implementers may use a selective subset of the GML 3.0 schemas sufficient to support the definitions in their application schemas. GML 3.0 also includes a sample packaging tool that creates a tailored schema containing only the required components from the GML core schemas. GML application schemas may also be constructed as part of a model driven process by automated translation to XML/Schema from conceptual models defined in other conceptual schema languages such as UML. A UML diagram is used to show the hierarchy of GML objects defined in the XML schemas. GML 3.0 uses an object hierarchy to define the various entities such as features, geometries, and topologies. (URL, 2003a)

Arc eXtensible Markup Language (ArcXML) is ESRI's flavor of XML. It is used for sending requests and receiving responses through ArcIMS' spatial server. (URL ESRI) LandXML is a common, open data format, or schema, which describes industry-specific data such as points, parcels and alignments. It is a specialized XML data file format containing civil engineering and survey measurement data commonly used in the land development and transportation industries. (URL LandXML) There are third party editors to help with programming in ArcXML. One such editor is called Xeena and can be downloaded from the IBM web site. Xeena is written in Java and is no-cost. Another editor is called XMLSpy but costs. A third option is Microsoft's XML notepad. (URL ESRI) ArcXML will eventually be a superset of GML. ArcXML provides the glue to link the parts of ArcIMS. For those using ArcIMS who are not programmers, there is no need to learn ArcXML; it is written automatically. ArcXML stores configurations and display information for web applications as well as playing a part in the movement of data from the server to the client. The response from a service might be ArcXML describing candidate geocoding points along with their x,y coordinates, a pointer to a zip file of shape files or the location of raster map images. (Schutzberg, 1999)

Written in XML, SVG and X3D are the application language choice for visualizing information in 2D and 3D, respectively. They can be integrated easily with other members of the large XML family -other XML application languages- and can also be processed using any XML-relevant tools and technologies. For example, to view maps in XML, SVG could be used to present GML data to the user by on the fly conversions using XML transformations such as XML Schema, XSLT or one could use SVG images within an XHTML web page that also contains forms using the XML-based Xforms specification. SVG is intended to replace many uses of bitmap graphics on the web and provide a 2D vector graphics standard that is not vendor-specific (compare Microsoft VML) and that is open source (compare Adobe's Flash/SWF). Microsoft has developed Vector Markup Language (VML) as an XML-based solution for vector graphics. Microsoft (MS) Office 2000 creates graphics in VML from MS Word and MS Powerpoint. On the viewing side, Internet Explorer is the only program capable of viewing these VML graphics. AutoCAD Map also outputs VML graphics. The widespread adoption of SVG clients, particularly those natively embedded in web browsers as it is in Firefox and Opera, but Safari and Internet Explorer requiring a plugin.

SVG is an XML-based language used to describe an image, especially for display in a web browser. It is a standard developed by the W3C. The use of the word "scalable" in SVG has two meanings. First, vector graphic images can easily be made scalable, i.e., they are not limited to a single and fixed pixel size. This means SVG format can be displayed on any device of any size and any resolution without changing the image clarity. This contrasts with raster image files, which are difficult to modify without loss of information. Second, a particular technology can accumulate a larger number of files, a large number of users, and a wide variety of applications on the web. Other characteristics of SVG include a smaller file size and searchable text information. Text information inside SVG is still text and can be searchable, while text information inside the raster file becomes integrated into the image and is no longer recognized as text. Further, SVG is also based on XML and therefore conforms to other XML-based standards and technologies, such as XML Namespace, XLink, and XPointer. XLink and XPointer allow for linking from within SVG files to other files on the web, like a GML data element, HTML pages, or other SVG files. (URL W3C)

Adobe SVG viewer is a plug-in for conventional web browsers. (http://www.adobe.com/svg) The Mozilla SVG implementation from the Mozilla project is a native SVG implementation. This is as opposed to plug-in SVG viewers such as the Adobe viewer which is currently the most popular SVG viewer. (http://www.mozilla.org/projects/svg/) Batik standalone SVG viewer (SVG toolkit) from the Apache Software Foundation can also be used Java applications to dynamically create and display SVG. (http://xml.apache.org/batik/) Other well-known vector-drawing tools such as Adobe Illustrator (version 9 and onward) and Corel (version 10 and onward) have SVG export facilities.

SMIL is a W3C recommended XML-based language, which facilitates the construction of interactive multimedia applications for the Internet and mobile devices and enables simple authoring of interactive audiovisual presentations. SMIL is a markup language like HTML and VRML with a different tags and simple structure to integrate and manipulate images, text, streaming audio, video and other multimedia for “rich media”/multimedia presentation on the web. SMIL also enables authoring of TV-like multimedia presentations. It is an easy-to-learn HTML-like language, and many SMIL presentations are written using a simple text-editor. (URL W3C)

Basically there are two major issues in using XML, one is how to generate an XML document and the other is how to parse an XML document. There are different XML, XSLT, XLink and XPointer tools available to achieve these issues, for instance an XML tool, such XMLSpy (http://www.altova.com/), or an XML editor, such as XMLwriter (http://www.xmlwriter.com). Open source Saxon is a Java-based XSLT and XQuery processor. (http://sourceforge.net/projects/saxon) Xalan-Java from the Apache Software Foundation is a Java-based XSLT processor for transforming XML documents into HTML, text, or other XML document types. It implements XSLT and XPath. (http://xml.apache.org/xalan-j/) Mozilla web browser implements simple XLink links. The most full-featured XLink processor is the XLiP processor from Fujitsu, which is a Java application. XLink Processor(XLiP) is an implementation of XLink and Xpointer.

(http://software.fujitsu.com/en/interstage-xwand/activity/xbrltools/xlip/)

New generation browsers such as the X-Smiles browser enable multiple XML languages to combined into XML-based Web pages. X-Smiles is a Java based open XML-dedicated browser for exotic devices. (www.x-smiles.org). It is intended for both desktop use and embedded network devices and to support multimedia services. The main advantage of the X-Smiles browser is that it supports several XML related specifications and is still suitable for embedded devices supporting the Java environment.

Formatting Object Authoring (FOA) is an authoring tool that applies XSL-FO styling to XML content. Authors can build, modify, or import a library of style components, which can be re-used across documents. Based on the style information, FOA generates an XSLT stylesheet, takes in XML content, and produces an XSL-FO document, which can then be rendered into different output formats. (http://foa.sourceforge.net/)

XDuce ('transduce') is a typed programming language that is specifically designed for processing XML data. One can read an XML document as an XDuce value, extract information from it or convert it to another format, and write out the result value as an XML document. Since XDuce is statically typed, XDuce programs never yield run-time type errors and the resulting XML documents always conform specified types. (http://xduce.sourceforge.net/)

3.4.4 XML-based "GeoCHEAF"

The CH community needs a global and standardized format for encoding CH data sets that are from different sources with different formats in order to integrate and present multiple data sources and types in a comprehensible fashion. In this manner, the user can focus on extracting meaning from data without being required to explicitly manage the heterogeneous data. Since XML provides a common medium of data description and display for diverse systems to understand each other, the eXtensible architecture of "GeoCHEAF" can describe virtually any type of CH data and it can also map to the structure of the data as a well-formed XML document and/or a highly structured hierarchical data storage like XML Native Database (XND).

XML is a commonly available export format for databases. The XML encoding procedure is independent of hardware and software, and therefore guarantees the easy transfer of files to different systems.

In SIS, XML might be used to define a query. A query in XML would not, in substance, be different than what it is asked of a SIS today: "take the area I describe below and please buffer it. Then, send me the answer". The response might also be delivered in XML. The content of the reply, again, might not be so different than a reply seen today: "Here's where to look for the bitmap showing the answer". The difference using XML is that the data (the geometry in question) and the request (in the example here, the buffer) is included in a single XML document. The reply, basically a pointer to the bitmap, is also within an XML document.

Taken together in the design of the extensible architecture, the use of open exchange format files (GML files) and the modular structure of the web-based SIS, customized with scripting languages, increases the level of cross-platform interoperability and Internet-based research. Consequently, for the CH domain, "GeoCHEAF" makes use of the ubiquity of XML and its family as:

- an X-recording language (*lingua franca for the CH domain*) for the storage, exchange and preservation of data and/or information about CH resources and/or artifacts
- an open- and industry-standard way of representing data and database, in particular, for the web
- a geospatial and non-spatial interoperability of the CH enterprises to share information source with one another, and to enable linked geospatial datasets through GIS services and web services

- a behind-the-scene language used to move structured data between web applications/services.

4. WEB-BASED DISTRIBUTED MULTI-TIER ARCHITECTURE

To make the architecture distributed, scalable, flexible, it is designed in a multi-tiered manner. Multi-tier architecture (may also be referred as an n-tier architecture in reference to the unlimited number -n) provides the simplicity of developing the system on one development machine and the flexibility of moving the components to several distributed machines in production.

A multi-tiered architecture design should be used as the high-level architecture design for dynamic web applications. It involves subdividing the web application into functional components and partitioning these components into a set of physical tiers. (Shen, 2004) A tier is composed of one or more computers that share one or more common characteristics. Tiers are used to allow servers and client computers to be optimized for specific tasks, such as interacting with users, serving web pages and hosting databases. In that way, the administration and deployment overhead required of distributed applications are reduced.

The multi-tiered architecture is fundamentally about servers. Key aspects of this perspective include the number of servers, the role each server plays in the solution, the relationship between servers and how the multiple servers collaborate together to meet enterprise-level operational requirements. It is also fundamentally concerned with components, includes packaging components into deployment units, mapping deployment units to operating system (OS) processes and mapping these processes to servers.

The multi-tiered architecture ensures a clean division of responsibility and makes the system more maintainable and extensible by structuring the servers and user computers, and distributing functionality across them to efficiently meet the operational requirements of the enterprise. Hence, it has become the dominant paradigm for large-scale enterprise web applications, and is reasonably popular for smaller-scale applications as well.

To deliver multi-tiered applications with separation of presentation, process, and data functions, the web-based distributed n-tier architecture of “GeoCHEAF” breaks the application logic into three basic tiers: the user tier, the middle-tier, and back-end tier. Nevertheless, the deployment of this architecture can vary due to the requirements and/or scale of an enterprise (see figure 4.1), such as four-tier architecture for larger enterprises like that the Ministry of Culture and Tourism of Turkey should address the four-tier distributed architecture scenario for their applications by separating the web servers and applications servers into their own tiers.

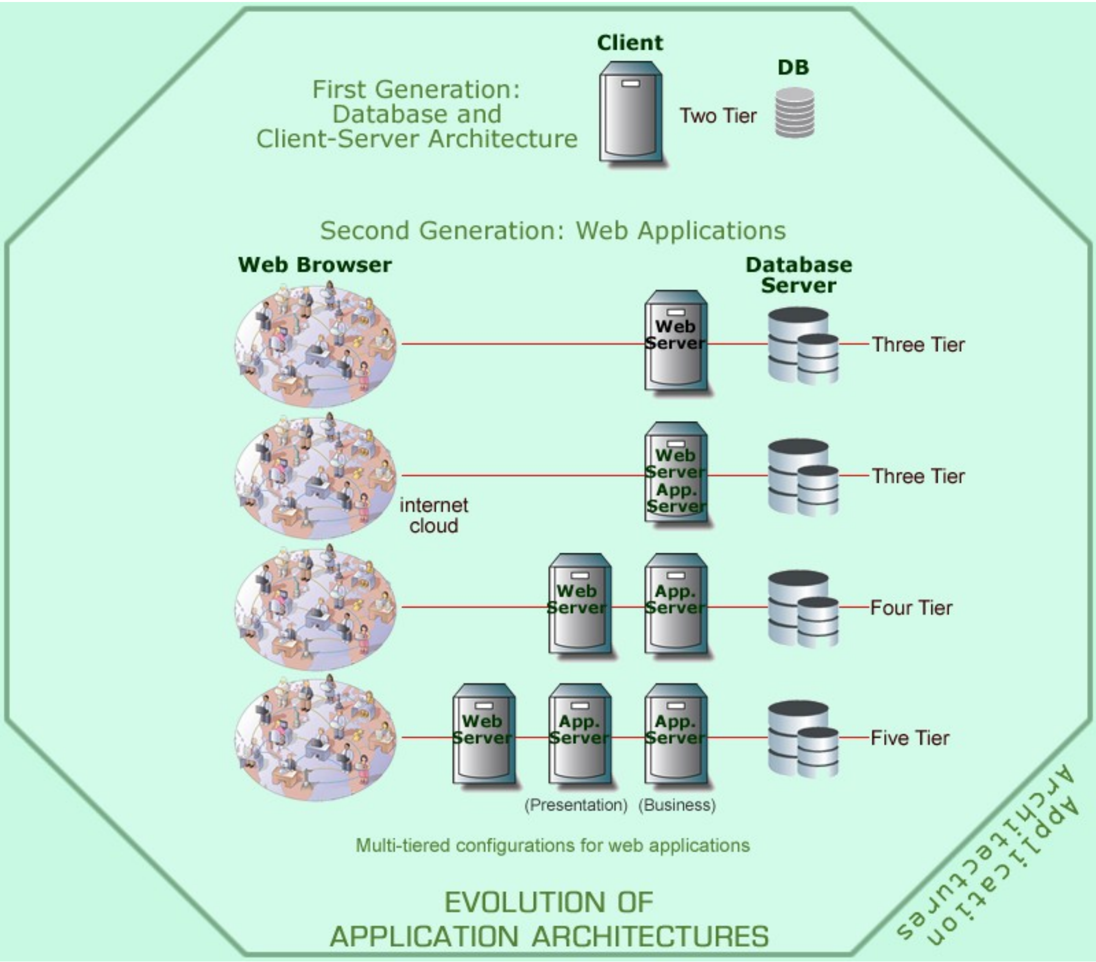

Figure 4.1: Application architectures

The distributed three-tier architecture of “GeoCHEAF” for “KaleTakimi”s web applications consists of three tiers and additional sub-tiers. Table 4.1 shows those tiers in process order. The multi-tier architecture of “GeoCHEAF” that supports web applications is shown in figure 4.2.

Table 4.1: The tiers and sub-tiers of “GeoCHEAF”

Tiers	***Sub-tiers***	***Function***	***Description***
User Tier		Web browser as a Thin User GUI or Thick Client	one or more applications or the Web browser
Middle-Tier			Web Application Tier
	Presentation Tier	Web Server	Also refers to Presentation Logic, View Layer, Web tier
	Business Logic Tier	Application Server	Business Logic
	Data Access Tier		Integration Tier, data persistence, persisting, data access concerns, object-relational mapping
Back-End Tier		Data Repository	Also refers to Underlying Tier, Data-Tier, and Enterprise Information System (EIS) Tier

The infrastructure required to support this architecture consists of servers to host the web and business components, and the data tier. Network devices (routers and switches) and communication protocols, like TCP/IP, connect servers within the enterprise.

The user tier is where the data model is consumed and presented. For a web application, the user tier is normally the web browser that communicates with the web server. (Shen, 2004) In this design, web-based distributed computing has been implemented using a thin client model that enables conversion of client/server applications to the web. A thin client makes it possible for all business processing to be performed in a controlled environment on a managed server (fat server). It also eliminates the requirement that clients download additional software in order to use the site. This distributed computing architecture enables large number of users to easily and efficiently access information from all over the world. A standard web browser is used to access and manipulate dynamic information over the Internet. (Guney et al., 2005)

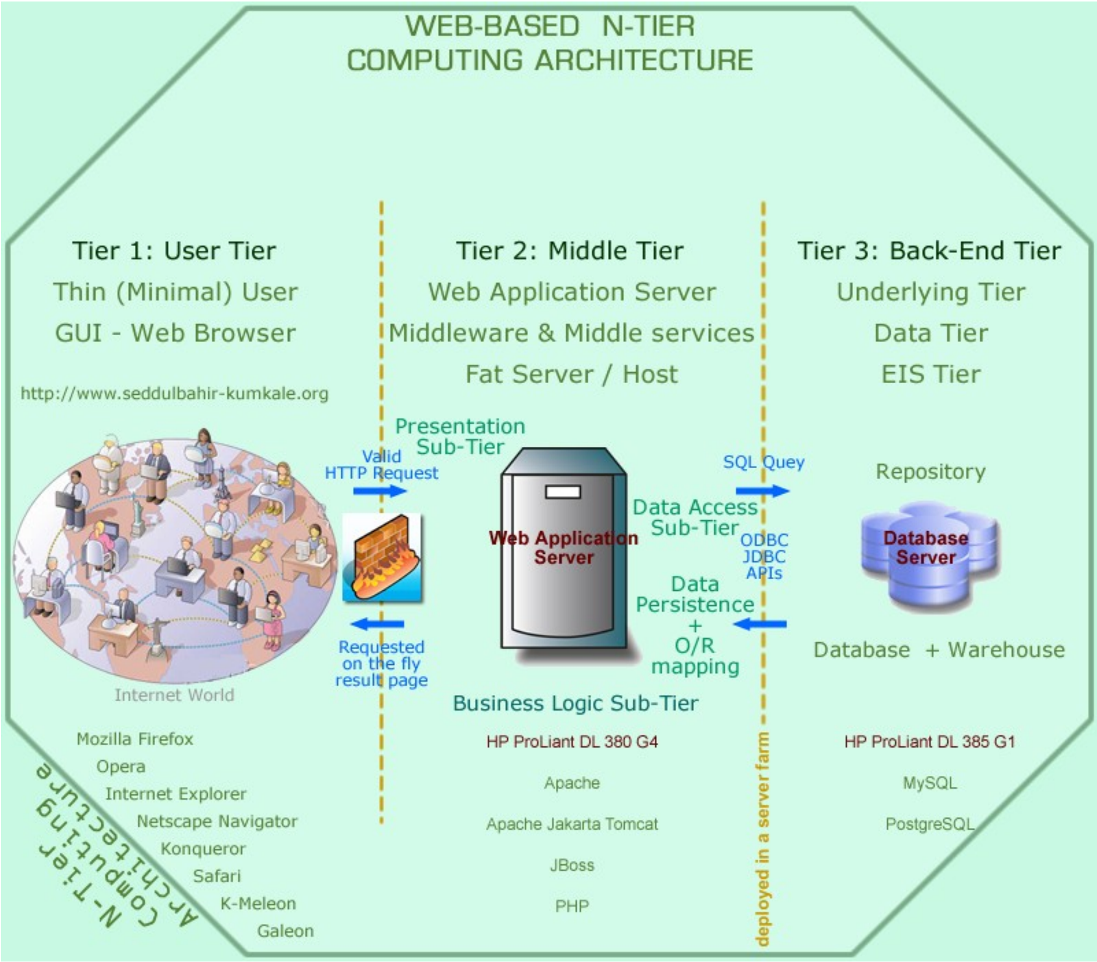

Figure 4.2: The multi-tier architecture of "GeoCHEAF"

Web browsers process user interface commands, format and send request messages to web servers, wait for and interpret server response messages, and render content within the browser's display window area. HTML, CSS and XHTML are the most common content types on the web. Browser extensibility features allow many other content types to be displayed by deferring their rendering to registered plug-in components (helper applications) that handle the content. Myriad browser plug-ins provide all sorts of client-side processing. The pervasiveness of HTML makes it a friendly target for dynamic content generation systems. (Doyle and Lopes, 2005)

The back-end tier of the multi-tier architecture stores the existing applications, files, and data required by the middle tier. It contains both database and warehousing storage environments through object-relational databases, XML databases and legacy systems. A more detailed description of data tier of "GeoCHEAF" is provided in the Data Architecture chapter.

The design issues associated with each application tier will be discussed in the section of middle-tier architecture in this chapter.

4.1 Evolution of Application Architectures

The web application architecture has evolved into an effective infrastructure for a wide class of complex, interactive services. Several factors shaped the mostly ad-hoc evolution of the web application development: ad-hoc programming like CGI, J2EE and .NET, web application development frameworks, web services. Throughout this chapter of the dissertation, an extensive investigation, categorization, strengths&weakness, cost-benefit analysis of and standards related to enterprise-class web applications and middle-tier technologies are presented. Evolutionary steps from earlier computing architectural frameworks in terms of the advances in web application technologies are categorized as following: (in table 4.2 and in figure 4.3).

Table 4.2: The generations of web application technologies.

Generation	***Application***	***Tier***	***Type***	***Computing***	***Model***	
Zero Generation	Mainframes					
First Generation	Database and Client-Server Applications	Two Tier	Document-centric	Distributed computing	Early Client-Server Model Fat Client	B2B
Second Generation	Web Applications	Three, Four, n-Tier	Application-centric	Web-based distributed computing	Internet, Web Browser, Middleware	B2B B2C C2H H2A H2H
Third Generation	Web services	Tierless	Service-centric	Web-based distributed computing	Internet Middleware	C2C A2A B2B H2A C2H

B: Business, C: Computer, A:Application, H: Human

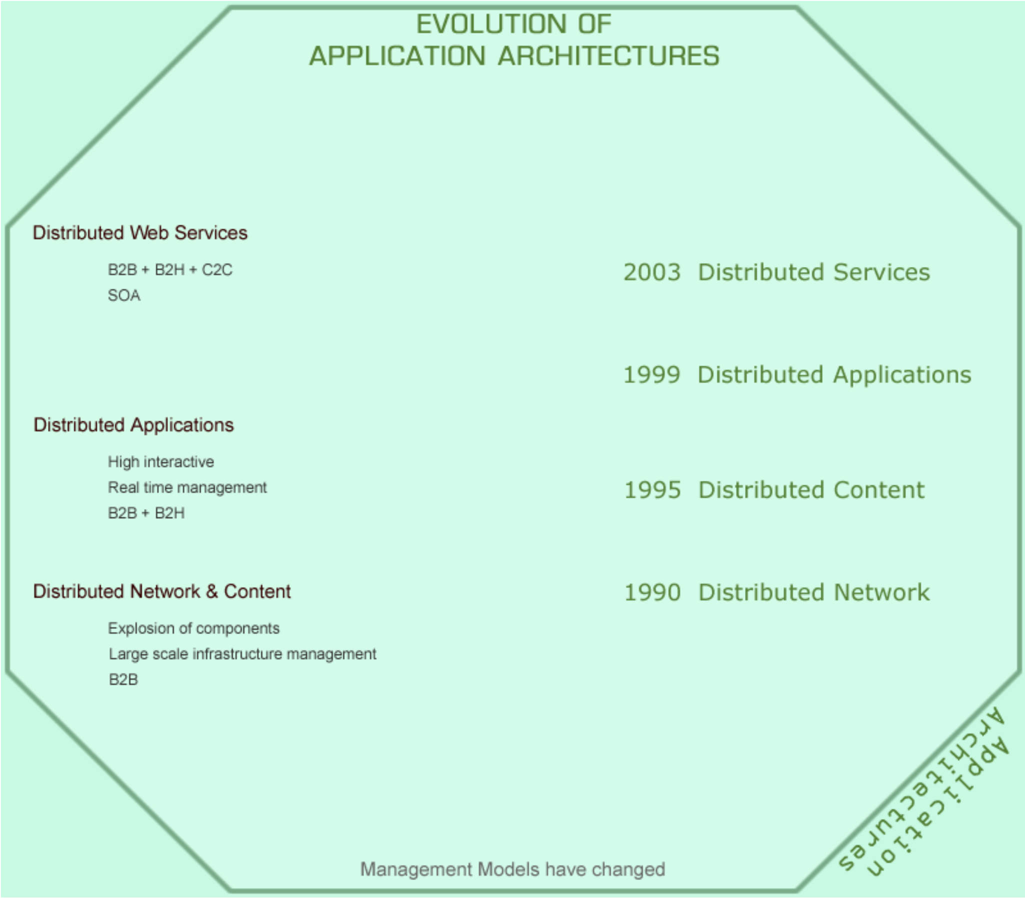

Figure 4.3: Evolution of web application architectures

4.1.1 First generation: database and client-server applications

The first client-server applications for business were built on a basic client-database design. A client application, running on a PC, issued requests to a database, using typically Remote Procedure Calls (RPC) and Structured Query Language (SQL). Thanks to the emergence of standardized database products in the 1980's, developers could build client-server applications based on off-the-shelf databases, rather than developing the entire application and database from scratch. The standardization of relational database architectures and programming languages coupled with advancements in PC hardware enabled the rapid proliferation of specialized database-driven applications. The clients run on the PCs with all of the presentation logic as well as some business logic embedded in them, leaving the other tier to host the solution's database. This is typically referred to as fat clients. (White Paper, 2003a)

The application builds on a standard database package, making it affordable, but the application has some limitations. Although the server can be accessed by more than one client, the client application requires a top-of-the-line PC, and all clients must be on the same enterprise's network. In addition, when the number of users exceeds 100 simultaneously, performance begins to deteriorate. Also, it has limited flexibility in moving program functionality from one server to another.

4.1.2 Second generation: web applications

The most important difference between the two generations is that, in contrast to a dedicated connection between the client and the server, web applications are designed to communicate "through the cloud," i.e. over the Internet –an enormous, publicly accessible network based on agreed standards (HTTP over TCP/IP). Hypertext Transfer Protocol (HTTP) is the standard protocol currently used to access the Internet. According to the W3C, HTTP 'is an application-level protocol for distributed, collaborative, hypermedia information systems'. (URL W3C)

HTTP does not remember past commands and will forget the current command as soon as it is executed. As such, it is very hard to make HTTP to be more interactive and dynamic without additional technologies such as JavaScript, cookies, PHP and other programming scripts. Nevertheless, efforts have been made to improve HTTP. From the first HTTP 0.9, through HTTP 1.0, to the latest HTTP 1.1, numerous improvements have been made. (URL W3C)

The architectural foundation of the web is the request-response cycle realized by the HTTP, HTML and XHTML standards. The Representational State Transfer (REST) architectural style provides a model architecture for the web that was used to rationalize the definition of the HTTP 1.1 recommendation. Modularity, extensibility, and inversion of control are characteristics inherent in the web that have allowed incorporation of features supporting dynamic content. Inversion of control is implemented on both clients and servers by various plug-in, content handling, and filtering interfaces that allow custom components to be invoked in response to events. (Doyle and Lopes, 2005) The web was originally designed for the delivery of online documents, but now serves as the primary vehicle for the delivery of dynamic networked applications.

Although early web architectures allowed web browsers to access databases directly, generally through a Common Gateway Interface (CGI) which is part of the web server, the advent of the application server proved even more useful when the client was no longer a PC-based application, but a web browser. As with the client-server architecture, web application servers brought increased performance and scalability, as well as enabling far more sophisticated business logic. (White Paper, 2003a)

The web gave enterprises the opportunity to serve clients directly over the Internet, but taking a business online entailed a number of challenges, including the enormous workload that would be placed on web servers and web application servers. Obviously, an online system would have to support an enormous number of clients. While even the largest first-generation client-server applications were designed to support hundreds of simultaneous clients, the Internet could open an application to hundreds of thousands, even millions of customers. (White Paper, 2003a)

Also, unlike dedicated PC clients, web browsers have no inherent knowledge about the systems to which they are talking because of the stateless nature of the protocol. Thus web servers must be highly scalable to handle the large number of incoming requests, as well as a more sophisticated outgoing presentation logic. Similarly, application servers must scale dramatically to provide load balancing and transaction management in communications with databases. (White Paper, 2003a)

While scaling up to the enterprise for the web application development, it would be practical to separate infrastructure concerns from architecture concerns like business logic and presentation. As the e-business grows, both the business tier as well as the data tier may need to be scaled to accommodate the growth. The middle tier may be expanded to include several web servers to serve a growing number of users, as well as dedicated servers to support middleware business logic components. Adding more database servers to accommodate the growing data may expand the data tier. More infrastructure is required to support this architecture.

4.1.3 Third generation: web services

Web services are enterprise applications, much like the ones in the previous section, so fundamentally they do what the second generation web applications do today. However, the way they do things is different. The difference is that they use languages and protocols based on a universally accepted XML standard to function more intelligently. Unlike typical applications, web services literally describe themselves to the outside world – telling what functions they perform, how they can be accessed, and what kinds of data they require. (White Paper, 2004b)

Just as the second generation of application architecture grew from first generation technologies, the web services architecture is based on –and incorporates the advantages of– its predecessors. It lies at the convergence of three technologies. First is the web with universal standardized communications using standard protocols such as HTTP and XML as a formatting language. Second is the evolution of Service Oriented Computing (SOC) where data and business logic is exposed through programmatic interfaces, like web application servers built on the J2EE environment using concepts from SOC. (White Paper, 2003a) Third is the best aspects of component-based development. Like components, web services represent functionality that can be easily reused without knowing how the service is implemented. Unlike current component technologies which are accessed via proprietary protocols, web services are accessed via ubiquitous web protocols (ex: HTTP) using universally-accepted data formats (ex: XML). (White Paper, 2003b) Though web services are based on the same foundation, they take application design to the next level of openness and interoperability. (White Paper, 2003a)

Web service represents an information resource or business process or programmable application logic that can be accessed over the web by another application, and that it communicates using standard Internet protocols. What distinguishes web services from other types of web-based applications is that web services are designed to support application-to-application communication. Other web applications support human-to-human communication (email and instant messaging) or human-to-application communication (browsers). Web services are designed to allow applications to communicate without human assistance or intervention. (White Paper,

2002) In other words, web services does for computer-to-computer interactions what the Internet and the browsers did for computer-to-human interactions. (White Paper, 2004b) This distinction makes XML-based web services a giant step ahead of any previous application model.

In a nutshell, web services are applications that do a better job of communicating with other applications because they are based on open standards, they are easy to learn and have a low price point.

4.2 Early Second Generation Technologies

4.2.1 Common gateway interface

The earliest technologies that allowed for interactive and dynamic content were HTML forms, the HTTP POST request method, and the CGI. (Doyle and Lopes, 2005)

The HTML forms capability naturally extends the web's document metaphor by allowing user input data (form data) to be entered on web pages that is submitted to a form processor on a web server in a request method (GET or POST message). The forms interface is simple, cross-platform, supports light data validation, and allows pages to be event-driven. The loosely coupled interaction between forms and their processors can be a source of problems related to reliability since there is no static guarantee that the data types of submitted data elements conform to the expectations of the form processor. By 1993, the availability of CGI completed the forms processing path by providing a means by which web servers could process and respond to submitted data from HTML forms. CGI allows server-side programs to be invoked in response to HTTP requests. (Doyle and Lopes, 2005)

The disadvantages of CGI scripting are related to scalability and usability concerns. CGI is not highly scalable because a web server creates a new process for each CGI request. For busy web sites serving thousands of concurrent users, the CPU and memory usage required to constantly create and destroy processes severely limits the number of concurrent requests that can be handled. The use of scripting languages further strains a web server's capacity due to the need to start an interpreter for each request. (Doyle and Lopes, 2005)

The usability problems of CGI stem from the limitations of its thin abstraction over the HTTP protocol. Programmers must understand the workings of HTTP, down to the level of formatting details of resource identifiers and messages, to be able to create CGI scripts. No page computation model is provided; the programmer is responsible for generation of the response by printing HTML to the standard output stream. Role separation between designers and programmers is diminished due to the fact that the presentation attributes of pages are embedded with print statements in programs. Web page authoring tools such as Dreamweaver or FrontPage can not be used since the presentation HTML is embedded within a program's logic. Other responsibilities including state management, security, validation, data access, and event handling are completely delegated to programmers. (Doyle and Lopes, 2005)

Additionally, CGI programs are stateless and do not know what the user previously requested. To preserve the state, HTML pages must be created to dynamically embed the state information as hidden fields, but this makes the architecture non-scalable. (Namuduri and Ram, 2001)

Despite its limitations, CGI is not obsolete. CGI was the first widely supported technology for interactive and dynamic content and is still in use mainly due to the increasing popularity of scripting languages, which can provide a straightforward, portable alternative to Java. In tandem with scripting languages including, but not limited to, Perl, Python, Ruby, C, and C++, CGI is a platform-independent solution with a simple, well-known interface. It natively exists within most web servers such as Apache and Microsoft Internet Information Server (IIS), in contrast to other dynamic content solutions that require additional component installation. According to the benchmark comparisons to other options for generating dynamic content, CGI is inefficient in handling concurrent client requests and therefore suitable only for low-traffic applications. Even though CGI architecture is functional, easier to implement than a scalable one, and many CH organizations have used it and have evolved from it successfully in the past, "GeoCHEAF" is not using CGI technology because it is not scalable and is becoming an obsolete technology.

4.2.2 Scalable CGI implementations

To address the scalability shortcomings of CGI, a number of software providers produced different schemes for communication between the core webserver and plug-in programs. One such e- commerce company was Open Market, Inc., which introduced FastCGI into their webserver product in the mid 1990s. FastCGI is a language independent, scalable, open extension to CGI that provides high performance without the limitations of server specific APIs. (http://www.fastcgi.com) FastCGI is a CGI implementation that maintains a pool of persistent processes that are reused for multiple requests to reduce process creation overhead. mod_perl is an optional module for the Apache HTTP server. It embeds a Perl interpreter into the Apache server, so that dynamic content produced by Perl scripts can be served in response to incoming requests, without the significant overhead of re-launching the Perl interpreter for each request. mod_perl can emulate a CGI environment, so that existing Perl CGI scripts can benefit from the performance boost without having to be re-written. (URL Wikipedia)

4.2.3 Web server extension interfaces

The initial reaction from web server providers to CGI performance issues was to create proprietary APIs with similar capabilities. All of the major web servers have APIs that can be used to introduce new functionality into a web server through extension modules. The most well-known examples are Netscape Server API (NSAPI), originally created for Netscape web servers by Sun Microsystems, Inc.; Microsoft Internet Server API (ISAPI) by Microsoft Corporation; and the Apache module API by Apache Software Foundation 2003. Extension modules are usually required to be written in C or C++ and compiled into dynamic link libraries that are linked into the web server at runtime. Extensions can run extremely fast since they are compiled code that runs in the web server address space. ISAPI and the Apache interface are representative of web server APIs in general. ISAPI supports the development of extensions and filters that modify the behavior of IIS. The corresponding Apache API constructs are modules, handlers, and filters. ISAPI extensions behave like CGI scripts; extensions are invoked directly by clients or through Uniform Resource Identifier (URI) mapping, and are responsible for handling requests and creating responses. On IIS servers, a well-known example is the mapping of 'Active Server Pages (ASP)' files to asp.dll, the ASP interpreter. A corresponding example for Apache is the association of 'Hypertext Preprocessor (PHP)' files to the mod php extension module. ISAPI filters perform additional behaviors in addition to the default behaviors, and can be used to implement custom logging, authentication, mapping, and retrieval features. The Apache API also filters as a modular way to manipulate request or response data streams. (Doyle and Lopes, 2005)

Web server APIs were originally designed as scalable replacements for CGI, but they are rarely used to build web applications directly. The APIs are complex, non-portable, and require advanced programming knowledge, so extension modules are difficult to build, test, and maintain. Reliability can be compromised due to the tight integration of extensions into web servers; a single flaw in an extension module can crash a web server. The cost of developing extensions is easier to justify for widely reusable features than for those supporting only a single application. In spite of their weaknesses, web server APIs are an important building block for dynamic content generation systems. In fact, for performance reasons most serverside technologies that support dynamic content are based on web server extension modules. They enable programmers to create web-based applications that are more sophisticated and run much faster than applications based on CGI scripts since they are more tightly integrated with the web server.

4.2.4 Browser extension interfaces

During the browser wars of the mid-1990s all of the major browser providers created proprietary APIs to differentiate their products. The Netscape Plug-In API and Microsoft ActiveX are examples of browser-specific APIs. For systems requiring dynamic interfaces, the key features of browser-specific APIs are support for plug-in components and access to internal browser methods and properties related to the presentation of content. Security that prevents downloaded components from performing undesirable actions is a key requirement for browser extensions. ActiveX makes use of “Authenticode”, a code-signing scheme that verifies that downloaded binary components are pristine as offered by a certified provider prior to their execution by a browser. (Doyle and Lopes, 2005)

Browser Extension Interfaces:

Applets

Java applets represent an extension approach that is not browser-specific since it leverages the portable Java byte code format. Applets are Java class files that are downloaded and interpreted by a Java Virtual Machine (JVM) running within the browser address space. The JVM executes applets only after verifying that their code is safe, meaning that it not been tampered with and contain no instructions that violate the client’s security policy. Applets can also be digitally signed and verified to provide an additional level of security. Java applets initially suffered from poorly perceived performance due to extended download times and slow interpretation; therefore the technology has been relegated to a secondary role, even though performance has since been vastly improved by the introduction of just-in-time (JIT) compilation to native code. The pervasive Adobe (formerly Macromedia) Flash animation player plug-in provides an alternative to Java applets that is now commonly used to embed dynamic presentations in web pages. (Doyle and Lopes, 2005)

Client Side Scripting

Interpreters for lightweight scripting languages such as JavaScript and VBScript were available for most browsers by the end of 1996. Client-side scripting languages interfaces are more accessible than browser extension APIs, since they remove the need to know an entire API to add pieces of useful functionality to an HTML document. Client-side scripts are slightly less efficient than plug-ins, but the advantages of easy access to browser properties and methods outweigh the performance penalty. Initially, each browser creator implemented a proprietary scripting language and API that was incompatible by design with other browsers. Scripting language standards, including ECMAScript and DOM, have improved the situation to the point that cross-browser scripting is possible. (Doyle and Lopes, 2005)

Rich Internet Applications

Increased demand for application responsiveness, interactivity, and disconnected access has promulgated a review of the applet concept under the guise of Rich Internet applications (RIA). The objective of the RIA concept is to break away from the page-centered constraints imposed by the web to support a more interactive user experience. RIA solutions that attempt to introduce a new plug-in architecture on to the web have attracted attention, but eventually lose momentum due to the requirement to download and install a plug-in. 'Laszlo' and 'Macromedia Flex' are RIA frameworks (sometimes referred to as rich client architectures or the executable Internet) that are attempting to exploit the large installed base of Flash users to provide improved interactivity without requiring plug-in installation. Laszlo applications are described using an XML application description language. The Laszlo Presentation Server is a Java servlet that dynamically composes and serves Flash interfaces in response to requests for Laszlo applications. RIA solutions can improve the responsiveness and presentation quality of web user interfaces, but have not reached the mainstream of development. More experience with the technologies is needed to assess their compatibility with the existing web infrastructure before widespread adoption of RIA will occur.

Expanded Use of Dynamic HTML

Dynamic HTML technology has been around for many years. Recently, Google's state-of-the-art web applications, GMail, Google Suggests, and Google Maps, have brought the standards-based DHTML development model back to the front pages. Google has demonstrated that the DHTML development model is capable of letting developers create visually appealing and highly interactive (RIAs). (Schiefelbein, 2005) Google and other IT giants are making a huge investment in developing the Ajax approach. All of the major products Google has introduced over the last year -Orkut, Gmail, the latest beta version of Google Groups, and Google Maps- additionally, the Amazon.com A9 search engine and Flickr are Ajax applications.

Ajax, shorthand for "Asynchronous JavaScript and XML", a web development technique for creating interactive web applications using a combination of a set of technologies that are based on open standards and partially avoids the issue of vendor lock-in:

- HTML (or XHTML) and CSS for presenting information (*standards-based presentation using XHTML and CSS*)
- The DOM manipulated through JavaScript to dynamically display and interact with the information presented (*dynamic display and interaction using the DOM*)
- The XMLHttpRequest object to exchange data asynchronously with the web server (*asynchronous data retrieval using XMLHttpRequest*)
- Data interchange and manipulation using XML and XSLT
- The JavaScript API for accessing web services (*JavaScript binding everything together*).

Ajax is not a new concept or even a single technology and it is not a technology in itself, but a term that refers to the use of a group of technologies together. It only gives a name to techniques that have been in use on the web for many years. In fact, derivative/composite technologies based substantially upon Ajax. Ajax applications use web browsers that support the above technologies as a platform to run on. Browsers that support these technologies include Mozilla Firefox, Opera, Konqueror, Apple Safari and Microsoft Internet Explorer.

AJAX solutions contain a client-side engine, consisting of JavaScript functions, which renders the user interface and communicates with the server in XML format. This engine sits in the web browser and does not require a plug-in or user install.

An Ajax application eliminates the start-stop-start-stop nature of interaction on the web by introducing an intermediary -an Ajax engine- between the user and the server. It seems like adding a layer to the application would make it less responsive, but the opposite is true. Instead of loading a webpage at the start of the session, the browser loads an Ajax engine -written in JavaScript and usually tucked away in a hidden frame. This engine is responsible for both rendering the interface the user sees and communicating with the server on the user's behalf. The Ajax engine allows the user's interaction with the application to happen asynchronously -independent of communication with the server. So the user is never staring at a blank browser window and an hourglass icon, waiting around for the server to do something. Every user action that normally would generate an HTTP request takes the form of a JavaScript call to the Ajax engine instead. Any response to a user action that does not require a trip back to the server -such as simple data validation, editing data in memory, and even some navigation- the engine handles on its own. If the engine needs something from the server in order to respond -if it is submitting data for processing, loading additional interface code, or retrieving new data- the engine makes those requests asynchronously, usually using XML, without stalling a user's interaction with the application. (Garrett, 2005) How Ajax is different from the classic web application model is shown in figure 4.4 and figure 4.5.

OpenLaszlo is a widely adopted open source application development platform that uses Ajax-style programming techniques, integrating XML and JavaScript to create rich and robust online experiences, and delivery of RIA on the web. It is released under the OSI-certified Common Public License by Laszlo Systems. OpenLaszlo -an XML framework for RIA- is designed to support deployment of Ajax applications across multiple runtimes and devices. OpenLaszlo is 100% pure Java and runs in server environments -J2EE application servers and Java Servlet Containers. The OpenLaszlo APIs provide animation, layout, data binding, server communication, and declarative User Interface (UI). OpenLaszlo is write once run everywhere. An OpenLaszlo application developed on one machine will run on all leading web browsers on all leading desktop operating systems. OpenLaszlo currently targets the Flash Player, versions SWF6, SWF7 and SWF8. (http://www.openlaszlo.org/)

Ajax-based RIAs are fast becoming the benchmark for web application front ends because they provide the best of both worlds: rich and reach. Ajax applications are as rich as desktop applications and highly responsive, and provide all data on a single page without page refreshes. They also have the reach of standards-based browser applications that can be deployed easily without any browser plug-ins or client-side applets. (Schiefelbein, 2005) The number of Ajax-based libraries and tools has flourished in both the commercial and open source sectors, creating many options for developers who want to use Ajax with minimal effort. Ajax-based RIA frameworks like open source Dojo (licensed under the BSD License) or proprietary standards-based Backbase allow developers to easily build dynamic capabilities into web pages and any other environment that supports JavaScript. (http://dojotoolkit.org/) (http://www.backbase.com) Some web-based resources like AjaxInfo (http://www.ajaxinfo.com/) and Ajaxian (http://www.ajaxian.com/) popularize new Ajax tools and techniques with incredible speed.

Other technologies that could be used to develop RIAs include 'XML User Interface Language (XUL)', 'Extensible Application Markup Language (XAML)', Java, Flash, and SVG. XUL is a high-performance markup language for creating rich, dynamic user interfaces. It's part of the Mozilla browser and related applications, and is available in Mozilla browsers (like Firefox). XAML is a high-performance markup language for creating rich, dynamic user interfaces. It is part of the Windows Presentation Framework, Microsoft’s next generation UI technology, and will be supported in future versions of the Internet Explorer browser. A Java Applet is a program written in Java that can be included on a web page. Applets are programs that require the proprietary Java plugin from Sun in order to run. Adobe (*formerly Macromedia*) Flash is a powerful presentation-layer framework that comes preinstalled on most PCs and Macs. It is possible to use Flash to build web-based user interface components that are highly configurable. SVG is an XML-based graphics language that describes images with vector shapes, text, and embedded raster graphics. It can be integrated with XML data sources or SMIL. It has good interoperability with CSS and JavaScript. (http://www.mozilla.org/projects/xul/) (http://www.xaml.net/)

When compared to competing UI technologies like XUL, XAML, Java, Flash, and SVG, it is understood why Ajax is such a big deal. Many of these alternatives offer opportunities for similar functionality with as-good-if-not-better UI capabilities, but either force the user to install plugins, as is the case with Flash, Java Applets, and SVG, or limit her to a specific browser or operating system, as is the case with XUL and XAML. In fact there are many examples of Flash and SVG being used in conjunction with Ajax to provide an even more immersive user experience. Ajax offers the chance for developers to start writing rich applications without learning new skills.

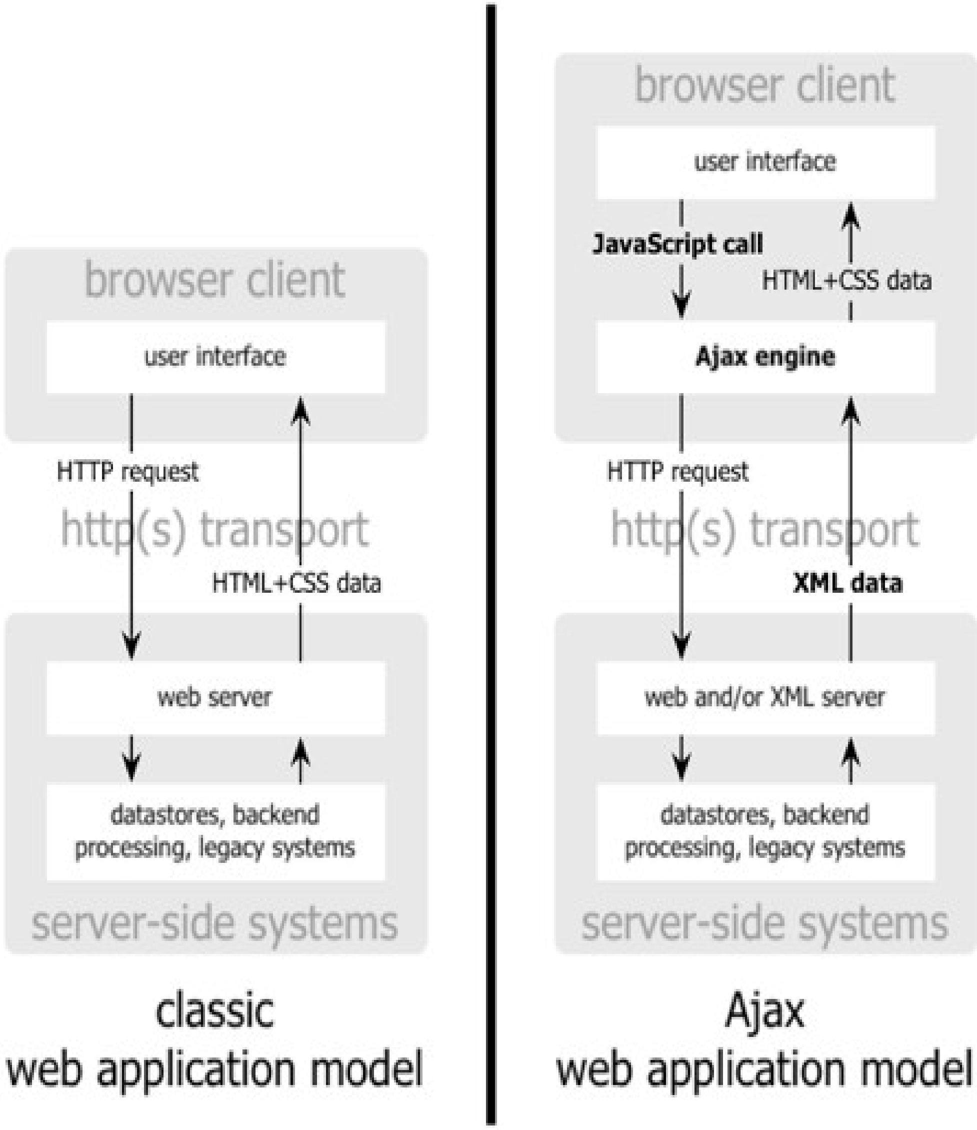

Figure 4.4: The traditional model for web applications (left) compared to the Ajax model (right). (Garrett, 2005)

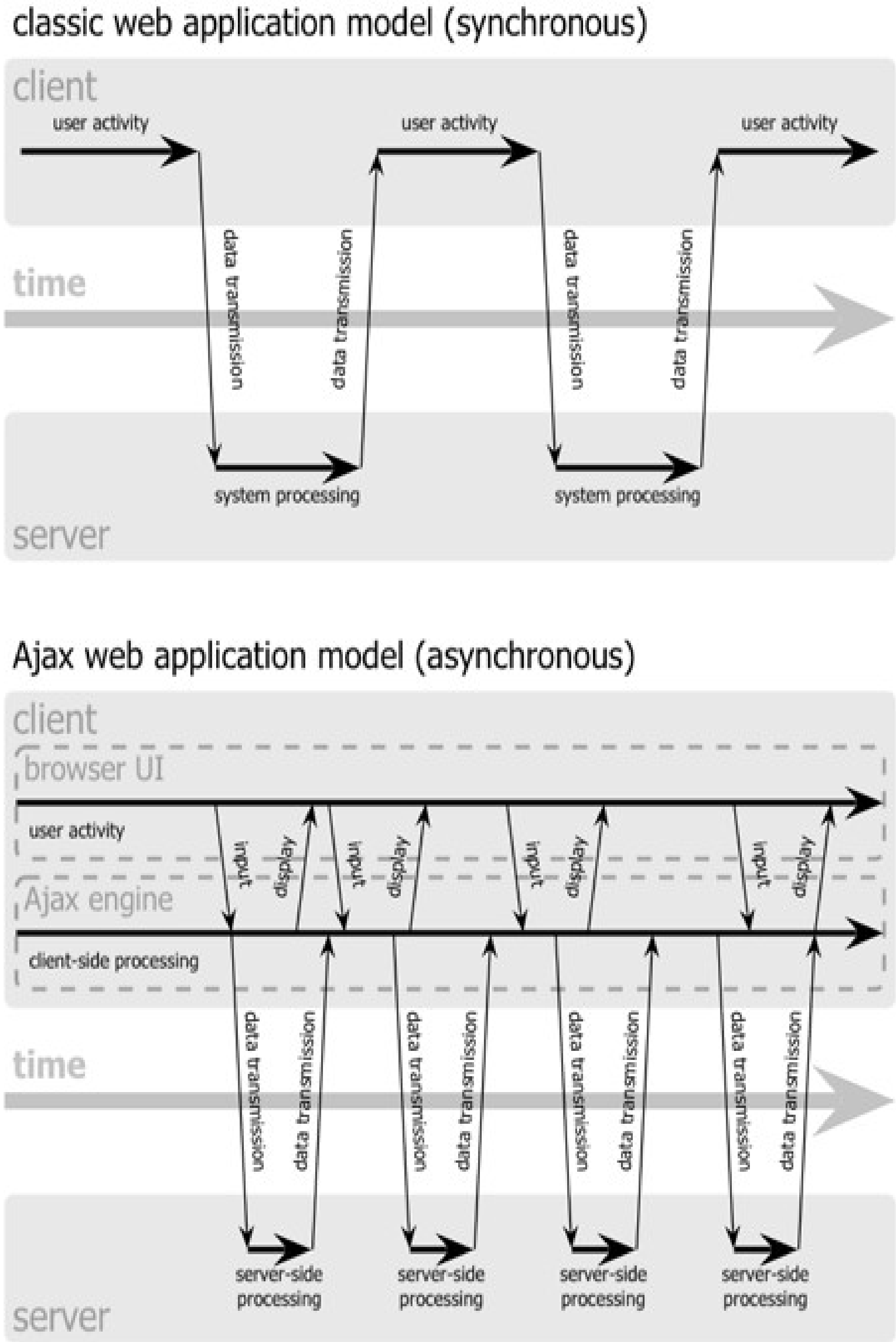

Figure 4.5: The synchronous interaction pattern of a traditional web application (top) compared with the asynchronous pattern of an Ajax application (bottom). (Garrett, 2005)

4.2.5 Interpreted template-based scripting

The use of templates is a common characteristic of pattern-based program construction systems. A template is a model for a set of documents, composed of fixed and variable parts, that is contextually expanded to yield conforming document instances. The variable parts of a template encapsulate programming logic such that each variable part exposes a program function that specifies how it is expanded in context. Predominately-fixed templates are easier to construct and comprehend than more variable templates since less programming is required and the defined structure is largely static. Many web sites consist of generally fixed HTML pages with small amounts of variable content. In contrast to template processing, CGI processing is more suitable for applications with mostly variable content, which are not as common on the web. The template model better supports the common web application pattern by embedding logic within fixed presentation markup. Templates reduce the programming skill needed to create dynamic content. Role separation is well-supported since the addition of logic can be delegated to programmers. (Doyle and Lopes, 2005) Interpreted template-based scripting:

Server-Side Includes

The Server Side Includes (SSI) capability was introduced by NCSA in 1993 as method for embedding trivial computations within HTML pages to be processed directly by the web server, instead of by a separate process as with CGI. SSI templates contain fixed HTML text and variable areas with commands that execute before a response is sent to a user. The technology is tag-centered in that dynamic behavior is specified by special HTML tags, and formatted comments that denote command keywords and parameters. The initial SSI implementation supported the include command for text file inclusion, the echo command for variable output, and the exec command for running external programs. Conditional processing and other features were independently added to SSI by web server providers. On Apache web servers, SSI plus several extensions is known as Extended SSI (XSSI). While infrequently used, SSI is not completely obsolete and the core set of commands is supported by most web servers. Role separation is better supported by SSI than by CGI since the fixed and variable areas of pages can be built independently. Web designers can work strictly with HTML to design the appearance of a page, adding exec commands to retrieve information where dynamic content is required. Development of logic invoked by exec commands can be delegated to programmers. The disadvantages of SSI are related to scalability and usability concerns. SSI is no more scalable than CGI, and can be worse for documents with multiple exec commands. Each exec command leads to a process creation, adding appreciably to the web server processing load even relative to CGI. The usability concerns are due to the primitive syntax and CGI-based process model. The syntax is error-prone and difficult to internalize, but does not not support complex processing other than through CGI via exec commands. The dependence on exec for non-trivial processing renders templates defeats role separation. For larger applications, the inevitable reliance on exec leads to barely maintainable, multi-language tangles of templates, scripts, and programs. While SSI is rarely appropriate for new applications, it provides an accessible, low cost alternative for non-critical, low-traffic web applications. (Doyle and Lopes, 2005)

Coldfusion

ColdFusion was introduced in 1995 by Allaire Corporation as an “easy to program” technology for creating dynamic content. The defining feature of the technology is the template-based ColdFusion Markup Language (CFML), originally interpreted but now JIT-compiled into servlets. CFML advanced the templating model of SSI by providing a large set of commands, originally focused on database processing but ultimately also supporting other functions including file management, flow control, and forms processing, that is designed to be comprehensive for web applications. ColdFusion is comparable to SSI, sharing many of its advantages and disadvantages. Templates are portable since interpreters are available for several web servers including Apache and IIS. Role separation between web designers and programmers is possible to a similar extent as with SSI. Database access is optimized compared to CGI and SSI. The syntax is more expressive than that of SSI, but still not well-suited for expressing complex logic. The size of the language, in terms of the sheer number of options, reduces its usability. (Doyle and Lopes, 2005)

Server-Side Java Script

The next widely-used technology for server-side scripting was script-centered templating as exemplified by the introduction of Server-Side JavaScript (SSJS) and the Microsoft ASP environment in 1996. In script-centered templating, blocks of logic are embedded in HTML pages. Script-centered templating quickly gained popularity among programmers as a more natural way to produce dynamic content. SSJS pages were constructed from HTML and JavaScript code and interpreted by an interpreter on the web server. The SSJS development and runtime environment provided server, application,database, client, and request objects that supported state management. SSJS preceded and influenced ASP but did not catch on with developers and is obsolete.

Active Server Pages

ASP is a server-side scripting environment for web applications that provides a scripting language engine that supports several languages, an object model, and an interface for accessing server components. The most commonly used scripting language for ASP pages is VBScript. JScript, a JavaScript variant, is also supported out-of-the-box, and other languages can be installed. The integrative power of ASP comes from the ability to access Component Object Model (COM) components on the server from within web pages. The COM is a Microsoft standard that provides a language-independent means for defining and referencing components as objects. In the hands of experienced programmers, ASP's combination of HTML, scripting language code, and access to COM components can be a powerful tool for building dynamic web applications. ASP became the most popular scripting-based templating technology on the web, at least partially due to the large installed base of Microsoft server operating systems. The emergence of ASP was a step forward for web application development; many systems supporting dynamic content that followed were influenced by the technology. (URL Microsoft) The disadvantages of ASP are related to portability, scalability, integration, reliability, and usability concerns. Since ASP is still primarily applicable only to Microsoft systems despite various porting efforts, applications are generally not portable and integration with other platforms can be problematic. Scalability is limited due to runtime interpretation, which consumes extra CPU cycles compared to compiled code execution. While COM integration provides access to an ad-hoc set of advanced features including support for transactions, the technology was not designed from ground up as a comprehensive, service-oriented framework, so critical concerns such as security and reliability are not integral to the environment. While the programming model is conceptually simple, the fundamental mismatch between the event-driven nature of applications and the page-centered interaction constraints of the web are not addressed. The script-centered approach is less accessible to non-programmers than tag-centered approaches, so role separation is diminished.

Hypertext Preprocessor

PHP is an open source, cross-platform, object-based scripting language for dynamic web applications that is analogous to ASP. Versions of PHP run on many operating systems and web servers, and interfaces are available to many database systems. PHP is available for Windows operating systems, but since ASP being generally the preferred option on Windows systems, PHP is most prevalent on Linux systems running Apache. The PHP syntax contains elements borrowed from C, Perl, and Java. While PHP has comparable advantages and disadvantages as classic ASP, the portability of PHP can be beneficial if an application needs to run on several platforms or web servers. The open source combination of Linux, Apache, MySQL, and PHP, commonly referred to as LAMP*, is gaining interest as a low cost platform for web applications.

4.3 An Evolutionary Step: Middle-Tier Architecture

The middle-tier architecture of "GeoCHEAF" consists of three sub-tiers: Presentation, Business Logic, and Integration. In this collocated architecture, these sub-tiers are physically located in the same web application container and well-defined interfaces isolate each sub-tier's responsibility. This collocated architecture makes the application simple and scalable.

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*LAMP (**L**inux-**A**pache-**M**ySQL-**P**erl/**P**HP/**P**ython)
WAMP (**W**indows-**A**pache-**M**ySQL-**P**erl/**P**HP/**P**ython)

4.3.1 Presentation tier

The browser-based thin/minimal client does not contain presentation logic; it relies on the presentation tier. The presentation tier exposes the business logic tier services to the users. It knows how to process a user request, how to interact with the business-logic tier, and how to select the next view to display. (Shen, 2004) Fundamentally, it contains web server, web container and web application framework technology components.

Web servers implement the server-side duties of HTTP, the application-layer protocol that governs message-passing between web users and servers (Doyle and Lopes, 2005) in order to make web pages viewable in web browsers. In the web server's delegation model, when an HTTP request comes into the web server, the web server simply passes the request to the program best able to handle it. To process the request, a web server may respond with a static HTML page or image, send a redirect, or delegate the dynamic response generation to some other server-side program such as CGI scripts, JavaServer Pages (JSP), servlets, server-side JavaScripts, or some other server-side technology. The server-side program usually provides for itself such functions as transaction processing, database connectivity, and messaging. Whatever their purpose, such server-side programs generate a response, most often in HTML, for viewing in a web browser. To summarize, the web server does not provide any functionality beyond simply providing an environment in which the server-side program can execute and pass back the generated responses.

