The design and implementation of an interactive mobile Augmented Reality application for an improved furniture shopping experience

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Abstract: Furniture shopping, when done in the traditional way, is a time-consuming task. A lot of time and effort is put to check different furniture items from different stores, and to make sure that these items match together. We propose an Augmented Reality based mobile application for furniture shopping. The main objective of the proposed application is to enhance users experience while shopping for furniture. We incorporate state-of-the-art technologies that enable interaction with the physical and virtual environment simultaneously. The proposed application allows users to view items from different stores, as well as 'try' them before buying using AR. Thus, users can choose the right color, shape and size while they are sitting at home. In this work, we followed the waterfall software engineering model and described each main component. Specifically, details of requirement gathering, software design and implementation, and software testing are presented here. The proposed application was implemented using Vuforia. The software testing verified and validated the developed application, and the results were compared in light of related work. For future work, we aim to further improve the users experience in furniture shopping by incorporating more state-of-the-art techniques, such as an AI-based shopping assistant or an ML-based recommender system.

Keywords: Mobile Application, Augmented Reality, Furniture Shopping Application, Android.

1. Introduction

Augmented Reality (AR) allows augmenting the real world with virtual objects. The potential benefits and applications of such technology are numerous, especially with the increasing demand for such applications. Given the current pandemic, there is an unprecedented need to incorporate state-of-the-art technologies for a safer and better user experience in all domains. This includes entertainment, education and retail, to name a few.

In this work, we focus on furniture shopping and aim to design and develop an application that enhances users experience and minimize issues currently faced by users when they need to buy furniture. The context of furniture shopping was selected specifically due to the importance of this task as well as to the potential benefits that state-of-the-art technologies can add to this domain.

The proposed mobile application will help users to try furniture in their room, with the ability to see how the room looks after placing furniture in it. By using Augmented Reality, users can virtually try out multiple combinations of furniture, without the physical movements of it. More importantly, it will not be necessary to go shopping, or measure to find out whether the furniture would fit in the customer's room or not. The main purpose of this project is to develop an application for different furniture items and to minimize the time spent in traditional shopping, which is a time-consuming activity. Namely, our objectives in this work are to:

- Decrease the time that the users spend searching for appropriate furniture.
- Decrease the time users take to make decisions and increase the confidence about the selected furniture items.

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- Provide the user with a view of the furniture in augmented reality in his/her house before purchasing it.
- Provide the user with the service of choosing furniture remotely by phone.

In this work, we describe the complete software engineering process of the proposed system, starting from requirements gathering and elicitation to software testing. The rest of this paper is organized as follows. Section 2 provides the background and context of the problem. Section 3 provides a comprehensive summary of the related work. Section 4 describes the methodology we followed to design and implement the proposed solution. Section 5 describes the requirements gathering and elicitation phase. Section 6 discusses the software design and implementation phase. Section 7 details the software testing phase. Finally, concluding remarks and future work are presented in Section 8.

2. Background

Advanced computer technology allowed for a wide range of human computer interactions. To understand the different interaction approaches, Milgram et al. (1995) have introduced the Reality-Virtuality (RV) continuum as shown in Figure 1. The continuum represents a continuous scale where a completely real environment is at one end of the spectrum and a completely virtual environment is at the other end of the spectrum. In this scale, the Augmented Mixed Reality (MR) covers the area between the two extreme points of the spectrum, where both Augmented Reality (AR) and Augmented Virtuality (AV) fall (Kim et al., 2018). The difference between AR and AV becomes clear in this spectrum. That is, in AR, the virtual component augments the real environment, while in AV, the real component augmented the virtual environment.

