

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE
ENGINEERING AND TECHNOLOGY

**THE USE OF LOCAL DATA IN ARCHITECTURAL DESIGN
THROUGH AUGMENTED REALITY**



Ph.D. THESIS

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Department of Informatics

Architectural Design Computing Programme

SEPTEMBER 2019

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**MİMARİ TASARIMDA ARTIRILMIŞ GERÇEKLİK
ARACILIĞIYLA YEREL VERİ KULLANIMI**

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To my family,



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ABBREVIATIONS

AR	: Augmented Reality
AREA	: Augmented Reality Engine Application
BIM	: Building Information Modeling
CD	: Cultural Data
DGPS	: Differential Global Positioning System
4D	: Four Dimensional
GPS	: Global Positioning System
HMD	: Head-mounted Display
MARS	: Mobile Augmented Reality System
ND	: Natural Data
POI	: Point of Interest
2D	: Two Dimensional
3D	: Three Dimensional



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THE USE OF LOCAL DATA IN ARCHITECTURAL DESIGN THROUGH AUGMENTED REALITY

SUMMARY

In architectural design, the architect produces spatial solutions by using a variety of data on the site to address architectural requirements. In the beginning of the conceptual design, data collection and analysis are the basic requirements for the architect to understand the current situation on the site. For many years, architects have used observational data to research places and regarded the data as input to architectural design. By the development of technology and data access facilities, this circumstance remain incapable to obtain data of the place. In the analyse process of the data, the current circumstance requires the architect to be physically detached from the site. The architect needs to be able to sort, visualize and navigate data to accelerate understanding in the process of analysis. In these processes, the architect tries to obtain data from different sources and evaluate them detached from the reality of the context, and certain problems arise related to accessibility, accuracy and location of the data. Besides that, the lack of a generally accepted data classification system for architects directs the study to a data classification framework to manage data. This study aims to enhance the site visit experience for the architect, to provide spatial observation of the data on site, and to help data collection and analysis during the site visit with the concept of local data through augmented reality. The main goal of the research is the development of a model that uses augmented reality for the presentation of local data on site.

This study is comprised of five chapters. The chapters focus on theory, review and model complement each other in the configuration of the thesis. The first chapter provides detailed explanations of the problems, aims of the research, the research questions, the scope of the research, and the methods used to conduct the research. Within the scope of the thesis, in the second chapter the theoretical part of the study that bases on the concept of local data is presented. In the third chapter, location based data representation through augmented reality in architectural design is evaluated through the literature review. In the fourth chapter, the model that provides local data usage through augmented reality in architectural design is developed according to studies mentioned in the second and third chapters. The fifth chapter concludes the thesis by evaluating the contributions, limitations and further studies.

In the second chapter, that focus on theory, the data needed in the field of architectural design are handled under the local data approach. Firstly, a relative perspective is adopted to provide a better understanding of the relationship between data, information and knowledge. It is aimed to prevent the use of the data, information and knowledge term interchangeably and to express their use in scientific studies correctly. Secondly, it is aimed to develop a fundamental data classification for architecture. When the origin of the data is investigated, it is seen that each data carries natural or cultural references. This indicates that the fundamental classification of the data can be organized under natural and cultural categories. Lastly, the concept of local data is

discussed, and a data framework for architecture is developed. In architectural design, a data framework is needed to classify local data under natural and cultural categories. In this respect through the literature research, architectural studies, site planning studies, and legal regulations in architecture and planning are evaluated to construct a data framework. Local data framework is formed by the combination of data classes, and it is also possible to classify this framework in different ways depending on the varied classification approaches. The classification of data through this framework provides a systematic approach to easily access to all data associated with the place in architectural design.

In the third chapter, that focus on review, location based data representation through augmented reality in architectural design is evaluated through the literature review. Firstly, it describes the field of augmented reality including the characteristics and requirements. Combining real and virtual, interaction in real time and registration in 3D are characteristic properties of augmented reality systems. These fundamental characteristic properties also demonstrate the technical requirements of the augmented reality system as the display, interface and tracking. Secondly, location based data representation in augmented reality systems is investigated. Location based augmented reality approach allows on site representation of data. MARS, Archeoguide, VIDENTE, CityViewAR, AREA and BIM based AR applications are surveyed as a state of the art by reviewing features. Developments to the recent conditions from the first implementations are revealed with components and significance of applications. Lastly, potential contributions of location based augmented reality systems and appropriate component structures are discussed for architectural design. When the applications are evaluated in terms of potential contribution to architectural design, it is observed that location based augmented reality systems can provide: on site representation of data, user's direct interaction with data, presentation of invisible data, quick review of surrounding data, presentation of data on urban scale, visualization of past and future situations, analysis of the proper data, and editable application layout for architectural applications. By evaluating the applications in terms of components, it is observed that which components in the field of augmented reality are suitable for location based augmented reality systems. These components need to be taken into consideration in planning location based augmented reality systems for architectural design.

In the fourth chapter, that focuses on model, augmented reality supported model for the use of local data in architectural design is developed in the direction of the studies in the second and third chapters. Firstly, the necessities of local data in architectural design and the potentials of location based augmented reality are discussed in the current state, and the possibilities that the conceptual model can provide are examined. Secondly, architectural scenario of the augmented reality supported model is described. Focusing on the data need of the architect during the site visit and site analysis before starting a conceptual design, the representation of local data through augmented reality with a certain classification is conceptually pointed out. The model classifies data in the scenario according to the local data framework developed in the second chapter. This framework is developed as the main part of the model for the classification of local data. It considers the location as the main context source while classifying other contextual factors. In the model, possibilities of augmented reality are expressed and supported by visualisations of the user scenario. Lastly, the technical structure of the model in augmented reality is presented with its components and workflow. In the determination of the model components, the studies in the third

chapter related to structures of the location based augmented reality systems are taken into consideration. The workflow of the model is extensively explained under the stages of data acquisition, data query and data display. In the acquisition of data, although relational databases are handled as the basic data acquisition method, different methods which emerged with developing technology are discussed in relation to the model. The query and display infrastructure of the model is explained based on the working principles of the studies carried out in the field of location based augmented reality.

The fifth chapter concludes the thesis by evaluating its contributions to the architectural design. In addition to the local data concept and framework, the relationship between data, information and knowledge is developed as a relative approach that can make significant contributions to other scientific fields besides architecture. Local data framework supports the architect by providing classified data related to the location for architectural design. Literature review of the study on augmented reality contribute not only to the model in this study but also to location based models and applications in the field of architecture. The model within the scope of the thesis provides local data presentation on site by using location based augmented reality. By converting the real environment to a working medium, the model connects the architect with local data on site for architectural design and assists the architect in the early design stages for data collection and analysis.



MİMARİ TASARIMDA ARTIRILMIŞ GERÇEKLİK ARACILIĞIYLA YEREL VERİ KULLANIMI

ÖZET

Doğası gereği mimarlık, yer ile doğrudan ilişkili bir tasarım alanıdır. Tasarımın gerçekleştirileceği alandaki veriler kullanılarak, mimari gereksinimleri karşılayan yerleşimler ve mekansal çözümler üretilmektedir. Mimari tasarımda veri toplama ve veri analizi, kavramsal tasarıma başlarken mimarın alana yönelik mevcut durumu kavraması için temel gerekliliklerdir. Bu nedenle alan ziyareti, mimar için büyük önem taşımaktadır. Mimarlık disiplini içerisinde yıllar boyunca mimarlar, tasarıma girdi olarak kullandıkları verileri alandaki araştırmalarına dayalı olarak birebir gözlemledikleri durumlar üzerinden sağladılar. Bu durum günümüzde değişen ve gelişen veriye erişim yöntemleri ile alana yönelik verileri toplamak için yetersiz kalmaktadır. Diğer taraftan mevcut durumda bu verilerin değerlendirilmesi için de mimarın fiziksel olarak alandan ayrılması gerekmektedir. Devam eden tasarım süreci içerisinde mimar, alanın kendisinden kopuk bir sürece girmektedir. Analiz için toplanan verileri sınıflandırarak, görselleştirerek ve haritalandırarak kavramaya çalışmaktadır. Mimari tasarım, bu doğrultuda alanın ve çevreleyen bağlamın analizine dayalı olarak geliştirilmektedir. Bu süreç içerisinde mimarın farklı kaynaklardan veri edinmeye ve bağlamın gerçekliğinden koparılmış olarak alanı değerlendirmeye çalışması; verinin erişilebilirliği, doğruluğu ve konumu ile ilgili sorunlara neden olmaktadır. Mimarın topladığı verileri sınıflandırmasında genel geçer kabul görmüş bir veri sınıflandırma sistemi olmaması da önemli bir eksikliktir. Tez çalışması bu problemlere odaklanarak yerel veri kavramı üzerinden artırılmış gerçeklik aracılığıyla çözüm sunmayı amaçlamaktadır.

Tez kapsamında öncelikle yerel veri kavramı incelenerek çalışmanın kuramsal altyapısı ortaya konulmuştur. Bir sonraki aşamada mimari tasarımda artırılmış gerçeklik aracılığıyla konum tabanlı veri temsili literatür üzerinden incelenmesi ve değerlendirilmesi gerçekleştirilmiştir. Bu çalışmalar doğrultusunda mimari tasarımda artırılmış gerçeklik aracılığıyla yerel veri kullanımı sunan model geliştirilmiştir. Tez çalışmasının yapısal biçimlenişi de bu kapsamda ilerleyerek; kuram, değerlendirme ve model odaklı bölümlerin birbirlerini tamamlayan yapıları ile bir bütüne dönüşmüştür.

Giriş kısmı birinci bölümde, araştırma problemi tanımlanarak araştırma soruları belirlenmiş, çalışmanın amacı ortaya konularak bu doğrultuda tezin kapsam ve araştırma metodolojisi geliştirilmiştir.

Kuram odaklı ikinci bölüm, mimari tasarımda alana yönelik ihtiyaç duyulan veriyi yerel veri yaklaşımı altında ele almaktadır. Öncelikle veri, enformasyon ve bilgi ilişkisinin daha iyi kavranmasını sağlayacak göreceli bir perspektiften elde edilen yaklaşım ortaya konulmuştur. Algılanan herhangi bir şeyin potansiyel olarak ifade ettiği en ilkel biçim olan enformasyon, bilgiye dayalı bir protokol aracılığıyla bilişsel bir sistemde anlam kazanmaktadır. Bu sayede oluşan bilgi, kişinin aklındaki bir sentez ürünü olarak, kişisel algılar ve deneyimlerle şekillenmektedir. Veri ise kişiden bağımsız olarak bilgi temelli bir yapıyla temsil ortamında enformasyonu ya da bilgiyi

tutmanın, depolamanın ve aktarmanın yoludur. Bu yaklaşıma göre temsil ortamında ‘veri’, gerçeklikte ‘enformasyon’ veya akılda ‘bilgi’ olma durumları ortaya çıkmakta ve birbirleriyle döngüsel bir ilişki göstermektedirler. Bu kuramsal çalışma sayesinde veri teriminin, enformasyon ve bilgi terimleriyle birbirlerinin yerine kullanımının önüne geçmek, bilimsel çalışmalarda kullanımını doğru ifade etmek hedeflenmiştir.

Verilerin kökeni incelendiğinde her verinin doğal ya da kültürel referanslar taşıdığı görülmektedir. Doğal veri, doğanın bir parçası olma durumundan kaynaklanırken; insan ve doğa arasındaki etkileşimin bir sonucu olarak ortaya çıkan veriler ise kültürel verilerdir. Antroposentrik bir bakış açısıyla insan, doğal ve kültürel varlıkları içeren verilerin ortaya çıkmasında ana etken olarak görülmektedir. Bu durum, temel sınıflandırmanın ‘doğal’ ve ‘kültürel’ kategoriler altında düzenlenerek, mimarlık ile de ilişkilendirilebileceğini göstermiştir.

Mimarlık doğrudan yer ile ilişkili bir disiplin olduğundan, sınıflanan doğal ve kültürel verinin yerel bağlamında tartışılması gerekmektedir. Belirli bir yerle ilgili olma anlamındaki ‘yerel’ ile doğal ve kültürel referanslar taşıyan ‘veri’ kavramları birlikte ele alındığında mimarlık için ‘yerel veri’ oluşmaktadır. Bu kapsamda, mimari tasarımda yerel verilerin doğal ve kültürel kategoriler altında sınıflandırılmasında bir çerçeveye ihtiyaç duyulmaktadır. Mimari tasarımda kullanılan verilere ilişkin olarak literatürde öne çıkan mimari çalışmalar, planlama çalışmaları ile mimarlık ve planlama alanlarındaki yasal düzenlemeler bir veri çerçevesi oluşturmak için değerlendirilmiştir. İncelenen çalışmalardaki veri türleri biraraya getirilerek, alt kategorilerin birbirleriyle ilişkilerine göre kümelenmeleri sağlanmıştır. Çalışmada ortaya konulan yerel veri çerçevesinde, ‘doğal veriler’ kategorisi topografya, jeolojik özellikler, su kaynakları, bitki örtüsü, iklim, vahşi yaşam ve koruma alanları, biyolojik çeşitlilik ve doğal afetler kategorilerinde; ‘kültürel veriler’ kategorisi alan kullanımı, yapılı çevre, altyapı, mevzuatlar, sosyal çevre, erişilebilirlik, duysal özellikler ve tehlikeler kategorilerinde biraraya getirilmiştir. Bu sınıflandırmadaki veri kategorilerinin de alt kategorileri bulunmaktadır. Yerel veri çerçevesi, açık bir sistem olarak gelişime açıktır. Yeni veri tipleri türediğinde sınıflandırma sistemi genişleyebilmektedir. Bu çerçeveyi, farklı sınıflandırma yaklaşımlarına bağlı olarak farklı biçimlerde ortaya koymak da mümkündür. Bu sayede verilerin sınıflandırılmasıyla, mimari tasarımda yere ilişkin verilerin ele alınmasında sistematik bir yaklaşım sağlanmaktadır.

Değerlendirme odaklı üçüncü bölümde, mimari tasarımda artırılmış gerçeklik aracılığıyla konum tabanlı veri temsiline literatür araştırması yapılmıştır. Artırılmış gerçekliğin karakteristikleri ve bu karakteristiklerine dayalı gereksinimleri incelenmiştir. Gerçek ve sanal ortamı bir araya getiren görüntüleme, eş zamanlı etkileşim sağlayan arayüz ve 3 boyutlu hizalanmayı gerçekleştiren takip bileşenleri artırılmış gerçekliği ortaya koymaktadır. Video, optik ve projeksiyon temelli görüntüleme teknikleri ile başa takılan, elle tutulan ve uzamsal görüntüleyicinin konumuna dayalı olarak aygıtlarla görüntüleme gerçekleşmektedir. Enformasyon tarayıcılar, 3 boyutlu kullanıcı arayüzü, somut kullanıcı arayüzü, doğal kullanıcı arayüzü ve çoklu model arayüzü olarak gruplanan farklı arayüzler vasıtasıyla kullanıcı ile aygıt arasında etkileşim kurulmaktadır. Sensör tabanlı, görme tabanlı ve hibrit takip teknikleriyle kullanıcının bakış açısına göre sanal içeriğin gerçek ortamda hizalanmasını sağlamaktadır.

Artırılmış gerçekliğin temel yapısından sonra, artırılmış gerçeklik sistemlerinde konum tabanlı veri temsili incelenmiştir. Konum tabanlı artırılmış gerçeklik yaklaşımı, verilerin yerinde temsil edilmesine olanak sağlamaktadır. Bu yaklaşım doğrultusunda,

literatürde alana sağladıkları katkılar ile öne çıkan uygulamalar detaylı biçimde ele alınmıştır. MARS, Archeoguide, VIDENTE, CityViewAR, AREA ve BIM based AR uygulamaları çalışma kapsamında incelenmiştir. İnceleme sonucunda, ilk uygulamalardan günümüzdeki gelişmelere kadar yer alan konum tabanlı artırılmış gerçeklik uygulamalarının önemi ve bileşenleri değerlendirilmiştir.

Uygulamalar incelendikten sonra, mimari tasarım alanına yönelik olarak potansiyel katkıları ve uygun bileşen yapıları tartışılmıştır. Değerlendirme yapıldığında, verilerin yerinde temsili, kullanıcının veri ile doğrudan etkileşime geçmesi, görünmeyen durumdaki verilerin sunumu, çevreleyen verilerin hızlı bir biçimde gözden geçirilmesi, kentsel ölçekte veri sunumu, geçmişe ve geleceğe ilişkin durumların görselleştirilmesi, analiz edilebilir şekilde yapılandırılmış veriler içermesi ve mimari uygulamalar için düzenlenebilir uygulama altlığı sağlama açısından uygulamalara katkılar sunabileceği görülmektedir. Aynı zamanda görüntüleme, arayüz ve takip bileşenleri açısından, artırılmış gerçeklik alanındaki hangi bileşenlerin konum tabanlı artırılmış gerçeklik sistemlerine uygun olduğu belirlenmiştir. Görüntüleme bileşeni açısından, video görüntüleme tekniğini kullanan elle tutulan görüntüleyiciler, yaygın erişime sahip olduğundan günümüzde tercih edilen görüntüleme aygıtlarıdır. Diğer taraftan, başa takılan görüntüleyicilerin eller serbest bir biçimde daha doğal bir çalışma ortamı sağladığından gelecekte daha fazla tercih edilebileceği düşünülmektedir. Arayüz bileşeni açısından ise enformasyon tarayıcıların, konum tabanlı artırılmış gerçeklik sistemlerinde temel arayüz olarak kullanıldığı görülmektedir. Bu arayüzün görevi veritabanlarından sağlanan veriyi tarayıp, ilgili konuma artırılmış gerçeklik aracılığıyla görselleştirmektedir. Takip bileşeni açısından incelendiğinde ise GPS ve akselerometre sensörlerine dayalı hibrit takip sistemlerinin, sanal ve gerçeğin hizalanmasında bir gereklilik olduğu ve görme tabanlı takiple de güçlendirilebileceği görülmüştür.

Model önerisi geliştirilen dördüncü bölümde, mimari tasarımda yerel veri kullanımına yönelik artırılmış gerçeklik destekli model, ilk iki bölümdeki çalışmalardan elde edilen değerlendirmeler doğrultusunda ortaya konulmuştur. Mimari tasarımda yerel veriye ilişkin ihtiyaçlar ve bu ihtiyaçlara yönelik konum tabanlı artırılmış gerçeklik olanakları birlikte ele alınarak kavramsal modelin veri sunarken sağlayacağı olanaklar maddeler halinde sıralanmıştır. Çalışma kapsamında bu olanaklar ortak ortam sağlama, veri sınıflandırma, veri haritalamaya uzamsal yaklaşım, bütüncül bakış, veri görünürlüğü, zaman bileşenli temsil, veri analizi, not alma ve paylaşma, mimarlara yardımcı olma ve uzmanlık sağlama başlıkları altında ele alınmıştır.

Sonraki adımda, artırılmış gerçeklik destekli modelin mimari senaryosu ortaya konulmaktadır. İkinci bölümde geliştirilen yerel veri çerçevesine göre model, senaryo içerisindeki verileri sınıflandırmakta ve ana bağlam kaynağı olarak konumu kullanarak sunmaktadır. Kullanıcı senaryosu altında, modeldeki;

- veriler için gerçek ve sanal ortam birleşiminde ortak bir ortam sağlanması,
- verilerin yerel veri çerçevesine dayalı olarak sınıflandırılması,
- verilerin alanda uzamsal olarak haritalandırılması,
- tüm verilerin birarada ele alınarak bütüncül bir bakış sağlanması,
- görünmeyen veriler için veri görüntülenmesi,
- verilerin geçmiş ve geleceğe yönelik zaman bileşenli temsil edilmesi,
- analize uygun yapıdaki verilerden analizlerin gerçekleştirilmesi,

- ziyaret sırasında alanda not alma ve paylaşım sağlanması,
- mimarlara yoruma ihtiyaç duydukları konularda yardımcı olma ve diğer profesyonellerin uzmanlıklarının yerinde sağlanması

olanakları ifade edilmiş ve görsellerle desteklenmiştir.

Modelin artırılmış gerçeklikteki teknik yapısı, bileşenleri ve iş akış düzeniyle sunulmaktadır. Model bileşenlerinin belirlenmesinde, konum tabanlı artırılmış gerçeklik sistemlerinin bileşen yapılarının incelenmesine yönelik çalışmalar dikkate alınmıştır. Modelin iş akışı üç aşamada oluşturulmuştur. Bu aşamalar; veri edinme, veri sorgulama ve veri görüntüleme aşamalarıdır. Modelde veri edinme, çeşitli veri kaynaklarından edinilen verilerin yerel veri çerçevesindeki sınıflandırma sisteminde ele alınmasıyla sağlanmaktadır. Veri edinmede mevcut veritabanlarından faydalanılabileceği gibi, kitle kaynaklı çalışma, veri madenciliği, büyük veri ve nesnelerin interneti gibi yenilikçi yaklaşımlardan da faydalanılabileceği tartışılmıştır. Modeldeki ikinci aşama olan veri sorgulama, belirli adımlarla gerçekleşmektedir. Öncelikle konum verisi, yön verisi ve yönelim verisi olmak üzere sensör verileri elde edilir. Daha sonra edinilen sensör verilerinden konum verisi ve etkin alan çapı verisi kullanılarak, yerel veri çerçevesinde düzenlenmiş olan verilerden yere ilişkin veriler sorgulanır. Son adımda ise sensörlerden edinilen yön ve yönelim verisi yardımıyla bakış açısının hesaplanması sağlanarak, sorgulama sonucu çıkan yerel verilerden bakış açısına dahil olanların görüntülenmek üzere belirlenmesi sağlanır. Üçüncü aşamada modelde veri görüntüleme, sorgulama sonucu elde edilen verilerle gerçekleştirilir. Bakış açısının, filtreleme ayarlarının ve etkin alan çapının değiştirilmesi görüntülenecek verileri etkilemektedir. Oluşan yeni durumlara göre, görüntüye dahil olan yerel veriler eklenmekte, görüntü dışında kalan yerel veriler çıkarılmakta ve görüntüde durmaya devam eden yerel veriler korunmaktadır. Model, teknik olarak işlerliğini bu şekilde gerçekleştirmektedir.