The most common web server implementations are the Apache HTTP server (URL Apache), which is open source and available for most operating systems, and the Microsoft IIS, available only for Microsoft Windows operating systems. Other web server implementations for several platforms are Sun Java System Web Server from Sun, proprietary Zeus Web Server form Zeus Technology, free and open source Jigsaw (the official W3C Java-based Web server) and Lighttpd (also called Lighty) (free and open source under BSD license). (http://www.lighttpd.net) (http://www.zeus.com/products/zws/)

Apache HTTP server has been the most popular web server on the Internet since April of 1996. More than 60% of the web sites on the Internet are using Apache, thus making it more widely used than all other web servers combined. (URL Apache) The November 2006 Netcraft Web Server Survey found that market shares for top developers Apache (60.32%), Microsoft (31.35%), Sun (1.68%), Zeus (0.51%). (URL Netcraft)

The web server software in the design of the middle-tier architecture of “GeoCHEAF” is internally modified version of the 'Apache Web Server' under GNU GPL. This system includes 'Secure Sockets Layer (SSL)' and 'PHP (ZEND)'.

Web applications that run within a web container (may also be referred as web engine) of a web server in the presentation tier are composed of web components and other data such as HTML pages. Web components can be servlets, JSP, other type of templates, web filters, and web event listeners. These components typically execute in a web server and may respond to HTTP requests from web users. Servlets, JSP pages, and filters may be used to generate HTML pages that are an application’s user interface. They may also be used to generate XML or other format data that is consumed by other application components.

In the servlet-based architecture, the servlet acts as a gateway between the outside world and the enterprise. It is an HTTP protocol-based request-response mechanism. (Namuduri and Ram, 2001) Servlets are modules of Java code that run in a server application (hence the name 'Servlets', similar to 'Applets' on the user side) to answer user requests. Java servlets extend web servers to support dynamic content generation.

Servlets are executed by servlet containers, also known as servlet engines, which are Java applications that manage threads through their life cycle. The use of lightweight Java thread in the servlet architecture instead of a complete process in the CGI architecture improves efficiency and scalability, while providing efficient access to global objects initialized by the container. Since successive requests to a servlet are handled by a continuous thread, local objects instantiated within the thread are available throughout a servlet’s lifetime. (Doyle and Lopes, 2005)

As mentioned earlier, the traditional way of adding functionality to a web server is the CGI: a language-independent interface that allows a server to start an external process which gets information about a request through environment variables, the command line and its standard input stream and writes response data to its standard output stream. Each request is answered in a separate process by a separate instance of the CGI script.

The Java Servlet API was introduced in 1997 as a Java technology's answer to CGI programming. Servlets are functionally similar to CGI scripts in that both are intermediary components that generate dynamic responses to HTTP requests. Problems areas for CGI addressed by servlets are performance, state management, and standardized access to middleware. The process model is similar to scalable CGI in that instances service multiple requests, but with servlets each instance is dedicated to a particular servlet. (URL Java)

Servlets have several advantages over CGI:

- A Servlet does not run in a separate process. This removes the overhead of creating a new process for each request.
- A Servlet stays in memory between requests. A CGI program (and probably also an extensive runtime system or interpreter) needs to be loaded and started for each CGI request.
- There is only a single instance which answers all requests concurrently. This saves memory and allows a Servlet to easily manage persistent data.
- A Servlet can be run by a Servlet engine in a restrictive Sandbox (just like an Applet runs in a web browser's Sandbox) which allows secure use of untrusted and potentially harmful Servlets.
- Servlets are written in Java, and can take advantage of Java's memory management and rich set of APIs. Servlets can also run on numerous platforms and HTTP servers without change.
- Java servlets are more efficient, easier to use, more powerful, more portable, and cheaper than traditional CGI and than many alternative CGI-like technologies.

The usability disadvantages of servlet programming are analogous to those of CGI. As with CGI, the servlet model provides only a thin abstraction over HTTP. Programmers must manually generate responses by writing to the standard output stream, so role separation is not well supported. Therefore, relatively few web applications are composed entirely of servlets. Instead, servlets are used as an underlying mechanism behind the template-based, model-driven, and framework-based technologies that were subsequently developed.

JSP is a templating technology for web application development that was introduced in 1999 to simplify servlet development. (URL Java) On the surface, the JSP is reminiscent of ASP, but the implementation is very different. While ASP pages are interpreted, JSP pages are transformed by a JSP container into servlets. A JSP container is a modified servlet container that also serves JSP pages.

JSP technology enables web developers and designers to rapidly develop and easily maintain, information-rich, dynamic web pages that leverage existing business systems. As part of the Java technology family, JSP technology enables rapid development of web-based applications that are platform independent. JSP technology separates the user interface from content generation, enabling designers to change the overall page layout without altering the underlying dynamic content.

JSP technology and servlets provide an attractive alternative to other types of dynamic web scripting/programming by offering platform independence, enhanced performance, separation of logic from display, ease of administration, extensibility into the enterprise, and most importantly, ease of use. (URL Java) Much of the subsequent innovation for web development has been motivated by a search for techniques that properly exploit the capabilities of JSP and servlets.

Other templating engines are generally designed to not allow Java code to be added to templates, so developers are not tempted to mix business and presentation logic in templates. Dedicated templating engines such as Velocity and WebMacro aim to replace JSP as a presentation technology for web applications.

Velocity is a Java-based template engine. It permits anyone to use a simple yet powerful Velocity template language to reference objects defined in Java code. When Velocity is used for web development, web designers can work in parallel with Java programmers to develop web sites according to the Model-View-Controller (MVC) model. In other words, web page designers can focus solely on creating a site that looks good, and programmers can focus solely on writing top-notch code. Velocity separates Java code from the web pages, making the web site more maintainable over its lifespan and providing a viable alternative to JSP or PHP. Velocity's capabilities reach well beyond the realm of the web. For example, it can be used to generate SQL, PostScript and XML from templates. It can be used either as a standalone utility for generating source code and reports, or as an integrated component of other systems. (URL Velocity)

Apache Tomcat from Apache is the most widely used web container (servlet/JSP container) used in the official reference implementation for these complementary technologies, the Java Servlet and JSP. It is a runtime shell that manages, executes/runs and invokes servlets and JSPs. (URL Tomcat)

Apache Tomcat web container was configured to run in-process in conjunction with the Apache HTTP server (may also be referred as 'in-process add-on' to the Apache web server) in order to execute servlets and JSPs in the presentation tier, instead of deploying Tomcat as out-of-process or stand-alone, since generally running in-process is easier to configure and gives better performance. (URL Tomcat)

When running Tomcat in-process, the Apache HTTP Server starts Tomcat as threads within the Apache HTTP Server job. Tomcat inside Apache in one server (in-process) integrating Tomcat as a plugin. In-process where Tomcat and the Apache Server run in the same process and communicate through a Java Native Interface (JNI). In-process Tomcat is a combination of a web server plugin and a Java container implementation. The web server plugin opens a JVM inside the web server's address space and lets the Java container run in it. If a certain request should execute a Servlet, the plugin takes control over the request and passes it to the Java container using JNI. (URL Tomcat)

When running Tomcat out of process (out-of-process add on), Tomcat is a separate job (or process) that can even be on a different computer than the Apache HTTP Server (two different farms), which communicates with the Apache HTTP Server via TCP/IP sockets. Out-of-process Tomcat is a combination of a web server plugin and a Java container implementation that runs in a JVM outside the web server. The web server plugin and the Java container JVM communicate using some IPC mechanism (usually TCP/IP sockets). If a certain request should execute a Servlet, the plugin takes control over the request and passes it to the Java container using the IPCs. (URL Tomcat)

It is important to note that if SSL support is configured between the web browser and the web server, the connection between the web server and the out-of-process Tomcat server is not secured with SSL. Running in-process allows developers to configure authentication through the HTTP server where out-of-process does not.

An in-process container is suitable for multi-threaded single-process servers and provides good performance but is limited in scalability. Running out-of-process allows more flexibility in the number and type of processes that can be configured. The response time of an out-of-process engine is not as good as in the in-process one but the out-of-process engine performs better in many measurable ways (scalability, stability, etc.)

Running Tomcat as a stand-alone server is another option. Stand-alone Tomcat is an integral part of the web server. Stand-alone is the default mode used by Tomcat. (URL Tomcat)

As a site grows in complexity, it is more and more difficult to manage the relationship between the various JSP pages, the back-end business logic, and the forms and validations that move around the site. A large number of web application development frameworks emerged in response to the increasingly common problem in web application development using J2EE and .NET platforms. A web application development framework helps developers build applications faster and better by providing prepackaged starter. It simplifies writing web applications and makes them much easier to develop and maintain. It also allows developers to create cross-platform applications and dynamic content generation systems.

Frameworks are an extensible module sets supporting rapid development of repetitive requirements in a reliable way through reusable skeletal design pattern realizations. The objective is to allow developers to concentrate on the problem domain rather than on low-level implementation details, while providing concrete benefits beyond the associated acquisition and learning curve costs.

Model-driven development technologies for web applications aim to simplify the development process by generating deployable sites from presentational, behavioral, and navigational requirements specified in models. In the tradition of prior work in automatic programming and CASE, which were not completely successful, model-driven development technologies aim to reduce the dependency on low-level programming by raising the abstraction model to a higher level.

One approach to designing technical architecture is MVC architecture. The MVC architectural design pattern for building interactive applications is commonly used in user interface programming to separate presentation, business, and state management concerns, thereby decreasing code duplication, centralizing control, and making the application more extensible. MVC that is a logical architectural choice for the presentation tier matches the event-driven nature of dynamic web applications. It also helps developers with different skill sets focus on their core skills and collaborate through clearly defined interfaces. (Shen, 2004) A Model View Controller-based development framework that enables developers to quickly assemble applications in a pluggable and extensible manner.

The benefits of using the MVC architecture are: (Namuduri and Ram, 2001)

- Clear separation of modules: This provides the ability to extend and replace modules with ease. When the business logic changes, the corresponding business component can be modified without affecting other parts of the systems. In the MVC architecture, changes can be confined to particular components or areas.

- Flexibility of the views: For the same function, different views can be generated. For example, the same data can be implemented as an HTML page, applet, spreadsheet, text document or PDF document.
- Ease of change: When technology changes, the model can still be used with the updated view components. For example, conversion from HTTP request to WAP request does not affect the underlying business model.

There are two types of MVC frameworks: application-driven and page-driven. While application-driven web MVC frameworks implement MVC using the Front Controller pattern, page-driven MVC frameworks implement MVC using Page Controller pattern. Page-driven MVC frameworks provide an event-driven model for web programming that recalls traditional desktop GUI programming. Relative to application-driven frameworks, the higher degree of page independence allows heavier abstraction over resource implementation details that supports rapid component-based development through drag-and-drop GUI page composition. The highly abstraction level may extend the learning even for experienced web programmers due to the need to become familiar with with a completely different object model. (Doyle and Lopes, 2005)

There are currently two types of web frameworks in Java: request-based and component-based.

Much attention has been focused on creating web MVC frameworks since 2000, when the potential for reuse and streamlining the development process became evident. As a result, many competing frameworks are available, many of which are products of open source development projects. While the most well known frameworks currently target the J2EE platform, several have been ported to .NET. Well-known web application frameworks are also available for server-side scripting languages such as Perl, PHP, and Python. Although View templates are normally JSP pages, some frameworks also allow other template engines to be used, including Velocity and WebMacro. Table 4.3 shows the most commonly used frameworks for web applications and user interfaces.

Table 4.3: Most commonly used web application development frameworks

Framework	***Provides***	***Built for***	
Struts	the most well-known application-driven MVC framework a request-based framework mature, well-documented, and effectively supports the requirements of a large class of interactive web applications	Java	open source by the Apache Software Foundation available since 2000
Web Objects	a page-driven, component-based approach	Java (Objective -C)	proprietary by Apple (NeXT) since 2000 (1996)
Tapestry	an object model for component-based development of Web Applications (influenced by WebObjects)	Java	open source by the Apache Software Foundation available since 2000
ASP.NET (WebForms)	a page-driven object model for Web programming (similar to the Tapestry object model)	.NET	proprietary by Microsoft
Turbine	servlet based framework		open source by the Apache Software Foundation
Cocoon	separation of concerns and component-based web development		Apache
Spring	MVC Web Framework “lightweight” container a lightweight J2EE alternative for building complex web applications		open source
Avalon	Spring is simpler		
PicoContainer	“lightweight” container		open source
Maverick			
Mozilla	cross-platform development framework Mozilla's component object model		Mozilla
JavaServer Faces (JSF)	a rich component model complete with event handling and component rendering a component-based Web application framework application-driven	Java	
Rails (Ruby on Rails (RoR))	database-driven MVC web applications in object-oriented	Ruby	open source by the Basecamp foundation and 37signals since July 2004

JavaServer Faces (JSF) is a server-side user interface component framework for Java-based web applications and is also a specification for a component-based web application framework built over servlets and JSP. JSF fits well with the MVC-based presentation-tier architecture. It offers a clean separation between behavior and presentation. It leverages familiar UI-component and web-tier concepts without limiting developers to a particular scripting technology or markup language. It can be used to bring rapid user-interface development to server-side Java, and link and manage user interface events. (URL Java)

JSF uses a similar architecture in Struts (the most popular open source JSP-based web application framework), but is more flexible and extensible. JSF also comes with server-side components and an event model, which are fundamentally similar to the same concepts in Swing (the standard Java user interface framework for desktop applications). JSF can be thought as a combination of those two frameworks.

JSF differentiates from other web frameworks with the following features: (Geary, 2002; Shen, 2004)

- **Swing-like object-oriented web application development:** The server-side stateful UI component model with event listeners and handlers initiates object-oriented web application development.
- **Backing-bean management:** Backing beans are JavaBeans components associated with UI components used in a page. The backing bean defines properties and handling-logics associated with the UI components used on the page. Backing-bean management separates the definition of UI component objects from objects that perform application-specific processing and hold data. JSF implementation stores and manages these backing-bean instances in the proper scope.
- **Extensible UI component model:** JSF UI components are configurable, reusable elements that compose the user interfaces of JSF applications. The standard UI components can be extended and developed a more complex component, e.g., menu bar and tree component.

- **Flexible rendering model:** A renderer separates a UI component's functionality and view. Multiple renderers can be created and used to define different appearances of the same component for the same client or for different clients.
- **Extensible conversion and validation model:** Based on the standard converters and validators, customized converters and validators can be developed, which provide better model protection.

There are more than 50 web application development frameworks available in the market. The frameworks are very various and are slightly different both in concept and implementation. Furthermore, there are a few good configurations, like Apache Velocity and Turbine, or Apache Cocoon and Spring. Apache Jakarta Velocity (Java-based template engine) provides template services for the Apache Turbine (Web application framework), together resulting in a view engine facilitating development of web applications according to a true MVC model. Apache Cocoon gives the flowscript and forms, the sitemap, lots of prebuilt components, a Portal, etc. whilst Spring is geared towards developing enterprise web applications. This duo is very efficient for building web applications. Since JSF represents an open source (de-facto) standard for Java-based web application frameworks and provides functionalities other web frameworks like Struts lack, "GeoCHEAF" concentrated on developing IDEs for JSF instead of developing an IDE for one of approximately 35 existing Java-based web application frameworks.

4.3.2 Business logic tier

The business logic tier contains an application's business objects and business services. It receives requests from the presentation tier, processes the business logic based on the requests, and mediates access to the back-end tier's resources. (Shen, 2004) The response or output from the business logic tier consists of the data or content, which is passed on to the user. The content may need to be converted to different formats depending on the users' and business' needs. The output may be formatted to an HTML, PDF, XML or a serialized object if the client is an applet. (Namuduri and Ram, 2001)

An application server is a component-based product that resides in the middle-tier of a server centric architecture. It forms the middle tier, acting as a container and runtime environment for business logic. Its performance is key in determining the performance of the overall enterprise web application. A web server mainly deals with sending HTML for display in a web browser whereas an application server provides access to business logic for user. Application servers can be also configured to work as web server. In short, application server is a super set of which web server is a sub set.

The application server does not drive the GUIs; rather it shares business logic, computations, and a data retrieval engine. Advantages are that with less software on the client there is less security to worry about, applications are more scalable, and support and installation costs are less on a single server than maintaining each on a desktop client. The application server design should be used when security, scalability, and cost are major considerations.

An application server exposes business logic to user applications through a component API, such as Enterprise JavaBean (EJB) components and various protocols, including HTTP, TCP/IP and many more protocols. Application servers provide containers for such components along with APIs to support the components. These APIs are to the existing systems and databases.

Business components, such as JavaBeans, Enterprise JavaBeans (EJB) components (enterprise beans), entity beans, session beans, run inside a EJB container of the application server in the business logic tier. Enterprise beans typically contain the business logic for a J2EE application.

The application server must provide one or more EJB containers. An EJB container that manages the enterprise beans contained within it. For each enterprise bean, the container is responsible for registering the object, providing a remote interface for the object, creating and destroying object instances, checking security for the object, managing the active state for the object, and coordinating distributed transactions. Optionally, the container can also manage all persistent data within the object.

EJB containers and servers handle transactions. EJB architecture encourages developers to focus on pure business logic by relieving them of technical responsibilities that are irrelevant to the business problem. Other advantages include portability, scalability, automatic state persistence and declarative transaction demarcation. J2EE is an EJB-based architecture that includes several other components to provide a component-based, scalable, distributed computing environment.

EJB technology supports both transient and persistent objects. A transient object is called a session bean, and a persistent object is called an entity bean. A session bean exists only for the duration of a single client/server session. A session bean performs operations such as accessing a database or performing calculations. Session beans can be transactional, but normally are not recoverable following a system crash. Session beans can be stateless, or they can maintain conversational state across methods and transactions. A session bean must manage its own persistent data. An entity bean is an object representation of persistent data maintained in a permanent data store, such as a database. An entity object can manage its own persistence, or it can delegate its persistence to its container.

Either EJB or Plain Old Java Objects (POJO) can be used to build the business logic tier. In the design of the architecture, EJB with remote interfaces was chosen to implement the business logic tier since the applications are distributed, rather than POJO with Spring Framework.

The web application server is the principal software system brokering service requests between users and the external services provided by back-end systems. These application servers can range from a simple runtime engine that supports server-side dynamic page generation in a manner similar to CGI programming, to large, complex enterprise transaction servers that might be hybrids of TP monitors or CORBA application servers.

The enormous processing demands, combined with a need for flexibility and adaptability, led to a new type of architecture for web application servers based on the Java platform. Standardized third-party web application servers emerged to provide a platform for a wide variety of specialized applications. The J2EE, released in 1999, provided a complete environment for application development, web-based communications, database access, and interoperability, based on modular components running on an application server. It quickly became the “standard” (albeit with no ISO or ECMA standard) for application server developers. (White Paper, 2003a) It is a comprehensive set of standards designed to provide a portable environment that supports the requirements of large, enterprise web applications, which was a flashpoint for the dynamic web J2EE 5.0 features some specifications unique to J2EE for components, including: (URL Java)

- EJB: Enterprise JavaBeans 3.0
- JSF: JavaServer Faces 1.2
- JSP: JavaServer Pages 2.1
- Java Servlets 2.5

When implementing an enterprise server-side web application, it is important to decide which services are required for the application to help determine the class of application server that is needed. High-end application servers that implement all of the J2EE specifications tend to be much more expensive than simpler servers that provide fewer services. In many cases, support for servlets and JSP is sufficient to meet the needs of an application.

J2EE has been successful and compliant application servers are available from many providers. The platform can be very scalable if properly exploited, but the size and complexity of the architecture can make it a difficult environment to work with. The learning curve for J2EE developers can be relatively lengthy, especially if EJB is used, due to the complexity of the component architecture.

There are a number of J2EE or .NET compatible robust open source, such as JBoss Application Server (JBoss), Jetty, JonAS, Geronimo, and proprietary application servers, such as Oracle’s Application Server, BEA’s WebLogic, IBM’s WebSphere, Adobe’s JRun, on the market. J2EE based JBoss application server was chosen in the design of the multi-tier distributed architecture of “GeoCHEAF”.

The JBoss is the leading open source, standards-compliant, J2EE based application server implemented in 100% pure Java (http://sourceforge.net/projects/jboss) J2EE 1.4 application server JBoss provides full support for J2EE web services and the SOA. It supports Aspect-Oriented Programming (AOP) model for developing middleware solutions. JBoss Application Server enables developers to get started with EJB and JSF to create web applications, create business logic with EJB 3.0 and persist data through the EJB 3.0 Java Persistence API. Essentially, JBoss Seam is an integration framework that seamlessly ties together the Java presentation layer and the transactional/database layer. Seam integrates JSF and EJB. (URL JBoss)

4.3.3 Integration tier

The heart of the middle tier that has been discussed so far is its 'request/reply' or 'services' or 'API' nature. The idea is not based on objects. Entity beans are completely object-based. The middle tier is seen as a collection of objects. This makes perfect sense if the back-end is an object database. When the back end is a relational database, two things seem to trip up entity beans. These are: (Komantineni, 2003)

1. Object-relational (O/R) mapping (or Object Relational Mapping (ORM)).
2. The fluid and changing world of relational databases and the fixed and typed world of objects.

The problems that EJBs are trying to solve are the same problems that object databases are trying to solve. The rigidity of types in OO databases, or the inability to accomplish fluidity in types, might be the reason for the lack of success on part of object databases. (Komantineni, 2003)

The integration tier is the bridge between the business logic tier and the back-end tier. It encapsulates the logic from web components, enterprise beans and application client components to interact with the back-end tier. (Shen, 2004)

The integration tier handles the data persistence with the relational database. Different approaches can be used to implement the integration tier: (Shen, 2004)

- **Pure Java Database Connectivity (JDBC):** This is the most flexible approach; however, low-level JDBC is cumbersome to work with, and bad JDBC code does not perform well. SQL/JDBC (plain JDBC SQL statements, Java API and Java code) is a common solution for solving persistence problem.

- **Entity beans:** An entity bean with container-managed persistence is an expensive way to isolate data-access code and handle O/R mapping data persistence. It is an application-server-centric approach. An entity bean does not tie the application to a particular type of database, but does tie the application to the EJB container.

- **O/R mapping/persistence framework:** Persistence frameworks aim to allow programmers to efficiently retrieve and update database information through encapsulated objects rather than through direct SQL calls, or through EJB entity beans. An O/R mapping framework takes an object-centric approach to implementing data persistence. An object-centric application is easy to develop and highly portable. Several frameworks (O/R mapping tools) exist under this domain: Hibernate, Java Data Objects (JDO), iBATIS, TopLink, TopView and CocoBase are a few examples.

Hibernate is an open source O/R mapping/persistence framework that stores Java objects in relational databases or provides an object oriented view of existing relational data. It relieves the need to use the JDBC API. It also provides data querying and retrieval functions in a Java environment. Hibernate supports all major SQL database management systems and offers facilities for data retrieval and update, transaction management, database connection pooling, programmatic and declarative queries, and declarative entity relationship management. The Hibernate Query Language (HQL), designed as a minimal OO extension to SQL, provides an elegant bridge between the object and relational worlds. Hibernate also does some XML data binding (XML mapping). (http://www.hibernate.org/)

While Hibernate is only for mapping relational databases and objects, JDO is more general -it can work with object databases and other technologies besides just relational databases. (http://java.sun.com/products/jdo/) However, Hibernate does not modify source or byte code to persist a Java object; JDO implementations either require a special interface be implemented or do bytecode modifications at runtime.

In the middle-tier design of “GeoCHEAF”, Hibernate is used as ORM solution to complete Java-based middleware design since it is less invasive than other O/R mapping frameworks, much easier to use than handwritten SQL/JDBC (by eliminating JDBC coding) and much more powerful than EJB entity beans. It creates a mapping between Java objects and database entities.

4.3.4 Configuration

Depends on the user and functional requirements of the CH domain, the configuration of the middle-tier architecture of “GeoCHEAF” was realized as following. Figure 4.6 shows the partitioning of the application tiers and the technologies chosen for each tier. It also serves as the sample web application’s deployment diagram.

The design of the multi-tier architecture of “GeoCHEAF” for component-based enterprise web applications supports a variety of application types from large scale web applications to small client server applications. In this architecture such components use services provided by the container, which would otherwise typically need to be incorporated in application code. Note this may not be ideal in all scenarios: for example, a small scale application might be a better fit for a light-weight Java technology solution (e.g. Servlets, JSPs, etc.).

The most useful frameworks supporting web application development can be categorized as web application and user interface frameworks, persistence frameworks, and lightweight containers. Java Servlets are designed to handle requests made by web browsers. JSPs are designed to create dynamic web pages. JSF makes web applications much easier to design, create, and maintain. Also, JSF fits into the MVC design pattern very well and can be used to implement the presentation tier. The Spring Framework can be used in the business logic tier to manage business objects, and provide declarative transaction management and resource management. Spring integrates with Hibernate very well. Hibernate is a powerful O/R mapping framework and can provide the best services inside the integration tier. The combination of and the interconnectivity among these three technologies provides a solid web application development framework.

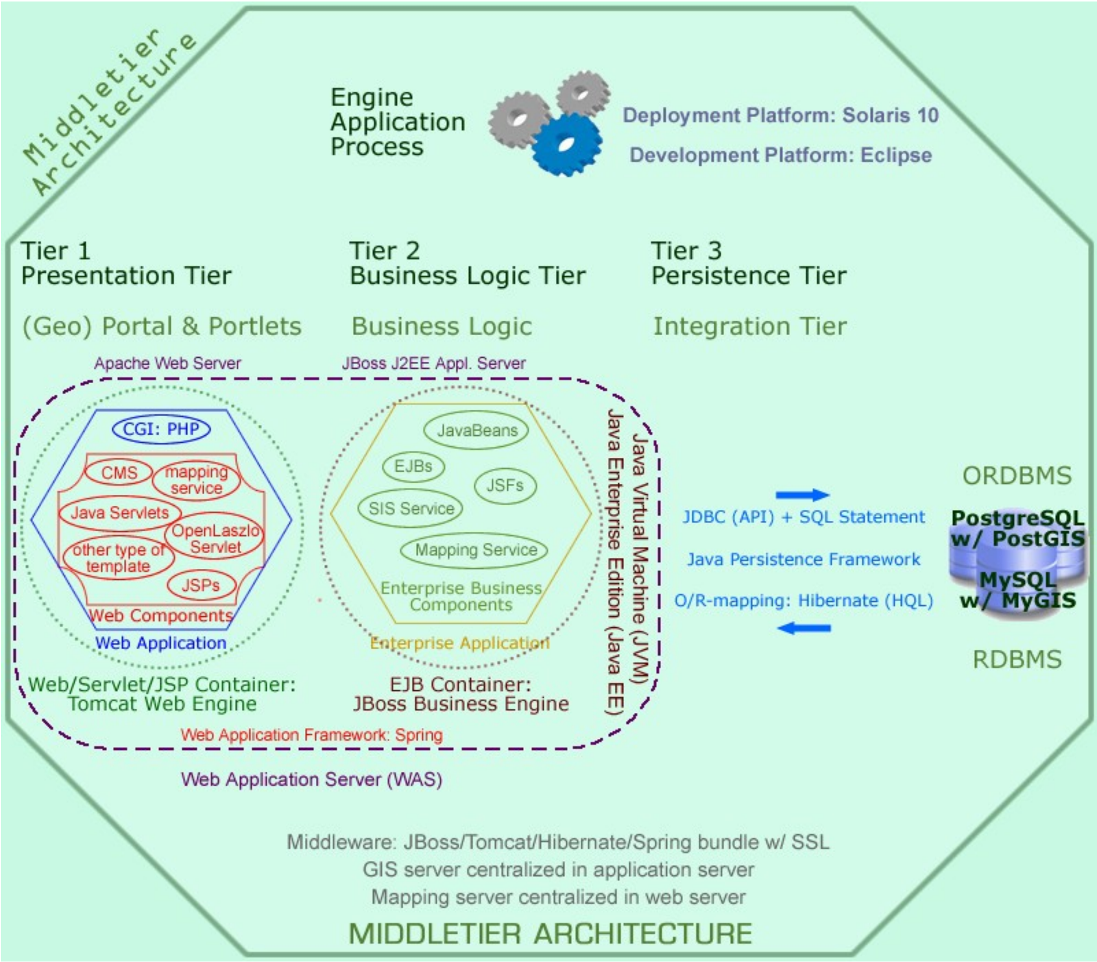

Figure 4.6: The middle-tier architecture of "GeoCHEAF"

The web application server in the design of the middleware architecture of "GeoCHEAF" consists of the Tomcat web container add-on the Apache web server and J2EE-based JBoss application server with Spring and Hibernate frameworks to provide full support for J2EE web applications and web services.

By partitioning the whole web application into tiers and programming against interfaces, the technology used for each application tier can be replaced according to the requirements of an enterprise. For example, in this design, Struts can take the place of JSF for the presentation tier, and JDO can replace Hibernate in the integration tier.

Deployment Platform: Java based web application development on Solaris operating system

Unlike Windows, which has only a few versions in production, all from the same vendor, Linux offers many different ones, called distributions (or 'distros' in Linux-speak). These are available from a long list of companies and individuals, priced from nothing to hundreds of dollars. Even restricting them to those that run on Intel x86 hardware leaves literally dozens of options. For those taking a closer look at Linux, an essential first decision is picking the 'distribution'. It is useful to group the distros into two categories: commercial and noncommercial.

Server OSs available for both x86-64 and i386 (64-bit CPU):

- Unix
  - Unix (BSD communities): FreeBSD, OpenBSD, NetBSD, etc.
  - Unix (Sun): Solaris
  - Commercial Unix: HP-UX (HP), AIX, IRIX
- Linux
  - Open source Linux for servers (GNU Linux OS):
    - Fedora Core Project (the community-driven Linux distribution started by RedHat)
    - OpenSuse (community-based development of Suse)
    - other Linux distributions (distros) Debian, CentOS, Ubuntu, Mandriva2006, Turbolinux, Slackware, etc.
  - Commercial Linux: Linux Enterprise Server (Proprietary Linux):
    - Red Hat Enterprise Linux (RHEL),
    - Novel Suse Linux Enterprise Server (SLES),
    - Caldera OpenLinux,
    - SuSE Linux,
    - TurboLinux.

- Microsoft 2003 Enterprise Server (for 32-bit or 64-bit) by Microsoft
- Mac OS by Apple
- Novell

Solaris 10 was chosen as an enterprise OS for the application environment of "GeoCHEAF" environment since Unix is more suitable for a production environment than the other ones. It really matches the needs and resources of the enterprise and its e-business.

Solaris Enterprise System, the only comprehensive and open infrastructure software platform available today - Solaris 10 OS, Java Enterprise System, development tools, N1 software, for no cost. (http://www.sun.com/software/solaris/)

Development Platform:

The Java EE platform works with an array of tools, including IDEs, performance and testing tools, and performance monitoring tools. Integrated Development Environment (IDE) (also known as an integrated design environment or integrated debugging environment) is a cross-platform programming environment integrated into a single software application that provides a GUI builder, a text or code editor, a compiler and/or interpreter and a debugger. An IDE is a necessity for enterprise developers who want to have all their productivity tools under one umbrella. The extensible open source development platforms for building enterprise Java applications: NetBeans (plus Java Studio Enterprise) (Sun), Eclipse (IBM), and Jbuilder (Borland).

In addition to general features, some features are best for enterprise development needs:

- Provide templates for quick creation of JSP pages, servlets and other web components
- Automatically create classes, methods, and properties
- Integrate with source code repositories, such as CVS
- Integrate with web application servers, such as Apache Tomcat
- Integrate with build utilities, such as Apache Ant

- Unified UI for debugging Java code
- Provide UML support

NetBeans and Eclipse, both projects aim to develop a flexible Java IDE, and both benefit from large industry support. The most visible difference is that NetBeans is Swing-based, while Eclipse builds on the Standard Widget Toolkit (SWT). Both Swing and SWT aim to offer a rich, portable set of Java widgets. NetBeans is written in the Java programming language. It is also the first IDE to fully support JDK 5.0 features.

The most important aspect in the architecture is that the HTML page sent by the web server to the web browser is generated dynamically and only upon request. It is not stored statically as a text file, and therefore, it is not necessary to manually maintain the information in static text files. Any dynamic data embedded in the HTML page is actually stored and managed in the DBMS and can be temporarily presented to users as HTML pages upon request.

While the J2EE-based web application server can be seen as an evolutionary step from earlier computing architectures, it is distinguished by a number of evolutionary features. Unlike earlier systems, a JavaEE-based application is built in components, which can be independently added, removed or updated with minimal disruption to the system as a whole. A result of the component-based architecture is the ability to develop chunks of code dedicated to specific functions, which -implemented properly- could run on the same application server and efficiently interact with other chunks of code dedicated to other functions. Unlike first-generation client-server applications, second-generation Internet-based applications had to communicate through a “cloud”, called the Internet. This was only possible through standards at every level -including networking (TCP/IP, HTTP), presentation (HTML), security (HTTPS, digital certificates), application logic (Java, JavaScript, CGI), etc. Internet standards enabled applications to run 'on both sides of the cloud'. The pieces of the application could run where it made the most sense for them to run. For example, while business logic ran on the server side, the server might download some presentation logic to the client in the form of JavaScript, style sheets, cookies and JSP.

4.4 A Revolutionary Evolutionary Step: Web Services & Web Services Architecture

'Web Service' is a software application or component that are loosely coupled, re-usable and distributed, semantically encapsulates business functionality and is programmatically accessible over standard Internet protocols. Technically, web services are built upon open, often already widely adopted standards such as HTTP and XML, which ensures interoperability between services, facilitating the integration of heterogeneous environments. Web services standards define an interface and communication protocol that can be invoked from an application client or provided through a server. Web services are applicable to any type of networking environment (Internet, intranet, or extranet) and can support business-to-consumer, business-to-business, department-to-department, or peer-to-peer interactions. Web services are identified by a Uniform Resource Identifier (URI) and accessed by a Uniform Resource Locator (URL). A Web Service consumer can be a human user accessing the service through a desktop or wireless browser; it can be an application program; or it can be another web service. (White Paper, 2003a; White Paper, 2004a; White Paper, 2003b; White Paper 2002)

4.4.1 A thorny problem: application integration

For years, enterprises have faced a thorny problem: how to flexibly modify, increment, and connect heterogeneous applications to meet the requirements of an enterprise. In second generation web applications, the data and logic of one application are basically useless to other applications. When an application and its data are isolated from other applications, it is called that they are in “silos”. After many years of ballooning applications within an enterprise, enabling cross-silo communications was the emerging business challenge in the 1990’s and it continues today. The first solution to the silo problem was the traditional Enterprise Application Integration (EAI). (White Paper, 2004b)

In traditional EAI solutions, an application communicates with another application through a bus (enterprise service bus (ESB)) or a hub that packages and translates information in one application according to specific rules provided by the receiving application. All of the packaging instructions for the receiving application are tied closely to the sending application, making each application 'integration' a one-to-one relationship, that is, a single application communicating with a single application. These relationships are describe as 'tightly coupled'. (White Paper, 2004a)

Although cumbersome, EAI was a big step forward, allowing enterprises to leverage their investment in their most critical business applications, rather than rewriting the application or migrating it to a new technology. However, traditional EAI presented a new set of problems revolving around the integration software costs, complexity of the effort, and inflexibility of the solutions. These three factors -cost, complexity, and solution inflexibility- have driven enterprises to choose the EAI solutions for only their most critical business requirements. (White Paper, 2004b)

The web services paradigm has emerged as a powerful mechanism for integrating disparate ICT systems and assets. It attacks the three problems identified above -cos, complexity, and solution inflexibility- with a new model that is lower cost, easier to learn and deploy, and more adaptable to changing business needs. The result is a faster, easier application-to-application integration, allowing enterprises to connect many more applications within their enterprise, and opening the door for more efficient business processes, within the enterprise and across businesses. Now many, rather than only the most critical, applications can talk to each other, presenting enormous opportunities for improved business performance. (White Paper, 2004b)

From a historical perspective, combining the best aspects of component-based development and the web, web services leverage a concept known as SOA. SOAs have evolved over the last 10 years to support high performance, scalability, reliability, and availability. (White Paper, 2003b) Using an SOA is an increasingly popular way of building distributed systems. (White Paper, 2003c) To achieve the best performance, applications are designed as services that run on a cluster of centralized application servers. A service is an application that can be accessed through a programmable interface. (White Paper, 2003b) A service is also a network-enabled component. Like components, services in general (and web services in particular) represent functionality that can be easily reused without knowing is the details of how the service is implemented. (White Paper, 2004a)

In the past, clients accessed these services using a tightly coupled, distributed computing protocol, such as Common Object Request Broker Architecture (CORBA), Remote Method Invocation (RMI), or Distributed Component Object Model (DCOM). While these protocols are very effective for building a specific application, they limit the flexibility of the system. The tight coupling used in this architecture limits the re-usability of individual services. Each of the protocols is constrained by dependencies on vendor implementations, platforms, languages, or data encoding schemes that severely limit interoperability. And none of these protocols operates effectively over the web. (White Paper, 2003b)

The Web Services Architecture (WSA) takes all the best features of the SOA and combines it with the web. The web supports universal communication using loosely coupled connections. Since web protocols are completely independent across vendor, platform, and language implementations, the result is an application that integrates well with the rest of the enterprise while being flexible enough to modify as business needs change. The resulting effect is an architecture that eliminates the usual constraints of CORBA, RMI, or DCOM. Web services support web-based access, easy integration, and service re-usability. (White Paper, 2004a; White Paper, 2003b)

4.4.2 The key characteristics of web services

Web services facilitate services reuse and provides support for greater business flexibility to meet enterprises' constantly changing business needs. Web services exhibit the following key characteristics:

- **Enables SOAs Loosely Coupled**:

In the SOA model, the business processes that make up an application are separated into independent, easily distributed components known as services. These processes inter-operate across processes and machines to create a complete solution for a business problem. Loose coupling means that each service exists independently of the other services that make up the application. This allows for easy changes to the application by inserting new and revised services into the application without having to modify the unrelated services. Loose-coupling is ably provided by web services through established standards that define services and how they inter-operate. (White Paper, 2004a)

Applications are developed independent of who accesses them and are exposed to other applications only through predefined interfaces (WSDL files). This means that the underlying implementations can be changed without changing the service requesting application. (White Paper, 2003a)

Recently, there has been a trend towards making services loosely coupled, which means introducing greater flexibility in the interface between the service consumer and the service provider. Most existing platforms have a very tight coupling between the client and server side. For example, CORBA Interface Definition Language (IDL) defines an interface in very precise terms, and any change to that interface usually requires significant rework across both the client and the server. This makes it difficult to evolve a service over time, as there are significant resulting effects. It also makes it more difficult to build applications that can change their behavior based on the services available at runtime. (White Paper, 2003c) Loose-coupling can however provide dramatic time and cost savings by rectifying the annoying and expensive syntactical differences that typically plague interoperability. In the web services domain, loose-coupling allows a service to be accessed using any arbitrary document format, regardless of syntax, providing the physical business data is present within, or can be determined from, the document contents. (White Paper, 2004c)

- **Ease of Integration and Business Flexibility**:

Historically, business applications are rather rigid. Updating them with new functionality to meet changing business requirements has traditionally been expensive, complex, and time consuming. Unlike other methods of integration, web services based integration solutions are more flexible, decreasing the time and effort required to meet changing business needs. (White Paper, 2004b)

Web Services communicate using platform-independent and language-neutral web protocols. These web protocols ensure easy integration of heterogeneous environments. (White Paper, 2003b) Thus, web services are becoming widely adopted across the entire software industry to integrate incompatible applications. (White Paper, 2004a)

- **Easily Accessible**:

Web services are distributed and easily accessible over the Internet. Web services make use of existing, ubiquitous transport protocols like HTTP, leveraging existing infrastructure and allowing information to be requested and received in real time. (White Paper, 2004a)

- **Openness:**

Web Services technologies are based on open standards. What makes a web service special is its XML-based components. Fortunately, the designs of these components are specified by independent standards bodies. (White Paper, 2004b) Because web services use these open standards, the cost point is substantially reduced. Enterprises do not have to use the more traditional and expensive EAI product suites to build successful solutions. In addition, the open standards are easier to learn and to use than traditional methods. The faster learning curve translates into faster deployment increasing the productivity of an enterprise.

- **Re-usability:**

For years it is known that reusing code, or parts of applications, rather than rewriting them for a new application increases productivity. Web services promote service reuse. Services reuse capability increases enterprise's productivity, reduces the amount of new services that need to be developed and makes it much easier to change and/or add services as enterprise needs change. (White Paper, 2004b)

Because the packaging and delivery information is isolated and maintained independently from either the provider or consumer application, business service developers need only focus on the business logic and functionality. The business logic remains neutral (or generic) and can be re-used for the overall needs of the web service. (White Paper, 2004b; White Paper, 2003b)

- **Granularity**

Web services are coarse grained in that they are usually mapped to business level processes as opposed to low level data or API functions. (White Paper, 2003a)

An often-asked question in distributed system building is what is a sensible interface size or granularity for an entity within the system? In previous generations for entities real objects, components or classes. In SOA they are business services used within the context of a business process that will need to be understood by business users. Therefore a business service interface should typically reflect real-world business documents: archives, archaeological excavation forms, and oral history records. Note that this is a much coarser granularity than previous integration models, which focused on low-level programming APIs. While earlier RPC or message-passing approaches used simple messages flowing between complex API endpoints, in the SOA case there is larger, richly typed, self-contained documents flowing between coarse endpoints. (White Paper, 2004c)

4.4.3 Internet middleware

Although web services are new, introduced in 2001, the concepts behind SOAs have been around for quite a while. Most standard distributed computing middleware technologies implement a SOA system (for application-to-application communication). The genesis for SOC is in technologies such as RPC, Message-Oriented Middleware (MOM), the OMG's CORBA IDL, Java RMI, the Open Group Distributed Computing Environment (DCE), Microsoft DCOM.

Each SOA system defines its own a set of formats and protocols that implement the core SOA functions. An SOA system often also defines an invocation mechanism, which includes an API and a set of language bindings. This approach ensures consistency among applications that share the same middleware, but prevents interoperability with applications that use different middleware. It also requires that every service producer and service consumer that engages in a conversation must have the appropriate middleware loaded on its machine. (White Paper, 2002)

SOAs almost always contain some formal mechanism for defining the precise interface provided by a service. For example, each of DCE, CORBA, and DCOM have a formal IDL. Unfortunately, each of these platforms has defined its own unique IDL, making moving from one platform to the other very difficult. J2EE relies on Java interface classes -there is no separate IDL, and tools use the Java reflection API to determine the makeup of each interface. (White Paper, 2003c)

SOAs also typically define a set of protocols for invoking remote services. CORBA and J2EE use IIOP, while Microsoft DCOM has its own proprietary protocol. Where these protocols are managed as open standards, they enhance interoperability between different vendors for a given platform, for example, IIOP is an open standard maintained by the OMG consortium. However, interoperability is still a major problem when trying to integrate different platforms such as CORBA and DCOM, because these protocols must be mapped at a very low level at runtime. (White Paper, 2003c)

Web services can be thought as a new form of middleware, 'Internet middleware'. But unlike previous SOA systems, Internet middleware does not require an entirely new set of protocols. The most basic web services protocol is the ubiquitous standard XML, which is used as the message data format, and is also used as the foundation for all other web services protocols. Today most Internet middleware systems are implemented using a core set of technologies, including: (White Paper, 2003b; White Paper, 2004a; White Paper, 2003a; White Paper, 2002)

- An encoding format for remote invocation: Simple Object Access Protocol (SOAP)
  SOAP defines a standard communications protocol for web services by which data is transported between a service requestor (or service consumer) and a service provider.

- An interface definition language: Web Service Description Language (WSDL)

  WSDL defines a standard mechanism to describe a web service.
- A directory service: Universal Description, Discovery, and Integration (UDDI)

  UDDI provides a standard mechanism to register and discover web services.

These technologies define the transport, description, and discovery mechanisms, respectively. Three XML-based specifications (or technologies) have emerged as the de facto standards for web services and that cover most every aspect of standard service communication. Each of these technologies are defined and implemented in XML. One important ramification of the use of XML is that any application, written in any language, running on any platform, can interpret web services messages, descriptions, and discovery mechanisms. No specific middleware technology needs to be available to converse using web services. (White Paper, 2003b; White Paper, 2004a; White Paper, 2003a; White Paper, 2002)

Typically, these standards are maintained by independent, non-profit standards organizations composed of a diverse membership. Members submit various requirements for the standard and agree to a specification after many review phases, resulting in a free and open standard upon which any group can build web service-compliant applications and tools. Three dominant standards boards lead this critical effort:

- World Wide Web Consortium (W3C): The driving force behind the largest number of highly adopted standards in the web services space including some web building blocks such as HTML. (http://www.w3.org)

- Organization for the Advancement of Structured Information Standards (OASIS): Source of the original specification from which XML evolved, as well as the home of the current XML and UDDI specification. (http://www.oasis-open.org)

- Web Services Interoperability Organization (WS-I): Acts as a watchdog group to ensure interoperability between implementations of web services standards. (http://www.ws-i.org)

4.4.4 Web services architecture and its specifications

Figure 4.7 depicts web services general view with core web services technologies.

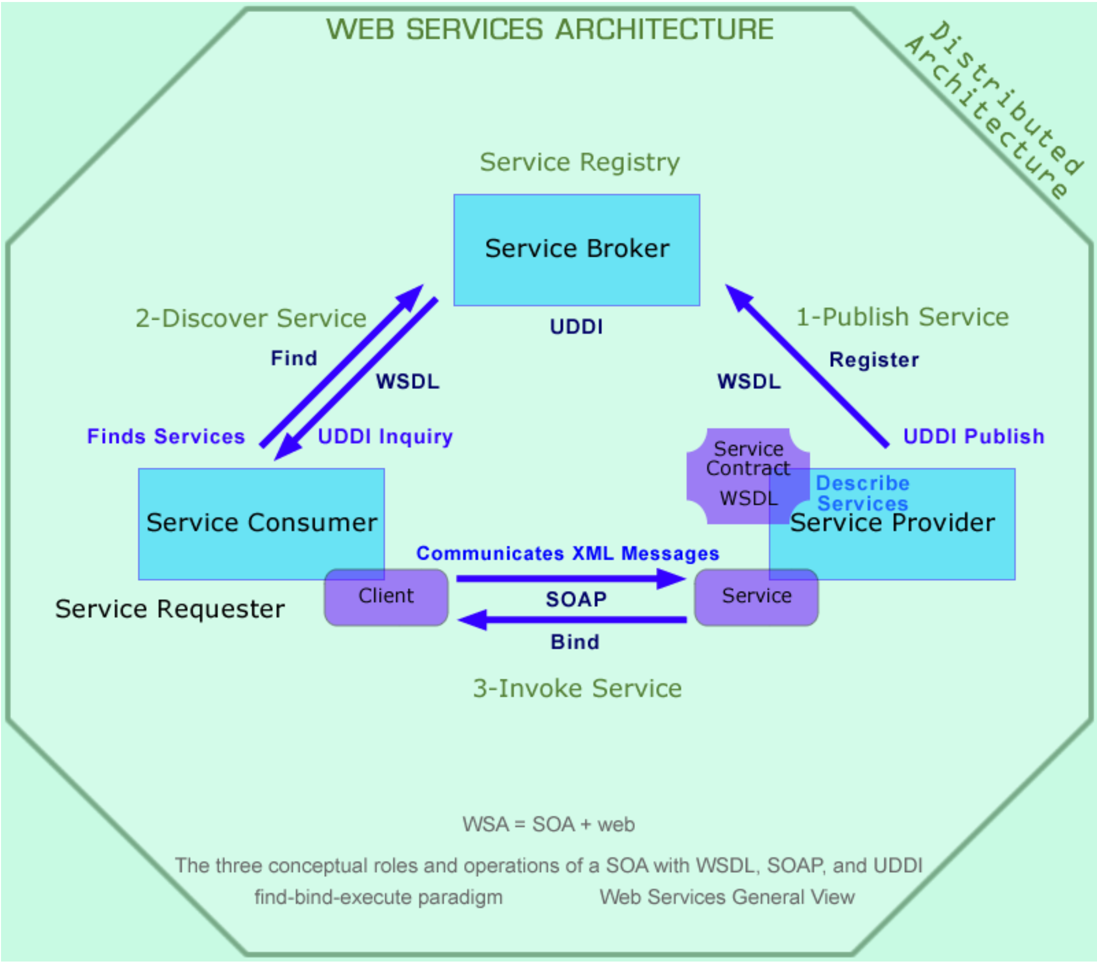

Figure 4.7: The general WSA based on the SOA

As shown in figure 4.7, the three basic conceptual roles of SOA are the service *provider*, the service *consumer*, and a service *broker*. A service provider makes the service available and publishes the contract that describes its interface. It then registers the service with a service broker. A service consumer queries the service broker and finds a compatible service. The service broker gives the service consumer directions on where to find the service and its service contract. The service consumer uses the contract to bind itself to the service. In order for the three conceptual roles to accomplish the three conceptual operations, an SOA system must supply three core functional architecture components: (White Paper, 2002)

- **Transport.** The transport component represents the formats and protocols used to communicate with a service. The data format specifies the data types and byte stream formats used to encode data within messages. The wire protocol specifies the mechanism used to package the encoded data into messages. The transfer protocol specifies the application semantics that control a message transfer. The transport protocol performs the actual message transfer.

- **Description:** The description component represents the languages used to describe a service. The description provides the information needed to bind to a service. At a minimum, a description language provides the means to specify the service contract, including the operations that it performs and the parameters or message formats that it exchanges. A description language is a machine-readable format that can be processed by a compiler to produce communication code, such as client proxies, server skeletons, stubs, and ties. These generated code fragments automate the connection between the application code and the communications process, insulating the application from the complexities of the underlying middleware.

- **Discovery:** The discovery component represents the mechanisms used to register or advertise a service and to find a service and its description. Discovery mechanisms may be used at compile time or at runtime. They may support static or dynamic binding.

Web services are an example of a SOA. In most Internet middleware configurations, the three core functional components *(transport, description, and discovery)* in the WSA are implemented using SOAP, WSDL, and UDDI, respectively. A UDDI registry plays the role of service broker. The register and find operations are implemented using the UDDI Inquiry and UDDI Publish APIs. A WSDL document describes the service contract, and is used to bind the consumer to the service. All transport functions are performed using SOAP. (White Paper, 2002)

In the WSA, when a service provider deploys a web service to make the service available to service consumers, it describes the service using WSDL and registers the service and its WSDL description in a UDDI registry to help service consumers find the service that matches their needs. The UDDI registry will then maintain pointers to the services and its WSDL description. When the service consumer wants to use the service, it queries the UDDI registry to find the service and obtains the WSDL description of the service, as well as the access point of the service. The service consumer uses the WSDL description to construct a SOAP message with which to communicate with the service. (White Paper, 2003b; White Paper, 2004a)

Transport

The transport functional component defines the formats and protocols used to communicate between service consumer (client applications) and services. The WSA formats and protocols are defined by SOAP. SOAP provides a simple messaging framework that allows one application to send an XML message to another application. (White Paper, 2002)

- **Data format**. The SOAP data format is XML. The mechanism by which the data are encoded is totally extensible, and in fact can be specified within each SOAP message. The data format can represent an RPC invocation, in which case the message body is composed as a structure containing the RPC input parameters or return value. The name of the structure indicates the method to be invoked. When using the RPC representation, the data are normally encoded using an XML-based encoding style. Alternately, the data format can be in the form of an XML document, in which case the data are normally encoded using a specific XML Schema.

- **Wire format**. The SOAP wire format is an XML document called a SOAP envelope. The envelope contains an optional SOAP header and a mandatory

SOAP body. The SOAP body contains the message payload, encoded in XML.

- **Transfer protocol**. SOAP defines an abstract binding framework that allows SOAP messages to be transferred using a variety of underlying transfer protocols. The SOAP specification defines a protocol binding for HTTP. Bindings have also been defined for HTTPS, SMTP, POP3, IMAP, JMS, and other protocols.

- **Extensions**. Additional information can be included with a SOAP message within a SOAP header. The SOAP header can provide directive or control information to the service, such as security information, transaction context, message correlation information, session indicators, or management information.

Description

The description functional component defines the language used to describe a service. The service consumer uses the description to bind itself to the service. The WSA description language is the WSDL. A WSDL document describes *what* functionality a Web service offers, *how* it communicates, and *where* to find it. The various parts of a web service description can be separated into multiple documents to provide more flexibility and to increase reusability. A WSDL implementation document can be compiled to generate a client proxy that can call the web service using SOAP. (White Paper, 2002)

- **Abstract interface**. The *what* part of a WSDL document describes the abstract interface of the web service. It essentially describes a service *type*. Any number of service providers can implement the same service type. The WSDL *what* part defines a logical interface consisting of the set of operations that the service performs. For each operation it defines the input and/or output messages that are exchanged, the format of each message, and the data type of each element in the message.

- **Concrete binding**. The *how* part of a WSDL document describes a binding of the abstract interface to a concrete set of protocols. The binding indicates whether the message is structured as an RPC or as a document; it specifies which encoding style or XML Schema should be used to encode the data; it specifies which XML protocol should be used to construct the envelope; it indicates what header blocks should be included in the message; and it indicates which transfer protocol should be used. The *how* part includes or imports the associated WSDL *what* part.

- **Implementation**. The *where* part of a WSDL document describes a service implementation. A service implementation is a collection of one or more related ports. Each port implements a specific concrete binding of an abstract interface. The port specifies the access point of the service endpoint. A business might offer multiple access points to a particular service, each implementing a different binding. The *where* part includes or imports the associated WSDL *how* part. A service producer should always publish the *where* WSDL part with the web service.

Discovery

The discovery functional component provides a mechanism to register and find services. Some discovery functions are used at development time, while others are used at runtime. The WSA discovery mechanism is implemented using a UDDI registry service. For the most part, UDDI is used at development time, although it can also be used at runtime. UDDI is itself a web service, and users communicate with UDDI using SOAP messages. UDDI manages information about service types and service providers, and it provides mechanisms to categorize, find, and bind to services. (White Paper, 2002)

- **Service types**. A service type, defined by a construct called a tModel, defines an abstract service. Multiple businesses can offer the same type of service, all supporting the same service interface. The tModel provides a pointer to the WSDL document that describes the abstract interface (the *what* part).

- **Service providers**. A service provider registers its business and all the services it offers. For each service offered, the service provider supplies the binding information needed to allow a consumer to bind to the service. The bindingTemplate construct provides a pointer to the WSDL document that describes the service binding (the *how* part). It also specifies the access point of the service implementation. The WSDL *where* part is usually co-resident with the access point.

- **Categorization**. When a service provider registers a service or service type, it can categorize the entity (business, service, or tModel) using a variety of taxonomies. The UDDI specification defines a core set of taxonomies, such as geographic location, product codes, and industry codes. Additional taxonomies can be added to the registry to support more focused or customized categorization and search.

- **Find**. When looking for a web service, a service consumer queries the UDDI registry, searching for a business that offers the type of service that it wants. Consumers can search the registry for services by service type or service provider, and queries can be qualified using the taxonomies. From the tModel entry for the service type, the consumer can obtain the WSDL description describing the abstract interface. The consumer can compile this *what* part description to create a client interface for the abstract service. This abstract interface could be used to access multiple implementations of the service type. From the bindingTemplate entry for a specific service, the consumer can obtain the access point of the service and the WSDL description of the service binding.

- **Static binding**. Developers can bind clients to services either at compile time or at runtime. Using the WSDL *how* part, a developer can compile a concrete SOAP client interface or stub that implements the binding required to communicate with a specific web service implementation. This pre-compiled stub can be included in a client application. The access point can be specified at runtime.

- **Dynamic binding**. Because a WSDL document is machine-readable, WSA also supports dynamic binding. Using just the WSDL *what* part at compile time, a developer can generate an abstract client interface that can work with any implementation of a specific service type. At runtime the client application can dynamically compile the WSDL *where* part (containing the *how* part) and generate a *dynamic proxy* that implements the binding.

- **Dynamic discovery**. Since UDDI is itself a web service, an application can query the registry at runtime, dynamically discover a service, locate its access point, retrieve its WSDL, and bind to it, all at runtime. The client interprets the WSDL to dynamically construct the SOAP calls.

UDDI is particularly useful if the service consumer does not know which type of web service it wants to use, which service providers provide the service, or where to go to find the services. If a service consumer already knows this information, then the consumer can use a simpler, more direct form of discovery as an alternate discovery mechanism, such as the Web Services Inspection Language (WS-Inspection18). WS-Inspection is an XML format that can be used to inspect a web site for available web services. Assuming that the service consumer knows the home page URL for the service provider, and knows which service type it is looking for, it can use WS-Inspection to find information (including WSDL *where* part descriptions) about all of the web services offered by that service provider. Given a WSDL *where* part description, a service consumer has everything it needs to bind to the service. (White Paper, 2002)

SOAP: Simple Object Access Protocol

SOAP was first developed in late 1999 by DevelopMentor, Microsoft, and UserLand as a Windows-specific XML-based RPC protocol. In early 2000 Lotus and IBM joined the effort and helped produce an open, extensible version of the specification that is both platform- and language-neutral. This version of the specification, called SOAP v1.1, was submitted to the W3C. W3C subsequently initiated a standardization effort, May 08th, 2000. The latest version of SOAP is version 1.2, approved version of the standard at June 24th, 2003. (http://www.w3.org/TR/SOAP/)

SOAP is a lightweight, extensible XML messaging protocol that provides a simple and consistent mechanism that allows one application to send an XML message to another application over a transport. It is an XML specification (or an XML-based standard) that defines an encoding for sending messages between service producers and consumers. (White Paper, 2004a; White Paper, 2003b; White Paper, 2003c)

Fundamentally, SOAP supports peer-to-peer communications. A SOAP message is a one-way transmission from a SOAP sender to a SOAP receiver, and any application can participate in an exchange as either a SOAP sender or a SOAP receiver. SOAP messages may be combined to support many communication behaviors, including request/response, solicit response, and notification. (White Paper, 2003b)

Figure 4.8 conceptually shows how an authentication token and a digital signature could be specified in a SOAP header.

