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Augmented reality applications in product design process

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Abstract

Computer aided design (CAD) systems as visualization tools play a vital role for designers in product design process. However, these systems itself become insufficient to achieve 3D interaction with virtual models. Virtual Reality provides alternative solutions to this problem, hence its maximum requirements and high cost makes the use of it in design process unpopular. Hence, Augmented Reality, defined as mixture of reality and virtuality and combining 3D virtual object with real environment, presents many advantages for product design process as a new technology. It allows the designers to display and modify modify the virtual model in real-time and have a 3D interactive experience with the virtual model in a real environment. This study aims to analyze in which stages, in what way and for which product groups AR would be used in product design process, and to understand the role of these applications on the perception of actual dimension and product-space relationship, the quality of evaluation and the amount of evaluation time. For this purpose, an interview study was conducted with nine designers from three different sectors that are design, interior design and furniture. The results have shown that if the AR applications are developed in parallel with firms' requirements, they could integrate and use them in design process more efficiently.

Keywords: Augmented reality, visualization tool, product design process, 3D interaction, product-space relationship

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1. Introduction

With the rapid development of technology, the designer's visualization tools using during product design process have been changed within the years. Computer-aided design systems (CAD) especially since 1990s have been inevitable tools frequently used in all stages from concept development to presentation and marketing by majority of designers. With 3D virtual models created with these systems, design process in terms of both time and quality have been progressed. However, these systems lock the designers to a computer-centered desk working and the because of viewing 3D model from 2D screen, relationships between model and space become vague. In addition, the designer's interaction with 3D model generally is restricted to 2D interfaces like mouse and monitor. This situation constrains the designer to carry out 3D design process with 2D activities. Virtual Reality and Augmented Reality technologies present alternative solutions to this problem. By means of Virtual Reality systems integrated with CAD programs, designers could interact with 3D virtual model in a virtual environment. However, because of both maximum equipment requirements and high costs, the use of Virtual Reality technology in design process could not become widespread.

On the other hand, despite the initial studies in 1960's, a new technology for many people compared with Virtual Reality, Augmented Reality technology emerged. Although it is not known with its name, "Augmented Reality" started to be used into daily lives through mobile applications and to be used in many areas effectively. With the help of these applications, the user can display and modify the virtual model in real-time and have a 3D interactive experience with the virtual model in a real environment. The technology is also started to use in design and manufacturing processes despite limited number of examples. One of these examples, DART (The Designer's Augmented Reality Toolkit), an open- source software, is developed for designers to use from concept development to final product testing (Macintyre, Gandy, Dow and Bolter, 2004). ARToolkit originally developed by Dr. Hirokazu Kato is presented as open-source software and this enables developing many applications (ARToolKit, n.d). By means of these developments, Augmented Reality becomes reachable technology for designers also. It is thought that this technology defined as mixture of reality and virtuality and combining 3D virtual object with real environment presents advantageous solutions to the problems faced in design and manufacturing process than Virtual Reality. However, as the use of this technology in design process is newly emerging, fieldworks in this area are limited. It is observed that some of these fieldworks about the use of AR in design process focus one specific process like sketching and 3D modelling (Santos, Graf, Fleisch and Stork, 2003; Nam and Lee, 2003), mock-up (Park, 2008; Jin, Kim and Park, 2007), prototyping (Balcisoy, Kallmann, Fua and Thalmann, 2000; Lee and Park, 2005; Sidharta, Oliver and Sannier, 2006; Verlinden and Horváth, 2006; Park, Moon and Lee, 2009; Porter et al., 2010), manufacture (Ong, Yuan and Nee, 2008; Doil, Schreiber, Alt and Patron, 2003; Nee, Ong, Chryssolouris and Mourtzis, 2012), and some of them are about usability studies on researcher's own AR applications (Gjosaeter, 2009; Carvalho et al., 2011; Bonardi et al., 2012; Moeslund et al., 2003).