Çalışma sonuçları ve öneriler sunan beşinci bölümde, genel bir değerlendirme yapılarak ileriye dönük çalışmalara katkısı tartışılmıştır. Tez çalışması ortaya koymuş olduğu yerel veri yaklaşımının yanında; veri, enformasyon ve bilgi ilişkisine getirdiği göreceli yaklaşımla mimarlık alanının dışında diğer bilimsel alanlara da referans niteliği taşımaktadır. Yerel veri çerçevesi, bir yere ilişkin veriyi mimari tasarım için sınıflandırılmış bir biçimde ele almayı sağlayarak kullanıcıyı desteklemektedir. Artırılmış gerçekliğe ilişkin olarak yapılan incelemeler ve değerlendirmeler, mimarlık alanında konum tabanlı olarak gerçekleştirilecek diğer model ve uygulamalara da katkıda bulunabilecek bir literatür araştırması sağlamaktadır. Tez kapsamında önerilen model, yerel veri çerçevesini kullanarak konum tabanlı artırılmış gerçeklik aracılığıyla yerel verilerin yerinde sunumunu sağlamaktadır. Bu sayede model erken tasarım aşamalarında, mimari veri toplama ve analiz aşamalarına yönelik olarak desteklemektedir. Alanla etkileşim halinde, mimarın çevresindeki yerel verileri doğrudan yerinde kavramasını sağlamaktadır. İleriye yönelik çalışmalar için bu modelin mimarlık alanında kullanılmak üzere uygulanması, gerçek ortamı bir çalışma ortamına dönüştürerek mimarın yerel verilerle etkileşimini güçlendirecektir.

1. INTRODUCTION

In the first two decades of the 21st century, enormous quantities of data about the place and behaviours of people have been generated related to the physical environment. The extensive data about the place and the people that live in it, offers new potentials to understand problems and opportunities. Besides, the development of new information technologies have presented practical digital tools to process these data. In time, the merits of using such data and new information technologies have been taken into account for planning and design processes. These new possibilities to understand places and people, can provide professionals to inform their decisions more deeply. Thus, significant outcomes can be revealed with the use of available data. There are great opportunities for architects to use various data and digital tools for better design.

1.1 Problem Definition

In architectural design, the architect produces spatial solutions to address architectural requirements using a variety of data. Due to the fact that architecture interacts directly with environmental factors, the architect needs to take into account the data about the surrounding context of the site while developing the design. Data collection and analysis are the basic requirements for the architect to understand the current situation related to the site (Anderson, 2011). Initially, it is necessary to collect data that present the characteristics of the site. Therefore, the architect visits the physical site to view features, take notes/photographs, and look for patterns while collecting data. For many years, architects have used observational data to research places and regarded the data as input to architectural design. Today with developed data access facilities, this kind of an act is insufficient to obtain data of the place. But also the site visit is important to experience the site's context and to observe data on site.

For the analysing of the data, it is necessary to manage the complexity of collected data that bases on various classes and sources. The architect needs to be able to sort, visualize and navigate data to accelerate understanding in the process of analysis

(Farrelly, 2012). For this reason, the condition of any site is mapped via spatial relations of data for architectural design. The architect correlates data which is spatially represented in the map to properly analyse the site and puts it to use in architectural design. Thereby, the current state in analysing requires the architect to be physically detached from the site (Wang et al., 2013a).

In these processes, the architect tries to obtain data from various sources and evaluate them as detached from the reality of the context, and certain problems arise related to accessibility, accuracy and location of the data. Besides, the fact that the lack of a generally accepted data classification system for architects points out the need for a framework to manage data. In architectural design, an approach under a classified data system is also necessary to obtain data for a location.

1.2 Research Objectives and Questions

The aims of the research are to enhance the site visit experience for the architect, to provide spatial observation of the data on site, and to help data collection and analysis during the site visit. The research is focused on providing solutions to defined problems with the concept of local data and augmented reality. The main goal of the research is the development of a model that uses augmented reality for the presentation of local data on site. In order to realize this model, it is essential to consider the need for a data framework to use in the model. Therefore, it is aimed to define a local data framework that uses location as the main organizer. Besides, it is aimed to determine the location based augmented reality systems that ensure the operability of the model through this framework. In order to achieve these research objectives, following research questions are formulated:

Q1- What is the basic relationship between data, information and knowledge?

Q2- How can data be classified according to their origin?

Q3- How can data be handled from local data approach to use data with the definite location?

Q4- Which data classes can be used in architectural design for data classification?

Q5- What are the possible contributions of location based augmented reality to architectural design?

Q6- What are the potentials of location based augmented reality with respect to the necessities of local data?

Q7- How can the model support users from an architectural perspective?

Q8- How can the model be developed in terms of technical structure?

1.3 Scope and Research Methodology

Within the scope of the thesis, firstly the theoretical part of the study that bases on the concept of local data is researched. Meanwhile, location based data representation through augmented reality in architectural design is evaluated through the literature review. The model that provides local data usage through augmented reality in architectural design is developed according to these studies. The sections that focus on theory, review and model complement each other in the configuration of the thesis (Figure 1.1).

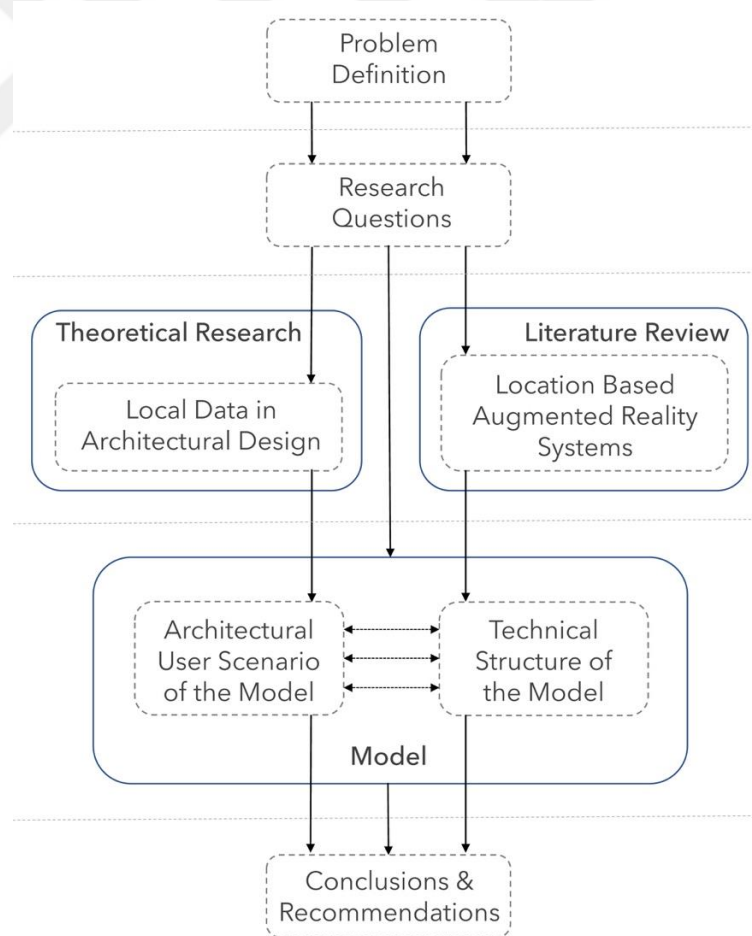


Figure 1.1 : Research methodology of the thesis.

In the theoretical part of the research, the relations of data, information and knowledge are questioned with the use of the basic meaning of them in a relative approach. The term data is seen as a basis for this study. Afterwards, the origin of the data is investigated to find the fundamental classification. This research directs to that each data carries natural or cultural references to classify. Thus, the basis is prepared for the transition to the concept of local data. The concept of local data considers the location as the main context source for data while classifying other contextual factors. In order to benefit from local data, a framework in which data is classified is needed. In this respect through a comprehensive literature research, architectural studies (White,1983; Unwin, 1997; Fawcett, 1998; Birkeland, 2002; Thomas, 2002; Spreiregen and De Paz, 2005; Farrelly, 2012; Bielefeld and Khouli, 2017), site planning studies (Lynch, 1971; Brooks, 1988; McBride, 1999; Beer and Higgins, 2000; Pitts, 2004; Towers, 2005; Carmona et al., 2010; LaGro, 2013), and legal regulations in architecture and planning (Regulation on Making Spatial Plans, 2014; National Planning Policy Framework, 2018) are evaluated to construct a data framework. By considering the mentioned data in the references, data classes that are related to each other are grouped. Local data framework is formed by the combination of data classes in these literature research, and it is also possible to classify local data framework in different ways depending on the varied classification approaches. This framework is developed as the main part of the model for the classification of local data. The classification of data through this framework provides a systematic approach to easily access all the data associated with the place in architectural design.

In the literature review, the field of augmented reality is described with their characteristics and requirements. After the review of the establishment of augmented reality systems, location based data representation in augmented reality systems is investigated. The featured applications from the first implementations to the recent conditions are surveyed as a state of the art (Feiner et al., 1997, Vlahakis et al., 2002, Junghanns et al., 2009, Lee et al., 2012, Geiger et al., 2014, Meza et al., 2014). Thus, developments are revealed with components and significance of applications. Potential contributions of location based augmented reality systems are associated with architectural design, and appropriate component structures are discussed. Consequently, these potential contributions and components are taken into consideration in the model.

The model that provides local data usage through augmented reality in architectural design is developed according to theoretical researchs and literature reviews. The necessities of local data in architectural design and the potentials of location based augmented reality are discussed in the current state with the support of literature, and the possibilities that the conceptual model can provide are examined. The model is generated with the association between the architectural user scenario and the technical structure of the model. The possibilities of augmented reality are expressed and supported by visualisations under the user scenario. The technical structure of the model in augmented reality is presented under its components and workflow. The workflow of the model is extensively explained under the stages of data acquisition, data query and data display. In the acquisition of data, although relational databases are handled as the basic data acquisition method, different methods which emerged with developing technology are discussed in relation to the model. The query and display infrastructure of the model is explained based on the working principles of the studies carried out in the field of location based augmented reality.

In the context of the model, although the target group of the model is architects, the model can be used by other professionals. It can be very useful for urban planners and urban designers by providing easy access to surrounding data spatially. In practical work, the model can be used to view the exact location of provided public services such as infrastructure on site. Besides all these, it can also be used by users who want to explore their environment spatially without being in any professional work.

1.4 Overview of the Thesis

Chapter 1 provides detailed explanations of the problems, aims of the research, the research questions, the scope of the research, and the methods used to conduct the research.

Chapter 2 describes the concept of local data that bases on theoretical studies. Firstly, a relative perspective is adopted to provide a better understanding of the relationship between data, information and knowledge. It is aimed to prevent the use of the data, information and knowledge term interchangeably and to express their use in scientific studies correctly. Secondly, it is aimed to develop a fundamental data classification for architecture. When the origin of the data is investigated, it is seen that each data carries natural or cultural references. This indicates that the fundamental classification can be

organized under natural and cultural categories. Lastly, the concept of local data is discussed for the place, and a data framework for architecture is developed. In architectural design, a data framework is needed to classify local data under natural and cultural categories. In this respect through the literature research, architectural studies, site planning studies, and legal regulations in architecture and planning are evaluated to construct a data framework. The classification of data through this framework provides a systematic approach to easily access all the data associated with the place in architectural design.

Chapter 3 reviews literature on location based data representation through augmented reality in architectural design. Firstly, it describes the field of augmented reality including the characteristics and requirements. Combining real and virtual, interaction in real time and registration in 3D are characteristic properties of augmented reality systems. These fundamental characteristic properties also demonstrate the technical requirements of the augmented reality system as the display, interface and tracking. Secondly, location based data representation in augmented reality systems is investigated. Location based augmented reality approach allows for on site representation of data. MARS, Archeoguide, VIDENTE, CityViewAR, AREA and BIM based AR applications are surveyed as a state of the art by reviewing features. Developments to the recent conditions from the first implementations are revealed with components and significance of applications. Lastly, potential contributions of location based augmented reality systems and appropriate component structures are discussed for architectural design. When the applications are evaluated in terms of their potential contribution to architectural design, it is observed that location based augmented reality systems can provide on site representation of data, user's direct interaction with data, presentation of invisible data, quick review of surrounding data, presentation of data on urban scale, visualization of past and future situations, analysis of the proper data, editable application layout for architectural applications. By evaluating the applications in terms of components, it is observed that which components in the field of augmented reality are suitable for location based augmented reality systems. These components need to be taken into consideration when planning location based augmented reality systems for architectural design.

Chapter 4 focuses on model that provides local data usage through augmented reality in architectural design. Firstly, the necessities of local data in architectural design and

the potentials of location based augmented reality are discussed in the current state, and the possibilities that the conceptual model can provide are examined. Secondly, architectural scenario of the augmented reality supported model is described. Focusing on the data need of the architect during the site visit and site analysis before starting a conceptual design, the representation of local data through augmented reality with a certain classification is conceptually pointed out. The model classifies data in the scenario according to the local data framework. In the model, possibilities of augmented reality are expressed and supported by visualisations under the user scenario. Lastly, the technical structure of the model in augmented reality is presented under its components and workflow. In the determination of the model components, the studies related to structures of the location based augmented reality systems are taken into consideration. The workflow of the model is extensively explained under the stages of data acquisition, data query and data display.

Chapter 5 concludes the thesis by evaluating its contributions to the architectural design. It also discusses the limitations and further studies related to this study.



2. LOCAL DATA: A NEW APPROACH TO DATA IN ARCHITECTURE

The indirect relationship between the referent and the symbol began to occur by the development of the thought and the reference system in the human life (Ogden and Richards, 1989; Giannakidou et al., 2014). Primarily, human observed stimuli in the nature, and has responded to existing conditions. Human's efforts to live together in the nature as a community began to form culture in time. The development of culture is based on information and language as the basic form of communication. Cultural references clearly emerged with the transition from nomadic to settled life (Weisdorf, 2005). With the advances in the Neolithic period, the need to organize and transmit knowledge directed human to the writing (Childe, 2010). Early samples of the writing appear in the form of what they symbolize through visuals. Then, it turned away from resembling the object by use of simplified characters and also began to symbolize sounds. The writing is the most basic form of transforming information to data. Referents are physically structured via writing to symbolize anything. These advances have led to the emergence of data, which is the concrete form of information or knowledge. Data is based on perception of referents in nature or culture, and also to be recorded with specific symbols.

It is necessary to understand the differences between information, knowledge and data for the proper use of the term data. Use of these terms with the fundamental meaning provide the better understanding of relations than the other assumptions. This point of view clarifies that why term data is used instead of information and knowledge. Afterwards the origin of the data is investigated, it shows that data contains natural or cultural references. Besides, data is inherently associated with place in architecture. Local data approach can be used as a framework to classify the data in terms of architectural design. Under this approach, local data covers all data that belong to a place and its surroundings under the categories of natural and cultural data. The systematic understanding of the data for the design to be developed through the local data helps the architect's design process.

2.1 The Relation of Data, Information, and Knowledge

The definitions and the relations of data, information and knowledge are accepted with different aspects in literature (Zins, 2007). Most of the researchers use Ackoff's (1999) definition for the hierarchy of data, information, and knowledge. According to this definition, data are symbols that represent the properties of objects and events. Information consists of processed data, that directed to increase the usefulness of information. Knowledge is know-how, and what makes possible the transformation of information into the instructions. This hierarchy shows that data can be used to create information, and information can be used to create knowledge (Rowley, 2007). Most of these definitions are described from an information systems perspective. They base on the processes associated with the transformation between data, information and knowledge. But this hierarchy is not useful to understand these concepts and has problems about reasoning.

Despite many studies at the definition of data, information and knowledge, there is not a common acceptance of what they are and the relationships between them (Liew, 2007). The use of the three terms is not consistent, and often conflicting. Especially, the terms of data and information are often used in an interchangeable manner (Chen et al., 2009). It shows that distinctions between information, knowledge and data need to be reconsidered.

The term of information with the basic meaning is used to refer to the communication or reception of intelligence (Webster, 2018a). Information is the most primitive form of anything perceived as potentially signifying something. It is the state of knowledge outside the mind and exists independent of human (Demir, 2000). Source of information encodes the information into the reality. The meaning of the information depends on the ability to be decoded by the receiver (Aksoy, 1975; Eco, 1998). Only a protocol based on knowledge can transfer information. The transferred information becomes meaningful as knowledge, and operable as data. If it is explained with an example to better understand, a voice such as human speech can be exploited. This speech is produced by a person in her/his native language to communicate. If it is nonsense to the listener, it is just a voice in the form of information. But if it is meaningful to the listener who understands spoken language, it is in the form of

knowledge. This speech becomes data when it is recorded on a paper or a voice recorder.

Knowledge is internalized information that has decoded inside of a cognitive system. It can be described as the conceptual model of the reality in the mind (Bayazit, 2004). The common view is that knowledge is the product of a synthesis in the mind of the knowing person, and exists only in knower's mind. It is embodied in humans as the capacity to understand, explain and negotiate concepts, intentions, and actions (Hey, 2004). It is shaped by knower's personal perceptions and experiences, and therefore individuals build their own knowledge. Only data can exist in a knowledge based structure as persistent or transient in any environment, regardless of the person.

Data is the structured statement of information or knowledge. It provides a format that can be processed by information systems (Demir, 2000). It takes shape in specific symbols by knowledge based protocols. This is the only way to capture, store and transfer the information or knowledge in a representation medium. Moreover, data has the ability to become information in reality or knowledge in mind. The type of transition depends on how the receiver gives meaning to data. Consequently, it can be said that, information, knowledge, and data have a transition which need to be simply explained (Figure 2.1).

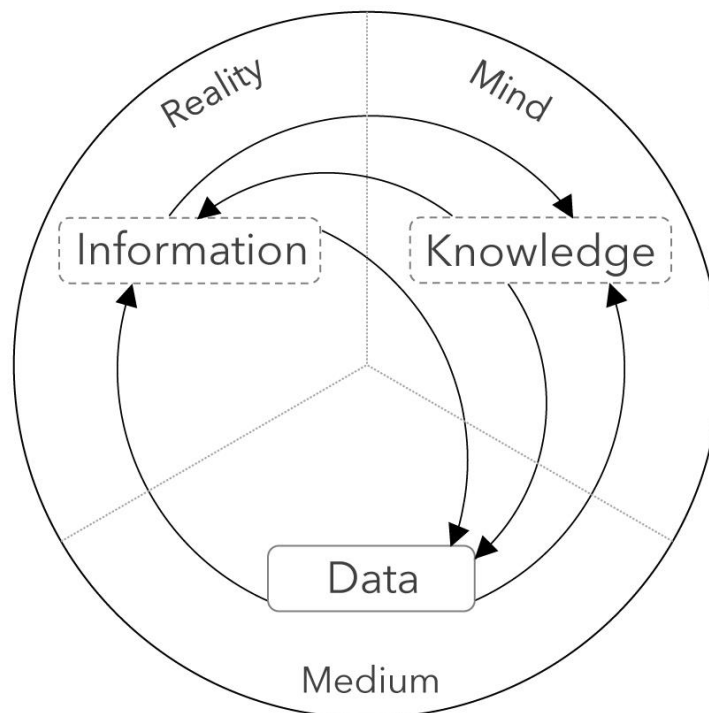


Figure 2.1 : Information, knowledge and data relation.

Information flow is continuous and everywhere; but in order to be useful it has to be the data. For instance, if you are the architect who takes notes at a given place for architectural site survey, you should see factors that affect your design. They can be in a wide range from topography, climate, landscape to legal boundaries, surrounding buildings, accessing to the site etc. But if you are not eligible to reach all architectural knowledge, you can just focus on one information like vista as an important factor for design. Although the existing information is identical in the site, data varies depending on the knowledge of the person. This case indicates that if person has not knowledge about information, the information cannot transform to data.

Most of the researchers claim that data, information, and knowledge are part of a sequential order (Baskarada and Koronios, 2013). But, this study's description provides a relative approach to information, knowledge and data. One of them can derive from others, therefore it shows a cyclical relation. The identical thing can be defined as information, knowledge or data, depending to where it happened in reality, mind or representation medium (Figure 2.1).