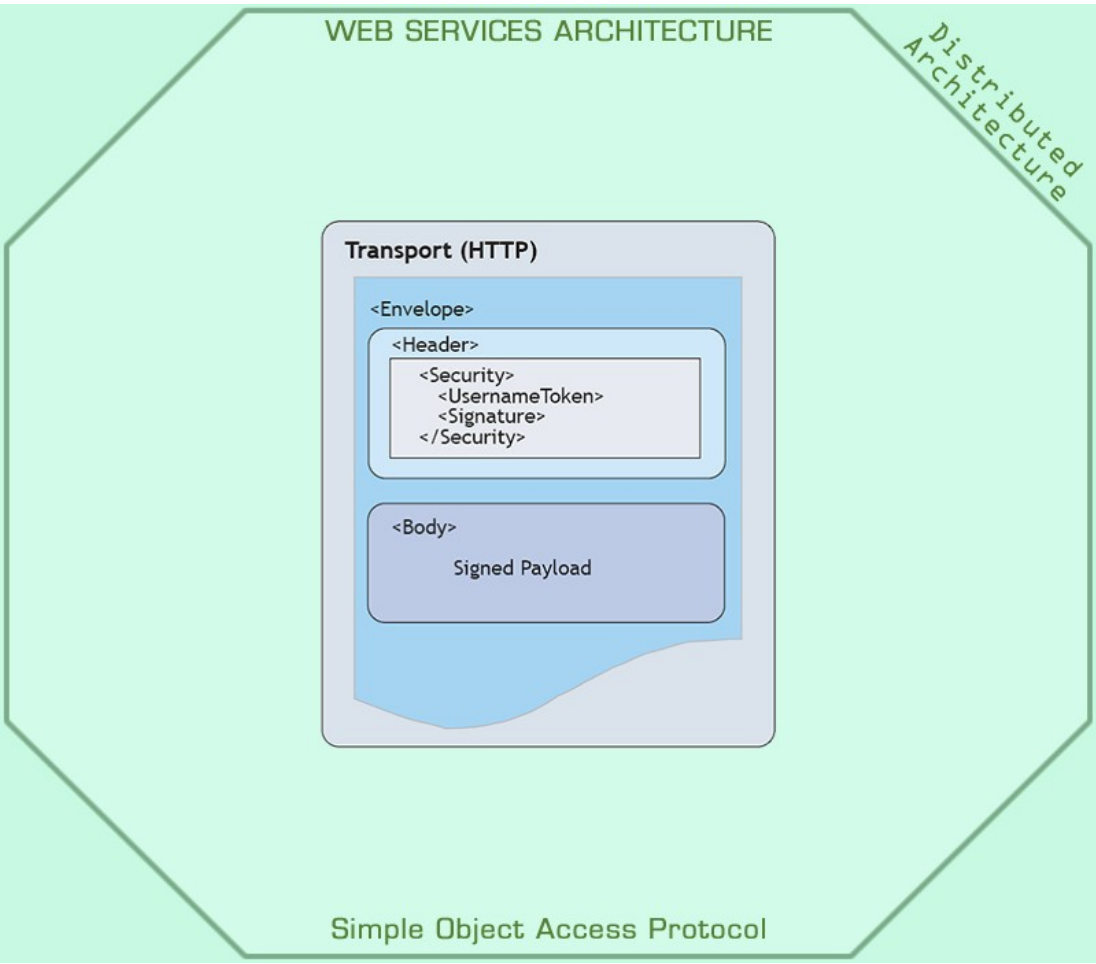

Figure 4.8: Using a SOAP header to pass security information

SOAP consists of four parts: (White Paper, 2004a; White Paper, 2003b; White Paper, 2003c; White Paper, 2002)

- **SOAP Envelope** - Describes the contents of a message and how to process it, and contains extra details such as security information or the final destination of the message. A SOAP envelope includes a SOAP header and a SOAP body. The SOAP header provides an extensible mechanism to supply directive or control information about the message. For example, a SOAP header could be used to implement among other things: Transactions, Security, for instance, using WS-Security, Reliability, using the upcoming WS-ReliableMessaging standard, Routing, Payment mechanisms.

  Many middleware capabilities can be added to the WSA using SOAP headers, such as security, transactions, conversations, and reliable message delivery. The transport delivery, context, security, and management functions are provided through SOAP extensions.

  All SOAP messages are encoded inside a SOAP envelope. The envelope can contain information on the encoding used in the message, as well as the body of the message, which contains the (message) payload sent to/from the service endpoint (as it moves between service producers and consumers).

  Basically, the SOAP envelope is sent in a standard HTTP request, with some extra information in the HTTP header to identify the target service.
- **SOAP Body**. The SOAP body contains the payload that is being sent in the SOAP message.
- **SOAP Transport Binding Framework -** An abstract framework for exchanging SOAP envelopes (messages) using an underlying protocol, including HTTP or other transports.

  SOAP defines the layout of web service requests and replies, but allows for bindings to different transport mechanisms. It is not tied to a particular transport. The core SOAP specification details bindings to HTTP and HTTPS (for encrypted communication) for basic web invocations, as well as an SMTP binding for sending SOAP messages by e-mail. Other bindings are POP3, IMAP, JMS and other protocols. Other mappings exist that allow web services to be readily integrated with platforms such as CORBA and J2EE, and Microsoft has evolved DCOM into .NET, which is based around a web service core.

- **SOAP Serialization Framework** - A set of SOAP encoding rules for expressing instances of application-defined data types, such as numbers and text, and a convention for representing RPCs and responses.

  SOAP provides a number of different encoding mechanisms, but it is recommended to use WSDL, XML Schema, and “literal” encoding, which are the up-to-date standards.

  Services may be designed to work on the raw XML payload, but it is more common for the payload to be mapped or bound directly to data types in the host language. This step is called serialization and is implemented by most web service implementations. Serialization is possible regardless of whether the payload is a literal XML document or SOAP encoded as both support common features found in the type systems of most programming languages and databases. This includes simple scalar types such as strings, integers, and floats, and complex types, such as structures and arrays.

SOAP RPC Style Messaging

SOAP supports a tightly coupled communication scheme based on the SOAP RPC representation. The SOAP RPC representation defines a programming convention that represents RPC requests and responses. Using SOAP RPC, the developer formulates the SOAP request as a method call with zero or more parameters. When the payload is constructed into a single structure the outermost element represents the name of the method or operation, and the innermost elements represent the parameters to the operation. The SOAP response is similar with an outermost element named in relation to the method name and the innermost parameters representing zero or more return parameters. (White Paper, 2003b)

SOAP Document Style Messaging

SOAP also supports very loosely coupled communications between two applications. The SOAP sender sends a message and the SOAP receiver determines what to do with it. The SOAP sender does not really need to know anything about the implementation of the service other than the format of the message and the access point URI. It is entirely up to the SOAP receiver to determine, based on the contents of the message, what the sender is requesting and how to process it. Note that even with Document Style Messaging it is possible to emulate RPCs by putting the method/operation name in the SOAPAction header of the HTTP request. (White Paper, 2003b)

SOAP with Attachments

The SOAP with Attachments binding can be used to transport non-XML data, such as multimedia files, as attachments to a SOAP message. This specification uses MIME to encode messages. This is useful if the application requires passing large binary data with a request or response, where the overhead of converting that data to XML would be high or unnecessary (for example, if the data was opaque). MIME is an Internet standard for formatting e-mail messages so that they can be exchanged between different e-mail systems. MIME enables messages to contain a wide variety of data types, including text, graphics, audio, and video. Though MIME is ubiquitous it is not necessarily the best mechanism for sending binary messages in a SOAP envelope. An alternate mechanism is called DIME, and the WSAttachments specification describes how to embed DIME in a SOAP Envelope. (http://www.w3.org/TR/SOAP-attachments)

The Apache Axis Project is an implementation of the SOAP submission to W3C. (http://ws.apache.org/axis/)

WSDL: Web Service Description Language

WSDL describes the interface to a web service. -it defines the operations together with the data a web service can perform, the formats of the messages that it can process and the protocols that it supports (how it communicates), and the access point of an instance of the web service (where it is accessible)- basically the content of a SOAP message. WSDL uses the XML Schema standard, so it can use all of the standard XML Schema data types. It is also possible to define new structured types (user-defined type) using the standard XML Schema constructs. (White Paper, 2004a; White Paper, 2003b; White Paper, 2003c)

A WSDL description defines a service as a set of network endpoints or ports operating on messages containing either document-oriented or procedure-oriented information. Each port is defined abstractly as a port type, which supports a collection of operations. Each operation processes a particular set of messages. A binding maps a port type to a specific concrete network protocol and data (or message) format to define the service endpoint. In other word, a binding maps the WSDL operations onto SOAP operations, and specifies the SOAP parameters and encoding used. A port instantiates a port type and binding at a specific network address, for example, a URL reference to a server's SOAP/HTTP listener. (White Paper, 2004a; White Paper, 2003b; White Paper, 2003c)

Most often, these messages are bound to the SOAP protocol and the HTTP transport, but these are not the only set of bindings supported. WSDL's abstract nature for describing services makes it very flexible for describing complex web services applications also by supporting other encoding and transport mechanisms. (White Paper, 2004a; White Paper, 2003b; White Paper, 2003c)

A WSDL document uses the following elements in the definition of network services: (White Paper, 2004a; White Paper, 2003b)

- **Types**– A container for data type definitions using some type system, such as XSD.
  The <types> element defines the data types that are used within messages. WSDL uses the data typing system defined in the W3C XML Schema Part 2: Data types Recommendation (http://www.w3.org/TR/xmlschema-2/) as its canonical type system, although any data typing system may be used. The type system supports simple scalar types and complex types. Schema types can be mapped to most programming language type systems. SOAP tools use the type information to encode and decode the data in SOAP messages.
- **Message**– An abstract, typed definition of the data being communicated.
  A <message> element defines the format of a message. Messages are used as

input or output structures for operations. A message can consist of one or more logical parts, each of which is associated with a type. When using the SOAP RPC programming model, each part represents a method parameter.

- **Port Type**–An abstract set of operations supported by one or more endpoints. A <portType> element defines a set of operations. Each <operation> element defines an operation and the input and output messages associated with the operation. When using the SOAP RPC programming model, each operation represents a method.
- **Operation**– An abstract description of an action supported by the service.
- **Binding**– A concrete protocol and data format specification for a particular port type.

  A <binding> element maps the operations and messages defined in a port type to a concrete protocol and data format specification. For example, a binding element might map a port type to a specific SOAP RPC interface using the HTTP transport protocol and the SOAP data encoding system.
- **Service**– A collection of related endpoints.

  A <service> element defines a collection of related ports.
- **Port**– A single endpoint defined as a combination of a binding and a network address.

  A <port> element maps a binding to the location (a URL) of an instance of the Web Service.

Figure 4.9 maps the three parts of a WSDL description to the specific WSDL definition elements.

All WSDL definitions follow the same basic structure. The top-level XML element is called <definitions>. This <definitions> element will contain one or more <portType> elements. Port types are basically the equivalent of class interfaces. They are basically sets of methods or operations, defined in <operation> elements.

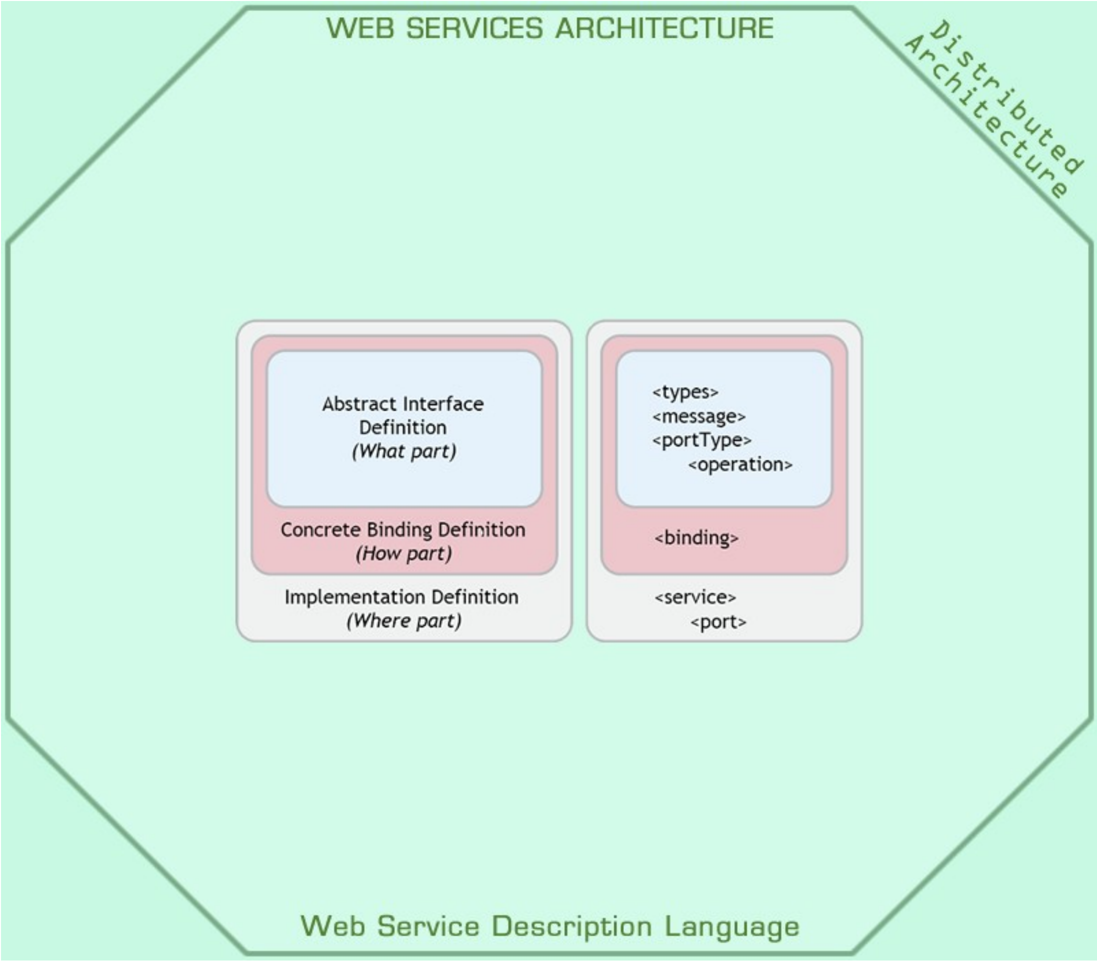

Figure 4.9: WSDL description

UDDI: Universal Description, Discovery and Integration

UDDI represents a set of protocols and a public directory for the registration, classification and real-time lookup of available web services and other business processes. UDDI is itself a web Service. Users communicate with UDDI using SOAP messages. (White Paper, 2004a; White Paper, 2003b)

Since any amount of information can be associated with a service, UDDI promotes a certain amount of polymorphism. That is, a client may chose to bind with a service not just by its name, but by other meta information as well, such as its version, or its applicable geography, and so on. (White Paper, 2003b) Basically, it is a combination of yellow and white pages. Services can be searched for by name or by matching properties. Entries in a UDDI repository can contain business information as well as web service APIs (that is, WSDL definitions). (White Paper, 2003c)

The information that can be registered includes simple data that help others determine the answers to the questions “who, what, where, and how?”: (White Paper, 2003c)

- Human-readable details include things such as entity name, contact information, product codes, and so on.
- Details aimed at machine consumers includes the URL or other service endpoints and references to details on service interfaces and other properties. These describe the behavior of a particular software package or technical interface. They are called tModels in the UDDI specification.

The UDDI standards process is managed by OASIS, with V2.03 being the latest version (19 July 2002). An important new feature of the UDDI V3 specification is Subscriptions and Notifications, which allow clients to automatically receive notification of changes made to registered web services. Without this, subscribers would not be aware of web service changes until they attempted to use the service. (http://www.oasis-open.org)

A UDDI Registry contains information about businesses and the services they offer. The information is organized as follows: (White Paper, 2003b)

- **Business Entity**. A business entity contains information about a business including its name, a short description, and some basic contact information. Each business can also be associated with unique business identifiers, including a Thomas Register identifier and a D-U-N-S number, and with a list of categorizations that describe the business. UDDI V2 products allow businesses or industry groups to create additional describing categories, a very powerful feature.
- **Business Service**. Associated with the business entity is a list of business services offered by the business entity. Each business service entry contains a business description of the service, a list of categories that describe the

service, and a list of binding templates that point to technical information about the service.

- **Binding Templates**. Associated with each business service entry is a list of binding templates that provide information on where to find the service and how to use the service. For example, a binding template may contain the access point of the service implementation. The binding template also associates the business service with a service type.
- **Service Types**. A service type, defined by a construct called a tModel, defines an abstract service. Multiple businesses can offer the same type of service, all supporting the same service interface. A tModel specifies information such as the tModel name, the name of the organization that published the tModel, a list of categories that describe the tModel, and pointers to technical specifications for the tModel. For example, a tModel may point to a WSDL document that describes an abstract service type.

4.4.5 Implementing web services

Developing web services-based applications requires a different approach than traditional web application development. Web services, and service-based development in general, require a strong focus on the design step of the development process. The application design will define the services, data types, and message formats, and how they interact. Web services require that the design is represented in a WSDL document. The WSDL document lists all the services and data types that make up an application in XML Schema format.

Internet middleware products, sometimes referred to as a web services platform, provide a ready-made foundation for building and deploying web services. The advantage of using a web services platform is that developers do not need to be concerned with constructing or interpreting SOAP messages. A developer simply writes the application code that implements the service, and the Internet middleware does the rest. A web services platform generally consists of development tools, a runtime server, and a set of management services. Figure 4.10 shows a typical web services platform runtime environment.

Development tools are used to create web services, to generate WSDL descriptions that describe those services, and to generate client proxies that can be used to send messages to the service. Development tools may also provide wizards to register or discover services in a UDDI registry.

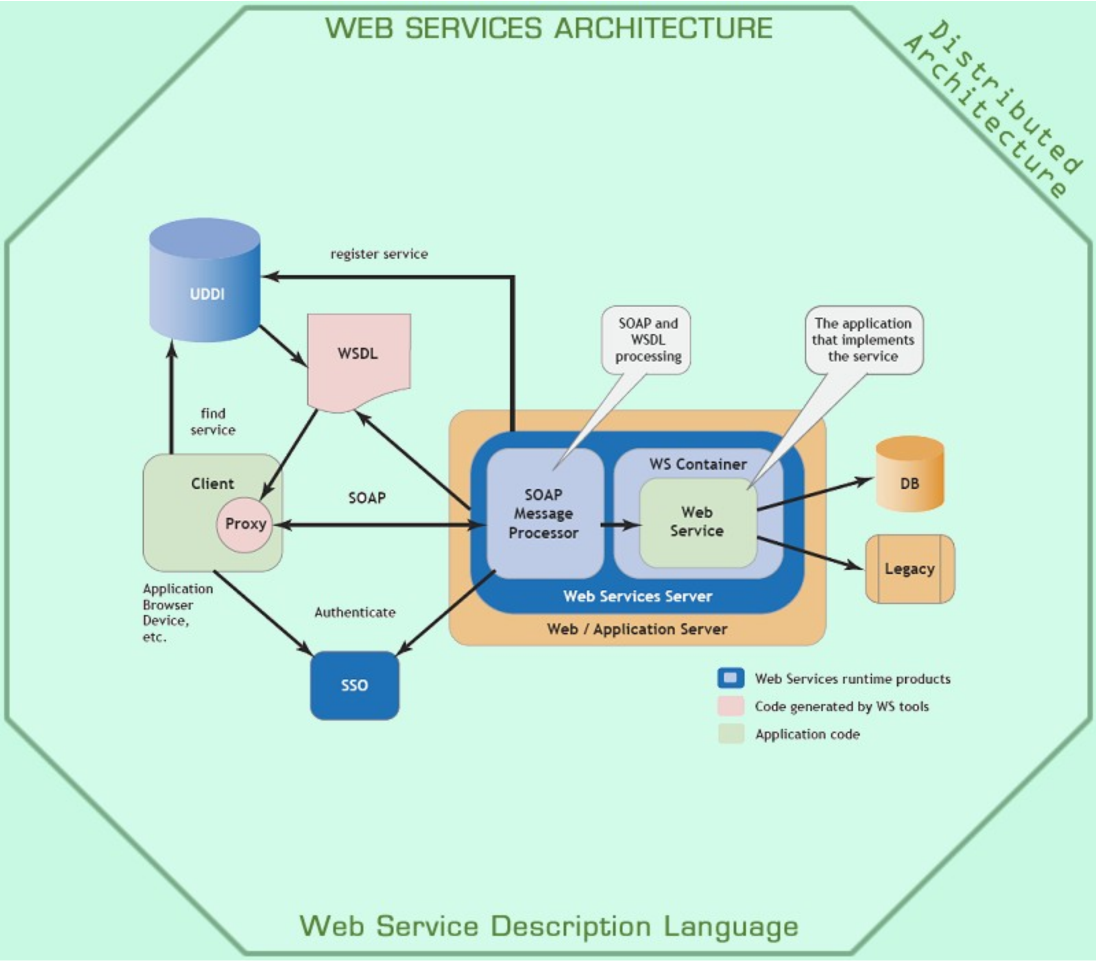

Figure 4.10: Internet middleware

A web services server (or runtime server) consists of a SOAP message processor and a web service container (or runtime container). The SOAP message processor processes an incoming SOAP message, translates it from XML data into the service's native (or programming) language data (e.g., Java), and routes the request to the application that implements the service. The application usually executes within the web service container, which manages the lifecycle of the application. When the application completes its work, the web service container translates the return value into XML, packages it into a SOAP response message, and sends the message back to the calling requestor. (White Paper, 2002)

Management tools provide mechanisms to deploy, undeploy, start, stop, configure, and administer the web services. An administrative console is obviously useful, and other potential management services include a private UDDI registry, a WSDL repository, a single sign-on (SSO) service, and runtime monitoring facilities.

The web makes WSA completely platform- and language-independent. Web services can be developed using any language, and they can be deployed on any platform. Currently there are two popular platforms (or environments) for web services, one based on the Java language and the J2EE environment, and the other based on Microsoft's C# language and the .Net platform. The two platforms are designed to provide the same functionality: detailed descriptions of a web service in correct WSDL, data transport via SOAP, and access through UDDI. Table 4.4 shows that the two platforms, though similar in structure, employ different technologies at virtually every layer.

Table 4.4: The tools and technology for building and deploying web services

Technology	***J2EE***	***Microsoft***
Programming Language	Java	C#
Transport	SOAP, ebXML, others	SOAP, DCOM
Just-in-time compiler	Java Virtual Machine	Common Language Runtime
Application Server	IBM WebSphere, BEA WebLOgic, iPlanet, etc.	Microsoft Windows/IIS/COM+
Database Access API	JDBC, EJB Entity Beans	ADO.NET

CORBA

According to CORBA's SOA model, CORBA defines the concept of a remote object, which corresponds to a web service. Each object must have its interface formally defined. CORBA specifies a language- and platform-neutral IDL for this purpose. Like WSDL, IDL allows developers to define new data types and to specify the operations, argument, and exceptional conditions used in an object's interface. (URL OMG)

For remote invocation, CORBA defines an encoding mechanism called Generic Inter-ORB Protocol (GIOP) and a binding for using GIOP over TCP/IP called Internet Inter-ORB Protocol (IIOP). These correspond to SOAP and the SOAP/HTTP binding, respectively. (URL OMG)

CORBA also defines a set of what it terms Common Object Services, which provide runtime support services. These include naming (lookup by name), trading (lookup by property), security, messaging, and so on. UDDI corresponds to a combination of CORBA naming and CORBA trading services. (URL OMG)

Wrapping CORBA components as web services requires three steps: (URL OMG)

1. Mapping IDL to WSDL.
2. Run-time mapping of SOAP to IIOP.
3. Integration of CORBA naming service, and so on.

WSA Invocation Mechanism

Unlike other SOA systems, Internet middleware does not define a specific invocation mechanism. The core Internet middleware specifications simply define the communication protocols. The specifics of how applications interact with SOAP and WSDL have been left as an exercise to the application community. Any application language can parse and process XML, so at a minimum, applications can simply construct XML messages directly, package them in a SOAP envelope and exchange messages. Such manual processing is not particularly conducive to developer productivity, and it does not exploit the fact that WSDL is machine-readable and can be compiled into application code. Hence the application community has produced a set of standard invocation mechanisms.

The Java Community Process has defined a set of standard programming interfaces for Java applications. (URL Java)

- The Java API for WSDL (JWSDL) provides an API to create, inspect, and manipulate a WSDL document. JWSDL is used when compiling WSDL files into client stubs and proxies, and it is used to process a WSDL file at runtime for dynamic binding and discovery.
- The Java API for XML based RPC (JAX-RPC), working with JWSDL, provides support for static binding, dynamic binding, and dynamic discovery. JAX-RPC also defines mappings between Java data types and XML types. The JAX-RPC client APIs automatically marshal and unmarshal SOAP requests on behalf of the client application.
- The Java API for XML Messaging (JAXM) provides an API to construct SOAP messages without the benefit of a WSDL document. JAXM works with *profiles* that define a template for a SOAP message structure, automatically constructing the SOAP envelope, SOAP header, and SOAP body. The client application simply adds the XML payload to the message.
- The SOAP with Attachments API (SAAJ) provides a low level SOAP API. Client applications can use SAAJ to manually construct and process SOAP messages.
- The Java API for XML Registries (JAXR) is an API that can be used to access a variety of XML registries, including UDDI registries and electronic business XML (ebXML) registries. Given that it is a generic registry API, the JAXR data model is different from the UDDI data model. There are a number of other UDDI client APIs that more closely match the UDDI data model, including two open source projects: UDDI4J and the Systinet UDDI Client API.
- Java Service Developer Pack (Java WSDP) is an integrated toolset that in conjunction with the Java platform allows Java developers to build, test and deploy XML applications, web services, and web applications. The Java

WSDP provides Java standard implementations of existing key web services standards including WSDL, SOAP, ebXML, and UDDI as well as important Java standard implementations for web application development such as JSP technology pages and the JSP Standard Tag Library.

Microsoft has defined a set of standard programming interfaces and class libraries for the Visual Studio .NET languages within the .NET framework, and the Microsoft SOAP Toolkit provides support for COM-based applications written in Visual Basic and Visual C++. (URL Microsoft)

4.4.6 Web services in the cultural heritage domain

Z39.50 communications protocol

Z39.50 is an American development intended to facilitate networked access to distributed database resources. Basically, Z39.50 itself is no more than a network protocol: the thing that controls how two or more computers talk to each other. The rest of the work is done by the database software or some other tool. There are currently two main flavors of Z39.50 -- Z39.50-1992 (version 2) and Z39.50-1995 (version 3, recently ratified as ISO 23950). The simpler Z39.50-1992 appears to remain the most frequent implementation, although this is changing gradually. (Miller, 1997)

More often used within academic information systems, Z39.50 is a protocol that can be used to communicate data between remote systems. However, it is a relatively outdated and rather cumbersome and static technology. (Miller, 1997) Z39.50 requires a dedicated Z39.50 server acting as a host to a number of Z-targets. Each of these targets need their database and related connections aligned to the Z39.50 protocol by using what are known as 'profiles' held on the server. A Z-client or gateway can then hook into the server, request a query and await results. Aside from being notoriously complicated to implement correctly, the use of specific server-side profiles to link the server to its related data sources thus present a somewhat tight coupling between the various remote systems. (Waller, 2005) A web service is not directly a web-based implementation of the RPC protocols, or indeed a technology designed as a replacement to the dated Z39.50 protocol. A web service is, however, a much simpler protocol that offers greater flexibility for achieving the same goal – the retrieval of information from a remote system. (Waller, 2005) It is for this reason that CH enterprises can use web services to embrace an altogether more efficient and flexible infrastructure for the search, retrieval and ultimately integration of remote datasets and information from remote systems.

As a nascent technology in the CH domain, the critical issue for web services is to determine what needs of the CH community are addressed by them, where they are used in the CH projects, how a common architecture would be established for them in which components are distributed and loosely coupled, and what the functions of that architecture should be.

SOA, web services and WSA enable the extended CH enterprises like "KaleTakimi" dealing with numerous stakeholders both internally as well as externally and being constantly engaged with systems, actors, disciplines, technologies etc. to be more agile and flexible by providing the powerful technology for doing a number of things from integration of applications, systems, processes within the enterprise to building better business processes that span across extended enterprise or multiple enterprises.

The integration of all business functions into a seamless process requires integration of the applications that support these functions -even if many of those applications belong to other CH enterprises. Hence, the various systems are speaking the same language even if they are owned by different CH organizations. This approach allows business processes or functionality residing on completely different systems and unknown to each other to communicate in a standard way.

"GeoCHEAF" is challenged to provide common pattern for implementing web services architecture, that best fits CH communities and organizations' needs and expectations, such as application integration, extended functionality for web applications, portal integration.

To realize the advanced degree of interoperability and openness that web services can deliver, "GeoCHEAF" designs, develops, deploys, executes and manages those services within the WSA. XML-based standards-compliant web services run on the J2EE-compliant 'Web Applications and Services Platform' of this architecture. In this platform, applications are building that query UDDI, parse WSDL documents, and construct SOAP requests. Web services can be developed and deployed using Java as a programming language and a platform. Apache AXIS uses to implement SOAP.

In the service-oriented, component-based web application architecture of "GeoCHEAF", web services are deployed in a web service server (or a runtime server) that runs as a servlet within the web server Apache. There is no need for any specialized software on the user tier to request a web service. Thin user is presented with HTML form-based view of the interfaces contained in the WSDL by a JSP, which run in any standard web browser. The web services client does not have to be a browser on a PC. The discovery could be through any type of Internet-enabled device and application. For example a web service request might come from a cell phone using Wireless Markup Language (WML). At runtime, in the presentation layer, the JSP is executed on Tomcat engine to create HTML pages dynamically by doing transformation between the HTML browser view and the WSDL/SOAP web service view. These pages are then displayed in the browser window on the client. JSP applications are packaged in web archive (WAR) files, which are the equivalent of JAR files in pure Java applications.

HTTP is currently the standard transport used for sending SOAP messages to a web service. HTTP is simple, ubiquitous, and scales well due to its stateless design. It can typically pass through firewalls without the need to make any changes to network topology. However, HTTP is not a suitable transport for many applications, because there is no guarantee that a message has reached its target process. HTTP is not transactional, meaning that if an error occurs while transmitting the message, the client may not be able to determine if the message was received by the server. Therefore, the public Internet is not sufficiently reliable for some types of message transfers. A client calling a web service that does not get a result before timing out has no way of determining if the message was received, fully or partially processed, or lost during the communication. In addition, message retries cannot ensure that requests are not duplicated. "GeoCHEAF" supports SOAP over HTTP, HTTPS, SMTP as a web service transport as well as Java Message Service (JMS) since using JMS overcomes these limitations.

A web service provides an interface that can be called from another program. This application-to-application programming interface can be invoked from any type of application client or service. The web service interface acts as a liaison between the web and the actual application logic that implements the service. (White Paper, 2003b) The operator of the client is not always a person, but is typically another application or web service. For example, one might develop a web service whose job is to summon other web services. In fact, the SOAP transport is designed to support these 'machine-to-machine' transactions. The function of a web service may involve issuing a request to another web service, and that web service may issue a request to yet another web service, and so on. This leads to what is called an 'n-tier' application model, in which an application comprises multiple web services. Finally, web services leave the client-server paradigm behind. (White Paper, 2003a) Web Services support loosely coupled connections between systems. Web Services communicate by passing messages to each other. The Web Service interface adds a layer of abstraction to the environment that makes the connections flexible and adaptable. (White Paper, 2003b)

5. DATA ARCHITECTURE

As ICT becomes increasingly integrated with the business operations, data also assumes a growing role in the ICT architecture, while data and data sharing is the main business concern in the enterprise. In particular, the ability to store and retrieve growing quantities of critical data according to usage and value is becoming a fundamental consideration when building a storage environment.

Other requirements including the variability of data value over time, differing content formats, protection from improper access, and the specific archival requirements of particular industries, are also promoting a new focus on incorporating data life cycle management within storage infrastructures.

An evolutionary path has been witnessed in the database industry in the development of the following functionalities: data collection, data modeling and database creation, data management (including data storage, retrieval and database transaction processing), data analysis and understanding (involving data warehousing and data mining), and ultimately decision-making relies on all those functionalities. In this manner, "GeoCHEAF" provides robust data life-cycle management to control and manage CH data throughout its entire life-cycle from collection, acquisition, modeling, storage, access, process, visualization, dissemination, usage, integration, protection and corruption to eventual deletion. In addition to data management, it promotes a new focus for information and knowledge management for the CH domain through data, information, knowledge, and wisdom chain. Figure 5.1 shows the data flow in the data architecture of "GeoCHEAF".

A repository is a collection of resources from multiple systems that can be accessed to retrieve information. Repositories often consist of several databases (or files) tied together by a common search engine that is directly accessible to the user. It is a central place where digital data is stored and maintained. (URL Wikipedia) In the design of data architecture “GeoCHEAF”, the repository of it is based on both the database concept and the warehousing concept, so that it can act both as a (transactional or integrated operational) database and a warehouse.

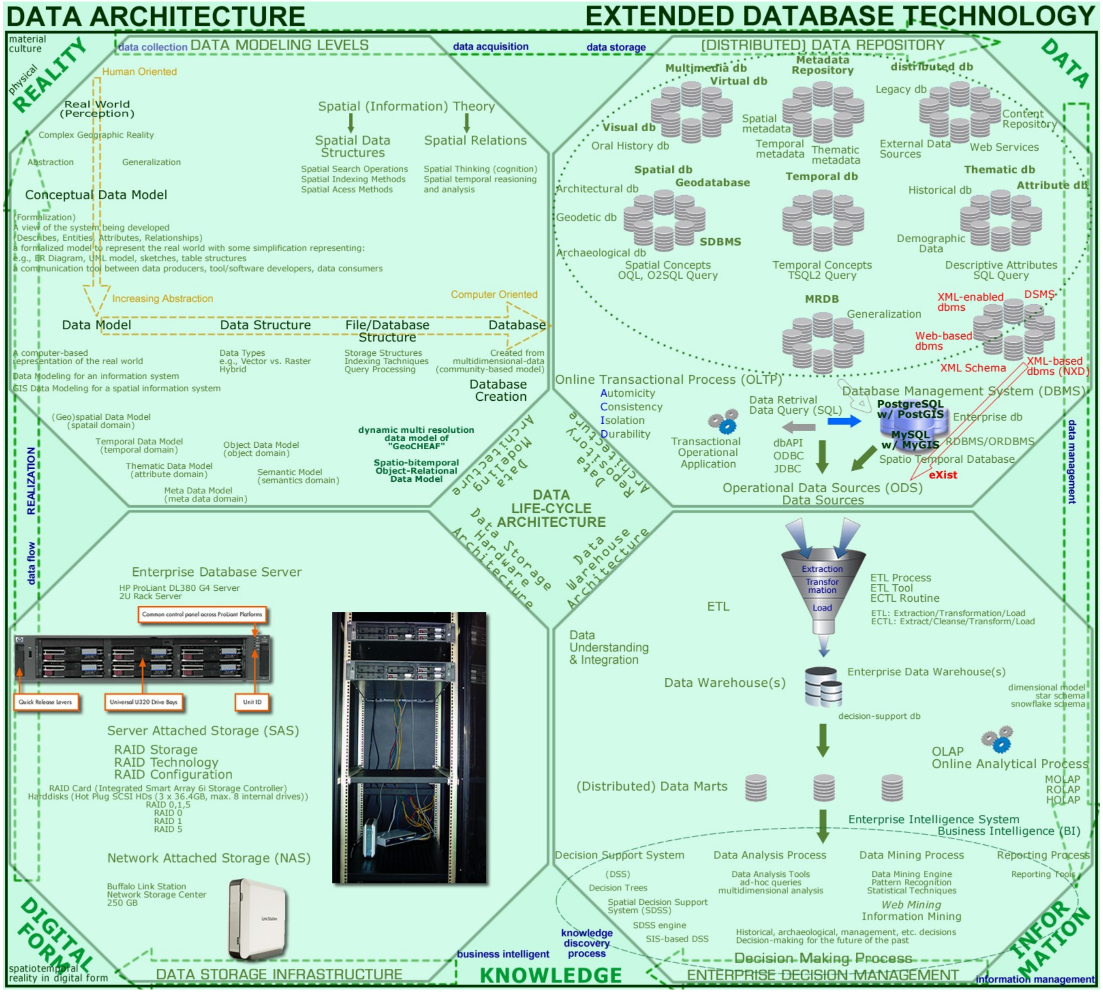

Figure 5.1: The framework designed for the data architecture

5.1 Conceptual Design

The data model is one part of the conceptual design process. The other, typically is the functional model. The data model focuses on what data should be stored and how data should be organized in the database while the functional model deals with how the data is processed and how the queries and analyzes are designed. (Guney et al., 2003a) The data modeling is the first stage in the process of the top-down data architecture (concepts to detail) of “GeoCHEAF”.

5.1.1 Data modeling

An CH enterprise requires a model of how the CH phenomenon exists in the real world; without the model, an CH organization has only the sample data and no inferences can be made about the behavior of the CH phenomenon in the real world. Since a data model provides the means to making it simple and clear, as the complexity of the enterprise increases, so does the importance of good modeling techniques.

A data model presents the conceptual core of an information system. At the same time a data model is a set of guidelines for the representation of the logical organization of the data in a database. It defines the data objects (with data object types, data type), the associations between data objects (relationships), operations, and the rules that govern operations on the objects to build a database and maintain its integrity. (Yuan, 1995; Nadi and Delavar, 2003; URL, 2003b)

A data model and its related data structuring must be independent of hardware or software constraints. Rather than trying to represent the data as a database would see it, the data model focuses on representing the data as the user sees it in the real world. It serves as a bridge between the concepts that make up real world events and processes and the physical representation of those concepts in a database. (URL, 2003b) To be effective, the data model must be simple enough to communicate to the end user the data structure required by the database yet detailed enough for the database design to use to create the physical structure. (Guney et al., 2003a)

There are two major approaches used to create a data model: the Entity-Relationship (ER) modeling and the Object Model.

ER is a conceptual data model that views the real world as consisting of entities and relationships. Thus, it is the traditional relational modeling approach. Originally, it unifies the network and relational database views. Database designers often use this methodology to gather requirements and define the architecture of the database systems. The output of this methodology is a list of entity types, relationship types, and constraints. ER modeling itself also defines the methodology used in the analysis and design of information-based systems. (Gornik, 2003) The major drawback of ER modeling is the lack of a tool facilitating conceptual data model design and its associated implementation. UML notation can be used for the graphic representation of ER diagrams while UML is a tool for designing an object-oriented data model.

Developing of a data model is an important step in order to integrate large volumes of different data. However, searching and analyzing the data can become very time consuming and complicated without a proper data model. Data modeling is probably the most labor intensive and time consuming part of the development process. Constructing functionally-integrated and coherent data model is on-going process since an incorrect or incomplete data model can cause potential conflicts. The data model is open ending so the designers/developers in the enterprise could accommodate new information without restrictions. (Guney et al., 2003a)

5.1.2 Geospatial data modeling

The real world and geographic variation in it is infinitely complex. Both natural and built environments have many levels of subcomponents. There are complex relationships and interdependencies among them. It would take an infinitely large database to capture the real world precisely. But computers are finite. Therefore, difficult choices have to be made about what and how things are modeled. It is very important to note that the modeling process is not attempting to develop a copy of reality. It is much more concerned with describing the important features of the systems in terms of processes and information considered important by the users like analysts and decision-makers in the enterprise. Data must somehow be reduced to a finite and manageable quantity by a process of abstraction and generalization, geographical variation must be represented in terms of discrete elements or objects; the rules used to convert real geographical variation into discrete objects is the geospatial data model. Maps and SIS are geospatial models of reality. Maps emphasize some aspects of reality in a cartographic representation and SIS emphasize some aspects of reality in a database representation while ignoring or greatly simplifying other aspects of reality. (URL, 2003c; Tomlin and Klinkenberg, 2004; Star and Estes, 1990; Maguire and Grise, 2001; Beaumont 2000)

The type of analytical operations that can be performed are strongly influenced by the way the real world is modeled. Therefore, a complete and rigorous geospatial data model is vital to the success of a SIS project to overcome the difficulty in understanding proximity, density, connectivity, and accessibility among real-world entities in the complex systems. (Maguire and Grise, 2001; URL, 2003c; Yuan 1995)

Since the type of phenomena the CH community study have different characteristics and each study use SIS for different purposes, there is no single type of data model that is best for all circumstances. There is not a universe data model for geographic reality. According to the goals and parameters of a project, various distinctive models can be built.

5.1.3 Object data modeling

Object data modeling is an object oriented approach to mimic a more natural way of defining systems and to model complex entities and relationships more intuitive than that offered by the traditional data and process modeling techniques. This approach reduces the conceptual and structural mismatch found in more traditional approaches between a problem's description and its computational solution. (Beaumont, 2000; URL, 2003c) Moreover, object-oriented data modeling can provide more functionalities and semantic constructs for modeling complex objects and inter-relationships among them.

The approach does not just mean that there is a database with objects in it, but that the system is organized around the concept of objects which have behavior (methods). Objects belong to classes which are arranged in a hierarchy (preferably a heterarchy). Subclasses inherit behavior and communication between objects is via a system of message passing thereby providing very robust interfaces. (Chance et al., 2003) In addition to domain related behavior, objects representing real world phenomena are linked to spatial classes from which they can inherit appropriate spatial behavior.

Furthermore, there is a hybrid approach -an object-relational data model- that gradually becomes an industry trend because it borrows rich data types and operations from relational models and concepts from object-oriented models.

In the relational model, all information is in the form of multiple related tables each consisting of rows and columns rather than putting all the data in one big storeroom, and relationships are presented by the use of values common to more than one table. The tables are linked by defined relations making it possible to combine data from several tables on request. This adds speed and flexibility. Other models such as the hierarchical model and the network model use a more explicit representation of relationships. (URL Wikipedia)

5.1.4. Spatiotemporal data modeling

Most phenomena are changed over time. From temporality point of view, there are two types of information; static information and dynamic information. Most of the phenomena in the real world are dynamic in nature. This static can only be used for objects such as cartographic maps, roads, facilities, utilities, etc. that may not change in a short period of time. However, all of these objects will change during a long period of time. Dynamic information refers to that information of geospatial objects that change in a short period of time. The length of this period is defined according to its usage fields.

Simply connecting a spatial data model to a temporal data model will result in a spatiotemporal data model that may capture time referenced sequences of spatial data or time spatial objects to model dynamic phenomena in SIS.

Designing three-dimensional (3D) and time-dependent data model in the CH domain is a key issue especially when using SIS for the CH projects to support decision-making based on analysis of and reasoning on 4D CH data objects of dynamic CH phenomena since many CH objects have attributes about location, time and geometry changing over time. Such spatiotemporal CH objects can only model with a spatiotemporal object (ST-Object) model. Additionally, a spatio-bitemporal data model that handles information about valid time and transaction time allows for retroactive as well as post-active changes.

Transaction time is defined as the time when a fact is stored in the database. Valid time is defined as the time when a fact becomes effective (valid) in reality or when an event occurred in the real world.

5.1.5 Data model of “GeoCHEAF”

To incorporate temporal information into spatial databases over 2D/3D base map, the dynamic multi-resolution data model of “GeoCHEAF” is a spatio-bitemporal object-relational data model designed as an open-ending and dynamic SIS data modeling for the CH projects according to the user requirements and expectations of the CH domain. It recognizes the composite structure of spatiotemporal CH objects with with spatial and non-spatial dimensions under the same architecture to implement a complete database system based on this geomodel. It represents the real world as a set of discrete objects hold in both space and time.

As presented in Figure 5.2, this multi-purpose data model fundamentally relies on six different data modeling aspect:

1. Spatial data modeling
2. Thematic data modeling
3. Temporal data modeling
4. Object-relational data modeling
5. Metadata modeling
6. Semantic modeling

Its general framework uses a set of geometry-based spatial objects to represent reality, such as representation of objects’ position is space (*spatial modeling aspect*). Thematic characteristics are represented as attributes of spatial objects (*thematic modeling aspect*). Temporal information is associated with time-stamping events or processes such as the capture of valid time of objects’ properties (*temporal modeling aspect*). Metadata and semantic modeling aspects extend the concepts both of spatial and temporal data modeling. Metadata modeling support spatial and thematic database queries and data selection for further evaluation processes.

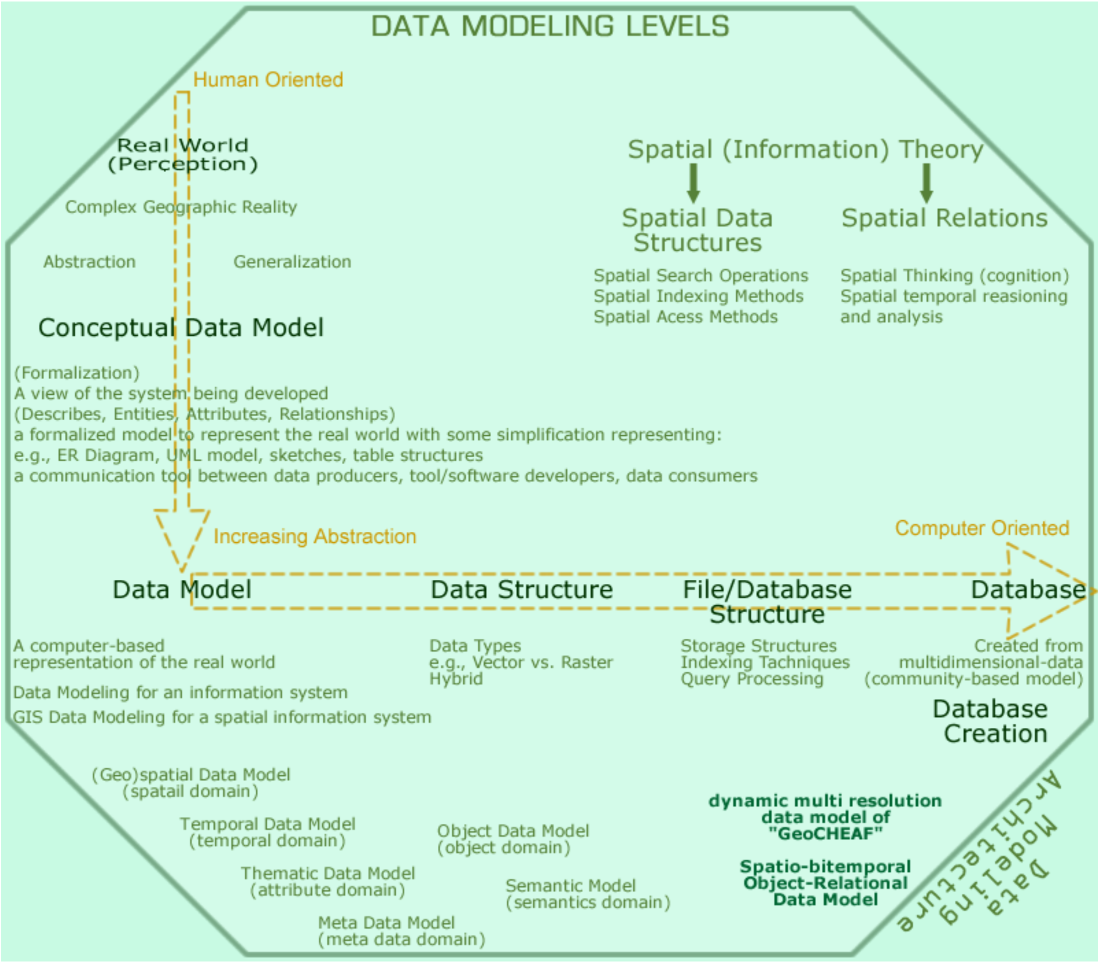

Figure 5.2: The data modeling component of the data architecture of "GeoCHEAF"

Although each system of the enterprise has its own data architecture component, which is part of the enterprise-level data architecture framework relies on the multi-dimensional and multi-scale SIS data model located at the heart of the system. The SIS data model as a means is general enough to allow the integration of all the themes and data types from each system in the enterprise. This design enables users of the enterprise to work not only on their own systems' data independently also on the total data set. This approach provides the users with the ability to organize, update and display spatial, and attribute data according to the their own systems, while they manage these complicated, interdependent datasets in one cohesive model using a GUI.

In developing the SIS data model, two more main principles were concerned. First, the SIS data model must match all the various types of data required in any system in the enterprise. Second, the data model must be strictly implementation independent whatever the evolution of database and application of computer technology.

In terms of the fortresses, problem appears in accurately modeling the phenomenon of 'life history of the fortresses' since the phenomenon has been continuously changing over time and conventional SIS data models merely emphasize static representations of reality. It is obvious that this kind of life history can only be modeled with the spatio-bitemporal object-relational data model of “GeoCHEAF” and captured by a database that handles changing information. Thus, the SIS application of the fortresses acquires a dynamic structure, so that CH data of the fortresses can be manipulated in multidimensional space including time (as the forth dimension) to describe various types of dynamic changes of historical objects. (Guney and Celik, 2003a; Guney et al., 2004)

With this type of data model both the present situation of the fortresses and the condition of the fortresses in the past can be recorded and the architectural changes from the 17th century to the present day can be determined more efficiently. Natural, economical, social and political events, which have caused structural changes to the fortresses and surrounding buildings and environs, can be discovered. (Guney, 2002)

Most of phenomena in the 17th century Ottoman fortresses are dynamic and have changed discretely over time. The value of time is represented by the number of years. For example, after the World War I the fortress was damaged and re-constructed. The shape of most buildings within the border of the fortresses architecturally changed. (Guney et al., 2004) Additionally, how the fortress developed and changed through several centuries of usage.

The discrete changes of a CH object of the fortresses during a time interval, from 17th century to today, can be seen as snapshots of that object, taken in time points of this time interval. Versions of the same facade of *Seddülbahir* in different time of the same period are shown in the figure 5.3. Changes occur to attributes of a phenomenon, behaviors of an event, or mechanisms of a process. (Guney et al., 2004)

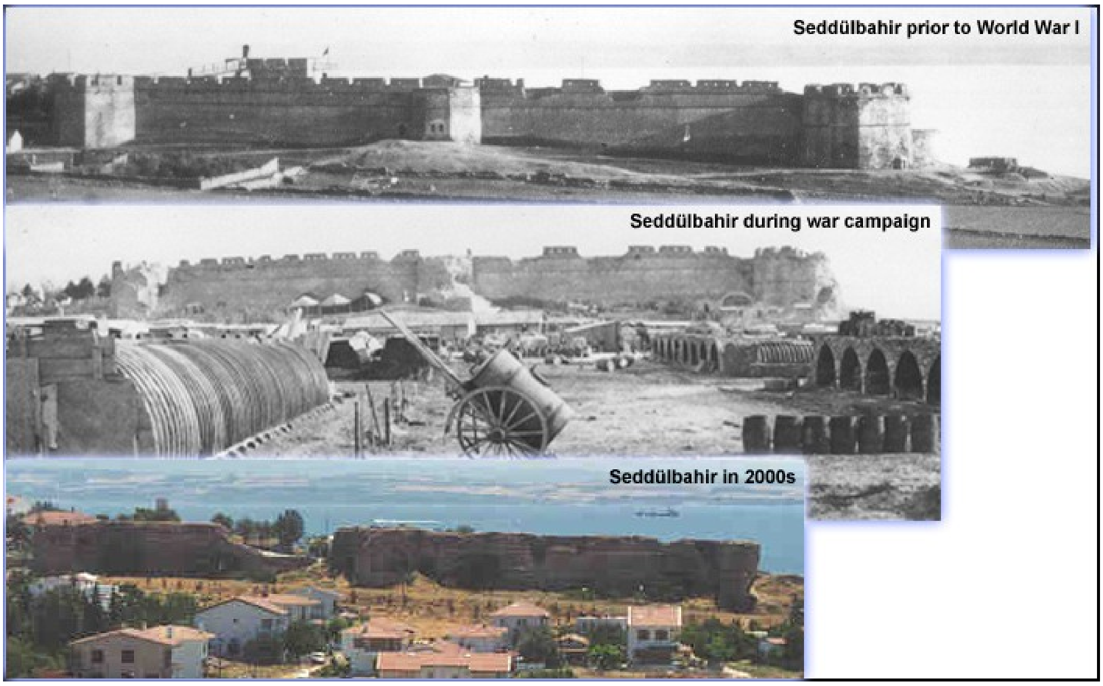

Figure 5.3: Temporal changes of the same facade of *Seddülbahir* Fortress in passed time (Guney and Celik, 2003a)

In addition to incorporating common SIS answers (e.g. what and where type questions), the temporal component of SIS answers the what, where, and when questions, such as, 'When did this mosque appear inside the fortress? and what was the general settlement status of the fortresses before and after Word War I?'. Queries such as, 'Who was the commander of the fortress?' or 'Of what material are the structures built?' would be meaningless if time is omitted. A proper query would be 'Who was the commander of the fortress in 1851?' 'What ancillary building were constructed on the grounds of the fortresses after Word War I?' (Guney and Celik, 2003a)

In summary, a top-down data modeling process of “GeoCHEAF” began with higher level abstraction and then carried on modeling in the object-orienting world. Four levels of data model abstraction of “GeoCHEAF”:

1. Reality, Planning and Requirement Analysis: Reality is made up of real world phenomena (fortresses, buildings, cemetery, people, settlement, etc.). The

first phase of modeling begins with a definition of the main types of objects and relationships to be represented in the SIS. An effective data model completely and accurately represents the data and data sharing requirements of the target users. This is typically done by examining existing documentation and meeting with the users of the enterprise. The designers/modelers/developers collect information about the requirements of the database by reviewing existing documentation such as previous publications, project reports, archival researches, oral history reports etc. Additional information is collected through interviewing users, reviewing of existing systems and producing several questionnaires to help users to conceptually identify key themes/data and primary issues to analyze which will be designed in the data model as an initial task in developing data model. (Guney et al., 2003a; Guney et al., 2004)

2. Conceptual Data Model: Second phase is a conceptual description of the main types of objects and relationships between them in a pictorial form. Because the diagram is easily learned, it is a valuable tool to communicate the model to the user. The conceptual model is a human-oriented, often partially structured model of selected objects and processes that are thought relevant to a particular problem domain. First, the initial ER diagram is figured out with the main types of objects and relationships and then refined the conceptual design for missing information and forgotten points.

3. Logical Data Model: Third phase is an implementation-oriented representation of reality that is often expressed in the form of diagrams and lists describing the names of objects, their behavior, and the type of interaction between objects in detail. Logical models are implementation independent and can be created in any SIS with appropriate capabilities. Both the attributes and behavior of objects are required for an object model. In the project, the logical design was conducted with the MySQL Workbench of the MySQL Tools. A conceptual implementation-independent data model is produced using UML as a modeling language. While the implemented archaeological database schema of *Seddülbahir* Fortress using MySQL

Workbench is shown in figure 5.4, the UML design of the SIS data model of Kumkale Fortress in terms of historic architecture using Poseidon for Community Edition graphic tool is presented in figure 5.5.

4. Physical Data Model: The final data modeling phase involves creating a model showing how the objects under study can be digitally implemented in a SIS. Physical models describe the exact files or database tables used to store data, the relationships between object types and the precise operations that can be performed.

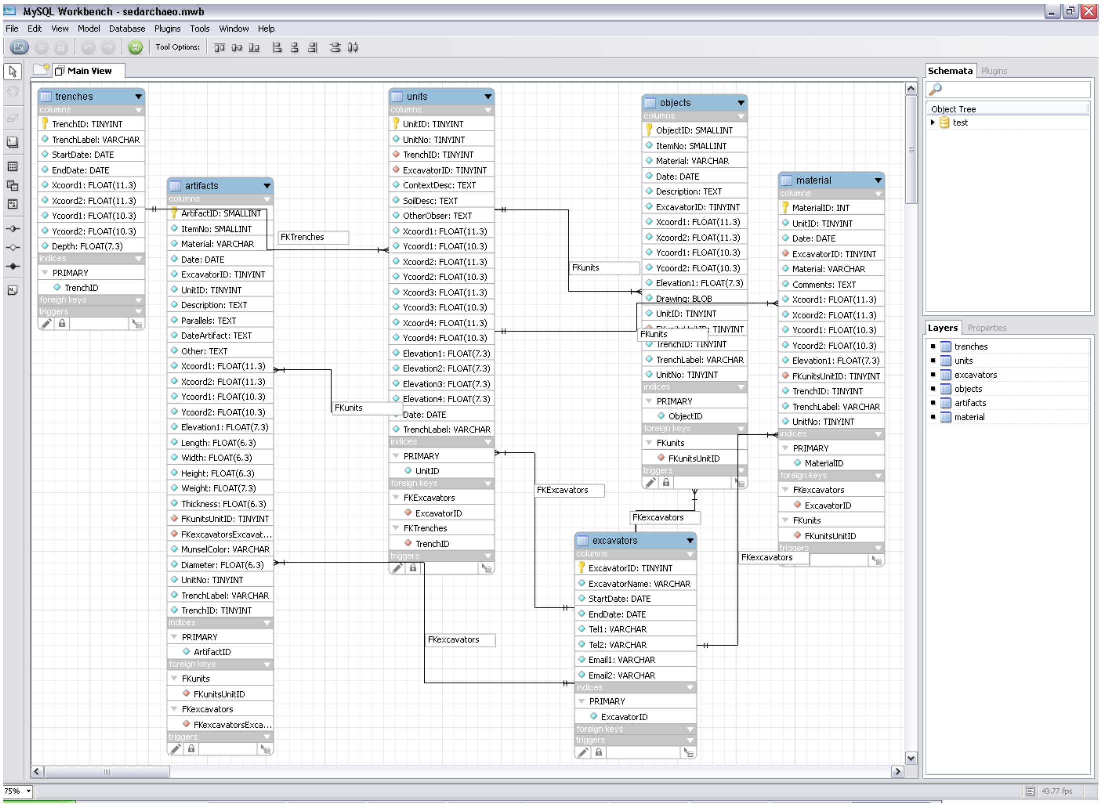

Figure 5.4: Data model schema of the archaeological database of *Seddülbahir* Fortress

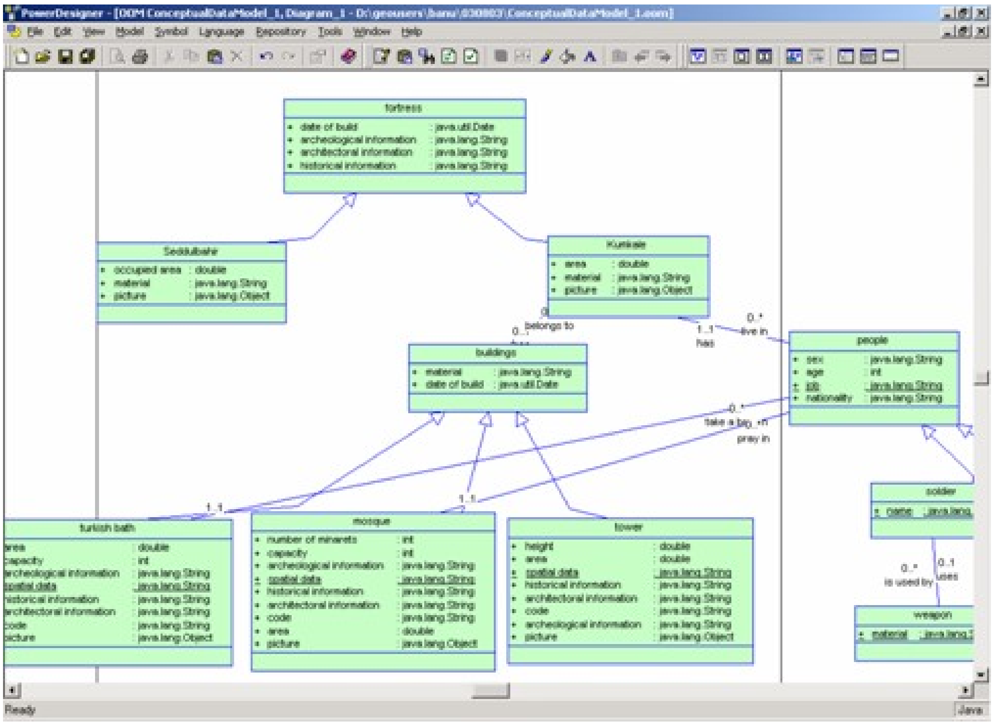

Figure 5.5: A part of the UML-based SIS data modeling of *Kumkale* Fortress (Guney et al., 2004)

This UML model incorporates the usage and architectural features of historical buildings, utilities and other structures, the cemetery, and the people who had lived in the fortress. It also includes topology rules for each feature dataset. Examples of structures in the fortresses include a residential place (within the fortresses and out of the fortresses, settlement); a market (with its associated fields and buildings); a war area (with its weapons and towers and bunkes); a religion lot (with its mosque and associated cemetery); a cleaning complex (with its hamams); Landscapes (such as cemeteries, farms, upper and lower courtyards); other structures (utilities, statues, mills, roads). (Guney et al., 2003a; Guney et al., 2004)

The changes that occurred in the fortresses reflected by the geomodel are:

- Representation of objects with position in space and existence in time
- Geometrical (or topological) changes of historical objects over time
- Positional changes of historical objects in space over time
- Change of historical object spatial attribute over time (variations in attributes over time)
- Any combination of the above changes.

