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INTERIOR DESIGN AND GARDENING APPLICATION USING AUGMENTED REALITY AND 3D MODELING

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Abstract

Although often overshadowed by virtual reality (VR), Augmented Reality (AR) is expected to take a great share of the market. According to one estimate, the AR market will be worth between $70bn and $75bn by 2023, while VR is expected to be worth between $10bn and $15bn. Even though it's mostly associated with games and entertainment, AR is a very versatile technology with many uses like retail, repairs and maintenance, education, design and modeling, and much more. The focus of this project will be on design and modeling. In this project, a mobile application will be developed to enable users to place and interact with virtual furniture and gardening décor in the real-world using AR or a 3D virtual environment. A simple prototype of an online shop will also be implemented to show the use of AR in retail.

Acknowledgments

First and foremost, we sincerely like to thank our project supervisor Dr. Ali Alsaffar, for all the timely support and valuable suggestions during the period of this project. Next, we would also like to thank all the people who uploaded online tutorials and provided open-source examples to help us understand the important concepts of the system we have developed. Lastly, we would like to extend our gratitude to all the friends and family that helped and supported us during this project.

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Chapter 1: Introduction

1.1 Introduction

Although Augmented Reality is mostly associated with games and entertainment, it's a very versatile technology that has many practical applications. Imagine you were in a store and bought a chair, a table, a carpet, or anything else, and went back home with the things you bought and realized they did not fit the room. Now you face two choices: either return the goods and go back to the start or learn to live with it. This is where this project comes handy. By using Augmented Reality, you can easily view real life-size furniture in your home before buying it. As proven by many huge home furnishing and interior design retailers like IKEA and Lowes, Augmented Reality is remarkably useful for interior design. By using Unity game engine, we can develop an AR interior design application with its AR development framework AR Foundation. We will also develop a 3D virtual environment that allows users to build an entire house and a simple shop with basic functionalities to demonstrate how an AR feature can be integrated into an e-commerce application.

Since this technology and the tools required to build an application using it are new to us, we must learn almost everything from scratch. We decided to divide the work based on the tools needed. This way each team member can focus on learning only the tools needed for their work and have enough time to implement it.

The team of this project consists of two Computer Science students. Osama Ebrahim worked on the system design and coding using C#, and Yusuf Saeed worked on coding C# and on using 3D modeling software's like Blender and Maya. As a result, Osama was responsible for implementing the AR and Shop components and Yusuf was responsible for implementing the 3D Builder component, designing the 3D models that will be used in this application, and help debugging AR and Shop components. Both students were responsible for the design of the user interface and writing the report.

1.2 Problem Statement

When people are modeling or remodeling their homes, they usually search online or look at catalogues for furniture. However, this requires taking measurements and visualizing how the object will fit in the room, and sometimes the actual size is different from the measured size taken by the customer. By using an augmented reality app to provide a 3D interactive environment the designing process will be simplified and more efficient.

1.3 Relevance/Significance of the project

The use of Augmented Reality will provide support and assistant data to individuals when embellishing and choosing objects and help clients feel the arrangement of objecting inside the rooms ahead of time before placing them,

1.4 Project objectives

1- To design an interior design and gardening application using augmented reality.
2- To provide users with a 3D interactive environment to be practiced in interior design and gardening.
3- To create realistic virtual objects (furniture, plants, etc.) like real objects.
4- To develop a system that uses augmented reality technology to enable users to place virtual objects in real-world environments.
5- To develop a system that uses 3D building technology to enable users to place virtual objects in a virtual environment.
6- To develop a simple e-commerce experience to best show the use of augmented reality and 3D building in interior design.
7- To develop a mobile application that integrates all e-commerce, augmented reality, and 3D building into a single system and provides the user with a full interior design experience.

Chapter 2: Literature Review

2.1 Introduction

A literature review is about searching and finding what information is published and what ideas are shared about a specific subject in a certain period. This literature review provides a summary of the sources. A literature review usually has an organizational pattern and combines both summary and synthesis. A summary is the main important information of the source, and the synthesis is taking the information and re-order, re-shuffle, and re-organizing the information that was gathered. Usually, it gives a combination of new and old interpretations. A literature review usually evaluates the sources and gives the reader advice on the most pertinent or relevant. This chapter will contain some related software with a comparison between them. Also, the advantages and disadvantages will be given for each of the selected related software.

2.2 Related Systems

Although the technology used in this project is relatively new, we were able to find many applications that meet our project specifications. In this review, we will be discussing three of these applications. The first is related to both the Augmented Reality and 3D aspects while the second and third are related to the Augmented Reality aspect. Our application will be built by adopting the positives and overcoming the negatives of each of these systems.

2.2.1. Planner 5D

Planner 5D is a mobile application made by Planner5D, UAB. It is a home modeling app for creating 2D & 3D blueprints, detailed designs, and photo-realistic images of your project. It also has an Augmented Reality feature that allows users to place virtual objects in real-world environments.

Advantages:

- Provides the user with multiple options to design their home (2D, 3D, AR).
- Wide collection of items to choose from.
- Users can edit items to their liking (custom colors, object patterns, etc.).
- The user interface is user friendly and easy to use.

