Enhancing User Experience of Interior Design Mobile Augmented Reality Applications

Ayman Kandil [1], Bader Al-Jumaah [2] and Iyad Abu Doush [2]

[1] Computer Engineering Department, College of Engineering and Applied Sciences, American University of Kuwait, Salmiyah, Kuwait

[2]Computing Department, College of Engineering and Applied Sciences, American University of Kuwait, Salmiyah, Kuwait

{S00038525, S00039500, idoush}@auk.edu.kw

Keywords: User Interface, Augmented Reality (AR), Indoor decoration, Mobile augmented reality application

Abstract: Intuitive user interface design is of utmost importance to mobile applications, especially when dealing with new technologies like Augmented Reality (AR). In this paper, a user study for evaluating AR 3D furniture arrangement mobile application user experience is presented. In our gesture design, we used one hand to ease the use of the application. Firstly, the user interface is developed based on the literature recommendations and users evaluate it using a set of five tasks in terms of System Usability Scale (SUS), Handheld Augmented Reality Usability Scale (HARUS), task completion time, and the number of user errors. The obtained evaluation results are then used to alter the user interface. The research outcome can be used to help in developing a better user experience for a wider range of AR applications.

1 INTRODUCTION

Augmented reality (AR) is a technology that glazes computer-generated information and place them in the real world [2]. As mobile devices become more powerful and capable, they are being increasingly used to run AR applications. Visualizing how to place a particular piece of furniture in a room is not easy for anyone [7]. AR can be used to accomplish such task to help users make designs faster and more efficiently.

AR can help to design, educate, or present interior design by using virtual furniture which is overlaid in a physical environment using the mobile phone. Users can simply start the camera from the application, select the virtual furniture, and then place it in the room. The furniture is integrated into the 3D scene and it can be shown along with the real furniture in the scene.

In this paper, we follow the AR user interface design recommendations found in the literature [1,4,5] to develop a solution for mobile devices that can be used for interior design. The developed interface is then evaluated by 25 users using task-based evaluation. The users' feedback is then used to alter the user interface and another user evaluation for the updated interface is conducted. As a result, a new set of recommendations for designing the user interface for AR interior design are proposed.

2 RELATED WORK

In this section some of the related literature on recommendations of developing user interface (UI) AR is discussed.

2.1 User interface for AR applications

Several researchers tackled the problem of identifying how to develop a usable AR UI. Dabor et al. [1] proposed an AR user interface design framework to reduce user's mental workload for tasks that requires multitasking activities. In order to do that they used the Cognitive Load Theory which helps in developing interfaces that allow users to maximize their working memory when solving problems. The following set of design guidelines are recommended: the application should be easy for both novice and expert users, users are in control of the next action instead of the system being responsible, users can modify/personalize the visual information displayed in the application depending on the preference of the user, the application should be intuitive and the steps of the task should require very little memorization, and textual information should be in an understandable format and easy to read.

Mona Singh et al. [2] presented the main features in an AR application and its challenges. First, an AR application needs suitable sensors to read the environment properly to recognize the scene. Second, after recognizing the scene, the AR application needs to use trigger matching and image augmentations to understand the scene discovered to place/display the augmented information. Third, AR application needs to provide technologies to allow interaction between user and trigger matching. Fourth, an AR application should provide an information infrastructure such as cloud services to help user's longer-term context. Lastly, AR requires a considerable computing and communication infrastructure to allow all previous technologies to work as expected. Several challenges can face users of an AR application such as information overloading. The AR application can have a lot of information and it is important to make sure that the user is not overwhelmed by the information. The second challenge is the alignment of the augmented objects with reality as sometimes the environment can change suddenly. Organizing the augmented information is the third challenge as the user needs to find it appealing and easy to use. The last challenge was that the AR application idea might not be accepted by consumers as first as it is an emerging technology thus preventing AR application from becoming popular.

2.2 AR for Interior design

Developing solutions for an interior design using AR can help ease the process of placing different pieces of furniture virtually into the physical room. Huilin Tong et al. [3] proposed a real-time AR application called AR Furniture which allows users to see the furniture in different colors and different styles. The solution utilizes deep-learning-based semantic segmentation and a fast-speed color transformation. The system uses eye-gaze to read the environment and provides virtual reality (VR) content. The system uses AR Headset with a mounted camera to capture the real-life scene, and it uses DeepLab3 MobileNetv2 model from Google to process the scene. Active Contour is used to achieve higher quality and more detailed segmentation results. It allows users to apply different colorizations and styles to real-life furniture.

