# Evaluation of Augmented Reality in Architecture Through Sample Applications

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## ABSTRACT

Today's technologies are constantly evolving and developing and the routines of everyday life are changing and new forms of making and producing are emerging. While computer systems are involved in every aspect of life in different forms, traditional methods leave their place to more up-to-date and technological alternatives. One of the rapidly expanding technological developments of recent periods is the augmented reality. AR can be described as a technology that combines real and virtual objects, and provides simultaneous interaction between them. It creates a feeling of improved and enhanced reality that creates a bridge between the virtual and the real. Although the origins of the AR are based on the middle of the 20th century, this term was coined in the literature in 1992. It is necessary to use virtual and real objects together, to provide real-time interaction, and to align virtual and real objects in three-dimensional space in order to form an accurate AR system. AR, which is now used in many areas, is intensively used in the fields of advertising, business, entertainment, education, health and design. AR, although technically a potential technology that can address all senses, is generally used over the most intense visual content. This study examines the properties of the AR and its implications to the field of design through sample applications. It is expected that the work will draw attention to the AR and architecture and contribute to the future works.

**Keywords:** Augmented reality, architecture, architectural augmented reality applications.

## INTRODUCTION

Rapid improvements in AR technology have also led to the use of AR systems in a lot of different areas. In parallel with the developing technology, the use of AR applications in architecture is also becoming widespread. In today's digital architectural environment, the expression of designs is provided by digital technologies and computer production rather than traditional methods. Final visualizations of design products are now almost entirely realized in 3D environment with 3D models or animations. With AR technology, media contents and 3D models produced in computer environment can be displayed in real physical environments. It is possible to say that the use of computer-generated virtual models or animations within the AR applications can be considered as a unique presentation method. From this point, it can be argued that AR and other digital technologies that is associated may offer brand new possibilities for the field of architecture. Present AR applications in architecture and related disciplines are generally developed for smartphones and tablets, but there are also applications that can work on different platforms. These applications are used in a wide range from architectural education to professional practice. Building systems, architectural design, urban design, interior architecture and decoration, building materials, archeology and restoration are the areas where AR applications are generally used.

## MATERIAL AND METHODS

This work focuses on architectural uses of AR technology. It examines the AR applications currently used on different platforms and discusses the contribution of this technology to the architecture. In the scope of the study, five different AR applications that can be used in different subdisciplines of architecture are examined. The innovations that emerged in architecture and other areas related to architecture by the AR technology and the benefits that these innovations provide to the designers are discussed. To increase the use of architectural AR applications, which are still not used effectively and widely today, is the aim of the study. It's expected that this study will form a base for the future work in this field.

## AUGMENTED REALITY

AR is defined as a technology that combines real and virtual objects, and provides simultaneous interaction between them (Azuma, 1997). AR, which forms a bridge between the virtual and the real world, creates an enhanced sense of reality. In other words, it creates an enriched sense of reality by manipulating real world perception through auxiliary hardware and software (Milgram *et al*, 1995). In short, AR is defined as real-time, direct or indirect observation of computer-generated data in the real world. Recently, AR and virtual reality (VR) technologies have been confused. In VR systems, objects are displayed in virtual environment, while in AR systems objects are displayed in real space. With this fundamental difference, AR technology departs from VR. In VR, digital information is displayed entirely in a synthetic space, while in AR sytems virtual and real objects are displayed in real physical environments. The reality-virtuality continuum of Milgram is shown in Figure 1.

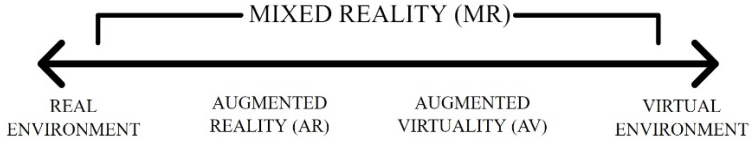



**Figure 1**. Reality-virtuality continuum (Milgram *et al*, 1995).

According to Milgram, there is a continuity between reality and virtuality. On one side of this process is the real world perceived by the naked eye while on the other side is a completely virtual world. The intermediate sections are regarded as mixed reality, in which real and virtual objects coexist.

