YILDIRIM BEYAZIT UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

INTERIOR DESIGN AND DECISION MAKING USING AUGMENTED REALITY

M.Sc. Thesis by

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Department of Computer Engineering

December, 2015

ANKARA

INTERIOR DESIGN AND DECISION MAKING USING AUGMENTED REALITY

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Çağrı Burak ASLAN

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M.Sc. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"INTERIOR DESIGN AND DECISION MAKING USING AUGMENTED REALITY"** completed by **ÇAĞRI BURAK ASLAN** under supervision of **PROF. DR. ABDULLAH ÇAVUŞOĞLU** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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I have prepared this dissertation study in accordance with the Rules of Writing Thesis of Yıldırım Beyazıt University of Science and Technology Institute;

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INTERIOR DESIGN AND DECISION MAKING USING AUGMENTED REALITY

ABSTRACT

Augmented reality is a new and trending technology across many fields of sectors. Technology is used mostly on commercial purposes. It eases the understanding as a teaching method and eases the perception of the 3d models while applying to reality. For example it is possible to see 3D modeled glass of milk on your kitchen table. It is not augmenting only 3D models but also videos, text and any kind of digital material.

While working with augmented reality, a problem has been seen among furniture companies. It was, customers wanted to try the furniture before they buy it. So companies must send the furniture to customers for them to try it. This was causing a major transportation expense.

Augmenting the furniture as photorealistic as possible in customers home via smart device is the aim of this thesis and the solution to the problem of the private sector.

Providing this solution contains 2 parts in general. First is to develop a mobile app with augmented reality capabilities. It will have a user friendly GUI and drag and drop functionalities. The second part is providing the app with appropriate 3D models. 3D models of the furniture must be transformed into “fbx” file format using various of 3D design software.

In the development process of the app “Vuforia SDK” will be assisting with the core functionalities for augmenting. It is an augmented reality SDK for developers that covers the tracking ability and some more features. The platform for the development will be “Unity 3D”. Unity will be used because of its cross platform compiling capabilities. By that, final app will be available for iOS and Android at the same time.

While developing with Unity 3D, programming language can differ to persons wish. It can be UnityScript(JavaScript), C# and Boo(Python like language).

Keywords: augmented reality, unity, furnishAR, vuforia, furnish

ARTIRILMIŞ GERÇEKLİK KULLANARAK İÇ DİZAYN VE KARAR VERME

ÖZET

Artırılmış gerçeklik, bir çok sektörde kullanılmaya başlanan yeni bir teknolojidir. Şu an için çoğunlukla reklam sektörüne hizmet etmektedir. Öğretim sürecinde kullanıldığında anlamayı kolaylaştırır, gerçek hayata uygulanan 3B modellerde ise algıyı kolaylaştırır. Örnek verilecek olursa eğer, 3B olarak modellenmiş bir bardak sütü, mutfak masanızda görebilirsiniz. AG ile yalnızca 3B modeller değil aynı zamanda resim, video gibi bütün dijital içerik kullanılabilir.

Artırılmış gerçeklik üzerine çalışılırken mobilya firmalarının bir problemi olduğu görüldü. Problem, müşterilerin ürünleri satın almadan önce evlerinde denemek istemeleriydi. Böyle bir durumda firmalar ürünleri müşterinin evine gönderiyorlardı. Bunun da bir mali külfeti oluyordu.

Mobilyaları olabildiğince gerçekçi modellerle, akıllı cihaz yardımıyla müşterilerin evlerinde göstermek bu tezin amacı ve sektörün yaşadığı sorunun çözümüdür.

Sorunun aşılmasında izlenecek yolda iki bölüm vardır. Birincisi, artırılmış gerçeklik özellikli bir mobil uygulamanın geliştirimesidir. Uygulamanın kullanıcı dostu bir arayüzü ve sürükle bırak özellikleri olacaktır. İkinci kısım ise uygulamaya uygun 3B modellerin sağlanmasıdır. 3B mobilya modelleri "fbx" formatına çevirilmelidir. Bunun için bir çok 3B modelleme yazılımı kullanılabilir. Tez kapsamında 3DS Max ile oluşturulmuş modeller fbx formatında çıktı alınacaktır.

Geliştirme sürecinde temel fonksiyonlar için "Vuforia SDK" kullanılacaktır. Vuforia bu sektörde geniç çapta kullanılan, izleme ve daha bir çok özelliği olan açık kaynak kodlu bir kütüphanedir. Geliştirme platformu "Unity 3D" olacaktır. Unity kullanılmasının asıl sebeplerinden biri platform bağımsız çözüm sunmasıdır. Böylelikle sonuçta çıkacak uygulama Android ve iOS'ta birden çalışabilecektir.

Unity 3D platformu kullanılırken 3 farklı programlama dili kullanılabilir. (UnityScript(Javascript), C# ve Boo) Tez kapsamında C# kullanılacaktır.

Anahtar sözcükler: augmented reality, unity, furnishAR, vuforia, furnish

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I want to thank to my dear wife for her patience during my master. I also want to thank to my father and mother, without their courage it would be a hard to finish. It would be a relatively long journey of writing this thesis if my dear friend Alparslan didn’t helped.

Lastly, I want to thank to my advisor Prof. Dr. Abdullah ÇAVUŞOĞLU for his efforts.

2015, 12 December Çağrı Burak ASLAN

CONTENTS

ABBREVIATIONS

ADT – Android developer tools

AR – Augmented reality

FOV – Field of view

HMD – Head mounted display

ISMAR - International Symposium on Mixed and Augmented Reality

OST – Optical see-through

PTAM – Parallel tracking and mapping

SDK – Software development kit

SLAM – Simultaneous localization and mapping

TMS – Target management system

UCD – User centered design

VST – Video see-through

LIST OF FIGURES

CHAPTER 1

Introduction

Augmented reality is currently the trending topic of computer graphics. It is basically overlaying digital content into to user's field of view. Contents can be 3D models, videos, sounds, texts etc. There have been many methods covering the overlaying of the content and with the latest developments it has reached to a new level. Developments of such technology actually depends on many things such as hardware, software and design. It first emerged as a sci-fi idea of writer L. Frank Baum. (1901) [30]

Since then technology got inside our lives as portable computing devices that we carry in our pockets. This transformation has led to many excellent and life comforting breakthroughs. Augmented reality got its chance again with this highly powerful devices. Because until current portable smart devices developed, augmented reality is merely a science subject that has researched at laboratories with high tech equipment. But after these developments it starts to become a part of our world too. Today there has been many end user experiences can be found online. (App Store, Google Play or various sites) Below picture shows some examples.

Figure 1.1 Some examples of current applications

Some of the apps which provides service to end users are based on furniture placement. There have been many methods to achieve this goal. One of them is getting a snapshot of the desired place and then placing 3D models on top of the snapshot. This technique is actually reducing the amount of CPU usage because working on a snapshot causes much less consumption than working on real time video feed. This is one of the advantages of this method. But there are also some downsides. One of them is working on a snapshot lacks reality. Because it is not real time and user feels furnishing a made up room. Another downside is the alignment of the furniture with the coordinate system of image. These kind of techniques generally used with markerless scenarios. Lacking of marker is known to vulnerable to disorientation of aligned objects. Below are some examples of different type of markers.

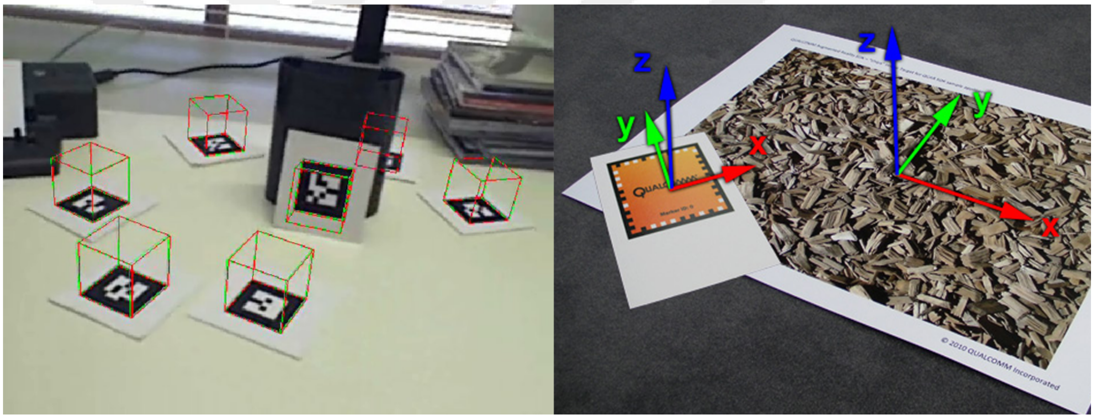

Figure 1.2 Different types of markers

Another approach, which will be used in this thesis, is using real time video feed. This approach is also divided into two categories which are marker based and markerless. Markerless technique uses some sensors to align 3D content to virtual space. Example of this technique can be found in below picture. These can be gyroscope, accelerometer and compass. This sensor information is used together with image recognition techniques to overlay 3D content into user’s field of view. But current technology in sensors make 3D content hard to stick to real world objects. Because of that, I preferred marker based solution to align content to virtually created space. Downside of this is the must of marker usage. User should have a marker to align apps from different retailers or going to their showroom, one platform can be developed containing different company's products.

This approach includes some challenges to be examined and overcome. One of them is to set a boundary to the maximum number of furniture to be added to scene. Because of the CPU limits of mobile devices, there is a limit to polygon handling. This should be examined and tested to define maximum polygon count of a 3D model and maximum number of simultaneous 3D models in the scene. Another challenge will be the user interface of the app. Serving many content in one medium can be a problem if UI wouldn't have considered ahead.

1.1 Cognitive Descriptions

1.1.1 Augmented Reality

Augmented reality is to overlay digital contents onto real world environments with computer graphics methods so that the digital contents become part of the real world. These digital contents can be a 3D model, a video clip or an animation combining both. By this technology every billboard can become a virtual video screen to play videos or it is possible to place virtual cup onto a real table as it is really there.

History of AR goes way back to 1900's. A writer named L. Frank Baum first mentions the idea of electronic devices overlay information onto people around. He called it "character marker". After a while, a scientist named Ivan Sutherland invented first HMD for both virtual and augmented reality in 1968. Until recently, AR is only used with HMD generally. So Ivan Sutherland was the first one to make a device that enables the usage of AR. The device was named "The Sword of Damocles". [24] A picture of the system is below. In 1990, Thomas P. Caudell first used the term "Augmented Reality". After 9 years, Hirokazu Kato created ARToolKit at HITLab. Later his toolkit was adapted to many platforms such as Flash, Android and iOS. After Kato's developments and also with the developing power of hardware, many major companies started to research and create products of AR. Until recently, AR was a research topic and couldn't reached to end user because of the expensiveness of the equipment that AR require.

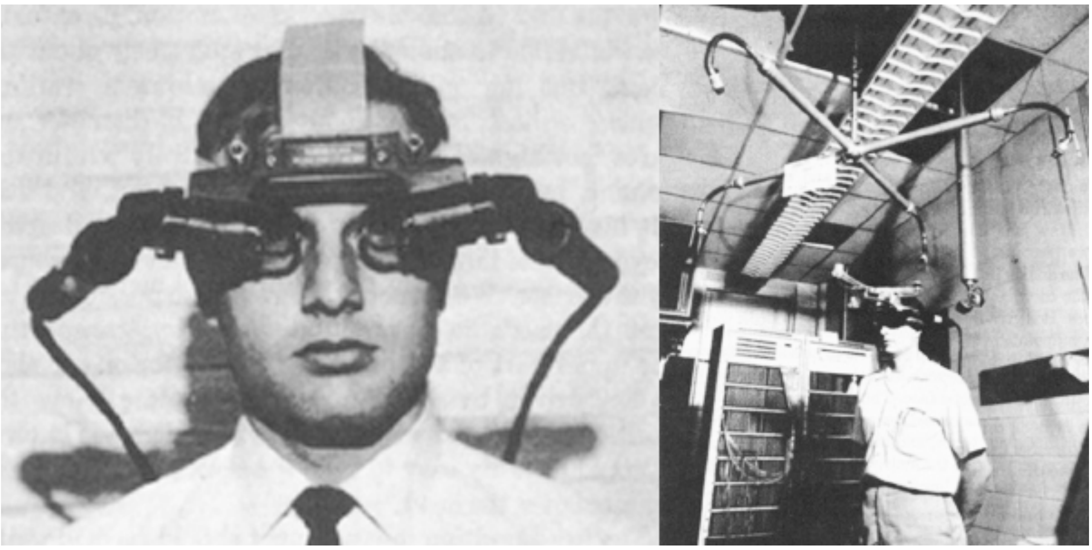

Figure 1.3 Illustration of The Sword of Damocles [24]

AR is based on hardware and software. Hardware components of the AR are basically processors, displays, projectors (in some methods) input devices and sensors. Processors are needed to maintain the calculations that taken place while image recognition and other sensory data is handled. Processed result is displayed on a screen or projected to a surface with a projector. This displays can be a computer screen or as used mostly in nowadays, a smart device screen. In spatial augmented reality users don't have to look at a display, instead augmentation is projected to user's surroundings or just to a specially designed surface. There are examples for both methods. Also there is another kind of display in development today. It is AR contact lenses. These bionic contact lenses will display augmented feed into the eye. Input devices and sensors can be treated together because both is used to feed to the program. Current devices come with plenty of sensors that can be used in AR. Some of the examples are gyroscope, accelerometer, compass. Also major input device is the camera itself. Because it is used to see what real world looks like and this data is used to decide where to put digital content.