Disadvantages:

- Object manipulation is slow and unresponsive sometimes.
- AR scene is always crashing.
- Objects in the AR scene are sometimes lost when moving the camera away from them and constantly vibrating when placed on detected surfaces.
- Users are not able to use AR functionality separately and can only view their 2D or 3D designs in it.

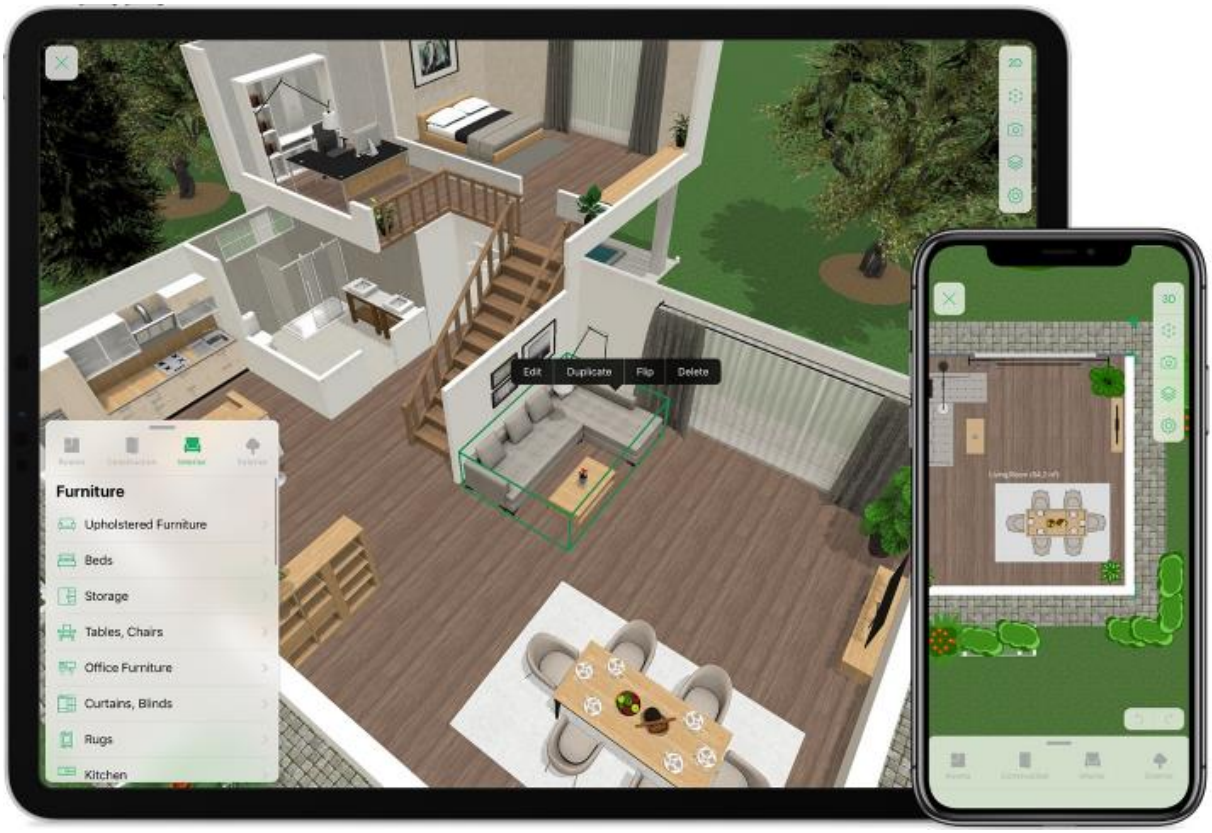


Figure 2.2.1 Planner 5D

Figure 2.2.1 shows a screenshot taken from the planner5D website. It shows a sample house built using the application and the user interface. The user interface as can be seen from the figure is simple and easy to use and the house can be viewed in both 2D and 3D.

2.2.2. Houzz

Houzz is a mobile application that connects homeowners and home professionals with a set of tools, resources, and vendors. It provides users with a shopping experience enhanced by AR technology.

Advantages:

- Well optimized for mobile phones.

- Wide collection of items to choose from.

Disadvantages:

- Internet-dependent (can't use it offline).
- Force the users to register and login to use most functions.
- Objects in the AR scene are sometimes lost when moving the camera away from them and constantly vibrating when placed on detected surfaces.

Figure 2.2.2 Houzz

Figure 2.2.2 describes the process of placing a virtual object in Houzz mobile application. First, the user must go to the item page and click on the AR button. Then the user will be taken to the AR scene so he can place the object in the desired location. The objects can be moved, rotated, duplicated, deleted, and added to the shopping cart.

2.2.3. IKEA Place

IKEA Place is a mobile application developed by Inter IKEA Systems B.V. The app allows users to place a true to scale 3D virtual objects from IKEA products in a real-world environment to make sure that the object is the right size and fit in the room.

Advantages:

- The user interface is friendly and easy to use.
- High-quality 3D items.

- Object manipulation is smooth, and the object is stable when placed on the detected surface.

Disadvantages:

- Constantly crashing.
- Most products are not available to view in AR.
- Area scanning is bugged and sometimes spawn the object with the wrong size.
- Not well optimized for mobile phone use (AR scene is slow).