Jiang Hui [4] proposes the AR3D model which creates a 3D model that is based on the original interior construction plan is presented. The AR3D model contains different sources of information to provide a generated environment with real and virtual objects. It allows users to interact with and get real-time feedback from the changes made as well as showing the relationship between the virtual and real objects and how both can get influenced by each other in the same space. The main advantage of the created AR3D model is to help in reducing design errors that happen due to inappropriate spatial partition, management, and construction problems. Moreover, AR3D models can help customers in understanding the interior design project and thus save costs and time for the designer when the physical construction is done. Finally, the AR3D model allows the designer to practice every possible design concept available from the user and get feedback in real-time.

Tsai TH et al. [5] present an approach that uses AR to model 3D objects of various home products and appliances. The application supports portrait view only and the UI was designed to accommodate two-handed use. As a result, the program's main buttons were placed on the lower edges making one-handed use impractical.

Wenbing [6] developed a 3D furniture AR application. The solution allows users to rotate the 3D furniture by pressing a button once to activate clockwise rotation and when pressed again will rotate the object counterclockwise.

Due to furniture arrangement being cumbersome Motwani et al. [7] propose to solve this issue by using AR on mobile devices. The AR use “Image Targets” that serve as reference points to the 3D objects being rendered in real-time. These Image Targets enable the application to maintain the position of the 3D objects even if the camera move. Once the object is fully rendered users can choose to transform, scale, or rotate the object. Transformation allows moving the object around the scene. Scaling allows for resizing the object.

3 METHODOLOGY

Our goal is to enhance user interaction when using AR interior design applications. We developed an AR solution called Furniture Augmented Reality App (FAR App). FAR App is developed using Android Studio, where Kotlin and Java are the main programming languages. Google’s ARCore is used to implement the AR component of the application. In addition, Google’s Sceneform was used to render the 3D furniture to be used in the real-world scene.

3.1 UI Design Choices

Our application uses the smartphone’s touch screen as the main source of input for the user. As a result, for the application to be easy to use, we were very careful in the placement of buttons on the screen to ensure that they can be easily reached by the fingers even in one-handed use. We also made sure that the main camera screen was not cluttered as to not obstruct the camera view while also not overwhelming the user with options.

The hand gesture interface to interact with the 3D furniture is selected based on its familiarity to users when they interact with other applications in the phone. The following are the selected gestures: pinch to zoom, tilt to rotate, and tab to place an object. In addition, a brief tutorial is available for users to help them get familiar with the app's different gestures.

Some other features were suggested to us by the users during the first phase of testing, such as the “undo last item” button among others to be detailed in a later section.

3.2 Participants

The total number of participants who evaluated the proposed solution is 25. Six of them are studying interior design. The users are young adult Android users in Kuwait whose education is between high school and university and who are fluent in English. The users are 20 males and 5 females. In addition, 21 of the participants are studying bachelor's degree and 4 are in high school. Furthermore, 17 of the participants are of ages between 18-24, while 19 of the participants speak Arabic as their native language. Lastly, 17 participants spend less than 4 hours a day on their phones.

3.3 Evaluation Procedure

3.3.1 Tasks

The first step in evaluating our application is to set certain tasks that will be unified for all users to follow. The following are the five tasks used to evaluate the proposed solution: choosing and placing specific virtual furniture, search for a 3D object, resize the selected object, rotate an object, reposition an object, and clear the scene (i.e., removing all objects).

The evaluation was conducted to gauge the efficiency of individual task completions and get feedback from users to improve the proposed solution usability.

3.3.2 Evaluation Process

The first step in the evaluation process is giving participants 10-15 minutes before the evaluation starts to familiarize themselves with the application. The solution starts with a tutorial that shows participants how to use the application’s various features. Afterward, the participants are asked to perform the five tasks while we record the time it took to complete each task. After that, the participants are asked to fill System Usability Scale (SUS) [8] questionnaire, Handheld Augmented Reality Usability Scale (HARUS) [9] questionnaire, and open-ended questions to measure the usability of er experience and user interface.