Information is usually used instead of data or knowledge in daily use by the reason of not defined very well. The essential nature of information has been considered as fundamental to our existence by many studies (Sanders, 2016). This study generates a new perspective to data, information and knowledge relation, with the basic meaning of information. It also shows that data is the most concrete form of them to use in processes. Apart from the common definitions and the relationships between data, information and knowledge, this approach can be more useful to grasp the terms.

2.2 Natural and Cultural Data

The nature covers everything and human is a part of nature. Human forms and develops culture, while nature imposes conditions that feed or restrict formation of culture. According to Marx, culture is everything that human beings create against the creatures of nature (Güvenç, 1994). Haila (2000) points out that culture may be viewed as an agent that actively struggles for domination over nature. The culture phenomenon can be recognized as a result of the interaction between human and nature. In these approaches, culture is expressed in an anthropocentric way despite the possibility of other species cultures. Human is seen as the main factor in the emergence of data that includes natural and cultural beings. The natural conditions forced human to act with

an adaptive behaviour against nature. These facts directed human to be aware of the natural beings. In order to survive in nature, human adopted to the order of living together as a community, and this way of life gives birth to culture (White, 2016). The attitudes developed against natural conditions and the living in the community have led to emergence of cultural beings. In this way, human began to consider the natural data, and derived the cultural data.

According to Demir (2016), there are two fundamental categories of being associated with architecture as natural and cultural. While all layers of being can be considered in the natural category, cultural category comprises the psychical and spiritual layers (Figure 2.2). This approach provides a fundamental classification to use in architecture as natural and cultural category.

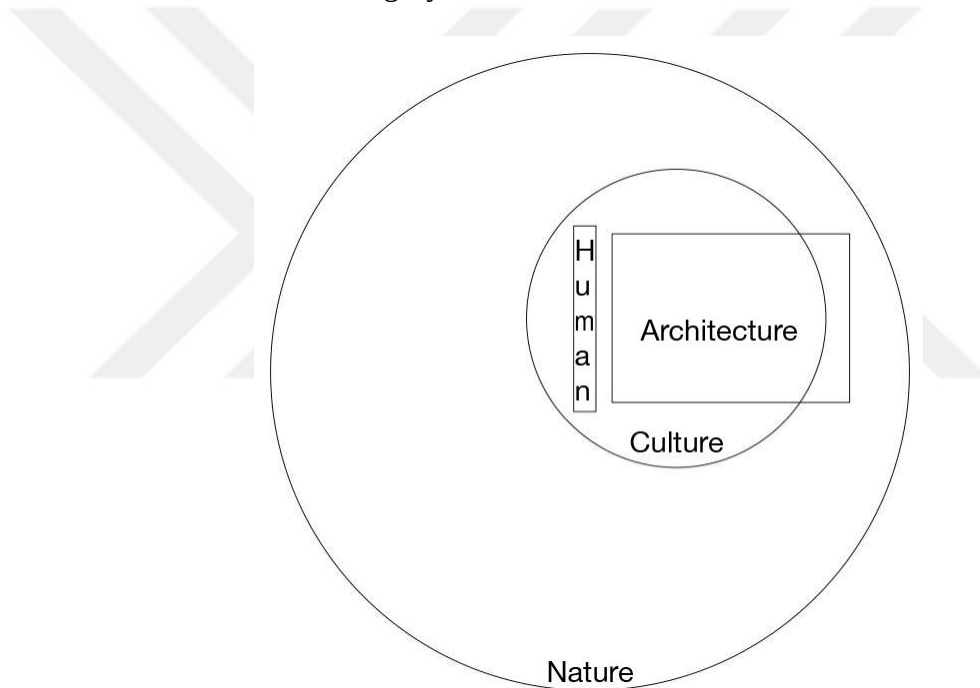


Figure 2.2 : Human / Nature / Culture (Demir, 2016).

Nature is often equated with the natural environment, but culture is just seen as customs, rituals, beliefs and other spiritual layers. This is an incomplete view of culture without physical artifacts of human. Rapoport (2005) suggests that culture can be interpreted in different ways. According to Rapoport (2005), three types of responses can be determined for what culture does. First, the purpose of culture is to provide a life design through a variety of rules that show how things should be done. The second view accepts the purpose of culture as creating a framework that gives meaning to parts. Objects can only gain meaning in their position relative to one another in such a

framework. The third view is that the aim of culture is to define groups. All these insights are gathered in a holistic perspective to make culture operational, especially as it relates to the physical environments (Rapoport, 2008).

It is seen that different conceptualizations of culture are useful to understand the most comprehensive meaning of culture. In this study, cultural layers of being are considered as the parts of the culture that gives meaning to anything. Thus, every kind of man-made being emerged from the interaction of human with the nature is considered to be the result of culture. Especially for architecture, it provides that physically existing components of culture are examined under the category of cultural data. On the other hand, everything that exists in nature itself and does not have any human interaction can be considered as natural data. These definitions are useful to understand the classification of cultural and natural data. For instance, agriculture is a cultural data despite of its natural structure, because it includes the effect of human.

According to Bunschoten, when the conditions of the site are seen for architectural design, architects have to understand the relations between the natural layers of the world and the cultural layers that are created by humanity. These natural and cultural layers interact with each other and struggle to outrival each other (Anderson, 2011). In architecture, natural and cultural data can be used to classify via origin of data. Thus, the architect can easily be aware of the natural conditions to protect nature and avoid hazards in design, and the cultural effects suitable for the users. The classification of these layers provides a systematic approach to deal with data for architectural design.

2.3 Local Data: A Data Framework for Architecture

Architecture is a discipline that is directly related to the place, unlike other design disciplines. Norberg-Schulz (1980) explains the basic act of architecture as being “to understand the vocation of the place”. Norberg-Schulz (1980) conceptualized “genius logi” to concretize the sense of place. This is done by means of buildings, which gather the properties of the place and bring them close to human. According to Wright (1957), architectural design is about being native to the place, and this kind of a point of view is one of the central design thought in modern architecture (Boyacıoğlu et. al., 2017). Architecture requires an appropriate relationship between the place and the building. Features of site give special character to places and shows how architecture can respond by creating a meaningful environment. Every community lives in the tension

created by the intersection of the natural environment and human culture, and each develops its architectural responses to that tension (Crouch and Johnson, 2001). Architectural design focuses on the data related to the characteristics of the buildings and context of the place. On the one hand architecture needs to respond functional requirements, whilst on the other it needs to take into account the natural forces and cultural accumulations (Baker, 2003).

Depending on the place, natural data is effective on placement and form of architecture. It is essential for architecture to provide spatial arrangements according to topography, to create a comfortable environment compatible with climatic conditions, to benefit from the natural materials of nearby place, and so on. Some of the decisions taken during the design process are based on acting in accordance with natural data. Therefore, it is important to use of natural data in architecture for maintaining the link between human and nature.

Cultural data includes physical components of culture in built environment and other intangible components of culture such as habit, tradition, and ritual. All these components cover everything that human does and creates. For this reason, cultural data is the primary factor in the emergence of the architectural environment and life style of a community. Even under the same natural conditions, cultural data allows for the emergence of different architectural settlements and formations.

In architecture, natural and cultural data are needed to be discussed by the context of “local”. Local means having a definite location (Webster, 2018b). According to Tekeli (2010), local serves as a framework that defines a specific place which includes the physical structures and the natural features of the environment. Alongside, community and their culture integrate with physical environment to make it meaningful. Every place has its own natural and cultural characteristics to exist as a distinctive place. Every place is unique, and there is really no other place like it (Leatherbarrow, 1993). It clearly shows that place is the source of local data for architecture.

Local data belongs to a specific place that is a whole with data around. In the context of the study, the concept of local data considers the location as the main context source for data while classifying other contextual factors. In order to benefit from local data, a framework in which data is classified is needed. Generally, architects use their observations about the place and accessible data for architectural design. This

circumstance directs architects to work on limited data rather than using an extensive data framework to check all related data. Therefore, firstly the fundamental classification is considered by natural and cultural characteristics, which are peculiar to place in architecture. Thus, it is seen that local data can be organized in a way that includes not only natural characteristics such as topography, climate, vegetation, natural resources etc., but also cultural characteristics such as buildings, utilities, legal boundaries, demography, cultural heritage etc.

Comprehensive literature research is needed to provide categories and subcategories of the natural and cultural data systematically. In the scope of the study, architectural studies (White, 1983; Unwin, 1997; Fawcett, 1998; Birkeland, 2002; Thomas, 2002; Spreiregen and De Paz, 2005; Farrelly, 2012; Bielefeld and Khouli, 2017), site planning studies (Lynch, 1971; Brooks, 1988; McBride, 1999; Beer and Higgins, 2000; Pitts, 2004; Towers, 2005; Carmona et al., 2010; LaGro, 2013), and legal regulations in architecture and planning (Regulation on Making Spatial Plans, 2014; National Planning Policy Framework, 2018) are evaluated to construct a data framework.

In Table 2.1, classes of natural and cultural data come together in different colours. These data classes are collocated by considering their relationships with each other in reviewed sources. It is observed that data classes have no differences in use and meet the common scope. Each data class contains basically the same approach from different sources. Consequently, this literature research reveals data classes as: land use, land types, boundary, density, built environment, building types, size and placement of buildings, neighbourhood patterns, local formation of buildings, construction techniques, materials of construction, topography, slope, drainage, scenery, geology, underground resources, hydrology, vegetation, wildlife and conservation areas, biodiversity, utilities, transportation, energy, electricity, gas, communication, water, sewage, waste, accessibility, pedestrian access, vehicular access, surrounding traffic patterns, public transportation, parking areas, sensory attributes, views, noise problems, odour problems, air pollution, climate, sunlight and shade, temperature, wind, humidity, precipitation, disasters, hazards, laws and regulations, social environment, demography, sociocultural context, historical development, cultural conservation areas, landmarks and historic buildings, conserved buildings, future visions and projects.

Table 2.1 : Evaluation of data classes for architecture in literature review.

Natural & Cultural Data	Lynch, 1971	White, 1983	Brooks, 1988	Unwin, 1997	Fawcett, 1998	McBride, 1999	Beer & Higgins, 2000	Thomas, 2002	Birkeland, 2002	Pitts, 2004	Towers, 2005	Spreiregen & De Paz, 2005	Carmona et al., 2010	Farrelly, 2012	LaGro, 2013	Regulation on Making Spatial Plans, 2014	Bielefeld & Khouli, 2017	National Planning Policy Framework, 2018
Land Use	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Land Types (Residential, Agricultural, etc.)	x		x			x	x	x	x		x		x		x	x		x
Boundary	x	x	x		x	x						x		x	x	x		x
Density	x	x	x			x	x	x	x	x	x		x	x		x	x	x
Built Environment (Existing Structures)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Building Types (Residential, Commercial, etc.)		x	x	x			x	x	x	x	x	x	x	x		x	x	x
Size and Placement of Buildings	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x
Neighbourhood Patterns	x	x						x	x		x	x	x		x	x		x
Local Formation of Buildings		x		x				x	x		x	x	x	x	x	x	x	x
Construction Techniques	x								x	x	x	x	x	x			x	
Materials of Construction	x	x		x					x	x	x	x	x	x			x	x
Topography	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Slope	x	x	x			x	x		x			x	x	x	x	x	x	x
Drainage	x	x	x			x	x		x				x		x	x		x
Scenery (Aspect)	x	x	x		x	x	x	x				x	x		x		x	x
Geology (Ground, Soil)	x	x	x	x		x	x	x	x			x	x	x	x	x		x
Underground Resources							x			x	x		x	x	x	x		x
Hydrology (Water Resources)	x	x	x			x	x	x	x	x			x		x	x		x
Vegetation	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x

Table 2.1 (continued): Evaluation of data classes for architecture in literature review.

Natural & Cultural Data	Lynch, 1971	White, 1983	Brooks, 1988	Unwin, 1997	Fawcett, 1998	McBride, 1999	Beer & Higgins, 2000	Thomas, 2002	Birkeland, 2002	Pitts, 2004	Towers, 2005	Spreiregen & De Paz, 2005	Carmona et al., 2010	Farrelly, 2012	LaGro, 2013	Regulation on Making Spatial Plans, 2014	Bielefeld & Khouli, 2017	National Planning Policy Framework, 2018
Wildlife & Conservation areas	x		x				x	x	x	x					x	x		x
Biodiversity (Flora & Fauna)	x		x				x	x	x	x	x	x	x	x	x	x		x
Utilities (Infrastructures)	x	x	x			x	x	x	x		x	x	x		x	x		x
Transportation (Road, Railway, Airline, etc.)	x		x				x		x						x	x		x
Energy	x	x			x			x	x	x	x		x		x	x		x
Electricity	x	x	x			x	x	x				x	x		x	x		
Gas	x	x	x			x	x					x	x		x	x		
Communicaton	x	x				x	x		x			x	x		x			x
Water	x	x	x		x	x	x	x	x		x	x	x		x	x		x
Sewage		x	x		x	x	x	x	x	x	x	x	x		x	x		x
Waste	x	x						x	x	x	x		x		x	x		x
Accessibility	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pedestrian Access	x	x	x		x	x		x	x		x	x	x			x		x
Vehicular Access	x	x	x		x	x		x	x		x	x	x			x		x
Surrounding Traffic Patterns	x	x	x			x		x	x			x	x		x	x		x
Public Transportation		x	x			x	x	x	x	x	x	x	x			x		x
Parking Areas	x		x				x		x		x	x	x		x	x		x
Sensory Attributes	x	x					x	x	x		x		x		x			
Views	x	x	x			x	x	x	x			x	x		x			x

Table 2.1 (continued): Evaluation of data classes for architecture in literature review.

Natural & Cultural Data	Lynch, 1971	White, 1983	Brooks, 1988	Unwin, 1997	Fawcett, 1998	McBride, 1999	Beer & Higgins, 2000	Thomas, 2002	Birkeland, 2002	Pitts, 2004	Towers, 2005	Spreiregen & De Paz, 2005	Carmona et al., 2010	Farrelly, 2012	LaGro, 2013	Regulation on Making Spatial Plans, 2014	Bielefeld & Khouli, 2017	National Planning Policy Framework, 2018
Noise Problems	X	X		X			X	X	X	X	X	X	X		X		X	X
Odour Problems	X	X		X			X		X						X			
Air Pollution							X	X	X				X		X			X
Climate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sunlight & Shade	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Temperature	X	X	X			X	X	X	X			X		X	X			X
Wind	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X
Humidity	X	X	X	X			X	X				X			X			
Precipitation	X	X	X	X		X	X	X	X	X		X	X	X	X			
Disasters		X	X	X							X				X	X		X
Hazards			X				X				X	X	X			X		X
Laws & Regulations	X	X	X			X	X	X	X	X	X	X	X		X	X	X	X
Social Environment	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X
Demography	X	X	X				X	X	X		X	X			X	X		X
Sociocultural Context		X	X	X	X		X	X	X		X	X	X		X	X	X	X
Historical Development	X	X	X	X	X		X		X	X		X	X	X	X	X	X	X
Cultural Conservation Areas		X		X				X						X	X	X		X
Landmarks & Historic Buildings		X			X		X	X			X		X		X	X	X	
Conserved Buildings		X					X	X					X		X	X	X	X
Future Visions & Projects	X	X		X			X		X				X			X		X

In literature review, data classes that are needed in architectural design are examined for data framework. By considering the relations of each data class to other classes, the data classification system has begun to form. When the data classes are collated, the interrelated data in sources are also grouped in Table 2.1. These relationships are considered to determine a local data framework in this study.

All of these data classes are organized to structure local data framework that has been emerged in Table 2.2. In this framework, all data belonging to the place are grouped under two main categories as Natural Data (ND) and Cultural Data (CD). Categories are also clustered with subcategories according to their relationship with each other. Natural data includes the categories of topography, geological features, water resources, vegetation, climate, wildlife & conservation areas, biodiversity and natural disasters. Cultural data includes the categories of land use, built environment, utilities, legislation, social environment, accessibility, sensory attributes and hazards.

The classification of the local data comprises various subcategories under the categories. When natural data categories are grouped by their relationships, the category of topography contains slope, drainage, and scenery subcategories. Geological features are classified as ground type and underground resources subcategories. According to reviewed sources, categories of water resources, vegetation, wildlife and conservation areas have not defined subcategories. The category of climate consists of sunlight and shade, temperature, air flow, humidity, precipitation subcategories. Biodiversity includes plant and animal varieties in itself. Natural disasters can be classified as geological, hydrological, meteorological disasters.

On the other hand, cultural data that have the effect of human are grouped. The category of land use contains land type, boundary and area, density, neighbourhood pattern, historical development and conservation areas, future visions and plans subcategories. The category of built environment consists of building type, size and placement of building, local formation of buildings, construction technique, materials of construction, landmarks and conserved buildings, future projects subcategories. Utilities are classified as transportation, energy, communication, water, sewage, and waste. The category of legislation without subcategories represents all laws and regulations which organize community life and structuring conditions. The category of social environment contains demography and sociocultural context subcategories.

Table 2.2 : Natural and cultural local data framework for architecture.

Natural Data (ND)	Cultural Data (CD)
ND₁ - Topography	CD₁ - Land Use
ND ₁₁ - Slope	CD ₁₁ - Land Type
ND ₁₂ - Drainage	CD ₁₂ - Boundary & Area
ND ₁₃ - Scenery	CD ₁₂ - Density
ND₂ - Geological Features	CD ₁₃ - Neighbourhood Pattern
ND ₂₁ - Ground Type	CD ₁₄ - Historical Development & Conservation Areas
ND ₂₂ - Underground Resources	CD ₁₅ - Future Visions & Plans
ND₃ - Water Resources	CD₂ - Built Environment
ND₄ - Vegetation	CD ₂₁ - Building Type
ND₅ - Climate	CD ₂₂ - Size and Placement of Building
ND ₅₁ - Sunlight & Shade	CD ₂₃ - Local Formation of Buildings
ND ₅₂ - Temperature	CD ₂₄ - Construction Technique
ND ₅₃ - Air flow	CD ₂₅ - Materials of Construction
ND ₅₄ - Precipitation	CD ₂₆ - Landmarks & Conserved Buildings
ND ₅₅ - Humidity	CD ₂₇ - Future Projects
ND₆ - Wildlife & Conservation Areas	CD₃ - Utilities
ND₇ - Biodiversity	CD ₃₁ - Transportation
ND ₇₁ - Plant Variety	CD ₃₂ - Energy
ND ₇₂ - Animal Variety	CD ₃₃ - Communication
ND₈ - Natural Disasters	CD ₃₄ - Water
ND ₈₁ - Geological Disasters	CD ₃₅ - Sewage
ND ₈₂ - Hydrological Disasters	CD ₃₆ - Waste
ND ₈₃ - Meteorological Disasters	CD₄ - Legislation
...	CD₅ - Social Environment
ND _n - ...	CD ₅₁ - Demography
	CD ₅₂ - Sociocultural Context
	CD₆ - Accessibility
	CD ₆₁ - Pedestrian Access
	CD ₆₂ - Vehicle Access
	CD ₆₂₁ - Surrounding Traffic Pattern
	CD ₆₂₂ - Public Transportation
	CD ₆₂₂ - Parking Areas
	CD ₆₃ - Bicycle Access
	CD ₆₄ - Disabled Access
	CD₇ - Sensory Attributes
	CD ₇₁ - Views
	CD ₇₂ - Noise Problems
	CD ₇₃ - Air Quality & Odour Problems
	CD₈ - Hazards
	...
	CD _n - ...

The category of accessibility contains pedestrian, vehicle, bicycle and disabled access subcategories. Vehicle access subcategory can be classified as surrounding traffic pattern, public transportation, and parking areas. The category of sensory attributes consists of views, noise problems, air quality and odour problems subcategories. Hazards without subcategories represents human induced dangers like crime rate, night security, and so on.

This framework provides an organized structure for local data and supports the classification of data related to the place. Given the nature of this framework, location is handled as the major context source to classify the other contextual factors. Instead of being evaluated in a separate framework, temporal context is embedded in subcategories like the other contextual factors. The combination of temporal factors with data leads to the derived subcategories such as historical development, future visions and so on.

The classification of natural and cultural data can also be carried out under different categories and subcategories. This classification is realised according to data classes of reviewed sources. It is also possible to classify this framework in different ways depending on the varied classification approaches. This framework is not absolute, it's open to development. When new data may be derived, the classification system may expand. For instance, if the effects that come from space such as meteor stream affect the world, it may be included in this framework as natural data.

Local data framework has been developed to classify data that are used for architectural design. In the architectural design process, the architect needs data related to the context of the place. Observing natural and cultural resources by visiting the site provides clues about how to produce an appropriate design response. Afterwards, the architect evaluates these natural and cultural data according to the required formal, functional and structural needs. Instead of this process that uses a coincidental approach to data acquisition, local data framework provides a systematic classification in relation to location. Local data framework contains all the data that should be considered when making design decisions. In the architectural site survey, the architect can check all available data according to local data framework. Thus, the possibility of missing important data is eliminated. For instance, forgetting to check land use or legislation can cause serious problems in the implementation of the architectural

design. In addition, the architect records data with its location information. Thereby, data's relationship with the place is maintained for the analysis process.