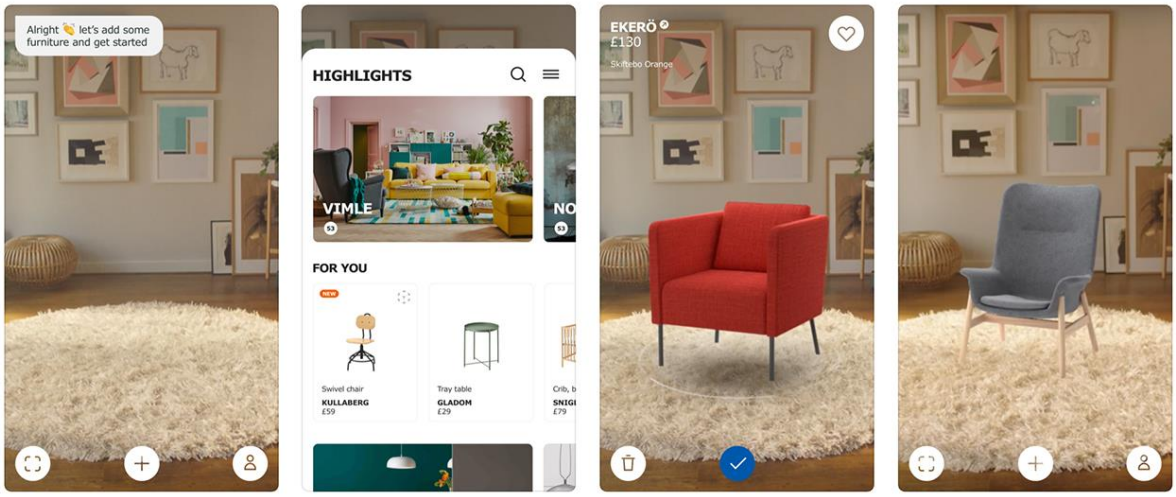


Figure 2.2.3 IKEA Place

Figure 2.2.3 describes the process of placing an object in IKEA Place application. By clicking on the + button the inventory will show up and the user can browse through the objects and choose the one to place.

Chapter 3
Project Management

3.1 Introduction

Projects must be done within a time period. They have a start date, a set of requirements that must be done according to a scheduled plan, and an end date. Project management is applying team members' skills and knowledge by using certain tools to accomplish the requirements of the project. It involves starting, planning, developing, testing, monitoring and finally closing the project.

3.2 Process Model

A process model is a detailed plan describing the phases of a product throughout its entire lifetime. Therefore, it is sometimes referred to as the Product Life Cycle. This covers every aspect of the product from the initial idea to the final installation of the product.

For this project, we have decided to go with the spiral model. The spiral model is a combination of the waterfall model and the iterative model. Each phase in the spiral model begins with a design goal and ends with the client reviewing the progress. The reason we choose this model is that changes can be made at later stages of the project and the continuous or repeated development helps in project management.