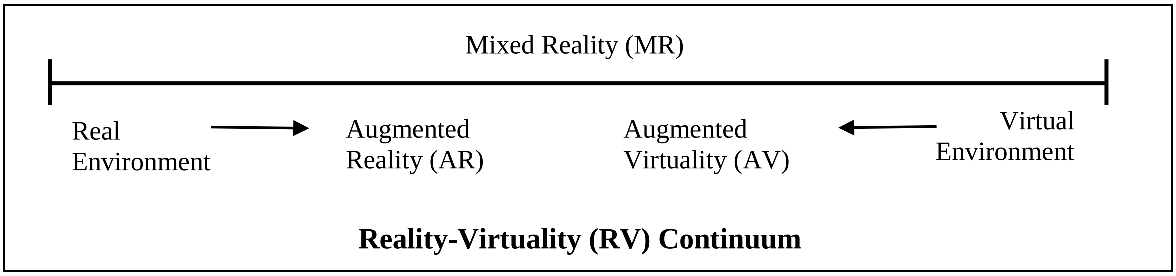


Figure 1. Simplified representation of an RV continuum (Milgram et al.,1995)

AR can be developed using a variety of hardware (devices). In fact, the state-of-the-art advances in hardware lead to the increased adoption of AR in different fields and domains, using a wide range of devices. For example, Hamacher et al. (2019) reviewed the performance of AR user interfaces on different devices. However, the recent advances in handheld mobile devices enabled the development of AR-based mobile applications. Consequently, due to the wide availability of mobile devices to the general public, AR found its way in many applications. For a comprehensive review of Mobile Augmented Reality (MAR), we refer the reader to (Chatzopoulos et al., 2017) and (Li & Fang, 2020). Examples of AR applications in different domains include: teaching (Lee, 2019), fashion (Boardman et al., 2020), science (Crofton et al., 2019), smart city (Ramos et al., 2018), consumer marketing (Wedel et al., 2020), and interior design (Sandu & Scarlat, 2018), to name a few.

Among these various applications, AR has continuously proved to have a positive impact on customer experience (Flavian et al., 2019; Xu et al., 2018). For example, Han et al. (2019) have studied the impact of AR on visitor experience in the tourism sector. Due to this positive experience, AR has found its way in many e-commerce stores (Martínez-Navarro et al., 2019), retail stores (Bonetti et al., 2018; Dacko, 2017; Heller et al., 2019) and stores (Bonetti et al., 2019). All used it with a main objective which is to enhance the users' experience.

With this in mind, we focus on the context of furniture shopping and aim to develop a mobile application that improves the users' experience. In this work, we will first identify the main issues and time-consuming tasks customers often encounter when shopping for furniture. This is covered in the requirements gathering and elicitation section (Section 5). Then, based on the identified needs and required features, we design and implement an AR-based mobile application for furniture shopping. This is further detailed and finally, we systematically test the implemented application, evaluate the user feedback, and compare our results with those of the previous works in Section 6.

3. Related work

Developing an AR-based mobile application for furniture shopping has been explored previously (Huang & Tedjojuwono, 2020; Ozturkcan, 2020; Ahmed et al., 2018; Motwani et al., 2017; Young & Smith, 2016). In (Huang & Tedjojuwono, 2020), the authors have designed and developed a system for a specific furniture store named Yenprima Mebel. The application has two main features to enhance the customers' shopping experience at that store. The first feature is providing the complete catalogue in the application, and the second is AR to evaluate the suitability of the furniture piece on the customers' place. In this work, the authors evaluated the usability of the designed application using a qualitative approach, and reported fulfilling the goals of their project. Similarly to Huang & Tedjojuwono (2020), Ozturkcan (2020) studied an AR-based mobile application designed and developed by IKEA furniture store. A similar application was designed and implemented in (Ahmed et al., 2018). The authors used Kudan SDK to develop the android application. Similarly to (Huang & Tedjojuwono, 2020), the authors evaluated the usability of the proposed application, and reported satisfactory user experience. The authors in (Motwani et al., 2017) designed and implemented a similar AR-based furniture application. The paper focused on describing the methodology, and did not report the evaluation of the proposed system. Lastly, the work from (Young & Smith, 2016) developed a calibration algorithm to improve the quality of the images. This work evaluated the usability of the developed application, and reported satisfied customer experience.