2.4 Conclusion of the Chapter

In this chapter, a relative approach is adopted to provide a better understanding of the relationship between data, information and knowledge. This is essential to understand why data term is used as a concrete form of information and knowledge. At the same time, this approach prevents the use of the data, information and knowledge term interchangeably and expresses their use in scientific studies correctly. When the origin of the data is investigated, it is seen that each data carries natural or cultural references. This indicates that the fundamental classification of data can be organized under natural and cultural categories. With the extreme increasing human impact on nature, the classification of data that base on being natural or cultural can become more important in the future. Through these theoretical studies, the basis is prepared for the transition to data in architecture.

Architecture is a discipline that is inherently associated with the place. Even though place could be seen as a limitation for architectural design, it actually offers many different possibilities. By the reason of two different sites are not exactly the same, place makes architecture original and unique. Each place offers different data in terms of understanding and interpreting the site. Considering the relationship with the place in architecture, the data in the field of architectural design are handled under the local data approach. By means of this approach, local framework associated with a place is defined for architectural design. Understanding the site and its surrounding potential through local data provides an analytical process for architectural design.

To take advantage of the local data concept, a data classification framework is needed to manage data. Primarily, data classes that are needed in architectural design are examined with their origin through literature research. Architectural studies, site planning studies, and legal regulations in architecture and planning are evaluated to construct a data framework. Afterwards, local data framework is developed with the use of fundamental classification as natural data and cultural data, and data classes relationship with each other. It is also possible to classify this framework in different ways depending on the varied classification approaches. To develop subcategories, more comprehensive research is needed for each data class. Although it is possible to

define each data class with its qualitative or quantitative parameters, the sources used in this study are not suitable for a research within this scope. This kind of study requires a more comprehensive research based on the practical use of each data in daily life. Local data framework is expressed as an open approach to development rather than a framework that is terminated in the study.

In addition to providing a theoretical basis, this study provides a framework for the practical use in further studies. Local data framework can be integrated into computational platforms that effectively interact with and utilize from data contained within the site. The classification of data through this framework provides a systematic approach to easily access to all data associated with the place in architectural design. Local data framework supports the architect in design by taking data into account.



3. LOCATION BASED DATA REPRESENTATION THROUGH AUGMENTED REALITY IN ARCHITECTURAL DESIGN

Architects carry out site visits prior to a design activity to understand existing conditions. They also need typical activities that includes data gathering, managing complexity, mapping and analysing site. These activities are the main tasks to start an architectural design from first site visit to analysis (Anderson, 2011). There is a fundamental need for an architect to visit the site where the project will be located. The site will suggest a series of characteristics that affect the architectural design (Farrelly, 2012). The natural composition of a site contributes to make it a distinct place through topography, landscape, natural resources and climate. Overlaid on its natural composition, cultural context also influences the way that people use the site and gives its character. Cultural context includes all human-made factors like religion, art, history, settlement, infrastructure, surrounding buildings, use of materials, etc. (LaGro, 2008). These natural and cultural characteristics of site need to be sought and gathered by the architect who designs there. However, it is necessary to manage the complexity of data from different parameters and sources. The condition of any site as a record of natural and cultural data can be mapped for organized complexity. The mapping provides to have read the site, and thoroughly understand it via spatial relations in architectural design. Architects correlate data which is spatially represented in a map to properly analyse a site and put it to use in their own project. At this point, architectural design needs to take advantage of information technologies for location based data.

Recently, location based augmented reality has come into prominence with the rise of the portable devices, the increasing availability of location based data and the accessibility of networks (Nóbrega et al., 2017). Location based computing makes it possible to link data to actual physical locations, thereby augmenting the real world with a layer of virtual information (Khan & Loke, 2017). Location based augmented reality systems can provide information about the contents of a place as the architect looks around the site. Therefore, an extensive study is carried out from augmented

reality characteristics and requirements to featured applications of location based augmented reality. Firstly, augmented reality characteristics and requirements are investigated to use in detailed analysis of applications. Additionally, these featured applications are evaluated with components, significance in location based augmented reality and potential contribution to architectural design. This chapter tries to suggest which augmented reality components are more suitable in recent conditions for use in architectural design related to the site.

3.1 Augmented Reality Characteristics & Requirements

Beginning in the 1960's, augmented reality has progressed from first augmented reality prototypes (Sutherland, 1968), to coin as augmented reality (Caudell & Mizell, 1992), and the developments continues with enabling technologies. Augmented reality complements the real environment with virtual content that creates a seamlessly coexisting spatiality. The goal of augmented reality is to enrich a user's perception and interaction with the real environment (Arnaldi et al., 2018). Combining real and virtual, interaction in real time and registration in 3D are characteristic properties of augmented reality systems (Azuma et al., 2001). These fundamental characteristic properties also demonstrate the technical requirements of the augmented reality system. An augmented reality systems need to have a display to combine real and virtual content, an interface that can provide interaction on a computer system and a tracking system to find the positions of virtual contents and user's view (Billinghurst et al., 2015).

3.1.1 Combining real and virtual: display techniques & types

In order to combine real and virtual content, some kind of display technology is needed. Depending on the display techniques and the position of the display, augmented reality display technologies are classified in two different approaches (Krevelen & Poelman, 2010). Table 3.1 shows display techniques, display types and display devices that emerged from the intersection of display techniques and types. Basically, there are three display techniques to visually present an augmented reality: video see-through, optical see-through and projection-based display (Verlinden, 2012).

In video see-through display technique, computer graphics are combined with captured video frames in real time. This type of technique digitizes the real environment scene through the camera, thereby the image of the real environment can be combined with virtual content by digital image processing (Carmigniani et al., 2011). Video see-through display is the most widely used technique in augmented reality systems due to the ease of accessing the display devices. A wide range of devices, from smartphones to tablets, include a camera that can be used to capture video for augmented reality.

Table 3.1 : Display techniques and display types for augmented reality (Verlinden, 2012).

Display techniques / Display types	Video see-through	Optical see-through	Projection-based
Head-attached	Head-mounted display (HMD)		
Hand-held	Hand-held devices	See-through	Spatial
Spatial	Embedded display	boards	projection-based

Another technique is optical see-through display that provides the virtual content with a direct view of the real environment. This technique uses an optical combiner to superimpose a computer-generated scene onto the real scene (Hua et al., 2011). With leaving the perception of real environment alone, optical see-through displays do not suffer from limitations in time delay or resolution. It's important for safety demanding applications that require a direct view of the real environment, such as military or medical application.

The third technique is projection-based display that projects the virtual content overlay onto real environment. While other techniques combine the real and virtual view at the scene's image plane, projection-based displays overlay virtual content directly on the surface of the physical object (Sand et al., 2016). Projection-based display has an advantage of not requiring the user to wear anything, but this circumstance limits the display because of being tied to certain positions. It is needed to project the virtual content onto the physical surface. Other limitations of projection-based display include being more sensitive to lighting conditions, and suffering from shadows created by other physical objects.

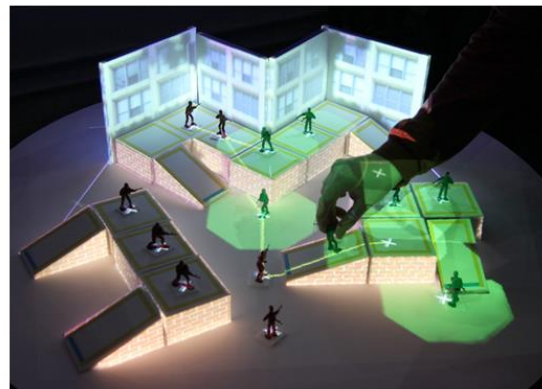
While augmented reality displays use different techniques to combine the virtual and real environment, they can also be categorized based on where the display is placed between the user's eye and the physical object to be augmented (Bimber & Raskar, 2005). Displays can be arranged in three different types: head-attached, hand-held and spatial display (Peddie, 2017). Figure 3.1 shows where the displays are located with respect to the observer and the physical object with example of displays.



Head-attached display



Hand-held display



Spatial display

Figure 3.1 : Head-attached display, hand-held display, and spatial display (Sketchup Viewer, 2018; Kincade, 2014; Nasman & Cutler, 2012).

Head-attached displays refer to head-mounted displays (HMD), which can apply either of the three display techniques. Users mount this type of display on their heads, providing virtual content in front of their eyes. No other physical objects come between the eyes and the virtual content from the display, which supplies the virtual content not getting blocked by other physical objects (Aukstakalnis, 2016). The main advantage of head-attached display is its hands-free nature. These displays provide visually immersive experience and high mobility.

Hand-held display describes augmented reality systems which can be held by the user. With advances in mobile device technology, hand-held displays became powerful enough to process augmented reality visualization. From smartphones to tablets, a variety of devices have been used as augmented reality displays (Yusof et al., 2016). Hand-held displays are considered to be personal and mobile, besides sharable with others as needed. They are also more socially accepted compared to head-attached displays.

Projecting the virtual content directly onto the surface of physical object is common approach used for implementing spatial display (Marner et al., 2011). Compared to head-attached and hand-held displays, spatial displays are usually installed at a fixed location and limited in mobility. As spatial displays allow a larger image in the outdoor environment, multiple users can readily see these displays as public. Spatial displays integrate technology into the environment and detach most of the technology from the user.

3.1.2 Interaction in real time: interface

One of the essential requirements of augmented reality is to create appropriate techniques for intuitive interaction between the virtual content of augmented reality applications and the user in real time. Depending on the interaction of augmented reality applications, different interfaces have emerged over time. There are five ways to interact in augmented reality applications. Figure 3.2 shows augmented reality interfaces: information browsers, 3D user interfaces, tangible user interfaces, natural user interfaces and multimodal interfaces (Billinghurst et al., 2015).

Information browsers are one of the representational types of augmented reality interfaces. In this interface, augmented reality displays are considered as a scene into an information space, and the main task of the user is to manipulate this scene to browse the information. Other types of interactivity common to information browsers includes filtering information shown, choosing different information to view, changing visualization style, and navigating into details of the information provided etc. Most of these interactions can be accomplished using traditional 2D graphical user interfaces and screen input (Langlotz et al., 2013). The interaction method provided is easy and simple to learn as the users can use their knowledge of traditional mobile user interfaces.



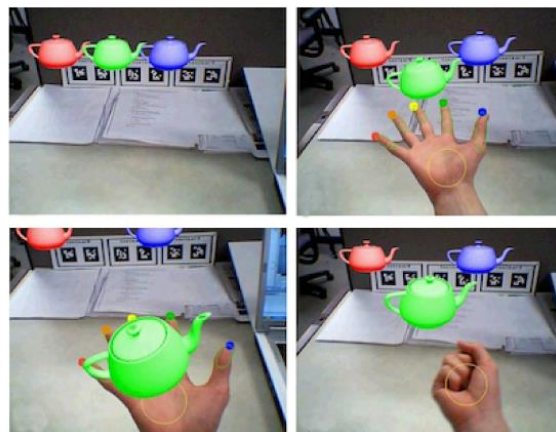
Information Browsers



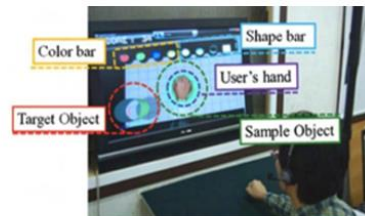
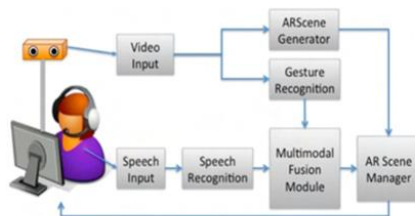
3D User Interfaces



Tangible User Interfaces



Natural User Interfaces



Multimodal Interfaces

Figure 3.2 : Augmented reality interfaces (Billinghurst et al., 2015).

3D user interfaces adopt 3D interaction techniques to manipulate virtual objects through controllers (Kulshreshth & LaViola Jr, 2018). 3D user interfaces can provide good interactivity in augmented reality applications for design, training and entertainment. Users can interact with 3D virtual objects in space in a familiar and natural way.

Tangible user interfaces use physical objects for representing virtual entities and information, and to bridge between the digital and physical. While tangible user interfaces provide intuitive and natural interaction with digital information through manipulating physical objects, they can have limitations with display capabilities,

either showing very limited information with different status of physical objects (Shaer & Hornecker, 2009).

Natural user interfaces provide the interaction of gestures and body motions. Sensors are used for tracking and recognizing body movements. With developments in computer vision technology, augmented reality systems became capable of recognizing user's gesture and body motion in real time without requiring the user to wear any sensors (Kaushik & Jain, 2014).

Multimodal interfaces are used to provide richer interactivity in augmented reality applications. Main goal of multimodal interfaces is to combine different modalities of input. Among different combination of input modalities, gesture and speech recognition combined is one of the most actively and widely researched combinations (Lee et al., 2013). This type of interface offers an expressive, robust, and highly mobile form of interaction to use in future augmented reality applications.

3.1.3 Registration in 3D: tracking

The registration in augmented reality is a process which properly aligns the objects in the real and virtual environments to each other. As users move their viewpoints, virtual contents must remain aligned with the observed 3D positions and orientations of real objects. The registration depends on accurately tracking the viewing pose, relative to either the environment or the annotated objects. Tracking is defined as the measurement of object position and orientation in a scene coordinate system (Yi-bo et al., 2008). Each type of tracking device has different level of accuracy that depends greatly on the type of system being developed. Tracking technology of augmented reality can be classified into three kinds: sensor based tracking, vision based tracking, and hybrid tracking techniques (Zhou et al., 2008).

Sensor based tracking techniques are based on sensors such as GPS, optical, inertial, mechanical, magnetic, or acoustic sensors. They all have their individual advantages and disadvantages while using in an augmented reality system (Pagani et al., 2016). GPS and inertial sensors are the most preferred types due to the ubiquity of mobile devices. These sensors are essential for detection of position and orientation in a location based application.

Vision based tracking techniques use image processing methods to calculate the camera pose relative to real objects. Objects are localized based on their pixel information including changes in brightness, intensity, and other local features. The advantage of vision based tracking is its high adaptability to unprepared environments. For instance, a cloud based system is able to present multiple 3D maps for an environment and the markerless tracking schemes can perform 3D registration based on image visual cues extracted from camera views (Yu et al., 2016).

Hybrid is the most common type of tracking for augmented reality systems by combining tracking techniques to comprise the advantages of both and support the disadvantages of the other. Hybrid tracking systems gain data from multiple sensors to enhance the accuracy of the individual sensors, overcome weaknesses of certain tracking methods, or add additional degrees of freedom. For instance, GPS tracking systems are often combined with inertial sensors and vision based tracking in order to obtain pose estimation due to their low accuracy and only providing positional information (Singh & Mantri, 2015).

3.2 Location Based Data Representation in Augmented Reality Systems

Augmented reality allows for an on-site representation of information that is registered to the physical environment. As computers decrease in size and increase in power, new wearable and mobile computing applications became feasible, promising users access to online resources continuous and everywhere. Significant improvement has been obtained by new generation smartphones and tablets, which are equipped with GPS, inertial sensors, and fast network connections (Shatte et al., 2014). With these opportunities, at the same time representation of spatial data sets has become important via location based services. The ability to supply location based data to users is a key aspect to make augmented reality more practicable (Pierdicca et al., 2016). The merge of location based services and augmented reality systems provides a valuable addition towards the presentation of data in the real world at the location of interest (Santana et al., 2017). Location based augmented reality systems facilitates a greater awareness spatially and better understanding of the environment (Riera et al., 2014; Pereira et al., 2018).

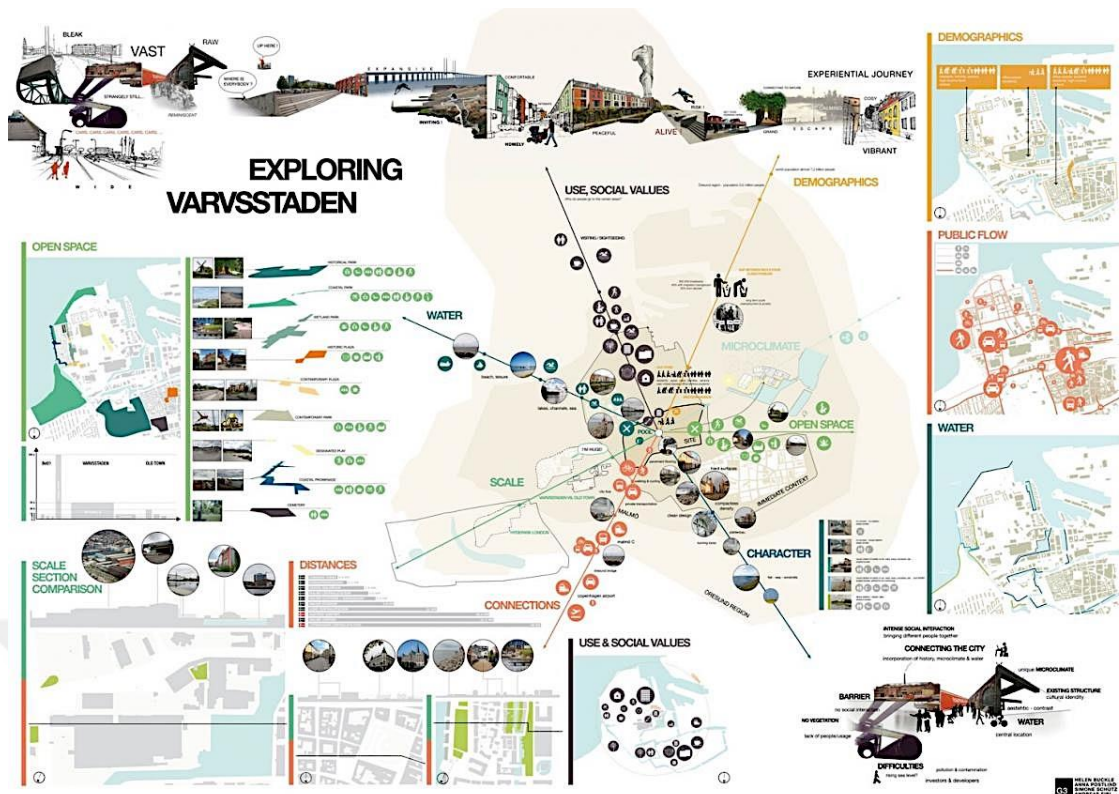


Figure 3.3 : An example of site analysis through mapping (Site analysis, 2017).

In architectural design, site visit is a fundamental need for an architect to understand existing conditions. Site visits provide clues about how to produce a design response. Architects spend time at the project site and make visits to experience the site's context. The architect's main efforts on the site focus on data gathering and absorbing the sense of place. However, it is necessary to manage the complexity of data from different parameters and sources. For this reason, the condition of any site can be mapped to have read the site, and thoroughly understand it via spatial relations in architectural design. Architects correlate data which is spatially represented in a map to properly analyse a site and put it to use in their own project (Figure 3.3). At this point, location based augmented reality can be used to map a site, and investigate it.

The use of location based augmented reality has become common with different applications in architectural design field (Freitas & Ruschel, 2013; Sato et al., 2016; Miyake et al., 2017). It makes possible a new class of applications that utilized surrounding contents of a place as the architect walks around the site. Thus, developments from the first implementations to the recent conditions have been revealed in location based augmented reality with featured applications. The sample applications included in this survey were selected based on their outstanding

characteristics and the improvements they have made. Potential contributions of these applications to architectural design are reviewed, whilst also providing an insight into attitudes towards utilising these technologies within the architectural site survey.

MARS

MARS, that means “Mobile Augmented Reality System”, is the first location based augmented reality project. Feiner et al. (1997) unites wearable computers with GPS tracking to present location based augmented reality interfaces for showing information on site in the real environment. The touring machine is an early prototype of MARS that presents 3D graphical tour guide information to campus visitors. The touring machine allows users to look around the university campus and access information via a tracked see-through display and hand-held display. The main theme of this application is to present contextual information of the university that visually connected to the physical world by combining multiple display and interaction technologies. The user is tracked through a combination of satellite based position tracking and inclinometer/magnetometer based orientation tracking. Besides GPS and inertial sensors, vision based approaches also are employed in MARS. Respectively to the current location, the browser provides information about the campus. As the user explores the campus, the see-through head-attached display overlays labels on buildings. When labels selected, each of them sends a link to an internet browser running on the hand-held device. With developing researches in MARS, 3D model of a building that once occupied Columbia University campus, is overlaid on its former site. This application also presents a situated documentary of the history in Columbia campus via showing the model of a historical building at its original location (Höllerer et al., 1999).

Figure 3.4 shows a different prototype of the MARS, indicates of restaurants in the university neighbourhood. This prototype offers an interface that is connected to a database of the restaurants in the city. Information about restaurants is presented either via an overview 3D map, so that the user can be guided to a specific place of own choices, or as direct annotations of the actual restaurant locations themselves. Having selected an establishment, the user can bring up a scene with further information on it: a short description, an image of the interior, restaurant’s menu and reviews (Höllerer & Feiner, 2004).



Figure 3.4 : MARS project as an augmented reality information guide (Höllerer & Feiner, 2004).

