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AN EVALUATION OF AUGMENTED REALITY-BASED USER INTERFACES IN THE DESIGN PROCESS

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Abstract

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Human-computer interaction, Augmented reality, User interfaces, User experience, Design process.

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ABSTRACT

The aim of this study is to evaluate the user interfaces that reflect different interaction layers in the context of Augmented Reality technology. Depending on the physical characteristics of human interaction with the computer, these layers were examined under four sections: Graphical User Interface (GUI), Tangible User Interface (TUI), Natural User Interface (NUI) and Spatial User Interface (SUI). In this context, a proposed Augmented Reality application interface has been developed to bridge the physical and digital environment. The use of AR-based applications in the design process provided a basis for evaluating the user interface in these interaction layers. In future studies, the interface and experience offered by this application have the potential to be supported by more comprehensive functions and a collaborative working environment.

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ملخص

الهدف من هذه الدراسة هو تقييم واجهات المستخدم التي تعكس طبقات التفاعل المختلفة في سياق تقنية الواقع المعزز. تم فحص هذه الطبقات اعتمادًا على الخصائص الفيزيائية للتفاعل البشري مع الكمبيوتر، ضمن أربعة أقسام: واجهة المستخدم الرسومية (GUI) وواجهة المستخدم الملموسة (TUI) وواجهة المستخدم الطبيعية (NUI) وواجهة المستخدم المكانية (SUI) . وفي هذا السياق، تم تطوير واجهة تطبيق مقترحة للواقع المعزز لربط البيئة المادية والرقمية. وقد قدم استخدام التطبيقات القائمة على AR في عملية التصميم أساسًا لتقييم واجهة المستخدم في طبقات التفاعل تلك. وفي الدراسات المستقبلية، يمكن للواجهة والخبرة التي يقدمها هذا التطبيق أن تدعمها وظائف أكثر شمولاً وبيئة عمل تعاونية.

الكلمات المفتاحية: تفاعل الإنسان والحاسوب، الواقع المعزز، واجهات المستخدم، تجربة المستخدم، عملية التصميم.

1. INTRODUCTION

In the design process, images and abstract ideas in the designer's mind, formal and environmental consciousness, spatial qualities, functional and aesthetic priorities are collected and represented by relevant media and tools. The reconsideration of the relationships between analog, digital, real and virtual allows the creation of new design environments to create a more integrated process (Asanowicz, 2002). The gap between the architectural data prepared in the physical environment and the digital environment (Koleva et al, 2003; Chen and Schnabel, 2011) can create a dilemma in the design process and it may be possible to bridge them with the technologies developed for human-computer interaction (Hsiao and Johnson, 2011).

The transfer of architectural knowledge in terms of the designer's intention and the design can gain a new perspective with not only the cycle of sketch, 2D CAD drawing and 3D models but also human-computer interaction in the direction of new technological innovations. Interfaces developed to examine the interrelation between designer and design, idea and representation, physical and digital media in the frame of physical representation and digital information (Ullmer and Ishii, 2001), provide a reinterpretation of the interaction through concepts such as immersion, interactivity, haptics, augmentation and simulation. In the design process, the perception and interaction between the designer and the digital model can vary according to the characteristics of the user interface developed (Kim and Maher, 2006). The interfaces used in the design process can support designers in creativity and communication and can be an assistant to work with maximum efficiency. Multi-layered information and representation forms such as Virtual Reality, Augmented Reality and Mixed Reality is being developed as a part of Graphical User Interface, Concrete User Interface, Natural User Interface and Spatial User Interface studies.

One of the methods that can be developed with the awareness of the potential and limits of the digital media and physical environment is Augmented Reality technology (Belcher and Johnson, 2008). Although it is used as a visualization tool for most studies, the areas where Augmented Reality (AR) can be used in the design process have much more potential (Seichter, 2007). AR can be classified into two main functions increasing the perception of reality and creating an artificial environment. These functions make a positive contribution to the decision-making process by increasing the understanding and perception of environmental and spatial information (Kipper and Rampolla, 2012). This method provides a successful framework for evaluating alternative ideas during the design process.