Azuma one of the leading researchers in the field of AR, mentioned three important characteristics of AR systems. According to Azuma; AR is a combination of virtual and real objects. AR systems provide a real-time interaction and virtual and real objects are used together in 3D environment. In order to form a proper AR system these three conditions must be met. In order for AR systems to be successful, a correct geometric relationship must be established between virtual and real objects. In this way there can be an accurate combination of virtual and real objects and a realistic 3D perspective perception (Azuma, 1997). Figure 2 shows a basic AR system.

**Figure 2**. Basic AR systems (Kipper and Rampolla, 2012).

AR systems can be used in different platforms such as computers, tablets and smartphones in today's conditions. 3D models, virtual objects such as text, images, video and animation can be used separately or together in applications. AR technology is constantly evolving from its appearance to day-to-day. Along with this development, the areas of use and the software and hardware used have also changed. Considering the continuity of the development of the technology, it is likely that there will be many changes in AR technology in the future (Kipper and Rampolla, 2012).

***A Brief History of Augmented Reality***

AR technology, first emerged with the idea of Morton Heilig, a famous cinematographer in the 1950s who was also recognized as the one of the founders of VR, to build a cinematic simulator that could address all senses. Heilig's system, which he designed as a motorcycle simulator, includes senses such as touch and smell as well as visual and auditory items (Url-1) (Figure 3). The Sword of Damocles, produced in 1968 by the Ivan Sutherland, is considered to be one of the an earliest examples of AR and VR systems (Figure 3). Sutherland's system was very primitive in terms of user interface and realism, and consisted of simple wireframe graphics (Url-2).

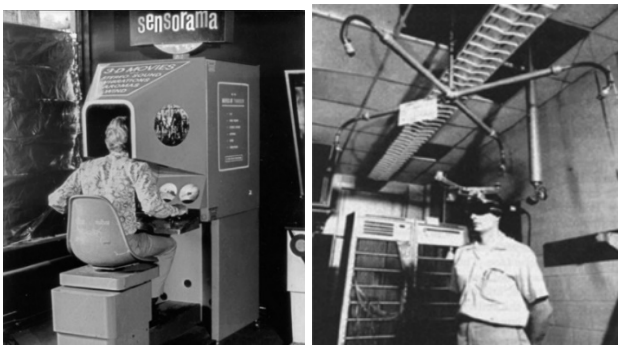



**Figure 3**. Sensorama (left) and the sword of damocles (right) (Url-1).

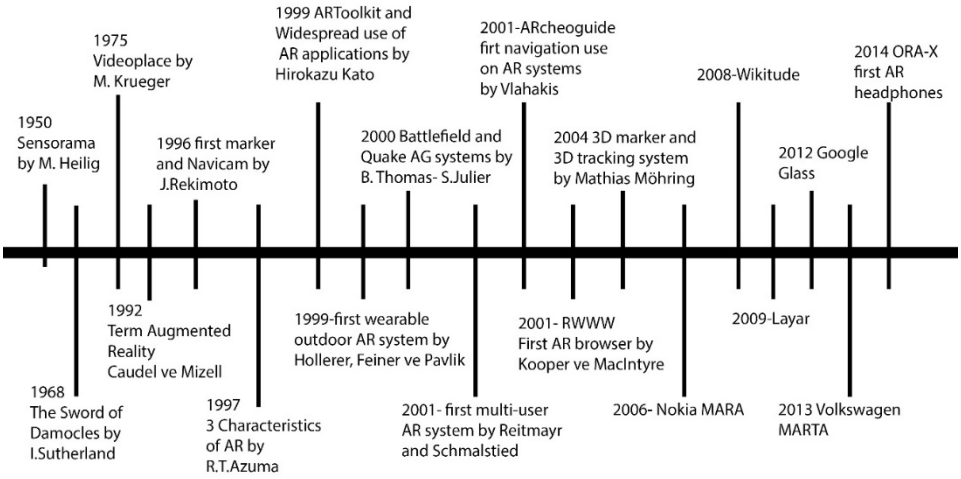
The VideoPlace system, created by Myron Krueger in 1975, is regarded as the first AR system which enables simultaneous interaction between virtual objects and users. Krueger intends to create an artificial reality that does not require external equipment such as glasses or gloves in the VideoPlace system that surrounds the user and responds to his movements (Kipper and Rampolla, 2012) (Figure 4). The term augmented reality was first used by Tom Caudell in the 1990s, although the origins of the AR was based on 1950s. Tom Caudell has developed a head-mounted display system that uses AR technology to direct engineers during

the installation of electrical cables and coined the term by naming it as augmented reality (Caudell and Mizell, 1992) (Figure 4).