As well as these researches present valuable outputs, it is observed that there is a need for a research investigating the use of AR technology in all design processes including both designers and firms from different sectors. In this context, the aim of this study is to analyze the role of AR applications on product design process through designers and to build empirical construct for the next research. In addition, the research questions feeding this aim are as follows.

- What is Augmented Reality? What are the technologies used? What are the application areas?
- What degree is the awareness level of firms and designers about Augmented Reality?
- How do Augmented Reality applications affect product design process?
- In which product design process would these applications be used more efficiently?
- For which product groups would these applications be used more efficiently?

- How do these applications affect product-space relationship and the perception of actual dimension?
- How do these applications affect the quality of evaluation and the amount of evaluation time?

2. Augmented Reality

Different definitions exist about AR, some researchers define it as the reverse of Virtual Reality, and some claim that it is a variation of VR. However, Azuma define AR with three specifications, which are widely accepted in literature (1997):

1. Combination with real and virtual
2. Interaction in real time
3. Including three dimensional objects

In terms of Azuma's definition, although in science fiction movies, there is a combination of virtual objects and real environment, due to the lack of interaction, it could not be called as AR. Milgram's reality-virtuality continuum is also important about positioning AR in reality and virtuality, as seen in Figure 1 (Milgram and Kishino, 1994).

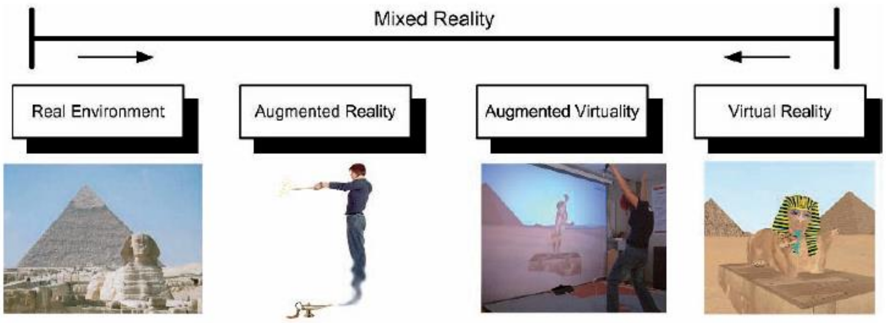

Figure 1. Milgram's reality-virtuality continuum
http://wibirama.com/dip/wp-content/uploads/2010/10/mixed-reality.png

The development of ARToolkit that is presented as open-source software in 1999 is a turning point of technology becoming widespread in this area. These open-source software products enable developing AR applications also (Carmigniani et al., 2011). From 2010, by means of mobile applications the technology starts to be used by more people (Van Krevelen & Poelman, 2010). Depending on the developments in the technology, it is predicted that the number of people using AR technology will increase dramatically (Chi, Kang & Wang, 2013).

The basic components of AR systems are hardware including displays, tracking systems and CPUs and software. Kipper ve Rampolla (2012) divide generally displays into three categories as wearable displays, hand-held displays and projection-based displays. Wearable ones are especially head-mounted displays and glasses. Due to their being aesthetics, lightweight and social-acceptability, AR glasses have been using more than others. Especially after Google Glass project, some firms like Vuzix, Meta, and Epson have been producing their AR glasses (Figure 2). These glasses integrated with AR applications have ability to reflecting high-resolution images without missing physical environment image.

Figure 2. An example of AR glasses: Meta 1 Developer Kit
http://i.ytimg.com/vi/b7I7JuQXttw/maxresdefault.jpg

Hand-held displays have more advantages than wearable ones as they are minimal and mobile (Figure 3). For mobile AR applications, tablet computers and smart phones have been commonly using. Smart phones are portable and widely used and having high- quality cameras and GPS, which makes them suitable for AR platforms. However, they have small screens that make them disadvantageous in terms of user interfaces. Thus, due to their wide screens and powerful CPUs, tablet computers are expected to be used more widely than smart phones (Carmigniani et al., 2011).