This study aims to evaluate GUI, TUI, NUI and SUI environments reflecting different interaction layers in the context of Augmented Reality technology. In this context, a proposed AR application interface has been developed to bridge the physical and digital environment. The use of AR-based applications in the design process has provided a basis for evaluating the user interface in these interaction layers. The creation, modification, animation and information functions in the content of the developed application, together with the connection with the physical environment, allow the designer to experience the interface. In addition to its GUI and TUI features, the system allows the user to interact physically with design thinking and offers an area where natural gestures and the real environment support the design in the digital environment.

2. AUGMENTED REALITY AS A DESIGN MEDIUM BRİDGİNG BETWEEN PHYSİCAL MODEL AND DİGİTAL DESİGN TOOLS

AR, where designers can use a real and virtual environment to create solutions to a common problem, creates an environment suitable for creative thinking and collaborative working activity for designers. Multilateral transferring of design alternatives between designers and making the designs that sometimes can have complicated connections more comprehensible can be possible by using AR technology (Chen and Schnabel, 2011).

Sketchand+ is one of the first applications to use AR in the field of architecture (Seichter, 2003). It has set out from a very basic need and aimed to be able to collaborate in the design of individual sketches and diagrams in the early design phase. The application was developed as a research study to keep the creative design process in the virtual environment at the beginning of the 2000s by using the technological equipment of the period. As another application, ARTHUR has been developed nearly the same period as Sketchand+. The study aims to create a program in urban planning to expand the areas of use in the architectural design process and added the existing CAD system to the AR environment (Broll et al, 2004). MultiTouch (Chen and Schnabel, 2011) and Arch4models (Costa et al, 2017), have more advanced features in terms of interface and technical content. Both applications have developed AR functions by placing the interaction with the physical model based on the study. The MultiTouch application uses predefined hand gestures for recognition and aims to enable users to communicate more naturally. On the other hand, the most recently developed Arch4models application uses a tablet interface.

3. USER INTERFACES İN THE CONTEXT OF AUGMENTED REALİTY

The term interface provides reciprocal communication as a feature of the assets. Interfaces facilitate human-computer interaction (HCI) by enabling computers to communicate with the physical environment through controllers and displays. In the process of communication established with the environment, commands of input through the controllers and output through the displays are processed in the interface. (Bongers, 2004).

Fig.1: Two-way interaction in the interface as input and output (modified from Bongers, 2004).

3.1. Graphical User Interface (GUI)

Graphical user interfaces are widely used form the 1980s to nowadays. Although there has been considerable progress in the development of computer devices and technological innovations, after GUI there has not been an accelerated change in the interface context used in the devices (Salih, 2015). GUI directs the user to enter a command using visual elements and generates information by answering this command. Icons, buttons, menu items, panels, or tabs organize the layout of the interface content and create an order that the user will follow and provide visual output such as labels, images, or text boxes (Lafkas, 2013). In the process of interacting with the user, GUI has a sharp separation between the input and output tools as control and display (Ghalwash and Nabil, 2013). The language developed to provide the interaction between the user and the computer involves moving and clicking the mouse in the horizontal plane. Terms such as one-click, double-click, drag-and-drop, scrolling and right-click are often applied to communicate computer via mouse (Lafkas, 2013). The most commonly used elements of a graphical interface are the icons of functions and applications, the windows where the icons are displayed, the menus and a marking tool used for selection.

Fig.2: Two-way interaction of GUI as input and output.

Although significant advances have been made in terms of program functions and ease of use of the graphical interface, the design options for design programs are limited to tools such as screens, keyboards, and mouse. In an AR environment, the GUI may be on the screen of the tool used, or it can be seen from the position determined as a virtual button in the physical space (Ortman and Swedlund, 2012).