For the project, the fundamental unit of the geomodel is historic architecture change of a CH object in the fortresses and its vector is presented as follow: (equation 5.1, citation)

SI-Tuple = {object identity, spatial data, attribute data, temporal data, topological relation, meta information} **(5.1)**

The major advantage of this representation is that there is a general view of all other definitions of dimension. Every element in this vector can have various dimensions. Geospatial position can have from one to four dimensions and temporal dimension can have one, two (bi-temporal) or many (multi-temporal) dimensions. (Nadi and Delavar, 2003) Table 5.1 displays some specifications of the components of SI-Tuple. (Guney et al., 2004)

An infinite number of tuples is required to describe geographic reality. Data modeling is the process of reducing the number of tuples required to represent reality to some finite set that can be represented digitally. (Yuan, 1995)

Table 5.1: Component of SI-Tuple (Guney et al., 2004)

Components	***Description***	***Question***	***Dimension (D)***	***Explanation***
Spatial Data	Positional Information	Where?	4D (X,Y,Z,Time)	Geo-reference of object (or entity) Position of a discrete object in the real world is described by coordinates in a coordinate system and time of positioning
Attribute Data	Thematic Information	What?	1D to many	Graphical variation of an object in the real world is described by variables (or attributes) such as soil type, temperature
Temporal Data	Time Information	When?	1D to many (Valid Time, Transactional Time, User-Defined Time, Institutional Time)	Temporal Aspects of the real world. Time varying information / Reference to time.
Topological Relation	Spatial Relationship	How?	1D	Geometrical Relation / Geometrical Properties / Point-Line-Polygon Topology
Meta Data	Quality Information	About?		

The main approach of the proposed data model is the abstraction and decomposition of geometry, topology and thematic information.

In this design, spatial concepts of spatial (information) theory is presented as following:

1. Spatial Data Structures (in spatial database)
   - Spatial Data Structures: R-tree (R: rectangular), R^+-tree, B-tree, Quad-tree (to visualize and organize large 3D SIS databases)
     (The R-tree: an efficient and robust access method for points and rectangles)
     (R, O) (Rectangle, Object) Minimal bounding rectangle (MBR) (a linear container)
   - Spatial Search Operations
   - Spatial Indexing Methods (*rapid access the data*)
   - Spatial Access Methods
2. Spatial Relations (*topologic, metric, direction, linguistic*)
   - Spatial Thinking (*cognition*)
   - Spatial Reasoning (*spatiotemporal reasoning and analysis, temporal reasoning, spatiotemporal modeling*)

Topological relations that are intelligent data that understands connectivity and adjacency were identified as a set of spatial relations that had to be formalized. The formalism for binary topological spatial relations:

- The 4-intersection (2 objects' interiors and boundaries)
- The 9-intersection (interior, exterior, boundaries)

In GIS it is not enough to know the position of an element, it is also essential to know how it relates to other elements in the system. For example, it is not enough to be able to locate the fire; it is also imperative to find the nearest fire station or to determine how the fire affects the region. But showing all possible spatial relations may be very complex and costly or maybe impossible. This is why some relations are explicitly defined and others must be calculated.

The research on spatial theory focus has shifted from the technical problem of how to represent geometric figures, and now is firmly centered on the question of how to represent geographic space and geographic phenomena in ways that are consistent with how people understand spatial situations.

People often use qualitative spatial thinking and reasoning in everyday life; however, current commercial GISs support primarily quantitative spatial queries and answers, and in general lack direct support for users to make qualitative queries about spatial relations. For example, point to point distance in metric units or direction in degrees does not necessarily conform to people's usage of terms and concepts in natural-language. People's spatial concepts are often more qualitative in nature, including such concepts in natural-language. People's spatial concepts are often more qualitative in nature, including such concepts as **north**, **near** and **far**. A qualitative GIS model that is capable of answering queries of the form, "Show me the road that goes around the fortresses" will complement the existing models. The incorporation of natural-language spatial relations such as **along**, **goes by**, and **through** will give GIS users a greater choice in formulating queries, depending on the task being performed. By better accommodating the human requirements, qualitative models will also contribute toward the greater utilization of GIS technology. Among the potential applications of such a model are road navigation system, tourist databases, etc.

Scientists and engineers using geographic databases need query languages with powerful spatial selection methods and capabilities to infer spatial information in a manner similar to a human expert. Crucial for geospatial databases, containing very large amounts of spatial data, are appropriate operators to access and manipulate spatial data in large-scale, geographic space, far beyond what is currently being offered by traditional database management systems. The objective of the design is to construct a coherent reasoning system that integrates spatial concepts about topology, cardinal directions, and approximate distances so that they can serve as a spatial extension to geospatial databases and query languages. The reasoning system focused on large-scale, geographic space. The hypothesis is that powerful and complex spatial reasoning can be formalized as the product of the interaction between relatively simple spatial relations with specific inference rules. First, individual spatial relations of topology, distance, and direction are formalized. Afterwards these formalizations were used to develop an integrated, comprehensive system, i.e., a more complex algebra, from the previously defined ones, adding more power through the coexistence of the different relationships in a single system. The major results are a set of primitives, with rules describing their combinations, for the design of domain specific spatial query languages.

5.2. Functional Model (Database Architecture/Component)

Database and database management have become the key components of a SIS. As the need for large and complex databases continues to grow, more effective access to the data is needed than ever. Figure 5.6 illustrates the data repository architecture of "GeoCHEAF".

The central concept of a database is that of a collection of related records stored in a computer in a systematic way, so that a computer can consult it to answer questions. The items retrieved in answer to queries become information that can be used to make decisions. Database Management System (DBMS) is the software or computer program for the management and operation of databases. (URL Wikipedia)

For better retrieval and sorting, each record is usually organized as a set of data elements (facts). Typically, for a given database, there is a structural description of the type of facts held in that database: this description is known as a schema. The schema describes the objects that are represented in the database, and the relationships among them. (URL Wikipedia)

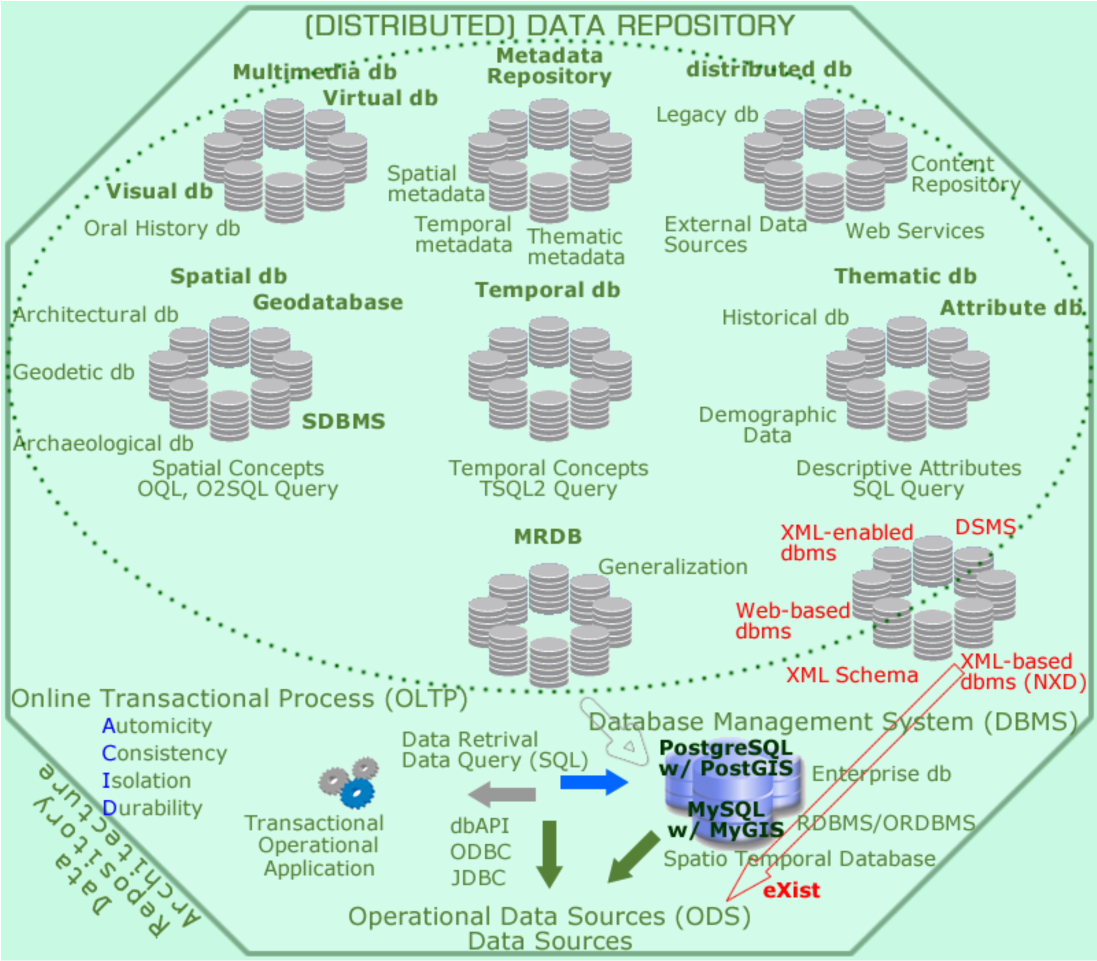

Figure 5.6: Data repository architecture of "GeoCHEAF"

Enterprise Data & Information Management software provides storage, access, modern and unbreakable management, analysis of data in any environment. DBMSs are usually categorized according to the data model that they support, like relational, object-relational, network, and so on. A great deal of the internal engineering of a DBMS, however, is independent of the data model, and is concerned with managing factors such as performance, concurrency, integrity, and recovery from hardware failures. In these areas there are large differences between products. The broad range of DBMS classification was realized as the following in the context of the dissertation.

1. File Management System (file-based repository)
    1. Flat file database servers (Tabular)
2. Database Management System (DBMS)
    1. Hierarchical (HDBMS)

2. Network (NDBMS)
3. Relational Database Management Systems (RDBMS)
    1. Open Source RDBMS
        1. MySQL 5.x by MySQL AB (MyGIS) (MaxDB)
        2. SQLite 3.x
        3. Firebird 2.x (the first new-generation descendant of Borland's InterBase)
        4. Borland's InterBase 6.0 Open Edition code (under the InterBase Public License (IPL))
        5. One$DB (open source version of Daffodil DB)
    2. Proprietary RDBMS
        1. Oracle 10g (Oracle Spatial 10gR2) (the first relational database designed for Grid Computing)
        2. Oracle 9i (Oracle 9i Spatial (Object Relational Model), map viewer)
        3. Oracle 8i GeoXML server
        4. Microsoft SQL Server 2005 (MSSQL)
        5. IBM DB2
        6. IBM Informix
        7. dBASE Plus 2.x
        8. Sybase Adaptive Server Anywhere 8
        9. InterBase 7.x by Borland Software Corporation
        10. Daffodil DB (the first Java RDBMS)
        11. Mimer SQL 9.x
        12. Microsoft Access
4. Object Database Management Systems (ODBMS)
    1. Smalltalk
    2. ObjectStore
    3. O2
    4. Orion
5. Object Relational Database Management Systems (ORDBMS) (Hybrid)
    1. Open Source ORDBMS

            1. PostgreSQL 8.x (PostGIS)
        2. Proprietary ORDBMS
            1. Oracle
    6. Spatial Database Management System (SDBMS)
        1. Open Source SDBMS
            1. MyGIS by MySQL AB
            2. PostGIS by PostgreSQL
        2. Proprietary SDBMS
            1. ArcSDE by ESRI (an advanced spatial data server for managing geographic information in numerous relational database management systems)
            2. Oracle Spatial
3. Data Stream Management System (DSMS)
4. XML Databases Management System (XDBMS) (or Web-based DBMS)
    1. XML-enabled DBMS
        1. IBM DB2
        2. Oracle
        3. SQL Server
    2. Native XML(-based) DBMS (NXD)
        1. Commercial NXD
            1. Tamino
        2. Open Source NXD
            1. eXist
            2. dbXML
            3. Xindice
5. Enterprise DB
    1. PostWest
6. Data Warehousing Environment
7. Multiple Representation Database (MRDB)

A spatial database system has been defined as a database system supporting spatial data types. Spatial data type objects not only have a non-spatial description such as name and population but also have spatial attributes associated with them such as location, geometry and neighborhood properties - distance and borders etc. A spatial database system has to provide various functionalities including input, storage, retrieval, selection, analysis and display of the information.

Database APIs that considered in the context of the dissertation are the followings:

- Open Database Connectivity (ODBC) by Microsoft (used to communicate with RDBMS)
- OLE-DB by Microsoft (used to communicate with all DBMS)
- Java Database Connectivity (JDBC): JDBC is the key Java technology for interacting with relational database and a Java API for executing dynamic SQL statements.
- MySQL Connector/J as JDBC driver
- JDO API
- SQLJ

Query languages that are available to access the database:

1. Structured Query Language (SQL)
    - SQL Standards: SQL-86 (1986) / SQL 89 (1989) / ANSI/ISO Standard SQL92 (1992) (SQL 2) / SQL-99 (1999) (SQL 3) / SQL-2003 (2003) (XML support)
    - SQL-compatible databases
    - Data Manipulation in SQL
    - SQL server / SQL client
    - SQL Programming
    - Interactive SQL / Embeded SQL
    - geoSQL
2. Object Query Language (OQL)
3. Object-Oriented Geo Query Language (OOGQL)

SQL is the most common standardized language used to access databases. The two most recent iterations are SQL-99 (also sometimes known as SQL-3) and SQL-92, both named for the years in which they were first released. (SQL-99 had been originally planned for release in 1996). More importantly, SQL-99 also added some basic support for object features, extending SQL's usefulness and blurring the distinction between relational and object approaches to databases. SQL-99 extends relational data model to include object-oriented constructs into language for object-relational models.

In the course of the design work of “GeoCHEAF”, highly scalable PostgreSQL 8.x and multi-threaded MySQL 5.x were chosen to implement multiple databases and to develop dynamic database-backed web sites, portals and applications, such as web-based database and SIS query. Both MySQL and PostgreSQL are two of the world’s the most popular enterprise-level open source free SQL-compliant relational database systems (de facto databases). PostgreSQL based on POSTGRES, Version 4.2, developed at the University of California at Berkeley Computer Science Department, is also object-relational DBMS. They are renowned for their wide range of capabilities to perform functions not available in many other databases. They are attractive alternative to higher-cost, more complex database technology with their speed, scalability, reliability, ease of deployment and features as sophisticated as the number one commercial database. They are powerful, compact client/server database management systems that can run on a variety of server and client operating system platforms, including Windows, Linux, and several other UNIX platforms. (URL MySQL; URL PostgreSQL)

MySQL runs on a multi-threaded database engine. This means that MySQL can handle many tasks and requests at the same time - clients connecting to a MySQL database server do not need to wait for other clients' queries or processes to end before their requests are executed. (URL MySQL)

MySQL GUI tools provided by MySQL AB is a single bundle including all GUI tools MySQL Administrator, MySQL QueryBrowser, MySQL MigrationToolkit and MySQL Workbench. MySQL Administrator is a visual console that allows a user access to a variety of administrative tasks, as well as performance and data structure information. (URL MySQL)

Addition to MySQL GUI tools, there are a number of third-party user interfaces to MySQL that make it easier to access and alter the data stored in the MySQL databases. The most popular of these, by far, is phpMyAdmin, a web-based open source application written in PHP. Like MySQL, PostgreSQL can be operated over the Internet using phpPgAdmin. (http://phppgadmin.sourceforge.net)

phpMyAdmin is a tool written in PHP to establish a web-based powerful interface for MySQL database administration and development. OS-independent phpMyAdmin is an open-source application used under GNU GPL. (http://www.phpmyadmin.net)

The PHP server-side scripting language and the MySQL database management system make a potent pair (like MSSQL and ASP) to build dynamic database-driven CGI applications. Both are open source products -free of charge for most purposes- remarkably strong, and capable of handling all but the most enormous transaction loads. Both are supported by large, skilled, and enthusiastic communities of architects, programmers, and designers.

PostgreSQL does not impose a limit on the total size of a database. Databases of 4 terrabytes (TB) are reported to exist. Some other key features of PostgreSQL:

- Database size: No limit
- Table size: 16 TB-64 TB
- Rows in a Table: No Limit
- Table Indexes: No Limit
- Field size: 1 GB
- Row size: No Limit

PostgreSQL and MySQL database management systems enable increased accessibility to spatial data with respectively PostGIS (under the license GPL) and MyGIS extensions. They provide a number of geometric types and functions to build a web-based SIS applications and to generate maps. They support the SQL with geometry types proposed by the OGC for efficiently storing and manipulating spatial data. This allows for efficiently storage and manipulation of spatial data.

PostGIS allows the use of GIS objects and other objects that appear in the OGC specifications. One can think of things like points, lines, polygons, multilines, multipoints and geometric collections. It works with Geometry Engine Open Source

(GEOS) as drive for the topological control. PostGIS, and generally any spatial extension to a RDBMS, allows a high flexibility, as it is possible to realize spatial operations at the source of the data. PostGIS is an extension for PostgreSQL and defines new types of data, creates two tables with relevant information to the system (data projection and a column that contains the geospatial information).

5.2.1 XML and databases

Although the original purpose of XML is as a way to mark up content, it also provides a way to describe structured data thus making it important as a data storage and interchange format. On one hand there is the document-centric model of XML where XML is typically used as a means to creating semi-structured documents with irregular content that are meant for human consumption. An example of document-centric usage of XML is XHTML which is the XML based successor to HTML. The other primary usage of XML is in a data-centric model. In a data-centric model, XML is used as a storage or interchange format for data that is structured, appears in a regular order and is most likely to be machine processed instead of read by a human. In a data-centric model, the fact that the data is stored or transferred as XML is typically incidental since it could be stored or transferred in a number of other formats which may or may not be better suited for the task depending on the data and how it is used. An example of a data-centric usage of XML is SOAP. In both models where XML is used, it is sometimes necessary to store the XML in some sort of repository or database that allows for more sophisticated storage and retrieval of the data especially if the XML is to be accessed by multiple users. Below is a description of storage options based on what model of XML usage is required.

In a data-centric model where data is stored in a relational database or similar repository; one may want to extract data from a database as XML, store XML into a database or both. For situations where one only needs to extract XML from the database one may use a middleware application or component that retrieves data from the database and returns it as XML. Middleware components that transform relational data to XML and back vary widely in the functionality they provide and how they provide it. The alternative to using middleware components to retrieve or store XML in a database is to use an XML-enabled database that understands how to convert relational data to XML and back. (Obasanjo, 2001)

Content management systems are typically the tool of choice for document-centric model when considering storing, updating and retrieving various XML documents in a shared repository. (Obasanjo, 2001)

In situations where both documentric-centric and data-centric models of XML usage will occur, the best data storage choice is usually a native XML database. Native XML database is a database that has an XML document as its fundamental unit of (logical) storage and defines a (logical) model for an XML document, as opposed to the data in that document, and stores and retrieves documents according to that model. (Obasanjo, 2001)

As can be seen from the above descriptions, there is currently no standard way to access XML from relational databases. This may change with the development of the SQL/XML standard currently being developed by the SQLX group. SQLX.org is a web site that makes the SQL/XML standard, and the technology that it includes, more highly visible to interested parties. SQL/XML (may also be referred as SQLX) is an ANSI and ISO standard that provides support for using XML in the context of an SQL database system. Because SQL is the standard language for accessing and managing data stored in relational databases, it is natural that enterprises and users worldwide need the ability to integrate their XML data into their relational data through the use of SQL facilities. SQL/XML makes it possible to store the XML documents in the SQL database, to query those documents using XPath and XQuery, and to publish the existing SQL data in the form of XML documents. In 2003, the first edition of the SQL/XML standard was published by the International Organization for Standardization (ISO) as part 14 of the SQL standard: ISO/IEC 9075-14:2003. (URL SQLX)

On the other hand, there is a big debate about XML databases in terms of the use of hierarchical data model (HM) rather than relational models (RM) in the fields of ICT and CH. In fact, hierarchical systems were tried and discarded years ago in database systems.

The RM is known simpler, more flexible, and more practical data model than the HM underlying XML. Due to their horrendous complexity and inflexibility, databases and DBMSs relying on the hierarchical model became obsolete in the 80's, at least technologically. (Pascal, 2005)

XML documents are organized as tree structures. Relational databases organize data in a tabular, or grid-like fashion, and use relational linking in order to expose hierarchical constraints on the data. Unfortunately, while it is generally very easy to map relational data into XML, trying to map XML, which can be very complex and freeform, into relational data can be incredibly difficult and lossy. (URL Xindice)

The fact is that XML was devised by text publishers (see Appendix A), not data management people, with whom the concept of markup tags originates. And it was intended mainly for data interchange, not data management, which requires an agreed physical format, not a data model. But the industry has a long history of blindly extending technology invented for one purpose to other, unintended purposes. (Pascal, 2005)

The both models -HM and RM- have pros. and cons. There is XML technology. It provides transmitting structured data to various users & other applications easily and prevents repeating fields in a hierarchical XML schema without difficulty. Indeed, some businesses have adopted XML, but more use XML only as a data transmission protocol, leaving the data in traditional databases on corporate computers. (Eiteljorg, 2005) NXDs have also extended functionalities such as Query and Update.

As the volume and complexity of e-business transactions increases, the overhead that is needed to convert back and forth between XML and some other data representation will seriously affect the speed, reliability and functionality of XML-enabled systems. Native XML servers that deliver not only the appearance, but also the reality of the XML architecture will run faster, more reliably and with less administration overhead. Although all NXD implementations have their strengths and weaknesses, due to the more features of eXist as shown table 5.2 and its better performance than other two NXDs, it is used as XML data management tool in the design of the data architecture of “GeoCHEAF”.

eXist is an open source native XML database featuring efficient, index-based XQuery processing, automatic indexing, extensions for full-text search, XUpdate support, XQuery update extensions and tight integration with existing XML development tools. It provides a powerful environment for the development of web applications based on XQuery and related standards. Entire web applications can be written in XQuery, using XSLT, XHTML, CSS and Javascript (for AJAX functionality). XQuery server pages can be executed from the filesystem or stored in the database. (URL eXist)

dbXML server is a native XML database from the dbXML group as an open source project under the terms of an MIT Style License. It is capable of storing and indexing collections of XML documents in both native and mapped forms for highly efficient querying, transformation, and retrieval. In addition to these capabilities, the server may also be extended to provide business logic in the form of scripts, classes and triggers. (URL dbXML)

Xindice is an open source based XML document management system and maintained by the Apache organization. It is written in Java. (URL Xindice)

Tamino XML Server is a commercial native XML server from Software AG for storing, managing, publishing and exchanging all kinds of data -specifically XML documents- in their native format, based on open standard Internet technologies. It is able to store and access XML documents in a true native XML data storage integrated in an XML server. Tamino XML Server stores XML objects without transforming them into another data format. In this sense, Tamino XML Server is a native XML database. It supports access to external data sources, such as relational database systems, and also process conventional data and context information. (URL Tamino)

Table 5.2: Discussion of 3 NXDs

	eXist	*dbXML*	*Xindice*
Storage	XML data stored as a document.	XML data stored as a document.	XML data stored as a document.
Schema/DTD Support	yes	no	no
Query	standard XPath query (the query speed is fast)	standard XPath query	standard XPath query
Update	uses XUpdate	uses XUpdate	uses XUpdate
Index	full text index	no full text index	no full text index
Basic DB function	no transaction control & very basic user, security and backup management & a GUI is provided to manage database, load data, backup etc.	no transaction control & very basic user and security management & only command line	no transaction control & no user and security management & only command line
Programming API	supports vendor independent XML:DB API which comes with DOM and SAX support	supports vendor independent XML:DB API which comes with DOM and SAX support	supports vendor independent XML:DB API which comes with DOM and SAX support
Other Tools	Integrates with Cocoon very well, allowing developers to create complex web applications entirely based on XML and related technologies.	none	none

5.3 Data Handling and Standardization

The project team has stressed the importance of standardization of the data quality required, both for the data collected and the information produced. When working in the field and in the office the following questions have shaped the approach taken to data collection and input: "Which data are necessary to produce the desired information?" "Which functions are necessary to transform the data into the desired information?" "Is the quality of the product adequate for the user?" (Guney and Celik, 2003a)

Especially in interdisciplinary work the integration of data from different sources is a central requirement of SIS. Standard formats for data interchange define a binding description of real world features, attributes associated with them and meta information. The main purpose of standardization is to promote interoperability and portability of data and data processing tools. Defining attribute encoding in the specific standards facilitates the transfer of self-describing databases. One of the goals of the standardizing in the dissertation is that geospatial data can be transferred between all kinds of CH SIS products and platforms. Obviously, SIS cannot be tailored to individual differences. However, the identification of specific SIS user groups and usage scenarios -representing users with similar abilities and skills making similar use of the same SIS functionalities- can be of enormous help in shaping the SIS for CH domain.

In the project, thousands of points like geodetic and topographic feature points and object detail points have been measured with different techniques, computed in one coordinate system and organized within SIS layers properly. Additionally attribute data handling is the other main capability required of a SIS. Without the ability to properly handle the related non-spatial information the technology of SIS would never have taken off as it has. (Guney and Celik, 2003a)

The project team has worked carefully to create a structure based on specific and high standards before developing SIS. All the sources that have been incorporated into the database like photographs, archives, slides, engravings have been given specific coding. Thereafter, the whole codes used in the repository matched the attributes perfectly. In addition to assigning the codes of info-sources, the team has identified key issues related to the project and the SIS, and carries on discussions on a regular basis about the required steps to further progress in achieving a useful SIS. This approach is time consuming, however, that forms the basis for standardization when developing a SIS project. (Guney, 2002)

This standardization and methodology can differ due to the building scale and the particular processes involved in the realization of a project, but in the CH projects there should be principle criteria in order to reuse and represent the survey data and the surveys of different periods which are used in the evaluation of the architecture.

5.4 Data Warehousing

All enterprises require a means to store, analyze and interpret the data they generated and accumulated in order to implement their solutions and decisions through their databases, which is called a data warehouse. Another requirement is that the user must also be able to access the data according to his or her particular needs through an easily understandable and straightforward manner of making queries, which is called a data mart. The data that is extracted in this manner by one user should be compatible with and translatable to other operations and users within the same system (component) or enterprise that rely on the same data, which is called data warehousing project.

In the design of the data warehousing architecture of “GeoCHEAF”, shown in figure 5.7, the operational data is cleaned and processed before putting it into the warehouse by using 'Extraction, Transforming (or Transporting) and Loading (ETL) solution'. Warehousing architecture is also customized for specific users within the extended enterprise by adding data marts, which are systems designed for a particular line of business. Hence, end users directly access data derived from several source systems through the data warehouse.

Data warehousing technology include data cleansing, data integration, and Online Analytical Processing (OLAP), that is, analysis techniques with functionalities such as summarization, consolidation, and aggregation, as well as the ability to view information from different angles.

5.4.1 Defining data warehouse

The universally accepted definition of a data warehouse developed by Bill Inmon in the 1980s is “a subject-oriented, integrated, time variant and non-volatile (read-only) collection of data used in strategic decision-making.” Ralph Kimball the co-founder of the data warehousing concept has defined the data warehouse as a “a copy of transaction data specifically structured for query and analysis”. Both definitions highlight specific features of the data warehouse. The former definition focuses on the structure and organization of the data and the latter focuses upon the usage of the data. However, a listing of the features of a data warehouse would necessarily include the aspects highlighted in both these definitions.

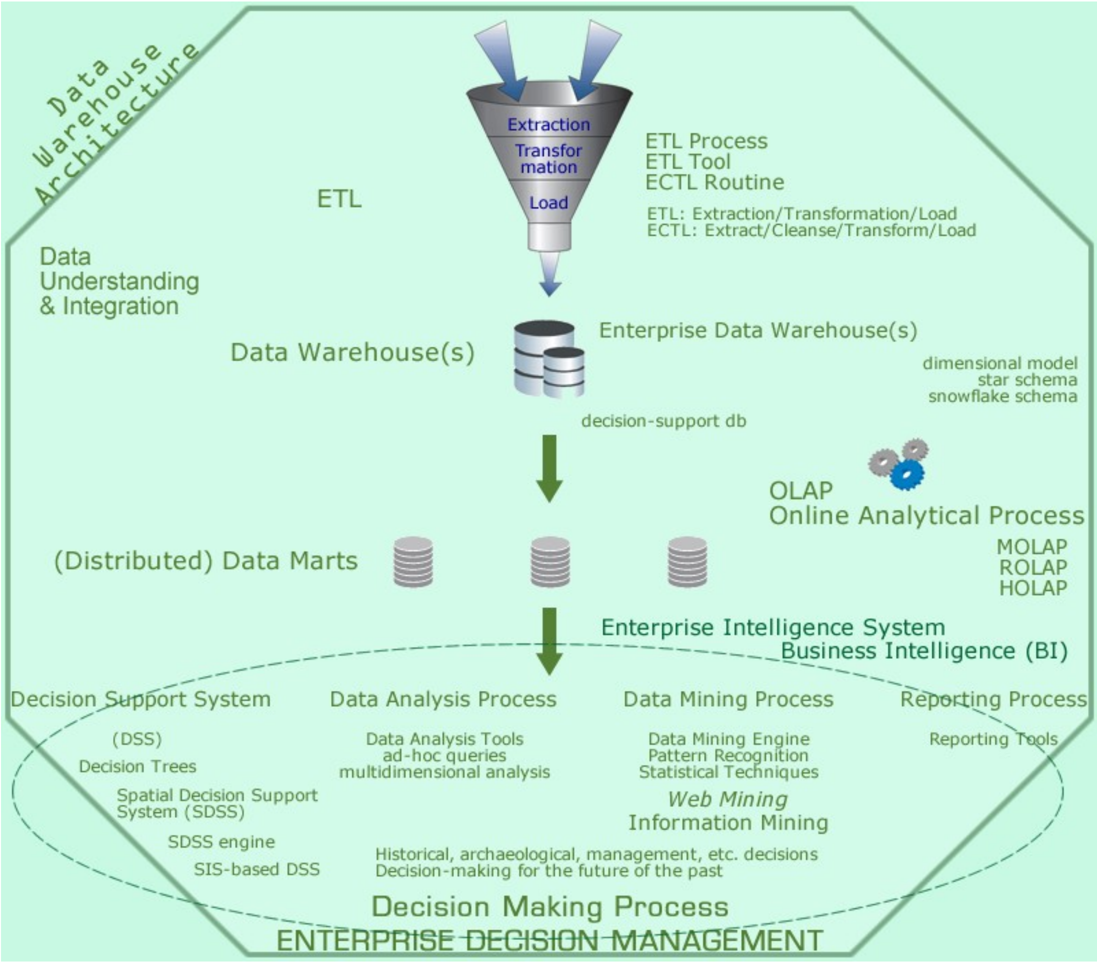

Figure 5.7: The data warehousing architecture of "GeoCHEAF"

In the context of this dissertation, a data warehouse, a repository of multiple heterogeneous operational data sources (ODS), loaded with a consisted format, organized under a unified schema at a single site in order to facilitate management decision-making. This makes it much easier and more efficient to run queries over data that originally came from different sources.

The On-line Transactional Processing (OLTP) database and the data warehouse are both relational databases. However, the objectives of both these databases are different. Data warehouse is the place where the application data is managed for analysis and reporting purposes, while OLTP database is the place where the data is taken as a base and managed to get available fast and efficient access. Typical relational databases are designed for OLTP and do not meet the requirements for effective OLAP (Naude, 2002). However, the data warehouse supports OLTP system by providing a place for the latter to offload data as it accumulates and by providing services which would otherwise degrade the performance of the database.

The OLTP database records transactions in real time and aims to automate clerical data entry processes of a business entity. Addition, modification and deletion of data in the OLTP database is essential and the semantics of the application used in the front end impact on the organization of the data in the database. The data warehouse on the other hand does not cater to real time operational requirements of the enterprise. It is a relational database that is designed for query and end-use analysis rather than for transaction processing. It usually contains and maintains historical data derived from transaction data (rather keeping it in the real-time OLTP database), but it can include data from other sources. It separates analysis and reporting workload from transaction workload (not to decrease the processing time of the OLTP database server) and enables an organization to consolidate data from several sources. (URL, 2006a)

In addition to a relational database, a data warehousing environment includes an ETL solution, an OLAP engine, analysis tools, and other applications that manage the process of gathering data and delivering it to business users. (URL, 2006a)

5.4.2 ETL process

Designing and maintaining the ETL process is often considered one of the most difficult and resource-intensive portions of a data warehousing project. ETL is the data warehouse acquisition process of extracting data from source systems and bringing it into the data warehouse to facilitate business analysis. (Naude, 2002; URL, 2006a)

During extraction, the desired data from one or more operational systems, including database systems and applications, needs to be identified and extracted. After extracting data, it has to be physically transported to the target system or an intermediate system for further processing. Depending on the chosen way of transportation, some transformations can be done during this process, too. Lastly, the new data (after transformation) needs to be copied into warehouse regularly. (URL, 2006a)

Many data warehousing projects use ETL tools to manage this process. Oracle Warehouse Builder (OWB), for example, provides ETL capabilities and takes advantage of inherent database abilities. Other data warehouse builders create their own ETL tools and processes, either inside or outside the database.

5.4.3 Warehouse schemas

Data warehouses often use denormalized or partially denormalized schemas (such as a star schema) to optimize query performance, while OLTP systems often use fully normalized schemas to optimize update/insert/delete performance, and to guarantee data consistency. (URL, 2006a)

The star schema is the simplest data warehouse schema. Snow flake schema is similar to the star schema. It normalizes dimension table to save data storage space. It can be used to represent hierarchies of information. (Naude, 2002)

5.4.4 Data marts

A data mart is a specific, subject oriented, repository of data designed to answer specific questions for a specific set of users. In contrast, a data warehouse is a single organizational repository of enterprise wide data across many or all subject areas. The data warehouse is the authoritative repository of all the fact and dimension data (that is also available in the data marts) at an atomic level. (URL, 2006b; Naude, 2002)

In top-down approach, “GeoCHEAF” has multiple data marts serving the needs of systems within the enterprise, such as archaeology, history, museology, architecture. While these data marts only contain the required subject specific data for their own analysis, the data warehouse is viewed as an enterprise-level single repository that feeds those subject-oriented data marts by keeping the meta data consistency and connectivity requirements. Data marts containing atomic or aggregated information, but they are based on the data warehouse and are really subsets of the data contained therein. In that sense, data flows from the data warehouse into the data marts. Most of the analytical activities in the Business Intelligence (BI) environment takes place in the data marts.

The data warehouse architecture design relies on a relational or Third Normal Form (3NF) design foundation with data stored at the atomic level in the data warehouse. Relationally designed data warehouse data stored at a low level of granularity can be used in a wide variety of ways, which is then aggregated and made accessible across the enterprise by exploration warehouses, data mining warehouses and OLAP data bases.

This architecture embraces the star schema design for the dependent data marts only, not for the design of the data warehouse, since the star schema is closely aligned to end-user requirements. Therefore, it does not produce a reusable form of data for the enterprise. It uses the dependent data mart as the source for star schema usage, solves the problem of enterprise-wide access to the same data, which can change over time. A data mart usually is organized as one dimensional model as a star-schema (OLAP cube) made of a fact table and multiple dimension tables.

5.4.5 OLAP

OLAP is a technology that enables a data warehouse to be used effectively for online analysis using complex analytical queries. OLAP provides multidimensional, summarized views of business data in the data warehouse and is used for reporting, analysis, modeling and planning for optimizing the business.

ROLAP, MOLAP and HOLAP are specialized OLAP applications. (Naude, 2002)

ROLAP stands for Relational OLAP. Users see their data organized in cubes with dimensions, but the data is really stored in a RDBMS. The RDBMS will store data at a fine grain level, response times are usually slow. (Naude, 2002)

MOLAP stands for Multidimensional OLAP. Users see their data organized in cubes with dimensions, but the data is store in a multi-dimensional database (MD-database, MDBMS). In a MOLAP system lot of queries have a finite answer and performance is usually critical and fast. (Naude, 2002)

HOLAP stands for Hybrid OLAP, it is a combination of both worlds. In a HOLAP system one will find queries on aggregated data as well as on detailed data. (Naude, 2002)

Normal relational databases store data in two-dimensional tables and analytical queries against them are normally very slow. Data in a MDBMS is stored as business people views it, allowing them to slice and dice the data to answer business questions. When designed correctly, an OLAP database will provide must faster response times for analytical queries. (Naude, 2002)

Although OLAP tools support multidimensional analysis and decision-making, additional data analysis tools are required for in-depth analysis, such as data classification, clustering, and characterization of data changes over time.

5.4.6 Data mining process

"GeoCHEAF" utilizes data mining approach that is the process of discovering knowledge in data to turn huge amounts of data into useful information and knowledge using pattern recognition technologies as well as statistical and mathematical techniques (by sifting through large amounts of data stored in repositories). The information and knowledge gained can be used for decision-making processes.

Data mining constitutes one or more of the following functions, namely, classification, regression, clustering, summarization, image retrieval, discovering association rules and functional dependencies, rule extraction, etc. Clustering is the process of grouping the data into classes or clusters so that objects within a cluster have high similarity in comparison to one another, but are very dissimilar to objects in other clusters.

5.4.7 Decision-making process

A decision is defined as the choice of one among a number of alternatives (or solutions), and decision-making refers to the whole process of making the choice, which includes: (Bohanec, 2001)

- assessing the problem,
- collecting and verifying information,
- identifying alternatives,
- anticipating consequences of decisions,
- making the choice using sound and logical judgement based on available information,
- informing others of decision and rationale,
- evaluating decisions.

Decision Support that is a part of decision-making processes. The term Decision Support contains the word 'support', which refers to supporting *people* in making decisions. Thus, Decision Support is concerned with *human* decision-making. (Bohanec, 2001)

There is a variety of artificial systems that also make decisions: computer programs, autonomous expert systems and software agents, etc. Decision systems, which (primarily) deals with computer-based programs and technologies intended to make routine decisions, monitor and control processes concern with machine decision-making. Machine decision-making is another part of decision-making processes. (Bohanec, 2001)

Decision Support encompasses a number of disciplines, including operations research, decision analysis, decision support systems, data warehousing, and group decision support. Data warehouse and OLAP refer two different components of a decision support system.

A Modern Scientific Discovery Process:

- Data Gathering
- Data Farming (Database Technology)
  - Storage/Archiving
  - Indexing, Searchability
  - Data Fusion, Interoperability
- Data Mining (or Knowledge Discovery in Database) (Key Technical Challenges)
  - Pattern or Correlation Search
  - Clustering analysis, automated classification
  - Outlier/anomaly searches
  - Hyperdimensional visualization
- Data Understanding (Key Methodological Challenges)
- New Knowledge

Knowledge discovery consists of an iterative sequence of the following steps:

1. Data cleaning (to remove noise and inconsistent data)
2. Data integration (where multiple data sources may be combined)
3. Data selection (where data relevant to the analysis task are retrieved from the database)
4. Data transformation (where data are transformed or consolidated into forms appropriate for mining by performing summary or aggregation operations, for instance)
5. Data mining (an essential process where intelligent methods are applied in order to extract data patterns)
6. Pattern evaluation (to identify the truly interesting patterns representing knowledge based on some interestingness measures)
7. Knowledge presentation (where visualization and knowledge representation techniques are used to present the mined knowledge to the user)

6. VISUALIZATION ARCHITECTURE

Visualization is computer graphic representation of reality. Visualization technology is used by a wide range of fields of science and engineering, such as in the CH sector for the analysis of the CH phenomenon, data and information. (see Figure 6.1)

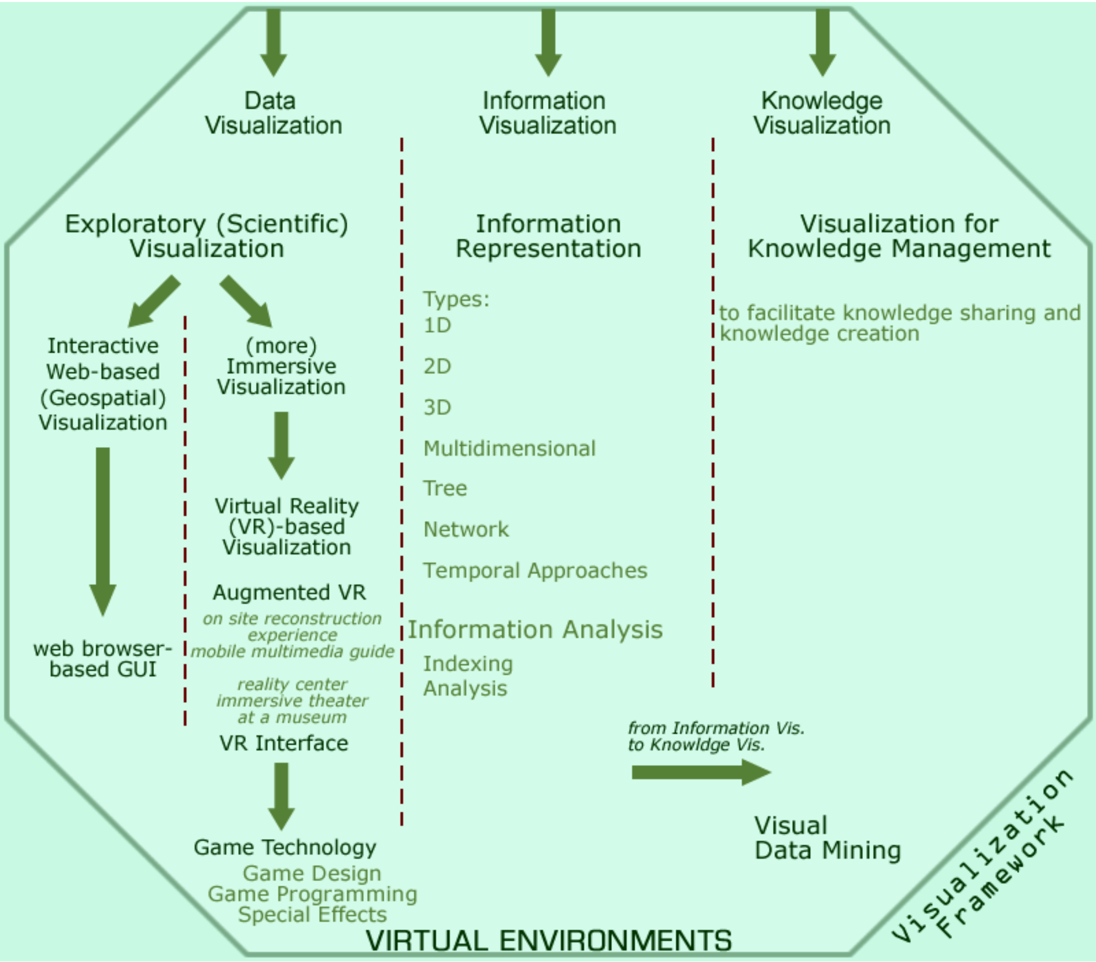

Figure 6.1: Data, information, and knowledge visualization

Two goals of visualization are **communication** and **discovery**. The growing number and variety of complex information makes visual approaches for communication a necessity. Visualization is an important technique that helps in the understanding and analysis of complex data with data warehousing and data mining techniques. In complex data, the structure, features, patterns, trends, anomalies and relationships are not easily detectable (Ying et al., 2006). Where the data collected is summarized, data visualization supports the extraction of interests by presenting the data in various visual forms with different interactions to aid in decision-making and in grasping the minute details and relationships of data sets (Ying et al., 2006). For instance, recreating the 3D fortresses in the project brings the discoveries to life for the users and public.

Collecting information is no longer a problem, but extracting value from information collections has become progressively more difficult. Visualization links the human eye and computer, helping to identify patterns and to extract insights from large amounts of information Visualization has been used to communicate ideas, to monitor trends implicit in data, and to explore large volumes of data from hypothesis generation.

The ability to visualize complex geospatial systems introduces fundamental new challenges to the theory and application of visualization. The key reason that these systems have not reached their full potential has been an inability to communicate either current system state or expected system state information to decision makers in a meaningful format. The system state description is derived from many data sources so to fuse this data and concisely define the state of the system is a daunting task. To go further to visualize this information so that a decision-maker can use it is even more difficult. Currently, only simplistic graphic maps are used for this purpose. Such maps fail to effectively capture temporal information or any level of spatial resolution. Such systems like CH management are characterized by presence of rich information. That information has significant geospatial and temporal characteristics and consists of large quantities of data from a variety of data sources. As information should be stored efficiently and then integrated in a common visualization framework. (Ying et al., 2006) It becomes ever more important to provide proper visualization architectures for the user interfaces of information systems.

CH is a fast growing area of visualization, simulation and virtual reality applications. Using all the existing technologies in 3D modeling and reconstruction a large number of monuments, museums, and sites are represented through virtual replicates over Internet, on DVD-ROM, and through immersive peripherals such as HMDs and CAVEs. For instance, CAD models of what CH specialists believe a structure looked like can be created based on excavation results, and then can be placed it into the modern landscape or a recreation of how CH specialists think the ancient landscape looked. However, large and complex populated CH resources are still not widely simulated in their integrability due to their complexity, lack of historical references, and high computational requirements. Recent advances in computer graphics hardware allows easier access to these computational requirements but still a clear methodology is to be drawn for the conduction of virtual restitutions of CH resources.

6.1 Visualization Architecture of "GeoCHEAF"

"GeoCHEAF" provides a uniform visualization architecture framework based on computer graphics technology for exploratory (may also be also referred as scientific) visualization that is for effective integration and web-based realistic presentation of complex heterogeneous CH spatiotemporal object data sources and types in a comprehensible fashion.

This framework facilitates interpretation, exploration and analysis of large volume of CH data with significant geospatial, temporal and semantic characteristics and effective communication between the developer and the user about promoting quality, usability and navigability of the visualization component. Advantages of this approach include improved visualization of geospatial and temporal raw data; better navigation and selection of data; and intuitive user interface. Thus, a user can focus on extracting meaning from data without being required to explicitly manage the heterogeneous data.

The framework for data visualization architecture of "GeoCHEAF" is illustrated in figure 6.2. It consists of four parts: general visualization component, exploratory data visualization component (the GUI of "GeoCHEAF"), visualization process component, and VRML development architecture component.

It was approached to come up with key features such as animation, simulation, real-time interaction, multimedia (image, movie, sound), behavior etc. in accordance with the users' requirements involving historical recording, preservation, cultural awareness and educational. It is a challenging work to design this artificial 3D visual model which is a most cutting edge technology utilized by a broad range of users. (Guney and Celik, 2004b)

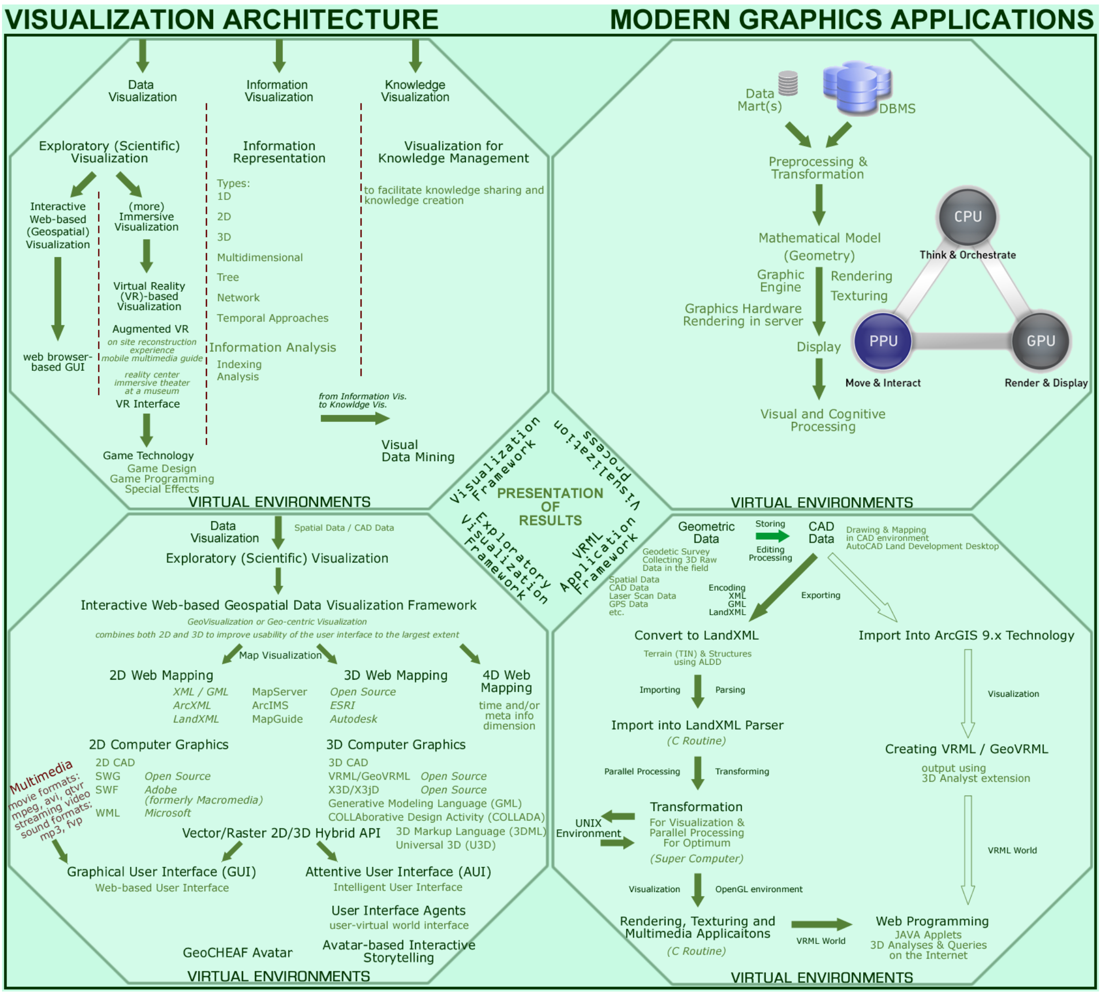

Figure 6.2: Methodology and technology used for designing the visualization architecture of "GeoCHEAF"

In the visualization architecture of "GeoCHEAF", the immersion, perception, realism and interactivity of the virtual environment are very important considerations. Some semantics and manipulation of environmental and atmospheric effects, such as hierarchical transformations, light sources, viewpoints, geometry, animation, fog, haze, clouds, sun illumination, material properties, and texture mapping, are integrated to the scenes of the CH sites to promote these considerations. For example, the addition of fog helps to blend the sky with the low-resolution portion of the terrain in order to hide rough surface features. It also gives the environment a better sense of depth and atmosphere. Another example is that the surveying architectural ruins were initially rendered realistically with image maps from photographs taken on site. In such way, the visualization framework creates more realistic images, including fog and scene-edge effects that make images fade into the distance. It also include capabilities to define camera paths that can be predefined vectors or interactively developed. The paths then are used to create an interactive video in AVI or MPEG format. Texture mapping is used to support realistic rendering of polygonal features such as walls, meadows, open water and background sky. Once the background has been created a number of people can be added around the scene to increase realism and movement.

A web-based graphical user interface (GUI) was designed as an interactive and immersive virtual reality interface for 2D/3D SIS applications to enable the researchers to easily perform complete and accurate spatiotemporal analysis of the data collected about CH resources.

In the context of the project, the GUI of "GeoCHEAF" represents graphically spatial reality of the fortresses, their surroundings and spatial relationships between the artifacts, the architecture, and the topography as realistic as in 3D display and full color that allows the user to more quickly recognize the issues within the life history of the fortresses through various visualization approaches with different levels of detail (LOD) such as terrain&plant modeling and landscape visualization, building visualization, facade visualization, human visualization, artifacts visualization.

To enhance reality of features displayed on 3D SIS, three methods to manipulate the appearance can be considered. First, it is to use realistic colors with well-mixed combination of RGB. In the commercial feature-based 2D GIS packages, feature vector data are usually drawn by primary colors and its simple combinations. Whereas, if one uses these colors to 3D virtual world, the reality will be so drastically diminished. Second, it is to use texture mapping. Using a single color has its own limitation in reality. Texture can be utilized to represent the appearance characteristic of 3D features more effectively. As a texture image, artificially drafted images such as various wall textures can be used. For more reality, the very picture of the feature taken by camera can also be used. The third is to use wire frame model instead of the simply extruded shape. Wire frame model can provide much detailed reality, which is more advanced through rendering process. This method takes relatively much computational time to load wire frame data and render them. From the visualization speed point of view, the first method is the fastest, and the second next, and the third is most slow. So, the second and the third method can be improper to real-time web SIS applications.

The geovisualization framework of "GeoCHEAF" was designed through visualizing CH objects, time and space:

- to reconstruct an accurate and realistic visualization of 3D CH site with 3D CH objects like monuments on the site in a computer-generated environment (*in terms of easy extensibility and flexibility*). For instance, recreating and visualizing both the present situation of the fortresses, the condition of the fortresses in the past and its evolution through time.

- to allow a user to be immersed in this 3D scene of the site (3D virtual world) via interactive navigation techniques like virtual flights over the virtual CH site (may also be also referred as virtual fly-through or fly-over or fly-by), a walkthrough on the web or real-time 3D (RT3D) walk-through (*in terms of increasing perception*).

- to integrate much more realistic graphics into the scene, such as a wealth of photographs and video clips of some of the finds and remains (*in terms of increasing realism*).

- to allow a user with avatars (or agents) to interact those CH objects within the scene of the site through standard SIS capabilities such as query, selection, spatial analysis (*in terms of increasing interactivity and spatial awareness*).

- to merge visualization technology and multimedia capabilities with SIS, particularly the incorporation of interaction and animation for the display of maps and their distribution through the web, in order to obtain better 3D spatial operations, such as geospatial query and analyzes, richer methods of presentation of data, easier systems for end-users and enhanced management of spatial phenomena.

- to reveal unknown in data by visualizing spatial uncertainty like non-visible connections between finds and building remains through 3D interactive maps and virtual 3D SIS (*in terms of making invisible visible*).
- to visualize multi-dimensional data to understand multi-dimensional databases
- to supply with more advanced decision-making methodologies.
- to exhibit a stunning VR presentation of 3D virtual tour of the CH site as a narrated show in an immersive (domed-)theater at the virtual museum or interpretation center of the site in terms of seeing CH resources projected on a large, immersive screen makes their impact even greater.
- to research the entire model of the CH resource in the real-time-a full interactive mode like an interactive cave or an immersive desk to exhibit by a museum expert. A user uses wands that have one joystick and three buttons.
- to enable to visitors to tour the entire CH site immersively and interactively using 3D model within mobile devices in the real-time, filled with the living, breathing activities of its long history.
- to make remote or destroyed CH site virtually accessible over the Internet to the public from anywhere in the world.
- to allow for improved education and bringing the value of the cultural resources to the public and decision makers.
- to achieve all these with the high graphic quality and visual accuracy, and the low cost.

The photo-realistic 3D virtual restitution framework of "GeoCHEAF" covers the modeling of the whole site, 3D model of exterior and interior of the structures, the geometrical restitution of the artifacts, the simulating historical high-quality virtual characters of that time (with the virtual human bodies and their clothes), and architectural evolution in one united and optimized model based on a very precise scenario. It is for the multi-resolution real-time and non real-time 3D realistic virtual simulation of the ancient life, the restoration and renovation process of ancient monuments, and the full understanding of the historical and social development of vast communities, with accurate choices of each phase of modeling, texturing, and lighting processes. The immersive experience could be heavily enhanced by the addition of 3D rendered sound sequences, like background music, in order to enhance the virtual acoustical restitution on the CH structure like secular structure, e.g. mosque, church. Finally the adoption of the large-screen stereoscopic projectors and 3D shutter glasses will enhance greatly the visualization experience.

The importance of a heritage site resides as well as in the historical characters and social interactions that were taking place there: this information allows better understanding of the function and the importance of the selected site in connection with the cultural aspects of the life at a certain time. In order to strengthen the feeling of immersion in a heritage edifice virtually restituted, it is important to recreate virtual life and describe the timely evolutionary aspects of the CH resources as well. In order to achieve an accurate simulation the social aspect must not be forgotten.

A simulation model considering above would be an immersive virtual environment that allows the visitors to virtually explore the site, to experience its architecture, dimensions, and atmosphere, and to obtain architectural, cultural, and historical information. A virtual guide, in traditional clothes, talks to visitors giving explanations about the CH resource.

In order to achieve a successful realistic 3D simulation of a selected heritage site, different aspects are critical: the choice of the appropriate modeling techniques, the preparation of the lighting models and the texture creation process (which heavily contributes to the surface appearance representation).

The Fortresses have a huge wealth of historically significant and cultural important material in the form of buildings and events. “GeoCHEAF” enables this information to be recreated as virtual reality worlds for the users and visitors to see for themselves how buildings once looked; to hear from virtual guides the history of significant buildings and events; to explore locations unavailable to them.

Interactive virtual tour guides called the avatars of “GeoCHEAF” was designed to talk to visitors in bilingual (Turkish & English) pointing out historical, artistic and architectural facts of the CH objects through an interactive story telling system, like 'the life history of the fortresses'. The use of an avatar (or multiple avatars) can provide a distinct point of view, attitude, and physical appearance to enhance effect of the interactively created story on the particular visitor or visitor group (URL EPOCH). Furthermore, users or visitors can chat with each other in a multi-user version of the avatar-based interactive story telling system.