The SUS is used to measure the solution usability, HARUS is used to test the user interface of the augmented reality aspects from the user's usage, and the open-ended questions are used to get recommendations from users.

Due to the current circumstances related to the COVID-19 half of our participants were tested remotely. Participants were asked to download the application along with a screen recording software before starting the evaluation. After downloading the applications, the participants perform each one of the tasks while recording their screens. Upon that, the recordings are sent to us to see the user's interaction and how much time it took to complete each task.

4 RESULTS

In addition to the SUS and HARUS scales for usability, we used the time-on-task as a metric to measure the efficiency of completing each task successfully. Successful task completion means users completed the task by performing it accurately (e.g., choosing the correct object to place), and in a reasonable time. In this section, the results are discussed, and the conclusion of the evaluation is presented.

4.1 First Version of The FAR Application

4.1.1 SUS Result

The SUS questionnaire is used to evaluate the overall application usability. The following table shows the 10 SUS questions used for the evaluation:

Table 1: SUS Questionnaire

	SUS Questions	Relevance to Application Usability
Q1	I think that I would like to use this application frequently.	Measures the application usage.
Q2	I found this application unnecessarily complex.	Tests the complexity of the application.
Q3	I thought this application was easy to use.	Measures the user interface of the application.
Q4	I think that I would need assistance to be able to use this application.	Measures the learnability of the application.
Q5	I found the various functions in this application were well integrated.	Tests various functions of the application.
Q6	I thought there was too much inconsistency in this application.	Test the consistency of the application.
Q7	I would imagine that most people would learn to use this application very quickly.	Measures the learnability of the application.
Q8	I found this application very cumbersome/awkward to use.	Measures the user friendliness of the application.
Q9	I felt very confident using this application.	Measures the simplicity of the user interface.
Q10	I needed to learn a lot of things before I could get going with this application.	Measures the learnability of the application.

Each question of the SUS has a possible score using a five-level scale. The results are demonstrated in Figure 1. According to the results, only 40% of participants said they will use the application frequently. However, 20% thought that they will not use it more frequently and 40% are neutral. Moreover, 72% of the participants thought that the application was not unnecessarily complex. In terms of learnability, 80% of participants thought that they do not need assistance before using the app. In addition to that, 92% of participants thought that most people would learn to use this application very quickly and 84 % did not see that they had to learn a lot of things before using the app. This illustrates that the UI created in the first version of the app was a success in terms of learnability with the majority of the participants agreeing that it is easy to learn how to use the application quickly with no complications. Moving on to another important aspect of the application which is the various functions that the application proposes. Below is a chart that summarizes the SUS questionnaire.

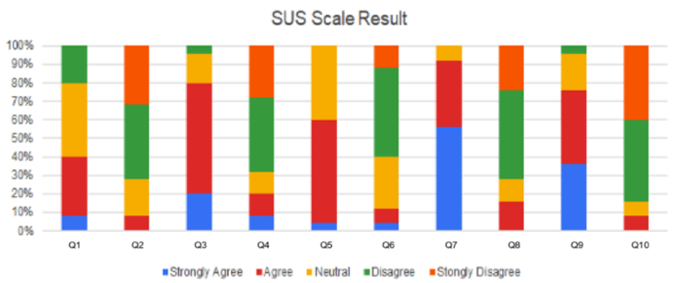

Figure 1: SUS Result

4.1.2 HARUS Result

The second part of our evaluation was using the HARUS questionnaire which is used to evaluate the usability of a Handheld Augmented Reality application. The following table shows the questions asked for the evaluation:

Table 2: HARUS Questionnaire

	HARUS Questions	Relevance to HAR usability
Q1	I thought that the information displayed on screen was confusing.	Testing the novel visualization metaphors that is introduced from AR.
Q2	I think that interacting with this application requires a lot of body-muscle effort.	Testing the application while moving around the real environment.
Q3	I felt that using the application was comfortable for my arms and hands.	Measures the strains on the hands and arms when using the application.
Q4	I found it easy to input information through the application.	Testing the novel interaction metaphors that is introduced by AR.