All previous works had one common objective which is to improve the customers' overall experience in furniture shopping. In all these previous works, this was achieved by enabling an AR feature that allows customers to see how the new item will fit in their homes. Some of these applications even allowed users to customize the furniture color and size, as in (Young & Smith, 2016), while others focused on providing the real dimensions of the furniture, as in (Huang & Tedjojuwono, 2020).

Similarly to previous works, our proposed application has the same main objective, which is to enhance the user experience. Additionally, our proposed application will be evaluated using usability tests. Our proposed application is designed to allow many furniture stores to register and add their furniture / items. Thus, this feature allows for a richer user experience, where the user can actually shop from different stores simultaneously and view how these items will appear in his / her home.

4. Methodology

In this work, we followed the waterfall software engineering model, illustrated in Figure 2. The figure visualizes the linear sequential flow of the model, where one component starts when the previous one ends. There are three main components of the model, which are described in details in the following sections. The three components are: requirements gathering and elicitation (described in Section 5), software design and implementation (detailed in Section 6), and software testing (described in Section 7).

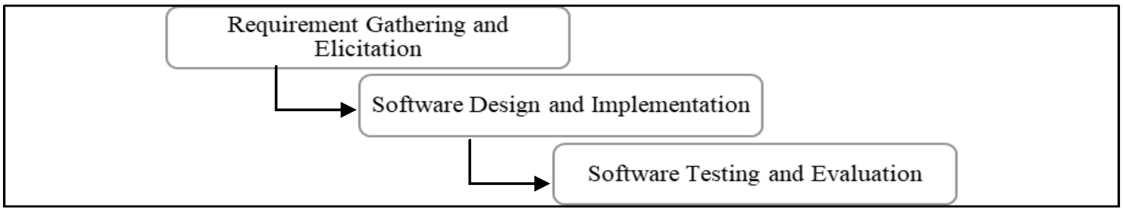


Figure 2. Main components of the waterfall software engineering model

5. Requirment gathering and elicitation

In this section, we describe in details the requirements gathering and elicitation phase. First, we utilized two well-known methods for requirements gathering, which are: surveys/questionnaires and interviews. Second, we describe the functional and non-functional requirements of the system, after we gathered and analyzed the requirements from our prospective end-users. Next, we describe each step in further details.

5.1 Requirment gathering and analysis

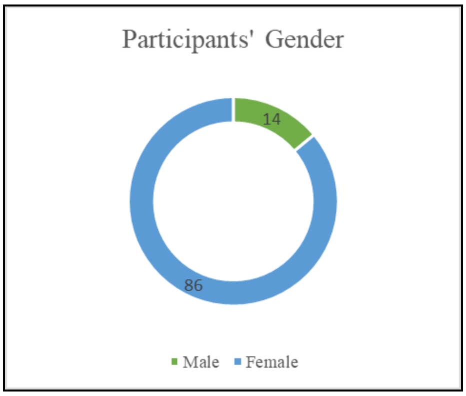
We gathered requirements for our furniture application using two methods: surveys and interviews.

Interviews: An interview was conducted by an associate professor of interior design from the University of Jeddah, College of Art and Design. The interview contained open-ended questions that aimed to understand the basic mechanisms behind designing rooms and selecting furniture. The interviewee explained the general steps followed, starting with creating a plan for the room with correct measurements. This is followed by selecting the preferred style of the room, which can be modern, classic or any other style. The next step would be to select the color plate, and the last step would be to choose the furniture that meet these requirements.

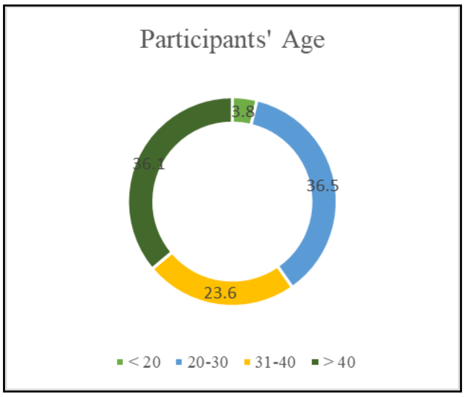
The data collected from this interview was very useful to us, as it gave us a clear idea of how interior designers design rooms. The result of this interview helped identify several functional requirements, and form some ideas about future work. For example, after this interview, the team decided to include the style and color attribute of each furniture item. This will allow the user to filter items by color/style. It will also be useful in future work, where we plan to develop a ML-based recommender system, or an AI-based shopping assistant.