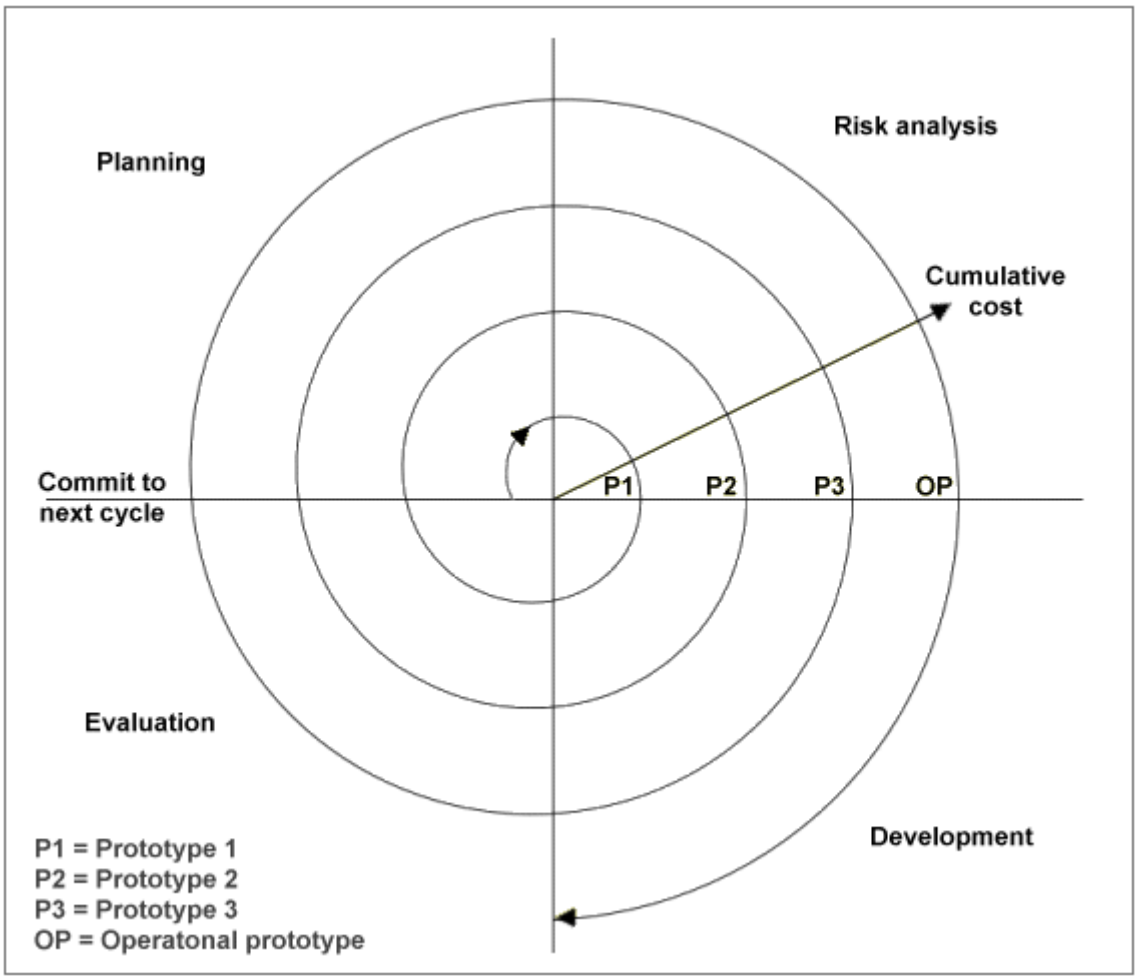


Figure 3.2.1 Spiral Process Model

3.2.1. Planning

In this phase, the system requirements will be collected.

3.2.2. Risk Analysis

In this phase, the process of identifying, analyzing, and finding solutions to possible risks is undertaken.

3.2.3. Development

In this phase, the development and testing of the system are done.

3.2.4. Evaluation

In this phase, the customer evaluates the output of the project to date before the project proceeds to the next spiral.

3.3 Risk Management

Risk management is the process of identifying potential risks that we may face during the project and to make necessary plans to minimize the efforts of such risks that might happen. It is an essential part of any project. There is a whole phase dedicated to identifying, analyzing and finding solutions to possible risks in the Spiral Process Model.

Risk Type	**Possible Risks**
people	Loss of team member
Project	Data loss
Schedule	Underestimating the time required to implement complex functionalities
Technical	The project is complex to implement
Operational	Lack of communication between team members

Table 3.3.1 Risk Identification

Risk	**Probability**	**Effect**
Loss of team member	Low	Serious
Data loss	Low	Catastrophic
Underestimating the time required to implement complex functionalities	Medium	Serious
The project is complex to implement	Low	Serious
Lack of communication between team members	Medium	Tolerable

Table 3.3.2 Risk Analysis

Risk	**Strategy**
Loss of team member	Re-divide the work among present team members
Data loss	Periodically back up system files and report in physical storage e.g. Flash memory and cloud storage e.g. one drive
Underestimating the time required to implement complex functionalities	Establish a plan for implementing each functionality including tools and skills required to better estimate the time needed to finish it.

The project is complex to implement	Divide the project into small tasks and start with the easy ones to build momentum
Lack of communication between team members	Create a meetings schedule for team members and if someone constantly skips meetings report to someone with higher authority e.g. supervisor

Table 3.3.3 Strategies Adapted

3.4 Project activities Plan

The project activity plan is a list of the project activities and an approximation of their start and end date. This gives the team, a clear path to follow and an idea based on approximation on how much time would each activity requires.

Title	T/M	Start	End	
Getting familiar with the engine and tools	T	02-Sep-19	20-Sep-19	15 days
Requirements Collection	T	21-Sep-19	28-Sep-19	5 days
System Design	T	29-Sep-19	06-Oct-19	5 days
Design 3D objects (furniture, trees, garden decorations, etc.)	T	07-Oct-19	09-Nov-19	25 days
System Development/Testing/Integration	T	10-Nov-19	10-Apr-20	110 days
Prepare system documentations	T	01-Apr-20	01-May-20	23 days

Figure 3.4.1 Activity Plan

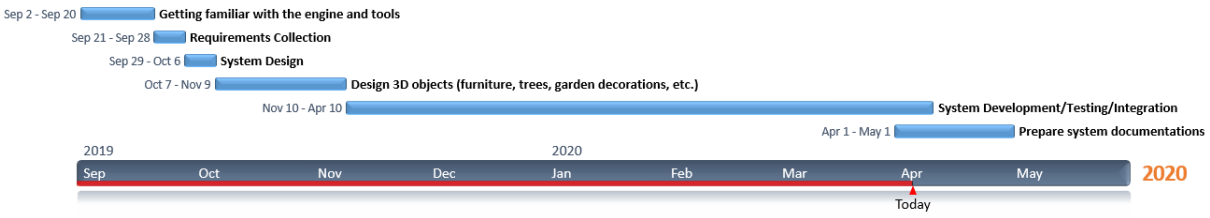


Figure 3.4.2 Gantt Chart

Chapter 4
Requirement Collection and Analysis

4.1 Introduction

Requirements collection is the process of determining the features and characteristics of a system and documenting them. The requirements have been collected through observations, analyzing similar existing applications and questionnaires. From the requirements collected, the functional and non-functional requirements of the proposed system are detailed and later analyzed using the Unified Modeling Language (UML).

4.2 Requirement Collection

The main goal of the requirement collection phase is to produce a set of system requirements that are as complete, consistent, and relevant as possible, creating a system that is ideal to the problem as much as possible (Somerville and Sawyer, 1996).

4.2.1. Quantitative data analysis

Quantitative data are measures of values or counts and are expressed in numbers. In this section, we will conduct some tests to collect some data and performance measures of the AR applications we discussed in the literature review. The data that will be collected are application size, loading time, memory usage, CPU usage, and battery life. The tests will be conducted on an iPhone XS device.