**Figure 4**. Videoplace (left) (Url-3) and AR system at Boeing (right) (Url-4).

After the main developments mentioned above, some important dates related to AR technology until today, are shown in Table 1.

**Table 1**. Timeline for major devolopments about AR (Akdağ, 2017).




### *3.2. Usage fields of augmented reality*

Today, AR applications have an increasing use in many areas. AR has the potential to be practically applied to almost every aspect of daily life. In this context, unlimited combinations can be produced in the classification of AR depending on its application areas. Within the scope of the study, a classification was made based on which area of the AR system was used. For example, while some applications serve mainly entertainment, some AR applications can also be used on artistic or commercial content platforms. Sport events, games, mobile applications, education, health, advertising and trade sectors can be examples where AR applications are widely used (Craig, 2013). With the technological possibilities provided by AR, a lot of possibilities can be contributed to the users. Systems that can not be experienced under normal conditions can be observed and understood using AR. Figure 5 shows the use of AR in different areas.


**Figure 5a**. AR usages in social media, commercials and medicine fields (Kipper and Rampolla, 2012).


**Figure 5b.** AR usages in mobile games, education and commerce (Url-5-6-7).

## AUGMENTED REALITY APPLICATIONS IN ARCHITECTURE

Rapid improvements in AR technology have also led to the use of AR systems in many different areas. In parallel with the developing technology, the use of AR applications in architecture is also becoming widespread. The concepts of expression and visualization, which form the basis of architecture throughout history, gain a new dimension with AR technology. Traditional visualization methods used until recently have left their place with digital content.

Thanks to the potentials of AR systems, new alternative methods of expression and visualization in the field of architecture have emerged. AR technology has the ability to display virtual data in real environment. This kind of use has never been experienced before for visualization or presentation purposes. From this point, AR and other digital technologies that may be associated may offer brand new possibilities for the architecture field. AR applications about architecture and related disciplines are generally developed for smartphones and tablets, but there are also applications that can work on different platforms.

The use areas of AR can be evaluated in a wide range from architectural education to professional practice. It's possible to summarize AR's areas of use in architecture as; structural systems, architectural design, urban design, interior architecture and decoration, building materials, archeology and restoration and artistic uses. Examples of AR's use in different areas of architecture through sample applications are covered in the following headings.

### *Ikea AR application*

The Swedish furniture company Ikea has developed an application that can be used indoors. In the app running on Android and Ios platforms, users are able to experiment furnitures in the catalog in their home before buying. Through the application developed by Ikea in 2014, users can see the furniture in the catalog at the desired point of the roomin real time with the

marker placed on the ground (Figure 6). In this system where more than ninety Ikea models are used, Ikea's own catalog can be used as a marker. When attempting to change the orientation or location of the furniture, it is necessary to rotate or move the catalog on the floor. The furnitures in Ikea's AR application are in one-to-one exact dimensions and can not be scaled. In this way, it can be seen exactly how they will seem in the space. This new system that uses AR technology can help to the interior designers and architects to make better and more accurate decisions in interior designs. In addition to observing the furniture in the interiors, products can be viewed as 3D from the smartphone screens on the catalog, thanks to the default graphics on the catalog pages at the same time. It is stated that this new application also changed the customers' shopping behaviors and reduced the return of the products and at the same time customers changed the way of looking at the brand. With this application, it is thought that the way of communication with the brand's customers also changed. It is stated that customers generally find the application beneficial to practice (Url-8).