Software behind AR is dealing with a lot of challenges since beginning. One of them is integrating augmentations realistically. This is achieved by constructing the coordinate system of the surrounding by the help of sensors and image recognition techniques. Markers are used as a base point and as an item to track. Firstly, interest points or optical flow should be detected in the images obtained from camera. At this point various methods are being used such as edge detection, corner detection etc. After detection a real world coordinate system is constructed. This is applicable if fiducial markers are present. Other methods are based on constructing the 3D scene of the surrounding without a marker. This should be done before augmentation is overlaid. This is called simultaneous localization and mapping.

Key point is to create a 3D space. It can be calculated via marker, 3D reconstruction of the real world or sensors.

1.1.2 Augmented Reality Usage Fields

1.1.2.1 Archaeology

Archaeology is one of the application areas of AR. AR has been used to recreate archaeological sites with the support of computer graphics. For example, when archaeologists hold up their iPad to the excavation area, they can see the place like thousand years before. Of course recreation of the historical site first done using modeling programs.

1.1.2.2 Architecture

Some constructional companies use AR to explain their projects to their customers more efficiently. Before the construction even started, they can create virtual 3D models of the project and augment the models on their brochures, flyers or magazines. Another usage in architecture is to use AR in the design phase. Architects can work on an augmented model. Example of such application screenshot is given below.

Figure 1.4 An example AR architecture application

1.2.2.3 Art

Many examples of using AR on art is present today. Artists are using AR to enhance the dimension and perception of their artwork.

1.1.2.4 Beauty

One of very first examples of AR was about a system which enables users to wear virtual make-up. This app looks like a mirror but the difference is you can select from various of make up selection and they are instantly applied to the user. After that, with the same principle some dressing AR applications have emerged too.

1.1.2.5 Commerce

Very well known example of this is the VW Beetle campaign. A screenshot from the campaign can be seen below. They have used AR to augment New Beetle car animation in front of a big VW billboard. People were pointing their smart devices to the billboard with the specified application and experiencing an AR commercial. Also some magazines, newspapers and product boxes are enhancing their commercial campaign with augmented content on their printed materials.

Figure 1.5 An example AR commerce application

1.1.2.6 Education

One example of educational AR is physics experiments enhanced by the developers to improve the tangibility of physics experiments. Also there has been research about how AR can improve pretend play on autistic children. [32]

1.1.2.7 Gaming

Recent developments show that next era is AR and VR era. There are plenty of games which enable AR in their gameplay. Some toy companies also bundled some apps with real toys for children to enhance their game play. As it can be seen below, virtual object is placed on real world as a part of the game.

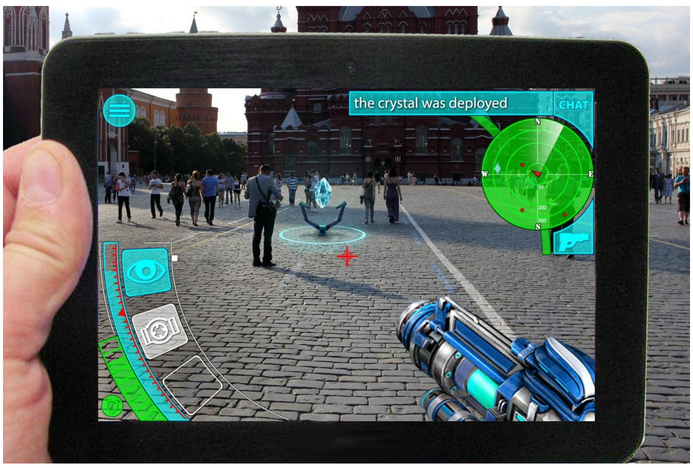

Figure 1.6 An example of AR game

1.1.2.8 Industrial Design

With development of collaborative AR, industrial design became more interesting. One of the in-development example of this is Google's Hololens. Demonstrated feature of Hololens is creating virtual 3D models together with your friend on your desk with your hands. An example is below. [34]

Figure 1.7 An example of industrial design system: Hololens [34]

1.1.2.9 Medical

AR is used to educate medical school students. One good example is seeing through patients' arm and seeing their bones or seeing their organs augmented at the place where they really exist. In some scenarios AR is used as a tool on surgery. [13]

Figure 1.8 An example of medical AR application

1.1.2.10 Military

There have been many DARPA-funded projects aimed to create AR applications or systems. Ivan Sutherland was one of the scientist has shed light on this matter. AR is also used in military in order to train soldiers. It has also been used to give related and area specific information to soldiers on site. [14]

1.1.2.11 Navigation

Navigation was among first topics that AR based work concentrated. Several AR browsers (Metaio, Wikitude etc.) showed information around us on the real time visual feed. These can be museums, shopping malls, cinemas etc. Wikitude also developed a app called “Wikitude Navigation” (formerly Wikitude Drive) which provides a GPS solution without and map inside and fully AR integrated. [47]

Figure 1.9 An example of AR navigation application

1.1.2.12 Collaborational Work

There has been many research about this topic. M. Billinghurst and H. Kato have demonstrated a system where users can see each other along with virtual objects to work on them together. Recent work on Microsoft’s Hololens has said to be implementing similar function.

1.1.2.13 Sightseeing

AR can enable tourists to see virtual simulations of the visited historical site real time. For example, PhillyHistory project provides users historical photos of places on the exact place. Users can use their smartphones to find point of interest and see historical photos of places. A historical image is overlaid onto real work in below example.

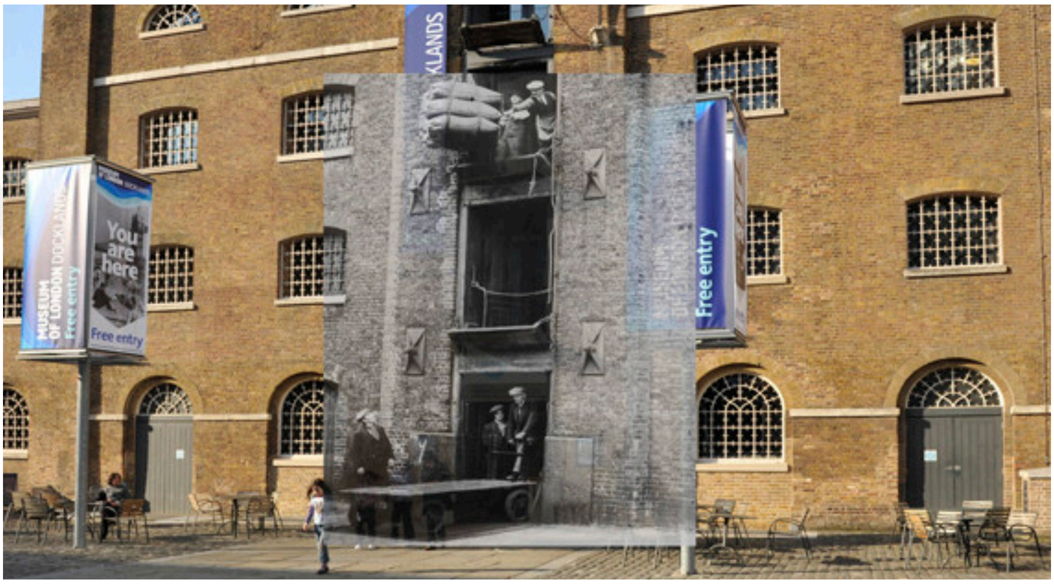

Figure 1.10 An example of AR sightseeing application

1.1.2.14 Task Support

Some complex tasks like maintenance, repair, surgery can be eased with placing information into user's field of view. Augmented reality can help with placing information into workspace or specifically onto worked object. For example, Hololens demonstrated a girl in need of plumbing can get help from his father. Father is on his mobile device and the girl is wearing Hololens in front of the pipe, he can draw 3D instructions to girl's field of view. It is known that some big companies like BMW, VW and Boeing use this technology on their production lines. Example of such usage is below.

Figure 1.11 An example of AR task support application

1.1.2.15 Tourism

Tourists walk and discover about the city they are visiting using AR browsers. AR browsers are mobile applications used to show information around us for example historical places, must-see destinations and also comments about them.

1.1.2.16 Translation

A new technology by Google utilized AR with its translation application. Users can point their device to the text and translation replaces the real text. It is currently limited to some languages.

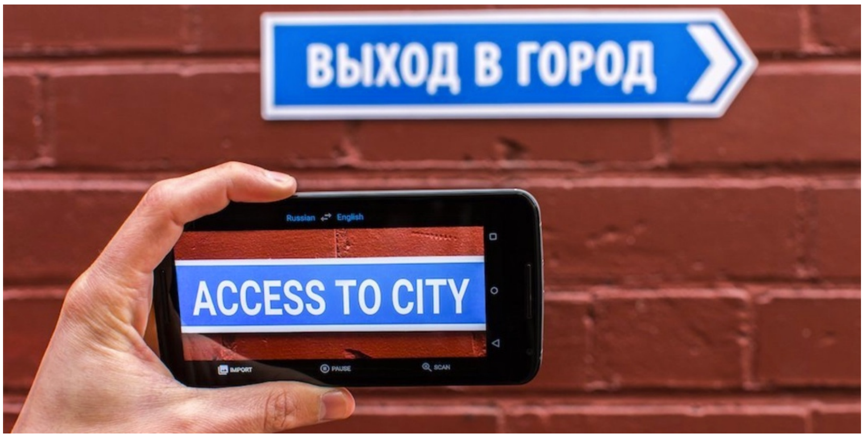

Figure 1.12 Illustration of Google's AR translator

1.1.3 Companies Working on AR

There are many companies founded solely for augmented reality applications. There various types of businesses about this subject. Some of them focused on creating applications. One other type of business is focused on the enhancement of augmented reality tracking techniques, increasing photoreality or other kinds of technology-development works. Here is the list of some companies provides SDKs to market.

- Qualcomm's Vuforia: This SDK will be used to develop the application of this thesis. Vuforia is the mostly used and supported SDK now. It gives several options using the SDK. One of them is for developers and it is free. They can make both on device detection and cloud detection. In cloud detection, developer can maintain markers without the need to change the application itself. There is a control panel that developer can add markers and content. This method is widely used by magazine AR application because markers are changing often.
- Wikitude: They have first come with a AR browser app. Then they have released their own SDK to market.
- Total Immersion D'Fusion: They are among the first companies in AR. They founded in 1999. They have also a SDK and a suite for creating AR applications.
- Metaio: They were the creator of the most stable and also expensive SDK in AR world. Their SDK has been used by many big companies. They also had a computer application the create AR apps effortlessly. They have been acquired by Apple and terminated all SDK and other operations.
- String: They are among the first examples of AR startups. The famous VW New Beetle commercial has been done with their SDK. They discontinued their SDK because they have said to be focusing another project.
- Daqri: They have been found on 2010, USA. They first started the work with AR platform with QR codes. After a while they started to built an augmented reality head mounted display. They also acquired one of the first augmented reality company, "ARToolworks".

There are also some big companies currently very interested about AR. Here is a list of some of them:

- Apple: They have not released or said anything about AR until this year. They have quietly acquired Metaio, one of the leading AR company. Yet, they have not disclosed why they have acquired or what will they do in terms of AR. But it is for sure they are onto something.
- Google: Google is working in this subject for a while now. They first started with Google Glass project but later that project discontinued but they said “The journey doesn’t end here” [48]. They also led the investment of $542 million to a company called Magic Leap. It is said that they are close to receive $1 billion funding round. They are creating a improved version of augmented reality called “Cinematic Reality”. Example screenshot from Magic Leap system is below.
- Microsoft: Microsoft was working on AR indirectly with its Kinect sensor. Many AR applications were made with Kinect. But company announced something far more interesting called Hololens. It is a HMD providing full AR experiences controlled with your hands and without the need of a marker. [34]

Figure 1.13 An example screenshot of Magic Leap

1.1.4 Some Examples of AR Products

There are some researches about this topic and they all seem to eliminate some specific problems. Some of the researches have finalized and products are ready for usage. Here are some well-known example applications with augmented reality used in furniture decision.

A study took place in Finland about user expectation and user evaluation of mobile augmented reality. It emphasizes that many researches about augmented reality is solely about display technologies, tracking techniques and other technical details. It also adds that there are very little research about what customers want and how they want to use augmented reality. [7]

To answer those questions, they have used five scenarios. A brief introduction about augmented and mixed reality was given to participants. There are several questions to be asked to participants about the scenarios and about their background. [7]

One of the scenarios is "Shopping furniture". In this scenario, users have had their room 3D modeled and this information is used to furnish it with virtual furniture. When users go to furniture store they can get price information, availability of the product and different colors. They can also use a separate room in the store to see the product in actual size projected to a wall. [7]

According to results, the most highly rated scenarios is "Shopping furniture". The participants found the service useful and valuable. A Finnish male, aged 26, said that "Checking the colors and the overall look seemed the most useful as they are so hard to picture in mind." [7]

As a result, it is said that the most valuable services are those that demonstrates usefulness for user such as saving time and effort. Among five scenarios, "Shopping furniture" has the most additional value and practical benefits to users. [7]

1.1.4.1 ViewAR

ViewAR is an AR app offer service similar to furnishAR. They make standalone white label apps for customers. They offer the development of the app and then customers have their own application. They also offer their customers that they can use the general ViewAR app and create channels there to present their products. Example screenshot from the app is below.