Q5	I think the application is easy to control.	Testing the novel interaction metaphors that is introduced by AR.
Q6	I think that interacting with this application requires a lot of mental effort.	Measures the amount of information presented on the small screen.
Q7	I thought the amount of information displayed on screen was appropriate.	Testing the novel visualization metaphors that is introduced from AR.
Q8	I felt that the information display was responding fast enough.	Measures the latency issues that are resulted from the limited processing power and network connection.
Q9	I felt that the display was flickering too much.	Measures the tracking and registration errors that are resulted from factors such as dynamics and lighting.
Q10	I thought the words and symbols on screen were easy to read.	Measures the legibility issues that are resulted from ambient light, glare etc.
Q11	I thought that the information displayed on screen was consistent.	Measures the tracking and registration errors that are resulted from factors such as dynamics and lighting.
Q12	I found the device difficult to hold while using the application.	Measures the grip and pose issues that might result from using the application.
Q13	I felt that I was losing grip and dropping the device at some point.	Measures the grip and pose issues that might result from using the application.
Q14	I think the operation of this application is simple and uncomplicated.	Testing the novel interaction metaphors that is introduced by AR.

Each question of the HARUS scale was scored using a 5 scale. The results are presented in Figure 2. It shows that 84% of the participants thought that the information displayed on the screen was not confusing. These results show that our application succeeded in allowing the users to understand the novel visualization metaphors that were introduced from the AR concept. Most MAR applications are used while moving in the real world thus some of them can be very hard to use if they consume a lot of body-muscle effort. Our application showed that 88% of users thought that the application did not need a lot of body-muscle effort while using it. Furthermore, our application showed great results when it came to having minimal strains on the hands of the users when using the application as 84% of the participants thought that their hands were comfortable while using the application. Additionally, our application gave the users a comfortable experience. When using the application 72% thought that they did not find the device difficult to hold while using the application.

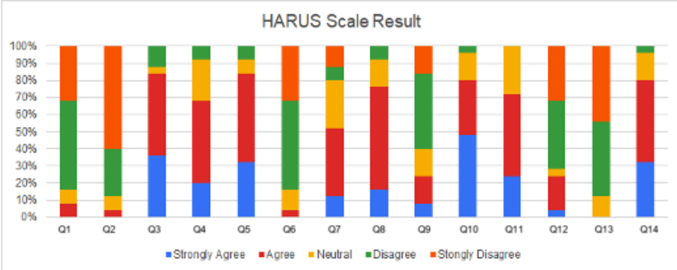

Figure 2: HARUS Result

Also, 84% of users thought that the application was easy to use. This shows that our application introduced simple and easy novel interaction metaphors that made the users understand how to use the application with all its features without being confusing. MAR applications are susceptible to show too much information on the small screens that most mobile phones have. This can lead the users to require a lot of mental effort to know how to use the application. The evaluation shows that 84 % of users did not think that interacting with our application required a lot of mental effort. We minimize the mental effort by developing a simple and intuitive UI that did not include a lot of buttons on the main AR interface activity. Small screens are not the only limitation for mobile phones, however, limited processing power and network connection can also limit the mobile phones' AR capabilities, 76% of participants thought that the information displayed was responding fast enough.

4.1.3 Time-on Task Result

The final part of our evaluation was calculating the time-on-task to measure the efficiency of completing each task successfully. The application was developed during the COVID-19 pandemic some participants are evaluated online, while others got tested in person. Participants that were tested online sent us the screen recordings to calculate the time it took them to perform each task successfully.

The minimum, maximum, and average times-on task for all users for each task is presented in Figure 3. The results show that the task with the highest average was the first task and the task with the second-highest was Task 5. This demonstrates that most users took a lot of time in finding the side menu that had the virtual furniture to place it in the scene and also took a lot of time to find the clear button that was also placed in the side menu.

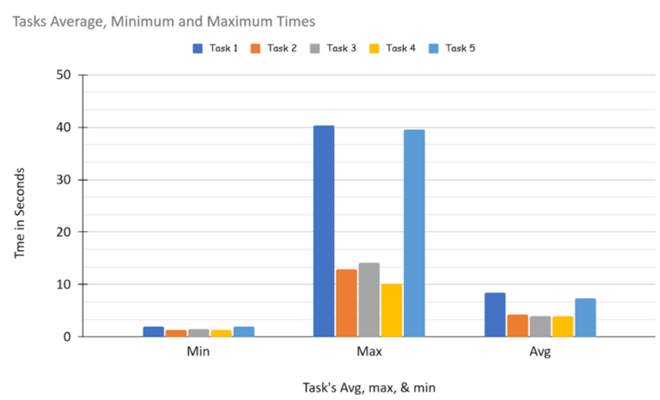

Figure 3: Version 1 Min, Max and Avg task times

4.1.4 User Recommendations

After testing, the participants sent multiple suggestions on how to improve the user experience from their user experience after using the app. Many participants wanted more options and buttons on the main UI screen. One of the participants suggested adding an undo button, while another suggested having a clickable button for the side menu, instead of dragging from the side.