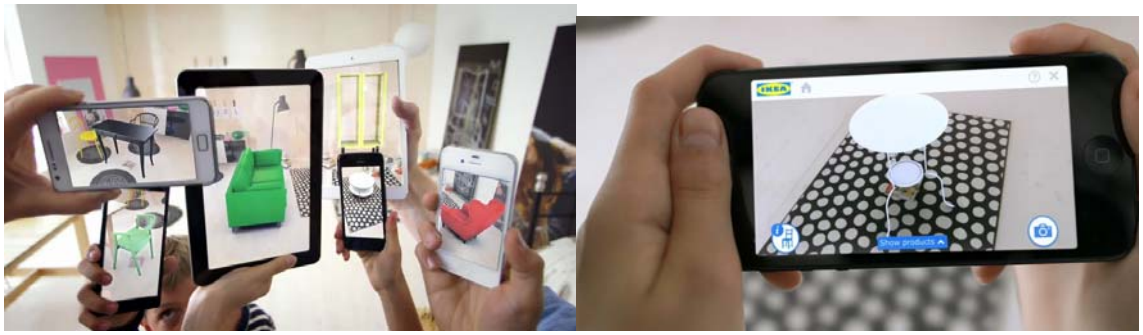


**Figure 6**. Ikea's AR application (Url-8)

***Magic Plan application***

With the Magic Plan application developed by Sensopia, plans can be produced by taking the measurements of the places. In the application using the cameras of intelligent devices, the corner points of the rooms are marked on the camera and a line is drawn to the next corner coordinate, and when all the corner points of the room are defined, the application automatically joins the points and forms the plan of the interior space (Figure 7). When the measurement and plan drawings of all the places in the building are completed, the application is managed by the user and all the spaces are connected. Through practice, drawings of spaces can be produced in a practical way and measurements can be given. The application utilizes a gridal zoning process to create these plans. Architectural elements such as doors and windows can be added to the room drawings if desired with the application (Url-9) The application draws a straight line between the two points, which is also visible from the camera of the device, while marking the points the user specifies to produce the drawings. In this way, users can check whether the drawn lines overlap with the wall lines and more accurate plans can be produced. Through the application, it is possible to take the drawings of the structures planned to be renovated in a practical way, or to document the current state of the structures to be restored. In this context, the application can be useful for architects and restorers.

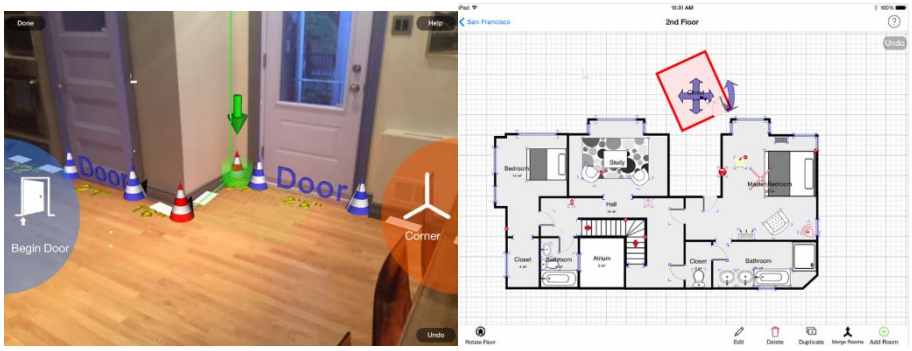



**Figure 7**. Magic plan application (Url-9)

***Bentley AR application***

In the AR application developed by Bentley Communities, users are able to make virtual construction applications with the aid of a head mounted display and input tools in real spaces (Figure 8). By means of the application, the structural elements can be transferred to the actual physical environment with desired dimensions and a structure can be constructed in the real environment with computer-generated virtual objects. Structural elements such as walls, columns, beams, doors and windows are utilized in the application. By combining the required architectural elements, virtual spaces are created that can only be experienced on the user's screen.

In app, users will be able to see the components of the structure to be built and how they will be applied and can simulate the problems that can be encountered during actual application. It is possible to experience and perceive places created by app before they are actually done. It is also possible to experience a building on the site before it is actually constructed and to prevent possible mistakes. With Bentley AR application, the manufacturing sequence to be followed in the construction process and the phases to be monitored can be visualized. In this case a more systematic field application is possible. It is also possible use of the program to give experience to the people who will be employed in the constructions of the buildings Virtual spaces produced within the program can be saved in the program memory and then used as 3D model outputs. With this feature, it can be said that the application has made the traditional 3D modeling process spatial. In its most basic form, the program can be said to be an AR platform that offers 3D modeling and virtual construction in the real physical environment (Url-10).