Figure 3. Tablet computers and Smart phones used in AR
http://static.businessinsider.com/image/5200e8edeab8eaff2e000029/image.jpg

Projection-based display systems (Figure 4) enable viewing digital images directly on a physical object by using a projector without the need for carrying an extra display (Furht, 2011: 11). These systems are also named as Spatial Augmented Reality. They provide more than one user viewing high-resolution images at the same time. Thus, designs could be evaluated by a design team without an extra device for each designer in the team. The most disadvantageous feature of these systems is their immobility (generally fixed) and unsuitability for mobile AR applications (Zhou, Duh and Billinghurst, 2008).

Figure 4. An example of Projection-based AR Display Systems

Tracking systems are one of the most important components of AR technology. These systems enable tracking user's position according to his environment correctly. Tracking systems used in AR applications must provide high accuracy and low waiting-period and be resistant against environmental changes (Ong et al., 2008). The most preferred tracking systems are software-based systems as there is no need for carrying hardware. Thus, image-based and hybrid systems have been used generally (Nee et al., 2012). Especially image-based tracking is the most used systems in AR applications. In this system, by using 2D image called marker the coordinates of 3D virtual object identified to this marker is found (Zhou et al., 2008). The general operation structure of marker-based systems is explained in Figure 5.

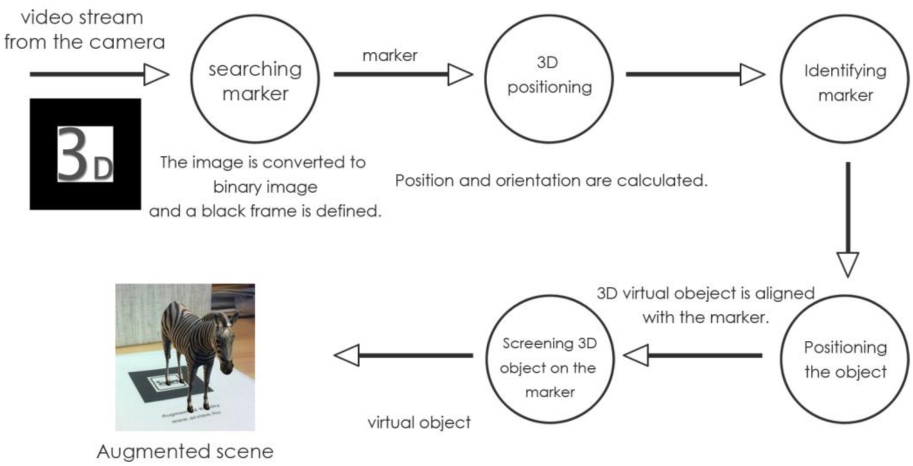

Figure 5. The general Operation Structure of Marker-based Tracking Systems

The design of marker is important for accurate tracking (Ercan, 2010). ARToolKit in marker-based systems has one of the most popular libraries. Hybrid systems are generally used for outdoor which combine GPS, accelerometer, gyroscope and electronic compass (Zhou et al., 2008). These systems are used generally for navigation purposes that smart phone users can easily reach.

One of the most important parts of AR systems is to register real-time interaction of virtual object with real environment. For this purpose, in recent years a good deal of algorithms and systems are developed and based on these algorithms, many AR platforms are set up enabling different AR applications (Ong et al., 2008). Some of these platforms are commercial while others present open-source software like ARToolkit and DART. As a commercial example, ARmedia which includes 3ds Max, SketchUp and Maya plugins provide especially CAD users with an AR experience.

3. Fieldwork

This section presents the methodology of the fieldwork, which aims to investigate the use of AR applications in product design process. It comprises the aim of the fieldwork, the data collection methods of the fieldwork, implementation of the fieldwork and the analysis of the findings.

3.1. The aim of the fieldwork

There are two main reasons for conducting this fieldwork. First reason is to evaluate the existing situation and finding out whether the study is meaningful or not due the lack of research about this area in Turkey. It is impossible to understand how important AR applications would be in product design process for designers and firms so this study is so crucial to resolve this uncertainty. Second reason is to analyze whether it is possible or not to reach the firms and designers, and when reached what level of information could be gained. Thus, it is important to test applicability of this study. The fieldwork aims to understand the role of AR applications on product design process through the firms and designers. The supportive questions feeding this aim are as follows.