4.2.1.1 Application Size

Application size is a big factor when developing a mobile application as users are becoming more conscious about whats apps to keep and what to uninstall especially those with smaller storage spaces on their devices. Also, large file sizes are known to take longer to load and use up more energy. Figure 4.2.1 shows the sizes of the three applications we tested. The average was 192.56 MB while the average app size for IOS is 34.3 MB. This is quite a huge difference and it's mainly because 3D models can result in large file sizes.

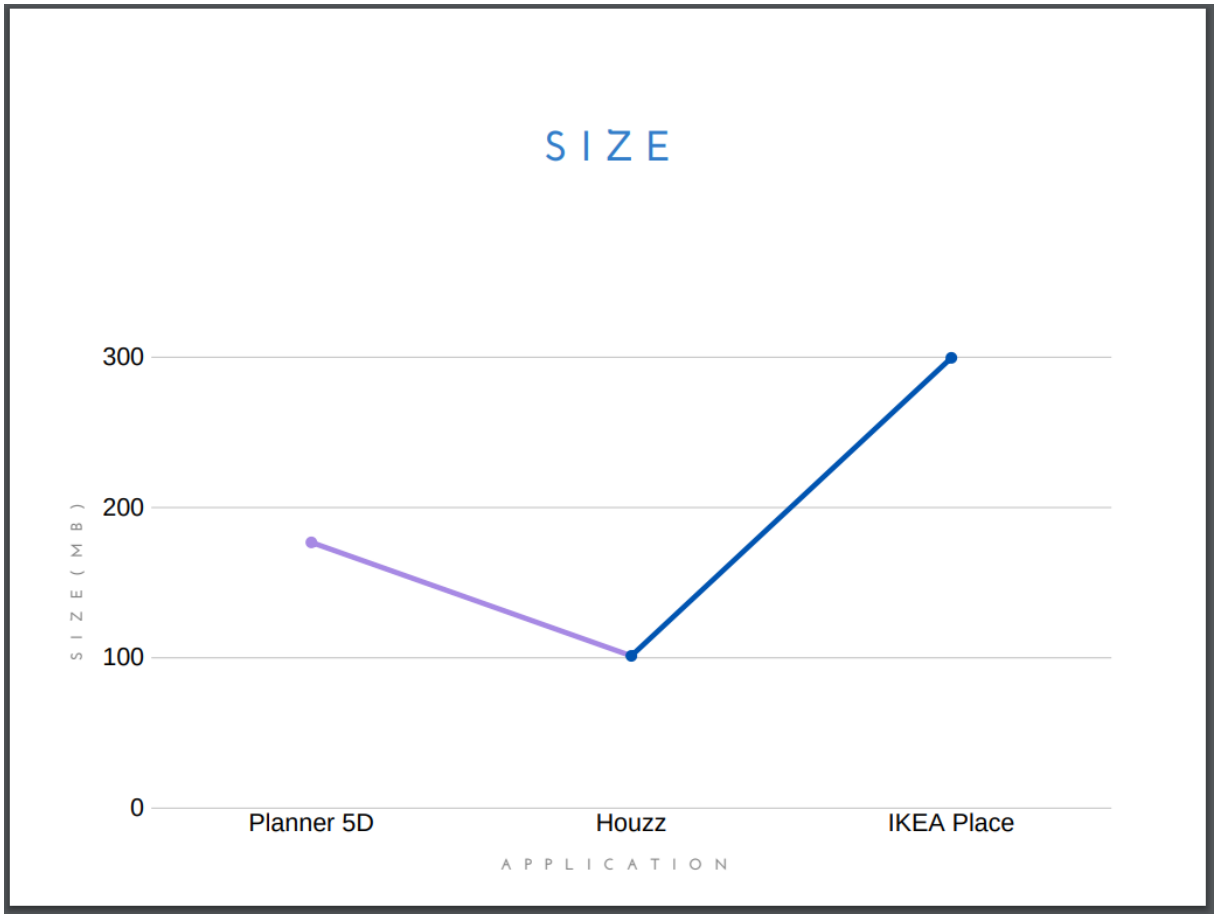


Figure 4.2.1 Application Size

4.2.1.2 Loading Time

For this test, we used windows timer application, and as soon as we'd tap on the application we would start the timer. We would then stop the timer once everything that was meant to show on the home screen appeared. This test was repeated 5 times to reduce the chances of the results being a fluke. The results were quite interesting. For two of the apps, the loading time was almost the same, Planner 5D loading time was 1.1 seconds and Houzz loading time was 0.75 seconds. The third application though, IKEA Place took 10.4 seconds to load. We couldn't find enough information on why the IKEA Place loading time was much higher than the other two as the only noticeable difference was the application sized difference, which still doesn't fully explain the huge difference between the loading times.