Suggested Features List:

- Dedicated button for the side menu / floating menu
- Undo button
- Move the “clear scene” button outside the side menu
- Tweak the tutorial
- Tweak calibration instructions

The last question on the survey asked participants if they encountered any problems with the application. Some participants reported that the tutorial when they start the app is too lengthy. Some of the participants experienced minor lagging and hiccups in the overall performance of the app. Others reported that they did not know there was a menu at the side due to the lack of visual indicator (see Figure 4). One participant reported that the initial calibration was inaccurate on white floors due to the calibration dots being white as well.

4.2 Second Version of FAR App

After analyzing the feedback given by the participants in the first testing round, the side menu is removed and replaced by a pop-up menu button on the main screen. The second thing that got modified was the length of the tutorial to be short and precise. In addition, a visual indicator is added for the menu as demonstrated in Figures 6.

The participants that were already tested in the first version evaluated the application after one month. In addition, they were not given any time to familiarize themselves with the application and the tasks are reordered to ensure unbiased results.

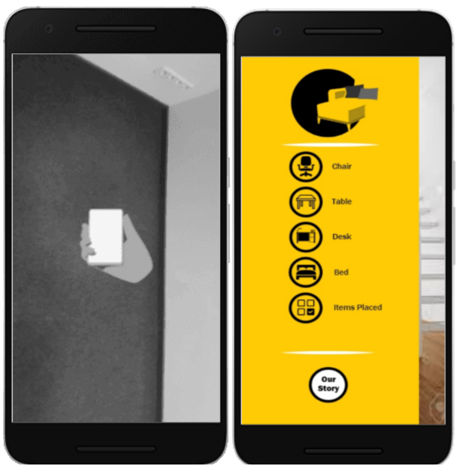

Figure 4: First Version of The Application

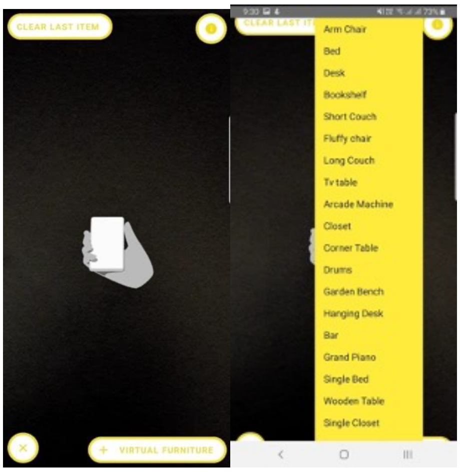

Figure 5: Second Version of The Application

4.2.1 SUS Result

Using the same SUS questions as the first version of the application (Table 1) and following the same procedure mentioned before we gathered the responses presented in Figure 6.

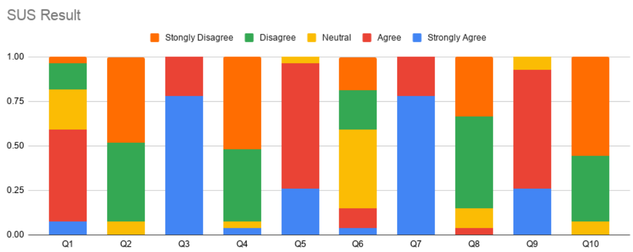

Figure 6: Version 2 SUS Result

In comparison to the first version, in terms of frequency of use, 59% of participants felt that they would use FAR App more often after the UI changes that were made. Another improvement is the reduced complexity of the application with 92% of participants stating that it is not unnecessarily complex to use. Furthermore, 100% of participants find the application easy to use this time. Also, 92% of users did not need assistance to use the application properly, compared to 68% in the first version. Lastly, 95% do not find the application awkward/cumbersome to use, while 92% felt confident in using the application, both up from 72% and 76% respectively.