Storytelling is a familiar and effective way to convey information to a general audience in the field of CH. Yet with the increasing use of standardized interactive applications in museums and historic sites, it is difficult to appeal to a wide range of visitor interests. This problem can be solved through the use of interactive storytelling, which allows the visitor to choose from a large selection of subjects and themes to create a personalized 'story', appropriate to his or her interests and the time available for the visit. (URL EPOCH)

Several historical scenarios created in the project was derived from investigating of the life history of the fortresses. Bilingual avatars (Ottoman virtual humans) exist in virtual life of the fortress within these scenarios, sometimes only appearing with a narrator’s voice, sometimes an actor/actress. For example, the avatar can be used to explore the identities and experiences of different persons who could have lived or been involved in the construction of the fortress. One could choose the figure of the patron of the fortress, the commander of the navy that was stationed there, the mason who built the Turkish bath etc. The common point for all scenarios is to give an abundant amount of historical information concerning the CH objects of the fortresses, the freedom of movement, interactivity and representation of spatiotemporal query results in an immersive 4D (3D+time) environment. (Guney et al., 2003b; Guney and Celik, 2003a; Guney, 2001)

The user can interactively navigate itself along with the avatars around the monuments and even query the monuments for information. For the project, upon entering the fortresses virtual site, there will be the option to view different layers of information. For example, if the user is not familiar with the site, s/he will probably want to view the terrain with the architecture only, to gain a frame of reference with 2.5D/3D map of the site. As the user becomes familiar with the setting, additional layers can be added for a more complex investigation. For instance, when a CH object such as mosque is selected by the user, a pop-up window can display a drawing of its interior spaces (in form of a 3D CAD model), a photo of its history, a database of architectural changes, a digital site plan, a short video of present situation, sound data related to the object, subdivision-documents, and 3D simulations (Guney et al., 2001). The user has access to the 3D interactive visualization of an object like turkish bath with a click option. The first click on the door of the turkish bath will allow the user to enter inside. The second click on the indoor will show the dynamic menu that gives links to the architectural plans of main parts of turkish bath and some query options. (Guney and Celik, 2004c) The avatar is be able to respond to questions from a range of users, therefore, speech is required to make interaction as natural and engaging as possible.

In the project of *Kumkale* Cemetery, a 'turtle' is the identifying tool on the web. The turtle navigates around an old 'mulberry tree' serves as the source of information about the tombstones and the cemetery. These ideas are supported with multimedia. For example tombstones could be used as vehicles for speech, the running text could appear on the tree along with photographs. The 3D animation developed for this scenario is shown in figure 6.3. (Guney and Celik, 2003a)

Depends on the classification of the gravestones in the *Kumkale* Cemetery, some sample hand drawings and 2D&3D digital models were produced to indicate the variety of the tombstones in the cemetery generally. Using “Autodesk 3ds Max”, “Adobe (formerly Macromedia) Flash” and “Adobe Photoshop”, standard electronic forms (e-form) were created for each gravestone in the *Kumkale* Cemetery in order to recognize and obtain detail information about a gravestone, shown in figure 6.4. This e-form includes the photograph, hand drawing with 1:10 scale, 3D model generated in digital environment, original epigraph in Ottoman language and attribute table of the related gravestone. Figure 6.5 displays some gravestone samples created in the digital environment. Figure 6.6 illustrates a multimedia approach of *Kumkale* Cemetery SIS Application. (Guney and Celik, 2003a; Guney et al., 2002)

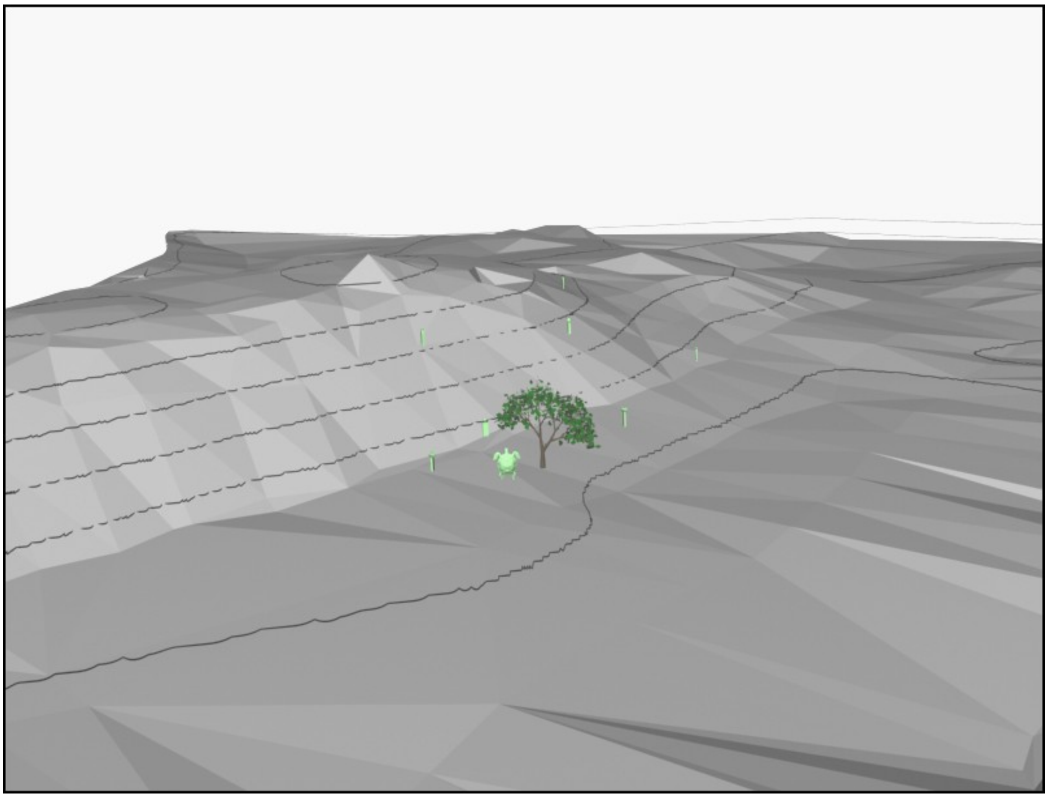

Figure 6.3: An animation example for *Kumkale* Cemetery (Guney and Celik, 2003a)

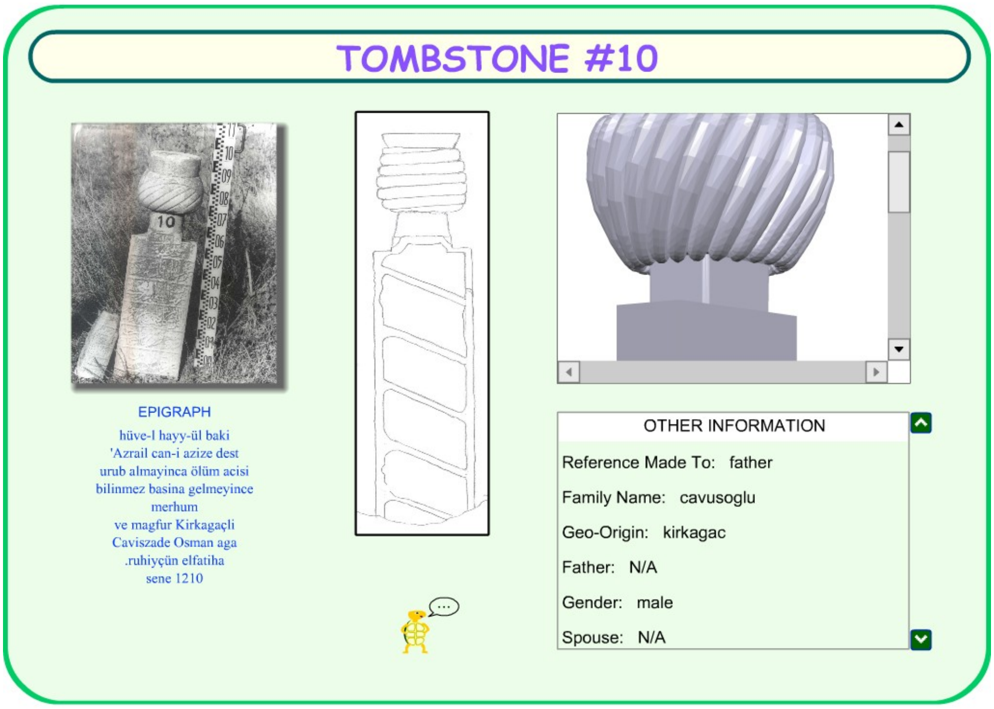

Figure 6.4: A sample electronic form for a tombstone (Guney and Celik, 2003a)

The quality of SIS user interfaces is a key-factor for efficiency and effectiveness of SIS use, for user satisfaction, and then for SIS diffusion. This quality must be improved for the users, especially since the technology is becoming more inexpensive and is therefore reaching more normally non-expert users within the general public. Such scenarios facilitate the distribution of information and keeping in mind much longer than the classic approach provided by the commercial software packages, like traditional modeling packages or SIS packages, which keep the information within unfriendly digital tables.

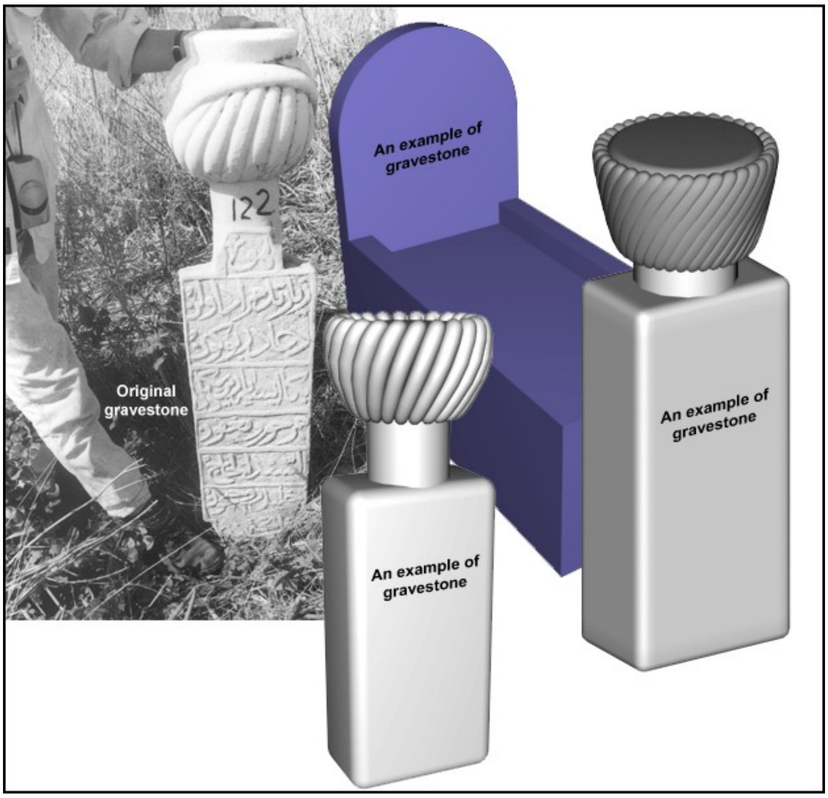

Figure 6.5: The generated tombstones samples for *Kumkale* Cemetery (Guney and Celik, 2003a)

With this architecture designed, the users neither need nor are required to have a previous knowledge of computers or SIS and they are unaware that they using SIS. While designing the system, it was kept in mind that the total system must be highly interactive so that the users can proceed in one of the scenarios offered to the user. The concepts and features of fortresses are explained through graphic illustrations, supported by brief textual descriptions. (Guney and Celik, 2003a) Some of the texts contain hyperwords, which are highlighted. By clicking on them one can get detailed information on these words. (Guney, 2001)

Figure 6.6: Multimedia application of *Kumkale* Cemetery SIS application (Guney et al., 2002)

6.2 Multi-dimensional Hybrid Visualization

Whilst a map can be defined as an abstraction and a representation of reality and map features symbolize objects in the real world. There are long established techniques, patterns and symbols to summarize the real world via visual references. (Koehnen, 2002)

In the book of Nature of Maps a map is defined as a 'graphic representation of the milieu' based on that the purpose of maps is to model reality. The use of the term milieu is interesting because it suggests much more than the flat, static maps being familiar with. It presents a challenge to step beyond the comfortable reach of two-dimensional representations to higher dimensions of (geo)visualization. Humans see in 3D & full color and 3D displays stimulate more neurons: involving a larger portion of the brain in the problem solving process. Visual information is processed and absorbed by human brains much more efficiently than textual, numerical and even diagrammatic data. With 2D contour map (2.5D capability), for example, the mind must first build a conceptual model of the relief before any analysis can be made. Considering the cartographic complexity of some terrain, this can be an arduous task for even the most dexterous mind. 3D display, however, simulates spatial reality, thus allowing the viewer to more quickly recognize and understand changes in elevation. (Swanson, 1996) Until relatively recently, however, SIS has focused primarily on static 2D imagery, although 3D (geo)databases and (geo)visualization are common.

The increased complexity of tasks in many applications seeks for an integration of 3D spatial and thematic data and mutual relationships. Existing systems either fall short of dealing with 3D geometry (2D SIS) or lack extended spatial and thematic analysis. For example, queries such as “show which buildings in the fortresses architectural changes”, “show how digital terrain models of the fortresses changed through World War I”, “show all important architectural features on the second floor of the south-east tower in the fortress of *Kumkale* still can not be accomplished by any of the commercially available systems.

Additionally the step from 2D to 3D causes several problems; building 3D models, storing them and providing a user interface to visualize and manipulate them. As 3D SIS applications become increasingly important, new database technologies such as OODBMS are essential. Object-oriented programming systems are now recognized as a key component in building powerful applications which are robust and maintainable and which are also to be seamlessly extensible. (Chance et al., 2003)

Advancement in technology and navigable 3D graphics has enabled cartographers to produce maps that are both interactive and animated maps, similar to most things experienced in reality. More recent developments in hardware and software capability and price have made three-dimensional output extremely affordable. People live in a 3D reality and the purpose of a map is to be an abstraction of reality; so the output of 3D SIS that can be both interactive and animated maps. The conventional 2D maps output by conventional SIS applications or 2D static/dynamic/interactive web mapping on the Internet, combining 2D maps with thematic information, adequately represent functional data, but cannot represent visual data well at all. On the other hand, 3D maps do an excellent job of representing visual data and are also capable of handling functional data. The coupling of 3D SIS and/or 3D web mapping with interactive and animated output can not only serve to further a map’s ability to accurately depict geospatial data, also gives the ability to immerse in 3D worlds, adding objects 'on-the-fly', generating sounds three dimensional and letting the user navigate with complete freedom of his movements. (Guney et al., 2003b) In both today's heritage sector and cartography, the most common dynamic streams are ubiquitous dynamic mapping, interactive Internet maps, cyber maps and animated maps. For example, the public, museum visitors or history students could see the Ottoman Empire rise and fall in an animated time series that shows the land mass of the conquered territories expand and shrink over time via 2D/3D animated maps of a SIS application.

Today’s some proprietary GIS/CAD software, like ESRI’s ArcGIS & ArcScene, Autodesk’s Land Development Desktop & Map Studio, is characterized by traditional 3D mapping techniques, such as wireframe terrain characterization with light-source-shaded perspectives as well as vector and image draping. These 3D views can be generated from specific x,y viewpoints, supporting a wide range of surface-definition parameters. Full-featured SIS software also supports image-rendering enhancements (e.g., atmospheric effects such as sky, fog and haze). Recent additions support the generation of map animations using standard MPEG encoding formats. However, SIS and CAD software typically do not have 3D object rendering capabilities. Some users have integrated SIS capabilities with photo imaging, but these are usually project-based efforts and typically do not reflect a readily available functionality. (Berry et al., 1998)

Recently, virtual SIS (VSIS) based on 3D geoprocessing methodology with navigable 3D graphics, and the Internet environment have opened an exiting research area for spatial informatics technology, virtual 3D GIS on the web. While, some 2D SIS software running on the web is appearing in SIS worldwide commercial market, but their functionalities are not satisfied with advanced SIS user requirements due to less spatial analysis functions and weakness of 3D data modeling. A 3D SIS should be a system capable of maintaining and analyzing 3D spatial and thematic properties of real geospatial objects. (Kim et al., 1998; Zlatanoval, 1999; Koehnen, 2002)

In the context of this dissertation, interactive web-based geospatial visualization techniques can be classified by whether data display is 2D or 3D based. Most of current CH organizations widely use 2D visualization techniques. On the other hand, there is an increasing interest in 3D representations of geospatial data, especially for the universal web access of such data.

Both 2D and 3D visualization have their own strength and weakness. When a large amount of data has to be presented in a limited space, visualizing in 2D will introduce a cognitive overload and thus heavily reduce usability. Instead, 3D visualization uses an extra spatial dimension to create a virtual world where information is presented. 3D modeling of the real world and the real-phenomena presents opportunities of scientific exploration and visualization that are not possible in 2D. Additionally some information is best experienced three dimensionally such as documentation and research of CH sites and structures. However, delivering 3D content over Internet is more technically challenging. The difficulty of the distribution and navigation of 3D content over the Internet is one of the main obstacles that prevent the popularity of 3D web sites. The creation of detailed and accurate 3D models is always time consuming and requiring hours of data collection, processing and rendering. Moreover, user interaction in a 3D environment is not always intuitive and may be difficult to learn.

Fortunately, recent innovative 3D computer graphic technologies being gradually developed on the web and state-of-the-art surveying methods such as remote sensing, photogrammetry, Global Positioning System (GPS), laser scanners and Total Positioning System (TPS), are providing a wealth of geodata that makes the third dimension possible in web mapping.

The visualization architecture of “GeoCHEAF” provides a good foundation to integrate various data sources and generate 2D, 2.5D, 3D and 4D worlds in an automatic way, and supplies highly interactive, flexible and intuitive GUI for users. It provides the option of viewing project maps in 2D (SVG graphics) and 3D (X3D graphics) format. The 2D map orients the user to the big picture and giving an overview of the whole CH site, while the 3D virtual world presents spatiotemporal CH objects in more detail, accurate and in a more realistic way. Both 2D and 3D environments can be presented with different LOD, like site, buildings, facade, artifacts,objects, features, or at different scales, giving the user a choice about the **granularity** of presented data. Current Web technologies: Scalable Vector Graphics (SVG), Virtual Reality Modeling Language (VRML&GeoVRML), and eXtensible 3D (X3D&X3jD), defined by the World Wide Web Consortium (W3C) provide a necessary foundation for such an architecture to explore the potential of 2D&3D visualization of reality.

The GUI of “GeoCHEAF” has been designed as that the left panel (larger window) is 3D virtual world in X3D, and right panel (smaller window) is 2D map in SVG, shown in figure 6.7. The 2D map provides an overview of the CH site, while the 3D world provides a more detailed and flexible view. The 2D map is also a navigator of the 3D virtual world. If user move mouse in the map, the viewpoint in the 3D world will change correspondingly. These two worlds are synchronized so as to provide user different references of navigation. For example, user moves mouse over the icon tower in 2D map, in the 3D world, user’s viewpoint will move close to the tower. User can also use mouse or key to control the viewpoint in 3D freely. The navigation facilities are provided such as zoom in, zoom out, walk, fly, pan, rotate, etc.

In most of the cases, the value of the selected data type or the result of probabilistic and statistical analysis is used to create a visual cue in the 3D virtual environment. The visual cues include both geometry and appearance. The preferred choice in this case is the vertical extrusion of the polygon specifying the region of the sensor. The amount of the extrusion is proportional to the value of the result of statistical analysis. In addition, a color coding is used to indicate different levels of data. The time dimension of the data is presented by animating the visual cues with appropriate scaling. Due to the spatial and temporal characteristics of the CH data, several selection mechanisms are available for interaction. User could use traditional dialog provided in HTML to select data type for a given CH object or a set of CH objects, as well as the time interval of interest. The user can also pick in the 2D and 3D virtual environment a region of interest to select specific thematic data sets mapped to that region. Typically these types of applications require intensive interaction, animation, user participation and exploration beyond what is capable with a page-, text-, or image-based format.

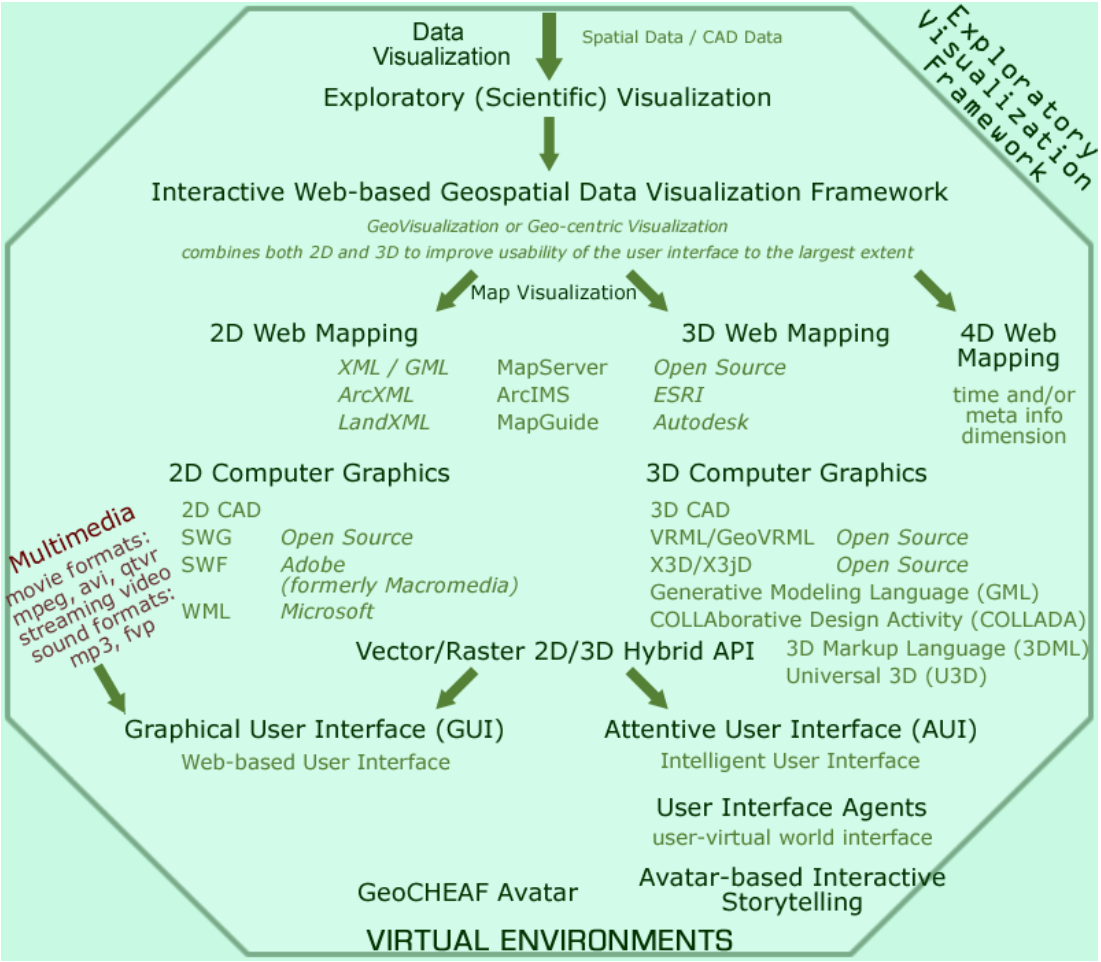

Figure 6.7: The design scheme of the GUI of "GeoCHEAF"

6.3 XML-based Visualization

SVG is a standard XML-based language for 2D web graphics from the W3C, which describes graphics with vector shapes, text, and embedded raster images. It is compact and provides high-quality XML graphics on the web, in print, and on computers and handheld devices. In addition, SVG supports scripting and animation and is used for dynamic, interactive, data-driven, personalized graphics and 2D web mapping. Its major strengths are quality (vector-based), feature manipulation on the client side (eliminates the need for a SIS application server & client-side interactivity), cost (free and open-source), and platform-independent. Its weakness is its text-based structure that causes larger file size and slower rendering speed than binary formats.

X3D is the ISO standard for real-time 3D computer graphics, the successor to Virtual Reality Modeling Language (VRML). It defines several profiles (sets of extensions) for various purposes, such as X3D Core, X3D Interchange, X3D CAD, X3D Geospatial and X3D Immersive, and browser makers can define their own extensions prior to submitting them for standardization by the W3C. (URL Wikipedia)

6.4 VRML and Building 3D Geospatial Scenes in VRML

VRML is used as a highly structured dynamic 3D scene description language, a simple 3D modeling tool and an effective 3D interchange format, which integrates three dimensions, two dimensions, text, and multimedia into a coherent model. It is open, standard, extensible, platform-and software-independent language in the form of human-readable text file (ASCII or UTF8) for describing and publishing interactive 3D objects, the behavior of 3D objects and 3D worlds delivered over the Internet and parsed by a web browser with VRML plugin that sensually renders the plain text document into an interactive form to display the geometry, lighting, and animation in the VRML file. It also allows “script nodes” by which the developer can add external programs (typically written in Java or JavaScript) to extend its functionality implementing programmed behavior for the objects in the created worlds. Such that the user can easily interact with the 3D model, predefined walking or flying around and through it. Script nodes can be inserted between event generators (typically sensor nodes) and event receivers. Events, (such as mouse/cursor/keyboard combinations) can be sent from the VRML scene nodes where they are detected to Java programs that react correspondingly. The converse is possible too. Scripts allow the developers to define arbitrary behaviors, defined in any supported scripting language. VRML allows fully immersive environments, interactivity and real-time animation capabilities. (URL Web3D; URL VRML)

Additionally, VRML files may contain references to files in many other standard formats on the web. These links represent interrelations that can be used to retrieve and visualize 3D spatial data and information. Thus, it can serve as a virtual 3D GUI to 3D SIS. JPEG, PNG, GIF, and MPEG files may be used as texture maps on objects. WAV and MIDI files may be used to specify sound that is emitted in the world. (URL VRML; Zlatanoval, 1999)

The current VRML specification is VRML97. The specification has been ratified by the International Standards Organization (ISO), where it is referred to as ISO/IEC DIS 14772-1, or (informally) as VRML 97. VRML 1.0 supports worlds with relatively simple animations while VRML 2.0 supports complex 3D animations, simulations, and behaviors by allowing Java and JavaScript programmers to write scripts that act upon VRML objects. (URL Web3D; URL VRML)

VRML browsers (or VRML viewers) work as plugins for common Web browsers and are currently available for most platforms. Plug-ins add functionality to the web browser. There are many freely available VRML browsers that can be used to view and interact with the model; although there is considerable variation in how well they render the models. (URL Web3D; URL VRML)

Geographic VRML (GeoVRML), as an extension to VRML, has addressed issues specific to geospatial data that VRML does not. The desire is to enable geo-referenced data, such as maps and 3D terrain models, to be viewed over the web by a user with a standard VRML plugin for their web browser. (URL Web3D; URL VRML)

Based on all the features of it mentioned above, VRML was chosen as a means of visualizing in 3D. In the project, once the all computer-aided design (CAD) drawings has completed and stored as DWG AutoCAD file format and imported into ArcGIS technology. ESRI’s 3D Analyst, which is one of ESRI’s ArcGIS extensions, has been used to create VRML output files for the historical site, shown in figure 6.8.

VRML output obtained the integration of CAD and SIS technologies is of particular importance to the CH domain with so many objects that are recreated in CAD packages due to standalone SISs lack the graphical capability and geometrical accuracy. In the visualization architecture of "GeoCHEAF", the approach to CAD/SIS integration is that CAD tools would be used to reconstruct, edit, and maintain geometrical information accurately and precisely. SIS tools would be used to model and analyze the data related to the geometrical information. The integration seems appropriate since both technology are meant to deal with spatial information. This output is stored in a data file external to the SIS, which is then loaded into a suitable VRML browser for viewing. The browser provides the functionality for the user interactively to explore the 3D model by 'walking' and 'flying'. The user is unable to modify the model in the browser. Modification of the model requires going back to stage one, making changes to the 2D SIS database, and then generating a new VRML model. However, this output (being program generated) tends to be large and cumbersome, often unusable for web delivery. Once one get started, it is actually easier to create effective VRML representations oneself using much simpler tools. With some guidance, the output becomes small and efficient enough to be of practical use for serving SIS data in three dimensions over the web. (Guney et al., 2003b)

Figure 6.8: Capture of VRML application of *Seddülbahir* fortress

As Figure 6.9 displayed, VRML files are being produced in this study with two different methods, open source and commercial ways. Figure 6.10 presents a capture of VRML application of the *Kumkale* Cemetery.

Digital Terrain Models (DTM) of the fortresses' areas and 3D architectural plans of the remaining of the fortresses were produced in the CAD environment with the 'DWG' format using "AutoCAD Land Development Desktop Release 2.0/3.0, Autodesk Inc." software. DWG-format 3D terrain models and 3D architectural models were converted to LandXML format, which is a version of XML developed by Autodesk in order to transport the geometric data to the program developed in (C++) Java using several libraries like OpenGL. This program is used to render the geometric data to use in the animations and other presentations. Thereafter, produced animation has broadcasted over internet with java applets, API functions and some plugins. System requirements are automatically provided with the system itself when the user has only a Java enabled browser and a VRML plugin respectively a VRML browser. This allowed land information to interoperate among various software solutions, to be explored interactively in OpenGL, shown in figure 6.11. (Guney et al., 2002; Guney and Celik, 2003a) The query capabilities on a 3D map about attribute data have been added the model.

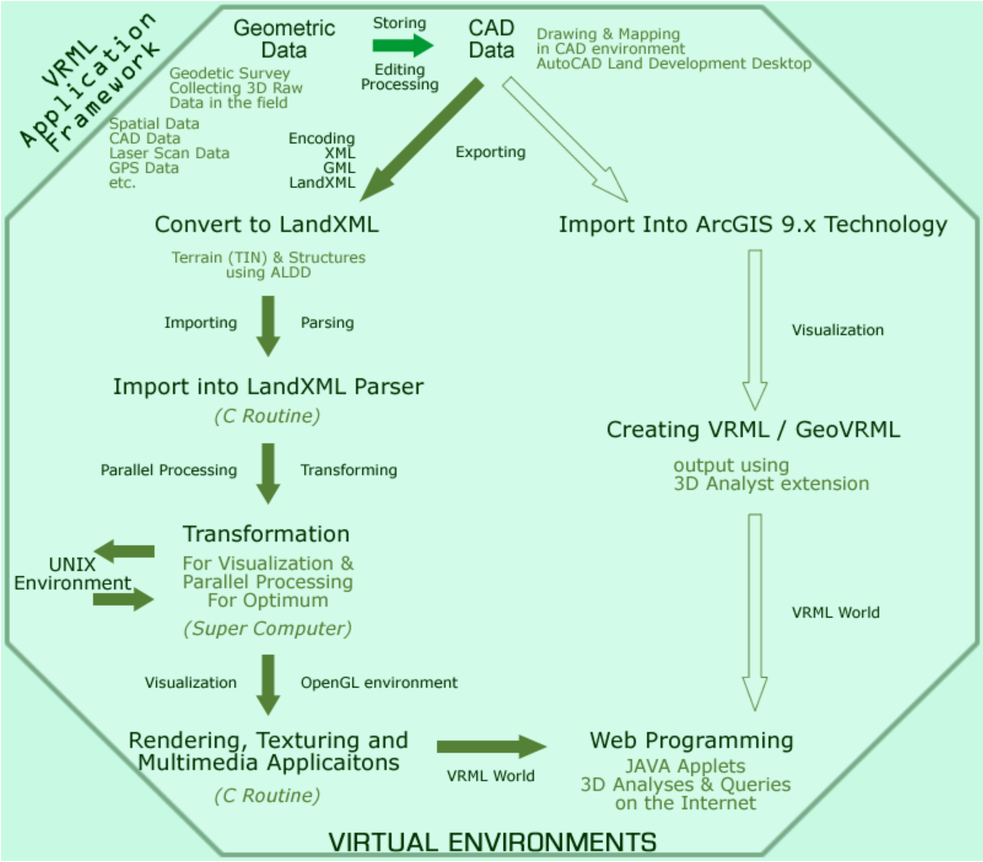

Figure 6.9: Methods of building VRML files

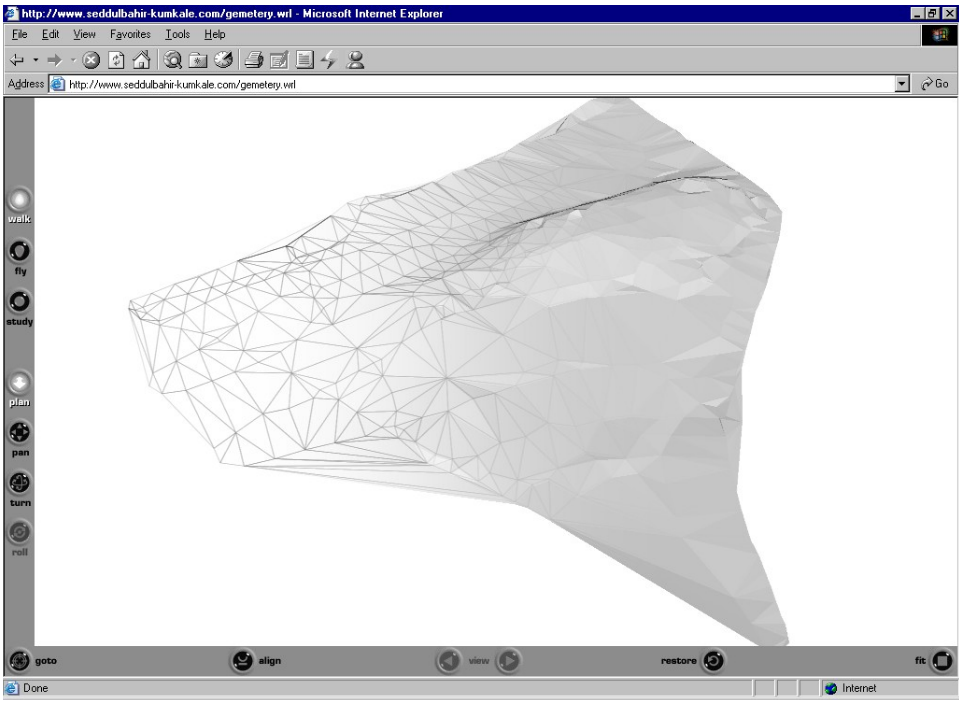

Figure 6.10: Capture of GeoVRML application of *Kumkale* Cemetery (Guney and Celik, 2004c)

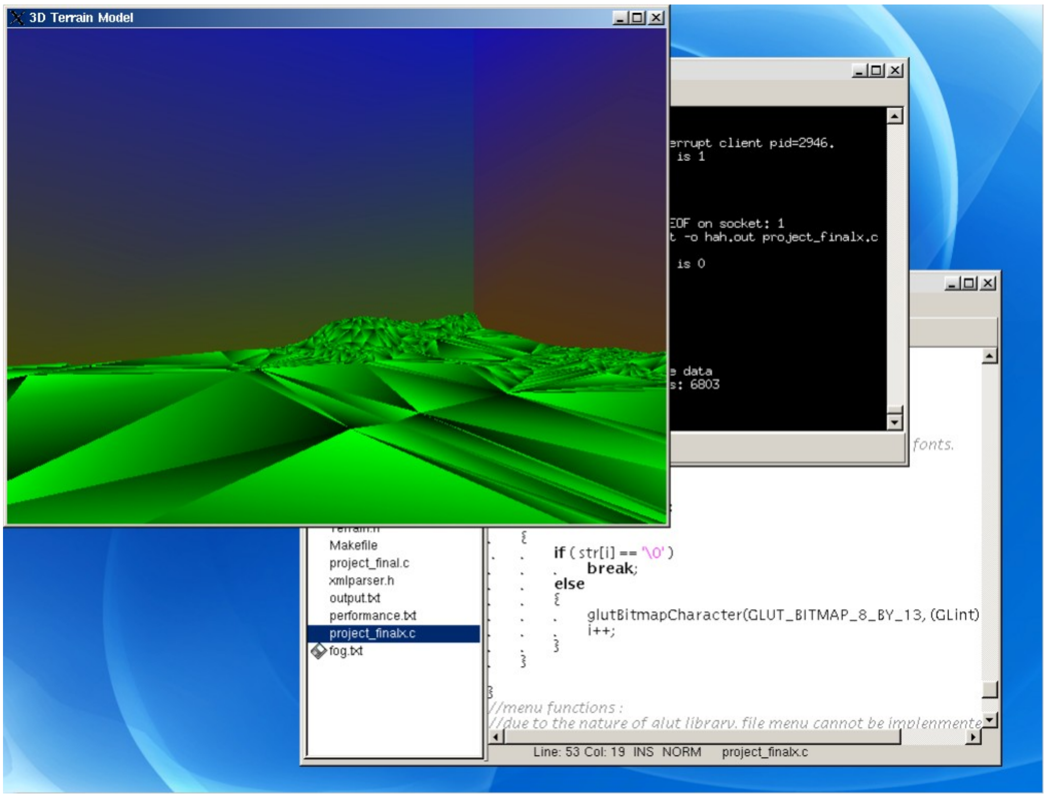

Figure 6.11: Visualization of *Seddülbahir* Fortress with OpenGL

The visualization architecture of "GeoCHEAF" uses programming Java in combination with VRML for 3D modeling, rendering, and dynamic interaction capabilities *(provided by VRML)*, complete programming capabilities, and network access *(provided by JAVA)*, which extends the ability to interact with the model and to animate CH objects within the scene really only limited by the creators imagination. (Guney and Celik, 2004c) 3D SIS functionalities are implemented with Java, and the visualization of 3D scene on the web were implemented with VRML. In this approach, the dynamic interaction based on Java/VRML interface techniques is vital to system stability and user accessibility. Because this system is implemented by Java applet, any client with Java-enable browser including VRML browser plug-in can utilize the new style of 3D SIS function in the virtual space. (Guney et al., 2002)

The connection between the data in Java applet and the nodes in the 3D geospatial world in VRML/GeoVRML file is implemented by a kind of API that is External Authoring Interface (EAI). EAI is an interactive user interface between the encapsulating HTML browser and the embedded VRML browser, and is used as a dynamic (geo)visualization tool through the Internet. It provides to access nodes and event structure from outside of VRML browser instead of comprehensive node access within VRML browser via a Script node that is another alternative using Script Authoring Interface (SAI) that is the interface between a script contained within a Script node and the browser functionality. This interactivity enables Java applet to build and update dynamically the data in VRML, and in turn, the applet's data can also be dynamically updated through the VRML interface. The changes in Java applet can affects the 3D geospatial world built in VRML file form. And the event occurred in VRML world can be detected and processed in Java applet side. Complex 3D spatial queries and analysis such as selection, 3D feature identifying, 3D buffering, 3D overlaying, and near operation can be performed on Java applet, and its result is visualized in VRML world. The result may also be presented in textual (numerical) or graphical form in the GUI of "GeoCHEAF". (Guney and Celik, 2004c) The interface provides two-way communication between the user and the VR terrain, not only extracting positional information from the model but also allowing the user to move between viewpoints and select the view required. (Guney et al., 2003b)

Multimedia data such as text, sound, images, animations and videos is also linked to 3D geographical features in a somewhat application level in the visualization framework of "GeoCHEAF", and it is partly similar to basic concepts within 3D hypermap. (Guney and Celik, 2004b)

6.5 Multimedia Applications

Multimedia combines multiple forms of media in the communication of information, such as audio, video, graphics, photographs, animation and text. The combination of several media creates a powerful and richer presentation of information and ideas to stimulate interest and enhance information retention.

While traditional SIS data are based on maps, multimedia SIS allows the user to access a wide range of georeferenced multimedia data (e.g., simulations, sounds and videos) by selecting resources from a georeferenced image map base. A map serving as the primary index to multimedia data in a multimedia georepresentation is termed a hypermap. Multimedia and virtual georepresentations can be stored either in extended relational databases, object databases or in application-specific data stores. (Guney and Celik, 2003a)

SIS is acquiring ever more multimedia functions. These multimedia abilities are potentially very useful in the CH activities to describe and visualize built environments. It is now possible to display pictures within a SIS, to run animations based on abstract maps as well as video clips and photorealistic VR panoramas, and to link such media to many of the data and functions of the SIS. Much graphics software is moving to web. It is now possible to develop extremely elegant and powerful animations, 3D design, and virtual reality systems in a networked environment using such technologies like VRML and QuicktimeVR (QTVR) variants. QTVR and streaming digital video multimedia techniques could be mixed for optimal viewing in order to construct the realistic model of the CH resources, or to visualize the existing environments and interiors of the historical structures. (Guney et al., 2002)

SIS and multimedia can be combined in various ways, for example, the output of SIS systems can be integrated with stand-alone multimedia authoring software or some simple multimedia applications present in commercial SIS packages. In this dissertation, SIS applications like spatial analyzes and multimedia implementations combined in the web using Java programming. Java, which is interpreted by the web browser, can be used to develop interactive web pages that check user input into forms, change the look of web pages, or display informative messages in the status bar of a web browser.

QTVR is one of the first 3D technologies for the web developed by Apple Computers. The concept of the QTVR technology is that it enables users to experience a fully navigable 360˚ panoramic scene of a site, from a particular location or node (Bodum et al., 1998). The Quicktime technology uses a cylindrical projection of the panorama, thus some distortion is evident when the panoramic image is viewed as an image.

Once the individual images have been captured for a node and stitched together, the panoramic image can be formed and saved as a QTVR movie. Before saving the panoramic picture and generating the QTVR movie, hotspots and other objects were placed inside the movie. The user can 'walk' around the fortresses' sites and enjoy a full 360° view of the area from specific points. This sophisticated technology allows the user to interactively 'look' in all directions and, in some cases, provides clickable features. With clicking at so called 'hot spots' that lead to the digital video of the present condition of interior space of the related feature. (Guney et al., 2002)

A very interesting part of the Internet multimedia technology is the possibility to integrate digital live video into the web pages. Although digital video demands a very high bandwidth on the Internet, the recent developments of video compression technology and the concept of streaming media create the possibility to observe digital video on the Internet.

6.6 Rendering and Real-time Graphics

"GeoCHEAF" allows developers to incorporate a broad set of rendering, texture mapping, special effects and other powerful visualization functions and provides a graphics pipeline that allows unfettered access to graphics hardware acceleration. (see Figure 6.12)

The two most widely used rendering libraries for PCs are DirectX and Open Graphics Library (OpenGL). Open GL is a library/software interface to create 2D and 3D graphics and animations. OpenGL is a cross-platform for 3D rendering/visualization and 3D hardware acceleration. The software runtime library ships with all Windows, Mac OS, Linux and Unix systems.

3D GIS functionalities are now being implemented with Java using several existing libraries, like OpenGL and API functions, like EAI or GUI. OpenGL is a software interface consisting of several hundred functions and procedures used to render high-quality 2D and 3D graphical images in applications. OpenGL allows geometric objects to be specified in two or three dimensions, along with providing commands to control how they are rendered. Some functions produce the geometric objects, and other functions control attributes such as lighting and color, and how the 3D object is represented on a 2D screen (Johnston and Wesley, 2000).

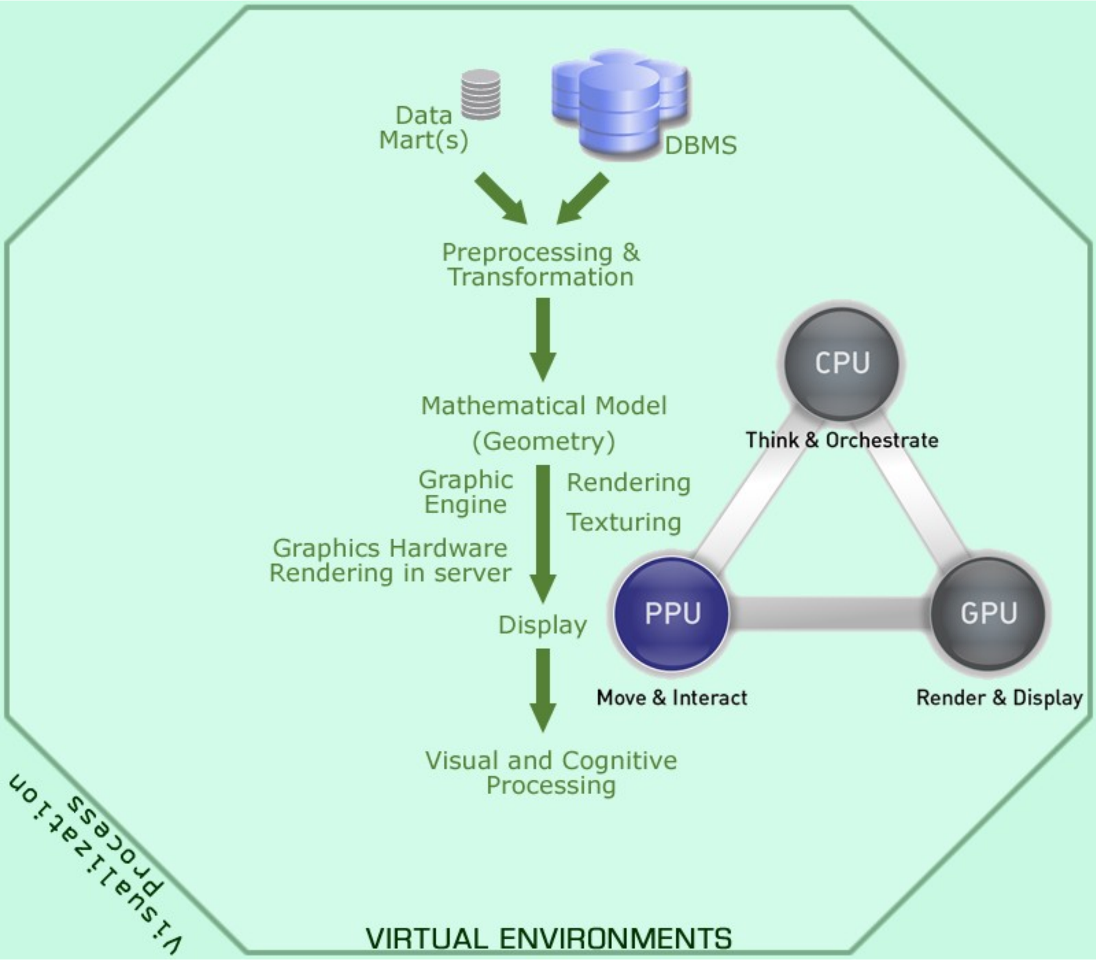

Figure 6.12: Graphics pipeline

Another interface that is used extensively is IRIS Performer. Performer is an extensible programming interface that extends OpenGL for real-time simulation. It contains high-speed rendering functions as well as functions to define geometric shapes, appearance, and lighting and special effect attributes. In addition, Performer contains a library for real-time visual simulation and high-performance, multi-processing database rendering to take advantage of IRIS symmetric multiprocessing CPU hardware. IRIS Performer also contains a library that serves as a foundation for building user-interface components for user interaction, as well as a library to import many of the most popular database object formats.

Realtime rendering in a PC cluster environment provided by Open source Scene-Graph (OpenSG) technology. Geovisualization supports for multidimensional clustering.

OpenGL ES is a cross-platform API for full-function 2D and 3D graphics on embedded systems - including consoles, phones, appliances and vehicles. It consists of well-defined subsets of desktop OpenGL, creating a flexible and powerful low-level interface between software and graphics acceleration.

Real-Time Graphics (Techniques) / Realtime interactive computer graphics

Early visualization systems were built from loosely integrated graphics and computational components. They were often based on mainframe computers facing strict limitations in memory, processor power, and disk speeds. To improve performance, high-performance computing (HPC) graphics pioneers focused on more tightly integrating system resources. Key to this effort was the specialized graphics processing unit (GPU), a hardware processor developed to render polygons. GPU-based workstations became the platform of choice for driving most demanding visualization applications.

The resulting bottleneck between CPUs and GPUs has not presented much of a problem for most applications. But as advances in scanning and measurement technologies create a data glut in HPC environments new problems are arising. Data sets are growing fast. And today's graphics acceleration hardware needs help carrying the load. While increasing visualization performance and image quality by combining the power of multiple GPUs is one solution, another is using a dedicated Physics Processing Unit (PPU) to handle physics computation, just like the GPU handles graphics.

6.7 Generating Web Images on the Fly

One of the web applications of "GeoCHEAF" is an easy-to-use image gallery GUI that lets authorized users view all old and current visual materials of on the two Ottoman Fortresses. This photo gallery application allows users to display images on a website as thumbnails with a large image that displays over the top of the thumbnails after clicking one. Some features of photo gallery GUI include: (Guney et al., 2005)

- Arrangement of images in categories and albums
- Automatic thumbnail
- Caption, title, description and user defined fields for each picture
- Image information stored in database
- Users can download images with Web interface
- Slideshow viewer
- Capture & Trim
- Print with associated data from database

PhotoGallery web application runs in a LAMP environment along with a Adobe Flash (formerly Macromedia Flash) front end that loads data through the standard Adobe Flash Remoting Components. This connects Adobe *Macromedia* Flash MX 2004 and application server, integrating rich Macromedia Flash content (Flash Client) with PHP (server) applications via another open source project called "*Flash Remoting for PHP* (AMFPHP)." According to the developers of AMFPHP, Flash Remoting for PHP enables objects in PHP to become objects in ActionScript. (Guney et al., 2005)

Flash Remoting Components extend the Adobe Macromedia Flash MX authoring environment to develop rich web applications, adding the ActionScript APIs needed to invoke remote services using Flash Remoting MX. (Guney et al., 2005)

Because Macromedia did not provide support for PHP in Flash Remoting, an open source project was started to give PHP coders the benefits of Flash Remoting under their preferred server-side language.

AMFPHP is a class library for the PHP scripting language, which is used to allow PHP programmers to access Flash Remoting objects natively in PHP and connect Macromedia Flash to data. (Guney et al., 2005)

AMFPHP is a free, open source replacement for the many commercial Flash Remoting packages provided by Macromedia for ColdFusion Server, .NET and Java. It is able to read the binary ActionScript Message Format (AMF) data sent from the Flash player to the server and can provide results back to the player in AMF format. AMF is a binary format that can describe any Flash variable of any data type. This format which is used by Flash to communicate with the server can be delivered over regular HTTP, is the core of Macromedia Flash Remoting. AMF is essentially a lightweight binary version of SOAP. (URL AMFPHP)

The AMF format was created by Macromedia as an attempt to obviate the need for XML objects when transferring data between a Flash movie and the server. XML objects proved to be quite inefficient; large amounts of data were required to describe simple objects, and the amount of bandwidth needed to transfer complex objects from some large Flash projects was simply not acceptable. (URL AMFPHP)

In this project, Macromedia Flash Remoting MX Components for Macromedia Flash MX 2004 Action Script 2.0 and AMFPHP 0.9.0 are used under GNU GPL. A dynamic graphics generation tool, GD Library 2.0.33, is also used under PHP on the application server. Figure 6.13 displays a snapshot of the application.

GD is an open source code library for the dynamic creation of images by programmers. GD is written in C, and “wrappers” are available for Perl, PHP and other languages. GD creates PNG, JPEG and GIF images, among other formats. GD is commonly used to generate charts, graphics, and thumbnails on the fly. Essentially, GD Library will convert the project’s uploaded images to a smaller physical size, so that each image uses less disk space and pages will load faster. (URL AMFPHP)

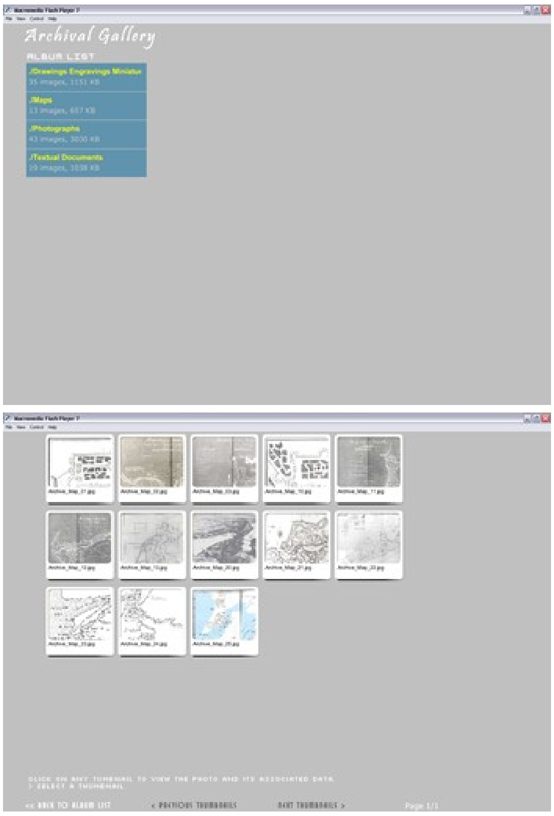

Figure 6.13: Snapshots of the photogallery application

6.8 Virtual Worlds on the Web

Real-time 3D is emerging as a first-class media type for the web. Network bandwidth and graphics hardware processing power are now sufficiently advanced to enable compelling web-based 3D experiences, including games, online virtual worlds, simulations, education and training. Commercial developers are expressing increasing interest in exploiting real-time 3D in web applications to enhance production value, create engaging immersive experiences, and deliver information in a more meaningful way.

To deploy 3D content and applications on the web is the need. The problem is that there is no standardized platform for deploying applications on the web -limited interoperability, poor integration with other web media and data sources, plugin problem.

Much of the infrastructure has been put into place to enable professional web 3D deployment in a cross-platform, open, royalty-free environment. Interoperability standards such as ISO standard X3D are now mature, fully functional and robust, and supported by multiple open source implementations and affordable production pipelines. However, those technologies only go so far, in that they are focused on the transportability of embedded rich content, and not on the applications that embed it. The industry is in need of a rapid development environment for creating scalable, highly interactive client-server 3D applications on the web.

Ajax has emerged as a preferred method for developing sophisticated web applications. Ajax makes client-server programming available to Javascript developers via Dynamic HTML, resulting in rich, responsive applications hosted in a web browser. While Ajax is being used to deploy some of the industry's leading applications, such as Google Maps and Netflix, current browsers are limited in their capabilities to render dynamic content, in particular high performance real-time 3D.

Ajax3D (the open platform for rich 3D web applications) combines the power of X3D, the standard for real-time 3D on the web, with the ease of use and ubiquity of Ajax. Ajax3D employs the X3D Scene Access Interface (SAI) -the X3D equivalent of the DOM- to access and control 3D worlds via Javascript. With the simple addition of an X3D plugin to today's web browsers, the awesome power of video game technology could be brought to the everyday web experience.

With Ajax3D, immersive virtual worlds can be deployed within a web browser, integrated with pages and other media. Ajax3D worlds can communicate with standard web servers using XML and Ajax technologies, enabling professional, scalable, industrial strength applications with high production value and visual impact.

Ajax3D was developed for the open source community by Media Machines, creator of the Flux 3D Player plug-in for Internet Explorer and Firefox on the PC. (http://www.mediamachines.com/)

Ajax3D.org is an industry forum dedicated to the research and development of online virtual worlds using 3D open standards and Ajax best practices. (http://www.ajax3d.org/)

Xj3D is an open source (LGPL) project of the Web3D Consortium focused on creating a toolkit for VRML97 and X3D content written completely in Java. It serves a dual purpose of being an experimental codebase for trying out new areas of the X3D specification and as a library that we encourage application developers to use within their own application to support X3D technology. (http://www.web3d.org/x3d/xj3d/) (http://www.xj3d.org/)

The Xj3D Toolkit is an open source API for developing an X3D/VRML 97 compliant applications, and is the sample implementation and test bed for the X3D specification.

The key to the success of the X3D standard is the plethora of browser implementations by different vendors. Having multiple vendors means that the X3D standard is not at the mercy of a single commercial entity. Each X3D browser implementation has its own strengths, and no one can provide a browser that fits the needs of everyone. In fact, the future evolution of X3D will be far better by having different browser vendors competing to be the most conformant and the most innovative.

FreeWRL VRML/X3D browser is an open source, cross platform VRML2.0, VRML97, and X3D compliant browser, with script and EAI support. Platforms supported: Linux; Mac OS/X, and other Unix-style platforms. A Windows port is not yet started, but will eventually happen. FreeWRL has been placed under the GNU Library General Public License (GPL). FreeWRL can be run standalone, or within browsers (platform dependent for now). FreeWRL can also be accessed via the EAI interface to enable control of visual content via an external programming interface. FreeWRL supports script nodes, and shortly will support the X3D SAI programming interface. (http://freewrl.sourceforge.net/)

Nexus3d: NeXus 3D X3D browser is a Java based X3D browser supporting the immersive profile (Apache Software License).

Cortona VRML Client from Parallel Graphics is a fast and highly interactive Web3D viewer that is ideal for viewing 3D models on the web. A set of optimized 3D renderers guaranties the best visual quality on both PCs with the latest video-cards and those with more basic video card capabilities. Cortona VRML Client works as a VRML plug-in for popular Internet browsers (Internet Explorer, Netscape Browser, Mozilla, etc.) and office applications (Microsoft PowerPoint, Microsoft Word, etc). (http://www.parallelgraphics.com/products/cortona/)

The free Flux Player from Media Machines allows developers and content creators to publish their interactive 3D animations, models and virtual worlds to a web browser using industry-standard X3D and JavaScript. This FLUX source code includes Flux Player, our light-weight, high-performance 3D player; an easy content authoring and publishing tool; and a set of server-side technologies for dynamic, database-driven delivery of 3D content and multi-user messages over the web. The complete source code to Flux is being licensed under the GNU Lesser General Public License (LGPL). Flux Player is free for personal use. It has some utilities and converters, such as GoogleSketchup KML converter (KML2X3D) (The open-source converter, KML2X3D, that translates Google SketchUp version 3 and Google Earth files (KML) into X3D files.), 3D Studio exporter, Maya exporter. (http://www.mediamachines.com/)

OpenWorldsTM is an open X3D-compatible system which extends new and legacy applications with immersive Web 3D graphics, multimedia, animation, and VR capabilities.

7. OTHER MAJOR ARCHITECTURES

7.1 Web Content Management Architecture

As the Internet has grown, so have the challenges associated with delivering static, streaming, and dynamic content to end-users. Tracing the evolution from traditional web caching to today's open and vastly more flexible architecture, today's web sites serve as an extremely effective vehicle for data and information exchange and transactions with users, project members and stakeholders, but the details behind these operations can be very difficult to manage. The ability to easily update web content is a key benefit of a dynamic web site. However, the scope of "Web Content Management (WCM)" is much broader than having the ability to edit a block of text on the web site.

Enterprise Web Content Management Architecture of "GeoCHEAF" refers to development, management, distribution of enterprise content in a collaborative environment through a web (geo)portal and portlets. It manages the lifecycle of content in the enterprise's resource repositories via a top-down framework. The architecture provides the same content/layout components to be rendered (reused) through various user devices in a number of different formats, such as PDA or WML. The architecture facilitates collaborative creation of following Web content types:

- HTML, XML, any text
- Images, photo galleries
- Documents, PDF files
- Publications articles, journals
- CH Project proprietary doc formats
- Forums

- Audio, video, streaming video
- Flash movies, SVG files
- Multimedia
- Hyperlinks/web resources
- Downloads
- Surveys and statistics
- FAQs
- Any other bits (or etc.)