Archeoguide

Archeoguide provides archeological tours on site through augmented reality. This application uses mobile computing, 3D visualization, outdoor tracking, and augmented reality techniques to enhance information presentation, reconstruct ruin sites, and simulate former life. Archeoguide project aims to develop new interactive methods for accessing cultural heritage information. Site information servers administer a multimedia object database storing 2D images, 3D models, video, and textual objects on the archaeological site. These objects are organized in a hierarchical tree structure, enabling grouping according to the information they represent. Mobile units provide information stored in the central database to the touring users and incorporate a hybrid system that contains GPS, inertial and vision based tracking for identifying the user's view. The system filters the information through user's position and orientation. The system can personalize the archaeological tour according to the user profile, and priorities of the user. Based on parameters like interests, age, education, and archaeological knowledge, the system draws up a tour and enriches it with corresponding information on the database. Moreover, the proposed interface allows choosing between several themes and media. Archeoguide especially provides an opportunity to visualize the 3D reconstructed site (Vlahakis et al., 2002), see Figure 3.5.

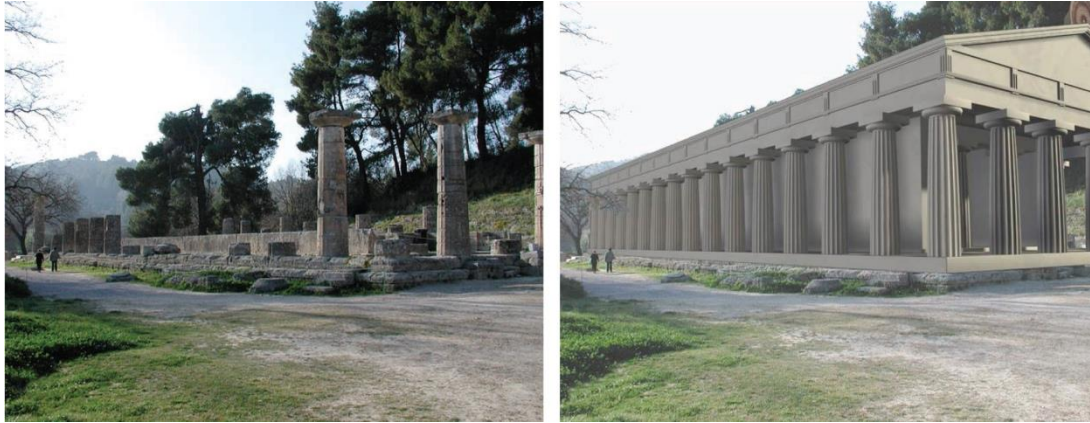


Figure 3.5 : Visualization of a cultural heritage on-site via Archeoguide (Vlahakis et al., 2002).

VIDENTE

With the advent of augmented reality applications running on hand-held computing devices, VIDENTE project develops a mobile augmented reality application to visualize subsurface characteristics. Unlike ordinary approaches, augmented reality provides a more intuitive interface to gain complex underground utility network data in the site. Users no longer have to transform map space into the real world since they obtain an integrated view of both at a time. From user's localization, it is possible to visualize in real time 3D representation of networks of cables and pipes hidden underground. Figure 3.6 shows the hidden pipelines superimposed as a computer graphics overlay on the road surface in front of the user. The rendered augmented reality scenes are adjusted continuously as the user moves around. The platform comprises a GPS module and an inertial measurement unit for respective position and orientation tracking. Geospatial objects originating from an operational location based database are delivered to the client application in online or offline mode. The application converts the delivered geospatial data into a corresponding 3D computer graphics data structure. Scenes are assembled as a video see-through at the hand-held device in real time by merging continuously streamed video footage with location based computer graphics considering the client's currently tracked position and orientation. By means of this application, users are enabled to visualize both hidden underground objects such as pipes, cables, and joins and abstract information such as safety buffers, or legal boundaries (Junghanns et al., 2009).

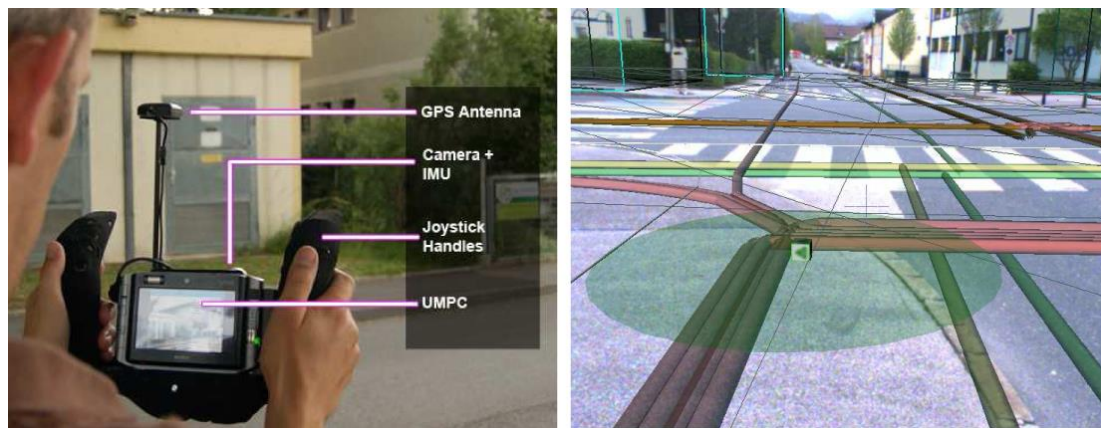


Figure 3.6 : Presentation of the subsurface infrastructure via VIDENTE project (Junghanns et al, 2009).

CityViewAR

CityViewAR provides information visualization on a city scale with the use of mobile outdoor augmented reality. The main aim of the CityViewAR application is to allow the user to efficiently access location based data with the interaction of the information browser. This application exploits sensors on mobile phones to provide information based on the current location of the user. Various visualization methods that include AR view, interactive digital map view, and list view, are used to meet different requirements of the users in application. The user can browse content with these three views as the main interfaces (Figure 3.7).

CityViewAR starts with the map mode that gives spatial context, and provides a starting point. The user can switch into the other browsing views using icons located at the screen corner, and then access various content including textual information and images (Lee et al., 2012). In the AR view mode, virtual information is overlaid on video background that is captured from the real environment using the camera. This type of application shows information on point of interest (POI) in the real environment. Location information is shown with textual informations and images of the related POI. Besides providing historical information about buildings, the application also provides 3D visualization of the former buildings on site. This application shows that making such information easily accessible to the public can help users to have richer experience about cities.



Figure 3.7 : Structure of CityViewAR application with browsing interfaces (Lee et al., 2012).

AREA

Alongside development of smart mobile devices, numerous techniques, concepts, and prototypes have been introduced, focusing on basic implementation issues of mobile augmented reality applications. Geiger et al. (2014) develops a mobile augmented reality engine that provides location based functionality. This augmented reality engine is denoted as AREA (Augmented Reality Engine Application). This augmented reality engine deals with the development of a generic mobile application, which enables location based mobile augmented reality for structuring applications. The basic concepts to enable location based calculations are developed to enrich the image captured by the mobile device's camera with virtual information about point of interests in the surrounding site. Figure 3.8 shows the algorithm realizing the location view in AREA.

AREA is integrated with several mobile applications such as LiveGuide. LiveGuide is used to provide tourists and residents of the city with the opportunity to explore their surrounding by displaying point of interests stored for the city. These kinds of applications take advantage of the modular design and extensibility of augmented

reality engine to realize such mobile applications on top of AREA. In the example of the LiveGuide application, the appearance of the point of interests is adapted to meet the user interface requirements of the concerned application. Moreover, the data model of the AREA is adapted to existing databases for the application. Figure 3.8 shows user interface elements as part of the LiveGuide application and originally implemented for AREA.

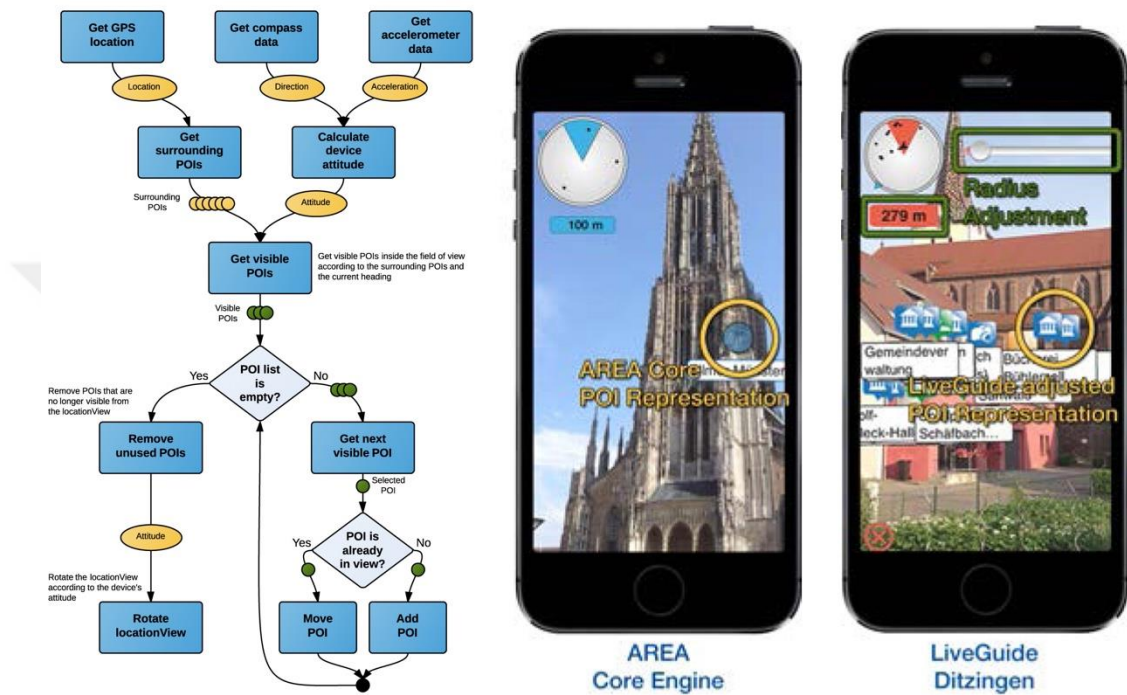


Figure 3.8 : Algorithm of AREA for presenting location view, and an adapted user interface from AREA core engine to LiveGuide (Geiger et al., 2014).

BIM based AR

Building information models (BIM) comprise an advanced form of documentation that can contain spatial information, schedule, and analysis etc. Architects have to rely on their spatial awareness to map the 2D drawings or 3D models into the context of the real environment, e.g. to use that information during the construction of the buildings on the construction site. Researchers tried to facilitate the process of mapping 2D design documentation to 3D real world construction reality by mixing virtual information with the real environment. Meza et al. (2014), focused on how to use the BIM information and feed it into augmented reality systems. They implement a BIM based AR system that consists of four activities: creating building information model, creating schedule, creating augmented reality model, and using augmented reality model on site (Figure 3.9).



Figure 3.9 : Presentation of BIM based AR (Meza et al., 2014).

3.3 Potential Contributions of the Augmented Reality to Architectural Design

These featured applications included in this survey were evaluated on their augmented reality components, significance in location based augmented reality and potential contribution to architectural design (Table 3.2). It shows that some of the components seem more appropriate to location based augmented reality systems. Hand-held displays that use video see-through display technique are mostly preferred type of display. It depends on widespread access to hand-held displays instead of head-mounted displays. On the other hand, head-mounted displays can be preferred as a natural platform with hands-free working environment in the future. This survey showed that information browsers are the most suitable representative types of augmented reality interfaces. These interfaces are designed for basic interaction tasks to view the visualized location based augmented reality scene and browse the information provided. Hybrid is the most suitable type of tracking systems to use in location based augmented reality. Reviewed applications showed that hybrid tracking based on GPS and inertial sensors is sufficient with the development of tracking technology. Furthermore, hybrid tracking can be enhanced with vision based tracking. For systems to be successful in architectural design, developers need to consider that augmented reality components need to be compatible, widely used, natural to interact with and precisely detectable.

Table 3.2 : Evaluation of featured location based augmented reality applications (Ünal & Demir, 2018).

Location Based Augmented Reality Applications	Display Technique / Display Type	Interaction Type	Tracking Type	Significance	Contribution to Architectural Design
MARS	Optical see-through display / Head-attached + Hand-held display	Information Browsers	Hybrid Tracking (GPS+DGPS+ Magnetometer+ Inclinometer+ Vision based tracking)	First use of augmented reality for the exploration of urban features	Representation of site information
Archeoguide	Optical see-through display / Head-attached + Hand-held display (Pen-tablet+Palmtop)	Information Browsers	Hybrid Tracking (GPS+DGPS+ Inertial Sensors+ Vision based tracking)	Use of different data representations and enhanced database structure	Visualization and simulation of former condition
VIDENTE	Video see-through display / Hand-held display	Information Browsers	Hybrid Tracking (GPS+Inertial Sensors)	Direct up to date data about the subsurface utilities	Presentation of hidden underground objects & legal boundaries
CityViewAR	Video see-through display / Hand-held display	Information Browsers	Hybrid Tracking (GPS+Inertial Sensors)	Information visualization on urban scale	Presentation of data on a city scale
AREA	Video see-through display / Hand-held display	Information Browsers	Hybrid Tracking (GPS+Inertial Sensors)	Engine application for location based augmented reality applications	Editable application layout for architectural applications
BIM based AR	Video see-through display / Hand-held display	Information Browsers	Hybrid Tracking (GPS+Inertial Sensors)	Building information modelling and augmented reality system integration	Visualization and simulation of 4D content (Information with a time component)

MARS is the first use of augmented reality with location based data for the exploration of urban features. It makes it possible to collect data of a site and represent it in real place for architectural design. This kind of application promises to make easier the design process by bringing the architect into more direct contact with the building site. They can enable architects to not only interact with surrounding contents throughout site visit, but also carry out design analyses while on the site.

Archeoguide introduces innovative approaches to organize multimedia objects in database for different data representations. In addition to that it can show historical information on archaeological site by use of 2D images, 3D models, videos, and textual contents. It can make contribution to architectural design about visualization and

simulation of former condition on site, such as older versions of buildings in view, or images of past events. It can also inform an architect to protect the archaeological areas on site.

VIDENTE converts location based data to three-dimensional computer graphics on a hand-held device. It provides direct up to date data about subsurface utilities. By means of this application, architects are enabled to visualize both hidden underground objects such as infrastructures and abstract information such as legal boundaries. It may allow architects to gain an instant check of a site's surroundings for finding the best place for architectural design.

CityviewAR is an essential application for the demonstration of information visualization on urban scale through smartphones. The main function of this kind of applications is to allow the user to efficiently access location base data in a city. It can enable a greater appreciation of a site's context for architectural design. Most of the information needed to understand a site's constraints and assess its merit can be provided to architect.

AREA is an engine application developed to enable location based augmented reality applications to be easily developed on smartphones. It can present information registered directly to places with point of interests (POIs). Information of POIs comes in a variety of forms, such as text, image, video, audio, or 3D model. It provides editable application layout for architectural applications.

BIM based AR focus on how to use the BIM information and feed it into augmented reality systems. The most familiar use of these applications is to overlay a real site with an intended virtual design at full scale. It can be used to present information with a time component via visualization or simulation of 4D content. This kind of application encourages architects to consider and evaluate their project site across a range of timeframes, and from multiple viewpoints. Given the data rich nature of BIM, it can be possible to perform site analysis in situ at full scale.

Location based augmented reality systems require that the user actually be at the place where the task is to take place. Being at the place is essential in architectural site survey. In a site visit, architects do not see these locations with comprehensive information. They have to collect site data from different sources and mediums. Then all collected data needs to be managed on maps that analyze the site. It is a long process

that takes time and work-force. Use of location based augmented reality systems can provide data presentation of locations as they are current condition. If a database of the environment is available, an augmented reality application can track data representations. With the use of augmented reality, an architect looks at project site and sees data directly overlaid on the site. Architects walking around the site with augmented reality systems would gain a much better understanding of the site. The power of augmented reality systems lies in their ability to visualize normally hidden or abstract features, such as infrastructures and boundaries. In addition to that augmented reality systems can show historical information of site. By providing information in a BIM format, location based augmented reality systems provide significant contributions to site analysis in scale with surroundings.

3.4 Conclusion of the Chapter

In this chapter, it is surveyed how location based augmented reality can be used in an architectural site visit. To understand the importance of location based data in architectural design, this survey is an extensive study from augmented reality characteristics and requirements to some featured applications of location based augmented reality. As can be seen, the main idea under the research is supporting architects with opportunities of location based augmented reality. Location based augmented reality has become increasingly popular in recent times due to the minimal hardware requirements, improved computational power of the devices, and the ubiquity of mobile devices. From this study, it is seen that hand-held devices are mostly preferred type of display with hybrid tracking. Information browsers are the most representative types of location based augmented reality interfaces. These display, interaction and tracking types can be used to design a location based augmented reality system for architectural design.

MARS, Archeoguide, VIDENTE, CityViewAR, AREA and BIM based AR projects are surveyed as a state of the art by reviewing features. It is tried to find common links between these featured applications and architectural site survey. Therefore, this chapter is intended to be a step towards establishing a model which supports architects in a site visit. An architectural design practice conducted using such a location based augmented reality system shows favourable response because the users think it is easy to understand a project site than a usual visit. On the other hand, the use of location

based augmented reality can make a decisive contribution to surveying project site. Location based augmented reality provides a platform to enable novel types of architectural design applications.



4. AUGMENTED REALITY SUPPORTED MODEL FOR THE USE OF LOCAL DATA IN ARCHITECTURAL DESIGN

Throughout the design process, architects interact with a variety of data to inform design decisions. Architectural design is closely related to spatial relationships of surrounding data. Local data can be used by architects to improve the design process to match natural and cultural context. Architects need local data of the site in the early design phase, therefore site visits come to the forefront for understanding the context in which a design is going to be located in. It is a well-known fact that architects spend considerable time to explore contextual properties of the site and afterwards local data from various mediums are collected to analyse the site before the development of the design (Skov et al., 2013). For this reason, the presentation of local data is important over the course of the site visit, site analysis and conceptual design.

Due to the increased amount of data necessary for evaluation, a holistic view to local data is needed. Digital technologies present great opportunities for architects to acquire and use local data. Technological developments have enabled to access large quantities and different types of data. Besides, mobile computing with portable display devices organises and presents spatially referenced data (Jo & Kim, 2016). All these developments reveal new possibilities to inform architects for understanding the context of the place.

In connection with the rise of digital culture, augmented reality provides to deal with the interface between the physical environment and virtual environment, rather than focusing one of these environments (Picon, 2010). Augmented reality can be used in a location based approach, that enables to produce constructive relationships on information with the use of the location. It offers an immersive experience of surrounding information from different viewpoints while on the move (Kim, 2013). It is also possible to acquire data of the site and present it in situ via location based augmented reality for architectural design. This study focuses on a location based augmented reality model which is based on the local data framework to classify the context by categories and provide contextual information about the site. Using such a

model for the exploration of the site supports the architect to collect and analyse local data. By bringing architects into more direct contact with the site, the model facilitates the architect to understand the surrounding local data in situ.

4.1 Necessities of Local Data in Architectural Design & Potentials of Location Based Augmented Reality

In architectural design, the architect produces spatial solutions to address architectural requirements using a variety of data on the site. The formation of the architectural design is bound up with the collecting and analysing of the data. Initially, it is necessary to collect data that present the characteristics of the site. For many years, architects have used observational data to research places and regarded the data as input to architectural design. This circumstance is insufficient to evaluate data of a place, it causes certain problems related to accessibility, accuracy and location of the data. The architect may visit the site to view, take notes and photographs, and look for patterns while collecting data. Afterwards, the architect continues the design process at the office to analyse collected data onto the map like studies. For the analysing of the data, the current circumstance also requires the architect to be physically detached from the site (Wang et al., 2013a). The architect needs to be able to sort, visualize and navigate data to accelerate understanding and decision making. Architectural design solutions are often developed through the analysis of the surrounding contexts (Farrelly, 2012).

Depending on the data collection and analysing method of the architect, certain problems could arise in the current design process. Therefore, the concept of local data is essential to cope with data on the site. Local data is formed by any piece of information that has an absolute or relative location. Location as an index into an information space provides a base to the systematic approach in local data. In architectural design, the information of the site can be categorised under the natural and cultural local data. These two main categories contain all of the data that need to be considered while understanding the site and its spatial features in the early design phase. The natural and cultural impacts of the surrounding context are critical to architectural design. Collecting and analysing of local data supports the establishment of the interaction between the site and the design. It helps the architect to determine the suitability of the design proposal with characteristics of the site.

During the design process, it is not possible for an architect to map in mind a great number of data on the location without using a computation tool (Skov et al., 2013). Augmented reality enables users to interact with their physical environment through the overlay of digital information, and empowers users in activities by spatially augmenting useful information. Combination of real and virtual elements in a mixed environment provides the ideal context for the architect to examine spatial conditions. The exact location of each data can be identified in the spatial context via augmented reality. Location based augmented reality systems have become crucial as a powerful presentation tool, which allows users to request and access information about a specific location (Lee, 2012). It has strong potential to provide on site experiences and the exploration of the connected nature of local data in the real environment (Dai et al., 2017). Especially at the beginning of the design process, local data can be presented via augmented reality to inform architects about the site. Augmented reality may allow architects to gain an immediate check of local data, and quickly contextualise their designs. Architects can thus obtain a holistic view of the possible interactions between the site and its surrounding context, which may eventually provide more effective design solutions. The use of augmented reality during the architectural design offers a number of advantages to present local data. In this study based on the literature research, the necessities of the data collection and analyzing are discussed with the current circumstances, and augmented reality possibilities that meet these needs are associated under following subsections.