Figure 1.14 ViewAR application

The app provides many features. The users have the possibility to select categories and within that categories models. They can place one or more models to the scene to see if they fit together. It also gives the opportunity to freeze the camera feed with the model on it. After that customers can share those screenshots on social media. But categorization is offered as a custom module.

The system behind the app also has some features. Models are downloadable from Internet. The company call this "Model Cloud". Model cloud enables the app to be small sized. One other advantage of the Model Cloud is to maintain many numbers of models with one app.

ViewAR system offer two types of tracking. One is markerless tracking. It basically reads the information from gyroscope and places the model to scene. But this has some performance problems as tracking with a marker is better for robustness. ViewAR can track frame markers, markers look like QR codes and any images. It has been said that "learning tracking" feature is useful for cases with no marker sight.

1.1.4.2 uDecore

uDecore is a platform created by a English company called Viutek based on London. An app called “DFS” which is developed based on uDecore, is examined in order to understand the principles behind uDecore. To clarify such systems are needed nowadays, DFS is a huge furniture company based on English Peninsula. Example screenshot is given below.

Figure 1.15 uDecore application

DFS app offers users to see and combine furniture basically. It has 4 different methods to examine the furniture:

- Camera view: This mode is using camera view and the digitally drawn furniture to experience real-time augmented reality which is the usual way.
- Choose a photo: At this mode user is asked to select a photo from photo library of the device. Later, the photo will be used to place the furniture. It should be a room picture that you want your furniture to be put.
- Browse styles: This mode gives the opportunity to select premade pictures of some rooms. After selecting the picture, products can be overlaid onto the picture.

- Plan this room in 3D: This mode is for creating a virtual room for the products to be overlaid. It has 3 different room shape: “rectangular, victorian and L shape”. User can also select the floor type out of 2 selections: “wood, carpet”. After selecting the proper types, virtual rooms is displayed and hereafter user can add products to this room.

DFS app also provides markerless and marker based augmented reality. For markerless tracking it seems to be using gyroscope of the device and it is not very convenient for realistic experience.

App provides some non-AR functionalities too. User can find the store addresses from the specified section. After creating a desired combination user can share it with e-mail or Facebook.

1.1.4.3 IKEA App

IKEA is publishing a new product catalogue every year to present their furniture and home decorations and the combinations between them. In 2014th catalog, IKEA decided to put some augmented reality to their catalog. This catalog is adorned with augmented reality in order to solve some problems and satisfy some customer habits:

- IKEA officials realized that smartphones and tablets are becoming widely used in the process of shopping,

- To solve the the problem of “does this product fit with what I already have” which customers often face.

With this app, users can see videos, picture galleries, 360°/180° view of rooms and 3D representations of IKEA products.

While testing the app, some usage difficulties have been seen. First of all, tracking was not very stable and the digital content was flickering. While on the page of a digital AR content, for example a sofa, if you want to see it in your room, you need to close the catalogue and allow the app to see the front page of the catalogue. After that you should put the catalogue wherever you want the product to be seen. AR content appears on the front page of the catalogue. Opening and closing the catalogue for every time you want to try a new product was noted as a little bit time consuming. As it can be seen in the below picture, catalog's cover is needed by the app to enable augmented models.

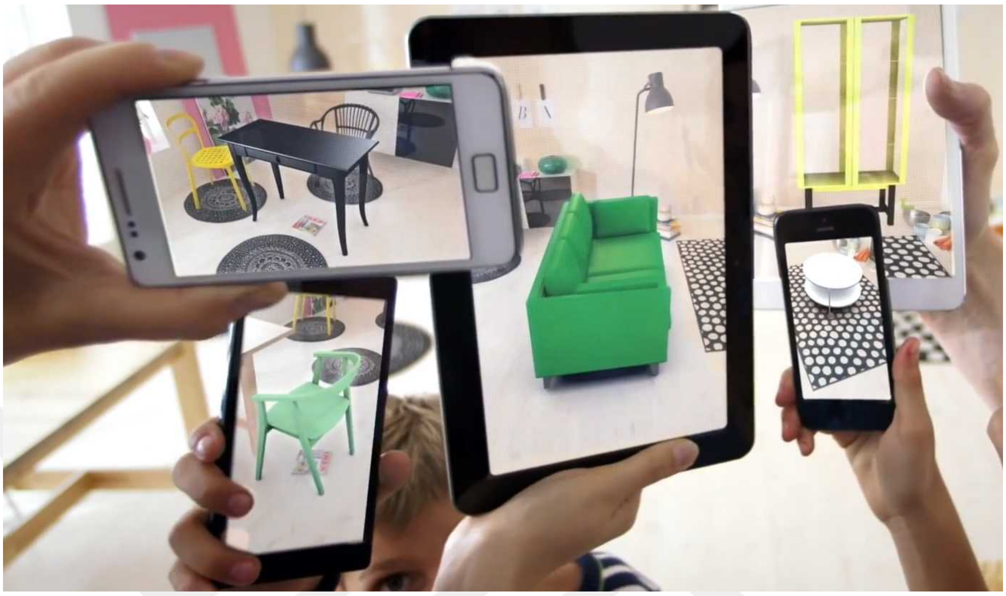

Figure 1.16 IKEA AR application

Despite of this challenges, IKEA app is the first of its kind in a large scale. It inspires many developers in this matter.

1.1.5 Future Usage of AR

As hardware get much more strong, AR is becoming more involved in our daily life. Collaboration with your colleagues while designing complex 3D models are not very well maintained with today's technology. But it is getting closer everyday. Using this technology, many of the surgical operations will be operated more easily within more hygienic conditions. Because they won't need to print anything and bring them to surgery. Another possible future use of AR is on military trainings. Soldiers will get training in a space where virtual targets are placed throughout.

1.1.6 Unity

Unity is a cross platform game engine to create video games basically. It first started as a game engine for only OS X platform but later they have expanded to many platforms such as Windows, Linux, PlayStation, Xbox, iOS, Android etc. It is used for primarily for creating video games. But its abilities are not limited to video games as it will be shown in this thesis.

1.1.7 Vuforia

Vuforia is an AR SDK built by Qualcomm. It can recognize images (image targets) and simple 3D objects with its computer vision capabilities. This recognition is used later to calculate the position of the virtual object corresponding to recognized images or objects so by this, virtual objects seem part of real world. This SDK is based on mobile devices, both Android and iOS. It has also support of Unity game engine.

1.1.8 iGui

iGui is a middleware written to be used with Unity. It makes it possible to create UI very easily on Unity. Latest version of Unity has added similar functionality but still it is easier to use iGui.

1.1.9 Xcode

Xcode is an integrated development environment for OS X based devices. It is used to create applications for iPhones, Macs and other Apple products. Development language is currently “Swift”. Swift is designed to coexist with Objective-C together.

1.1.10 3ds Max

Autodesk 3ds Max was formerly named 3D Studio Max. Autodesk Media and Entertainment has developed it. It is a professional 3D computer graphics program used by many kind of areas. It can be used for making 3D animations, models and images. It has been generally used to create and edit professional 3D models. With its plugin architecture working on 3D projects is very convenient. Program is built for Windows platform and there isn’t any version or any alternative for OS X. It is also pretty common in the area of movie sector. Movie effects and pre-visualization is also possible with 3ds Max.

1.1.11 APK

APK means Android application package. It is used by Android operating system to installation of applications. It has a similar feature like MSI packages (Windows) and DEB packages (Debian based operating systems). It is basically an archive like ZIP, containing pre-compiled Android program and its codes, resources etc. They can be installed on Android devices pretty straight forward. But firstly, untrusted sources shouldn't be disallowed on the Android device which the program is wanted to be installed.

1.1.12 IPA

This is an archive file for iOS applications which contain all of the needed files for that particular application. It has the binaries for ARM architecture.

1.1.13 FPS

It is a widely used measurement unit for frame rate on computer graphics, video capture and motion capture devices. FPS stands for frame per second. In this thesis' context, it stands for the number of rendered content in a second.

1.1.14 Polygon

Polygons are the core part when creating 3D graphics. A polygon consists of a finite number of sequential lines which forms a closed planar path. The lines forming polygons are named edges or sides. Place where sides meet each other is named vertices. It is generally used to define the sharpness and detail of 3D models. For example, the first image below is a high poly model. The image on the middle is same model but has a lower number of polygons. It is common on computer graphics optimization to use low poly images with normal maps to increase reality and decrease CPU or GPU usage.

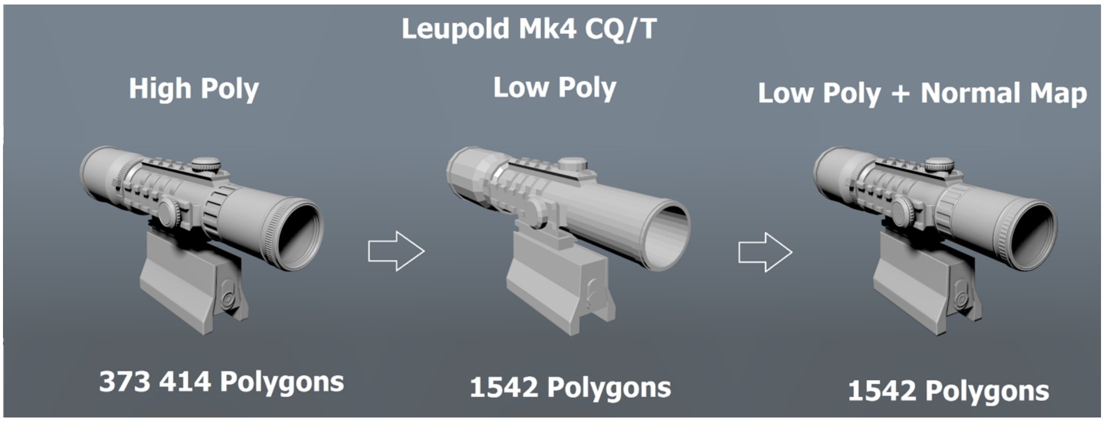

Figure 1.17 Polygon comparing

1.2 Purpose

Main goal in this thesis project is to facilitate the process of buying furniture with augmented reality. To achieve that, there are several problems to be solved. Here are the problems:

- Users spend too much time to select the best furniture to their needs. They go to furniture company's showrooms in different locations mostly. They generally look for different models to choose the one they like for a quite long time.

- After eliminating from many options, users generally come back to the store they like mostly with their companions (family members or friends) to show them and get their opinion. Because taking a photo doesn't give the idea of how big they are and the pattern or color.

- On showrooms, user should comply with the one or two selection of furniture pattern or color. Because in showrooms, generally there aren't many options of color and pattern. They offer a range of patterns and colors in small fabrics. But it is usually hard to imagine how it looks.

- The last big problem is combination and fitting issues. In our contacts some furniture companies said that they sometimes send the furniture to user's house if they fit well to the space they have or combine well with other furniture they already have. This also brings extra cost to companies. This problem is both for users and companies.

With the specified problems above, furnishAR, which is the final concept of this thesis, will solve the problems and offer the users and the companies many ease. By furnishAR,

- Users will be able to combine different furniture,
- They will have a chance to try the furniture with their actual size to see if they fit well in their space,
- They will be able to share the desired combinations with social media to get their family or friends suggestions and comments,
- They will be able to select from various types of colors and pattern for furniture,
- Companies will be able to reduce the cost of trial delivery of the furniture because clients will be able to try them at their home with augmented reality,
- Companies will have a platform that users can interact in a more technological way so this will boost up their sales.

A survey took place in USA at July, 2013 shows that 69.1% of participants use Internet to gather information when they decide to buy furniture. Same survey also says 64.1% of participants like to look at different brands online. One other data they show is 63.7% of participants look for online information before going to a furniture store. The numbers have risen about 25-30% with regard to 2008 values. This shows that people are using technology more than before and it is rising continuously. [6]

Nowadays trend in the world is “going mobile”. A research by Google and Ipsos show that 69% of users in Turkey are using their smart devices to gather information when they see a billboard, magazine or poster commercial. The tendency of going mobile is inevitable and some companies already saw the future world and tries to catch up with it.

CHAPTER 2

Literature

2.1 Tracking

There are some conceptual elements used in producing augmented reality applications. First of all, the application should examine the world around it and create a 3D virtual space of the real environment. Then it should associate virtual space with real world, in other words it should bind them. By doing that it makes it possible to place digital content into the virtual space and automatically into real world. Creation of the 3D mapping of the real world can be done with several ways. One of them is to use “markers”. Markers are the images that the applications can identify. Application estimate the distance from markers to camera and after that it is possible to create a 3D map of the real environment in accordance with the marker. It can calculate the distance because at the beginning size of the markers are provided to the application. These are called “Vision-Based Tracking Techniques”. These techniques include artificial markers and also natural markers. Artificial markers are markers that generally contain two colors with the shape of square or circle. They are processed by image processing methods like line detection, edge detection to position itself in virtual spaces. [1]

Throughout the years some papers have been published about natural occurring features to be used to estimate camera position. These features can be points, lines, edges or textures. By this technique, artificial features can be extended with natural features and continuously updates pose calculation. This allows tracking to be valid even the artificial marker is not in sight. An example of this kind of tracking can be found in Vuforia’s latest releases. [1]

One other tracking method of Vision-Based Tracking is model-based tracking. This is first presented in ISMAR in 2003. These techniques use a CAD model or 2D template of the tracked objects to track. After its first presentation it became a major tracking technique presented in ISMAR. [1]

Another method, which doesn't contain a marker, is to use sensors. Nowadays nearly all of the smart devices have various sensors from gyroscope to accelerometer. With the feedback of the sensors, applications can estimate the position of the device relative to digital content. There is also some image processing needed in order to stick the 3D content to real position. But using markerless approach generally decreases realistic feeling of augmented reality. Because digital content is not very stable and keeps its position as precise as marker based augmented reality.