- What is the firms and designers' level of awareness about AR applications?
- Which firms are prone to use AR applications in their design process?
- In which stages of design process could these applications be used?
- How do these applications affect the quality of evaluation and the amount of evaluation time, the perception of actual dimension and product-space relationship?
- What are firms and designers' possible expectations about these applications and their suggestions if exists?
- In which firms among furniture, interior design and design and for which product groups could AR applications be used more effectively?

3.2. Methodology selected for fieldwork

As data collection methods, interviews and observations are selected for the fieldwork. As three from each of furniture, interior design and design firms, in total nine designers who have been working or had worked in the field of product design were interviewed within this study. It is aimed to conduct a balanced study by interviewing with three designers from each sector. This semi-structured interview includes 13 open-ended and 1 close-ended questions. In order to understand the designers' opinions deeper, it is structured as flexible conversation based on interview questions. Thus, in terms of the flow of interview by putting different questions it is provided to access deeper information.

3.3. Implementation of the fieldwork

After explaining the purpose and approximate duration of the interview to the designers, interview consisting of three main headings, namely Questions related to Firm, Questions related to CAD and Questions related to AR were carried out.

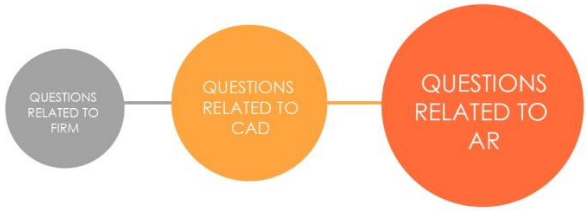

Figure 3.1. The Structure of Interview

3.3.1. Questions related to Firm and Their Motivations

In this section, three questions were asked which are the areas the firm works, disciplines of employees working in design activity and stages of design and/or manufacture process. These questions when combined with questions in AR section give some tips about in which firms AR applications would be used more effectively. Firms providing only design services or providing both design and manufacture services would be separated from each other considering design and manufacture processes.

3.3.2. Questions related to CAD and Their Motivations

In the second part of the interview questions, in the first two questions, whether the designers use CAD programs or not in design process and if they use which programs and in which stages of design process they use were asked. These stages are identified as concept development, idea generation, prototyping, presentation and marketing due to facilitating the analysis of the responses. These questions are addressed in order to be able to make inferences that which firms comply with AR applications. Third question is that whether they use models of space while using CAD or not and if they use in which stages of design process they use. The firms that need space models are assumed to use AR applications more likely, so it gives clues about which firms are more appropriate for these applications. In forth question, how the designers evaluate CAD programs in terms of the perception of actual size and product-space relationship. This question aims to obtain data about whether CAD programs are enough in terms of the perception of actual size and product-space relationship or these firms need to be supported with AR applications. The fifth and final question of this part is that whether the firms develop CAD-supported physical prototype or test product before manufacturing or not. The aim of this question is to deduce about AR applications would be replaced with CAD-supported prototype or test product.

3.3.3. Questions related to AR and Their Motivations

In the final part of interview as a first question, it is asked what the designers know about AR applications. This question is intended to measure the designers' level of awareness about the AR applications. Second question is whether they use these applications in their design process and if they use in which stages of design process they use, which also aims to learn the designers and firms' level of awareness about AR applications. After this question, examples of AR applications were presented to the designers who do not know anything about AR, and thus obtaining general information about AR was provided. Hence, the next questions are based on the designers' possible assumptions associated with these applications. On the other hand, it was thought that these presentations would be useful for the designers who have seen or used but not known its name as AR.