Common medium

In order to access local data, it is necessary to acquire data from various sources. Therefore, architects often need to search various sources in different mediums for local data. Local data is represented in a number of ways, ranging from traditional methods that include hardcopy documents and physical models to modern methods that include digitally presented documents and 3D models (RIBA & ARUP, 2013). There is a common medium requirement to bring these various sources together. Considering the other mediums, collecting the local data from various sources with traditional and modern methods is more difficult. Augmented reality produces interactive relationships with information in various sources. It acquires all local data into a hybrid space where both real and virtual share the same environment. Thus, the use of augmented reality lowers the frequency of switching between mediums by

integrating the required information into a medium. It reduces the data loss associated with repetitive switching. It is also important to reduce transmission errors between the mediums, such as from hardcopy to digital (Wang et al., 2013b).

Data classification

During the exploration of the site, understanding and classification skills of an individual are exceeded under the numerous data on the site. In order to comprehend the local data of the site, natural and cultural data need to be handled under the classifications that are based on general assumptions or individual approaches (LaGro, 2008). One of the largest difficulties of collecting data on site is the large quantity of uncategorized data problem. Augmented reality systems need to display the most relevant information to the classification instead of overloading too much information onto the user's attention (Choi et al., 2011). A data classification framework needs to be used to manage and filter local data. Depending on the user's goals, the classification can be changed for the presentation of information on the site. Augmented reality systems are proper to work under a classified system due to its informatics based structure.

Spatial approach to data mapping

The process of understanding correlations or associations between the data and the site, imposes additional cognitive load to an individual to map data (White & Feiner, 2009). Thus, a considerable amount of time and effort may be undertaken to determine the location as well as related information. Besides, the barriers have directed for many years to transform the communication of a 3D space into 2D representation methods. 2D data representations are often considered insufficient to address comprehensive 3D design problems (Marques et al., 2017). It is necessary to provide 3D representation environment to overcome limits related to 2D representation. Instead of being handled in 2D representations, evaluating the data under the 3D conditions is important to analyse spatial relations. Above all, the main problem is the being separate of mapped data and the physical site. Augmented reality can be used to solve these mapping relationships by carrying local data onto the site. 3D representation of the properties can be visualised directly on the site with augmented reality. It can also indicate more clearly the potential source of the existing data on the site. Besides, mapped data in 3D

form of representation within the augmented reality may inspire conceptual thoughts related to architectural design (Dai et al., 2017).

Holistic view

The holistic view of the local data is essential due to the increased amount of data necessary for architectural design. It provides to evaluate the data together with other categories rather than within their each categories (Anderson, 2011). Augmented reality can increase the legibility of layers in complex relations. It makes easy to detect overlaps between different data on site. The causal links between data and site can be better recognized and understood in a holistic view through augmented reality visualization (Lin et al., 2014). It is also important to overcome intensive data exposure in urban sites and weak data problem in rural sites. Augmented reality helps to control the density of data in urban sites and increase access to the cultural data as much as natural data in rural sites.

Data visibility

In the site, there are properties that are not visually apparent with the naked eye. Even though most of the local data are observable on the site, some of them are unable to be recognized. Augmented reality is an opportunity to make hidden data visible such as subsurface properties, or properties obstructed from the view. It can also visualize what cannot be seen such as site boundaries, flood level, air quality, and so on (Patti et al., 2017). Augmented reality can be seen from all viewpoints, thus it enables users to experience a site from different perspectives (Reinwald et al., 2014). Different distances and angles can be used to capture the interrelationships between data in a holistic view. Augmented reality helps to improve the visibility of the local data on the site.

Representations with time component

Local data with time component offers the understanding of the site in temporal dimensions. Architects sometimes find it difficult to imagine the spatial impact of the past, existing and possible future conditions. 4D representations of the local data can be built to reflect the past, existing and possible future conditions of a site with the actual or proposed appearance (Marques et al., 2017). By overlaying time-sensitive local data onto the physical site, augmented reality enables a new way of looking at

information. It can provide an on site realization of historical ruins, underground cities, future buildings, future arrangements and so on. In augmented reality, local data with time component not only show the historical development and future planning but also show a comparison to the current situation (Abboud, 2014). Moreover, realtime data that represent a feature can be visualized on site such as sunlight & shade, surrounding traffic pattern, air quality, and so on. It could allow a better understanding of needs in the temporal dimension and help to create spaces that better meet those needs.

Data analysis

In the analysis process, architects use their collected data as a basis for the generation of the required analysis. The traditional method of architectural analysis evaluates the collected data for each category in itself and between categories. Analysis of the site creates the opportunity for architects to create designs that are better attuned to the site (Fawcett, 1998). Currently, architectural analysis typically occurs outside the site after the site visit and data collection, and delays the starting of the conceptual design. Progress in technology also allows enabling advanced possibilities of analysis in augmented environments (Krakhofer & Kaftan, 2015). There is a limited field that analysis in situ in professional practice today, but opportunities abound in augmented reality. Augmented reality can make much easier to carry out analysis by visualizing interactively while on the site and help architects to make design decisions based on these analyses. As an example, the analysis of the topographic change can be provided on site by the use of topography elevation data. Thus, the architect can readily decide on more suitable parts of the site for building placement. This provides analysis for evaluating a data category in itself. Within the scope of this example, when the topographic change is analyzed together with the legislation about the legally useable area, the suitable parts of the site can be specified more precisely for building placement. This also provides to evaluate data between different categories for data analysis related to the site. As a basic method, maintaining multiple versions of each data according to time or change can be a basic way to get analysis for augmented reality systems (Guptill, 2015). It is also important to use BIM data that is quite suitable for analysis as the information source of augmented reality systems. Augmented reality can visualize and analyse BIM data in the context of the site (Wang et al., 2013b).

Taking note & sharing

In architectural design, the site visit is important to make observations about the site. During the site visit, architects need to take notes and share their observations of local data with other colleagues. These notes that may direct the architectural design, are recorded while on the site for preventing to forget. Thereafter, these notes are shared with other colleagues to draw attention to the current state of the site. Augmented reality allows users to directly place their own observations on site, and to use annotations for drawing attention on existing local data. All commentary information can be fed to a data store accessible to other users (Abboud, 2014). For architects working on large and complex sites, the ability to quickly leave a note about local data via augmented reality on site may enhance communication between the members of a project team. Moreover, it enables the precise placement and arrangement of digital content over the physical site to be augmented. In an augmented reality system, multiple users may share the same physical space and help the data collection through crowdsourcing. It allows the users to participate data collection in such a way, that they can create their collaborated content rather than only using content presented by other sources (Langlotz et al., 2012).

Helping architects & providing expertise

It is not possible to have knowledge about every detail about architecture and other associated fields. In architectural design, architects may need help about interpreting local data, and there may be situations where more experienced or specialist professionals' opinions may be needed. Incorrect interpretation of local data can be prevented by the use of augmented reality (Broschart et al., 2013). For instance, legal distance to a pipeline that is defined in legislation can be visualized on the site for construction limit. It is often difficult for architects to gather knowledge and expertise from other professionals at the starting of the architectural design. The architect interacts with other professionals about certain data related to architectural design, and augmented reality systems can easily provide expertise to related data from a database or communication platform (Wang et al., 2013a). For instance, the structural system can be proposed for the special conditions of the ground in the site from civil engineering expertise.

The advantages of augmented reality and the necessities of the local data collection and analyzing are discussed around common medium, data classification, spatial approach to data mapping, holistic view, data visibility, representations with time component, data analysis, taking note and sharing, helping architects and providing expertise. In order to summarize, Table 4.1 shows the current state of local data in architectural design and the potentials of location based augmented reality. It clearly states that advantages of the augmented reality are incontrovertibly more than the current state. From data collecting to analysing process in architectural design, augmented reality can be appropriate for a site to manage local data complexity. A model in which location based data is presented to use of augmented reality, can be used to support the architect's relation with the local data. This model can be seen as the augmented representation of the site, by nourishing the physical site with local data. The usage of this kind of a model, prevents the architect to be detached from the site, and supports the integration of local data with the site to interpret more realistically in terms of the spatial awareness.

Table 4.1 : Current state of local data in architectural design and the potentials of location based augmented reality.

	Current State of Local Data in Architectural Design	Potentials of Location Based Augmented Reality
Common Medium	searching various sources in different mediums	common medium to bring various sources together
Data Classification	data classification based on observations	managing data classification with a framework
Spatial Approach to Data Mapping	understanding the spatial relations in/between 2D/3D representations	spatial approach to data mapping on the site
Holistic View	bringing together local data outside the site	holistic view of all local data on the site
Data Visibility	observable local data with naked eye	providing visibility of hidden properties
Representations with Time Component	imagining the spatial impact of temporal dimension	representations with time component on the site
Data Analysis	using collected data after the site visit for analysis	advanced possibilities of analysis on the site
Taking Note & Sharing	taking note and sharing observations	commenting on site and placing observations
Helping Architects & Providing Expertise	needing help to interpret and meeting for expertise	providing interpreted local data and expertise on site

4.2 Use Scenario of Augmented Reality Supported Model with Architectural Perspective

The general priorities of the architectural design related to the site are to get a sense of the physical site, find patterns, and discover new insights about the physical location and its characteristics. With the use of augmented reality at the site visit, architects can actively be engaged in the exploration of the environment. This study introduces a model that can help architects to understand the spatial impacts of the surrounding context better, particularly during the site visit. Local data can be presented on site by retrieving and visualizing all the properties and details concerning. It is possible to make local data visible and reduce barriers access to data by using augmented reality.

The site includes natural and cultural factors that vary in terms of categories for architectural design. Primarily, the proposed model needs a data classification framework to manage data. For this reason, prominent studies about data needs of architectural design are reviewed in Table 2.1 to determine a local data framework in this study. The framework of the local data is structured around a combination of natural and cultural data in Table 2.2. These two main categories are natural and cultural data which represent the context of the site. The classification of the local data comprises various categories and subcategories under the main categories. This framework is developed as the main part of the model to manage local data for architects. It enables the classification of location based data in the model. For understanding easier in the model and the use in the sample interface, local data framework is illustrated from Table 2.2 as seen in Figure 4.1. Natural data categories are held on the left side, and cultural data categories are held on the right side of the illustration.

According to local data requirements in architectural design and the potentials of the augmented reality, a use scenario is presented to explain what this model can provide with the architectural perspective. At the same time, the use of the model is explained in detail under this scenario to point out how this model works.

Before starting to use the model, the user should be ready on the site where local data to be observed. The model can be used on portable display devices, because of the need to move freely on the site. Initially, the model sends current location information to request the related local data. Then, local data is provided based on the selected

categories to display on the site by scanning in a given field diameter corresponding to the current location. When the user looks at the site through augmented reality, surrounding local data is shown on the display device (Figure 4.2). As a common medium via augmented reality, the model represents local data overlaid on reality. The model helps to present local data in an augmented environment without being in different environments for hardcopy or digital sources. This circumstance makes easier for the user to focus on local data. The user observes all the virtual content directly with the real environment.

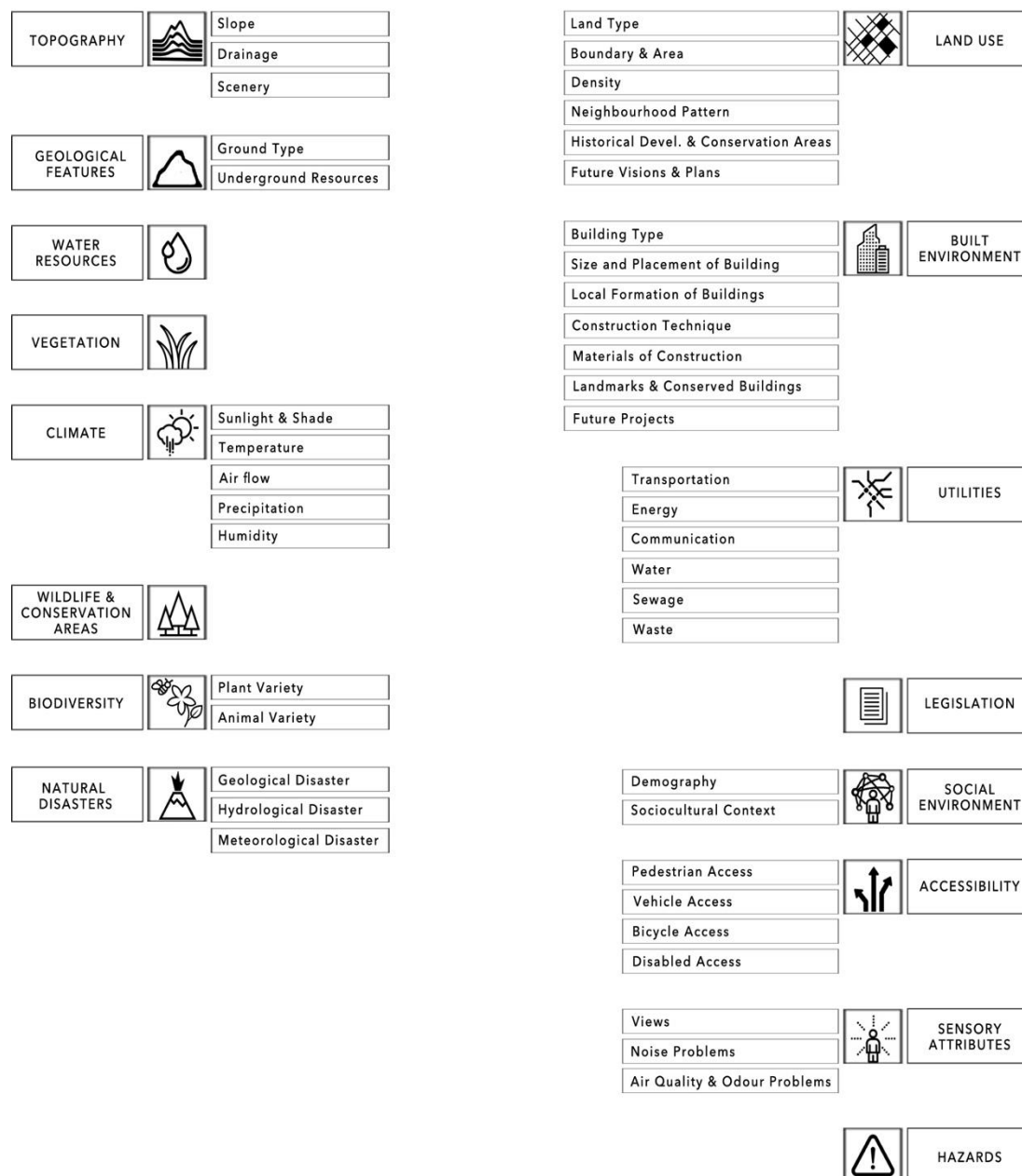
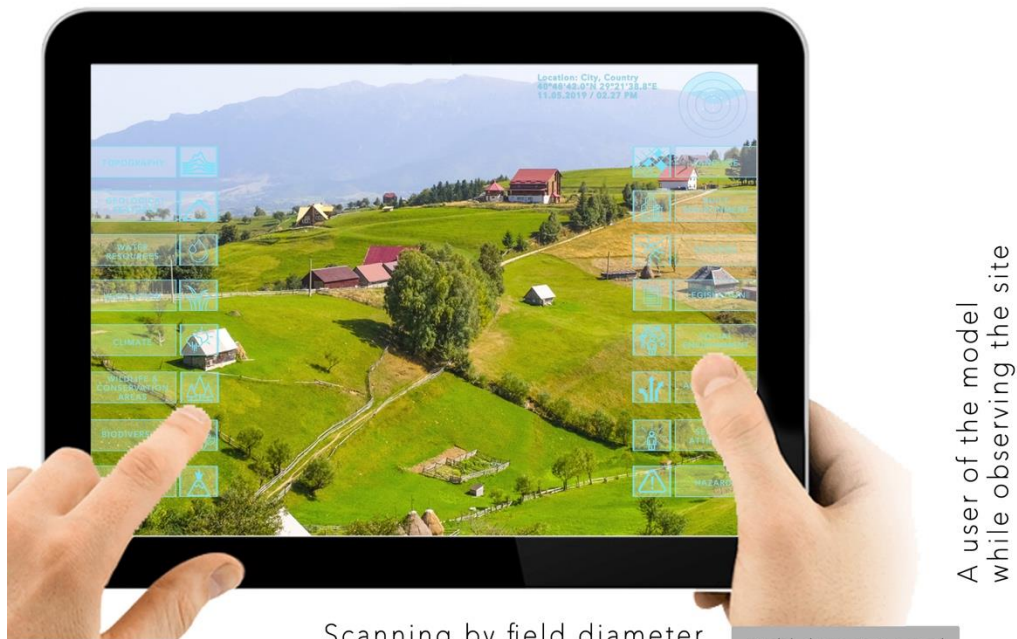


Figure 4.1 : The illustration of local data framework.

Without any classification and filtration, an explosion of data occurs in the augmented representation of the site. Though the user can access information from various categories, it is necessary to classify data in the model. Therefore, local data framework is used to manage data by the model. It provides local data under certain categories in accordance with the data classification required by the architect. In order to avoid getting mentally overloaded by viewing lots of content, the user should be able to choose the preferred local data from each category. The user can filter the local data by the selection of the categories on the provided framework. When user selects a category in the model, all of the local data that are connected to this category corresponding to the location, are shown on display device. The user can filter the local data by multiple selections of categories. The user also may choose specific categories to view the local data in a less crowded scene. This makes it easy to find out the content that user is interested in. It clearly shows that filtering is an important tool to obtain effective data for the model (Figure 4.2).

Selection of each data is carried out on their icons or short descriptions by tapping or gesturing it to depend on the display device. Each category can be described by a specific icon that is a representative thumbnail image in the model. When the user selects a category to bring the content, a detailed view of the local data is overlaid on the screen. This detailed view can provide various types of contents to explain the associated local data. The types of content can be text description, 2D image, 2D video, 3D wireframe, 3D data, 3D model, 3D animation, audio and so on. In addition, content can consist of many media types like text descriptions and 3D models to describe the local data. Thus, the user can access further details related to the selected local data. If needed, translucent background can be used to draw attention on local data. Besides, different colours can be used by the model to provide the visibility of interface. In order to see other local data, the user can then bring back the category filtration screen.

The model enables a fully interactive augmented environment that allows the user to navigate in the real environment. Instead of being fixed to an environment, the augmented reality encourages users to move freely within the space. In model, data visibility is provided firstly by the user's perspective of view. Besides, the model presents local data around the user according to the field of radar which is controlled over the interface. Changing the field diameter is useful for displaying local data among the crowded data (Figure 4.2).



Filtering the local data by the selection of categories

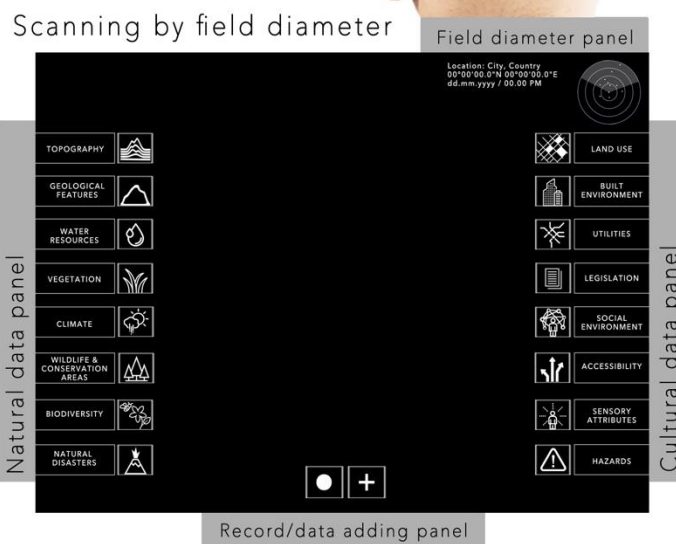


Figure 4.2 : A sample user interface with tools of interaction for the model.

The model provides a spatial approach to data mapping on the physical site. There is a strong need for 3D representation to visualise the data in a proper form. The model breaks the constraints imposed by 2D representation, moving toward 3D representation of the environment. For this model, a particularly important aspect of the augmented reality is its ability to make the user feel naturally surrounded by local data. The model can give users powerful new ways to observe relationships and connections between the local data. Augmented reality is able to display integrated views of local data in a spatial context. Figure 4.3 shows the mapped data in 3D form of representation within the model. Moreover, 2D representation of the properties can be visualized by changing into a map mode in which each local data is presented 2D. Through its map mode, the model allows the user to explore local data on the map view in case of need by holding parallel to the ground plane (Figure 4.3).



Figure 4.3 : 3D & 2D representations on the model.

In addition to working on the site, the model can also record during the site visit and afterwards display local data with the site. Local data can be taken from the site to use in design through the model. The data to be considered in the design can be marked among the local data presented in the environment. Besides, the user can take location based notes, photographs and so on to add data or comments. Thus, the user also can share added local data with other users through the model.