3.2. Tangible User Interface (TUI)

Tangible user interfaces (TUI) provide digital information to a physical object used for control and display and establish a computable relationship between digital representations and physical objects (Ullmer and Ishii, 2001). TUI takes advantage of the available usability experience and tactile interaction skills that users can have with objects in the physical environment (Ghalwash and Nabil, 2013). Tangible interfaces develop as a conceptual search at the point of removing the sharp distinction between input and output in graphical interfaces. They base on the complementarity of physical and digital representations. (Ullmer and Ishii, 2001). As the process between the controller and the display in the current GUI system can be interrupted and can have a complex appearance (Hsiao and Johnson, 2011), TUI also includes physical objects to improve the process.

The AR environment has advanced viewing possibilities and it is a convenient interface for viewing virtual objects while TUI can perform intuitive manipulation of virtual data very well, but it is insufficient for imaging (Billinghurst et al, 2002; Billinghurst et al, 2008). In this sense, AR and TUI interfaces can be used together, as a new method to eliminate the distinction between real and virtual worlds (Billinghurst et al, 2002), that can be named Tangible Augmented Reality (TAR). In the AR environment, the physical environment is superimposed with information in a virtual environment, but in TAR, digital data corresponds to a physical object. One of the studies using the TAR environment is MagicPaddle (Kawashima et al, 2001) a physical object is defined as a marker for AR. Virtual objects can be added, removed, or moved to the virtual scene and displayed by HMD, using the physical paddle. The interaction between the user and the object is provided with the keyboard and mouse in a CAD program, but in the TAR environment, it is established in the physical environment with the help of a touchable object and supported by virtual images (Koleva et al, 2003).

3.3. Natural User Interface (NUI)

In the NUI concept of interacting naturally with technology, interaction forms, such as speech and view, comes to the forefront instead of mouse and keyboard (Ballmer, 2010). While with the GUI, a command that is received entirely through a device is processed into the digital environment, physical objects were also included partially in the process with TUI. However, the Natural User Interface (NUI) sets out to interact directly with physical and digital objects. This interface system combines the detection area and the field of action by recognizing the movement of people or the condition of a physical object in a horizontal working area with visual, auditory, or other sensors (Rauterber et al, 1997). Based on the natural communication between people, the natural interaction between the user and the application is examined under this type of interface.

NUI represents a more comprehensive interface concept and TUI can be considered a subset of NUI (Ghalwash and Nabil, 2013; Lafkas, 2013). NUI, as one of the new generation UI, aims to improve the user experience by using the attributes such as speech, touch, face and hand gestures as data (Salih, 2015). According to Lafkas, particularly the ability to understand speech is an important step for NUI, because the words or phrases can be defined in the interface and appropriate responses can be created. Environmental sensitization beyond user demands also means that contextual awareness is possible in NUI. Exemplary, depending on the ambient light, it is possible to adjust the display brightness of the device used, or to turn the display off and on according to the user's viewing direction (Lafkas, 2013). In the process of interacting with the user, the graphical interfaces on a device should have information about the contents of the menus or buttons created, while the NUIs begin with the subjective movements of the users. NUI provides intuitive, flexible ease of use, interface training is rarely needed and users can change the interface according to their demands (Aliprantis et al, 2019). In the interaction process with the GUI, tools such as keyboard and mouse are evolved from the visual or auditory human source data or the position of a moving object (Kaushik and Jain, 2014). It means that the original data such as voice, walking or handwriting is now digitally can be detected with NUI.