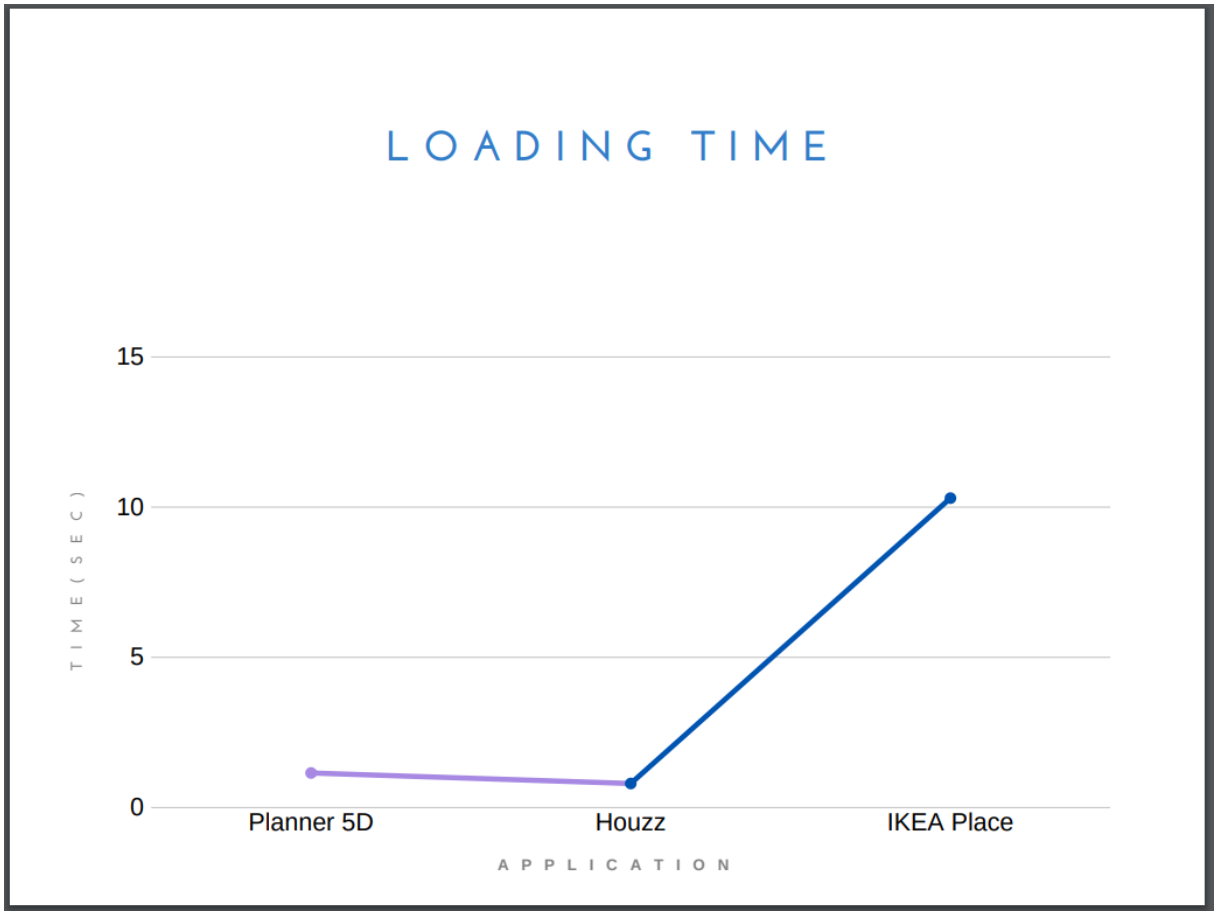


Figure 4.2.2 Application Loading Time

4.2.1.3 Memory Usage

For this test, we used a third-party application called “Lirum Info Lite” to look at the device performance measures. Before opening the app we checked the available memory and once each app is loaded we checked the available memory again and substracted it from the intimal reading. Figure 4.2.3 shows the result. From the results, it appears that the application size is a contributing factor in memory usage.