Web content management is usually a collaborative effort that involves various roles, including authoring, viewing, editing, approving, and players, including administrator, editor, end user, approver, designer, junior editor, website manager. The idea is to allow both technical and non-technical personnel to easily work together in order to simplify and streamline the process of creating and serving high-quality, accessible web portals. Thus, it is a communication means among various developers and various users.

Web Content Management divides logically into three areas:

- Web content creation and contribution: web page composition, authoring & adding to the site
- Web content management and administration: editing & updating the site
- Web content publishing and serving: Approval & Workflow / user submission and publishing logic

A CH enterprise requests for a designer to build an HTML page for the project. The page is built by the designer in their tool of choice such as any text editor, WYSIWYG XHTML editor, or hardcoding editors like Adobe Dreamweaver, Adobe GOLive CS2, NetObject Fusion 9, Microsoft FrontPage 2003, and saved to a web site manager content repository. Then, the editors are given a reference of a wording change and slight HTML format adjustment in the web pages. Through the use of the web-based content templates and inline editing tools available in the website manager, editors opens the content file on the web and make the necessary change.

The content approval process or workflow functionality or management, which can be as simple as a link that emails new content to a single person for review, or a full-fledged web-based workflow or process that includes multiple approvers and roles. This full-fledged approval workflow or process supports to allow editors to make changes to new versions of the content and construct or build approval requests through a web-based interface, delivered to assigned approvers for acceptance or rejection of ready to be published content. If accepted, the requested content versions are now available for publishing. If not, the requesting Editor is notified with comments on the reason(s) for the rejection.

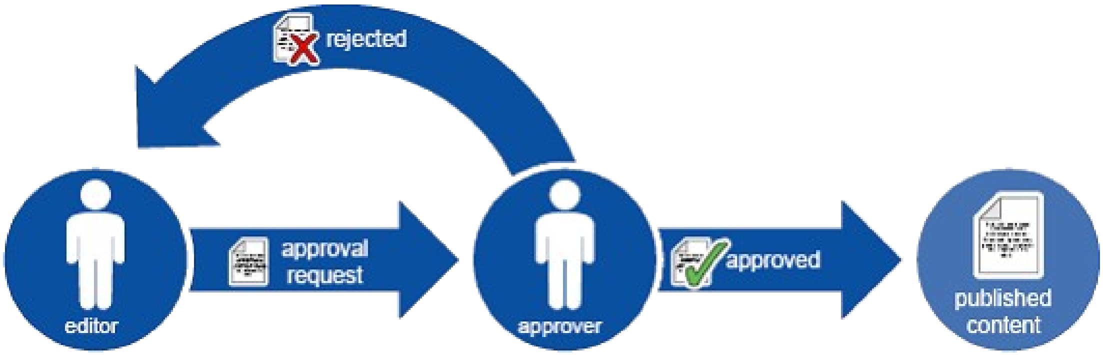

Figure 7.1: One Editing Use Case

“GeoCHEAF” requires a software tool for constructing and editing enterprise web contents. The market for content management systems remains fragmented, with many open-source and proprietary solutions available. Choosing the right browser-based web content management system for the enterprise web content management architecture framework of “GeoCHEAF” requires a good understanding of the capabilities needed to meet the CH enterprises’ current and future user requirements, such as content management, search, reporting, processing, delivery requirements.

For this project, several open source and proprietary content management systems were evaluated. After exhaustive evaluation, Typo3 was selected as an enterprise-class full-featured Web-based open source Content Management System and Development Framework to provide better enterprise solutions for the CH community. Then, it was customized and deployed to address the content-centric needs of the users of “GeoCHEAF”, used to build dynamic, content-driven Web sites and portals.

The features of the enterprise web content management architecture of "GeoCHEAF" are the following: The enterprise web content management architecture of "GeoCHEAF" provides:

- Content separated from design by using presentation templates, so the two can be changed independently.
- Management of content can be done by the CH specialist or CH project members, without day to day involvement of technical staff. Often this is accomplished through simple customized web interfaces included with the Content Management System (CMS), though many systems can work with content from third party HTML authoring tools.
- Content is stored in a content repository that is a centralized place to edit content, with prior versions tracked and available for review (or restoration) as needed. Content Versioning automatically saves previous updates to content, allowing administrators to browse and publish previous changes to production systems. Each new update to a piece of content saves off the previous version. CVS is the Concurrent Versions System, the dominant open-source network-transparent version control system. CVS is useful for everyone from individual developers to large, distributed teams:
- Locking lets concurrent users work safely and efficiently without fear of overwriting someone else's work.
- Granular security control (or multiple security levels) ensures that only authorized user can administer content. Different users can have different access levels — for example an archaeologist may be allowed to add some excavation information but not modify the homepage.
- Audit trails track who made what change and when.
- Approval (workflow) process functionality, which can be as simple as a link that emails new content to a single person (editor) for review, or a full-fledged web-based workflow process that includes multiple approvers and

roles. This full-fledged workflow approval process support to allow Editors to make changes to new versions of the content and construct approval requests, delivered to assigned Approvers.

- Search functionality that helps users find content quickly. Searching feature of CMS uses open standard full text searching technology, and provides programming API's to allow third party data and projects to interface, providing fast reliable searches.
- Scheduling to automatically publish (or remove) content at a predetermined date/time — so the webmaster does not have to stay up until midnight to do that.
- Syndication to let one feed dynamic content from outside partners directly into your site (or visa versa).
- Multi-lingual support that makes it easier to provide content in multiple languages, potentially increasing the audience.
- Manages the users who author content (access; rights; workflow)
- Control who has access to Web pages, or specific assets, and who is responsible for reviewing and approving changes before they are published to a live Web site.
- Manages the publication of content (Structures content for delivery)
- Facilitates the upholding of standards.
- Content contributors can focus on content instead of getting bogged down in web technology or manual coordination with web masters and content approvers
- Cost savings resulting from a more efficient content management and publishing process

- Eliminate the unnecessary duplication of work, mistakes and inefficiencies that occur when those responsible for creating new content run into those responsible for publishing and maintaining the information on the live Web site.

- Better utilize resources and empower team members to take ownership of their job responsibilities

- Improve workflow and accountablity

- Streamline implementation and management (the flexibility of Web-based access more appropriate for your needs)

- the privileges at multiple defined role levels: Viewer, Editor, and Approver

Many web services currently exist that provide information sources and functions for Content Management Systems. Such services include search engines, address validation, and bibliographic lookup. The major problem is integrating these web services into existing CMS tools and environments. AXIS, a toolkit for deploying and using web services, allows developers and CMS users to integrate web services into their CMS applications without the need to learn SOAP or other low-level Internet protocols.

"GeoCHEAF"s approach is based purely on XSLT (XSL Transformations) to manage the content repository and to assemble and publish sites. This framework is based upon an XML vocabulary called the Web Page Composition Markup Language.

CMS facilitates delivery of web content and applications to specific audience segments or individuals, so that only certain users have access certain content:

- Dynamic Web Sites (Public Front End)
- Portals ((Public) Internet) (Public Front End)
- Intranets (Private Front End) (The intranet is accessible only to the users who log in the system successfully.)
- Extranets (Private Front End)

7.1.1 Web portal architecture

The web allows CH community to make much more comprehensive information available to a wider variety of users. The web portal architecture of “GeoCHEAF” serves up its valuable content, information and web applications pertaining to CH resources and CH projects through a fascinating graphic design considering that the design of a portal has to be flexible enough to meet diverse users’ and visitors’ needs, yet structured enough to accommodate a wide range of content and visual elements. (Guney et al., 2005) It allows various users and stakeholders share data, information, content, application, service about the enterprise and its CH projects.

The web geo-portal of “GeoCHEAF” is a dynamic, interactive, extensible, object oriented, easy-to-use portal framework. Both administrators and users can change the look of the entire web site with just a click of a mouse since there are many themes are available on the portal.

The web portal architecture of “GeoCHEAF” provides two distinctive phases in terms of concept: general project content for a free-access public web site and intra project content for a secured private web page for the authorized enterprise constituencies. These two separate sets of capabilities are encompassed for internal and external use. Figure 7.2 outlines this design philosophy. (Guney et al., 2005)

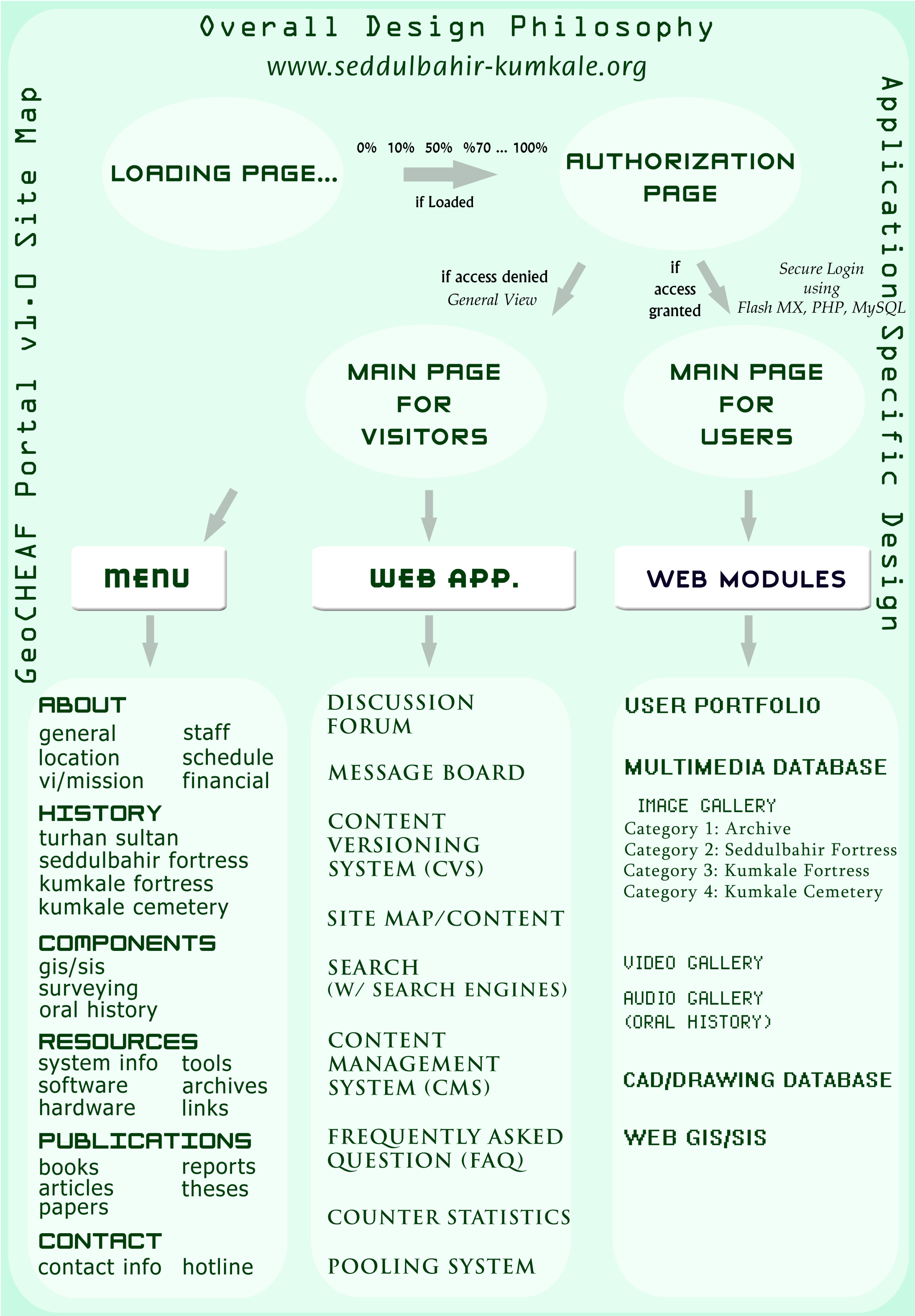

Figure: 7.2: Design philosophy of the portal

A complete Java-based enterprise and community portal framework has been designed for managing the multi-participant CH projects over the Internet transforms a data source into communication hub and a collaborative analysis tool effectively with the following web pages:

- GUI: It acts as a GUI.
- Enterprise-level institutional portal: Project scope, purpose, target audience, tasks, labor (human) resources, costs, publications, discussions, forums, virtual meetings, chat rooms, charts, reports, schedule, articles, events, contact (address/phone) book, status, terminology, bills & invoices, polling systems, guest book for survey and feedback, public relations (PR) activities, search engine, page visit counter & statistics, etc. which are semi-secured public web pages. (e-management)
- Blog (weblog), photoblog, podecast, vlog (short for videoblog) for visitors (unique visitors, fist time visitors, returning visitors) and users (registered users, project users) regarding the CH resources through open source blog server like Roller (Java-based).
- It provides web features, such as discussion platform, e-mail lists, a notice board, an online calendar of events and a help-desk.
- Data Portal (especially an XML based portal for low-bandwidth communications): Inhouse project spatiotemporal database which is a secured private web page for the enterprise constituencies only to store the various different data sets. Discussion platform that is open for exchanging comments, options and ideas based on phpBB.
- Spatial portal: Project Location and Site Query/Analysis using a SIS viewer which is a free-access public interactive web-based SIS system. It has also map functionality (or feature) that provides the ability to view results on a map interface.

phpBB is a high powered, fully scalable, and highly customizable Open Source bulletin board package. phpBB has a user-friendly interface, simple and straightforward administration panel, and helpful FAQ. Based on the powerful PHP server language and your choice of MySQL, MS-SQL, PostgreSQL or Access/ODBC database servers, phpBB is the ideal free community solution for all web sites. (http://www.phpbb.com/)

The portal architecture framework of "GeoCHEAF" is a multi faceted and multi dimensional and its web business strategy is comprised of the followings. (Guney et al., 2005)

1. Web designing (Web Portal Design Strategy)
    1. Determining goals & target audience, who sees content (What, When, Why)
    2. Generating usable content (web page document/component composition/generating)
    3. Developing attractive graphic (layout or site) design (Aesthetic graphic design requirements)
        1. Graphic Design involves screen resolution including best viewed and at least resolution, web image resolution, image editing, logo design, banner design.
2. Web building
    1. Developing web services/applications/modules (using web building technologies including standards like HTML, XHTML, XML etc. and other technologies like scripting languages such as PHP)
    2. Domain name registration and web hosting
    3. Broadcasting (publishing) (server etc.)
    4. Testing (testing web page and application through all web browser)
3. Web managing
    1. Optimizing
    2. Updating content

While a Web Content Management System is a producer-facing tool for building and maintaining web content for web sites, a web portal is an end-user facing content and service aggregator. CMS software can be a content a aggregator, a content tagging system, however, it is not a content delivery system.

Content-related Portal Functions:

- Aggregate content
    - A portal combines content, information and services from multiple, distributed resources in a meaningful way and renders them as a

collection of channels

- Personalize content (users can personalize their own settings)
- Customize content (authorized users can edit their profiles)
- Recommend content
- “Excerpt” or summarize content
- Contextualizes and frames large content sets
- Delivers personalized or customized content to audience segments or individual end users
- Manages access to published content and applications (single sign on)

The project web site has been developed as a hybrid Macromedia Flash-based website with Action Script, the XHTML with CSS attributes and XML, and script languages (PHP) and Ajax.. It has been designed for at least 1024x768 screen resolution, tested using Mozilla Firefox. It uses XML with Flash MX and CSS to define the content to be displayed, since XML is only a semi-structured document that holds content. XML can be transformed at runtime into a presentation markup language, such as HTML or XHTML. (Guney et al., 2005)

Adobe Flash animation is the most effective form and remarkable small size of interaction with web site visitors by combining expressive graphic images, 3D animation, exclusive sound and action script. Basic site (non-flash version) guaranteed to work in all browsers. (URL Flash) Alternatively SVG capabilities in HTML pages took place in the design.

This all leads up to the interactive part of the site where the user can choose to view the data in three ways. (Guney and Celik, 2003b)

- Data can be viewed in a Flash Presentation of Kumkale Cemetery’s with scenario animated.
- Data can be viewed in 3D in VRML and QuickTime environments. (VRML, GeoVRML, X3D, X3jD, Ajax3D)
- The data can also be viewed in an interactive map. Users can also identify the gravestones and find out information about them.

A device/platform independent and major open source and vendor web browsers compatible, verified with major web/3D/audio browsers (Mozilla Firefox, Opera, Internet Explorer, Netscape) and various deliver channels (smart phones, Macintosh computers, PCs, pocket PCs, kiosks), web-based GUI of "GeoCHEAF" can be visited at the project web address http://www.seddulbahir-kumkale.org via any web browser with Flash Player. (Guney et al., 2005)

Portlets are distinct, functional components of a portal. They are implemented in Java and are based on a well-defined portlet API. The component model of portlets is closely related to JSF, which features integration with the Java Portlet API. Portlets are managed Java components that respond to requests and generate dynamic content. Java Portlet API specifies how to compose component portlets into combined portals that aggregate content from portlet subject to personalization. A similar component model is provided by the ASP.NET WebParts framework.

If the portal is the container, portlets can be thought of as the building-blocks that make up the content. Essentially, portlets are used by portals as pluggable user interface components that provide a presentation layer to information systems. In a typical institutional portal, portlets are presented across a predefined collection of pages arranged by tabs. The user can edit existing pages or create further pages within the portal by choosing 'which' portlets he/she requires, and 'where' they are to be arranged on the page.

There are a number of different portal and content management solutions available, ranging from leading commercial packages such as IBM's WebSphere Portal or Oracle Portal Server, to open source products such as Java Architectures–Special Interest Group (JA-SIG)'s uPortal or Apache's JetSpeed 2. (http://www.uportal.org/) (http://www.ja-sig.org/) Other enterprise open source portals are Liferay (http://rollerweblogger.org), JBoss Portal (http://www.jboss.org/products/jbossportal)

As the number of different portal frameworks has grown, so too has the need to create portlets that can be used within each of these differing platforms. By defining the Java Specification Request 168 portlet specification (JSR-168) (JSR-168 Portlets), Sun and partners have potentially allowed developers to create a one-hat-fits-all solution to providing portability. In other words, if a portlet has been written to be JSR-168 compliant, then any portal framework that supports the JSR-168 specification can host it. Although this specification is indeed Java-specific, it has nevertheless been adopted as one of the definitive standards from which to base portlet development. (Waller, 2005)

The standard method for deploying JSR-168 portlets is literally to 'plug' the portlet component into the various portal systems. Each portlet needs to be installed on the same machine as the portal, which can lead to issues regarding portlet maintenance and updates. For example, if changes need to be made to the portlet code then the host would need to acquire the latest version of the portlet and reinstall it into the portal system. When portlets have been developed in-house, this may not necessarily be too much of a problem. However, for institutions that have outsourced portlet development or perhaps acquired portlets from various online repositories, this could indeed become a concern. (Waller, 2005)

The Web Services for Remote Portlets (WSRP) v1.0 OASIS open standard was approved in 2003 to help address such issues. WSRP is a web services protocol for aggregating content and interactive web applications from remote sources. By using WSRP, the institutional portal can consume and aggregate a portlet within its framework without the need to host the actual portlet itself. This allows the most up-to-date version of the portlet to be displayed upon request. (URL, 2004b)

One of the biggest shortcomings of the JSR-168 specification is the lack of support for Inter Portlet Communication (IPC). The fact that individual portlet applications can communicate between themselves is an invaluable asset to the specification and promotion of the idea of portlet-based research toolkits. Indeed, the current trend for the development of Virtual Research Environments, such as the Sakai project, which also supports JSR-168, could well benefit from the inclusion of a standardized method for IPC. (Waller, 2005)

The JSR-168 specification makes it apparent that it is possible to package several portlets together to create what is known as a 'portlet application'. Further, all portlets contained within a portlet application have access to a shared 'portlet session' – an area where various information can be stored that is explicitly related to the individual users session. An IPC mechanism was achieved by exploiting these two features drawn from the specification. (Waller, 2005)

The WSRP mechanism is relatively straightforward: a WSRP Producer is responsible for hosting the portlet and offering it as a service, while a WSRP Consumer, such as uPortal, sends SOAP requests to the Producer for a portlet instance. The Producer sends the relevant mark-up back to the Consumer in order for it to be aggregated along with other local or remote portlets on a portal page. This 'handshaking' is a continual relationship throughout the portlet lifecycle – when the user clicks a portlet action, the relevant code is sent back to the Producer which in turn performs the required actions and sends the updated mark-up back to the Consumer.

The Java portlets of “GeoCHEAF” instance uPortal was designed to conform with the JSR-168 specification; consequently the portlet can be 'plugged' into any JSR-168 compliant portal framework. Apache's WSRP-4J Producer software is used to communicate with uPortal's own WSRP Consumer interface. This portal exploits computer communications technology to enable users to carry out simultaneous searches of four geographically separate databases.

In the e-tourism through e-cultural route application within the web portal, each user can discover CH his own way even before or after the visit. Prior to a visit, users can easily plan their own route, they can search for routes and sites that match their interests, they can fully plan their trip by adding sites, museums, events etc. to a personal and printable route-program. During the visit, they can acquire digital souvenirs and content that are added to their portal. After the visit users can publish a personal travel journal and share their experiences and ideas about certain routes, sites, their architectural styles and artifacts, and their continuing tangible and intangible legacy with other visitors, friends and family, creating a digital community around the route theme. This way the portal will be a unique two-way communication medium that lives from constant input by museums, local authorities, communities, tourist professionals as well as involvement from visitors, schools, families. (URL EPOCH)

Local Cultural Route Systems can take many different forms, ranging from marked walking tours with PDAs to car routes with brochures. This molecular structure gives each city or region the freedom to develop and maintain their own route as a part of the bigger cultural route concept, a common database structure however binds these different micro-routes together and provides the central portal website with the necessary information. (URL EPOCH)

7.2 Mobile Computing Architecture

All devices exist in the physical infrastructure of “GeoCHEAF”, such as servers, workstations, laptops, tablet PCs, pocket PCs, PDAs, smart mobile phones, multimedia phones, and smart kiosks, are in a distributed environment in order to support problem solving and decision-making at any time and any place. Incorporating both mobile communication and spatial data, these applications represent a novel challenge both conceptually and technically.

Mobile phones and other mobile digital devices are rapidly gaining location awareness and web connectivity, promising new spatial technology applications that will yield vast amounts of spatial information. Examples of such applications include in-the-field data entry and access, and mobile geoprocessing like mobile SIS and field mapping applications. All data traffic “over-the-air” from a mobile device to the Wi-Fi network is encrypted for secure wireless communication network. Luckily, mobile devices getting affordable and GPS instruments are getting cheaper and cheaper. Some Java ME phones are location aware and provides a location API. However, wireless and mobile telecommunications also pose the following security challenges: more connectivity resulting in more points of vulnerability; information is more easily intercepted; and devices, being more portable, are more easily lost or stolen.

The basic integration of four technology components for field application are:

- Lightweight, low cost, hand-held mobile data capture devices (hardware) like Pocket PC with phone or smart phones or multimedia phones or uggedized field PCs.

- Location positioning (GPS) (GPS-enabled mobile devices like Pocket PC with GPS or field-based Tablet PCs with integrated/add-on GPS) (also compatible with TPS)
- Wireless communication (CH site wide wireless connections with enhanced security for Internet access) (like GSM, Wi-FI (IEEE 802.11), WiMAX (IEEE 802.16))
- Mobile SIS

Traditionally, the process of field data collection and editing has been time consuming and error prone. Geospatial data has traveled into the field in the form of paper maps. Field edits were performed using sketches and notes on paper maps and clipboards. Once back in the office, these field edits were deciphered and manually entered into the GIS database. The result has been that GIS data has often not been as up-to-date or accurate as it should have been. Consequently, GIS analysis and decisions have been delayed. Recent developments in mobile technologies have enabled GIS information to be taken into the field as digital maps on compact, powerful mobile computers, providing field access to enterprise geospatial information. This enables CH organizations to add real-time (or near real-time) information to their enterprise (geo)database and applications, speeding up analysis, display, and decision-making by using up-to-date, more accurate spatial data. It extends GIS capabilities to staff in the field and gives them access to entire mapping systems on laptop, tablet computers and other hand-held devices.

GPS-enabled mobile devices like a Pocket PC can be incorporated into a hypermedia-SIS system to bring it one step closer to virtual reality in the field as a real time for the researchers and visitors of the CH site. While Pocket PC would enable the attainment of real time information input, display and query, GPS allows more accurate reference to locations one can see himself on the screen of Pocket PC in real-time. (Guney et al., 2002)

Pocket PC devices are small yet increasingly powerful. Onboard processors rival clock speeds of desktop PCs from five years ago, memory sizes of more recent PC vintages, excellent color displays that can be read even in bright light, easy expansion, linkage to GPS receivers, mobile telecommunications and desktop PCs using either card slots/serial, USB, infrared ports or bluetooth.

Mobility component of "GeoCHEAF" designs wireless covering entire CH site like fortress wide wireless connections and features enhanced security based on the industry-leading 802.1x authentication standard. Devices in the distributed environment of "GeoCHEAF" support the wireless application protocol.

7.3 Security Architecture

In this age of widespread virus infections, worms, and digital attacks, no one can afford to neglect network defenses. Since "GeoCHEAF" relies on open web technologies, there is a need to set up some form of open security to protect it from unauthorized access or malicious use. Security for enterprise, web applications, web services, data and information at the portal is one of the key concerns in any enterprise deployment. There is no single 'fix' for security, because precise requirements vary from one enterprise to another. There are several standards in this area, each of which addresses a particular aspect of security issue. Security architecture framework of "GeoCHEAF" involves not only network security (hacking) concern but also firewalls, power supplies, backup (restore) issues.

The security architecture supports the standard Java Authentication and Authorization Service (JAAS) framework, which makes it easy to integrate existing authentication mechanisms such as Lightweight Directory Access Protocol (LDAP) directories. In this case, it is not necessary to provide a separate user directory or password store (although this can be done, if required). Secure protocols such as Secure Socket Layer (SSL), Secure HyperText Transport Protocol (SHTTP), Digital certificates and secure cookies are used in the architecture.

There are four different functions that fall under the network security component: (White Paper, 2002)

- **Authentication and Proof of Identity**. Authentication is the process used to verify an entity's identity in order to ensure that only valid users can use data/content/application/service. There are a number of mechanisms that can be used to authenticate an entity, such as HTTP Basic and HTTP Digest authentication, a PKI certificate authority, and a Kerberos login. Once an authentication authority has verified user's identity, user may receive an authentication token that user can use in future interactions as proof of identity. Such an authentication token could take the form of an X.509 certificate, a Kerberos ticket, or a SAML19 authentication assertion.

- **Authorization and Access Control**. Authorization is the process used to determine if an authenticated entity has permission to perform a particular action or function. Authorization establishes privileges granted to a login. Access control policies are defined for all services at a given location, for individual services, or for specific operations in a service. Access control or auditing provides finer-grained control over who can access what, even down to determining which constituent parts of a service may be used by which users (White Paper, 2003c).

- **Confidentiality and Integrity**. Encryption protects the confidentiality and integrity of message communication. Confidentiality prevents unauthorized access to the contents of the message. Integrity prevents unauthorized modification of the message.

- **Proof of Origin**. A digital signature provides proof that the signed data was sent from a specific authenticated identity. All or part of the message may be signed.

The servers in the infrastructure of “GeoCHEAF” supports encryption using the SSL protocol through the standard Java Secure Socket Extension (JSSE) package that implements SSL and Transport Layer Security (TLS) over TCP/IP. SSL is a public key-based protocol that provides authentication, privacy, and message integrity for communications between distributed software components.

In SSL authentication, a component proves its identity using a combination of a private key and an X.509 certificate. Each certificate contains information about the caller's identity. It must also be signed by a certificate authority to indicate that it is valid. OpenSSL is an open source implementation of the SSL and TLS protocols. (http://www.openssl.org/)

SSH, the Secure Shell, is a popular, powerful, software-based approach to network security (in client/server architecture). Whenever data is sent by a computer to the network, SSH automatically encrypts (scrambles) it. Then, when the data reaches its intended recipient, SSH automatically decrypts (unscrambles) it.

In computing, Secure Shell or SSH provides secure encrypted communications between two untrusted hosts over an insecure network.

SSH is a set of standards and an associated network protocol that allows establishing a secure channel between a local and a remote computer. It uses public-key cryptography to authenticate the remote computer and (optionally) to allow the remote computer to authenticate the user. SSH provides confidentiality and integrity of data exchanged between the two computers using encryption and message authentication code. SSH is typically used to login to a remote machine and execute commands, but it also supports tunneling, forwarding arbitrary TCP ports_and X11 connections; it can transfer files using the associated SFTP or SCP protocols. An SSH server, by default, listens on the standard TCP port 22. (URL Wikipedia)

Open Secure Shell (OpenSSH) is a set of open source computer programs providing encrypted communication sessions over a computer network using the SSH protocol. (URL Wikipedia) OpenSSH allows remote access and secure file transfer between servers and clients.

LDAP is an Internet protocol that email and other programs use to look up information from a server.

Kerberos, the single-sign-on authentication system originally developed at MIT. Kerberos makes your network more secure and convenient for users by providing a single authentication system that works across the entire network. One username, one password, one login is all need.

Remote Access Architecture: 'HP Integrated Lights-Out (iLO)' remote management solution is a management processor on the mainboard and firmware developed by HP for HP servers that enables virtual administration of the servers. Web-based graphical remote console of iLO provides full “in-front-of-the-server” control over the host server display, keyboard, and mouse to remotely control systems whether or not the system is operating normally. Virtual Media (Virtual CD, Virtual Floppy and Virtual USB keys) enables efficient firmware updates on remote host servers over the Internet or LAN from an image on the client PC floppy diskette, CD-ROM, or web server. Two-factor authentication provides strong authentication to restrict iLO access in more advanced security environments. iLO provides strong security for remote management by using 128-bit SSL encryption of HTTP data transmitted across the network. SSL encryption ensures that the HTTP information is secure as it travels across the network. Remote Console data is protected using 128-bit RC4 bidirectional encryption. (URL ILO)

7.4 ICT Infrastructure

“GeoCHEAF”s ICT “**in**-ternal **fra**-mework structure (**infra**structure)” has two compatible infrastructure: Physical infrastructure, including enterprise hardware, network, storage, and computing infrastructure, including enterprise software, services and other resources. Since the computing infrastructure has already mentioned in the previous chapters in detail, the physical infrastructure of “GeoCHEAF” will be discussed in the following section.

7.4.1 Physical infrastructure

Whereas hardware configuration requires high budget, there is also upgrade and expenditure budget for the hardware configuration. Generally, equipment is bought and replaced over time with a four-year life cycle. If that approach was followed and purchased this equipment incrementally, enterprise would have found itself in that multiple different machines running different software. This occurs because each year vendors change and when one purchase in stages the equipment is a little bit different than what was purchased last year. In which case, well-thought infrastructure design compatible with computing architecture is required for mature and cheap technology:

- Seamlessly and independently scale compute, memory, graphics I/O
- Start small and expand to meet the needs of the enterprise
- Ensure portability over heterogeneity

More database servers may be added in the data tier to meet the demands of user growth. The database servers may also be geographically distributed for convenience and improved performance. For example, the databases in the southern and northern regions of an organization might represent customer data in each of those regions. An enterprise also may have multiple databases to store and retrieve different types of data such as human resources and inventory. Data replication is another reason for maintaining multiple copies of databases. Data replication increases the availability of the enterprise systems.

To accommodate growth, the architecture needs to be scaled appropriately. Scaling may require expanding the business and data tiers to include more web and database servers to accommodate growing enterprises needs. Clustering may be used as a solution for this purpose. A server cluster is a group of independent servers running Cluster service and working collectively as a single system. Server clusters provide high-availability, scalability, and manageability for resources and applications. Several smaller, slower and less expensive machines can be clustered together to gain enough processing power to handle the workload in the middle tier. Clusters also improve the availability of servers because other machines can do the processing if a member of the cluster goes offline. Another benefit of clustered servers is that computing capacity can be added incrementally without disrupting clients.

Today’s distributed, complex ICT infrastructures -made up of heterogeneous servers, routers, switches and other devices- are challenging environments to control and manage. The main goal of the infrastructure of “GeoCHEAF” is to configure physical infrastructure by taking account computing infrastructure requirements and enterprise's scalable growth, while keeping costs down. Additionally, it delivers flexible, high-performance, reliable, secure and extensible enterprise 64-bit computing platform solution throughout the extended enterprise in order to have improved access to information, faster response times, more fault tolerance, more efficient integration between data and applications. As with any performance or comparison analysis of any hardware component of the infrastructure, the benchmarks must have been first looked at. Figure 7.3 shows general ICT infrastructure of “GeoCHEAF” connected to the campus network of Istanbul Technical University.

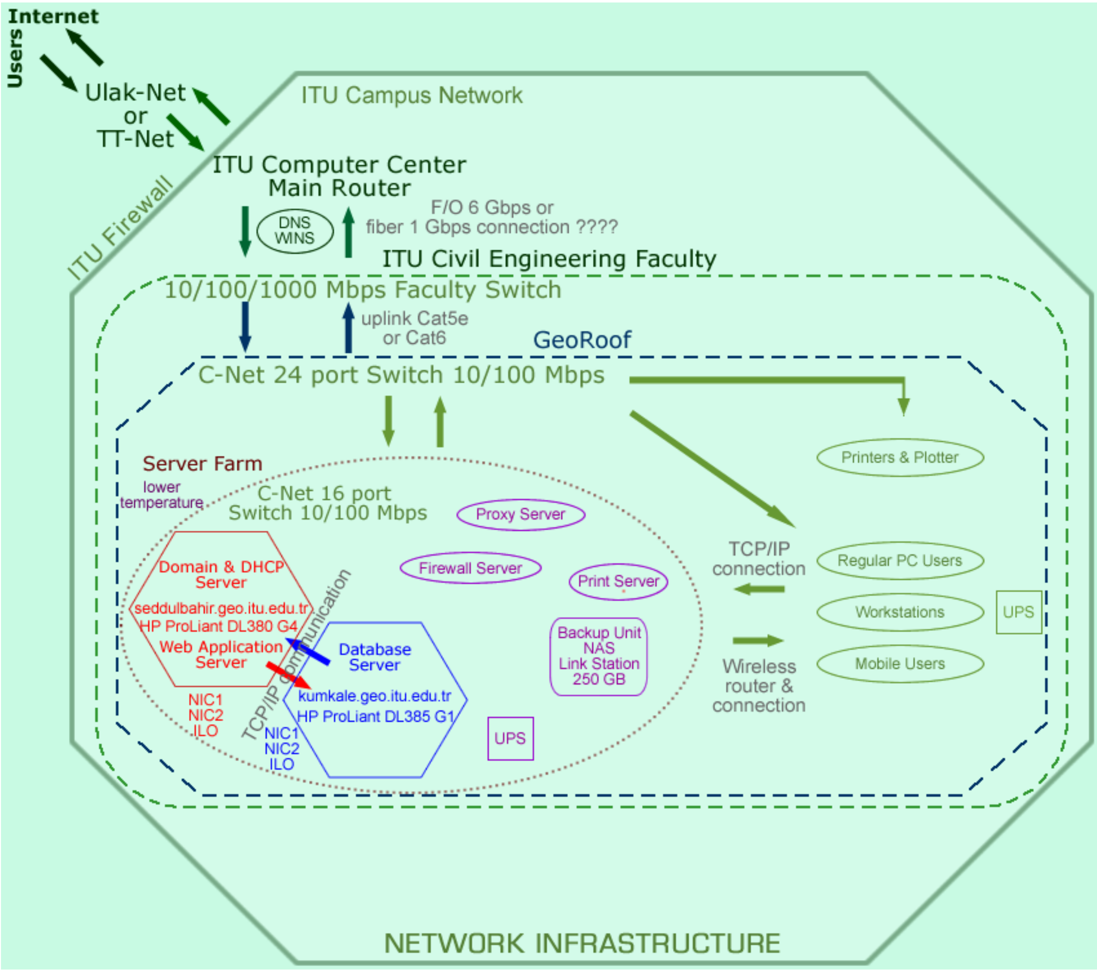

Figure 7.3: The ICT infrastructure of “GeoCHEAF”

The key component of the infrastructure is the server farm. Any machine can ostensibly work as a server, but performance can vary according to the features of the machine. Three major server features are the most important in determining the infrastructure’s servers performance: the memory, hard disks, and processor. Since these features are the biggest server bottlenecks, the design of the infrastructure must be focused the budget on beefing up these features before splurging on less necessary items like remote management cards. In addition, if the server farm is under too much strain, it will slow down the whole network.

The single biggest hardware issue affecting Web server performance is memory. Like databases many things are memory hungry, they have to be fed. Random Access Memory (RAM) types are:

- DRAM: Stands for Dynamic RAM
- SDRAM: Short for Synchronous Dynamic or Single Data Access RAM
  - (PC-66, PC-100, PC-133)
- DDR SDRAM: Double Data Rate SDRAM
  - DDR-200, DDR-266, DDR-333, DDR-400
  - PC-1600, PC-2100, PC-2700, PC-3200
  - DDR RAM with 400 MHz clock rate: DDR-400 PC3200 SDRAM 3.200 GB/sec. bandwidth
- DDR2 SDRAM
  - DDR-400, DDR-533, DDR-667, DDR-800
  - PC-3200, PC-4200, PC-5300, PC-6400
  - DDR2-800 PC2-6400 MHz SDRAM 6.400 GB/sec. bandwidth

DDR2-SDRAM is high-performance main memory. Over its predecessor, DDR-SDRAM, DDR2-SDRAM offers greater bandwidth and density in a smaller package along with a reduction in power consumption. In addition DDR2-SDRAM offers new features and functions that enable higher a clock rate and data rate operations of 400 MHz, 533 MHz, 667 MHz, and above. DDR2 transfers 64 bits of data twice every clock cycle. DDR2-SDRAM memory is not compatible with current DDR-SDRAM memory slots. (http://www.webopedia.com)

32-bit processors can address 4 GB of memory and even larger amounts through memory address extensions such as Intel Architecture 32 bit extended (IA-32e). By moving to a fully 64-bit platform, existing memory scalability limits are significantly increased, allowing developers the flexibility to create more powerful applications with greater features and functionality.

64-bit processor architectures:

- Intel's 64-bit CPU architecture is known as IA-64, and it is being sold under the Itanium name.
- x86-64 AMD's 64-bit architecture (under the names Opteron and Athlon)

The goal is to choose the right CPU for the OS that was already chosen. For instance, the Linux kernel was originally written for the Intel 80386 (or i386) CPU. This CPU is part of a family of CPUs known as the 80x86, x86, or Intel Architecture 32 (IA-32) family. Multi-processor dual core 64-bit CPU-based X86 server platforms are the ideal solution for multithreaded and multi-task usage environments.

The infrastructure enables enterprise a seamless transition from one storage architecture to another or hybrid architecture as the storage requirements grow. Operations can continue while the transition is in progress, and data is always consistent and available. The storage architectures are:

- Direct Attached Storage (DAS): Disks, tapes, optical devices
- Storage virtualization / Storage virtualization using RAID
- Network Attached Storage (NAS) (*LinkStation Network Storage Center 250GB from Buffalo Technology, additional drive capacity via USB 2.0 Ports*)
- Server Attached Storage (SAS)
- Storage Area Network (SAN)
- Storage networks

Figure 7.4 displays the data storage infrastructure of "GeoCHEAF".

Distributed storage model provides scalable, high-performance storage solutions for consolidation, data access, heterogeneous data sharing, data protection and robust data lifecycle management.

For desktop and laptop PCs, regular Integrated Drive Electronics (IDE) hard drives are fine. When configuring a server or high end custom computer, SCSI and/or SATA with a wide variety of flavors have to be considered. Two interface standard in the hard disk market:

- Advanced Technology Attachment (ATA)
  - Single-tasking
  - Cheaper
  - Parallel ATA (PATA)
  - Ultra ATA
  - Serial ATA (SATA) (1.5 Gbps)
  - SATA II with SATA II RAID controller (up to 300 MB/sec data transfer speed) (SATA II solution feature sets comparable to UltraSCSI 320 solutions.)
- Small Computer System Interface (SCSI)
  - Multitasking
  - Expensive
  - SCSI bus is capable of 80MB/s transfers
    - Fast-20 UltraSCSI (up to 40 MB/sec data transfer speed)
    - Ultra2 SCSI (up to 80 MB/sec data transfer speed)
    - Ultra160 SCSI (up to 160 MB/sec data transfer speed)
    - Ultra320 SCSI (up to 320 MB/sec data transfer speed) (Parallel SCSI) (the fastest version currently on the market)
    - Ultra640 SCSI (under development)
  - Serial Attached SCSI (SAS) (up to 300 MS/sec data transfer speed)
    - Too expensive

SCSI controllers provide fast access to very fast SCSI hard drives. They can be much faster than the IDE controllers. SCSI controllers have their own advanced processing chips, which allows them to rely less on the CPU for handling instructions than IDE controllers do.

Some very high-end ATA and SCSI controllers support Redundant Array of Independent (or Interface or Inexpensive) Disk (RAID) technology. RAID is capable of linking together multiple hard disks for improved speed (performance), improved reliability (fault tolerance), or both. There are two different types of RAID: hardware RAID and software RAID. Although there are number of different RAID levels, roughly RAID 0 means striping, RAID 1 means mirroring and RAID 5 means support.

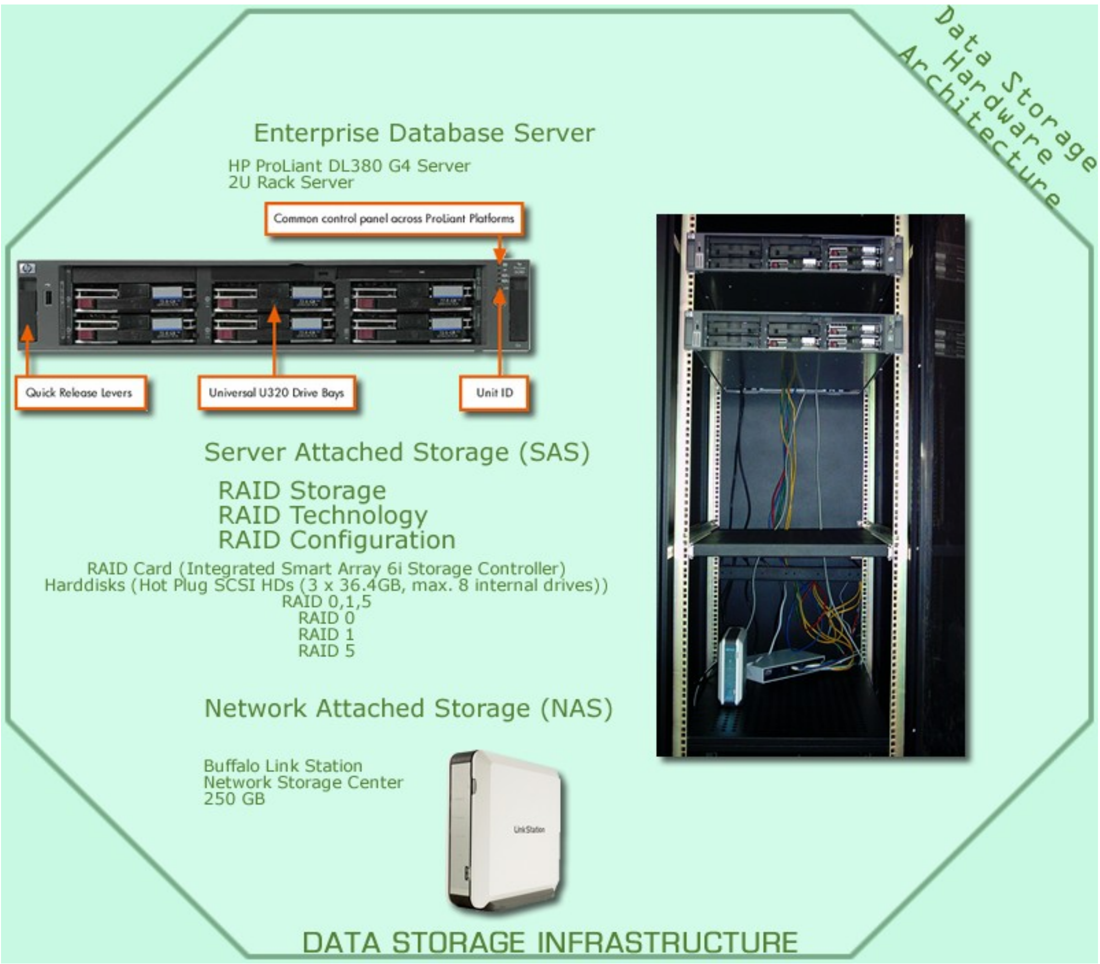

Figure 7.4: Data storage infrastructure

PCI eXtended (PCI-X) is an enhanced Peripheral Component Interconnect (PCI) bus. PCI-X is backward-compatible with existing PCI cards. It increases performance of I/O high bandwidth devices and it improves upon the speed of PCI from 133 Mbps to as much as 1 Gbps. PCI-X.

Graphics hardware technologies:

- Graphics servers (visualization application can be delivered through the Internet by realizing render work of the visualization on the server in order to provide fast access to the visualized products on the web portal)

- Graphics (graphical) workstations, such as Macintosh computers (workstation rendering) (CAD or 3D workstation)
- Parallel processing configuration for rendering and analyzing
- Multi-tasking
- Graphic cards, such as NVIDIA GeForce 6150 GPU
- XGA projection technology for multi-channel projection systems
  - Spherical Screen (passive and active stereo projection, Immersive VR, simulators)
  - Cylindrical screen
  - Flat screen

High performance computers and HPC are increasingly used to solve the large and complex problems that can no longer be solved productively on the desktop.

Remote server management & monitoring products designed to give systems administrators direct access to remote machines and ease management tasks.

The open and robust 64-bit Solaris 10 enterprise operating system running on scalable enterprise-class rack-mounted 2U HP servers (server farm) were chosen for the project because of the results of benchmark tests, lower price and HW/SW compatibility.

(Java-based) Web Application Server (Front-end server): HP ProLiant DL380 G4 [$3462.00+VAT (*February 2006*)]

- Dual processor dual core 64-bit CPUs: Intel Xeon IA-64 3.2GHz 800MHz FSB 2MB L2 cache per core (with Extended Memory 64-bit Technology (EM64T) & Hyper-Threading Technology)
- 2GB PC3200 400MHz DDR2 SDRAM DIMM Memory Kit (4 x 512MB) (Max. 16GB)
- 108GB (3 x 36GB) 15K-rpm Ultra320 SCSI HDD Hot Plug (Hot Swap) U320 HDDs (Max. 6 x 300GB)
- Smart Array 6i RAID Controller (integrated on system board) (supported RAID configuration: RAID 0, or RAID 0+1, or RAID 5)
- Integrated ATI RAGE XL Video Controller with 8MB Video Memory

- NC7782 Dual Port PCI-X Gigabit Server Adapter (embedded) (NICs) (Dual integrated 10/100/1000 Mbps Ethernet)
- 3 years guarantee
- 24X Slim CD-ROM, No FDD
- 3 RJ-45 (1 for ILO), 3 USB, 1 serial, 1 graphic, 1 mouse, 1 keyboard ports
- I/O Slot: 3 x 64-bit/133MHz PCI-X Non HotPlug)
- Integrated Lights-Out (iLO) remote management

Database Server (Back-end server): HP ProLiant DL385 G1
[$4309.00+VAT (*February 2006*)]

- Dual processor dual core 64-bit CPUs: AMD Opteron x86-64 2.2GHz 1MB L2 cache per core (with HyperTransport Technology)
- 2GB PC3200 400MHz DDR SDRAM DIMM Memory Kit (4 x 512MB) (Max. 16GB at 400 MHz or 32GB at 333 MHz)
- 108GB (3 x 36GB) 15K-rpm Ultra320 SCSI HDD Hot Plug (Hot Swap) U320 HDDs (Max. 6 x 300GB)
- Smart Array 6i Controller (integrated on system board) (supported RAID configuration: RAID 0, or RAID 0+1, or RAID 5)
- Integrated ATI RAGE XL Video Controller with 8MB Video Memory
- NC7782 Dual Port PCI-X Gigabit Server Adapter (embedded) (NICs) (Dual integrated 10/100/1000 Mbps Ethernet)
- 3 years guarantee
- 24X Slim CD-ROM, No FDD
- 3 RJ-45 (1 for ILO), 3 USB, 1 serial, 1 graphic, 1 mouse, 1 keyboard ports
- I/O Slot: 3 x 64-bit/133MHz PCI-X Non HotPlug)
- Integrated Lights-Out (iLO) remote management

A Proxy server accepts request for clients, forwards them to the real servers, and then sends the real servers' responses back to the clients. There are two reasons why a proxy server required:

- The proxy might be running on the far side of a firewall giving its users to access to the Internet.
- The proxy might cache popular pages to save re-accessing them

A web proxy server is a specialized HTTP server. The primary use of a proxy server is to allow internal clients access to the Internet from behind a firewall. Anyone behind a firewall can now have full web access past the firewall host with minimum effort and without compromising security. The proxy server listens for requests from clients within the firewall and forwards these requests to remote Internet servers outside the firewall. The proxy server reads responses from the external servers and then sends them to internal client clients. In the usual case, all the clients within a given subnet use the same proxy server. This makes it possible for the proxy to cache documents efficiently that are requested by a number of clients.

Today the problem is energy. A Uninterruptible Power Supply (UPS) with at least one hour running time is strongly recommended. UPS types are online and Line-Interactive, which are CPU controlled and have Automatic Voltage Regulator (AVR) feature.

8. SPATIAL INFORMATICS TECHNOLOGY ARCHITECTURE

8.1 Overview

Everything happens somewhere, from the cradle to the grave and in all aspects of life. Positive events like births, schooling, work, marriage, as well as negative ones such as crime, disasters and death, all occur at a location. As a result, 80% of information has some spatial connection to location (URL, 2003a). Increasingly, because technology makes it possible, the linking of that location to people or incidents has become a powerful tool to understanding, analyzing and managing the world mankind live in. Technology does not just help to predict future events and manage them but it also to helps evaluate a past situation and reconstruct it again as effectively as possible.

Fast developing technology in the area of geo-informatics makes the use of SIS exciting to utilize and an opportunity to challenge much better decision-making for many fields like history, archaeology etc. SIS can be used to analyze any issue with a spatial component in these fields.

(Geo)Spatial Informatics Technology Architecture of “GeoCHEAF” provides the ability to gather (geo)spatial data, information and associated attributes about the location and characteristics of man-made and natural features and events above, on and beneath the surface of the earth by encompassing a broad range of disciplines including geodesy, surveying, remote sensing, photogrammetry, archaeology, history, etc. It then is capable of utilizing (geo)spatial data and information to model, analyze and interpret spatial relationships by encompassing cartography, mapping, generalization, SIS technology, etc. Subsequently, it provides the ability to present and distribute results to enable better decision-making by surrounding SIS technology, Internet, cartography etc. Eventually, it provides the ability to track man-made and natural features as they change over time and space through SIS technology, etc.

When implementing a management information system with a SIS component, the technical capabilities of the SIS are probably the least difficult issue to be considered. Yet they often receive the most attention, perhaps because it is easier to focus on technical issues rather than organizational ones.

The main business objective of this architecture is to apply geo-informatics to the widest possible range of users in the enterprise by embedding spatial data and technologies, and SIS functionality in the enterprise applications, and to enable the CH enterprises to freely exchange and apply spatial information, applications and services across networks, different platforms and products through OGC's open interface specifications.

(Geo)spatial vision in the business architecture and SIS-driven technical architecture of “GeoCHEAF”:

- Lead to a better understanding of the potential of geospatial sciences in enabling enterprises take better decisions
- Turn the enterprise into the spatially-enabled enterprise
- Maximizes use of geospatial data through enterprise repository
- Ensure the architectures supports SIS and “traditional” business applications
- Integrate SIS into the business process to obtain geospatial intelligence business solutions
- Use data standards to integrate business processes with SIS
- Integrate SIS with other enterprise systems or information systems like management information system to enable information sharing
- Aim to advance geo-processing interoperability across the enterprise
- Use open source low-cost geographic information technologies

The architecture enables the decision-makers to carry out spatial analyses more easily, to tailor maps exactly to the needs, to support management of spatial objects. It may even be possible to produce spatial information that has not been available before, such as determining location of the tower within the fortress area that does not exist now. The contribution of the architecture may be of different nature, improving the decision-making, speeding up decisions, serving the user better, reducing the cost of operation etc.

The heart of “GeoCHEAF” is the SIS. In the context of the dissertation, SIS is mainstream and integral part of any process that tries to visualize complex interrelationships of data or information with a specific purpose of generating spatial intelligence.

The SIS architecture of “GeoCHEAF” is emerging based on some new technologies that allow all SIS functions to run in a centralized server environment and be accessed a variety of users wherever it is needed from any device on a network, to a browser-based or kiosk-based user to onsite mobile computing devices in the field to GIS services.

In the design of “GeoCHEAF”, to provide a spatially-enabled enterprise, SIS functionality and data are embedded inside other applications, like functions embedded within word processing documents and spreadsheets, or mapping provided within non-SIS applications.

Another objective is to develop an open SIS architecture including open source SIS software and open standards in SIS. Both open source GIS databases PostGIS from PostgreSQL and MyGIS from MySQL have been selected to store spatial data. MapServer developed by University of Minnesota is used as a SIS map server in the architecture. Since more than 65 spatial data formats are available in SIS market, to retain the interoperability, the architecture is based on open standards, in particular, OGC standards, such as GML, WMS, WCS, WFS, JPEG2000, GMLJP2.

The spatial informatics technology architecture of “GeoCHEAF” includes not only geospatial information systems, but also mapping, earth imaging, sensor webs, and mobile wireless services. It also highlights the importance of OGC web services standards as part of information technology best practices for integrating geospatial processing into service-oriented architectures and enterprise workflows.

8.2 SIS Subsystems

SIS comprises three major subsystems as follow. A useful, general purpose SIS needs capabilities in all these areas. (Morais, 2000; Maguire, 2003)

1. Data Management (Geodatabase)
2. Geoprocessing (Operations and Analysis)
3. Mapping (Rendering and User Interface / GeoVisualization)

The mapping subsystem deals with the manipulation and visualization of geospatial information. It is here that users will find projection and datum transformations, map to page transformations, symbology models, map displays, 2D and 3D visualization tools, editing components, and the framework for interacting with geospatial data in the form of a map. (Morais, 2000; Maguire, 2003)

The spatial analysis subsystem implements a series of geospatial analysis functions for overlay analysis, grid analysis (watershed modeling, intervisibility analysis, etc.), network analysis, three-dimensional analysis (calculation of slope, aspect, etc.), proximity analysis, and data conversion (import CAD data, export graphics, etc.). The operations and analysis functions refer to the actual logical processing of the data, including things like feature overlay and map projection. (Morais, 2000; Maguire, 2003)

The data management functions refer to the reading and writing of spatial and non-spatial attribute data to some type of permanent storage media, usually a hard disk.

DBMS products have been widely used in SIS because they allow users to create a single, centralized data repository (avoiding redundancy and duplication); they facilitate data sharing (by establishing de facto standards); they support multiuser editing of continuous geospatial databases; and they allow users to employ DBMS backup and recovery tools. However, the limited support for advanced geographic data types; the weaknesses of SQL as a geospatial data access and programming language; and concerns about scalability for operations, such as topology management, have instigated a reexamination of the role of DBMS in SIS and have prompted the development of n-tiered GIS applications.

8.3 Evolution of SIS Technologies Followed by ICT Evolutionary

Throughout the course of the last 40 years , GIS technology has been implemented using a variety of contemporary computer architectures. The earliest systems were built to run on mainframe and minicomputers, then came workstations, next PCs, and now system designers are recommending web-based technologies for distributed systems. (Maguire, 2003)

The architecture of early GISs developed during the late 1970s and early 1980s resembled a stovepipe because all three components were tightly coupled and sold as part of a single entity. In other words, the earliest GIS software was responsible for providing functionality related to all three aspects of the GIS. Not surprisingly the weakness of this approach was quickly exposed when the software produced during this era could not adequately perform all three tasks. Even worse, there was little or no interoperability between software packages. (Morais, 2000)

The evolution in systems architecture presented a new paradigm in the early 1990s as a solution, the client-server architecture. The client-server approach disaggregated the data management duties from the rendering and user interface. This approach benefited from the introduction of commercial relational database technology and inexpensive client-side desktop PCs or UNIX network terminals. Many of the GIS installations today still use a client-server architecture. For example, an organization which stores spatial data on a central server in an ArcSDE or Oracle Spatial database, but uses ArcView or ArcInfo to manipulate this data, is taking advantage of the classical client-server architecture. The client-server approach provides an amicable distinction between the data management and user interface responsibilities, but suffers because there is no well defined place for the operations and analysis logic. For example, if one has to find all features within a certain distance of a given point, is it the responsibility of the data management or the user interface component of the GIS to do this. (Morais, 2000)

The most recent evolutionary stage in systems architecture is the distributed n-tier approach. In n-tiered architecture the operations and analysis component is explicitly restricted from being coupled to the user interface and data management components. So, the architecture can be easily extended in the future and interacted with other software which it has no prior knowledge of. (Morais, 2000)

In this type of configuration the client has sophisticated capabilities and, in advanced systems, can comprise several hundreds of megabytes of code (a so-called “thick” client implementation). This configuration has served GIS users well for the last decade and will continue to do so for advanced GIS tasks such as editing, cartographic compilation, three-dimensional modeling, and spatial analysis. However, in recent years users have become dissatisfied with this type of architecture for less demanding tasks because the cost of client machines and software is prohibitive, it is expensive to maintain and update widely distributed PCs.

An alternate, in the design of more centralized architecture of “GeoCHEAF”, the three SIS subsystems are deployed on the distributed multi-tier architecture of her. All the SIS components -topographic and thematic mapping, spatial analysis, geospatial processing and data access functions- are deployed on the middle-tier and run on the web application server. The presentation sub-tier is responsible for interfacing with the network and for allocating requests to server containers within the business logic sub-tier that perform the actual work. The server containers obtain the data required to fulfill a task from the data management subsystem that runs on the DBMS in the data tier. A thin client can be used to initiate processing requests and display the results of SIS tasks. Addition to Internet delivery of comprehensive GIS functionality, the design involves a central SIS web portal for information discovery and use.

In the same way that the adoption of the client-server approach was assisted by the introduction of relational databases and desktop computers, the n-tiered architecture will require the introduction of industry standards and improvements in component software technology. The industry standards in SIS generally come in one of two forms. Data standards have been developed by industry consortiums, such as the simple features specification of the OGC, or in a de facto manner if a particular proprietary format is popular enough, the ESRI shapefile is a good example. The second suite of standards are processing standards, such as the OGC's services model and catalog, that relate the operations that must be made available in a piece of SIS middleware.

The open standards-based approach to data management, application development, and data and processing access makes the SIS architecture of "GeoCHEAF" ideal for providing SIS services to a wide range of distributed users, from stakeholders to end-users. The architecture has a number of benefits -the low cost of maintenance, high scalability, and excellent reliability- for the enterprises. For instance, because all data and processing capabilities are centralized in one location, costs of upgrade and maintenance are minimized (e.g., software updates do not need to be pushed out to hundreds of PCs), SIS servers can be installed alongside an enterprise's other servers, and the same ICT staff can be used to maintain both.