In the DreamHouse example, the study aims to integrate NUI features with a realistic AR environment (Park et al, 2016), users can change the size, position and rotation of virtual objects displayed in HMD using only their hands. Users can simulate the decoration of their homes with virtual furniture in this study. It enables the user movement in the physical environment to be simultaneously transferred to the computer and then interacts directly with the virtual environment. In an AR environment that places digital information contained in the user's field of view, human interaction with virtual objects is possible with NUI to perform gestures used in everyday life (Aliprantis et al, 2019). The use of NUIs in an AR environment that aims to provide an uninterrupted user experience has the potential to alter majorly the boundaries of user interaction.

3.4. Spatial User Interface (SUI)

Spatial User Interface (SUI) is one of the recently developed user-oriented interface types and based on the user's freedom of movement. Within the scope of the user's spatial perception and awareness, the movement within an area can be defined spatially by using SUI. A spatial interface is for data that is likely to change continuously within an interactive volume. It can be considered as the whole of speech, hand and face gestures, bodily movements and orientations, physical and digital interactions and position changes within the space (Bongers, 2004). The UI development process started with GUIs in HCI and continued with the virtual identification of physical objects in TUIs. In SUIs, no natural intervention is required, the natural environment itself is generated and direct manipulation can occur due to the consistency between the environment and the object in interaction (Marner et al, 2014). The usage areas of SUIs are mostly in the game industry. In a virtual immersive reality environment, players can play with their natural movements and although they are in a completely virtual environment, they do not feel independent of the real environment. In addition, the objective of using spatial interfaces is to enrich the working areas. The ability to edit the data in a virtual environment in a way that the user wants in a physical environment creates a more user-focused, intuitive experience than switching between tabs on a single digital screen (Ens and Irani, 2017). Spatial Augmented Reality (SAR) is a method of identifying physical objects with the help of projectors and manipulating them without HMD and mobile devices for viewing. The environment is only possible to interact with when projected onto a physical object with the projector (Ens and Irani, 2017).

4. EVALUATING USER INTERFACE CONCEPTS THROUGH AN AR-BASED APPLICATION PROPOSAL

Within the scope of this study, an application interface proposal was developed that bridges the design information in the digital environment with the physical model through AR. In the study, starting from the interface concepts, the GUI interface on the tablet and the 3D model in the real world were supported by the interaction of the designer with the model spatially. The proposed design environment is based on the development and control process of design information around a physical model to work individually or in groups. One of the most important features that make the application different is the use of a 3D object's scanning data as the marker recognition method required for AR. In addition, due to the widespread use of mobile devices in recent years, a tablet is preferred rather than HMD as a display device to reach more users and provide mobility. The digital components based on the platform of the application used in this study are Unity and Vuforia. As the software language supported by Unity, C# was used to create the contents of the interface and functions. To create an AR environment, 2D or 3D objects in the physical environment must be recognized on a digital platform. In this study, these objects, recognized and stored as databases in Vuforia Target Manager, are assigned as targets to the AR camera created in Unity. In this way, when the camera of the device on the AR application is installed can recognize the defined objects as a marker in the physical environment and the displaying screen of the device can represent the data in the digital environment. The fact that haptic communication with objects in the physical environment is easier to perceive than the use of visual data only on the screen (Gillet et al, 2005; Schkolne et al, 2001) is also an important factor in representing design ideas. In this study, the aim of developing the AR environment centered on the physical model is to enable the users to design with virtual elements without breaking away from the physical environment with the model that they can perceive by touch. Despite the innovations in digital design media and tools, the use of the physical model in the design process is due to the demand of the designers to touch, measuring and manipulate physically. For this reason, the proposed interface takes the physical model into the center.

4.1. The Interface Components

In the application interface, the main menu panel is displayed when the physical model defined as the database is scanned in real-time on the AR camera. There are four menus under the main menu panel, Generate, Modify, Inform and Animate and each menu has its sub-menus. Each sub-menu opens as a new panel so that there are not too many panels or buttons on the tablet screen. In this way, it is aimed to simplify usage by displaying as few buttons as possible on the screen. Within the scope of the menu contents in the application, basic arrangements such as creating basic geometries such as cubes, spheres and cylinders, adding digital models ready for the scene and deleting unwanted geometries can be made. In addition, color, size and position changes can be made on these models.