On the hardware side of augmented reality, there are some requirements that mostly every new smart device provide. One of them is camera. It is used to get the real life feedback, after receiving the feedback; image-processing methods are applied to that. With high pixel valued cameras, distinguishing markers are easier. Another component is screen. It can be a mobile phone screen or a projector or an augmented reality glass. Because after receiving the real time feed from camera, overlaid digital content should be presented to user's field of view.

Lastly, in situations which only one method is not enough, hybrid tracking techniques can be used. In hybrid tracking, sensor data and vision-based tracking are used simultaneously. This provides robustness and reduces jitter. [1]

2.2 Interaction

Augmented reality applications are evolving in a manner that people can use and benefit from them easier. One of the interaction techniques in AR is tangible AR. In tangible AR one can use the real objects as inputs to the application and therefore virtual content can be manipulated with them. One example to the tangible interfaces can be VOMAR application developed by Kato. In VOMAR, person can use a real paddle to select and position the furniture to a augmented living room. Motions of the paddle are programmed and various motions become commands like place, erase etc. [2]

Besides tangible AR, later studies showed that remote or co-located AR applications allow users to perform collaborative activities. Examples of this collaborative AR are the Studierstube [3] and Shared Space projects [4]. Collaborative AR makes it possible to work and communicate with the people on a same AR scene.

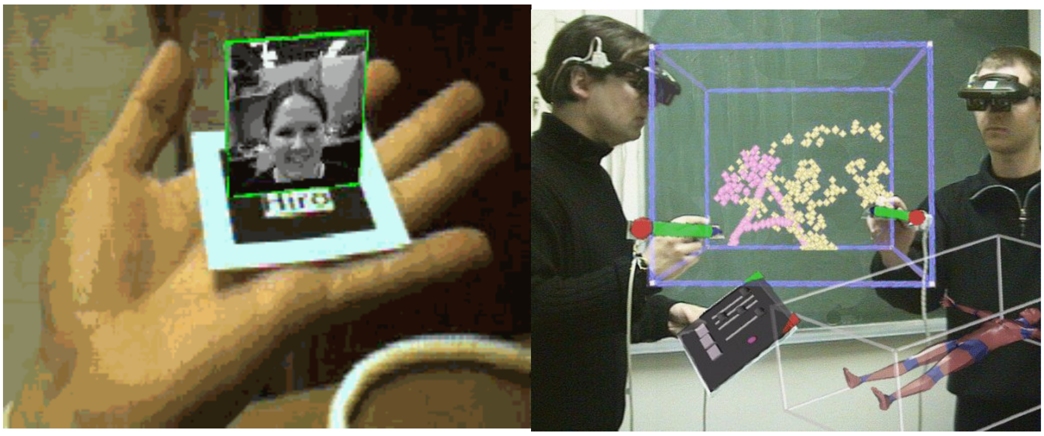

Figure 2.1 Two examples of interaction types of augmented reality [38] [39]

2.3 Displays

Display techniques usually split into three types. These are see-through head-mounted displays, handheld displays and projection based displays. Below figure shows some examples of them.

Figure 2.2 Examples of displays and AR systems

Head-mounted displays allow users to free their hands while interacting with AR scene. An optical system or video screens can do superimposing of virtual objects. Optical systems are generally called “optical see-through (OST)” and video screen used head-mounted displays are called “video see-through (VST)”. OST systems allow users to see the world around them and overlay the virtual content to a see-through screen like half silvered mirror. Most important advantage of OST's are seeing the world in a clearer way. [1]

VST systems gets the visual feed from around you and overlay the virtual content onto it and give it to the mini screens. Their advantage is the consistency with the real world and virtual content. [1]

Handheld displays can be any mobile device. This includes tablets, cell phones and smart phones. Using handheld displays have the advantage of portability. They are also easy to use and generally can be carried in real life. One of the most important advantage of them is they are socially acceptable. [1]

Projection based AR systems generally focuses on the environment. [5] While using projection based AR systems, person doesn't have to wear or hold anything because generally cameras are installed onto projectors. Advancing technologies in this topic allows users to interact with the projected augmented content with their bodies. Several sensors such as Kinect sensor makes it possible. One of the example for projection based AR with depth sensors is Augmented Reality Sandbox. Different altitudes on the sandbox are distinguished and lower parts are filled automatically with water and higher parts are colored in darker color in Augmented Reality Sandbox. It can be manipulated with a shovel and results are affected in real time. [37]

In 1999, H. Kato and M. Billinghurst published an article about a system using augmented reality. The article was one of the key articles that speed up the development of augmented reality. Their proposal was an AR conferencing system overlaying virtual images into user's field of view. Contributors were represented on "Virtual Monitors" and those virtual monitors were overlaid onto markers. By that their position could be changed to a desired position. There was also a shared virtual whiteboard where users can collaboratively work on it. Remote contributors were using PC and the person using the system was wearing a HMD with a camera attached to it. User could also work on the white board with an illuminated pen to draw shapes onto it. Example of the pen and the board is below. Their main motivation was to build a collaborative working system without effecting how people work very much. [8] They also described video-based registration and calibration methods. The results were fine when the markers are not very far. They also found that their new calibration method was more easy to use compared to other calibration techniques used in AR. [9]

Figure 2.3 Illustration of the AR board and teleconferencing system

An early example of a system for task support usage of AR was published by T. Caudell and D. Mizell (1992). Project was held on Boeing Computer Services. Their purpose is to built a system for the use of the manual manufacturing processes. They said that in airplane manufacturing, it is really hard to implement an automation process. Because it nearly consists of about five million parts and most of them required manual effort to assembly at that time. Because of that reason they came up with an idea of a system that reduces human effort of organizing assembly information and using them also reduce the errors on manufacturing processes. The concept is creating a see-through HMD with magnetic head tracking for factory workers so they can use the HMD and by that HMD can provide relevant and important information to the worker's field of view. Drawing of the HMD is below. It is said that this system can also be used with long manufacturing lines by expanding the head tracking by placing many magnetic transmitting units. HMD should sense the closest one and act accordingly. This prevents simultaneous and maybe overlapping sensor information to cause problems on the system. It is concluded that this system may provide efficiency and quality in worker's performances. It is also said that more usable systems can be made after the developments on tracking technology. [10]

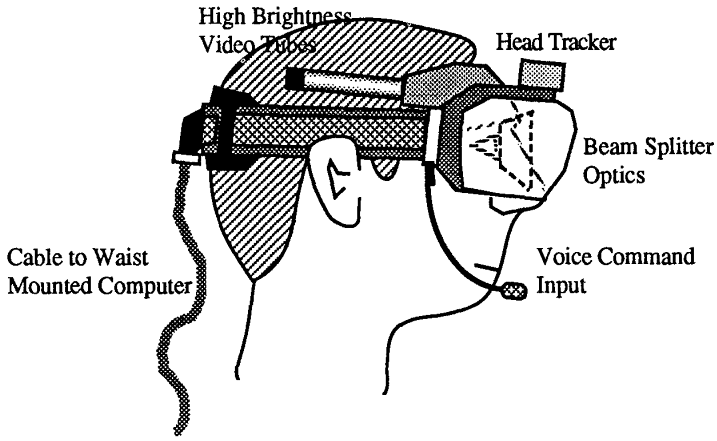

Figure 2.4 Drawing of Caudell's HMD [10]

Another milestone in AR literature is "Studierstube". It is published by Z. Szalavari et al. (1998) Studierstube is a multi user, collaborative working system, where users wear light-weight see-through HMDs to work on the same spatially aligned model. HMDs have magnetic head tracking. Usage of see-through device is to avoid losing connection with the real world. One important feature is every user can work on the model independently. For example, everyone can change the viewing angle and work on different layers. In Studierstube system, it is preferred to be in the same room to enable natural interaction. So it is not a remote collaborative working system and social communication is not interrupted. An example interaction can be seen below. Users can interact with scientific dataset with "Personal Interaction Panel - PIP". It consists of a position and orientation tracked handheld panel and a pen. With the use of PIP, virtual model can be explored deeply. The interaction is based on a screen and a mouse. It is inferred that viewing and working on a 3D model using augmented reality is superior to 2D interaction tools like screen and mouse and this is a drawback of this system. Results show that acceptance of unskilled users of the system is encouraging. [3]

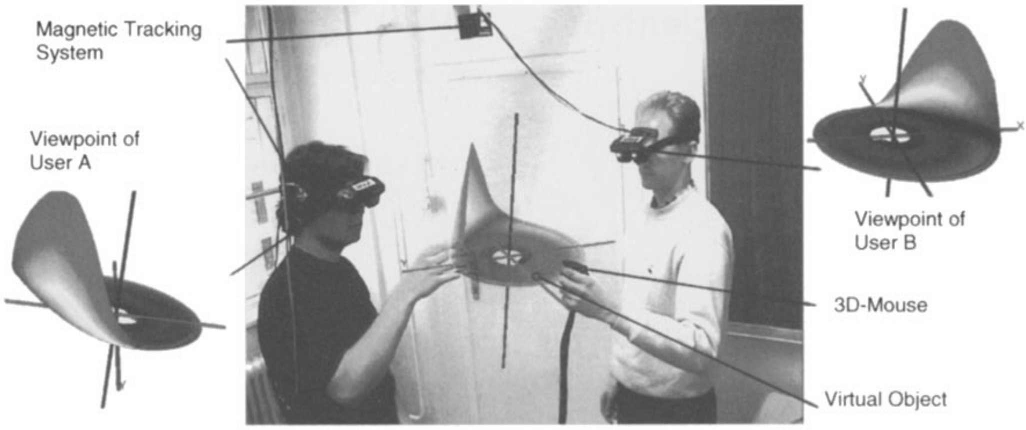

Figure 2.5 Illustration of Studierstube [3]

In augmented reality, overlaying of the virtual content sometimes depends on markers and sometimes markerless scenarios are used. Without the use of and image as reference point, device should calculate the map of the environment to successfully bind virtual objects to real world. One of the methods of the mapping of an unknown environment is called SLAM (simultaneous localization and mapping). Method is derived from the solution to the problem of a robot to build map of the surrounding and simultaneously determine its position accordingly while moving. To answer this question, researchers tried to apply estimation-theoretic methods. It is inferred from the conversation from IEEE Robotics and Automation Conference (1986) that consistent probabilistic mapping is the main problem in robotic vision with important conceptual and computational problems. This problem has been solved with many approaches today and SLAM is widely used in robotics and computer vision. [11]

D. Murray and G. Klein (2009) published an article about using camera phone for parallel tracking and mapping. At that time iPhone 3G has been used as implementation device. Although the mobile devices lack processing power compared to PCs, there are several researches about mobile image tracking. Main motivation behind the article was demonstration of capability of phones that can extract FAST corners and detecting SIFT features by Wagner et al. [12] PTAM system is used in this article. It is clarified that there are two problems while conducting such research. One of them is the lack of processing power. Because SLAM method uses somewhat brute-force approach while mapping. The other challenge is the camera. Cameras used in SLAM system generally have high frame rate (iPhone has <15Hz), doesn't have rolling shutter and has decent field of view. These three factor is quite the opposite in iPhone 3G. Processing power is reduced by collecting fewer map points. Also rolling shutter correction applied in order to reduce the effect of it. Results shows that a single iteration of bundle adjustment with 300 points takes almost 750 ms. Also rolling shutter can't be reduced more than %50. Compared to a PC system employing the same localization technique, phone-based system is far less precise. Despite this challenges on camera phone, it is inferred that iPhone can create small maps at full frame rate in real time. Tracking and map creating is effected by CPU power and camera's field of view as said before. It is said that more powerful devices can show more performance. [15]

One other method for localization and mapping is PTAM (parallel tracking and mapping). The difference between SLAM and PTAM is in PTAM, tracking and mapping is divided into to separate jobs. Then these separate jobs are executed in different threads parallel to each other. [16] R. O. Castle et al. introduced a PTAM system to cover wide-area places and multiple regions. Creating of maps in large scale areas can be done with multiple cameras simultaneously as they mentioned. To create such system, it is said that there are some costs. One of them is monoSLAM's quadratic complexity and operable limit of map size is around 100 for 30 Hz operation. Because of this maps are generally limited. Another cost is coming from strong motion modelling. When modelling starts temporal evolutions is important as it is the core part to recursive filtering. One of the methods of this article is handling less predictable motion tracking to use particle filter to stand for pose. But the correlations between camera and scene features are very expensive. Results show that system can create multiple maps with multiple cameras and successfully augment some info onto real world in room based spaces. As an application of this method to wide area locations, Oxford University Museum is selected. At the end of 45 minutes of continuous use of the wearable camera and the system altogether, museum is mapped and some augmentations are added. The outcome of the mapping and augmenting can be seen below. [17]