4.2.2 HARUS Result

Following the same process, we compare the HARUS survey questions results with the first version. The results are demonstrated in Figure 7. The second evaluation shows that 92% of participants thought the amount of information on the screen as appropriate. No participants thought that the information on the screen was confusing, which was 8% in the first version. Whereas, 92% of participants thought that it was not difficult to hold the device while using the application, and 96% thought they had a solid grip on the phone while engaging with the application. Furthermore, 93% of participants thought that the application was easy to control and 89% found that it was simple to use, up from 84%

and 80% respectively. Finally, 88% of participants thought that interacting with the application required little mental effort, up from 84% in the last version.

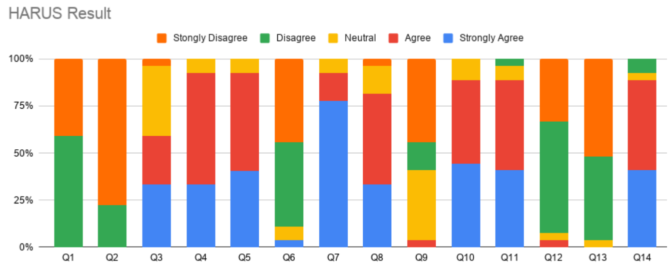

Figure 7: Version 2 HARUS Result

4.2.3 Time-on Task Result

The average, maximum, and minimum times for completing each task by users' results are presented in Figure 8. The data shows significantly lower times for achieving the tasks when compared to the version 1 results demonstrated in Figure 3.

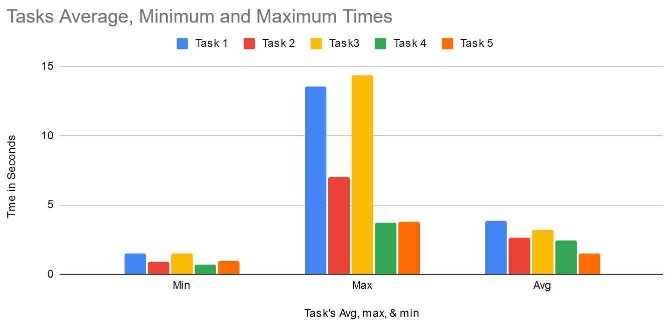

Figure 8: Version 2 Min, Max and Avg Task Times

4.2.4 Final User Recommendations

For the second version users suggested the following additions:

- Adding sound cues.
- Have more notifications in case users fail to calibrate the AR view or any other task.
- Better colors for readability.
- Add a visual indicator that shows which item is currently selected/to be placed.
- Use visual indicator (e.g., highlighted circles) that tells users objects can be resized, moved, and rotated.

Unlike feedback from the first version, many users noted that they encountered no issues while using the application.

5 DISCUSSION

As is apparent in the results, these are the tasks that are specifically affected by the changes made in the second version of the application:

- Object placement / searching.
- The “Clear all” function.

These two tasks were affected due to making the items menu easier to access and because of having the “Clear all” button directly accessible from the main screen. The results of our changes are summarized in the following two graphs:

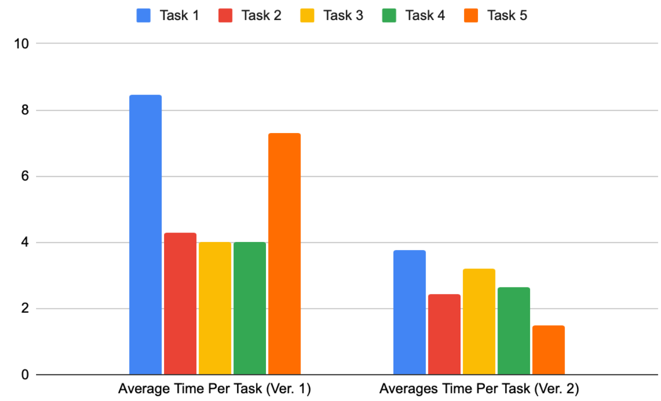

Figure 9: Average Time per task comparison

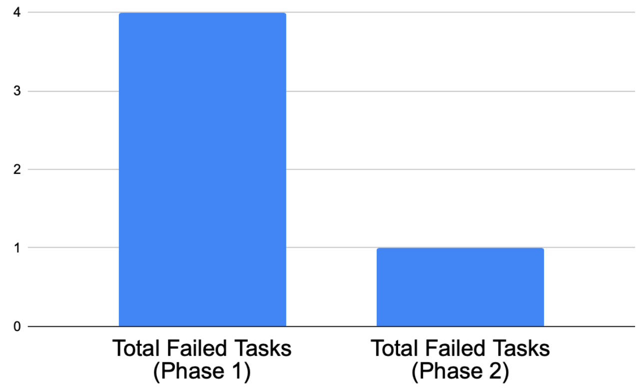

Figure 10: Comparison of failed tasks

As evident by the graphs there is a significant improvement in the task success and time on task.