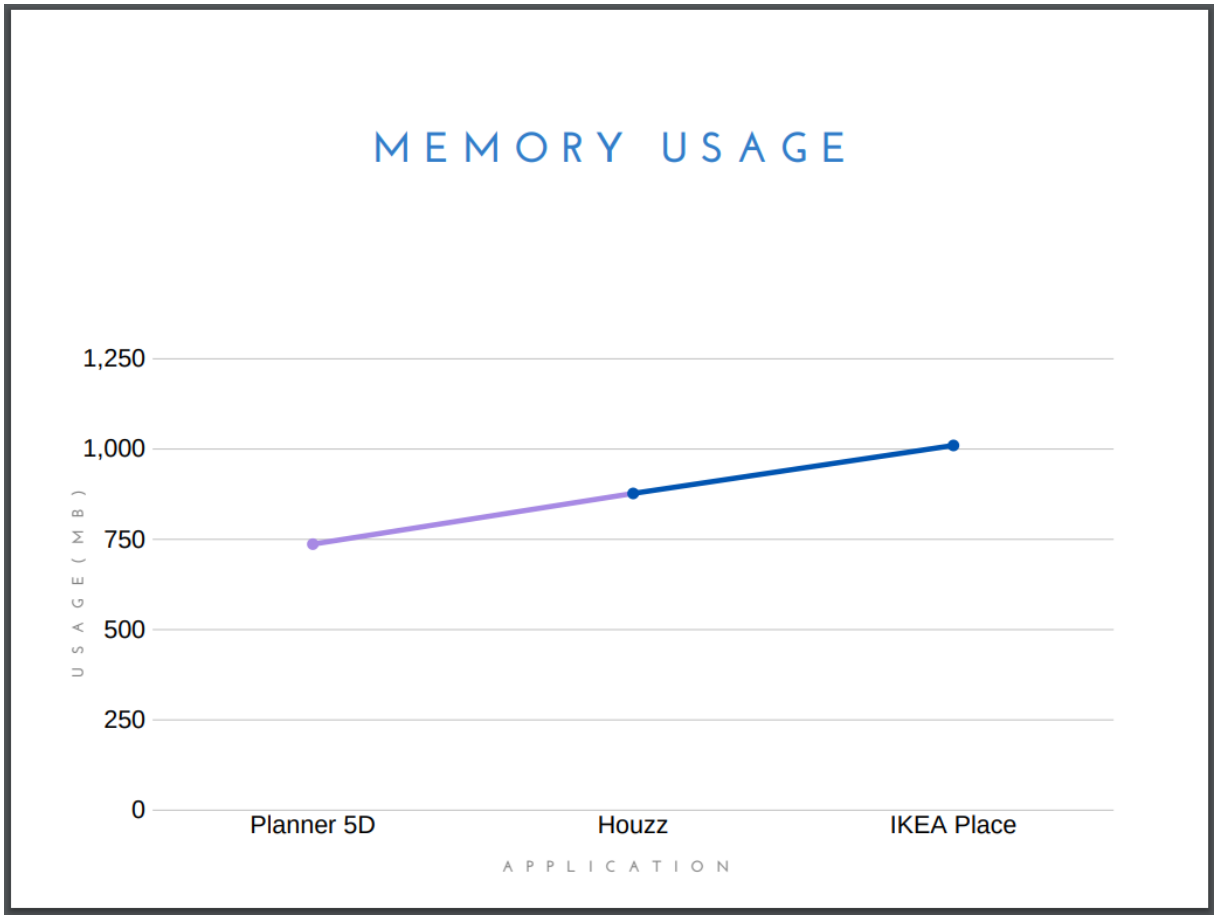


Figure 4.2.3 Application Memory Usage

4.2.1.4 CPU Usage

For this test, we did the same thing as we did with the memory usage test. We used the same application to record the CPU usage reading before and after opening the application. Figure 4.2.4 shows the results. It appears that file size was not a contributing factor in the CPU performance as IKEA Place usage is lower that Planner 5D which has a smaller size.