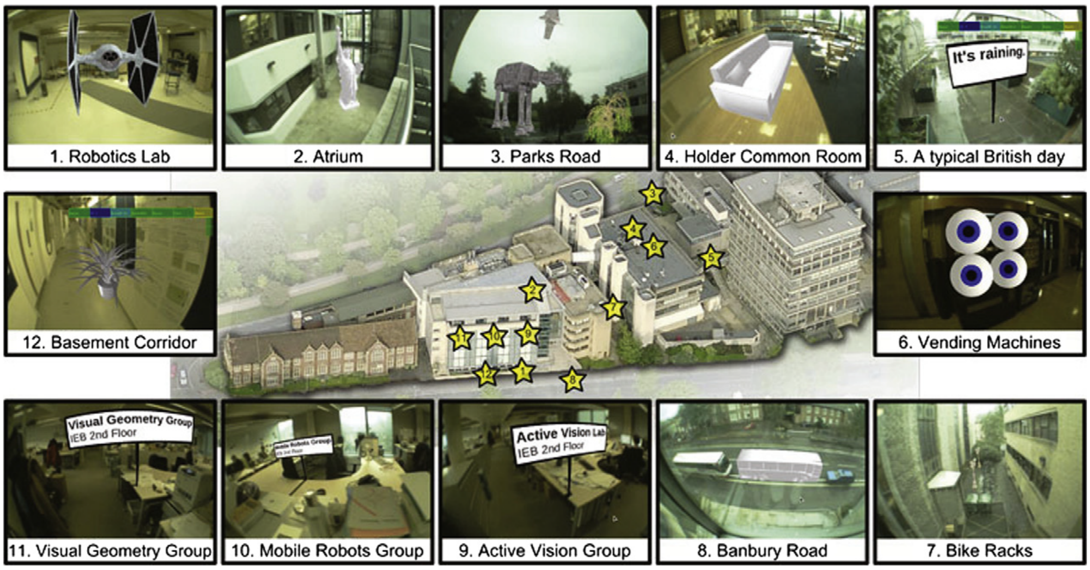

Figure 2.6 Wide-area mapping for AR [17]

It is inferred that to apply wide area augmented reality this system can be used to create maps just by walking around without elaborated guidance. It has been used in natural history museum to place AR content on the point of interest locations. One important feature of the paper is by using multiple maps, it is possible to modify maps partially without the need of changing all of the museum's maps. Editing of the maps are easier this way. [17]

Like tracking problems have been addressed in augmented reality, photorealism has always been researched by scientists. When an AR object is placed, there are some factors effecting association of the virtual models with real world. As example, correct lightning and shading, occlusions, good tracking, pixel matching can be given. A paper has been written by Georg Klein et al. about compositing virtual artifacts and video feed in order to increase realistic effects of AR. They use low-cost cameras for augmented reality compositing. Paper concentrates on pixel matching problem of video feed and the rendered objects. Emulating of imaging process in small cameras is the purpose of the article. The process then can be applied to the virtual object to match pixel clarity. After emulation it is proposed to apply 10 distortion techniques such as radial distortion, motion blur, Bayer sampling, sharpening and quantization etc. In augmented reality part PTAM system is used. It is inferred that although this new process adds 6 ms of rendering time (with NVIDIA

GeForce 9800 GTX) results are promising. An example change can be seen below. [15]

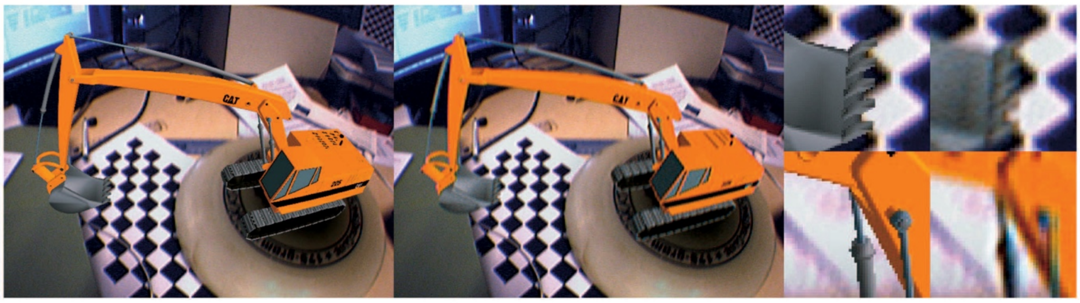

Figure 2.7 Image on the left is without any alteration, in the middle is altered image [15]

It is also mentioned that one drawback of the system is indiscrimination of the method. If a crosshair is needed in the scene, same distortion steps are applied to crosshair also. In some cases, this may be impractical. It is said that using less than the 10 techniques mentioned in the paper, one can implement a quicker and lightweight version of this integration. [15]

Creating applications, tracking techniques and photorealism research are really important steps of developing and contributing to augmented reality medium. But when it comes to end-user, some other perspective is necessary. T. Olsson et al. focused on user evaluation of mobile augmented reality scenarios (2012). This research is built upon user-centered design (UCD) approach. It is a framework of processes that put user in the center of design process. It is also underlined that by this approach successful and engaging user experiences can be created. This method is based on iterations. So user feedback is taken into consideration every round of design and according to feedback design is evolved. There are some cognate concepts in UCD. One of them is user acceptance. It refers users' eagerness to embrace and use the systems or services. [33] The other is user experience. ISO standard defines user experience as a person's apprehensions and reactions as a result of the use or expected use of a product, system or service. The paper emphasizes on the expected experience part as well. It is said that expected experience needs to be highlighted because of the effect to the overall user experience. Several scenarios are demonstrated in the article, like on the bus, shopping furniture, virtual mirror etc.

Participants are generally young adults aged between 21 to 36. 262 people was surveyed and the results were analyzed. In the scenario of buying furniture, first, users get their living room 3D modeled so that they can place virtual furniture inside. At the same time, they visualize 3D models on AR-based system. This scenario is considered useful overall. According to survey the most useful part is being able to see different colors and different orientations, because it is not easy to picture every combination in mind. In spite of general satisfaction of the service, seeing the furniture in real size isn't made much impact because only 4% of the respondents mentioned that. AR part of the system is based on a projection room. This is the most important disadvantage of the system because it brings complexity. Respondents also raised concern about the correctness of the furniture size. The results show that among all of the scenarios, shopping furniture is one of the most useful three scenarios. Shopping furniture is seemed to have the most additional value among others. It is inferred from the article shopping furniture and virtual mirror scenarios appeal women more than men. [7]

A similar approach is published by M. Billinghurst et al. about evaluating the user experience of educational AR. It is no secret that computer technology is changing the way of education. This leads to enhanced understanding of students and increased number of achievements. [19] AR is one of the trending technology in education. There are many books enhanced by augmented reality for school kids. These kind of books contain augmented reality content which can be activated with HMDs or some kind of handheld device. It is said that a powerful advantage of augmented reality books is their interactivity. Users, in this case students, can use books as input devices to AR system to manipulate AR content. For example, throws in physics can be implemented to an AR book with this technique. As it is mentioned earlier, writers said that it is not the augmented reality makes people understand the topic, it is how one use augmented reality while creating systems or applications. It is said that AR has a little part in storytelling but it has much effects on getting students into the topic more than traditional educational methods. In this paper, a small experiment has done. Children work in pairs collaboratively to solve puzzles and continue into a story with some paddles to move virtual characters. Two group attend the experiment, one is high-ability and the other is low-ability group of students according to their teachers. AR book has two parts consisting of a text based sections and AR based sections. Results show that on text based parts, high ability group is more successful than the other group. But when it comes to AR based parts, there is not significant difference on remembering the key points between two groups. Children who attended the experiment call the system a “game” and enjoyed mostly the AR parts. Which means more engaging students when used AR. Another comparison has done with two groups of students on the topic of electromagnetism. Picture from that AR setup can be seen below. [18]

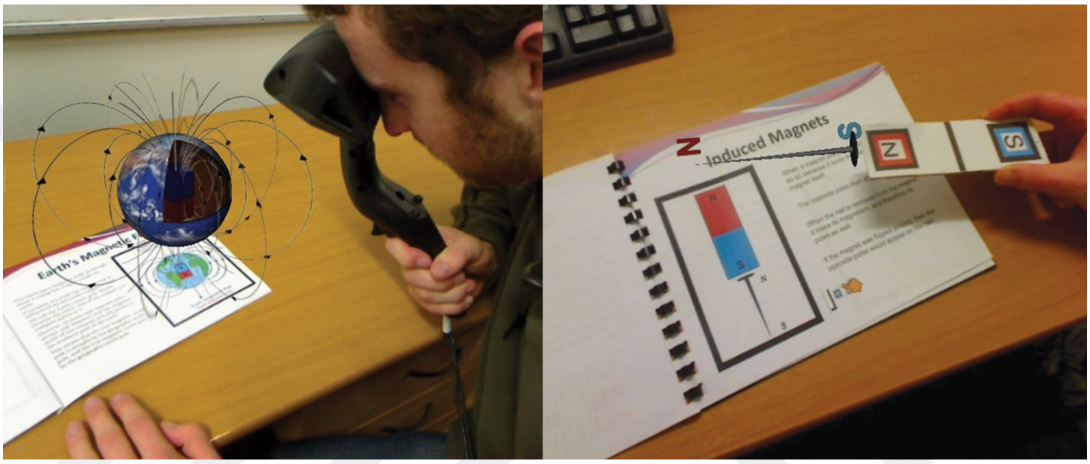

Figure 2.8 Educational setup of electromagnetism using AR [18]

One group is provided with text books and the other group is provided with AR books. At the end a test has been administered. Students with text book scored a mean score of 60 percent while students with AR book scored 70 percent. One important inference that the writers made is AR should complement traditional methods instead of replacing them. This is because of the hardness of the transfer of all documents into AR. Complementation is more effective than replacing. [18]

A similar research has been conducted with this thesis in 2012, by Y. Shinagawa et al. They compared two different input methods for furniture placement. One is a table top control board system, consisting of a tablet to control the positions of furniture. There is a reference marker present with the table top system but only one reference marker is enough. The other system is placing furniture with a marker based system. User should lay markers into the empty room in order to position furniture. NyARtoolkit, QPtoolkit and ARtoolkit are used in this research. Schematic of the system is below. [20]

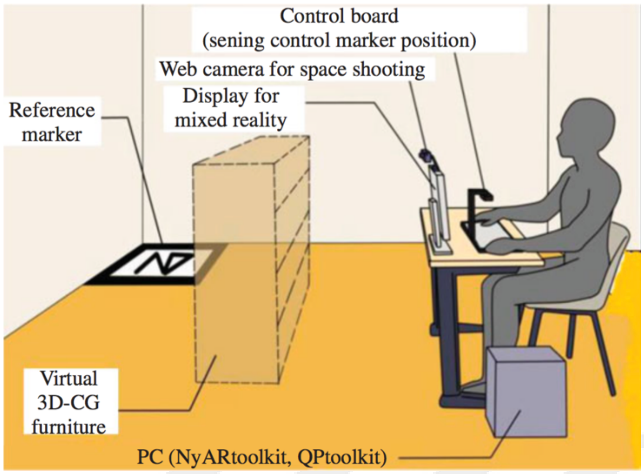

Figure 2.9 Schematic of the system described [20]

The results of this research shows that using table top control board system produces smaller number of average and standard deviations. This means that table top system is more effective than laying markers. They pointed out that future work will contain the research on different size of real spaces. [20]

A. Karhu et al. introduced a development framework called MARW (mobile augmented reality web). It is said that there are many commercial mobile applications empowered with augmented reality. They are all standalone applications which are needed to be downloaded and installed. It is remarked that these applications generally need special care in order to be run on various platforms. It is mentioned that developing web technologies enables the use of cross platform browsers as AR platform. But it is seen as a challenging task because of the performance issues. The framework is built upon HTML5, WebRTC, XML3D and Xflow. Alvar is used as AR SDK. [35] The resulting system is evaluated with different browsers and devices. Overview of the system is as follows: first video frames are converted to XML3D texture, then visual features are tracked and lastly produced XML3D texture is fed into HTML5 canvas. Tablet, smart phone and laptop are used as a testing device. Chrome and Firefox are used as a testing software. Results show that Firefox performed better than Chrome because of the JavaScript version of Alvar produced from C++ using asm.js. This script gives better performance with Firefox. It is also inferred that when marker size grow, processing time is also growing. A chart about this issue is below. [21]

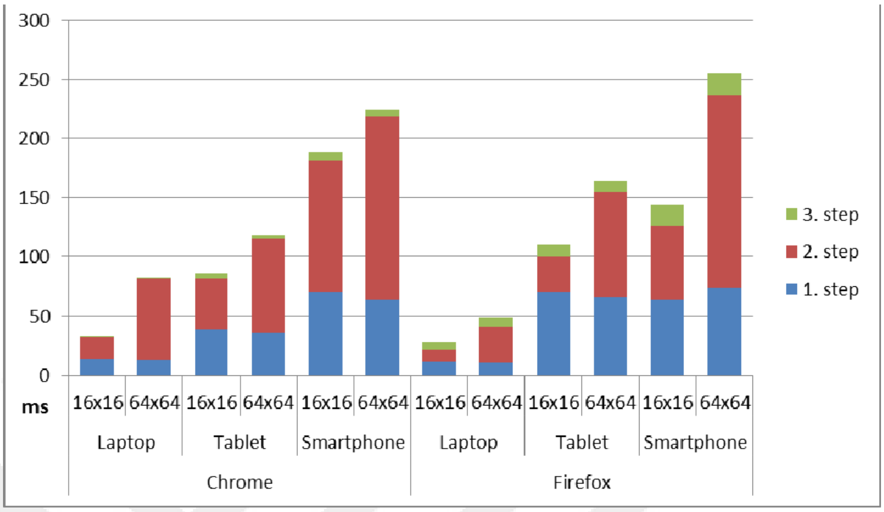

Figure 2.10 Comparison of marker sizes and devices [21]