Fig.3: 3D modelling by using basic geometric forms on AR environment, on the right. Pre-installed digital models on the physical model, on the left.

Functions have been added to the objects in Unity for operations such as moving, resizing, and rotating 3D objects added to the screen by taking advantage of the possibilities of the AR environment. For the application to work properly, the scanned physical model must be viewed uninterruptedly by the tablet camera. If rotating the physical model or walking around the model with the tablet does not reduce the imaging quality of the AR camera, it provides the user with the opportunity to design from different angles.

4.2. Design Activity in AR Environment

To evaluate the use of the application in the early design stages, data were obtained in line with the positive and negative feedback on the current state of the application with a Test study. These data have formed a framework for how the application used in the design process in the AR environment can be developed. To test the application by users, a group of 5 students continuing their graduate education in architecture was determined. The case study carried out is based on the experiences of 5 students who created an alternative to the given mass settlement program using the developed AR application and the physical model. In this context, the mass settlement program requested by the students consists of a 4-unit dormitory, a 2-unit cultural center, a dining hall and a sports area. In addition, they also showed the pedestrian and traffic flow to show the general circulation and entrances and exits in the area where they designed their projects. While students P3, P4 and P5, who designed the placement of these units in the project area within 10 minutes in the AR environment, had AR experience before, students P1 and P2 had not experienced the AR environment before. In the design process, the interaction with the physical model was observed in two ways. One is the participant changes their own position around the table by moving. The other way is for the participant to change the position of the model by touching the physical model. During the test study, participants P1, P2 and P3 preferred standing. Users P4 and P5 completed the process by sitting down. The interaction of the participants in terms of positioning with the physical model is shown in Figure 5. During the design process, the participants exhibited behaviors such as bending around the table, examining their designs by holding the tablet in line with the model in the horizontal plane, or changing the position of the tablet according to the physical model.

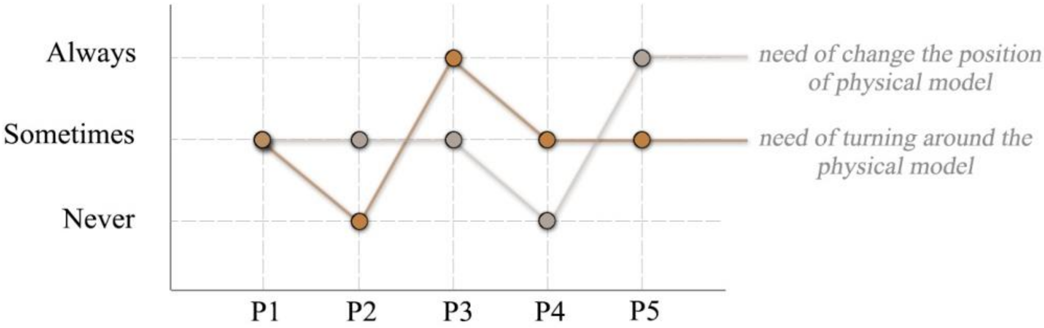

Fig.4: In the interaction of the participants with the physical model, the frequency of changing their own positions and the position of the model.

Participant P1 requested the feature of being able to zoom in on the image in the application, since the 3D scanning process of the tablet with the AR camera of the tablet is interrupted in the positions where it gets too close to the physical model or too far from the model. P2 stated that designing with an AR application is more difficult than they thought. P3 stated that the desired view was obtained only from certain angles. P4 also stated that her designs are positioned as she wishes only when viewed from certain perspectives. The participant who interacted the most by touching the physical model was P5. He had difficulty holding and modeling on the tablet, as he constantly needed to turn the physical model with one hand. For this reason, he requested that the tablet be placed on a tool such as a tripod.