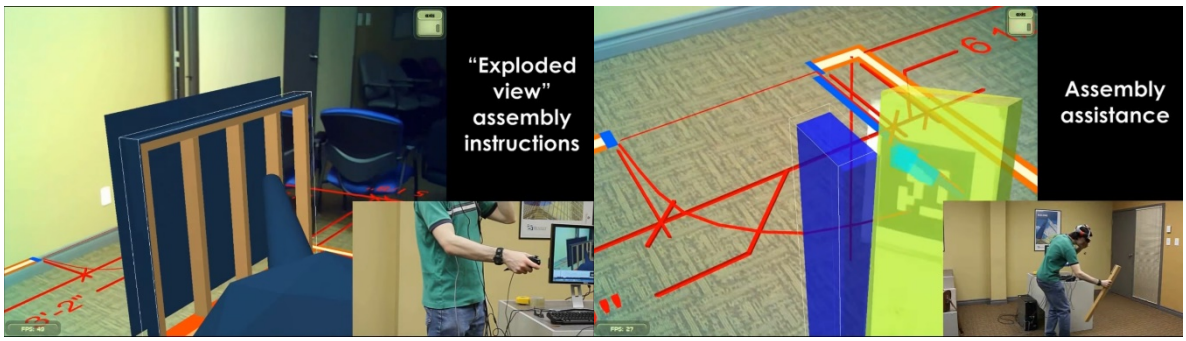



**Figure 8**. Bentley AR application (Url-10)

***Marshall see&paint application***

The see & paint application developed by Marshall, a paint brand, is a project that offers different colors to the user, indoor or outdoor, and the opportunity to experiment in the desired regions and elements of the structures. With see&paint application, users can make color experiments at the places they want to dye and can test the effects of the colors on the surface without applying them. Another implication of the practice is that it can display color shades suitable for the character or design of the space without actual painting application (Url-11). In this way, designers or users can pre-experiment the effects of the paint over the space without actual painting which will provide a more accurate decision. Especially in interiors, color harmony with the furniture and stuff is an important consideration by the designers. In this context, it can be said that this app contributes designers for making accurate decisions. The features of the application can direct arhitects and interior designers to color preferences. It can be argued that the app is functional in terms of being able to test conformity with the urban periphery and urban texture also at the urban scale. The current app allows to apply company's own products in the color scheme to the facades and walls (Figure 9). With the development of the application and availability of different materials and textures, not just color, can lead to a more comprehensive material experience.