Naturally, FPS values are higher in laptop than other devices. The least FPS values are produced in smartphones. This kind of platform for AR is important because of its deployability against standalone applications. The results show that browsers are promising land for AR applications but current limitations such as single threadness of JavaScript makes it hard to optimize the platform. It is concluded that sensor based tracking and position is not really an CPU-expensive process. But in this manner, realistic registration of models is problematic. On the other hand, vision based tracking is really expensive and with high-end tablet devices only 10 FPS is achieved. According to article it is tolerable but not very interactive enough for continuous usage. Because of this, further development in this area is necessary. It is said that with the advancements in browser development, JavaScript execution is getting faster and this will effect their system positively. Another point is recent adoption of WebCL (a JavaScript binding of OpenCL) will also allow this system to work more effectively. [21]

HMDs are started to widely used in the field of AR. Latest cutting edge technologies such as Hololens try to enhance our daily life with the aid of HMDs. A recent research by H. Benko et al. addressed a common problem while using HMDs. (2015) Current HMD technologies used in augmented reality often limits the user's field of view to less than 40 degrees. They have proposed a system to solve this FOV problem. It is basically a combined system consists of a projection based augmented reality and an optical see through eye wear. It is called "*FoveAR*". Proposed system has nearly 100 degrees of FOV, view dependent graphics and extended brightness and color. It is said that compared to eye's field of view of nearly 180 degrees of horizontal and 130 degrees of vertical FOV, current HMDs lacks ease of use because of its FOV. There have been only a few studies about extending FOV but in a costly manner. This brings less image quality and display resolution. [22] [23] Despite of classical systems FoveAR proposes a hybrid system where an OST HMD is used together with projection based spatial AR display. This kind of research has been done before but in a different way. Such as controlling the backlight lightning [25] or object highlighting [27]. In the system Lumus DK-32 with the resolution of 1280x720 is used with ceiling mounted Optoma GT760 DLP. Microsoft's Kinect is used also and all of the equipment are connected to a Windows 8 machine. To adjust the perspective, a retro-reflective spheres are mounted to HMD in order to be tracked by OptiTrack Flex 3 system. Project is a proof of concept of a hybrid system. It offers private stereoscopic images, per-pixel controlled ambient lightning. Results show that besides extending FOV, these improvements are much beneficial also. Results can be seen below. [28]

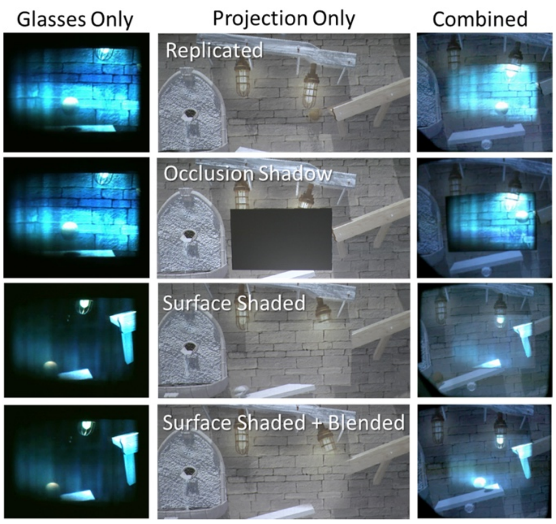

Figure 2.11 Results of the FoveAR system

An interesting research about the usage of AR has been presented by Z. Bai et al. (2015) Research focuses on eliciting pretend play for autistic children. Pretend play is a really important and involved with the topics of symbolic thinking, social interaction and language. It appears in the last two quarter of the second year. [29] One importance of pretend play is that it is closely related to understanding other's mind. [31] It is said that capability of AR such as understanding the environment better is the main motive behind the research. It is tried to interpret the real world into a symbolic and figurative situation. An AR system is developed to create a pretend play environment and resulting effectiveness of the study is measured by an empirical study. System is built with Goblin XNA [36] and ALVAR tracking library [35]. Created system is also examined by the psychology experts and positive feedback has been received. System is designed as an AR mirror and it is said that all of the participants adapt to the system without any problems except one child with selective mutism. He needed some extra time to get used to system. Results show an increased elicit pretend play duration compared before. Participants also engaged with the pretend play more often during the experiment. One other metric is the relevance of the pretend play, because participants are required to be consistent to suggested themes. System is also increased the relevance of the pretend play. System is greatly accepted by the participants and even they created many play ideas. The most powerful effect of the system is on the children with least pretend play development. The system can be seen below. [32]

Figure 2.12 AR pretend play system [32]

Another recent interesting development is on the medical use of AR. The system is called "*Pico Lantern*". Pico Lantern is a small projector which can be dropped into the patient and picked up therein. It projects a pattern onto tissues to guide surgeon by providing surface depth and surface reconstruction. It is designed for enhancing laparoscopic surgeries by surface reconstruction of organs, objects, detecting blood vessels etc. It is also mentioned that the major problem in laparoscopy is not seen inside in three dimensional form causes problems sometimes. Augmented reality part is to project what is calculated onto the surgical scene. It is said that the concept was mentioned before and their system has some advancements over current work. Some of the advancements are using a projector which can be moved to a desired position by a laparoscopic tool, a better AR tool to display reconstructed data, a good combination of two side by side organs when reconstructing, surgical can see the inners from any point where Pico Lantern is. Two surface reconstruction method is experimented. The first method is using a stereo laparoscope with an untracked Pico Lantern. It is accurate as other stereo laparoscopes. But it is less accurate when it comes to sensitivity of detection of check board. Because a simple correspondence method is used. The second method is surface reconstruction with a mono laparoscope with tracked Pico Lantern. Results show that method two is more consistent because there is a wider baseline between the camera and laparoscope. It is inferred that the surgeon can move the lantern as close as to a desired position with the tradeoff of accuracy and FOV. Example setup of the system can be seen below. [13]

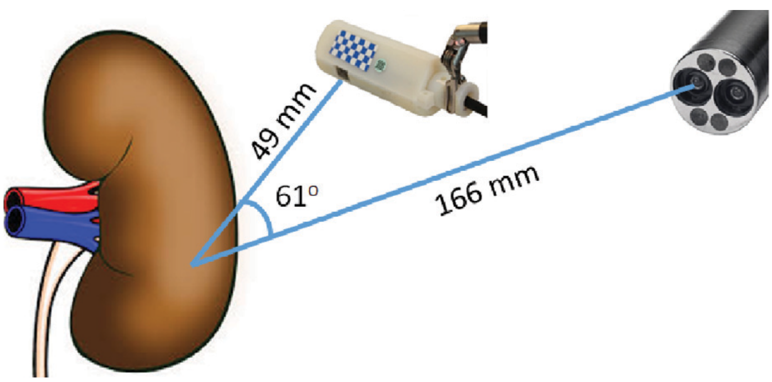

Figure 2.13 Pico Lantern system

CHAPTER 3

Implementation of the Mobile Application

3.1 Preparation for Development Phase

In the development of this application several hardware and software has been used. This process has been maintained on a MacBook Pro Retina. As testing device iPad 3th generation and iPhone 4 has been used. A table for hardware specifications are below. Coding and scene creation has been done with Unity. A middleware called iGui has also been used to create user interface of the application. 3DS Studio Max is used to create and modify 3D models which used in application. Created 3D models have been placed onto image targets using Vuforia SDK.

		iPhone 4	iPad 2
DISPLAY	Type	LED-backlit IPS LCD, capacitive touchscreen, 16M colors	LED-backlit IPS LCD, capacitive touchscreen, 16M colors
	Size	3.5 inches (~54.0% screen-to-body ratio)	9.7 inches (~65.1% screen-to-body ratio)
	Resolution	640 x 960 pixels (~330 ppi pixel density)	768 x 1024 pixels (~132 ppi pixel density)
	Multitouch	Yes	Yes
	Protection	Corning Gorilla Glass, oleophobic coating	Scratch-resistant glass, oleophobic coating
PLATFORM	OS	iOS 4, upgradable to iOS 7.1.1	iOS 4, upgradable to iOS 9.1
	Chipset	Apple A4	Apple A5
	CPU	1 GHz Cortex-A8	Dual-core 1 GHz Cortex-A9
	GPU	PowerVR SGX535	PowerVR SGX543MP2
MEMORY	Card slot	No	No
	Internal	8/16/32 GB, 512 MB RAM	16/32/64 GB, 512 MB RAM
CAMERA	Primary	5 MP, 2592 x 1936 pixels, autofocus, LED flash	0.7 MP, 960 x 720 pixels
	Features	1/3.2' sensor size, 1.75 µm pixel size, geo-tagging, touch focus, HDR photo	No
	Video	720p@30fps	720p@30fps
	Secondary	VGA, 480p@30fps, videocalling over Wi-Fi only	VGA

Figure 3.1 Hardware information

Work with all of the above first Xcode has been installed on MacBook. This is mandatory to develop applications for Apple devices. After installation, a valid Apple developer account has been used to develop with Xcode. If ones have distribution purposed they should pay the fee of 99 dollars to buy Apple developer account. Also it is needed to create provisioning profiles and the devices should be added to Apple developer portal. This process can be automatically done by signing in on Xcode and connecting your device when Xcode is open.

After setting up Xcode for application to be installed on testing device, Unity has been installed. There is not much specific installation instructions for Unity. Only thing is a version of Unity capable of iOS and Android development should be installed. Because there are various of development platforms with Unity.

After installation of Unity, a middleware called iGui has been added to project to create user interfaces. It was added simply by dragging and dropping into the project screen. From this point any created project can be built for Xcode to push to device. There are some options about building a project for iOS. You can see a screenshot of the options mentioned below.

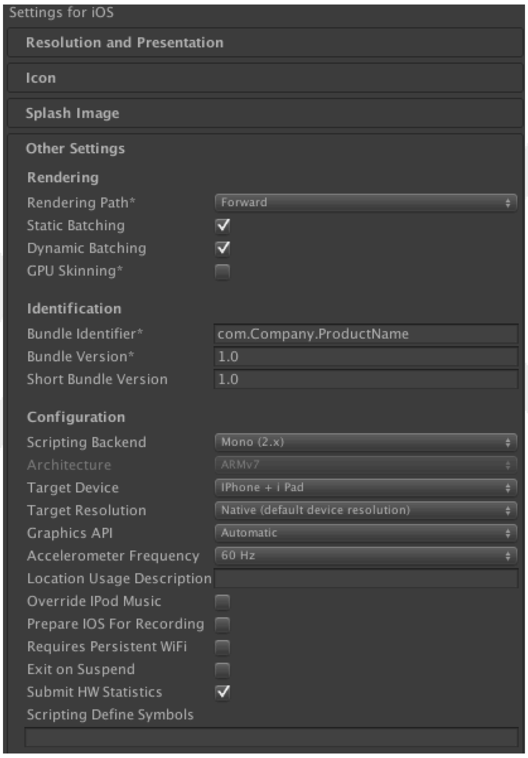

Figure 3.2 Build options of Unity

Even though Apple devices have been used as a testing hardware, using Android devices are pretty straight forward. To deploy Android applications to Android devices, only Unity is enough to do the job. First development platform should be changed to Android. After project should be built and run when Android device is connected. At this point developer options of the Android device should be activated. The activation process varies from device to device. After activation USB debugging also need to be activated. Example setup configuration is given below.

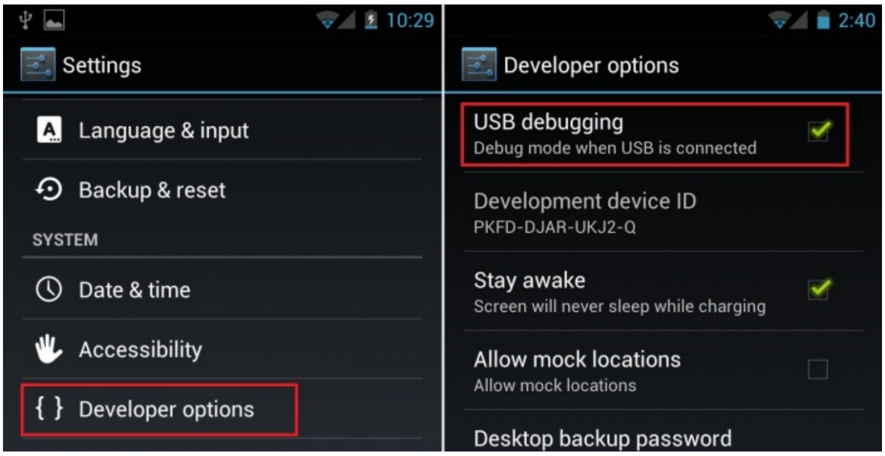

Figure 3.3 Android USB debugging

In the development of the application some tools, platforms and a SDK have been used. The purpose of the selection of each element is described in the corresponding sections. Here are the tools that have been used.