As a sample to architectural use of the model from the site, topographical contour lines and legal boundaries can be visualized on the site. Generally, architects take drawings of the site from the local municipality to consider height changes and boundaries on the site. Then, architects need to interpret these heights and boundaries for their designs without breaking the relationship with the site. Architects can have a printed copy of the site drawing with them during the site visit, otherwise they wait for working on digital format of the site drawing. This model can present height changes and boundaries from the digital drawings that can be provided open access from the local municipalities or national government database. It can draw topographical contour lines from height points in a computational process (Figure 4.4).

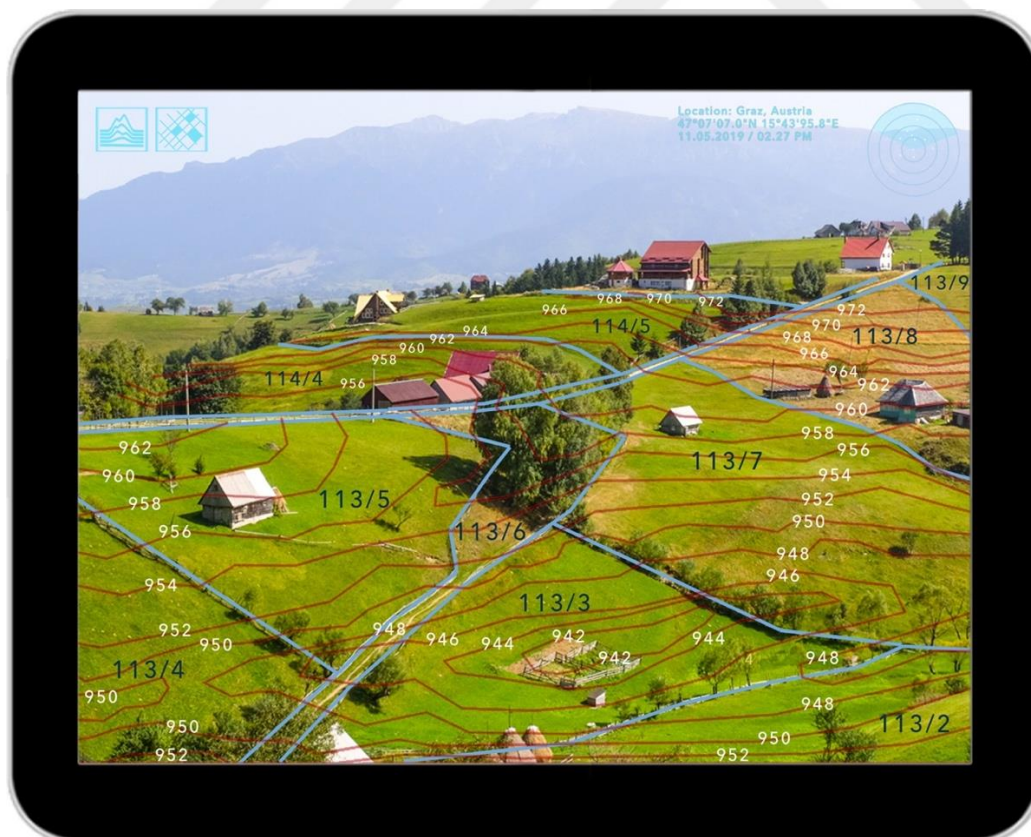


Figure 4.4 : The visualization of topographical contour lines and legal boundaries via augmented reality.

When evaluating the site from the architectural perspective, the use of the surrounding area and the built environment must be taken into consideration. Therefore, the architect firstly checks the current state of the surrounding area and the built environment through the site visit. Although it is important to observe the site with the current state, it does not provide comprehensive data for the architect. It is necessary to obtain the city development plan that contains the data of the existing structures from the related municipality or its web service. This model can present land use and built environment data by covering the view of the site (Figure 4.5). The user of the model can easily evaluate current state with provided data for architectural design. In this model, the scope of the databases that are used to provide the data is important, because it may be restrictive on data. For example, it may be comprehensive enough to provide data about the residentials on a building block for architects. Therefore, municipalities and government agencies are important in providing such data.



Figure 4.5 : The presentation of land use and built environment data on site.

The presentation of local climate data can be provided through the model for the architect while on the site. When the user selects climate category, the sunbathing and prevailing wind direction data can be visualized on display. Besides, graphical

comparisons based on annual periods such as temperature, daylight, precipitation and humidity can also be presented to the user from related databases (Figure 4.6). The databases of meteorological research institutions can be used to obtain such climate data. By observing and considering climate data on site with the use of this model, the architect can develop design decisions against natural conditions such as the sun and wind effects.



Figure 4.6 : On site access to local climate data with the use of model.

As an example of effective use of natural data, this model can provide detailed data about vegetation. Taking advantage of the natural vegetation of the environment is important in order to act respectful to nature and to increase the comfort of the building. In this context, the model can present data of the local vegetation to the user while on the site (Figure 4.7). In addition, if there are specific trees in the site where the design is to be performed, the model can provide in situ data about these trees by matching from the database. These are possible with the databases of national government agencies or universities that conduct inventory studies on the natural environment.

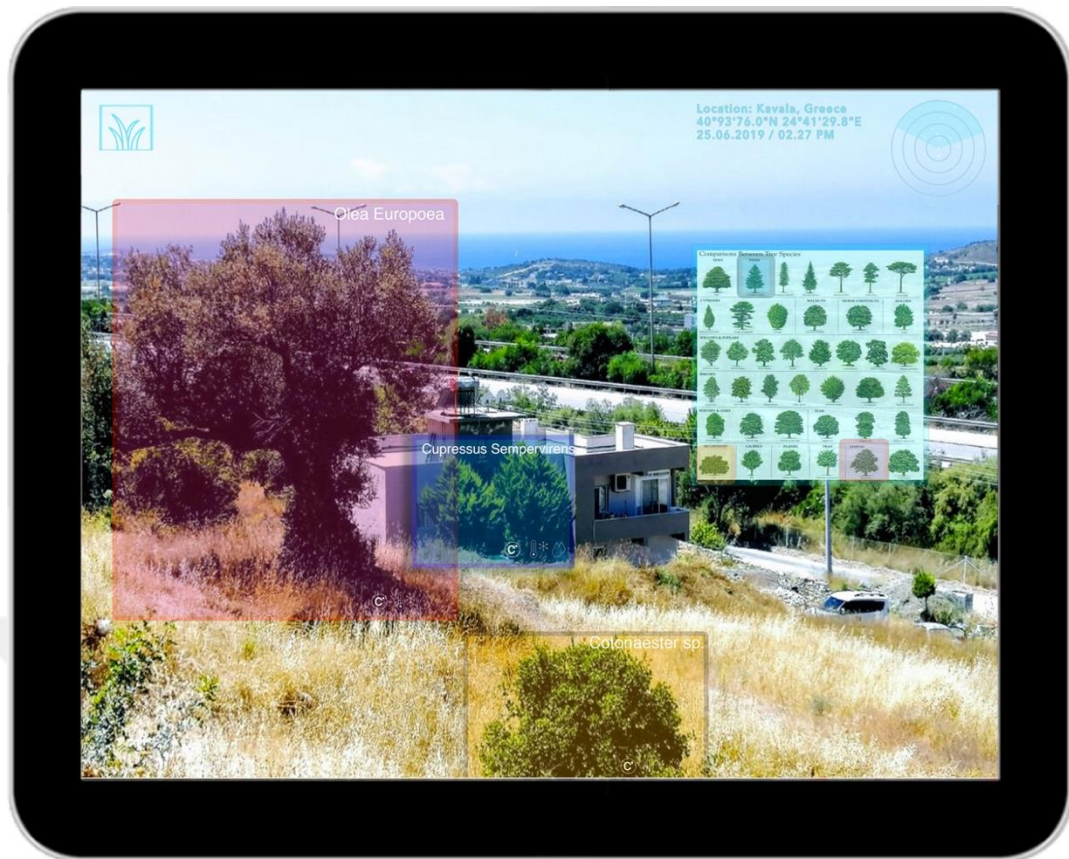


Figure 4.7 : The presentation of local vegetation data on site.

Architects do not always design in new urban development areas. Most of the times, architectural design needs to be carried out in areas of cultural importance in specific contexts. In this case, the architect must obtain data about this context. The building components which are used in the architectural design may be determined for the preservation of areas under specified inventories. Besides, the architect may keep using the cultural context of the area in order to maintain integrity in the environment. For such a work, it is necessary to investigate the current local data extensively. As shown in Figure 4.8, the local door and window styles can be displayed via the model on site. In addition, the windows or doors on the existing buildings can be matched from the library of the local door and window styles with the image matching structure that can be developed in the model. With the help of this matching system, architect can easily experiment and decide about architectural design components, materials and general adaptation of new building with existing building at the site. That kind of an approach gives architects decision making opportunities in urban form, building façade and opening/solid ratio in design as soon as the architect visit the area. Moreover, matching system can collect other similar inventory from the database and show them for the use.



Figure 4.8 : A view of the local components of the buildings.

This model especially supports to interact with properties of a physical site that do not have a natural or perceivable visual representation. The user can also focus on the invisible properties of the site beyond the visible properties. For instances, subsurface infrastructure elements can be superimposed into the view of the user. Figure 4.9 shows a subsurface infrastructure of the city that contains natural gas distribution shafts, electrical cable shafts, internet cable shafts, sanitary shafts, and future infrastructural shafts which are projected but not built yet. In the representation, information of subsurface infrastructure shaft can be obtained by local municipal authorities. It also get infrastructural informations from transportation ministries, private companies about energy, internet or heating. Therefore, architect can easily get the data about the provider opportunities and designing details about infrastructural use. In another example in Figure 4.10, model can provide local flood data of a site which occasionally live flood emergencies. By the vision of that, architect can get architectural design decisions with the data of annual flood levels. These datas can easily be collected and then provided by institutions about natural reservations and disasters. This kind of a data augmentation of local environmental characteristics save the architectural design from fatal mistakes.

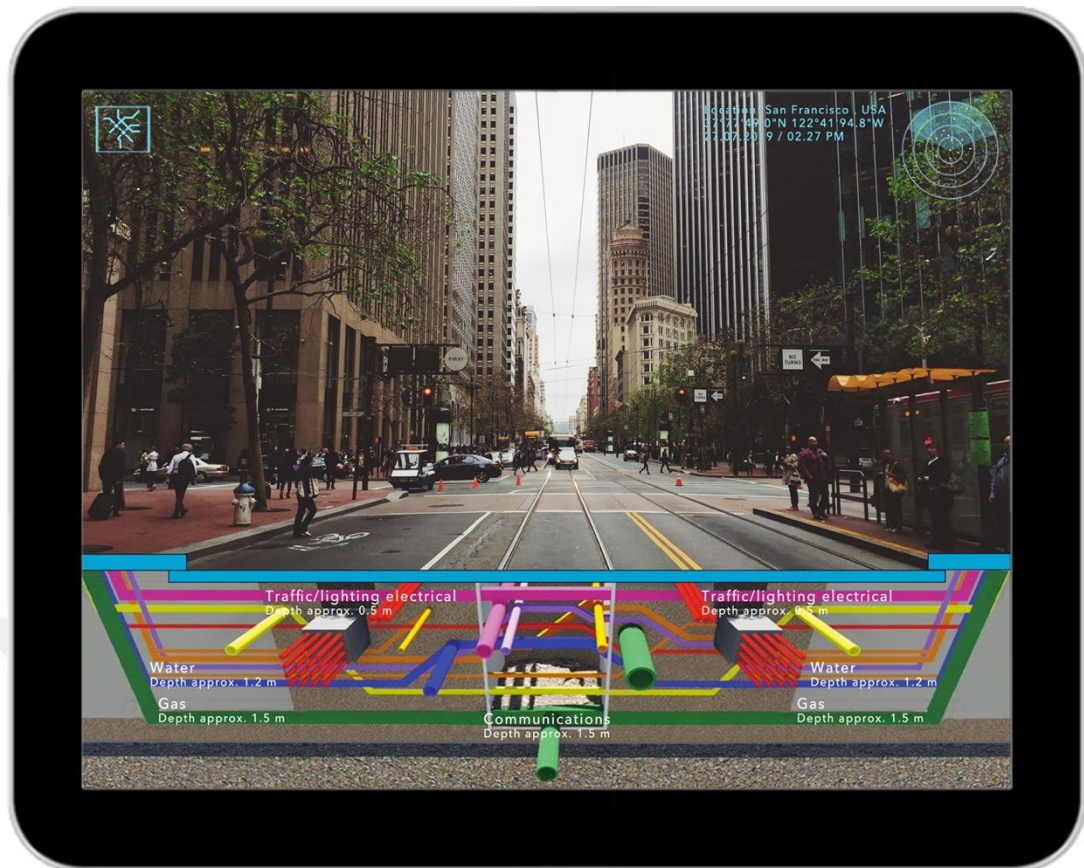


Figure 4.9 : Representation of invisible properties on site.

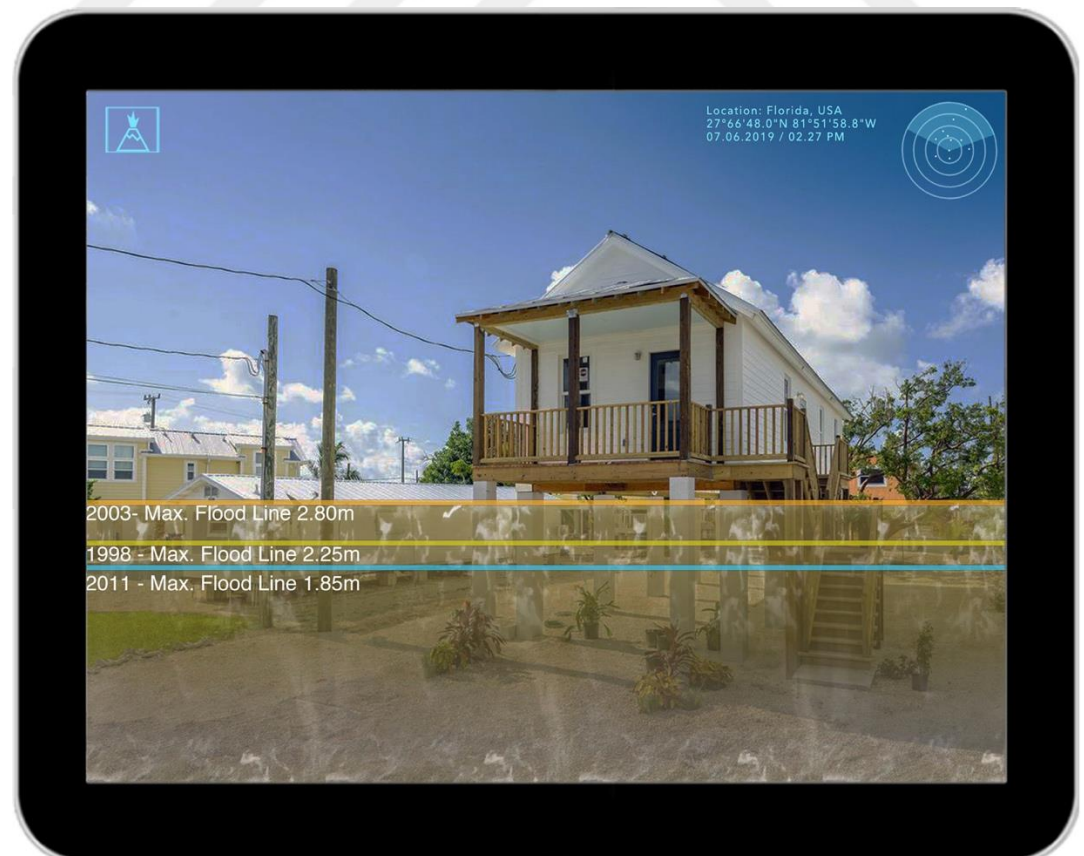


Figure 4.10 : The visualization of flood data on site.

The model provides glimpses into temporal dimensions of the site. The users are able to view the historical elements and planned projects on site via augmented reality. As in Figure 4.11, model can expose archeological conservation areas under sites which are selected by an architect or a construction company as potential construction areas as soon as the first site visit of the architect. Such a scenario makes architectural design easier for the conservation of archeological site and the design of site plan from the very beginning of the work. These data can be obtained by the councils of conservation of cultural and natural properties, and local universities. Moreover, the model can allow users to view the old images that are matched to their locations, virtual reconstructions of historical elements onto the historical site.

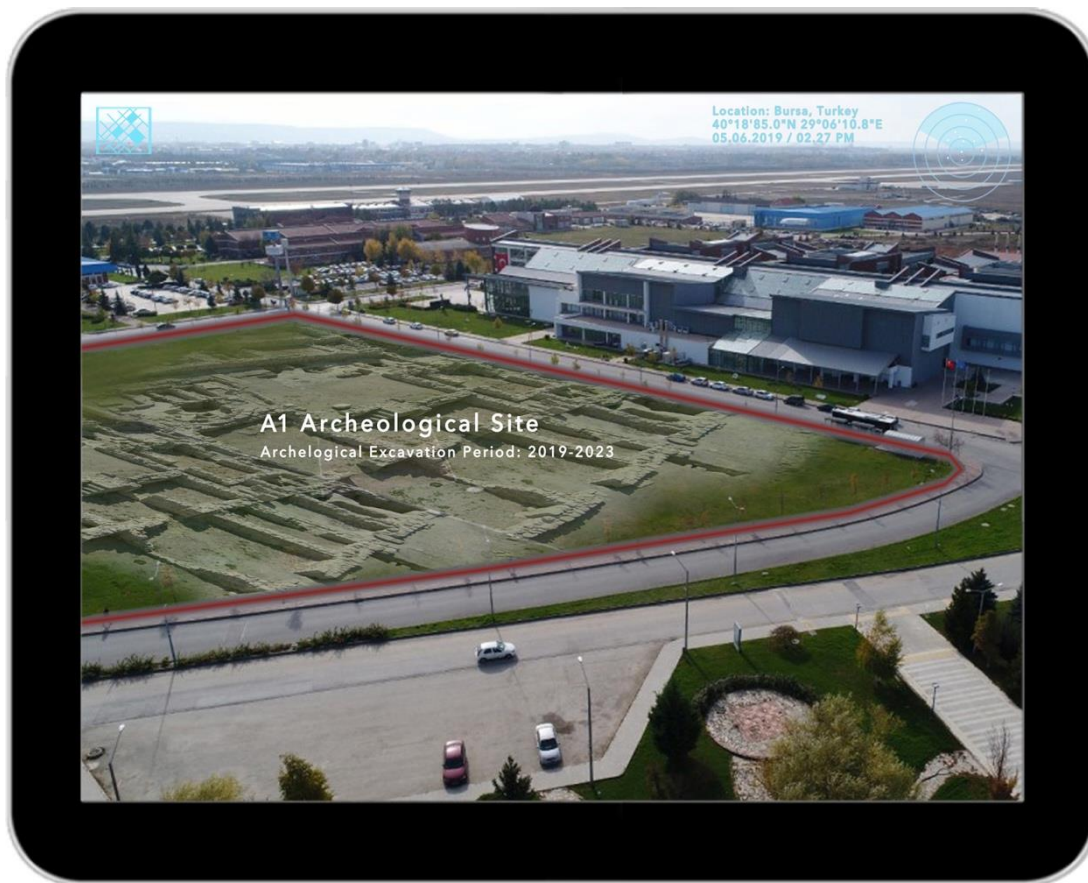


Figure 4.11 : Exposing archeological conservation areas with the use of model.

Figure 4.12 shows an example of how local data can be presented with the time component. Recently developing BIM systems can also be used as design documentation and delivery of the projects to the local municipalities or national authorities. Additionally, BIM systems can be used for programming the construction stages upon financial or developmental projections. Therefore, municipalities can easily upload projected datas of the city, such as projected architectural designs of the

buildings, to the system and model can easily share this information with other user architects. This kind of an access provide architectural design data by projected building to the architects of other surrounding projects. For instances, when the architect starts to check how the other buildings impact the view from the site, the architect can realise that a new building totally blocks the view of the site in future planning with the use of this model. While on the site without losing time, the architect is therefore forced to reevaluate the position and orientation of the design according to the local data.