Surveys: We used surveys/questionnaire to reach a wide range of potential end-users, and thus better understand the users' needs. We made our questionnaire using Google forms. It had eight questions related to our application topic. We shared it in social media and sent it to our friends on WhatsApp and Twitter. 470 people participated in the survey, both men and women of different ages.

Figures 3, 4 and 5 show the results of the survey. Figure 3 illustrates the demographics of the participants. 14% of the participants were male, and 86% were female (Figure 3-a). Most of the participants were between 20 and 30 years old (36.5%), and 36.1% were older than 40. 23.6% of the participants were between 31 and 40, and only 3.8% of the participants were younger than 20 (Figure 3-b). The demographic of users who participated in our survey is ideal to understand the requirements of our proposed furniture application.



(a) Participants' Gender

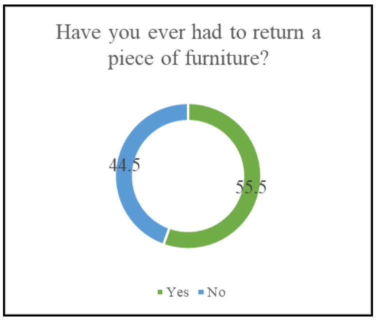


(b) Participants' Age

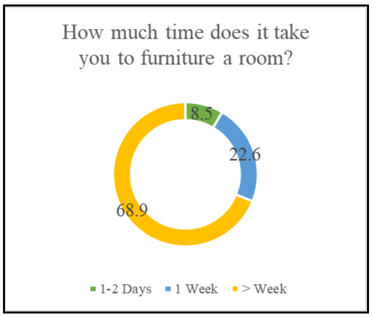
Figure 3. Analysis of questionnaire results (part 1)

88% of the participants indicated that they shop for furniture from multiple stores (Figure 4-a). 44.5% of the participants indicated that they needed to return a store-bought furniture (Figure 4-b). 68.9% of the participants declared that they needed more than one week to shop for a furniture piece (Figure 4-c). 73% of the participants confirmed that if an application allows them to see the furniture in their home before buying it, they will use it to design a complete room as well as to add touches to an existing room (Figure 4-d). 61.5% of the participants indicated that they preferred to use the application in the Arabic language (Figure 4-e).