Finally, "GeoCHEAF" foresees a future in which traditional, architecturally closed and centralized information systems (GISystems), designed as isolated islands, will become increasingly less attractive, maybe disappearing altogether. Even, most of the current web-based GIS applications cannot be shared and are not interoperable because of their heterogeneous environments. However, the open and distributed Internet GIS services architecture (GIServices) would be common in any area by means of ICT technologies, such as distributed component technology, XML, network communication and programming technologies in order to access heterogeneous servers dynamically.

8.4 Standards for the Development of Internet GIS

Internet GIS has been the most rapidly developing field in the geospatial technology industry. Many commercial Internet GIS programs have been developed, such as: ESRI MapObject IMS and ArcIMS, Autodesk MapGuide, Geomedia WebMap Server, and MapInfo MapXtreme, GE Smallworld Internet Application Server and ER Mapper's Image Web Server. Although these commercial Internet GIS programs greatly increase the accessibility of GIS data and tools, there are two problems associated with the current Internet GIS programs. First, current Internet GIS programs are not interoperable. This non-interoperability has two aspects. The first aspect is the data interoperability issue; the data created by different programs cannot be shared by others without data conversion. This causes problems for real-time data access, especially at the feature level. The second aspect is the access interoperability issue; data on the server can only be accessed by its own client. Other clients cannot access data due to proprietary access methods implemented by different Internet GIS programs. For example, a GeoMedia Web Map client cannot access data on the ArcIMS server. Enabling interoperability among heterogeneous systems and geospatial data is a challenging task for the development of Internet GIS, both technically and institutionally. The second problem of current Internet GIS is that the graphic output of most commercial Internet GIS programs is in raster image formats such as GIF and JPEG. The graphic quality of raster images is limited, and becomes blurred when zooming in. Delivering spatial data in a high-resolution vector format over the web is becoming more important as data availability and global sharing increases. “GeoCHEAF” proposes a standard-based architectural framework for interoperable Internet GIS.

This architectural framework uses GML as a coding and data transporting mechanism to achieve data interoperability, WFS as a data query mechanism to access and retrieve data from the heterogeneous systems at the feature level on the web to achieve access interoperability, and SVG to display GML data on the web as vector graphics to improve the display quality of map graphics. The combination of the three standard technologies provides efficiency in promoting interoperability of Internet GIS programs and improving cartographic quality of Internet GIS visualization on the web.

GML, SVG, and WFS are standard technologies, and each has a unique role on the web and Internet GIS. As mentioned in the section of 'Extensible Architecture', GML models the world in terms of features based on the OGC Abstract Specification. A feature is an abstraction of a real world phenomenon; a geographic feature is any real-world object that is associated with a location. The Web Feature Services (WFS) is an another OGC implementation specification that allows a client to retrieve geospatial data encoded in GML from multiple Web Feature Services. The WFS is written in XML and uses GML to represent features, but the database (or datastore in

OGC's term) could be in any format. In fact, the structure of those databases should be opaque to client applications. Any access to the database should be through the WFS interface. WFS has a tight relationship with GML. The WFS allows the client applications to access, query, create, update, and delete data elements from the GML feature database server. The WFS provides interfaces for four basic data manipulation operations on GML features: create a new feature instance, delete a feature instance, update a feature instance, and get or query features based on some spatial or non-spatial query constraints. Client applications can post requests for feature level data in XML. Such a request can include query or data transformation operations, which can be applied to one or more features in one or more database, locally or remotely. The WFS server reads and passes the request and returns the result in the form of GML. (URL OGC) Finally, W3C's SVG standard is used to display spatial data as vector maps on the web browser.

GML is an effective means to encode, store, and transport geospatial data. It is also an efficient means to foster data portability and interoperability. SVG produces high-quality graphics on the Web, which is ideal for displaying spatial data and making intelligent maps. The OGC Web Feature Service works well with querying and retrieving GML data from different servers. The advantage of this standard-based approach is interoperability. Users can gain access to data that are stored in different Internet GIS servers that conform to the same standard. Data in their original formats can be retrieved using WFS and transformed into GML on the fly. Thus, the end user can retrieve information at the feature level from different data sources with different data formats.

The user can search, access, and retrieve spatial data at the feature level through a web-based search engine. A user's query goes through the web server and WFS to the respective geodatabase. The retrieved feature data will then be displayed as SVG in the user's web browser and/or applications. The main purposes of this architectural framework are twofold: to facilitate users to access data from the heterogeneous systems at the feature level in real time on the Web, and deliver high quality vector GIS by SVG on the Web.

8.5 Scope of Geospatial World

Depending on the needs of the user, currently two kinds of SIS software fulfill the main requirements: the light web client or the heavy client, also called Desktop SIS. While the first one only offers basic tools, the desktop GIS offers authoring, sharing, managing and publishing geospatial information.

In the last years, open source software has been getting very popular. Numerous software areas already offer an equivalent option to proprietary products. But until now, the market segment of SIS and CAD software did not provide series alternatives to the expensive and sometimes oversized market-leading software packages. On the other hand, the market of software that is dedicated to modify and treat spatial information and cartography has been monopolized by a few proprietary products that shown in table 8.1. Due to this lack of selection, the main part of the fast growing community of SIS users has been bound to use certain softwares. So, the selection of a SIS normally was neither a well-considered decision nor the result of an analysis of the existing possibilities. The situation in many SIS evaluation processes is that not the most suitable product is selected but the most habitual one. Normally, the software user is not aware of his requirements and functions he needs. Although users often only need certain basic functions, they are constrained to buy expensive software with many complex, but unnecessary tools. The logical decision should not be buying the most common software, but buying software that fulfills the user's requirements best. One can think of language, comfort, price, comprehensibility, and compatibility, to mention a few in a SIS evaluation process.

Is open source SIS software really an alternative for commercial GIS software? Yes and No. No, because of lack of capabilities for analysis, which means there is no server-side logic and the files are hosted on a web server, such as Google Earth's KML file. Yes, because the goal is to make spatial data available online to the researchers, general public, government institutions or companies.

Table 8.1: G-World

Which GIS toolkit/software?					
Open Source Thick (Heavy) Clients? / Open Source GIS Processing Tools?	Geographic Resources Analysis Support System (GRASS)	**Free but not Open Source?**	Diva-GIS by Lizard Tech, Inc. and University of California	**Proprietary (Closed Source)?**	*ESRI* ArcGIS
	Open Source Software Image Map (OSSIM)				*Autodesk* Map, MapGuide, MapGuide Enterprise, MapGuide Studio
	Quantum GIS (QGIS)				*Intergraph* GeoMedia & GeoMedia Professional
	uDig				*Bentley* Microstation GeoGraphics
	System for Automated Geoscientific Analyses (SAGA)				*MapInfo* Professional
	MapWindow GIS				*CadCorp* SIS
	GeoTools				*Ionic* RedSpider
	Generic Mapping Tools (GMT)				*Snowflake Software* Go Loader & Publisher
	JUMP Unified Mapping Platform (JUMP)				*PCI Geomatics* IMAGiS
	gvSIG				*Northgate Information Solutions* StruMap
	Thuban				*GE Energy* Smallworld
Open Source Thin Clients? / Open Source GIS Map Servers	UMN MapServer			**Proprietary Thin Clients? / Proprietary GIS Map Servers**	*ESRI* ArcIMS & ArcServer
	GeoServer				*Autodesk* MapGuide
	deegree				*Intergraph* Geomedia WebMap
	JMap Server				*MapInfo* MapXtereme
	ka-Map				
	Mapbender				
	MapBuilder				
	OpenLayers				
	Autodesk MapGuide Open Source				
	Intergraph OGC WMS Viewer				
database spatial extensions	PostgreSQL – PostGIS			**database spatial extensions**	Oracle Spatial
	MySQL – MYSQL Spatial (MyGIS)				ESRI ArcSDE for Microsoft SQL Server and Oracle
	Spatial DB in Box				
Geospatial Libraries	Geospatial Data Abstraction Layer (GDAL)				
	Geometry Engine Open Source (GEOS)				
	Java Topology Suite (JTS)				
	GeoTools				

In fact, this client-server computing model has been so successful that many only think of SIS within this context. However, the SIS vision is expanding. Recent developments in computing -the growth of the Internet, advances in DBMS technology, object-oriented programming, mobile computing, and wide GIS adoption to- have led to an evolving vision and role for SIS. Therefore, besides the proprietary products, now also several open source projects are getting a competitive alternative for the versatile use of SIS.

In addition to SIS desktops, SIS software can be centralized in application servers and web servers to deliver SIS capabilities to any number of users over networks. Focused sets of SIS logic can be embedded and deployed in custom applications. And increasingly, SIS is deployed in mobile devices for field (or mobile) SIS. Table 8.2 provides the query "Which SIS solution is yours?" since there are many SIS solution for different SIS projects.

In this context, SIS software can be increasingly thought of as ICT infrastructure for assembling large, sophisticated multi-user systems.

Table 8.2: GIS-matrix

Which GIS solution is yours?		
Traditional monolithic GIS	Desktop GIS	Embedded GIS
Internet GIS	Participatory GIS	Field GIS
Web-based GIS	Augmented GIS	Archaeological GIS
Distributed GIS	Sensuous and reflexive GIS	Conservation GIS
Mobile/Wireless GIS	Object-Oriented GIS	Sustainable GIS
On-line GIS	Error-sensitive GIS	Enterprise GIS
Networked GIS	TeleGIS	ESRI GIS
Internet mapping	Cognitive GIS	Open GIS
Multimedia GIS	Intelligent/Artificial GIS (agents)	Standards-based GIS
Virtual GIS	Temporal GIS	OGC compliant GIS
2D/3D/4D/5D GIS		

Spatial informatics technology architecture of “GeoCHEAF” covers all technologies and their products, and standards pertaining to the geospatial infrastructure, its data and metadata.

There is currently a trend within the SIS user community toward more sophisticated uses of raster data, for instance, feature and/or information extraction from geoimagery, long-term monitoring. So, today, organizations are searching for solutions that provide easily integration of raster data with vector-based data and for tools to effectively search these vast and growing collections of photos and images.

Spatial data acquisition techniques and measurement technologies matrix for the CH domain, which can be directly entered into the SIS:

- Imagery
    - Remote Sensing / Satellite Imagery (spectral resolution (low spatial resolution) & geometric resolution (ultra-high spatial resolution))
        - Satellites
            - QuickBird-2
            - IKONOS
            - OrbVIEW-3
            - Satellite Pour l'Observation de la Terre (SPOT)
            - LandSAT (Landsat 5, Landsat 7)
            - European Remote Sensing Satellite (ERS)
        - Enterprise Geospatial Imagery Solutions (software packages):
            - ERDAS Imagine (*Leica Geosystems*)
            - ER Mapper
            - ENVI
            - PCI
            - Idrisi
            - GeoExpress 6 (*LizardTech*)
    - Aerial Photogrammetry
        - Stereo aerial photographs from aircraft, zeppelin, balloon, kite
    - Terrestrial Photogrammetry
    - RADAR Imagery

    - Synthetic Aperture Radar (SAR)
    - LIght Detection And Ranging (LIDAR)
    - InterFerometric Synthetic Aperture Radar (IFSAR)
    - Integration of LIDAR and IFSAR for high resolution multispectral imagery and mapping
- Laser Scanning (*Hybrid approach for surveying facades: 3D Laser-based photogrammetry*)

  Benefits of using 3D laser scanning in the CH domain:
    - Better measurements and much faster than manual documentation methods
    - Ability to measure inaccessible structures accurately
    - Rapid scanning time reduced the minimized the project life cycle
    - Collection of additional measurements for future use (The output data directly kept in digital format for future reference (no digitization is required like stereophotogrammetric images, however, required some algorithms, like point thinning algorithm, and special software, like Geomagic Raindrop studio or Cyclon))
    - Ability to do as-builts without disrupting the tourists and ongoing works
    - Captured details of the complex structures

  The point cloud could be used to prepare the following deliverables:
    - 2D Drawings in CAD environment
    - 3D Models of the existing structures
    - Sectional drawings
    - Virtual walk through of the CH complex
    - Registered point cloud data in digital format
- Historic Imagery
- Image Processing
    - Digital Surface Models (DSMs) (*generally first pulse signal equal DSM*)
    - Digital Terrain Models (DTMs) (*last pulse signal processed and filtering and additional processing required*)

        - Digital Elevation Models (DEMs)
        - Orthorectified Radar Images (ORIs)
    - Pictometry technology combines packages of oblique and vertical aerial aerial images with a viewing software application designed to enable accurate measurements.
    - Geophysical (or Ground) remote sensing (*used to know ho and where to excavate*)
        - ground penetrating radar
        - resistivity
        - magnetometry
        - sub-bottom profiler
- Positioning
    - Total Positioning System (TPS)
    - Global Positioning System (GPS)
        - A-GPS
        - Internet GPS
        - Underwater GPS
    - Hydrographic Survey, Conventional Bathymetry, Bathymetry from Space, Geodetic Altimetry (satellite altimetry, airborne altimetry, shipborne altimetry)
        - Geodetic/Geophysical Satellite (GeoSat)
        - European Remote Sensing Satellite (ERS)
        - Seasat
        - TOPEX/Poseidon
    - Cellular Network Positioning
- Mapping
    - Computer Assisted Design (CAD)
    - Internet Mapping Services
        - Geography Networks
        - Google Map/Earth/3D warehouse
        - Yahoo Local Map
        - MapQuest

        - Windows Live Local
        - Virtual Globes
            - Google Earth
            - TerraExplorer (from Skyline Software Systems)
            - NASA's World Wind
    - Historic Map Collections (georeferencing the historical maps using polynomial transformations)
    - Mapping Standards
        - XML
        - GML (DXF/SHP to GML approach)
        - Autodesk DWG/DXF
        - Intergraph GeoMedia Warehouse
        - MapInfo MID/MIF
        - MicroStation Design
        - Oracle and Oracle Spatial
        - ESRI shp file
        - JPIP Streaming (JPIP: JPEG 2000 Interactive Protocol)
        - MrSID: the industry-standard image compression format
        - GeoTIFF format
        - JPEG2000 (ISO-standard) (open standard)
        - GMLJP2 (OGC's standard GML + JPEG2000)
        - TOP10NL (the Dutch standard format for sharing GIS data across multiple platforms)
        - etc.

The raster data management component of "GeoCHEAF" stores orthorectified and georeferenced satellite imagery (acquired from satellite image data services) and aerial photogrammetry (aquired from aerial photogrammetric archives) data in the multi-resolution image database. Then, "GeoCHEAF" integrates imagery data with other spatial data sources to generate the image-based maps to extract information from images and thematic maps to visualize queries' results.

8.6 Narrowing the Scope for the Cultural Heritage Domain

The benefits of modern SIS for the CH domain have so far not been fully realized due to uneven spread, missing capacities, differing databases and systems and lack of information exchange mechanisms.

Since the days of Heinrich Schliemann's search for Troy, archaeologists have been confronted with the dilemma of how to record the spatial characteristics of archaeological data, and once recorded, how to analyze those data. This spatial information has historically been recorded on paper maps of varying accuracy and scales. When researchers wanted to perform analyzes of these data, they were required to spend hours, if not days, transposing this information to new paper maps and making arduous measurements by hand. (Brandon et al., 1999) Before GIS, each field season produced a unique set of paper maps and photo prints that were difficult to integrate with each other, or with other data. (Madry, 2004) This time-consuming process has come to an end as researchers have moved to take advantage of GIS for spatial analysis. (Brandon et al., 1999) Now with GIS, all of the data, as it becomes available, are entered into a single, integrated database where archaeologists can analyze the data at any scale, from a single excavation to regional analysis of the patterns of many sites across the landscape. (Madry, 2004)

If an archaeologist links the geometry of features from an excavation site to collection data tables using GIS, s/he can dynamically update the maps to show, for example, all the rooms that date to a specific time period or the rooms where a certain type of object was found. Instead of sitting at a drafting table to create a single site map, archaeologists can now sit at their computers and make the same basemap with their GIS software. The time required to add the feature geometries to the GIS is no greater than that previously invested in manually drafting static site maps or using CAD or drawing packages to create illustrations for publication. However, after they draw in the features and attribute them with feature identification numbers, they can use database join operations to link data from analysis tables to the map. This lets them interactively create multiple maps showing different aspects of the collected data. This is a powerful new way for archaeologists to explore and present their findings. (Booth, 2006)

Archaeologists were at first slow to adopt GIS, in part because the technology was difficult to obtain and the available data limited. But that began to change in the 1990s, thanks in part to the availability of better terrain and ecological data. Remote- and geophysical-sensing equipment and methods improved, the quality of aerial photography and satellite imagery went up, and the GPS became much more accessible. Improvements in computing power, display, output technology, and software have made GIS more powerful and easier to use. (Booth, 2006)

Although much work is still being done using static maps, the percentage of archaeologists who are beginning to adopt GIS to map, manage, and analyze sites and collections is increasing. Some archaeologists are starting to take laptops into the field and using GIS softwares to do their mapping. Others are recording site data on paper and transferring the data into a GIS at the end of each day or week of the field season. Mobile computing units are becoming standard equipment for archaeological surveys, and some archaeologists are now taking their GIS data with them, too, connecting pocket PC to their GPS to locate and record sites. Archaeologists are now using satellite imagery, digital aerial photogrammetry, close-range photogrammetry, historic and modern maps to enhance their traditional methods. Aerial photography, close range photogrammetry, satellite imagery, image processing, GPS, GIS, visualization and simulation, all are rapidly being adopted by archaeologists around the world, and with excellent results.

In these days, another kind of problem has arose as a result of dramatically growing digital data capturing, storing and manipulating technologies. The modern CH specialists can be overwhelmed with the huge quantity of data generated from contemporary measurement and scanning technologies. This problem is further compounded by the vast quantity of data types, format and representations in use today. CH specialists generally use GIS only for mapping tool, however, enormous potential of GIS is much beyond of that. Traditional 2D GIS are nowadays widely used by CH specialists in order to gather a large amount of data into a single visualization. These software systems remain a simple layer manager that do not provide high level visualization and navigation tools.

One characteristic of the bulk of archaeological GIS applications has been the tendency to reduce, abstract and simplify the full complexity of the archaeological data under study. This is perhaps best typified by the frequent reduction of complex, socially enmeshed cultural landscapes down to discrete dustings of arguably meaningless points, the only virtue of which appears to be their statistical suitability for spatial analysis. (Gillings and Goodrick, 1996)

Spatial patterns that are obscure when seen in tables and graphs quickly become apparent using GIS. For example, without a GIS, an archaeologist studying stone tool manufacturing at a site might look at the collection data tables and identify peaks on a histogram that represent excavation units with high volumes of toolmaking debris. They would then need to refer to a hard-copy map of the site to see how those units are related spatially. However, when using a GIS, the archaeologist can easily plot the toolmaking data on the map and see the patterns immediately. The archaeologist might use dark green to represent high concentrations of stone tool flakes and light green to represent low concentrations of stone tool flakes. After spotting a spatial pattern, s/he could resymbolize the data to show the ratio of one type of stone tool flake to another (or the ratio of flakes to tools or to another artifact type, etc.). (Booth, 2006)

Archaeologists can create elevation surfaces for individual levels (strata) within a site based on opening and closing elevation measurements of excavation units. As shown in figure 8.1, artifacts and features from the site can be shown in 3D, draped on or extruded through the appropriate levels. (Booth, 2006)

Throughout history the physical and cultural environment has influenced location and distribution of settlements. One important question in archaeological research is what are the causal relationships between environmental factors on the one side and location and distribution of settlements on the other? To find the answers to this question, CH specialists should be capable of using GIS as a powerful analytical tool. The spatial distribution of the remains of CH resources is the result of human decision-making activities within the possibilities and conditions presented by the time and environment.

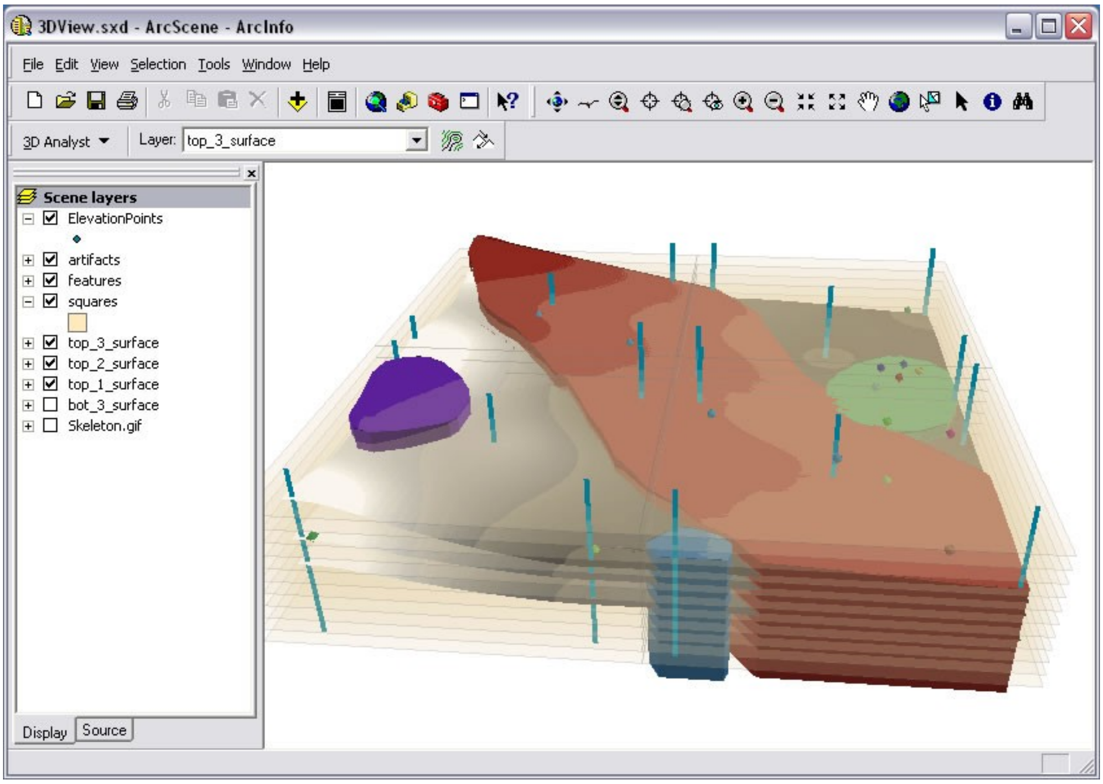

Figure 8.1: A 3D view of an archaeological site from ArcMap, ESRI. (Booth, 2006)

The real heart of the GIS for archaeologists is their ability to conduct spatial analysis on the patterns and relationships between archaeological sites, and between sites and their environmental context, for example distributed analysis of CH sites based on GIS and/or archaeological network analysis. Archaeologists want to understand the patterns and relationships between sites and natural resources, between sites and sites of the same time periods, and how those patterns change over time. They conduct spatial statistical analysis, including advanced exploratory data analysis techniques, to discover the changing patterns of settlement and land use over time. Archaeologists can now quantitatively test theories of political, economic, and environmental patterns that were not possible without these powerful tools. They routinely create predictive models of archaeological site distribution, based on combinations of environmental (elevation, slope, distance to water, and soil types, for example) and cultural data (such as political boundaries, religious and economic centers). (Madry, 2004)

GIS normally have the ability to selectively depict thematic layers and produce results of analytical queries and analyzes. One of the other problem is that the application of mathematical and/or statistical models in the cultural heritage projects is quite limited because of the difficulty of preparing input data and interpreting model output. Another reason is that GIS is generally not designed for the cultural heritage domain, despite the growing use of the technology within the domain. GIS is also a tool driven by market demands of a non-archaeological nature. Hence, there are the limitations of GIS within the CH domain. There is a need to develop the GIS applications to be more appropriate to the CH domain's demands.

It would be enlightening to analyze how GIS is applied in archaeology through a survey that relies on 140 individual responses. Figure 8.1 shows how GIS is applied in Archaeology and figure 8.2 shows the most successful GIS applications in archaeology.

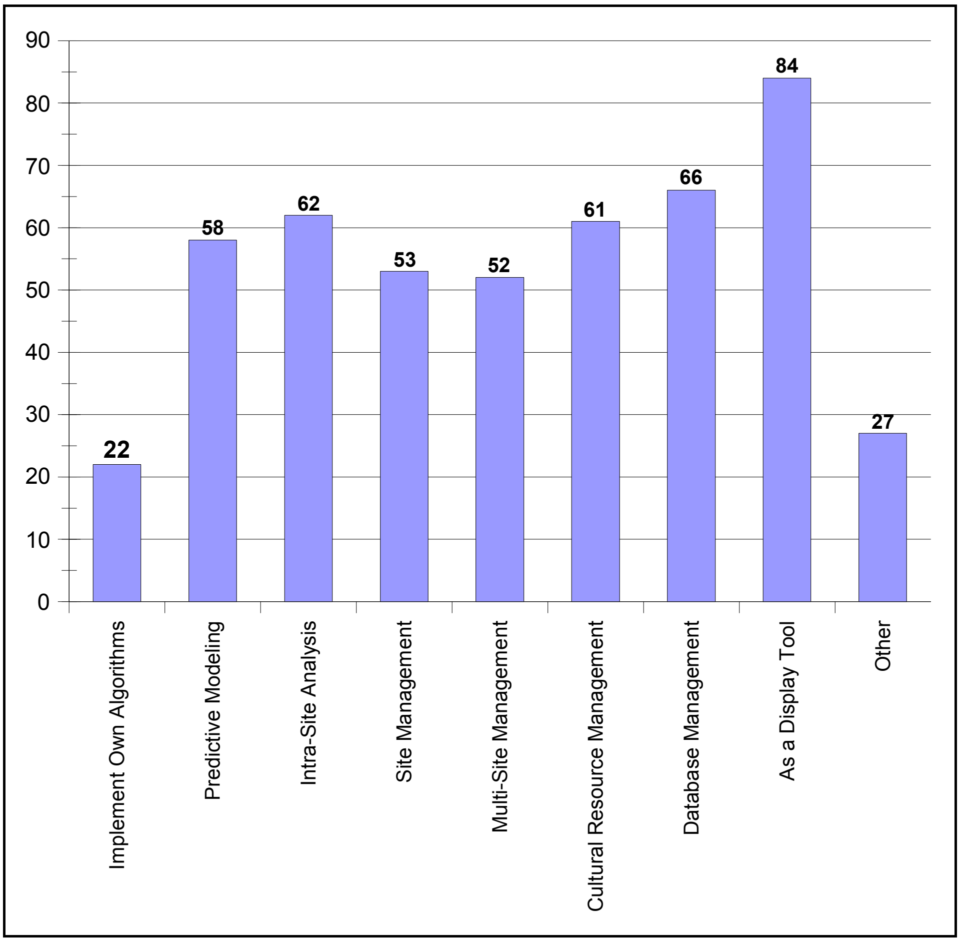

Figure 8.2: GIS usage in archaeology (Gourad, 1999)

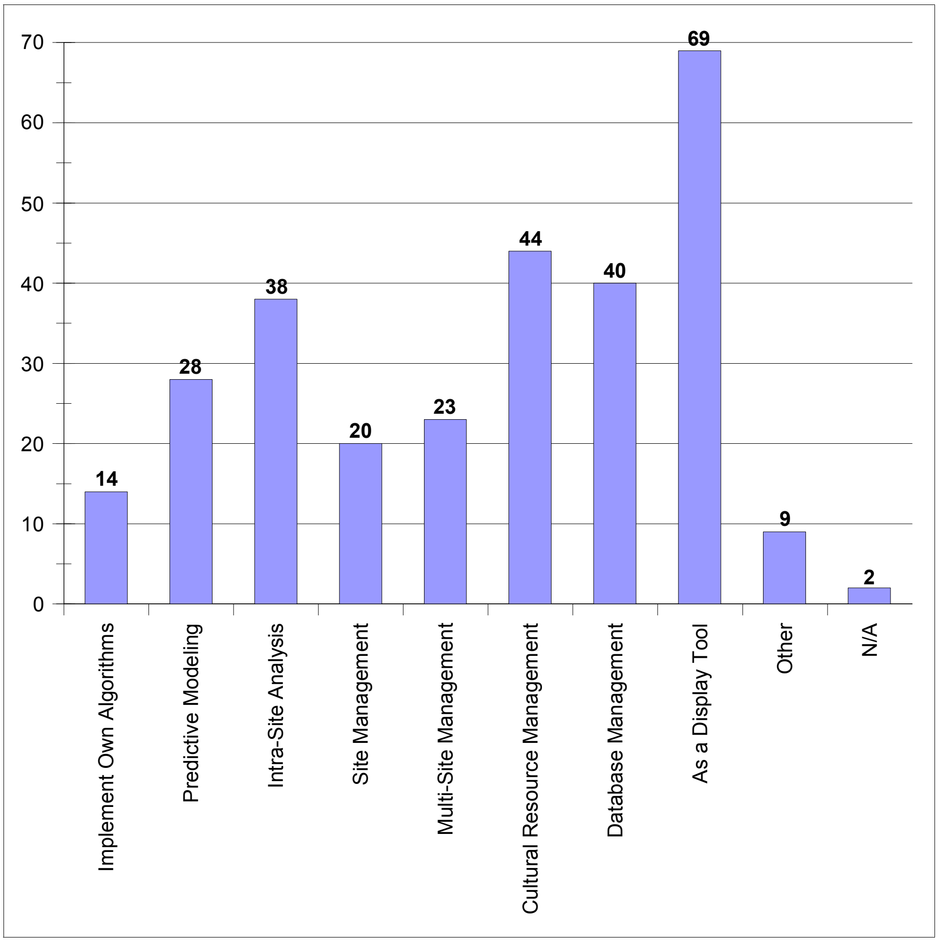

Figure 8.3: The most successful uses to which GIS has been applied within archaeology (Gourad, 1999)

8.7 Proposing a Leading SIS Architecture for the Cultural Heritage Domain

SIS in CH projects must be considered as an enterprise-wide multi-purpose and multi-participants ICT project. To achieve this, the consultants and SIS developer must be part of CH project team and each discipline in the project contributes to the SIS with its science domain by defining the specific problems and expectations since it expects different outputs rather than other science domains. (Guney and Celik, 2004d) In this context, the SIS application will have various purposes for the different level users such as decision makers, users, end-users. For instance, the SIS application of the fortresses has been generated with a cross disciplinary approach which integrates information and research from a variety of other fields including geodesy, land surveying, photogrammetry, architecture, archaeology, Ottoman history, art history and oral history.

SIS requirements influence how SIS software is chosen and used. SIS, similar to other information and communication technologies, must be treated in a manner that easily allows applications to support each organization's workflows and business requirements. This is accomplished by providing a SIS architecture that provides comprehensive support for the complete range of geospatial knowledge elements as well as comprehensive tools for data management, editing, analysis and display.

Clues to the relationships between environmental factors and location and distribution of settlements are preserved in many existing maps. Combining these maps with remote sensing data and non-spatial information from a variety of sources in a geospatial data management system (geo-DBMS) enables the creation of virtual models of cultural heritage sites and querying relationships or adjacencies between disparate forms of physical and social data at household, cluster, site and regional level. Such SIS has the potential to incorporate a limitless amount of information for proper spatiotemporal analyzes, to predict the presence of undocumented archaeological sites and to discover heretofore-unidentifiable relationships.

To ensure valid analyzes and robust conclusions, the SIS architecture should be coupled with proper spatiotemporal statistical methods including multivariate spatial statistical analysis, overlay analysis of thematic data and spatial intersection, buffer generation, neighborhood analysis, vector-based grid generation, network analysis, (raster) surface modeling and land use & land cover analyses. In the multivariate spatial statistical analysis, spatial weights computed, spatial autocorrelation on predictor variables assessed, and probability scenarios of mapped variables explored based on modeled changes in regression coefficients over time, with unparalleled computational speed and ease.

The engineering-oriented SIS architecture of “GeoCHEAF” provides all the capabilities necessary to support this enlarged vision for the CH domain:

- Spatiotemporal object data modeling and spatial data structures, and a comprehensive 4D (3D+Time) geo-processing model for implementing and maintaining spatiotemporal applications
- Multi-resolution data storage scheme for 3D GIS

- Geodatabase to store and manage all geospatial objects; efficient and flexible data management
- Geospatial data accessibility through a web-based interactive mapping interface
- Extensive support of coordinate systems (including coordinate transformation) and map projections
- An interactive interface on the web to manipulate the historical information
- Modeling historical changes in the CH resources with temporal SIS development using an extensible database system
- Spatial analyzes and viewing results on interactive maps as well as tables and distribution charts
- Towards a model for multimedia supported SIS
- Decision-making
- Modular software components (engines) to embed SIS logic in other applications and build custom applications
- A web-based network for distributed geospatial information management and sharing.
- Geospatial information services for multi-tier centralized SIS systems and web services: mapping, geoprocessing, shared geospatial data and services
- On-the-fly queries, data integration, digital web mapping, thematic mapping, time-based interactive mapping, animated mapping, etc.

The SIS architecture of "GeoCEHAF" integrates spatial data with non-spatial data to create essential topologies, including dynamic topology, enhanced topology, on-the-fly topology, 3D topology, planar topology, non-planar topology, to perform queries and spatial analysis using these topologies and finally to produce thematic maps presented as choropleth (grey-scale) maps, dot-density maps, proportional circles, contour (isopleths) maps, etc.

In term of the project, after generating all topographic maps and architectural plans for the two sites and collecting a substantial amount of historical information about the fortresses, the architecture combines layers of information involving topography (contours, DEM, DTM), planimetric data (monuments, roads, trees, sea-coast), architectural data (the 2D and 3D architectural plans of cultural remains, walls, structures), land use (residential, agricultural, plants), utilities (water and sewer installations, heat system), cadastral data (ownership), art historical data, Ottoman historical data, oral history data, archaeological data and past plans (historic maps, past maps, plans, residential, natural reserves) and defensive considerations. Interpreting the interplay of these multiple thematic layers of information related to these and their various permutations may reveal identifiable patterns that reflect actual human behavioral patterns and choices. In this context, it identifies the fortresses, displays the locations of historical and topographical features; pertinent aspects of the environment like soils, plant cover; the location and condition of existing structures, roads, other facilities; and traditional use areas such as cemeteries. Finally it records architectural changes and expands the system to incorporate data and compare the fortresses from other fortresses in the region for further research.

First, the SIS of the fortresses was set up to serve users with specialized training in art and architectural history, Ottoman history, and archaeology. The SIS must be tailored to the information needs of these researchers and facilitate the analytical tasks that they must perform. Each discipline in the project team collects the information necessary for a decision and then uses this information in making the decision. Therefore, SIS developers in the project team must always be concerned about the type of information that is necessary for these researchers and which form of information is easiest to understand within these disciplines. Information in this context is defined here as “answering a question of an art-historian” in the beginning. A successful SIS must provide useful information to a user and it is essential that a constant dialog occur in order for the SIS developers to best adapt the existing SIS programs to the specialized needs of the users, in this case the historians and archaeologist on the project and those who will make decisions related to the future preservation of the structures. Second, the intention of the SIS for the fortresses is to anticipate the questions that people from other disciplines may have about the historical development of these fortresses and their environs. (Guney and Celik, 2003a)

Most data manipulation and analysis functions would not be practical or feasible without a topologic data structure in a vector based SIS. The appropriate topology structures have been applied for the fortresses depends on the goals of the spatial queries and analyzes. Since the gravestones are the spatial objects, node topology was created for them in the "*Kumkale* Cemetery SIS application". On the other hand, polygon topology was generated for the enter gate, which is called "*Bab-i Kebir*", and its environs in the fortress of *Seddülbahir* in order to track the temporal changes of "*Bab-i Kebir*". (Guney and Celik, 2003a)

With accurate position data and necessary epigraphic and morphological attribute data of the tombstones that corresponds to the identical physical objects, which users want to analyze, combined node topology structure in order to develop powerful "Ottoman Cemetery GIS application". This means that the structure of the physical object data in the GIS data must be attuned to the types of application that the system is meant for. The idea is that data has to be structured in a certain way to carry out certain types of spatial analysis. (Guney and Celik, 2003a)

Queries and analyzes realize on the various topologies present the researchers valuable information to find out some inferences. Prosopographical index in *Kumkale* Cemetery was generated using node topology and SQL queries. The relationships among the gravestones were presented with thematic maps. The temporal changes of the main gate of the fortress of *Seddülbahir* were traced and explained using various interrogations. (Guney and Celik, 2003a)

Visitors unfamiliar with the cemetery often have difficulty locating graves. If the cemetery provides paper maps showing the location of each grave, however, these paper maps often causes problems of their own due to their age (sections of the cemetery are 250 years old) and over recording of information – e.g where there is more than one deceased in a grave, recording and providing details becomes increasingly complicated. To alleviate these problems, 'Cemetery Management System' has been implemented as a web-based mapping system using Autodesk technology. The web-based mapping system based on Autodesk's MapGuide solution provides project staff and the public with accurate and reliable information. That using the web-based mapping system, the cemetery is able to provide the public with the ability to research the location of deceased relatives via the Internet, in comfort of their own homes, giving them access to a detailed location map and sufficient information to easily locate the grave within the cemetery prior to making the visit. At the system value is measured in term of being able to provide information in timely and efficient manner to the public. The solutions are of immense value to the public, providing them with correct information quickly and easily.

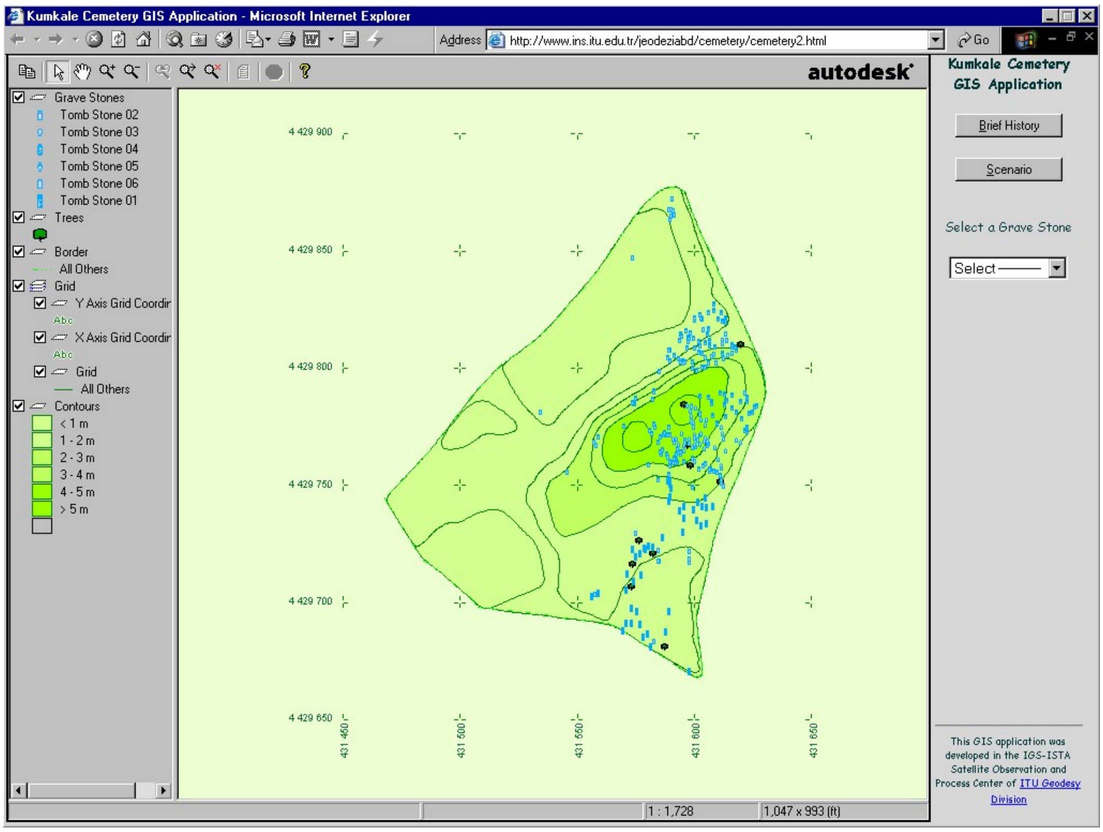

Figure 8.4: Web-based GIS application of *Kumkale* Cemetery

The specific plan of the entrance tower at *Seddülbahir* is not clearly known, but an examination through SIS based inquiry of several other entrance plans of Ottoman fortresses from the 15th century through the 18th century can be made to determine if there are any similar architectural components. This type of query can then be extended to include the entire plan of the fortress and make a comparative assessment of its design with examples of fortifications from the early modern Mediterranean region. Theoretically, as more cultural heritage projects turn to SIS for their data organizational needs, and put their data on the web, the power of this kind of system can be tremendous. “GeoCHEAF” provides web-based technologies that are based on open standards to stick interoperability and promote sharing of geospatial data and thematic & topological database queries regardless of country, application, or format. Moreover, graphical and geometrical overlay can be performed.

“GeoCHEAF” delivers geospatial data using following OGC compliant standards for GIS web services and web mapping since OGC specifications support interoperable solutions: Geographic Markup Language (GML) encoding specification (*may become de facto technology for data exchange*), Web Map Service (OGC WMS), Web Coverage Service (OGC WCS), Web Feature Service (OGC WFS) and Styled Layer Descriptors (SLD) implementation specifications.

OGC WMS technology enables users to easily query operational geoinformation using a standard web browser, simple hardware and limited bandwidth. Via the OGC transactional WFS, users can retrieve original feature-level data originating from distributed operational databases. The WFS transforms this data into standard GML encoding. The use of WFS separates the application logic from the database, thus improving interoperability between diverse data sources. (URL OGC)

In the design of the SIS architecture of “GeoCHEAF”, open source PostGIS/MyGIS and OGC-compliant (WMS, WCS) web map servers from Minnesota University (UMN's MapServer) have been selected because architecture has been already using PostgreSQL/MySQL database. Benefit of using PostGIS/MyGIS is map and other data being stored in the same database. Mapserver includes PHP scripting abilities and offers support of WMS and WCS. Maps are created by MapServer, data is queried directly by SQL. UMN's MapServer is used to broadcast the SIS applications over the web. Then, the connection between SIS application and some multimedia applications developed using Java Applets. This system design allows users to collect the geo-spatial data, author maps and layers, and create the application all in one central place in order to quickly publish maps and spatial applications to the web. It also allows users to integrate with GIS-based services, like Google Earth/Map or Map Quest, and GIS networks, like ESRI GIS Network.

MapServer is a CGI application that, although not being a full-featured GIS, offers enough core web-GIS functionality to create map-based web applications. Communication between the portlet and MapServer was achieved by using both a JavaBean acting as a wrapper for the CGI application, and a basic MapFile template that returned MapServer output variables as a java collection. This mechanism allowed the creation of maps with dynamically generated points to be used within the portlet.

The PHP MapScript module is a PHP dynamically loadable module that makes UMN MapServer's MapScript functions and classes available in a PHP environment.

MySQL has proved adequate for the task although PostGIS probably has better geospatial capability. PostGIS includes support for GiST-based R-Tree spatial indexes, and functions for analysis and processing of GIS objects.

UMN MapServer may be installed like a CGI or a module on a web server (in case of Apache). PostGIS possesses interfaces for the data exchange with MapServer.

A SIS is a tool that uses various forms of data as inputs to produce a map as an output. Because these maps are easier to understand than raw data, they can be used as a tool to communicate geospatial information to a general audience. SIS is a great success in both areas, but as time goes on, the more expected things have come. Until recently, 2D maps have been the only format available to visually process geospatial information. This is no longer the case because modern sensors, such as laser altimeter data, global positioning system, laser trackers, photogrammetric techniques and remote sensing, are providing a wealth of information that makes the third dimension possible in mapping. People wish to use SIS to manage data without being constrained by the inherit limitations of 2D maps. Internet, distributed mapping and 3D visualization technologies will make 3D web mapping common in the near feature.

While one problem in the past was lack of data, today, the problem in mapping is too much and too complex data and how to present and distribute these dense data to the public on the web. Many organizations have large volumes of data stored in SIS systems, and there is increasing pressure to make such data available to the public. However, simply making SIS data available on the web may not be the answer as shown in the figure 8.5. Therefore, in this dissertation, the design work also focus on the importance of cartography -cartographic quality, generalization capabilities, generalization technologies, cartographic design, cartographic publishing- to create high-quality, readable and legible map outputs from SIS, suitable for printing or publication on the web.

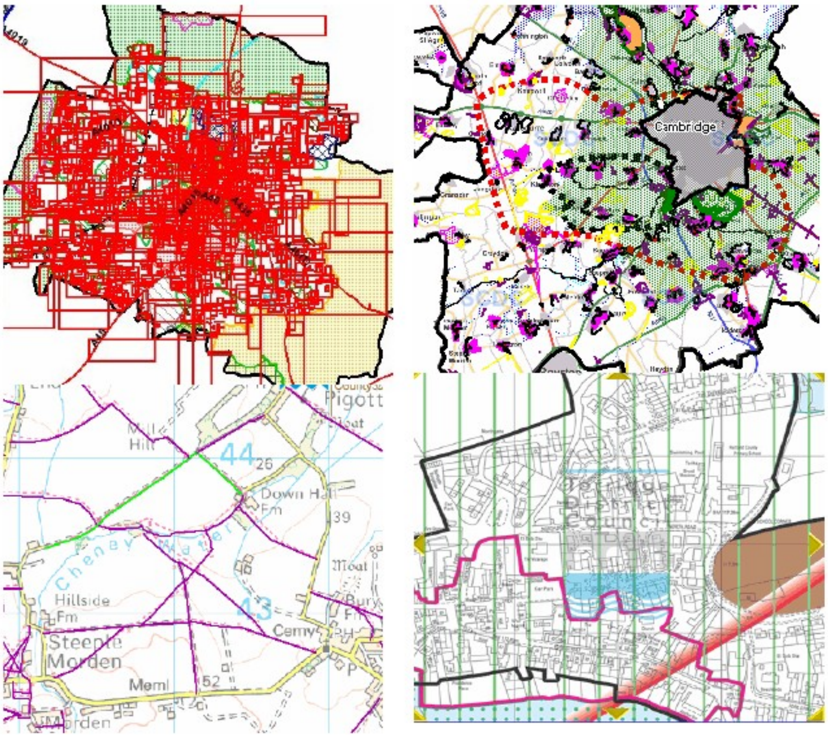

Figure 8.5: Bad web map samples

The development of GIS can be characterized as information rich and knowledge poor. That is, the amount of geospatial information collected using geospatial technologies, including remote sensing, global positioning systems and digital mapping technology, has been growing rapidly, whereas geospatial knowledge or 'useful information', for decision-making in terms of real-world problem solving is rather limited. Terabytes of geospatial information in the form of satellite imagery, aerial photos and maps have been integrated into Google Maps and Google Earth so that ordinary people using a decent Internet-connected home computer can zoom from space right down to street level and easily pinpoint their individual houses. Yet these services are considered information providers rather than knowledge suppliers. Current GIS still lack relevant tools for uncovering geospatial knowledge in various forms of patterns, structures, relationships and rules. This is another challenge today to be resolved. “GeoCHEAF” utilizes the data warehousing architecture within geospatial informatics architecture for spatial data mining and knowledge discovery.

8.8 Spatial Data Infrastructure

A Spatial Data Infrastructure (SDI) is a mechanism that unites and standardizes spatial information in and between organizations. The history of the SDI started in the year 1994, when the then North American president, William J. Clinton, published a presidential order to develop the National Infrastructure of Spatial Data for the USA (NSDI). The main idea behind this: “sharing knowledge is a source of economical growing”. In the year 2004, the European Commission also decided to create a SDI inside the European Community, called INSPIRE. The European SDI was composed like a puzzle, created by several parts of national and local SDIs. The aim is to maximize access to spatial data and minimize the redundancy of investments. (Alvaro and Wehrle, 2006)

SDIs are ideal way to acquire spatial data in different levels as follows:

- Global level (world-wide)
- National level (Turkey-wide)
- Regional level
- Local level

High accuracy positioning is now a reality for all users. There is a trend to capture data at highest resolution and then, use various resolution. There is also demand to access spatial data through geoportals that are the key components of the SDIs. A few main existing SDIs and SDI initiatives at different levels of development worldwide are shown in the table 8.3. Figure 8.6 illustrates spatial and non-spatial data acquiring component of “GeoCHEAF”.

Table 8.3: Main SDI activities

Place	*SDI Name*	*Level of SDI*	*SDI Initiative*
USA	US National Spatial Data Infrastructure (NSDI)	National Level	Geospatial One-Stop initiative with its web-based service, Geodata.gov
UK		National	GIgateway
Europe	European Spatial Data Infrastructure (ESDI)		INSPIRE, the INfrastructure for SPatial InfoRmation in Europe

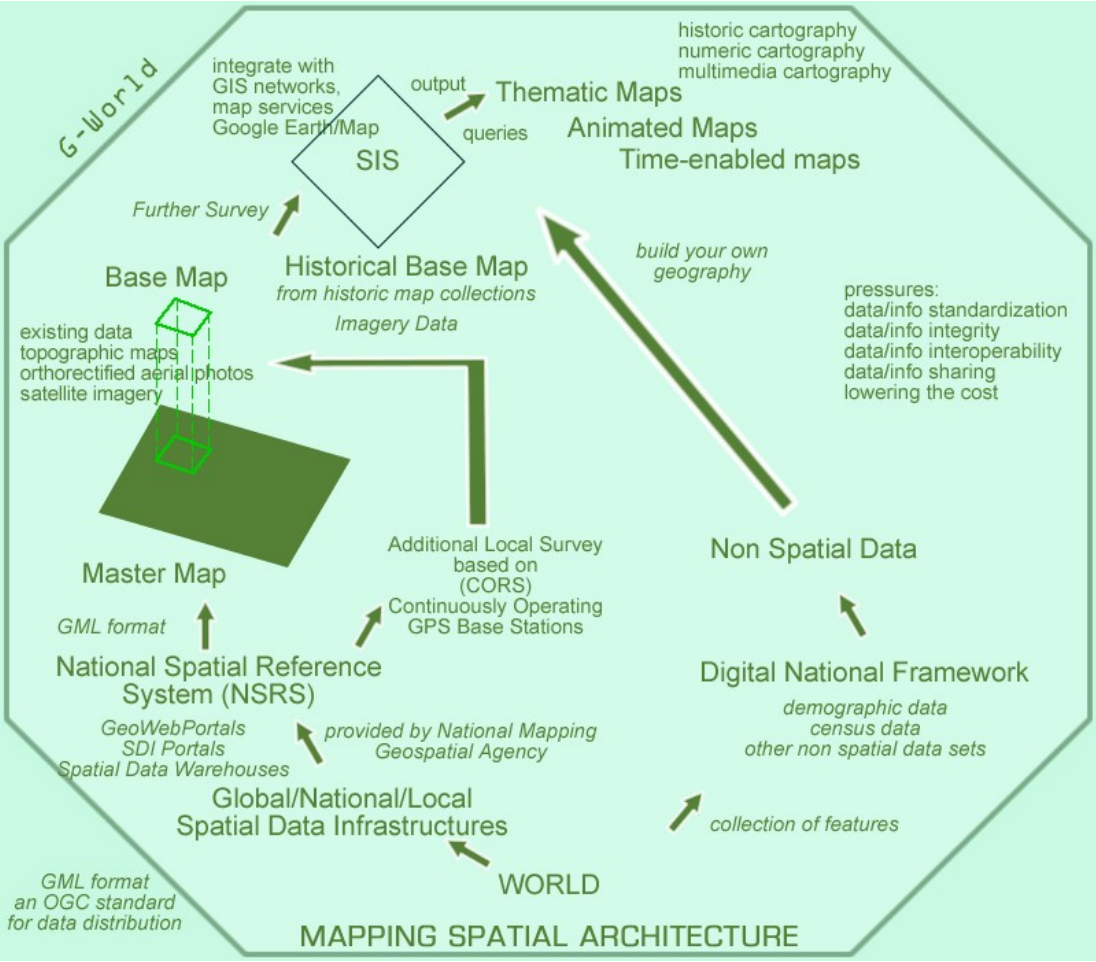

Figure 8.6: Interoperable spatial and non-spatial data cycle

There are two major organizations that set standards for the exchange of geospatial data sets:

- The Open Geospatial Consortium, Inc. (OGC) (http://www.opengis.org)
- The Technical Committee tasked by the International Standards Organization (ISO/TC211). (http://www.isotc211.org)

Both organizations were founded in 1994. ISO is an international organization and its members are mainly from the public sector, including national standards bodies and organizations. For example, the US national standard body is American National Standards Institute (ANSI). OGC's members come mainly from the private sector, including software vendors and GIS companies, such as ESRI Inc, ERDAS Inc, INTERGRAPH Corp, AutoDesk Inc etc. OGC puts great emphasis on working prototype implementations as validation for the effectiveness of a given standard whereas TC211 uses international representative consensus and review. OGC has a cooperative relationship to ISO such that OGC standards can become ISO standards (such as GML, location-based services, and metadata contents).

8.9 Geospatial Information Infrastructure for the Cultural Heritage Domain

If anyone was to ever calculate how much time is spent obtaining data, integrating it and cleaning it to make it fit with other data it would typically account for around 30 percent of a project or ICT development budget. If anyone then consider that this is happening in countless organizations in the CH sector as well as all other sectors, it is not hard to understand that a lot of energy and investment costs are being devoted to processes that are not really necessary. If this gathering, cleaning, and standardizing was undertaken once and reused -that money could be more wisely invested on developing the services. This would provide a better service to the end user and a much more cost-effective solution for the provider.

World is collection of objects of cultural and natural heritage resources. Each application projected in the CH sector takes a different view of the time period of the CH resource. In other words, the projects belongs to same time period but in different place could be correlated each other through a geoportal using standard data formats. To integrate spatiotemporal data, information, application and then share them, the CH community needs a "**Digital Global Heritage Framework**". Not only spatial data sets, topographic and thematic maps but also demographic data, geo-demographic data, census data, archaeological, architectural, historical data (including date of recording, recording by, structural changes (shape, size, width, length, height), construction date-material, technique, archaeological finds (ceramic, lithic, metal, textiles, bone, other), architectural features) and other geodata or geoscience data, and SIS files are shared via open standard formats, such as XML, and services on the web through a geoweb portal.

"Digital Global Heritage Framework" is primarily concerned with geospatial information and is relationship to other data and information from multiple sources for interoperable geospatial data sharing online relies on web-based geospatial data standards and services by OGC, such as GML.

Uncontrolled exchange, involving transformation, transfer and exchange, of data/information/content between enterprises (*organizations*) and systems (*departments*) within them is the reason for spatial data quality degradation.

Recently there have been some important archaeological advances with geospatial tools. An ancient Roman city has been deciphered and signs of a city that matches Atlantis have been unearthed based on geospatial tools. Even though such cases could happen different places across the world. There needs to be aggregation of the various disparate, yet exciting cases onto a common platform for sharing and dissemination.

Fundamental mission of "Digital Global Heritage Framework" should be: 'Generating a virtual globe on the web like CH-specific Google Earth for the CH community, which organizes the world's CH information by enabling users to publish their own data/information/content in whatever format, so long as it is compliant with OGC specifications, and make all them universally accessible for the CH community'. In this manner, users can search, find, see and analyze their concerned topics using a free search, visualization and sharing tool. Additionally, they can add value on the maps either to customize their own data set or to enrich the globe.

If the CH sector uses the geoenterprise architecture like “GeoCHEAF” individually, then integration of standard project based architectures could be done easily through a portal since, in the near future, more CH organizations will use GIS to share their results via the web, to visualize site data in 3D, to create animations, and to create and visualize multidimensional datasets. There will be tremendous potential in almost every subfield of the CH sector by utilizing a network-based CH-specific geospatial information services to access geospatial information, spatial analytical tools, and GIS web services (GIServices). The contents of the “Digital Global Heritage Framework” include not only displaying Internet maps or sharing on-line geospatial information, but also providing advanced GIS analysis functions and new information services. In this way, the entire framework would be open, distributed, interoperable, sharable and exchangeable rather than traditional architecturally closed and centralized information systems (GISystems). With the comprehensive architecture for bridging heterogeneous GIServices, researchers, scientists, stakeholders and agencies can easily share their geospatial data, GIS models, and knowledge.

9. CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

As stated in the introduction, the purpose of this dissertation is to explore the enormous potential inherent in an intimate relationship between the geoenterprise architecture concept and cultural heritage conservation and management challenges. The theoretical concepts underlying the approaches to be advocated here concerned the CH domain-driven science-oriented technology-enabled business-sensitive CH studies. The intention in this dissertation was to establish connections between post-modern approaches to the organization of knowledge and information and the implementation of this in the CH domain.

This dissertation began with a management introduction to the concept of the EA approach and its accompanying framework and methodology for the CH domain. It continued with a brief description of the interaction of technology with business by taking a holistic view of the natural cohesion of Business&Technology. Thereafter, business concepts were mapped to information technology concepts. Throughout this dissertation the motivation was to understand this interaction on a conceptual level and attempted to convey the message that geoenterprise architecture framework, which involves a strong business model and a strong technical architecture, should be considered as a necessity for the growth, maintenance and success of today's small, large-scale or complex CH organizations.

There is only one Enterprise Architecture for an Enterprise but there may be more Enterprise Solution Architectures within the scope of an Enterprise. “GeoCHEAF” was created to have the most optimum overall coherent geoenterprise solution for the CH domain, and provides a common basis for recognizing, understanding and communicating how systems (constituent parts) and their inter-operation and inter-dependencies in the extended enterprise are effectively structured to meet business strategic goals. The conceptual design of “GeoCHEAF” was explained and completed. However, a great deal of implementation work of it is now in progress.

Years of experience with distributed systems have led to the inevitable conclusion that it is practically impossible to eradicate incompatibilities between interfaces through standardization. Despite the best intentions, and investment in standardization initiatives, there will always be problems due to political, technical, geographical or philosophical boundaries. Hence, “GeoCHEAF” investigated technologies and their fusion to develop the best model that ensures the standards-based interoperability available across the entire enterprise, which transcends these boundaries by aligning business and ICT strategies in the enterprise architecture framework concept.

A meaningful mission of this dissertation is first to put “GeoCHEAF” to work via the projects regarding the Ottoman fortresses *Seddülbahir* and *Kumkale*. “GeoCHEAF” became the blueprint of the “KaleTakimi”s business goals, processes and underlying IT infrastructure. Subsequently, “GeoCHEAF” was developed as a design pattern that has proven solutions for the business requirements and goals of the CH domain indicated above. Lastly, it is being developed as an EA pattern, including semantic approaches, which have proven architecture blueprints for the CH enterprises. Open and ready-to-manipulate capabilities of the “GeoCHEAF” allow the other CH organizations to tailor their solutions freely and easily. Hence, the concepts and principles presented in this dissertation can be also applied to other cultural heritage projects.

The design of “GeoCHEAF” utilized open interoperable technologies (specifications, guidelines, software, and tools) to bring the power of cutting edge ICT technology to the study of CH resources and to create a modern-day enterprise CH e-business computing platform to support the entire life cycle of CH information: documenting, preserving, managing, presenting and communicating CH.