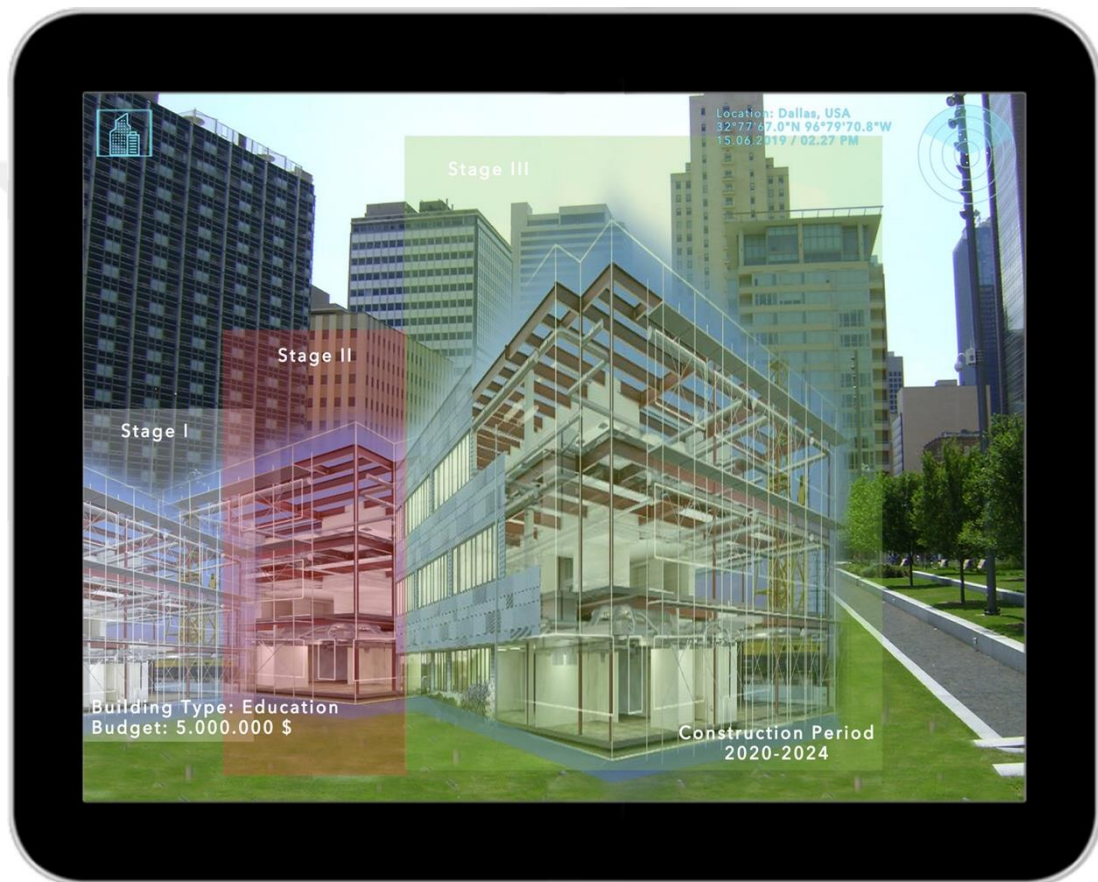


Figure 4.12 : BIM based local data with time component.

The model can help architects to provide interpreted local data of the site. Especially for architects as an example, legal regulations that generally requires a translation from regulation to 2D plan can be shown on the site in 3D visualization via augmented reality (Figure 4.13). Moreover, users may need knowledge about various elements from different fields and learn relevant knowledge with this model. The model can provide expertise from related fields such as civil engineering and geological engineering.

This model puts in order local data that can be used during architectural design by responding to the natural and cultural context of the site. It is presented as a conceptual scenario of how local data can be used in architectural design through augmented reality. This model facilitates greater awareness especially when it is used during the architectural site visit. It enables users to more profoundly explore the site by interacting local data. The use of augmented reality can make a decisive contribution to collect and analyze the local data, thereby encourage users to consider the surrounding context.

Figure 4.13 : Helping architects with interpreted local data.

4.3 Technical Structure of the Model in Augmented Reality

The conceptual use scenario that explains how to use the model also provides a description of the architectural contributions of the model in a site visit, however, the operability of the model also correlates with the technical structure. The technical structure of the model in augmented reality is presented under its components and operation.

4.3.1 Components of the model

Augmented reality has received increasing attention as an interactive medium that allows users to search for information in a realistic 3D space (Kim et al., 2017). Especially, the improvements in mobile devices and the use of location as the basic resource for context aware services have provided useful components for using augmented reality in the field of architecture (Riera et al., 2015; Grubert et al., 2017). Most of the location based augmented reality systems are designed to present information about point of interests, similarly, the proposed model offers local data regarding an architectural site survey. In the determination of the model components, the study related to structures of the location based augmented reality systems in Table 3.2 are taken into consideration (Ünal & Demir, 2018).

The current devices on location based augmented reality use hand-held or head-attached displaying. This model targets hand-held and head-attached devices to display local data while on the site. Hand-held displays come to the forefront with the widespread access, while head-attached displays provide natural platform with hands-free working environment. For introducing the model, hand-held displays are used because of being widely available range from smartphones to tablets.

Augmented reality encompasses user interfaces that allow for interaction with digital content embedded into the physical environment of users. Information browsers, as an augmented reality user interface, provide to monitor and control information that is registered to the physical site. When the capabilities of the information browsers are taken into account, facilities of the filtration and the radar are the significant tools during the display of the site. Consequently, information browsers are the most suitable interface type for this model and can be used without any experience. The design of the user interface in the model should be simple and user-friendly. Therefore, the

interface needs to be organized based on the user, the environment and the data. The sample visualizations of the model in the user scenario are kept as simple as possible.

Hybrid tracking based on GPS and inertial sensors is sufficient with the development of the model. Nowadays, mobile devices from smartphones to tablets are already equipped with GPS and inertial sensors. It also shows that these types of equipment are provided automatically by the hand-held devices. These display, interaction and tracking types can be used to realise this model.

4.3.2 Operation of the model

The operability of the model is provided by an integrated workflow. The workflow of the model is extensively explained under the stages of data acquisition, data query and data display (Figure 4.14). In the acquisition of data, commonly used methods and different methods which emerged with developing technology are discussed in relation to the model. The query and display infrastructure of the model is explained based on the working principles of the studies carried out in the field of location based augmented reality.

Data Acquisition on the Model

The data acquisition system is needed to provide, manage, and filter the data of the model. Data is obtained from sources according to the data classification in local data framework that is specified for architectural design in the model. It is presented as a well-structured framework which could be readily used by augmented reality systems to support architectural site survey. On the other hand, this model also needs access to available and reliable data sources. It is necessary to link the model to databases that contain necessary information associated with the site.

Regarding databases, firstly, the model can acquire data from relational databases. Relational databases provide structured data according to required parameters and different levels of accuracy depending on the source. In the case of a data format, it may be necessary to convert or adapt to other formats for local data, compatible with the model. Therefore, standardization of data type formats may facilitate communication between different databases. If databases contain different data associated with a location, they can be compared directly to provide a way to validate

by data comparison facilities. Generally, these databases are stored in a cloud system to access information about the current location when needed.

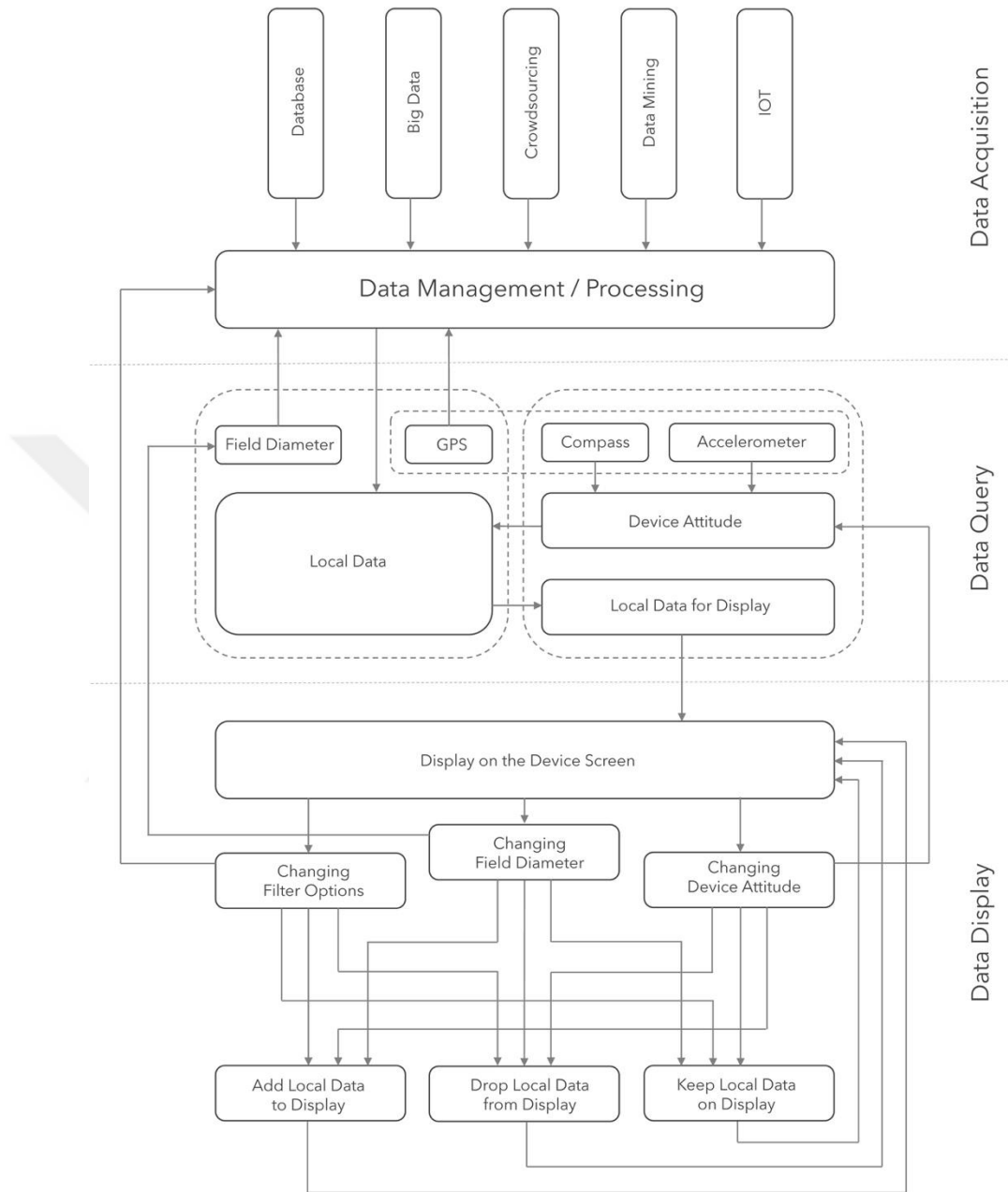


Figure 4.14 : Workflow of the model.

Beyond the relational databases that are primarily used in data acquisition, big data and crowdsourcing methods can be utilized to acquire data (Bermejo et al., 2017; Huang et al., 2014; Vico et al., 2011; Ioannidi et al., 2017). Big data can analyze the data that has a location information without any data classification. Any data fed into this model with big data has to be pre-processed, in this way it provides classified data that can be used. Therefore, it is necessary to develop an automatic and intelligent

domain information extraction mechanism to always provide relevant information with respect to the local data classification. By crowdsourcing method, users can upload their individual data to a cloud database system that is integrated into model. This allows users to actively participate in the local data creation process by sharing content in situ in an augmented environment. Besides, IOT allows a variety of information to be collected by sensors linked to the internet (Leppänen et al., 2014). It allows users to access heterogeneous data from different pervasive sources in a site visit.

Data Query on the Model

In the model, data is queried in specific steps. Firstly, GPS as location, compass as direction, and accelerometer as orientation information are acquired to provide sensor data. When the acquired location information is sent to the query to obtain local data, direction and orientation information are used to calculate the point of view. By the use of location information and effective field diameter, local data is queried from the data arranged in the local data framework. The effective field diameter allows the querying of data in a specific distance from the current location. In addition, the use of filtration through data categories affects query results. By the calculation of the point of view with the use of direction and orientation information, local data results are queried to display.

Data Display on the Model

In the model, data display is performed with the data obtained from the query process. Local data is presented to the user when it is covered by view angle, filter options and effective field diameter. The change of the point of view affects the data to be displayed. According to the new point of view, the local data acquired during the query process is taken into the display process. Besides, the change of the filter options affects the data to be displayed according to the preferred data classes. When the effective field diameter is changed, local data is queried again according to the new field diameter. According to changing situations; local data newly included in the display is added, local data outside the display is removed, and local data that remains in the display is preserved. In addition, the model allows local data to be displayed on site with appropriate visualizations of the data. Data visualization is to be considered for the representation of each local data in the local data framework.

4.4 Conclusion of the Chapter

This chapter introduces a model that present local data in a location based augmented reality system to use in early stages of architectural design. By considering the necessities of local data in architectural design, the potentials of location based augmented reality are utilized in the development of this model. The proposed model is presented in a use scenario to explain how to use the model and express its contributions from the architectural perspective. Besides, technical requirements for the operation of this model are stated with suitable components and workflow. Thus, this model is extensively handled by different viewpoints.

Focusing on the data need of the architect during the site visit and site analysis before starting a conceptual design, the proposed model provides data on site according to the local data framework through augmented reality. Using such a model for the exploration of the site supports the architect about common medium, data classification, spatial approach to data mapping, holistic view, data visibility, representations with time component, data analysis, taking note and sharing, helping architects and providing expertise. By bringing architects into more direct contact with the site, the model facilitates to understand the surrounding local data in situ and supports the reasoning process to design. As local data can be made easily available within the context of the site, architects can carry out site survey more effectively and efficiently.

The model has potential to be the base with the local data framework to the applications of architectural design in augmented reality. This model presents a medium around the user in order to be aware of surrounding conditions accordingly to the current local data. As a further study, this model can be developed as an in situ design platform for architectural design.



5. CONCLUSIONS

In this study, the current conditions related to the data in architectural design are expressed. According to the specified necessities, the proposed model is developed to provide data to the user in the current location. The model presents relevant virtual data directly in the context of the physical site with the use of augmented reality. Besides getting data about the site, the model supports user's design thinking during the site visit. Exploring the environment with the factors that affect the design makes way for design ideas pertinent to place.

5.1 Contributions of the Study

The theoretical framework of the study emerges from the data, information and knowledge relation which is explained in a relative approach. The main contribution of the study is that it provides a basic explanation of these terms and their relationship between each other for preventing the misuse in scientific studies. The origins of the data which draws attention to natural and cultural references indicate that the fundamental classification can be organized under natural and cultural categories. With the extreme increasing human impact on nature, the classification of data that base on being natural or cultural becomes more important. According to have a human impact or not, the state of being natural or cultural data can be determined easily. While this distinction clearly can provide to take into consideration the preservation of natural conditions, it can also enable to benefit from cultural gains of humanity for architectural design.

Considering the relationship with the place in architecture, the data in the field of architectural design are handled under the local data approach in this study. By means of this approach, local framework associated with a place is defined for architectural design. To take advantage of the local data approach, a data classification framework is needed to manage data. Therefore, data classes that are needed in architectural design are examined with their origin through the comprehensive review of the related studies. Architectural studies, site planning studies, and legal regulations in

architecture and planning are evaluated to construct a data framework. Afterwards, local data framework is developed with the use of fundamental classification as natural data and cultural data, and the relationship of data classes with each other. Alongside local data framework as a guide to classify data, it also indexes data by the use of location information. The classification of data through this framework provides a systematic approach to easily access to all data associated with the place in architectural design. Without a systematic approach, data acquisition bases on the person, and it can cause to forget or ignore some related data. Understanding the site and its surrounding potential through local data provides an analytical process for architectural design. It supports the architect in design by taking data into account. Local data framework is provided specifically for the architecture field, but it can be used by other fields like site planning and design.

The review section of the study contributes literature review with the evaluation of augmented reality systems in the context of architectural design. First of all, augmented reality characteristics and requirements are reviewed to draw attention to the current state. It is seen that combining real and virtual, interaction in real time and registration in 3D are characteristic properties of augmented reality systems. Besides that these fundamental characteristic properties also demonstrate the technical requirements of the augmented reality system as the display, interface and tracking. Afterwards, location based data representation in augmented reality systems is investigated to allow for on site representation of data. MARS, Archeoguide, VIDENTE, CityViewAR, AREA and BIM based AR applications are surveyed as a state of the art by reviewing their features. Developments to the recent conditions from the first implementations are revealed with components of systems and significance of applications. The potential contributions of location based augmented reality systems and appropriate component structures are discussed for architectural design. When the applications are evaluated in terms of their potential contribution to architectural design, it is observed that location based augmented reality systems can provide;

- on site representation of data,
- user's direct interaction with data,
- presentation of invisible data,
- quick view of surrounding data,

- presentation of data on urban scale,
- visualization of past and future situations,
- analysis of the proper data,
- editable application layout for architectural applications.

By evaluating the applications in terms of their components, it is observed that which components in the field of augmented reality are suitable for location based augmented reality systems. This study clearly shows that although head-attached devices can be used in location based augmented reality, hand-held devices from smartphones to tablets are mostly preferred type of display because of the widespread access. Besides, information browsers are only interface option to represent excessive data for location based augmented reality. Finally, hybrid tracking based on GPS and inertial sensors is essential to locate and direct the data for location based augmented reality. This study also indicates that these components need to be taken into consideration when planning location based augmented reality systems for architectural design.

The proposed model is developed in the direction of all these studies. Moreover, the necessities of local data in architectural design and the potentials of location based augmented reality are discussed in the current state, and the possibilities that the proposed model can provide are presented. Using proposed model for the exploration of the site supports the architect about;

- common medium that combines real and virtual environment to present data,
- classification of data based on local data framework,
- spatial mapping of data on the site,
- holistic view of data,
- data visibility to hidden data,
- data representations with time component,
- data analysis from the proper data,
- taking notes and sharing observations during the site visit,
- helping architects to interpret data,
- providing expertise from other professionals.

In this study, the proposed model is presented in a use scenario to explain how to use the model and express its contributions from the architectural perspective. Local data framework is used as the main part of the model for the classification of local data in use scenario. The possibilities of augmented reality in the proposed model are supported by visualisations.

Technical requirements for the operation of this model are stated with suitable components and workflow. In the determination of the model components, the studies related to components of the location based augmented reality systems are taken into consideration. The workflow of the model is extensively explained under the stages of data acquisition, data query and data display. In the acquisition of data, although relational databases are handled as the basic data acquisition method, different methods which emerged with developing technology are discussed in relation to the model. The query and display infrastructure of the model is explained based on the working principles of the studies carried out in the field of location based augmented reality.

Focusing on the data need of the architect during the site visit and site analysis before starting a conceptual design, the proposed model provides data on site according to the local data framework through augmented reality. By bringing architects into more direct contact with the site, the model facilitates to understand the surrounding local data in situ and supports the reasoning process to design. Within the scope of the study, although the user is the architect, the professionals from urban planning, urban design and other related professions are the potential users of the model. The model also can be useful to architecture students for educational purposes.

5.2 Limitations of the Study

In this study, local data fundamentally contains a limitation with the location. Considering the nature of local data framework, location is handled as the major context source to classify the other contextual factors. Therefore, instead of being evaluated in a separate framework, temporal context is embedded in subcategories like the other contextual factors as identity and action in this study. This arrangement is important to classify data with the use of location as an index.

Local data framework is formed by considering the relations of each data class to other classes in reviewed sources. Categories are clustered with subcategories according to their relationship with each other. Although emerging from a comprehensive study, local data framework is based on the data classes in reviewed sources as a limitation. However, local data framework is expressed as an open approach to development rather than a framework that is terminated in the study. When different classes of data are acquired from new sources, this classification system can expand.

It is possible to classify local data framework in different ways depending on the varied classification approaches. The classification of natural and cultural data can also be carried out under different categories and subcategories. To develop subcategories, more comprehensive research is needed for each data class. Considering that it is not possible for each data to be accepted with generally accepted parameters, the model should be able to use each data class under different parameters. Although it is possible to define each data class with its qualitative or quantitative parameters, the sources used in this study are not suitable for a research within this scope. This kind of study requires a more comprehensive research based on the practical use of each data in daily life.

There is no integrated database that provides access to all data classified in the model. Therefore, data must be obtained from different databases and these databases vary by country and its organizations. Within the scope of the study, it is emphasized what kind of data acquisition approaches can be used rather than where data can be provided. It is necessary to link the model to existing databases that contain all the necessary information associated with the site. With developing technology, existing databases are not the only data source. Different methods that allow accessing data such as big data, crowdsourcing, data mining, IOT can be used for the model.

In terms of architectural perspective and technical structure, the study has been put forward in detail to be applied as a model. The realization of the model as an application is not covered in this study. It can be carried out with long-term work under a scientific research project and it needs a team working in interdisciplinary structure both in architecture and computer fields. Within the scope of the thesis, instead of realizing an application that can succumb to time with developing technology, it is considered to propose a fundamental model.

5.3 Further Studies

In addition to providing a theoretical basis, this study provides a framework for the practical use in further studies. Local data framework is developed to determine the appropriate information that should be provided to architects. It can be integrated into computational platforms that effectively interact with and utilize from data contained within the site. The proposed model has potential to be the base with the local data framework to the applications of architectural design in augmented reality. This model is important because of presenting a medium around the user in order to be aware of surrounding conditions accordingly to the current local data.

Moreover, the proposed model can be moved one step further with the change of working styles. It is possible to widespread acceptance of the platforms and tools to design on site beyond designing at the office environment, in the near future. This model with the improvements to be realised can also allow the user to design on site interactively with local data. Thus, it can serve as an in situ design platform for architectural design. Besides, the structure of the model which is intended only for a single user to observe local data, can be transformed to design facilities on site for multiple users.

Data acquisition for the model can be developed in detail to put into practice within further studies. Recent technological advances led to data acquisition methods that can be successfully used. In the future with the developing technology, big data, crowdsourcing, data mining, and IOT technologies will be the easily utilized data acquisition methods. The use of these different data acquisition methods may provide data analysis even more easily for augmented reality applications.

It is also possible to improve model components to access more comprehensive data. In this context, drones can be added to model components for a better field view. In this way, the user can observe the site with local data from different heights and more dominant positions.

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