3.2 Unity

Unity is a cross-platform game engine to develop video games for web, mobile and desktop. It started as an OS X game development tool and now it can be used in Windows as well. Currently it can deploy project to following: iOS, Android, Windows, Blackberry 10, OS X, Linux, web browsers, Flash, PlayStation 3, Xbox 360, Windows Phone 8 and Wii. [38]

Unity uses various rendering methods for various platforms. For example; Unity uses Direct3D for Windows and Xbox; OpenGL for Mac, Linux, PS3, Windows; OpenGL ES for Android and iOS. It can also accept assets from 3DS Max, Maya, Blender etc. [39]

One can use three programming languages when scripting with Unity. They are Unity Script (it is referred to as JavaScript by the creators of Unity) and C#. [40]

Physics implementation is essential when developing games with physical interactions. Unity has built-in support for NVidia's PhysX physics engine. It also adds couple functionality on it too. [41]

Unity has been used as a development platform throughout this thesis. Because of its flexibility it is easier to mix UI and code. While designing UI, a Unity 3D middleware called "iGui" is used. Further information will be provided in corresponding section. Code selection among JavaScript, Boo and C#; C# is considered most suitable of all. This is because of its elasticity while designing object-based widgets of the application.

3.3 Vuforia

Vuforia is an augmented reality SDK created by Qualcomm. It is widely popular among developers because it is free and offers many recognition techniques. It supports Android, iOS and Unity 3D development. The SDK can be downloaded freely from their web site as a "unitypackage" (extension). "unitypackage" is a package with some Unity projects, codes, plugins etc.

With Vuforia based application, mobile devices display becomes a "magic lens" or looking glass into an augmented world. [46] The application renders the video as a representation of the physical world and it superimposes virtual content to that real world video. Here is a list of features comes with Vuforia:

- Faster target detection
- Simultaneous detection of 1M targets with cloud recognition
- User-defined targets are possible for runtime applications
- Detection and tracking of cylindrical surfaces.
- Recognition of printed texts
- Augmentations are not lost easily with camera movements
- Tracks 5 targets simultaneously
- Realistic graphics rendering
- Extended tracking feature for when the target is out of sight

Here is the overview of the SDK and a figure illustrating it can be seen below:

- Scripting integration of Unity
- High-level access to use hardware units
- Multiple trackables/tracking types:
    - Image Targets
    - Multi Targets
    - Cylinder Targets
    - Word Targets
    - Frame Markers
- Real-world Interactions
    - Virtual Buttons

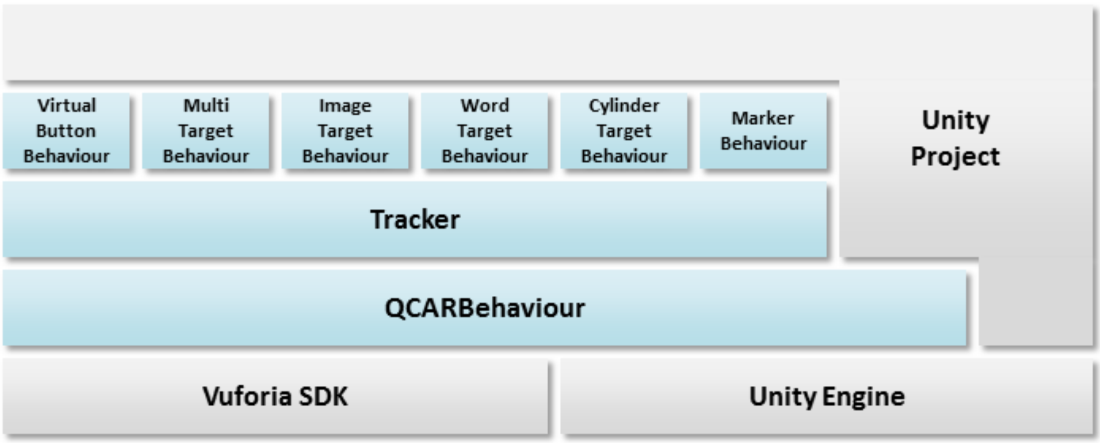

Figure 3.4 Schematic of Vuforia Unity SDK [42]

3.3.1 Development Process with Vuforia for Unity

Here is a figure the map the development process of Vuforia app using Unity:

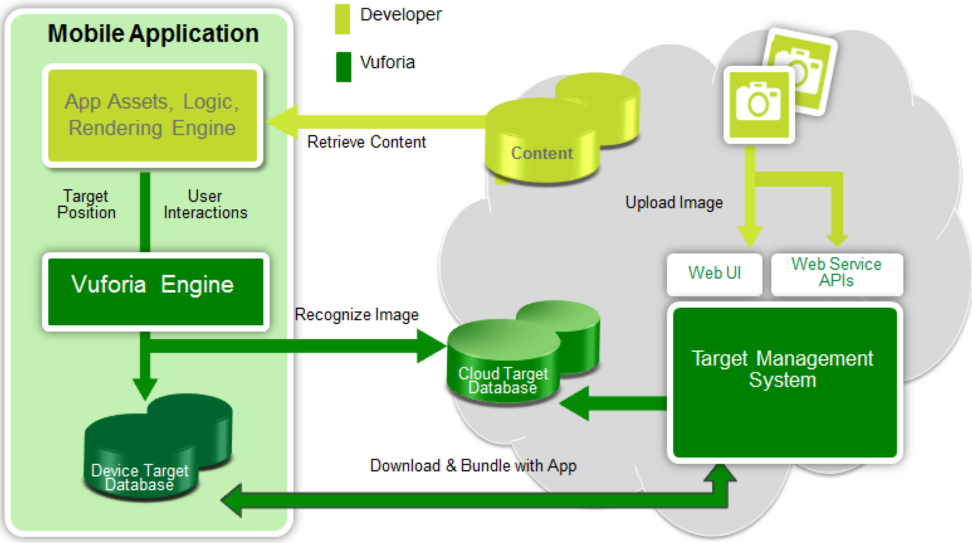

Figure 3.5 Application development process of Vuforia [43]

To create a Vuforia based mobile app with Unity there are some steps to set up the environment:

- Setting up the necessary native SDK's: In order to develop an Android application firstly ADT-Bundle should be downloaded. If an iOS application will be developed Xcode should be installed with necessary iOS development tools. Because in order to deploy the app to corresponding platform native tools will be used.

- Adding Vuforia Extension: Adding Vuforia SDK(extension) is quite easy task. It can be downloaded both from Unity Asset Store or Vuforia's web site. If downloading the the extension is preferred, after finishing download extension should be dragged and dropped into "Project View" of Unity. It will compile and add the extension.

- Creating AR scene: To make a simple Vuforia based app, there should be a scene with "ARCamera" replacing the "Main Camera". After that trackables

(Image Target) should be added to the scene. This is done by adding "ImageTarget", which is a Vuforia prefab, to the scene. The last thing is to add virtual content as a child to ImageTarget.

This figure below represents a simple AR scene described above, created with Unity and with the help of Vuforia.

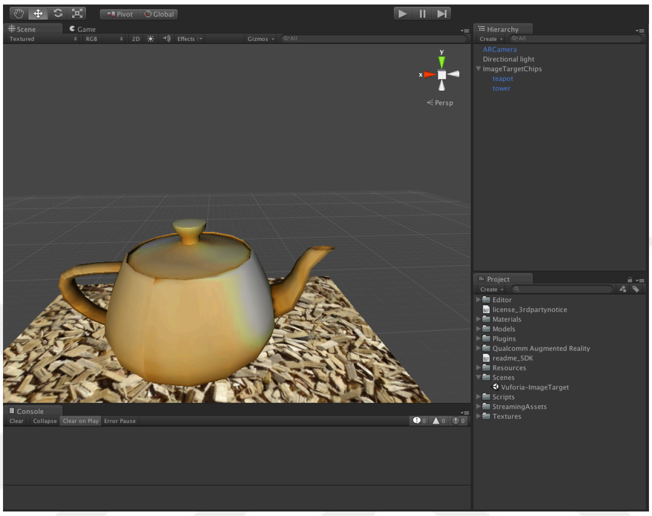

Figure 3.6 Example Vuforia Unity project screen

After clicking play button of Unity. App will render the camera feed as physical world and the teapot will be always on top of the chips image. This is a brief explanation of creating a Vuforia based Unity app.

3.3.2 Image Targets

Image targets are the images that AR content is superimposed onto. They are called "markers" or "trackables" too. They are basically the key to show the virtual content as a part of physical life. Virtual content is overlaid and positioned accordingly to image targets. After this binding, virtual content becomes the part of a physical world element (printed image, image target).

3.3.2.1 Creating Image Targets

To create image targets, Vuforia's Target Management System (TMS) should be used. There are 4 types of image targets in TMS:

- **Single Image:** This type is the regular type of image target. It can be used for flat and 2D surfaces like magazines, walls etc.

- **Cube:** This option can be used to detect cube shaped real life objects. But when you select this option you have to provide 6 different images for each face of the cube.

- **Cuboid:** This option is nearly same with "cube" option. Again, you have to provide 6 different images for the faces of the cuboid.

- **Cylinder:** This option is useful when targeting a cylindrical real life object. At this option you have to provide 3 different images; top, bottom and the side surface.

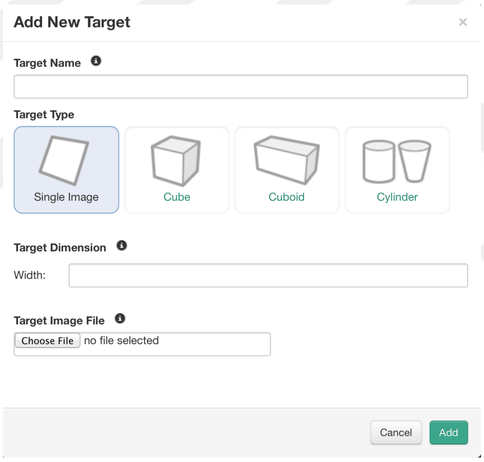

Figure 3.7 New target adding in Vuforia Web panel

Firstly, the image/images which is/are wanted to be an image target, should be uploaded to TMS. After upload TMS does some calculations and gives a feedback whether the image target is trackable or not. Rating system of TMS gives a star based score. Figures below shows the rating of the image targets.

Figure 3.8 5 star image target

Figure 3.9 5 star image target with features visible

After creating image targets they can be downloaded via TMS in various formats to be used in Android, iOS and Unity projects. Downloaded image targets should be added to Unity project in order to be used.

3.3.3 Image Target Detection Criterions

There are some criterions that effect the detection of the image targets. These should be taken into consideration while creating and using image targets.

3.3.3.1 Contrast

Using image targets with high contrast really helps the enrichment of the features. With some dark and light areas in the target, edge detection can be performed easier.

3.3.3.2 Distance to Image Target

There is no specific distance to be obeyed. It depends on the marker size. To be clear it is important that how much of the device screen is covered with the target. Because the features from the target should be visible to the application. Distance also depends on the quality of the camera. High resolution cameras get images more sharp instead of low resolution cameras. This effects the distance allowance.

3.3.3.3. Light Conditions

Under low light conditions features on the images may not be seen detailed enough. Low light causes the contrast of image to drop in respect to AR camera.

3.4 iGUI

iGUI is a middleware written for Unity to design UI. It welcomes the concept of WYSIWYG (what you see is what you get). It eases UI design with drawing the UI on the scene. As an additional information developer of the iGUI is Turkish and it is widely used in the game industry.

To use iGUI, first you need to activate the iGUI toolbar from "Window>iGUI>Toolbox". After that iGUI Root game object should be created at the scene in order to be using iGUI. Here is a picture of the iGUI toolbox and a simple scene.

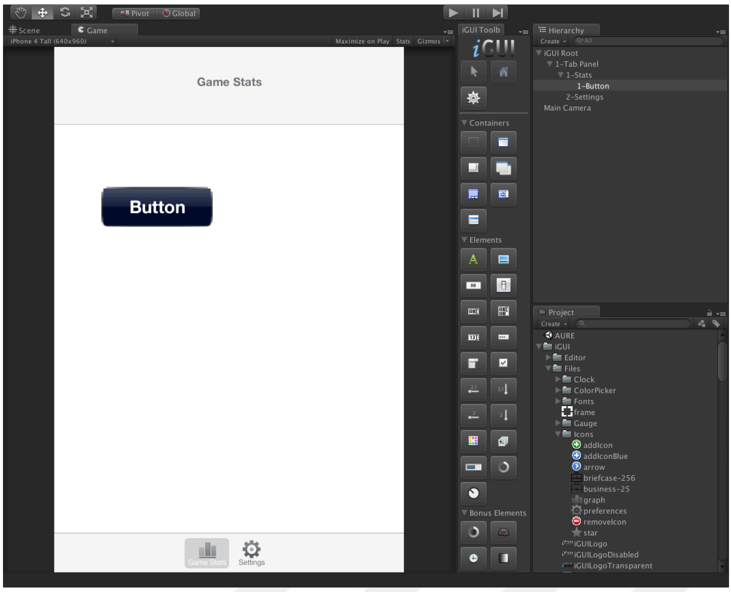

Figure 3.10 Example iGui applied Unity project

From the toolbox any element can be selected and afterwards can be drawn to the scene with desired width and height. For example, drawing a button inside of a tab panel will make that button a child to the tab panel. By that, design process becomes tidy and steady. A simple project drawn with iGUI can be seen above.