In the third question, designers' predictions about in which phases of the design process AR applications could be used were asked. The aim of this question is to deduce for further research that in which phases of design process AR applications should be included. Based on these data, it is thought that the sample of the further research could be decided. For example, for a marketing oriented conclusion, participants from marketing department would be included in the further research. In forth question and in fifth question, how these applications would affect the quality of evaluation and the amount of evaluation time, the perception of actual dimension and product-space relationship were asked. Although the applications have been introduced to those who have never used these applications before, a more comprehensive study is required to get definite answers. The purpose of this question is to obtain data for further empirical research by analyzing the assumptions of the designers. In the last question in this section, as firms whether they intend to use these applications or not and in which stages of design process they intend to use them, were asked. With this question, it is aimed to obtain data about in which firms and in which stages the use of these applications would be significant.

4. Findings

The findings obtained in the research were analyzed and recorded. Results within this period were evaluated and common findings were titled.

4.1. The Awareness Level of the Firms about AR

It is observed that interior design firms' awareness level about AR is too low. It is understood that the design and furniture firms' awareness levels are relatively higher than those of interior design firms. None of the firms interviewed have been used these applications in design process before is determined.

4.2. The Tendency of Firms to AR Based on CAD

It is appeared that interior design firms have mainly used AutoCAD in 2D instead of 3ds Max, thus the tendency of these firms to AR requiring 3D model is at a minimum level is analyzed. On the other hand, furniture and design firms since they use 3D modelling programs like Rhinoceros and 3dsMAX are more prone to AR applications in terms of model infrastructure is concluded.

4.3. The Use of AR Applications in Product Design Process

According to data obtained from the three firms, it is determined that AR applications would be mainly used in presentation and marketing stages in product design process and these are especially the end-user-oriented applications.

4.4. The Effects of AR on the Quality of Evaluation and the Amount of Evaluation Time

It is determined that these applications would affect the quality of evaluation positively especially when they are used for presentation to end-users or customers (firms getting design support) whose ability of three-dimensional thinking are low. Since more arguments are added to the evaluation process, which makes difficult to choose, the amount of evaluation time might both extend and shorten. It must be supported with an experimental study to achieve accurate results.

4.5. The Effects of AR on the Perception of Actual Dimension and Product-Space Relationship

AR applications might affect the perception of actual dimension and product-space relationship both positively and negatively is occurred. It is determined that when they are used properly and scale and perspective are maintained accurately, they could affect the perception of actual dimension and product-space relationship positively even develop the ability of three-dimensional thinking. Otherwise, the improper usage might cause false perception, which could mislead the users and affect the process negatively. It is also analyzed that there might be differences between the use of these applications by the end-users and the designers and result in different conclusions.

4.6. The Use of AR Applications Based on Firms

Although the results indicate that AR applications could be used in all three firms at different scales, uploading 3D virtual model to the application, adjusting the actual size according to specified marker size, making coating, light and shade adjustments as a result creating a product library require both time and cost. When taking into account these factors and presentation, and marketing oriented usage scenarios, it is understood that these applications would be used more effectively in terms of both time and quality in firms, which have certain product line and mass production bringing creating product library more easily.

4.7. The Use of AR Applications Based on Product Groups

When assuming that these applications are end-user-oriented, it is concluded that the use of these applications for the products, which have strong relationship with the space and the other products in the space is feasible. In addition, the products, which are difficult to estimate its actual size and volume like furniture and more of the same, rather than handheld products will provide further contribution to the product design process.

5. Conclusion and Future Work

This research examined the use of AR applications in product design process by conducting a fieldwork with the designers from three different sectors. All of the firms would integrate AR applications to their design process in different stages of process in different rates. Since, when the AR applications are developed according to firms' needs, they could be better integrated with design process and used efficiently. The most essential expectations of firms are the ease and simplicity, saving of time, accuracy and realism of the system.

Generally, these applications would have a positive impact on design process, however it is vital that they must be used properly, in other words, scale and perspective must be maintained accurately. Still, it is needed to conduct an empirical research to base on practical data.

On the other hand, it is concluded that as a visualization tool, these applications could be used in presentation and marketing stages more efficiently and they are mainly end-user-oriented applications. In addition, it is effective to use AR applications for the product relatively larger in volume and having strong relationship with the space.

Future work should include the implementation of an empirical study with the potential end-users based on AR application with a product library created according to criteria mentioned above.

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