Examples of tasks not being performed successfully include users unable to complete the task in a reasonable amount of time or placing the wrong object as in Figure 11.

Figure 11: For example, instead of placing a chair, the user places a sofa

Based on our findings we can summarize how developers can enhance their furniture based/interior design AR application in the following main points:

- Having all of the application's main features directly accessible in the main screen/view is vital for showing users the available options at their disposal. We find that placing features in sub-menus reduces the speed at which users access these features.
- Having some sort of tutorial is beneficial in allowing users to use the application effectively. However, in our case, since we have a simple application with limited features, we received feedback that it was too lengthy, so we simplified the tutorial.
- When designing an AR application gesture interface, it is important to follow what users already familiar with. For instance, resizing 3D objects in both AR and non-AR applications is done using the pinch gesture so deviating from this method instantly adds an unnecessary learning curve.

6 CONCLUSION AND FUTURE WORK

In this paper, a solution for AR 3D/virtual furniture interior design is developed and evaluated by two user studies. The first version of the developed solution is evaluated using five tasks in terms of System Usability Scale (SUS), Handheld Augmented Reality Usability Scale (HARUS), task completion time, and the number of user errors. The first evaluation recommended having a clickable button for the side menu instead of dragging from the side, having undo button, move the "clear scene" button outside the side menu, and the calibration was inaccurate on white floors due to the calibration dots being white as well. These suggestions are utilized to update the UI of the solution. After that, a second evaluation is performed using the same measures and the obtained results show improvement in user satisfaction and system effectiveness. In the future, researchers can consider applying the suggested recommendation to a wider range of AR applications. Also, researchers can study the positioning of the 3D furniture on the room based on its real measurement as this can help in boosting the advancement of the usage of AR 3D/virtual furniture interior design.

7 REFERENCES

[1] Dabor, O., Longford, E., & Walker, S. (2019, September). Design Guidelines for Augmented Reality User Interface: A Case Study of Simultaneous Interpretation. In 2019 11th Computer Science and Electronic Engineering (CEEC) (pp. 164-166). IEEE.

[2]Singh, M., & Singh, M. P. (2013). Augmented reality interfaces. IEEE Internet Computing, 17(6), 66-70.

[3]Tong, H., Wan, Q., Kaszowska, A., Panetta, K., Taylor, H. A., & Agaian, S. (2019). ARFurniture: augmented reality interior decoration style colorization. Electronic Imaging, 2019(2), 175-1.

[4] Hui, J. (2015, August). Approach to the Interior Design Using Augmented Reality Technology. In 2015 Sixth International Conference on Intelligent Systems Design and Engineering Applications (ISDEA) (pp. 163-166). IEEE.

[5] Tsai, T. H., Chang, H. T., Yu, M. C., Chen, H. T., Kuo, C. Y., & Wu, W. H. (2016, July). Design of a mobile augmented reality application: An example of demonstrated usability. In International Conference on Universal Access in Human-Computer Interaction (pp. 198-205). Springer, Cham.

[6] Seow, H. W. (2018). Online furniture shopping using augmented reality (Doctoral dissertation, UTAR).

[7] Motwani, K., Sharma, S., & Pawar, D. (2017). Furniture Arrangement Using Augmented Reality. In: International Research Journal of Engineering and Technology (IRJET), 4(4).

[8] Brooke, John. (1995). SUS: A quick and dirty usability scale. Usability Eval. Ind.. 189.

[9] Santos, Marc Ericson & Polvi, Jarkko & Taketomi, Takafumi & Yamamoto, Goshiro & Sandor, Christian & Kato, Hirokazu. (2014). A Usability Scale for Handheld Augmented Reality. Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST. 10.1145/2671015.2671019.