The coding of the UI elements is done by double clicking the element itself. Once after double clicking, “Mono Develop” is opened automatically. Code part of the iGUI is opened with “Mono Develop” which is an integrated development platform (IDE). Mono Develop comes within Unity 3D as an IDE. You can see a screenshot from Mono Develop with a sample code of iGUI.

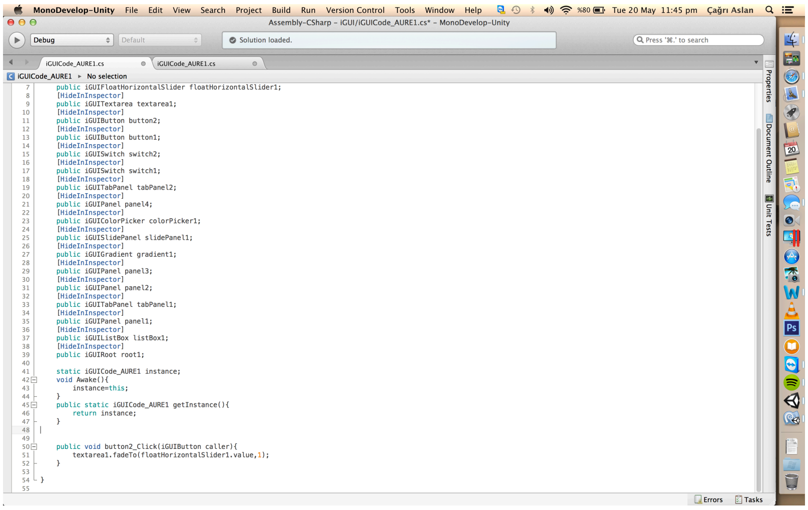

Figure 3.11 Example of iGui script

Once MonoDevelop has been opened it ask for a code to be run when event is occurred. By double clicking on the element, typically the event is considered as touch or click event. If another type of event is needed you need to right click on the element to select desired event and write code for that event. For our screenshot this code is written there:

```
textarea1.fadeTo(floatHorizontalSlider1.value,1);
```

This code is inserted by the user to invoke such code when this method is called:

```
public void button2_Click(iGUIButton caller){
  //
}
```

The code above simply changes the opacity of the text area (textarea1) to value of the horizontal slider (horizontalSlider1) when the button is clicked or touched. The other argument (1) is the speed of change. There are plenty of methods like this to be called. Coding of basic functionalities are generally easy using iGUI.

3.5 furnishAR

"furnishAR" is a mobile application which is used to visualize desired combinations of furniture and home decoration. This combination can contain actual furniture in home and the digitally created ones. It is relatively easy to visualize these combinations on a mobile device screen rather than visualizing only at mind. Here are the parts of the application. Its purpose is to create a platform where every furniture company can be a part of it. Users can find many companies and lots of furniture at one place. This allows users to compare products and select the best possible option.

3.5.1 Home Screen

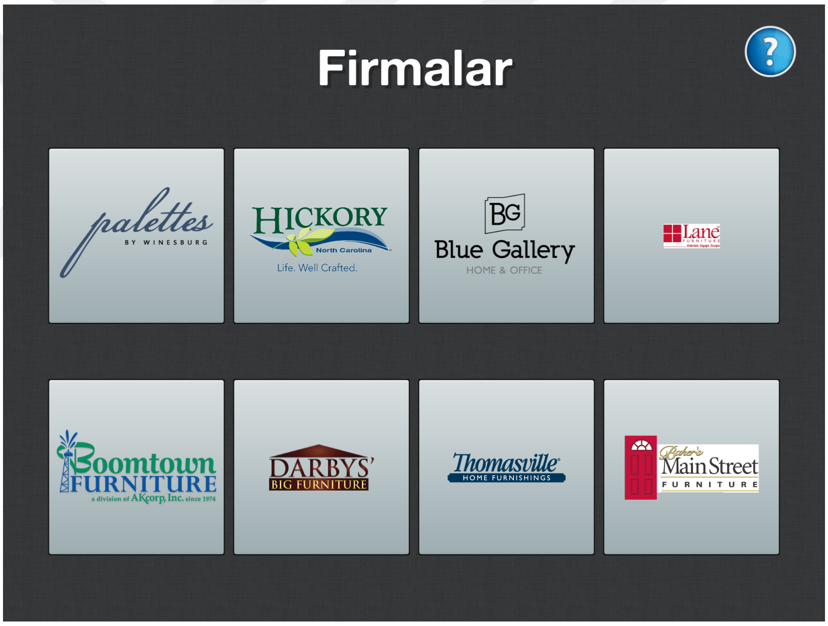

Figure 3.12 Screenshot of home screen of furnishAR

At the launch of the app, a basic screen is showed first. In this screen there are 8 furniture company logo containers. This number can be increased at will. If more than 8 companies are present, home screen of the application becomes slidable. There is a question mark on the upper left corner of the screen. It is used to help users about the usage of the application. Users can select a company here and continue to the next screen.

3.5.2 Furniture Selection

Figure 3.13 Screenshot of furniture selection screen

Furniture selection screen is where all categories, models and skins exist. There is also information about the company in the middle of the screen. This information can contain a short introduction to company, address, telephone number and e-mail. As you can see in the picture above, the menu at the upper side (blue buttons with white labels) is categories menu. Users can select desired category of furniture there. (Tables, beds etc.) After selecting the category, on the right panel, user can see all the models corresponding to the category. User can slide up and down to find a model. When furniture is selected, as you can see in the picture below, information about the furniture is brought to the container in the middle.

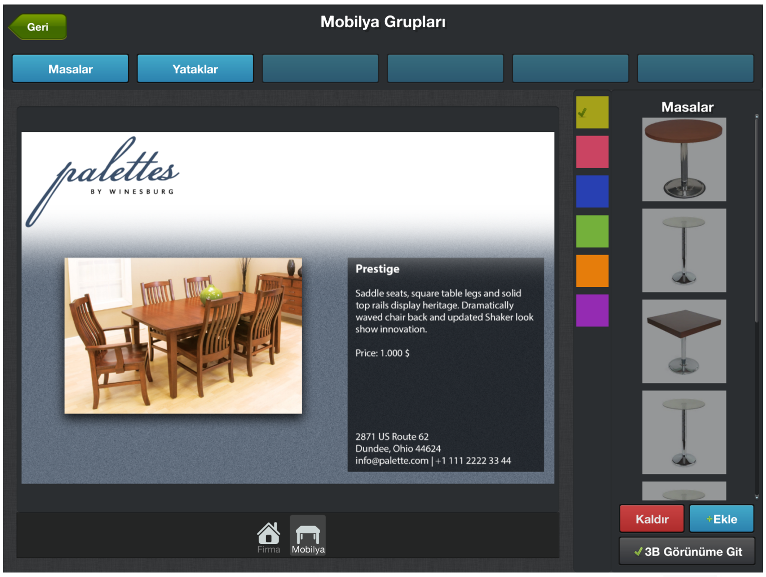

Figure 3.14 Screenshot of furniture information screen

After selecting desired furniture, users can also select the color or the fabric of the furniture on the left side of the furniture selection panel. After finishing the furniture and color selection users should click on the blue button (button with title of "+Ekle") on lower right side. This adds the currently created model to AR scene. If users want to make a combination of a bed with a table, they can repeat the process and add a new model. After finishing adding furniture, users should click the button with the title of "3B Görünüme Git" (go to 3D).

3.5.3 AR Scene

AR Scene is the part where augmented reality part of the application is active. In this scene, user is welcomed with a brief introduction of how to move and rotate the furniture. This introduction includes both text and visual materials as you can see on the upper left corner of screen. When AR scene launched, camera should see corresponding image target initially. After initial sight, users are free to move the camera away from the image target. Initial sight is important because with the help of the image target, calculating of the camera position relative to image target and 3D virtual world mapping are occurred. After initial sight, application is able to create natural features out of the environment to use as image targets but of course reference to current image target.

Figure 3.15 Screenshot of augmented sofa in AR scene

There is a button to take a screenshot on the upper right side of the screen. When this button is clicked an image is automatically save the current screen to photo folder of the device. Purpose of this is to share the image with family and friends in social media or with mail to get their opinion. Users can go back to the selection screen by clicking the button on the lower right side called "Menü".

Here is an example picture of the virtual sofa under staircase.

Figure 3.16 Another example of an augmented sofa in AR scene

CHAPTER 4

Results

furnishAR was designed and coded to satisfy customer needs while shopping furniture and home decoration. But it was also designed for the companies, which want to benefit from the commercial positive effect that augmented reality has. They can also reduce transportation cost for trial use.

The language of the application is currently Turkish. Also application hasn't published in any stores yet. This is because making a platform like this needs more than one companies otherwise it wouldn't be a platform at all.

In the application, very low polygon models (100 polygons) were used in order to maintain stability. Reality was ensured by using bumped maps instead of high poly models. Higher polygon usage was also tried by adding many furniture to the scene. Until 100k polygons, FPS was reasonable around (23 FPS) on iPad where iPhone was only reasonable until 60k. Findings are below.

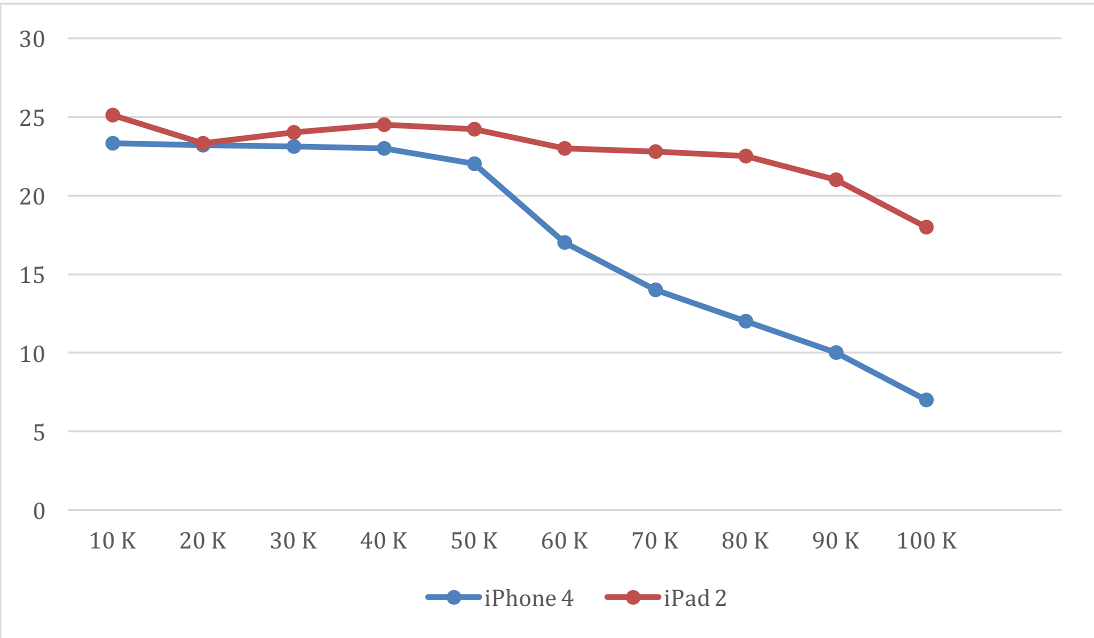

Figure 4.1 Comparison between iPhone and iPad when polygon rises

CHAPTER 5

Conclusion

There were several problems while developing this application. One of them was to use cloud based model storage. Models used in this application are built within the application. Models should be included in the application in the beginning. This has some advantages and also disadvantages. Main advantages of this are users will not need to download anything besides the application. It is good for the people who don't use 3G or EDGE. Main disadvantage of built-in models is, if the platform contains many companies and many models, application size will rise to one gigabytes. Many of the users will pass because of the size. Current version uses built-in models.

Another problem was to decide image target number. There was a possibility to use different image targets for different companies. The advantage of this is to convince companies to be a part of this platform. Because companies can improve brand awareness by making users use their logos or desired images as image targets. But disadvantage of this issue is forcing users to print different image targets to use application. According to our investigations users will not be pleased to print many image targets. Hence, one image target is used in furnishAR.

Also furniture number in the scene is important because of the stability and FPS count. Texture and polygon count effect performance. Low poly and small textured models should be used in the system.

5.1 Future Work

In previous section some problems have been discussed. One of them was to use cloud based model storage adoption. Future versions of the application should contain that feature in order to allow many numbers of models to be used in furnishAR. Otherwise it will fail to achieve what it tries to offer.

Another upgrade will be about offering furnishAR as a service to companies. Based on our contacts with companies it has been figured out that some companies may want all of the functionalities of furnishAR but they didn't want to be a part of a platform. They want to make it their own application. To satisfy the need of the companies, a white label application will be designed among furnishAR platform to be used in these situations.

Another future work will be integrating the application with social media. Currently users can manually share desired combinations in social media. With the built-in social media integration users will be able to share combinations directly from furnishAR itself.

One other major development will be company portal. Where companies can add their own models via web-based panel to the categories they want. They will also be able to get statistics about "How many times is this furniture used in an AR Scene?", "How many times is our models shared in social media?" etc. By this panel companies can manage their promotional plans according to the statistics.

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