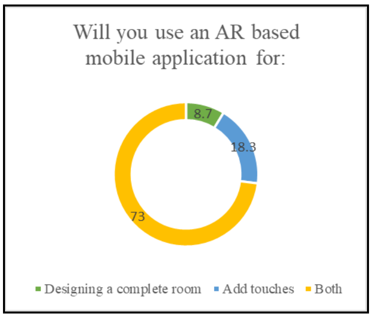
(a) 1 vs multiple shops



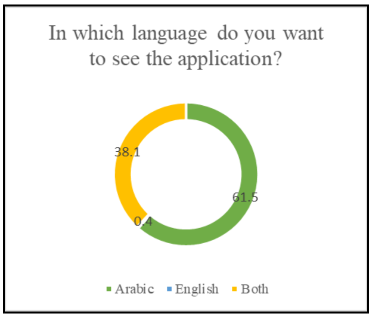
(b) Return vs no return



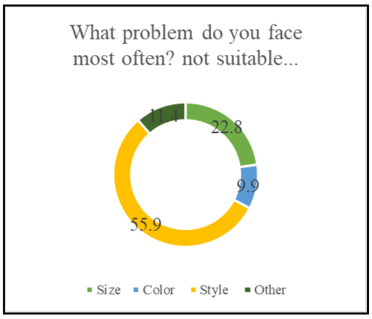
(c) Shopping time



(d) Application usage



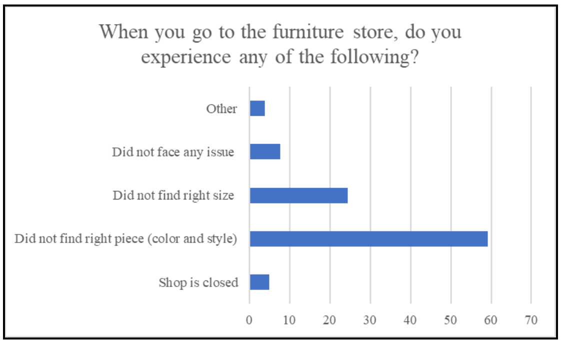
(e) Application language



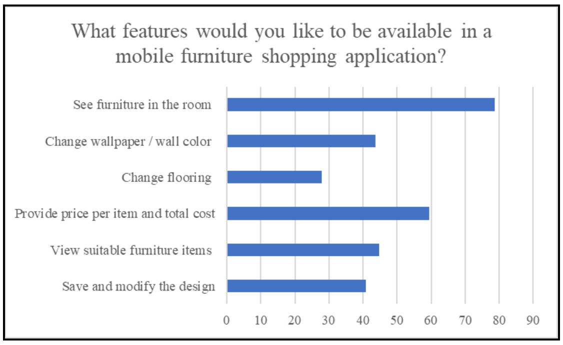
(f) Common problems

Figure 4. Analysis of questionnaire results (part 2)

Additionally, Figure 4-f displays the main problem shoppers faced when returning a bought item. 55.9% of the participants returned the items because the style of them was not suitable. 22.8% of them returned it because the size was not suitable, and 9.9% of them returned it because the color was not suitable. 11.4% returned it for other reasons. Additionally, Figure 5-a illustrates the answers of the participants when they were asked about the common problems they face when they go to the stores (traditional shopping). 59.1% reported not finding the right item, 24.5% reported not finding the right size. Only 7.7% of the participants reported not facing any issue, and 4.9% reported the store being closed at time of arrival. 3.8% reported facing other problems, but did not specify them.



(a) Common problems of traditional shopping



(b) User requested features

Figure 5. Analysis of questionnaire results (part 3)

Lastly, the participants were asked to select the features they would like to see in our proposed application. They were encouraged to select the three top features they wanted. The results of this question can be visualized in Figure 5-b. The list of features ranked by popularity are:

- See the furniture in the room (78.7%);
- Provide the price for each piece, and calculate the total of all the selected pieces (59.4%);
- View suitable furniture pieces 44.7%;
- Add / change wallpaper or wall color (43.6%);
- Save and modify the created design (40.9%);
- Add / change flooring (27.9%).

The results of the two conducted requirement gathering techniques gave us clear insight on what functional requirements would be desirable to end-users. Details of the selected functional and non-functional requirements are provided next.

5.2 Functional and non-functional requirements

The previous data collection and analysis resulted in the following functional and non-functional requirements for the proposed mobile AR furniture shopping application:

Functional requirements: the functional requirements are described in terms of three types of software users: end-user, admin and seller.

The user requirements:

1. The user should be able to scan the place successfully.
2. The user should be able to place the furniture in his/her home.
3. The user should be able to change the place of the furniture.
4. The user should be able to share and save the designed room.
5. The user should be able to filter furniture by style.
6. The user should be able to filter furniture by type.

The admin requirements:

1. The admin should be able to add a seller.
2. The admin should be able to delete a seller.

The seller requirements:

1. The seller should be able to add furniture.
2. The seller should be able to delete furniture.

Non-functional requirements: the following is a list of the main nonfunctional requirements:

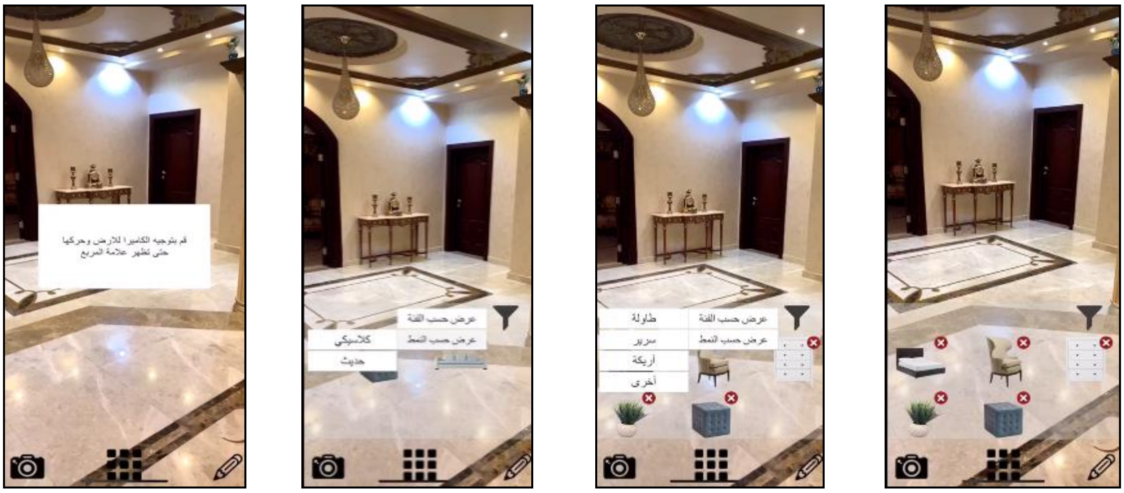
- Accessibility: ability to access the application without account, the application provides buttons in each page to make user navigation easy;
- Extensibility: ability to add a new item or product;
- Usability: ability to use the application without training. This can be achieved by designing a user friendly interface, following common design patterns;
- Performance: fast and easy to navigate.

6. Software design and implementation

The application was implemented using Unity3D development framework. Unity3D is a cross-platform 3D development framework and game engine. The primary language for development in Unity3D is C. Compared to other development frameworks, Unity has a strong focus on 3D content, which makes it ideal for applications that rely heavily on 3D content. Additionally, Vuforia is used as the main AR SDK for the proposed application. Compared to other AR SDKs, Vuforia is a cross-platform and can run on both iOS and Android.

Figure 6 shows the main pages of the designed application. When a user first opens the application, a splash screen including the logo will show up. Then, it will directly open the camera. After that, the user should point the camera to the desired location and press the button that will let him/her to choose the furniture (Figure 6-a). Then the user can:

- Filter and view available furniture items by style (modern and classic) as in Figure 6-b;
- Filter and view the available furniture items by type (table, bed, sofa and other) as in Figure 6-c;
- Select and place the desired item as in Figure 6-d;
- Move or delete the added furniture;
- Enter a text in the screen;
- Capture the image and save it to share with your family or friends.



(a) Main Page (b) Select by style (c) Select by type (d) Select item

Figure 6. Main interfaces for the implemented application

7. Software testing and evaluation

The software testing phase is critical to any designed system, as it determines if the application is ready for deployment. The objective of this phase is two-folds. First, it rigorously tests the designed system for errors and bugs and strives to fix them (i.e., verification). Second, it confirms that the designed software meets the user requirements (i.e., validation). In this work, we applied three types of testing: unit testing, system testing and usability testing.

Unit testing was done rigorously during the development and implementation phase, as well as after complete system implementation. Manual unit testing was conducted with the purpose to test and identify unexpected results in each unit separately. Unit testing is considered successful if it identifies errors / bugs in a unit. Table 1 presents a summary of main unit testing scenarios applied to our developed application. It contains the seven main functionalities of the application, namely: adding items, taking screenshots, writing comments, deleting items, filtering items by style, filtering by category and moving items. For each functionality, the input, expected result, and actual result are presented. As the main goal of unit testing is to identify bugs or errors in the system, we conclude that the unit testing was successful taking into account that we identified an error in the filter by style functionality of the application.