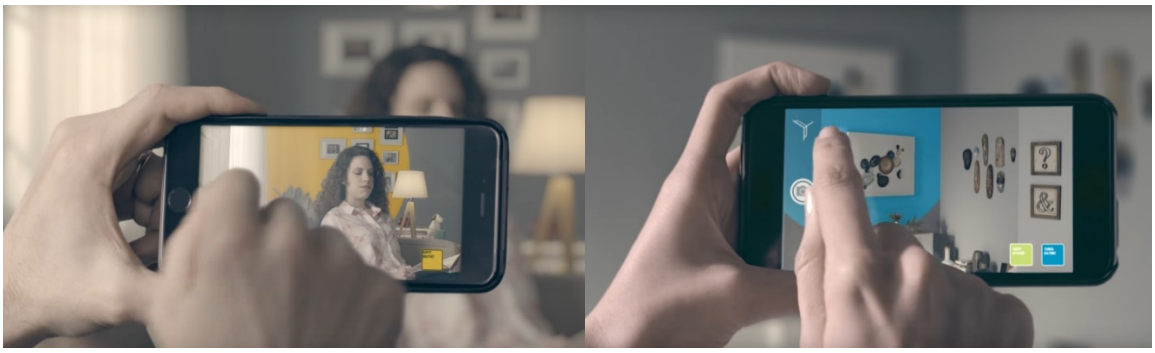


**Figure 9**. Marshall see & paint application (Url-11)

***ARki Application***

ARki is an AR platform that can offer real-time visualization for architectural models developed by Darfdesing. The AR application can be used both in the visualization of 3D models and as a tool feeding the design process. Through multi-interacting layers, it can be said that real-time observation of 3D models can provide a more interesting and impressive experience than traditional visualization and presentation techniques. The application can be used on smart devices that use iOS and android operating systems. Users can transform the 3D models they create in real-time and real environment, and can observe them from different angles (Figure 10). To do this, default logo of the company has to be printed and used as a marker. In Arki, 3D models can be superimposed on existing 2D floor plans, enabling real-time visualizations that designers can use in their projects. In app, besides real-time visualization, there are many features that can enhance reality such as real-time shadow analysis and material selection. Users can record animations and visuals of models during 3D real-time visualization in ARki application. This feature also allows users to share images and animations they have recorded directly from the application, e-mail and social media (Url-12).

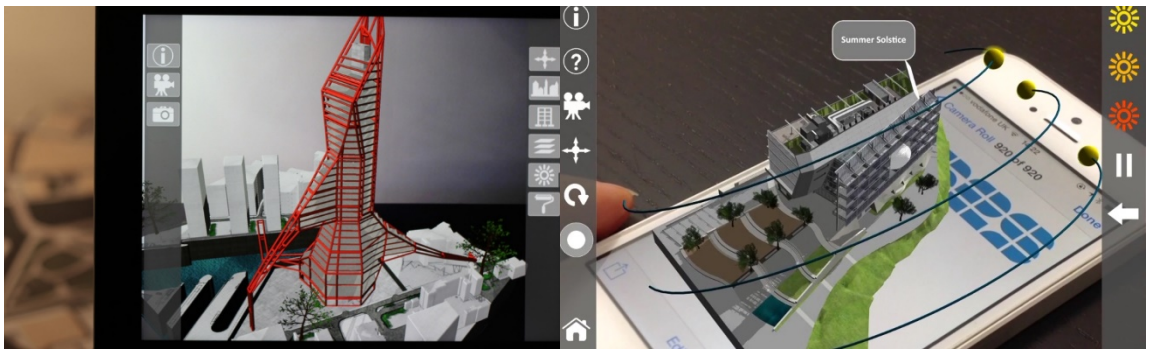



**Figure 10**. ARki AR application (Url-12)

The method used in ARki is the most basic use of AR technology. In this context, it can be said that AR technology is a very suitable platform for architectural representation and visualization. The technique used in app is very close to traditional (physical) model use. The only difference is that the displayed data is computer-generated and experienced through a display hardware. In the application which is fed with digital contents, it is possible to interact with the virtual models, to examine the structures from different angles and scales and to obtain photorealistic images.

## CONCLUSIONS

Today, technological developments are very fast. In parallel with the evolving technology, traditional techniques of making and producing are quickly leaving their place to alternatives where digital technologies are used. One of the rapidly changing fields with technological improvements is architecture. Especially after the second half of the 20th century, the computer-aided design applications started to become widespread, and the architectural profession, which has been practiced with traditional techniques for many years, is made almost entirely with the help of computer software. In recent times, even 3D models and animations have become traditional uses. AR, which has become increasingly popular lately, is a technology that has been intensively studied for alternative uses in architecture in recent periods. The AR is a technology based on the 1950s, but it is still not very common and effective in architecture.

In this context, it is important that the alternative uses of this technology in architecture are known and actively used. In the scope of the study, five different AR apps which serve different points of architecture have been examined and evaluated. It has been seen that, through the applications examined, AR technology can provide significant contributions to many different areas of architecture and provide a lot of facilities for designers. It is also the result of the study that new presentation techniques which can not be produced by the methods used up to AR technology can be developed. In addition, it's stated that there are many different AR apps that serve to the design field which have contents and spesific features for sub-disciplines like interior design, urban design, archeology, restoration and so on. Although AR applications currently used can not produce effective and successful results yet, it is likely that AR will be transformed into a technology that designers can use more effectively with new software and hardware which will develop with technology. It's expected that this study draws attention to the relationship between the AR and the architecture for future developments.

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