It is a common communication problem with technology architectures that contain parts that are front ended by different languages that it is not possible to integrate them properly. For example, a graphics system for mapping, which is hooked into a database, typically does not allow the full power of the database to be accessed from within the graphics command language, nor can the power of the graphics system be invoked from within the database query language. What is really needed is that all data and functions can be accessed and manipulated in one seamless computing environment. “GeoCHEAF” was designed to have interoperability in an open, seamless web computing environment in which all object- and service-oriented technologies and applications communicate in the same language.

The open, semantics and eXtensible architectures and standards-based interoperability feature of “GeoCHEAF” provides the ability to quickly and easily exchange, share, and distribute CH information to anyone and in any format.

“GeoCHEAF” was defined as a various visualization and interaction techniques supported GUI delivering on the web through distributed multi-tier architecture, based on spatio-bitemporal data model to manage the CH resources, to manipulate the CH research for fellows, to promote the CH teaching activities for students and to use as an edutainment means for pupils, children and their parents. It is also anticipated that delivering the described systems online is the change in the society’s perception of the CH resources. People can explore and appreciate all the information gathered about the CH resources.

“GeoCHEAF” was designed to assist the CH community by offering an innovative approach to simplify cultural heritage including (e-Heritage/e-Culture/e-Tourism as an e-business) management complexities, decision-making, virtual research environment, edutainment (education + entertainment), knowledge sharing, documentation service, a central storage and retrieval point for all data/information relating to the CH resources, sharing of them and knowledge across the extended enterprise and public users.

“GeoCHEAF” anticipates that its audience will be both the CH community involving archaeologists, historians, art historians, architects, conservation experts, museologists, curators, decision makers, stakeholders, sponsors, suppliers, other partners and the end-users such as visitors, and tourists on a global level. The capabilities of the framework will be housed on both DVD-ROM and a high-speed Internet server, thus allowing for many visitors, who are interested in, tourists and people who are interested in trying to discover the past.

While the comprehensive and sophisticated design of “GeoCHEAF” aims to illuminate the road towards the “future of the past” with a cross-disciplinary approach it hides the size and complexity of ICTs used behind an easy to use interface. However, the crucial point of the design is to position the web based-SIS at the center of the enterprise architecture framework and integrate with those ICTs in a coherent conceptual model with an executable architecture for optimized use.

“GeoCEHAF” provides an e-solution to let users in the systems within the enterprise, such as archaeologist and art historians, simply integrate the enterprise's base map with their own thematic geo-referenced information along with associated text information through the web-based SIS architecture of “GeoCHEAF”.

SIS must exist through a commitment to developing and exploring cultural heritage modes of inquiry, thus the usage of spatiotemporal SIS with 2D/3D hybrid web mapping instead of conventional SIS is unavoidable and dominant within the design of “GeoCHEAF”. To insure that SIS can benefit from other technical architectures of “GeoCHEAF” such as visualization architecture, including GUI and virtual reality technologies, and data architecture, it is essential to include data modeling and data management, where significant advances are needed to meet requirements of users whose profiles and needs have drastically changed.

The combination of an object oriented approach, such as object oriented programming&database management systems, and service-oriented architecture is one of the key components in building powerful applications which are robust and maintainable and which are also seamlessly extensible.

At the core of the framework is a *language* as a modular data encoding system which provides a technology to enable the data sets in various levels of detail to be handled in a structured manner. The need for a highly formalized language, in order to avoid ambiguities and misunderstandings in the data sets is required, as is the use of markup languages as a tool for documenting, querying, analyzing and subsequently interpreting the features of the CH resources in hypertext format. In this manner, the pervasive XML processing technologies are fundamental for this project because it is extensible and flexible; it can be used for exchanging information in a structured and definable way, and in applications with radically differing needs.

It is important to understand that XML is an elementary technology used for a broad range of purposes: XML can be used to exchange, format, search and transform data. For the CH domain, XML is a simple and convenient solution to the intractable problems of working with cultural heritage data, and is in fact the only technology that gives the CH community the means to share information between interoperable technical platforms, convert information between different data formats, document information in a structured and established information standard, and preserve information in a long-term, vendor-neutral format.

Markup languages playing a central role in the exchange of information. In this design, XML has been used as a documentation language (web markup language), UML has been used as modeling language, XHTML and CSS 3.0 has been used as an extensible web page formatting for the desktop and mobile Internet and all XML-enabled devices.

XML, the lingua franca of web services, is a web standard developed by the W3C and is the fastest evolving technology for web applications. It is a standard for describing, storing and transporting data across the web. The Internet is the hot medium for delivering information and GIS applications as it is playing a central role in the exchange of information. Markup languages open up new opportunities to build a semantic context model and to specify and exchange ontologies. The portal of "GeoCHEAF" relies on XML to make disparate pieces of information web-accessible in a common form. As such, it is presented as a prototype for the exchange of spatial information through a semantic context model.

XML can allow for the integration of data from disparate sources, with middleware applications pulling data from different databases and translating it into neutral XML for client-side processing. An XML document can contain descriptions of data that can be used in multiple applications, each application using the specific tags and delivering appropriate views for their particular tasks. As a behind-the-scenes language in web applications, XML, can readily combine together a wide variety of data types including text, graphics, audio, voice, spatial and more. This means that geometric data can readily be integrated with a wide range of semantic data types thus greatly enhance the value and accessibility of spatial information.

XML technology has the capability to serve as a communication protocol (or language) for information integration in a web environment, XML-based information mediation, among the distributed heterogeneous systems, applications, databases, web portals and portlets, data providers and CH specialists because of the following reasons:

- Text-based information exchange protocol ensures platform independence and easy implementation.
- The data provider can be any system with any data format as long as it can generate XML documents.
- The generated XML document is application independent, which can be used in any applications as long as the application can parse XML documents.

Java servlet programs are written to translate data in distributed websites into an XML document. Data in distributed websites can be stored in a flat file, relational database, object-oriented database or object-relational database. A Java servlet program in the mediator server will retrieve the data from related distributed websites in the XML format upon a request from the client side, parse the retrieved XML documents, perform merge or other operations on the retrieved XML document to build a new XML document and send it back to the client side. When the client side gets the requested data from the mediator, it will parse the returned XML document and draw it inside the browser using a Java applet.

Another key component is XML-based technologies for information integration in the XML-based web (as long as the web-based semi-structured information expressed is in tag-based XML). The third generation web applications (which may also be also referred as second-generation web) allows the developers to mark up the meaning of web data to make them understandable and automatically processable computers. They also open up new opportunities to build a semantic context model, and to specify and exchange ontologies. On such a semantic web, everything, from web documents to technologies for their visualization, tends to be presented using

XML. XML, SVG and X3D are the language choice for visualizing information in 2D and 3D, respectively. They can be integrated easily with other members of the large XML family and can also be processed using any XML-relevant tools and technologies.

The transition to the modern dynamic web and beyond has generally been neither organized nor orderly. Rather it was accomplished through independent innovation by many individuals and groups, sometimes collaboratively, sometimes competitively, and often in isolation. As a result, the web development landscape is cluttered with a variety of technologies and tools, and littered with obsolete or failed options that can trap newcomers. Besides newcomers face a long learning curve before they can become productive.

Many technologies are available, including application servers, distributed objects, and integration servers. The choice of technology is likely a mix of products and vendors that, together, meet the needs of an enterprise. It is very rare for a single vendor to be able to solve all problems. Even when using the most advanced frameworks or development environments to program simple applications, programmers must internalize several programming modes and languages within a single implementation stream. Examples are abundant, as in the case of the .NET Web programmer who must be minimally be familiar with HTTP, C#, ASP.NET, JavaScript, HTML, XML, WebForms, VisualStudio.NET, and various middleware interfaces of the .NET Framework, including ADO.NET for access to databases, before even starting to build an application. For example, in heterogeneous and changing software environment, today's Windows-based data-entry system may need to run on tomorrow's GNU/Linux tablet PC.

Technology selection is a difficult process that requires a great deal of time and effort. Creating the criteria for technology and products, understanding available solutions, and then matching the criteria to those products is hardly a piece of cake. To be successful, this "marriage" of criteria and products often requires a pilot project to prove that the technology will work. The time it takes to select the right technologies could be as long as the actual development of the SOA. While this might seem daunting, consider the alternative: picking the wrong technology for the problem domain. A bad choice practically ensures the failure of the SOA applied.

An extensive survey, several categorizations, comparisons and assessment of technologies related to web programming, web application development and dynamic content generation systems have been presented. The classification was based on (1) foundational technologies; (2) integration with other information sources such as integration with SIS; and (3) dynamic content generation. The several figures and tables presented throughout the dissertation can serve as a roadmap for platforms, languages, frameworks and choosing technical artifacts according to specific application needs. Although the infrastructure problems of the web applications have largely been solved, web application development is still hard and the cacophony of technologies for web-based applications reflects the lack of a solid model tailored for this domain.

This dissertation has proposed the following ideas:

- Multiple tiers are better than a single tier.
- Business logic is better represented in objects.
- One must work only with objects and not data.
- Transactions should be controlled by the framework and not by the business components.
- One object for one service.
- Write for single tier, but deploy in a multi-tiered environment.

Middle tier architecture is taking a turn towards the well tested SOA. SOA and web services technologies will drive the standards-based interoperability mechanism between distributed services. Web services and web services architecture is a new paradigm for web application design within the enterprise. Leveraging the expressiveness of XML and web services bring interoperability and flexibility to enterprise applications. By leveraging the progress made to date through the standardization of databases, application servers and Internet communications, web services present a model for the applications of the future. Web services are revolutionizing the way enterprise systems are designed, integrated, and shared.

Within a decade of its inception, the web evolved from a static hypertext presentation medium into a standard user interface technology for a growing class of interactive information systems. The initial web implementation, defined by its static nature and a purposefully low barrier to entry, was sufficient for sharing documents but inadequate for more advanced applications. Up-to-date information and effective user interfaces, essential requirements for online service applications, could not be practically implemented with only static content. Methods for providing dynamic content on-the-fly in response to user requests were developed to meet the demands of web service applications.

The development model for dynamic and interoperable Internet GIS applications is based mainly on the dynamic integration of Internet GIS components by applying XML, XML Web Service, GML, and SVG, etc. The web-based GIS applications highlight the concept of "service-oriented" rather than "system-oriented". In the scope of the dissertation, the following ideas are also propagated:

- Internet GIServices are user-centered: In the past GIS users were forced to rely on GIS professionals to interface with geographic information sources. Misuse of geographic information results from miscommunication between the GIS users and the GIS professionals. Future GIS service interactions will reduce miscommunication by giving end-users direct access to GIS components and service agents tailored to the particular task.

- Internet GIServices focus on long-term, evolution-type operations: Distributed GIServices will emphasize long-term information services rather than project-based, short-term GIS solutions. Traditional GIS are difficult to be migrated and upgraded into a new system. Internet GIS with dynamic architecture can easily be upgraded to a new framework and continue their services in the long run.

- Diversified GIServices are required: In the demanding applications of the future, different users will require different information services, different tasks require different information sources, and different countries require different information interfaces. Internet GIS will provide a dynamic architecture and customizable GIS components in order to create the diversified, customizable information services necessary for diverse situations.

Data Streaming is also another key component. The "GeoCHEAF" concentrates on combining diverse data sets -*spatial data sets* taken from geodetic, photogrammetric, architectural and archaeological surveys, and *non-spatial data sets* taken from documentary research, oral history and excavations- within a model of an integrated SIS. Geospatial and attribute data is retrieved from the data storage tier and is to be further analyzed based on requirements using data mining techniques. The analysis results are presented in various visual forms. The data described and stored in GML can be extracted and customized to suitable graphical representation either by direct rendering, or preferably by transforming the XML encoded geographic features (GML) into XML encoded graphic formats such as SVG or X3D since the GML encoding is not concerned with the visualization of geographic features. XSLT could be applied to the geospatial content (GML) to generate 2D (SVG) and 3D (X3D) cartographic presentation. Such a transformation can be done anywhere in the processing chain between the data store and the visualization component. Within this context there is a tight integration of 3D visualization technology with already widely spread enterprise level database technology. At the same time modern object relational database management systems provide a basis for extending a database with user defined data types and functions. These ORDBMS are therefore predestined to integrate external technologies such as visualization technologies.

Digital data that is being created, converted, syndicated or scanned needs a repository to reside in so it can be accessed by a content management system and served to a user. These database systems must be secure, reliable and expandable to create a stable environment for the storage of content. This can often only be guaranteed through the implementation of a dedicated storage environment.

The CH community has been too much on its own; it has neglected to look around and see how the gaming industry has found better ways to make large datasets viewable in an interactive way. The potential is greatly increased for visitors to engage in virtual experiences of the CH resources, such as the fortresses, the access to which is limited by physical distance, conservation requirements, or limitations on exhibition space. In the virtual fortresses, the documentation of the fortresses is available at any time online. Using VR technologies, a series of low-end, 3D models have been constructed that are navigable through the web. This gives the visitors the opportunity to visualize, explore and learn about historical sites in their original content.

Applications have been moving to the web in various shapes: simple forms, scripted pages (DHTML), AJAX and RIA using client side frameworks like Java or Flash. Each component in a solution framework comprises a SOA that can fit within existing server-side technical infrastructure and a client-side RIA component (Ajax) that implements the look, feel and functionality of the component.

The visualization architecture of "GeoCHEAF" presents a modular software- and hardware-independent framework for the 3D reconstruction in the area of cultural heritage. This framework can be used for the digitization of 3D cultural objects, monuments, and sites. The clouds of 2D or 3D scanned points (matrix oriented or scattered) and even the 3D wireframe model are acquired by photogrammetric techniques (for example, digital cameras or laser scanners) using different digitizing strategies in various fields of cultural heritage. This input can be processed using an efficient algorithm for the reconstruction of the digitized object. If the digitization delivers a complete set of scanned 2D or 3D data from all sides of the object, then the volume or so-called solid structure can be calculated. In addition to this, using special objects such as mummies, jewels, or, in general, metal or ceramic artifacts that have interior structures (holes), the internal geometry can also be measured through the use of x-ray scanners, and in this way the complete 3D reconstruction of the object can be achieved. Furthermore, the development system can generate the exchange of the processed data with other systems (CAD/CAM, e-libraries, e-museums) into 3D data sets in standard data exchange formats (IGES, STEP, VDAFS), as well as to VRML format for the visualization by a standard browser on the web. A variety of visualization techniques can be used for different multimedia and virtual reality applications.

Building 3D models, storing them and providing a user interface to visualize and manipulate them require new database and graphic technologies and robust programming languages. What is really needed is a framework where all data and functions can be accessed and manipulated in one seamless programming environment. “GeoCHEAF” has been designed in order to build an open, seamless development environment.

The holistic, adaptable and achievable design of the technical architecture of “GeoCHEAF” which comprises of streaming model of web computation that is from real to virtual, from low-cost to high-tech (high-performance), a digital infrastructure, cross-platform architecture and services with wide public accessibility, takes the best advantage of a common modular component-based design approach.

“GeoCHEAF” offers the followings business benefits for the CH domain:

- achieves sustainable and successful management of systems, users, resources, services, data, information, knowledge and contents
- ties all these components together in an all-in-one model
- improves team collaboration, cost and efficiency savings
- responds quickly and effectively to changing circumstances, opportunities, emerging threads at reduced cost and risk
- stores and centralizes massive and complex data, metadata, information and tremendous content in one united repository
- collects data once, uses it many times; avoids duplication and inconsistencies in data/information; reduces data management costs
- enables dynamic interaction, advanced visualization and manipulation of vast volumes of data/information
- presents and distributes digital content through a unified web portal to its various users in a highly secure and reliable manner on a 24x7 availability basis
- uses cutting-edge visualization solutions and data harvesting techniques to improve data/end-user interaction
- applies a virtual time-space approach based on SIS

- makes all business processing web-centric (web-based)
- facilitates process, interpretation, exploration, query and analysis of large volume of data/information with significant geospatial and temporal characteristics through web-based SIS applications that meet critical business needs
- provides service-oriented applications, dynamic & interactive web mapping services through a web geoportal.
- reduces solution delivery time and development costs
- improves interoperability among various systems
- shares knowledge internally and externally
- supports better decision-making
- makes effective use of emergent technologies, solves technology integration challenges, streamlining the technology; reduce complexity and cost
- ensues adequate security & authentication
- proposes Ajax supported dynamic web applications and XML-based web services over the semantic geoweb in a SOA model as ways of building high quality and flexible enterprise-scale e-heritage solutions in the CH sector
- exploits web services together with portal/portlet technology to create a more efficient model for access/reuse of existing networked data.

"Sharing" is the major concept of "GeoCHEAF". To sharing data, information, and knowledge among the CH community, standardized communication protocols, standardized metadata contents, and interoperable programming interfaces are essential for the success of "the future of th past". Therefore, "GeoCHEAF" is a sharing hub for the proposed efficient interoperable global CH network or all interconnected systems of the enterprise, which exposes how the CH data/information/content/application can benefit from the dynamic interoperability and distributed services issue through the following scenario:

- On site, CH recording is achieved by a mobile computing component (a local fieldwork unit) and uploaded to the server farm in XML format and automatically validated by the XML program and checked by the CH manger without the need for extensive printing and posting of reports. Depending on the status of the record and the role of the user, this record could be requested for amendment and validation, either via the same or similar portlet interface or perhaps a local application, and returned to the system. At some point, the same record could be marked as 'public' where it would automatically become available for request by the general public.

- CH spatiotemporal object data/information/content/application are encoded and presented with a structured XML document along with its standard CH-specific & CH community-wide defined schema rather than a common XML schema, such as MidasXML, OCHRE (formerly XSTAR), ArchML or Dublin Core (consolidation will be more useful than elaboration), that can be validated to ensure data integrity and coherence without the need for human interaction. For an SOA system to be truly effective, the use of various XML schema are considered necessary to ensure that all interconnected systems of the enterprise can design their systems to be interoperable. The CH data can be prepared in such a way that lends itself directly to the concepts that drive the SOA model.

- After the CH information can be structured in a standardized manner, the developers create an application that can find, extract and present information to the user in a more appropriate format.

- CH communities expose their NXD repositories as XML-based web services, portal technology, and inter-communicating portlets. The portlets of CH communities' portals send queries to each of the data sources, returning results as a collection of XML formatted data, and then, XSLT transformation can be exported in a number of different formats (e.g. Word, PDF, txt etc.), in a way best suited to a portal environment.

- Heritage organizations, museums and libraries considering making data sets available through web-portals (Inter-operable systems and people)

- Global CH data/information/content/application discovery network for diverse information collection, collation, aggregation, integration or presentation services. (a standards-based CH (re)search tool across different data sets on the web - virtual research environment)

- Data mining and web mining, (looking for information on the Internet, not just data files for downloading but actual data from within such files), and decision support and making. (realize the benefits of a network of semantic websites)

When conducting online portlet-based research, aggregating information from these searches across the different datasets, and making data available from different sites in different locations for different user groups need dynamic interoperable data sharing on a global scale for the CH domain via XML-formatted datasets.

GIS is inherently distributed and its databases have cumulative nature. Today, there is widespread recognition that the data layers and tables in most geographic information systems come from multiple organizations. Each GIS organization develops some, but not all, of its data content. At least some of the layers come from outside the organization. The necessity for shared GIS data drives users to acquire their data in the most effective and timely manner include acquiring portions of their GIS databases from other GIS users. Thus, GIS data management is distributed among many users.

How information from different sources pertaining to the historic environment can be gathered together and presented in one place to improve and accelerate the flow of information about CH resources is defining standard service components for interoperability among geospatial data and information portals.

The archaeological community must attempt to create standards for artifact descriptions or to encourage/enforce the use of existing standards, various archaeological organizations from many countries would need to be involved, as would archival organizations in the collection, management, exchange and long-term preservation of CH data.

The main purpose of standardization is to promote geometric and non-geometric encoding standards as these are particularly important in facilitating the transfer of self-describing databases. To do so, all data sets must be documented, and a seamless interpretative framework must be established. XML is intended to facilitate the exchange of information in a well-structured yet highly flexible manner.

Another archiving strategy that must be defined is the process of data transformations from one XML format to another. While the process still entails that a 'mapping' between schemas that is created manually by someone familiar with both, the mapping itself can be read by most XML software applications for large-scale data transformation.

The CH organizations increasingly face the challenge of integrating various web services, applications, and other technologies into a single network. With this mechanism, “GeoCHEAF” hopes to provide information, strengthen co-operation and networking among CH community members, as well as to provide assistance for the improvement of CH management.

In addition to developing technical solutions, a series of recommendations and management are required for the effective workflow of information, from local fieldworker to regional heritage curator to national agencies and the public. How fieldworkers report surveys, excavations is one example. Bringing information resources together in a web-portal depends on policy decisions made at senior levels in organizations, funding agencies and in government departments.

The key to faster, better, discovery of CH information is metadata which can be quickly and thoroughly searched by computers and presented in an understandable form to users. Therefore, the CH domain needs standardized metadata entries and a standard metadata framework or frameworks.

Whichever method is used to support technical interoperability, web-portals also need to achieve semantic interoperability between databases to return useful sets of results to its users to share information on the semantic web.

For CH enterprises, using “GeoCHEAF” based on structured methodologies and proven ICT processes help to increase its key features: interoperability, flexibility, extensibility, scalability, re-usability, reliability, adaptability and to reduce complexity, risks and costs associated with multi-tier development. It is widespread, device-independent, and provides access to a SIS for large numbers of contributors and users. These specifications of “GeoCHEAF” enhance productivity and overall effectiveness of the enterprise to build more understandable, easier to configure, more rapid development, and lower cost systems.

In addition to all these benefits of “GeoCHEAF”, the implementation of it is cost-, labor-, as well as time-effective. Since the computing infrastructure of it relies on standards-based open source technologies, it can be scaled to the user's future needs and/or exponential data growth with the lowest operational and administration costs. Furthermore, users will be able to avoid redundancy and consequently reduce both cost and time during each CH project.

Having the right technology might be important, but not as important as having the right combination of skill sets to address and deliver. None of the features are novel, but the packaging of the features within a single environment as depicted in Appendix B is timely and has gained momentum with developers. As mentioned above, each of these capabilities alone is useful, but the ability to fully integrate these in the overall “GeoCHEAF” context creates a powerful synergy effect. When implemented “GeoCHEAF” will reduce redundancy, enhance decision-making capacity and improve operational efficiency. This architectural approach allows enterprises to make hardware and software choices best suited for themselves, requiring only correct measure of ICT penetration when using and applying of technologies.

“GeoCHEAF” was developed as a modular customizable framework for the CH community to make them more effective in almost every sense if they re-envision their own specific CH business and informatics technology priorities through the “GeoCHEAF”. Although the remarkably capable and reliable conceptual design of “GeoCHEAF” benefits from business and technical innovations, “GeoCHEAF” should not be seen as panacea to solve all CH related problems.

It must be remembered that the proposed conceptual model is largely based on observations of technology gained from specific literature, rather than as a result of direct working experience with each and every component despite some of the required technology utilized for the documentation, survey, restitution, restoration and re-usage project of *Seddülbahir* and *Kumkale*.

It is the time for change. Computers have changed a lot, but people have not. When CH organizations and the related research in this field are able to expand the more narrow and traditional definitions of business the conceptual framework will be greatly enriched and the sharing of CH resources and information will be greatly facilitated. The challenge of change begins with the “GeoCHEAF”s motto: 'think globally, act regionally'. Under this motto “GeoCHEAF” seeks to reach out across the CH domain for partnering with CH enterprises' research, development and solutions.

In conclusion, this dissertation was intended to be a pioneering study for the CH domain, which assists the organizations and researchers methodologically to ensure information-based CH management, to develop new approaches to the CH field and to facilitate further research for exploration and communication of the past regardless of dealing with complex business and technical issues addressed in this dissertation.

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APPENDIX A

LANGUAGES

To communicate with the CH community the languages are needed.

Spoken language is very intricate, dynamic and exists as a moment in time. Written language often includes special style formatting, for example, references to another text are represented in by a footnote or endnote, simply do not exist in spoken language -the context is specific to the realm of written or printed language. Special written symbols have been created to augment limitations of verbal language, for example, mathematical and scientific symbols. Written text often intended to contain far more information than conversational language. The issue of referencing paragraphs and quotations non-existent in spoken language. Computers have dramatically changed construct of written language. Concepts such as hypertext links, which are now often taken for granted, really supersede written language and are plainly irrelevant to spoken language. The web has started to cause a paradigmatic shift. Traditionally written language has been static. As the basic web page is superseded by complex on-the-fly parsing, direct user participation and the intermeshing of 3D video display with text, rich audio, and other sensory features, the medium of printed text is losing its staticiticy at an immense rate. (Tworkowski, 2001)

Languages:

1. Spoken Language
2. Body Language
3. Written Language
4. Computer Languages
    a. Markup (Encoding) Languages
    b. Programming Languages
    c. Database and Query Languages
5. Geographic Language ("Cartography")

A document with markup can do nothing by itself. A programming language can easily process the information in markup for different uses. Markup languages identify similar units of information and aids the way in which an application can read and process the document.

MARKUP LANGUAGES

"*With the invention of the telegraph, we saw the beginning of what is known as the Information Age. This machine was a tool that could transmit information over long distances. Dots and dashes, known as Morse code, is the "language" that is used to convey the message. The telegraph machine doesn't "know" anything about the information being transmitted. Today, the computer is at the heart of the Information Age. As our demand for information has increased, so has our demand to have the machine "understand" the information and make use of it."* (Zijm, 2000)

The term *Markup* has its origin in publishing and printing industry. The stylistic instructions were written on a manuscript prior to being typeset are known as *Markup* to provide the typesetter with instructions as to how things should look. (URL, 2004a; Zijm, 2000) Basic markup has existed for centuries, for example, notes in the margins of medieval texts, Gutenberg's "reminders-to-self" as to how to set up the next page on his infamous press. The origins of markup can be traced back to the simple markup of written language from the days of antiquity. The marking up of written language is probably as old as written language itself. (Tworkowski, 2001)

In the electronic world, *Markup* is text that is added to the data of a document in order to convey information about it. (Courtaud, 2002) Markup is code that is included when a document is created often to provide display instructions, but also to provide meaning or semantics to words or phrases or to provide processing instructions. If one used the first word processors s/he will probably remember including codes as s/he typed to make text bold or *italicized*. Modern word processors still use these codes, but for the most part they are hidden from the end user who applies them with a click of a mouse. (URL, 2004a)

Why markup matters? (Courtaud, 2002)

- Preservation
  - How does markup affect a document's "longevity"?
- Access to information content
  - How does markup affect a document's "processability"?

A *markup language* is formalized way of providing markup that is a group of tags which is inserted into document's content. It is a kind of text encoding (or code) that represents text as well as details about the structure and appearance of the text. A common feature of many markup languages is that they intermix the text of a document with markup instructions in the same data stream or file. (URL Wikipedia) Very popular markup languages are HTML, XML, and XHTML.

Several generalizations about markup can be made: (Tworkowski, 2001; Courtaud, 2002; Brooks, 2004)

- simple (or procedural) markup (physically based markup schemes - physically formatting, presentation)
- descriptive (or declarative) markup (logical structure - logical document model of a document independent of its physical representation)
  - structural markup and semantic markup

Declarative markup separates the physical formatting of a document from its logical structure. (Cameron, 2003)

Another categorization could be done to the type of user (human versus machine) for whom they are designed and to compare what computers need with what people need. For example, when parsing data, machines decode, while humans read.

There is a specific grammar or syntax that needs to be used when elements are created so that computers will be able to understand. (URL, 2004a)

Brief History of Markup Languages

There is a direct lineage between markup as used by typesetters to layout complex documents and the markup languages common today. The roots of Markup languages go far and wide. There have been many people that contributed to the development of past and present markup languages. In an effort to keep this appendix brief, only some of the major events and people involved will be mentioned. Although there have been other markup languages in use over the years, the following language families are of particular importance.

1. Birth of the modern markup languages

Starting with a simple system to run off a document on computing systems of the 1960s, **troff** (typesetter run off) or **Runoff** or **nroff** represents the culmination of a family of markup languages that have been widely used with UNIX. **Scribe** is the first widely used markup system based on the logical document model. (Cameron, 2003)

Most people believe that modern markup languages had their beginnings at a government meeting at the Canadian Government Printing Office, in Ottawa in September of 1967 when an American William Tunnicliffe made a presentation titled "*The Separation of Information Content of Documents from their Format*". He presented for the first time the idea of separation between the contents and formatting of a document. During this period of his life he was chairman of the Composition Committee of the Graphic Communications Association (GCA). At the same time, Stanley Rice, an editor and a book designer at a Major Publishing house in Newyork was writing about "*Standardized Editorial Structures*", a set of labels allowing to describe a so-called *editorial structure*. This was the beginning of a movement to separate the formatting of a document from its content. GCA took this idea together with Tunnicliffe's work to create the GCA Gencode Committee and a project named **GenCode** stemmed from the works of Tunnicliffe and Rice. Some main conclusions of the committee after many meetings: (URL, 2004a; Brooks, 2004; Zijm, 2000; Courtaud, 2002; Tworkowski, 2001)

- It is impossible to describe all the documents with one set of codes
- Markup should be descriptive rather than procedural
- Markup should take into account the hierarchical structure of the document.

GenCode was created as a generic typesetting codes for clients who sent data typeset differently to different vendors. GenCode allowed them to maintain an integrated set of archives despite the records being set in multiple types. Some important concepts that exist today are the product of this committee. In 1969, Charles F. Goldfarb, a young attorney practicing in Boston and two years out of Hardward Law School joined IBM to lead a project to create an integrated juridical information system. Charles Goldfarb resumed the works of Rice and Tunnicliffe for GCA Gencode committee and extended them creating the concept of well defined documents with his colleagues at IBM Edward Mosher and Raymond Lorie. They cerated a markup language with nested structures specifically to make searching through legal resources more manageable and they called **GML** (initials of the creators). (URL, 2004a; Zijm, 2000; Brooks, 2004; Tworkowski, 2001; Courtaud, 2002) GML proposed by Charles Goldfarb based on the premises that: (1) markup should describe a document's structure rather than its physical characteristics, and (2) markup should be rigorous so that it can be unambiguously understood by a program or a human interpreter. (Zijm, 2000)

GenCode and GML are first two attempts at managing structured documents in a standard open format optimized for free, cross platform exchange and manipulation.

2. From GML to an international norm: SGML

In 1978 American National Standards Institute (ANSI) created The Computer Languages for the Processing of Text Committee and this committee invited Goldfarb to elaborate a norm for text interchange and a markup language for future processing based upon the GML language. Despite the surrender of GenCode, GCA joined this committee. Several years later and with the influence of hundreds of people, **Standard Generalized Markup Language (SGML)** was born and new concept of structural markup with first working draft of SGML was introduced in 1980. (Courtaud, 2002; Zijm, 2000; Brooks 2004)

SGML added additional concepts that were not part of the GML project such as link processing, concurrent document types and most importantly the concept of a validating parser that could read and check the accuracy of the markup. (Zijm, 2000)

SGML is a well-documented markup language that provides a standard-based storage and exchange format.

In the 1970’s the popularity of GML and SGML grew as the benefits became obvious. By 1980, 90% of IBM’s documents were produced using GML. In 1983 GCA recognizes the Sixth Working Draft (WD) of SGML as a GCA norm (GCA 101-1983). Department of Finance (IRS) and Department of Defense (DoD) were first important academic users of SGML in the USA The DoD began using GML in the 1980’s and eventually the Army required that contractors submit documentation using SGML. SGML was becoming more standardized and, at the same time, was growing as a standard both in the US and internationally. In 1984 ISO joins the WG of ANSI and Goldfarb leads both committees. (Courtaud, 2002; Zijm, 2000) SGML was the next iteration on GML and was promulgated as an ISO international standard in 1986 (ISO 8879/1986). (URL, 2004a; Brooks, 2004; Courtaud, 2002)

The SGML document structure is an inverted tree structure -a root component branching out into leaves. There are three objects: (Courtaud, 2002)

- **Elements** are the basis structural components
- **Attributes** are qualities of elements
- **Entities** are a short representation of special characters

SGML differs from other markup languages in that it does not simply indicate where a change of appearance occurs, or where a new element starts. SGML sets out to clearly identify the boundaries of every part of a document. To allow the computer to do as much of the work as possible, SGML requires users to provide a model of the document being produced. This model, called a DTD, describes each element of the document in a form that the computer can understand. The DTD shows how the various elements that make up a document relate to one another. (Brooks, 2004) The documents (or the syntax of the SGML file) can be validated against DTD. It is possible to do these controls automatically and programs which do this job are called parsers.

SGML is the basis for various markup languages that are in common use today. (Tworkowski, 2001) SGML with thousands of applications and options is extremely complicated and more powerful than needed for most applications, therefore SGML can provide detail markup for just about anything – music, archaeological digs, movie scripts, etc. (URL, 2002; URL, 2004a; URL Wikipedia) Despite its advantages, SGML remains a niche market in the 1980's, not well supported by the major editors of the software market since SGML specification was complicated and not designed for easy implementation. (Courtaud, 2002) It appeared that SGML would be limited to niche uses while "What you see is what you get (WYSIWYG)" tools (storing documents in proprietary binary formats) would take over the vast majority of document processing. (URL, 2002; URL, 2004a; URL Wikipedia)

During this period new user paradigms: (Courtaud, 2002)

- Networks are developing themselves
  - ARPANET created in 1968 has hundreds of computers
  - Network protocols are created: TCP/IP (1974 - 1978)
  - First ideas of a network of networks
- Hyper navigation
  - Theory: Ted Nelson (1982)
  - First implementation: Hyper Card (Apple) (1985)
- First Information systems: WAIS,Gopher (1985 - 1990)

3. Subset of SGML: HTML and Web's birth

The credit for the development of HTML and the web is given to Tim Berners-Lee, who is a network engineer, with his knowledge of the networks, the hypertext and SGML while working at CERN (Conseil Europeen pour la Recherche Nucleaire - European Organization for Nuclear Research) in Geneva. In his World Wide Web Proposal (WWWP) explicitly outlines the need for an electronic networking infrastructure model from human networking infrastructure. In 1989 March, Tim Berners-Lee and a collegue, Robert Caillau, were working on a linked information system to make it easy to share scholarly information between physicists. Their system used a NeXT computer and incorporated the concept of hyperlinks. Tim realized the need for a markup language that was easy to use and implement into their system to facilitate links ("click-here-to-go-here" type links) between documents and for display in a browser, and so HyperText Markup Language was born along with the web in 1991. (Zijm, 2000; URL, 2004a; Tworkowski, 2001; Courtaud, 2002)

At the beginning of web three main concepts of web:

- a network protocol HyperText Transfer Protocol
- an SGML compliant hypertext markup language HTML
- a hypertext document location system Uniform Resource Locator (URL)

In October 1994, Tim Berners-Lee founded the World Wide Web Consortium (W3C). The mission of W3C is to create an open forum in which to lead the technical evolution of the web. HTML went through several versions as new features were added along the way: (Zijm, 2000; Courtaud, 2002)

- 1991: HTML 1: first implementation by Tim Berners-Lee on a NeXT computer at CERN
  - Use of SGML tools to create HTML language (DTD, parser)
  - Simplicity of the language and universality of the web against Wais or Gopher are the basis of the web success
  - Many HTML compliant text browers: Viola, Cello (CERN), Lynx, etc.
- 1993: HTML 2 = HTML 1 + Images + Forms
  - First graphical web browser: Mosaic at NCSA
  - Evolution of HTML reflects the new Mosaic capabilities
  - The *killing application* of the Internet is born
  - Number of web servers explode; HTTP precedes FTP on the networks
- 1995: Beginning of the competition
  - Microsoft retires MSN (Microsoft Networks) to adopt the web
  - Marc Andreesen and his colleagues leave NCSA to found Netscape
  - Beginning of the specification of HTML 3
- 1996: Beginning of the commercial web
  - Apparition of Internet Explorer and Netscape Communicator
  - Divergence of the set of supported HTML tags between IE and Netscape
  - Standardization of HTML 3.2 long and difficult
  - New technologies: Java, DHTML, etc.
  - Creation of the WWW Consortium to safe the standards of the web
- 1996-1997: Needs for a more powerful web
  - Explosion of the HTML tags with an increasing incompatibility between the various browsers
  - HTML 4 standardization seems difficult or even impossible (it was finally standardized in 1999) due to different interests between scientific or technical applications and commercial ones
  - Explosion of applications
  - HTML and the web are used for applications they have not been designed for
  - Legacy applications want to be able to use the web technologies
  - Needs for a more abstract and a more semantic language

HTML is a document-layout and hyperlink-specification language. It defines the syntax and placement of special, embedded directions that are not displayed by the browser, but tell it how to display the contents of the document, including text, images, and other support media. (Brooks, 2004)

Adding effective DHTML content to the pages requires an understanding of other technologies, specified by additional standards that exist outside the charter of the original HTML Working group. DHTML is an amalgam of specifications that stem from multiple standards efforts and proprietary technologies that are built into the two most popular DHTML-capable browsers, Netscape Navigator and Internet Explorer, beginning with Version 4 of each browser. (Goodman, 2002) Technologies covered by Goodman: (1) Cascading stylesheets and (2) JavaScript. In 1994 Hakon Lie proposed the concept of Cascading Style Sheets (CSS) to aid web authors produce more consistent and expressive HTML pages. (Brooks, 2004; Abrams, 1997) CSS1 (Dec. 1996) allows incorporation of page style (e.g., fonts) and layout (e.g, positioning) info. CSS2 (May 1998) supports additonal features and improvements in CSS3 (2000s).

As an SGML compliant language, HTML has a DTD. It has also a fixed set of tags of the SGML syntax as a simplified version of SGML and/or an online subset of SGML. At the beginning, the number of tags are limited (~10) and are very easy to remember and to use. (Courtaud, 2002) The situation changed dramatically. In HTML the markup consists of a set of “known” tags that handle common formatting tasks. However the language was originally created to markup simple scientific papers and therefore had to be greatly expanded in order to offer the rich content the web has today, and for this reason the additions often follow no logical design, although recent efforts have attempted to address this. HTML is likely to be the most used document format in the world today. (URL Wikipedia) It is the first only encoding system most people know.

HTML was originally designed to handle only the logical structure of a document: headings, paragraphs, links, quotes, etc. Web authors wanted more expressive documents so HTML acquired more and more tags devoted to fonts, margins, colors, etc., hence the development of style sheets. Style sheets can be used to give a common or consistent "look and feel" to either one very voluminous web page and/or thousands of web pages. What if an organization (e.g., Ford motors, a law firm, etc.) has thousands of web pages available and everybody was doing their own thing? Different fonts, different colors, different logos, etc. Common Look and Feel (CLF) becomes important in creating and maintaining a certain *image*, or to use a big word, *aesthetic*. (Brooks, 2004)

4. SGML comes back: XML

As markup languages go, SGML is powerful, flexible and **complex**. HTML, a subset of SGML is on the other hand easy to learn but not nearly as **powerful**. (Zijm, 2000)

As the Web grew significantly in complexity, a new more powerful markup language, which provides structure and meaning within documents, and facilitates the exchange data, was needed to support the evolving demands. A markup language was needed that was easier to use than SGML but still would be capable of describing the content. The result was XML.

Since 1995, SGML afficionados were thinking about using SGML on the Web. Problems to solve:

- SGML appeared as too complex to people having the habit to use HTML
- Some technical issues had to be clean up (instruction for typewriters for instance)
- The validation process of SGML seemed to be difficult across a network

In July or August of 1996, SGML experts met, led by Jon Bosak at Sun. Wanted to know how to re-inject SGML into web, especially SGML's extensible tags. John Bosak at Sun and small group of SGML experts proposed new W3C working group to devise modified SGML. Three phases:

1. XML: the syntax itself
2. XLL (Extensible Link Language): the linking semantics of XML
3. XSL (Extensible Stylesheet Language): the presentation of XML

In November of 1996, the initial working draft for eXtensible Markup Language (XML) was presented and afterwards, XML 1.0 became a W3C specification at February 10, 1998. XML is less complicated than SGML, but more powerful than HTML. XML took power and extensibility of SGML with the simplicity of HTML. (URL, 2004a; Zijm, 2000; Abrams, 1997; Courtaud 2002)

XML technology has also evolved in response to the limitations of HTML. (Lake, 2001) XML was not meant to replace HTML. The goals of each are different in that XML focuses on the *structure of data* and *what the data is* while HTML focuses on *how it looks*. In addition, XML is quickly becoming a standard way for applications to *exchange information* in a structured, human-readable and machine-readable way. (Zijm, 2000)

XHTML is a markup language that has the same expressive possibilities as HTML, but a stricter syntax. Whereas HTML was an application of SGML, a very flexible markup language, XHTML is an application of XML, a more restrictive subset of SGML. XHTML 1.0 became a W3C Recommendation on January 26, 2000. (URL Wikipedia)

PROGRAMING LANGUAGES

There are thousands of programming languages and new ones are created every year. Few languages ever become sufficiently popular that they are used by more than a few people. Different programming languages support different styles of programming and require different levels of detail to be handled by the programmer when implementing algorithms, often in a compromise between ease of use and performance.

Computer Programming Languages:

- Assembly Programming Languages
- System Programming Languages (or Hard-Core Programming Languages)
  - High-level Programming Languages
    - Fortran
    - Lisp
  - Logic Programming Languages
    - Prolog
  - Object-Oriented Programming Languages
    - COBOL
    - C, C++
    - C#
    - Java
    - D
- Enterprise Computing Platforms (Multi-tiered Object-Oriented Platforms for Enterprise Web Application Development)
  - Open Source Platforms
    - CORBA (Common Object Request Broker Architecture (CORBA) is an open industry standard that is managed by the OMG)
    - Java EE (with Java general purpose (system) programming language from Sun Microsystems)
  - Proprietary Platforms
    - .NET (with C# general purpose (system) programming language from Microsoft)
- Scripting Languages (Script Programming)
  - Server-side Scripting Languages
    - Python
    - Jython
    - IronPython
    - PHP
    - Ruby
    - JRuby
    - Perl
    - ASP
    - Tool Command Language (Tcl)
    - Smalltalk
    - Magik
    - Scheme
  - Client-side Scripting Languages
    - JavaScript
    - JScript
    - VBScript
    - ECMAScript
    - Adobe's Flash ActionScript

Java Technology

Java technology, consists of both a programming language and a platform, is based on the power of networks and the idea that the same software should run on many different kinds of systems and devices. As such, it standardizes the development and deployment of the kind of secure, portable, reliable, and scalable applications required by the networked economy. Because the Internet and web play a major role in new business development, consistent and widely supported standards are critical to growth and success. (URL Java)

The Java programming language is a popular general-purpose, garbage-collected, object-oriented, concurrent language developed by Sun Microsystems. Its syntax is similar to C and C++, but it omits many of the features that make C and C++ complex, confusing, and unsafe.

Java programs are run on -interpreted by- another program called the Java Virtual Machine (JVM). Rather than running directly on the native operating system, the program is interpreted by the JVM for the native operating system. This means that any computer system with the JVM installed can run a Java program regardless of the computer system on which the application was originally developed. [80] It is the component of the technology responsible for its hardware- and operating system-independence, the small size of its compiled code, and its ability to protect users from malicious programs. This component makes the Java technology cross-platform, that is "Write Once, Run Anywhere (WORA)". Enterprise-worthy programs run in the browser, from the desktop, on a server, or on a consumer device. The portability of Java applications between platforms that support JVM implementations is a particularly valuable feature for the web, the most diverse computing environment imaginable (Doyle and Lopes, 2005). JVM provides a unique "sandbox" for each application, so the failure or corruption of an application would not interrupt the system as a whole.

Although Java initially gained attention on the web as a client-side technology for running secure applets within browsers, its impact has ultimately been greater on the server-side.

The Java platform was initially developed to address the problems of building software for networked consumer devices. It was designed to support multiple host architectures and to allow secure delivery of software components. To meet these requirements, compiled code had to survive transport across networks, operate on any client, and assure the client that it was safe to run.

The Java platform is a software-only platform that runs on top of other hardware-based platforms. Because hardware-based platforms vary in their storage, memory, network connection, and computing power capabilities, specialized Java platforms are available to address applications development for and deployment to those different environments. Java technology has grown to include the portfolio of specialized platforms listed below. Each platform is based on a JVM that has been ported to the target hardware environment. This means, for example, in the case of

Desktop Java, desktop applications written in the Java programming language can run on any JVM-enabled desktop without modification.

- Java 2 Platform, Standard Edition (J2SE), provides an environment for "Core Java" and "Desktop Java" applications development, and is the basis for "Java 2 Platform", "Enterprise Edition (J2EE)" and "Java Web Services" technologies. It has the compiler, tools, runtimes, and Java APIs that let developers write, test, deploy, and run applets and applications. J2SE software is the premier platform for rapidly developing and deploying secure, portable applications that run on server and desktop systems spanning most operating systems. [J2SE (Core/Desktop)]

- Java 2 Platform, Enterprise Edition (J2EE), defines the standard for developing component-based multi-tier enterprise web applications. It is based on J2SE and provides additional services, tools, and APIs to support simplified enterprise applications development. It is implemented by web application server providers, that defines a standards for enterprise middleware services that provide infrastructure for large scale web applications. [J2EE (Enterprise/Server)]

- Java 2 Platform, Micro Edition (J2ME), is a set of technologies and specifications targeted at consumer and embedded devices, such as mobile phones, personal digital assistants (PDA's), printers, and TV set-top boxes. [J2ME (Mobile/Wireless)]

- Java Card Technology adapts the Java platform to enable smart cards and other intelligent devices with limited memory and processing capabilities to benefit from many of the advantages of Java technology.

Here are the releases of the J2SE platform: J2SE 5.0 and J2EE 1.4.2

The J2SE API consists of technologies organized into two groups: Core Java and Desktop Java. Core Java provides essential functionality for writing powerful enterprise-worthy programs in key areas such as database access, security, remote method invocation, and communications, to name a few. Desktop Java provides a full range of features to help build desktop applications that provide a rich user experience. Desktop Java consists of deployment products such as Java Plugin, component modeling APIs such as JavaBeans, GUI APIs such as the Java Foundation Classes (JFC) and Swing, and multimedia APIs such as Java3D. Desktop Java technology in conjunction with the Core Java technologies, one has everything s/he needs to create PC desktop applications and applets with rich client interfaces that are secure, portable, and high-performance that run on almost every popular operating system including Linux, Macintosh, Solaris, Windows and others.

There are two principal products in the J2SE platform family: J2SE Runtime Environment (JRE) and J2SE Development Kit (JDK). The JRE provides the Java APIs, JVM, and other components necessary to run applets and applications written in the Java programming language. It is also the foundation for the technologies in the J2EE for enterprise software development and deployment. The JRE does not contain tools and utilities such as compilers or debuggers for developing applets and applications. The JDK is a superset of the JRE, and contains everything that is in the JRE, plus tools such as the compilers and debuggers necessary for developing applets and applications.

Java Platform, Standard Edition or Java SE formerly known up to version 5.0 as Java 2 Platform, Standard Edition or J2SE 5.0 (Tiger). As of 2006, Java SE 6 (Mustang) is being developed. Java Platform, Enterprise Edition or Java EE is formerly known as Java 2 Platform, Enterprise Edition or J2EE up to version 1.4. The J2EE 1.2 includes software developed by the Apache Software Foundation. The J2EE 1.3 SDK was first released by Sun as a beta in April 2001. The J2EE 1.4 SDK beta was released in December 2002. The Java EE 5 specification is the final release and was released in May 2006.

Java EE is the latest version of the Java Platform technology that is the industry standard for developing portable, robust, scalable and secure server-side Java applications. Building on the solid foundation of Java SE, Java EE provides web services, component model, management, and communications APIs that make it the industry standard for implementing enterprise class SOA and Web 2.0 applications. It supports rich thin-client technologies such as AJAX, technologies that are crucial for building applications for Web 2.0. [http://java.sun.com/javaee/] The GlassFish community is building a free, open source application server that implements the newest features in the Java EE 5 platform.

.NET Architecture

.NET is an enterprise computing platform which is provided as a set of products for Microsoft operating systems. .NET provides an environment for enterprise web applications that is comparable to J2EE. While designed to be a cross-platform environment, .NET is most relevant for Microsoft operating systems, although the open source Mono project promises to bring .NET to Linux. Due to the large installed base of Microsoft operating systems, .NET has been steadily gaining traction with developers since its initial production release in 2001.

The main components of the .NET platform are the Common Language Runtime (CLR) and the .NET Framework class library. The CLR is a virtual machine that dynamically compiles Microsoft Intermediate Language (MSIL) byte code into native executable code at runtime. .NET is a multi-language environment in that multiple source languages can be compiled into MSIL byte code and executed by the CLR. The Common Type System (CTS) defines how types are declared and used in the CLR, providing a basis for type interoperability between modules implemented in different languages. Self-describing components, known as assemblies within .NET, are managed and executed by the CLR. The .NET Framework class library is large class library that provides similar functionality as the Java Platform APIs. Assemblies and the types they define are hierarchically grouped into namespaces that can be referenced by programs. While many programming languages are supported, the primary development language is C#, which is very similar to Java. ASP.NET is a reworked version of ASP that enables rapid development of web applications that make use of the capabilities of the .NET framework.

Scripting Languages

Scripting languages and system programming languages are complementary. The languages are typically used together in component frameworks, where components are created with system programming languages and glued together with scripting languages. However, several recent trends, such as faster machines, better scripting languages, the increasing importance of graphical user interfaces and component architectures, and the growth of the Internet, have greatly increased the applicability of scripting languages. In the design of “GeoCHEAF”, an integrated approach of system and scripting programming languages together has been considered. Python and PHP have been preferred as a single-purpose language below to general-purpose language, Java since one language can not do it all, and monolithic applications and on the contrary spaghetti code are not desired in the computing architecture of “GeoCHEAF”. Additionally, Python and PHP are ideal for scripting (glueing together) components build in Java, C# or C++; easy reuse through classes, polymorphism, operator overloading and even multiple inheritance. Moreover, they boast speed improvements over Java

Python is a robust dynamic object-oriented scripting language created by Guido van Rossum in the early 90's to bridge the gap between shell and C programming. Originally designed as an advanced scripting language, it is a rapid application development language for web, database and GUI applications as well as for distributed systems and mobile code. Python's elegant, remarkably easy to use and learn syntax (no curly braces, no semicolons, dynamic typing and so on), high-level data types (lists, maps, big numbers, and more), elaborate library, portability, and ease of extending and embedding in C/C++ all contribute to Python's popularity. It offers strong support for integration with other languages and tools, comes with extensive standard libraries -it can be integrated with COM, .NET, and CORBA objects. Python is distributed under an OSI-approved open source license that makes it free to use and distribute, even for commercial products. The Python licenses administered by the Python Software Foundation. While Jython is used an implementation of Python for the JVM, IronPython is the implementation of Python for .NET. Jython is a 100 % Java version of the Python scripting language that allows developers to compile Python scripts to Java byte code that runs on any JVM. Jython offers seamless and smooth Java integration: all Java libraries can be accessed from Python, applets or Java beans can be built. IronPython is a new implementation of the Python programming language running on .NET. It supports an interactive console with fully dynamic compilation. It is well integrated with the rest of the .NET Framework and makes all .NET libraries easily available to Python programmers, while maintaining full compatibility with the Python language. (http://www.python.org) (http://www.jython.org)

PHP is a widely-used object-oriented scripting language useful for many things, but with particular focus on the web and web development, back-end services, and desktop applications. It was written as a set of CGI binaries in the C programming language by Rasmus Lerdorf in 1994, to replace a small set of Perl scripts he had been using to maintain his personal homepage. Today, it is an HTML-embedded scripting language. Much of its syntax is borrowed from C, Java and Perl with a couple of unique PHP-specific features thrown in. The goal of the language is to allow web developers to write dynamically generated pages quickly. PHP generally runs on a web server, taking PHP code as its input and creating web pages as output, but command line scripting and client side GUI applications are part of the three primary uses of PHP as well. Available under the PHP License, PHP is an open source language and is considered to be free software by the Free Software Foundation. The LAMP architecture has become popular in the web industry as a way of deploying inexpensive, reliable, scalable, secure web applications. PHP is commonly used as the “P”in this bundle alongside Linux, Apache and MySQL. PHP can be used with a large number of RDBMS, runs on all of the most popular web servers and is available for many different operating systems. This flexibility means that PHP has a wide installation base across the Internet. (www.php.net) (URL Wikipedia)

Ruby is a dynamic, open source object-oriented scripting language with a focus on simplicity and productivity, written in C and created by Yukihiro Matsumoto in 1995. It is free under an open source license. (http://www.ruby-lang.org) JRuby is an 100% pure-Java implementation of the Ruby programming language. (http://jruby.codehaus.org/)

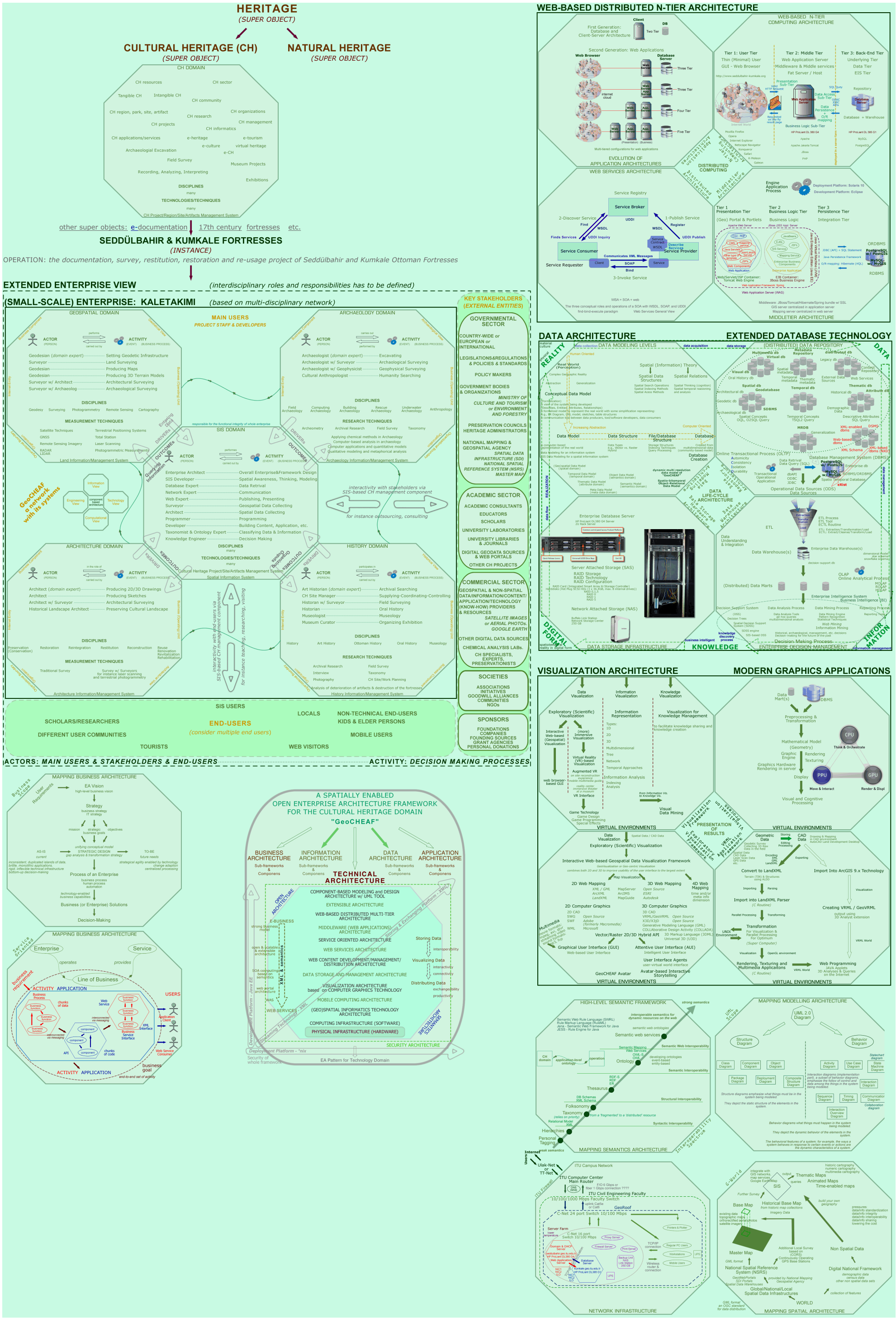
Jelly is a Java and XML based scripting and processing engine for turning XML into executable code. It is open source under Apache license and official Apache Jakarta Project. (http://jakarta.apache.org/commons/jelly/)

JavaScript is a scripting language, similar to a programming language. The primary difference is that JavaScript is interpreted by the web browser. JavaScript can be used to develop interactive web pages that check user input into forms, change the look of web pages, or display informative messages in the status bar of a web browser.

Rhino is an open source JavaScript engine. It is developed entirely in Java and managed by the Mozilla Foundation. It converts JavaScript scripts into Java classes and is typically embedded into Java applications to provide scripting to end users. The Foundation also provides an implementation of JavaScript in C known as SpiderMonkey. SpiderMonkey and Rhino have implemented support for the ECMAScript for XML (E4X) standard. (http://www.mozilla.org/rhino/) (URL Wikipedia)

Ant is an open source Java-based software build tool developed by the Apache Software Foundation. It is similar in purpose to build tools such as Make, but is based on XML and is extensible through a Java interface for adding new tasks. Ant is extremely widely used throughout the Java community. (White Paper, 2003c) Ant is a software tool for automating software build processes. It is similar to Make but is written in the Java language and is primarily intended for use with Java. (http://ant.apache.org)

APPENDIX B: Overall mapping "GeoCHEAF"



BIOGRAPHY

Caner GÜNEY is a research&teaching assistant at the IGS-ISTA Satellite Observation and Processing Laboratory of the Division of Geodesy at the Istanbul Technical University (ITU), Turkey, since 1999.
He is currently a PhD student in the Program of Geomatics Engineering at the ITU since 2002. He completed undergraduate in 1999, and, in 2002, received an M.Sc. in the Department of Geodesy and Photogrammery Engineering at ITU. His master thesis' title was “Multimedia Supported GIS Applications over the Internet and Geodetic Infrastructure (Case Study: The Documentation of Cultural Heritage Resources)”.
He was visiting scholar in the School of Design at the University of Pennsylvania, Philadelphia, USA, from 01.12.2004 to 01.08.2005 and Marie-Curie “Cultural Heritage Informatics Research Oriented Network (CHIRON)” research fellow in the Department of Archaeology at the University of York, UK from 03.10.2005 to 29.09.2006.
He has also been working as a surveyor, GIS developer and web master in the documentation, restoration and reusage project of two 17^{th} century Ottoman Fortresses on the Dardanelles, “*Seddülbahir*” and “*Kumkale*”.
His main scientific and technical interests include the use of information and communication technologies for the area of Enterprise Architecture, Geomatics, GIS, Navigation, and Cultural Heritage as well as designing new technical approaches for these domains.
His informatics skills on the web-based GIS applications, 2D/3D visualization technologies, database management systems, programming, design and modeling techniques.

E-mail: guneycan@itu.edu.tr