Table 1. List of unit testing

Functionality	Input	Expected result	Actual result
Add item	Press the list button and chose the item	Successful added	Pass
Take screen shot	Press the save button	Successfully saved picture	Pass
Write a comment	Press the pencil button and write a comment	Successful added	Pass
Delete item	Press the list button and then press the delete button	Successful deleted	Pass
Filter by style	Press the list button and press the filter then choose filter by style	Successful filtered	Fail
Filter by category	Press the list button and chose the filter and then choose filter by category	Successful filtered	Pass
Move item	Press the item and move	Successful moved	Pass

System testing, on the other hand, tests the integration between all the system units. This is usually conducted by designing comprehensive test scenarios that test the interfaces and communication between several system units. Table 2 lists eight system testing scenarios that we used to manually conduct our system testing. All scenarios passed the test result which indicate that our system is ready to be released.

Table 2. List of system testing scenario

Test scenario	Test result
open app > read the floor by moving the camera > press list button >choose item > choose another item > write a comment > delete an item > take a screen shot	Pass
open app > read the floor by moving the camera > press list button >choose item > write a comment > take a screen shot	Pass
open app > read the floor by moving the camera > press list button >choose item > choose another item > write a comment > delete an item > take a screen shot	Pass
open app > read the floor by moving the camera > press list button > press on filter > sort by style > choose classic > choose item > write a comment > take a screen shot	Pass
open app > read the floor by moving the camera > press list button > press on filter > sort by style > choose modern > choose item > write a comment > take a screen shot	Pass
open app > read the floor by moving the camera > press list button > press on filter > sort by category > choose table > choose item > write a comment > take a screen shot	Pass
open app > read the floor by moving the camera > press list button > press on filter > sort by category > choose sofa > choose item > write a comment > take a screen shot	Pass
open app > read the floor by moving the camera > press list button > press on filter > sort by category > choose chair > choose item > write a comment > take a screen shot	Pass

Lastly, usability testing was conducted to quantitatively evaluate the application from the end-users perspective. Twenty participants participated in usability testing, (15 women and 5 men). 60% of the participants were between 20-30 years old. Table 3 lists the usability testing metrics and the results obtained per each metric.

Table 3. List of usability testing metrics

Metric	Definition of Metric	Agree	Disagree	No opinion
Q1	Did the application meet your expectations?	90%	5%	5%
Q2	Do you think you will use the application before you buy a furniture?	85%	5%	10%
Q3	Do you think that adults of all ages can use this app?	85%	15%	0%
Q4	Do you prefer to visit the store to see the furniture before checking it first in the application?	35%	45%	20%
Q5	Do you need instructions to use the app?	20%	80%	0%
Q6	Do you directly find what you are looking/searching for?	5%	95%	0%
Q7	Did you face any problems while using the application?	20%	80%	0%

Our results are consistent with existing work. Namely, similarly to (Ahmed et al., 2018) and (Young & Smith, 2016), usability testing showed that the designed application is useful and easy to use. The usefulness of the designed application is depicted in metrics Q2 and Q4 from Table 3. 85% of the participants indicated that they will use the designed application before shopping for furniture, and 45% of the participants preferred to check the furniture first in the application before visiting the store. Additionally, the ease-of-use of the designed application is portrayed in metrics Q3 and Q5 from Table 3. 85% of the participants believe that this application can be used by adults of all ages, and 80% believe that no instructions are required to use the application.

8. Conclusion

In conclusion, this work has demonstrated the process of designing and developing an augmented reality-based mobile application that enables distance furniture shopping. The importance of this work lies in the increasing demand for such applications, which significantly improves the shoppers experience and reduces time and effort often associated with furniture shopping. More importantly, it allows for a safer shopping experience especially in the current pandemic context, where social distancing is a major requirement. The paper describes the methodology including the key software engineering activities followed to design, develop, and test the proposed augmented reality application. Future work includes incorporating more advanced features to improve the user experience, and make it more realistic and natural. Some of these advanced features include developing a machine-learning based recommender system or an artificial intelligence-based shopping assistant to help shoppers in selecting the best furniture pieces for their homes.

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