Fig.5: The changing positions of the participants according to their interaction with the physical model.

Each participant differed in the focus points they paid attention to in practice and their approach to design tasks. For this reason, the order of use of the commands and the resulting images in the design alternatives they created using the same design tools also varied. Even though the functions in the application may cause some bugs in the process they are used, the existing problems do not prevent the physical model from being informed. To create different layers of information on the physical model, the functions included in the application were examined in terms of usability and interaction with the physical model. The term usability refers to here how positively the functions they used could have responded according to the design ideas that the participants wanted to apply.

Both the usage of the functions in the application and the interaction of the application with the physical model are evaluated as shown in Figure 6.

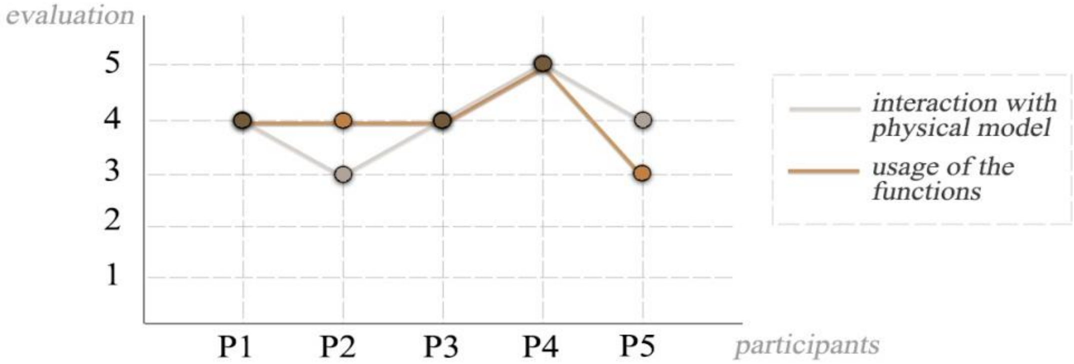

Fig.6: Evaluation of the application functions and interaction with physical model.

5. DISCUSSION AND CONCLUSION

Users interact with objects in the digital environment through interfaces. With the developments in software and hardware, interfaces based on graphical representations have become possible to allow different approaches within HCI. As a result of the widespread use of technologies such as AR/VR, a more natural communication can be established with interfaces.

Within the scope of this study, AR-based user interfaces were evaluated and an AR-based interface proposal was prepared to be used in the early stages of design. The advantages and limitations of an integrated interaction model, where designers interact more naturally with graphical and tangible user interfaces, are explored. The usability of the application in the design process was experienced with the case study conducted during the development of the application. The application, is basically a study aimed at enriching the physical models frequently used in the architectural field with different layers of information. In this sense, the AR interface was prepared using a 3D model scan and provided an advantage in terms of connecting the layout designs made with the real scale.

The AR-based GUI, developed within the scope of the study, is also supported by the real physical model, offering an area where the user can interact physically. This bridge that the GUI builds with the physical model creates a powerful TAR example for users. The fact that the GUI on the tablet has different scanning and usage scenarios depending on the physical model makes it necessary for users to interact with the model in different bodily positions. This paves the way for a more natural digital design process that extends to the designer's interaction with the physical model during the conventional early design process.

As a result of the evaluation data obtained by testing the application by the users, it is thought that the use of the AR environment in the design process will contribute positively to the design in terms of interacting with the physical and digital environment. Especially, enriching the physical models with an AR application and turning them into a tool that supports the digital design environment, is important in terms of both designing with mobile tools and using them as a different representation tool than the existing representation methods. In the next stages of the study, it is aimed to expand the case study on the use of the application in the design process and the evaluation of the developed functions. It is planned to expand the model and material libraries in the application content in order to provide users with more options for creating design alternatives. Making improvements in the interface and functions in line with the data to be collected through a test study with more participants are factors that can increase the usability of the application and its contribution to the design process.

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