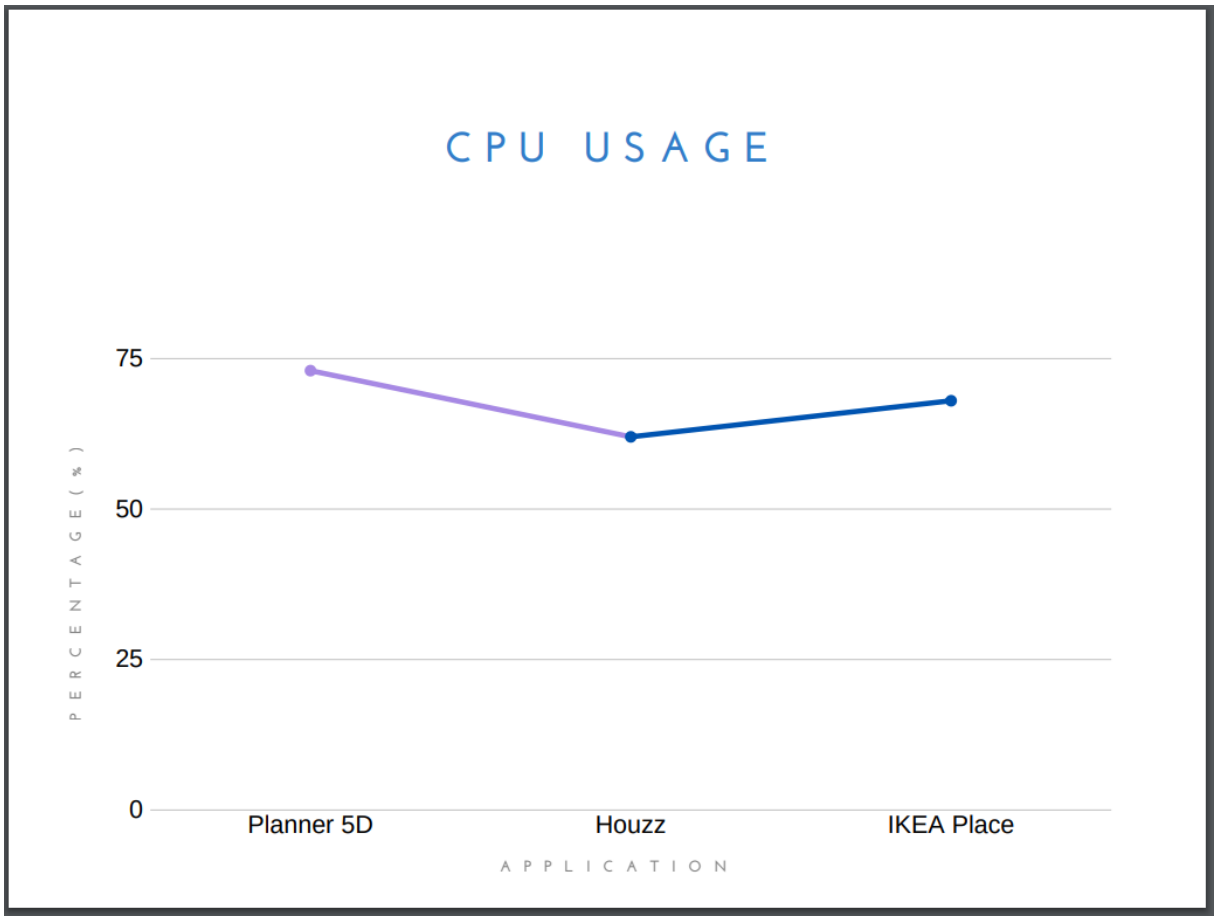


Figure 4.2.4 Application CPU Usage

4.2.1.5 Battery Usage

For this test we recorded the battery life before opening the app then once each app loaded we started a timer we had set for 10 minutes. Once the 10 minutes were over we substracted the starting battery life from the final battery life. This test was conducted 2 times for each app to ensure the results were not a fluke. Figure 4.2.5 shows the battery usage of the apps we tested. As we mentioned earlier it appears that the application size is a contributing factor to a mobile app battery life

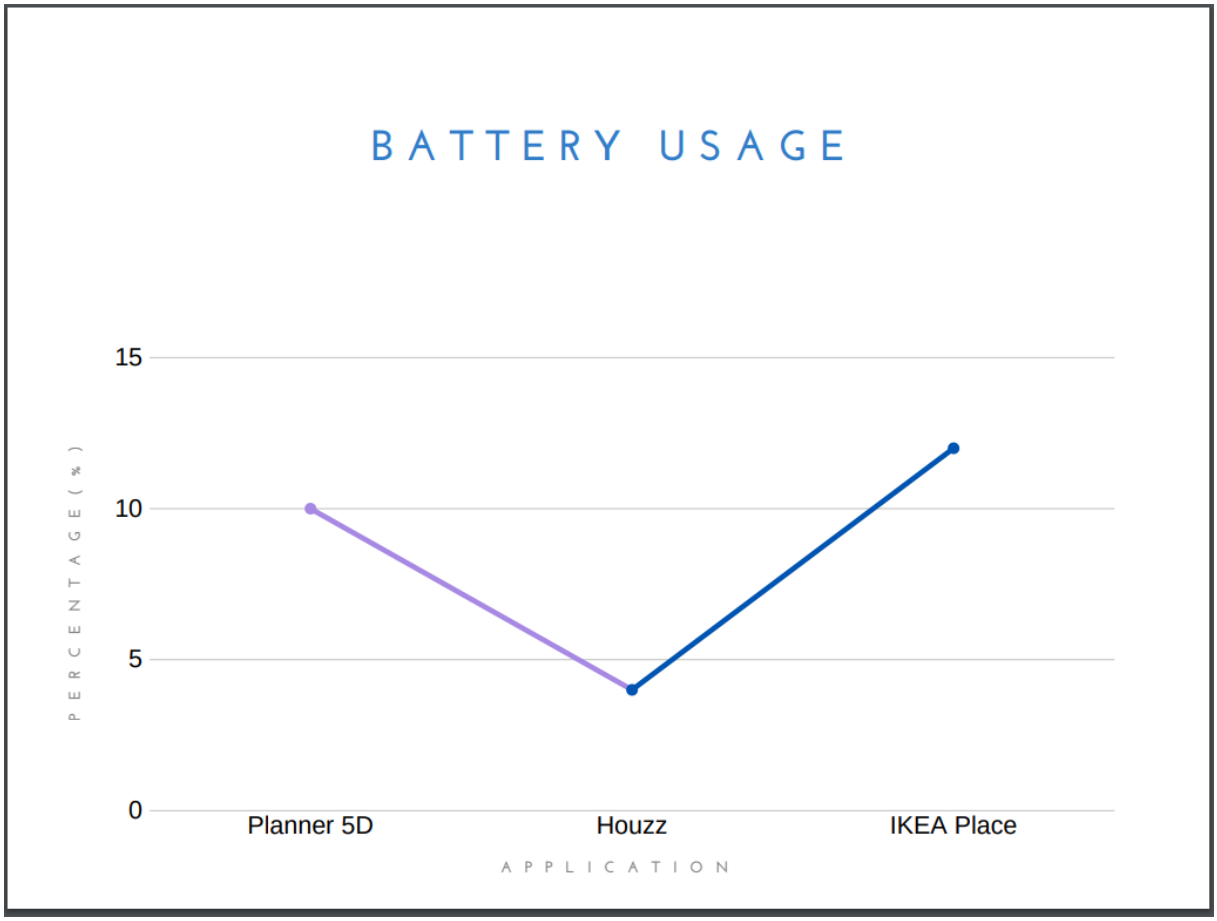


Figure 4.2.5 Application Battery Usage

4.2.1.6 Conclusion for Quantitative testing

Sometimes developers can get fixated on details like how the app looks and the quality of the 3D models and miss other important factors to making a great app. For example, when Pokemon GO came out players loved it because they could see pokemon virtually in the real world. The player's excitement though was interrupted by the application killing their batteries and using up their data.

4.2.2. Questionnaire

A survey has been made available for the public to help us collect some requirements for the system. The survey has a sample size of 53 and their responses are as follows.

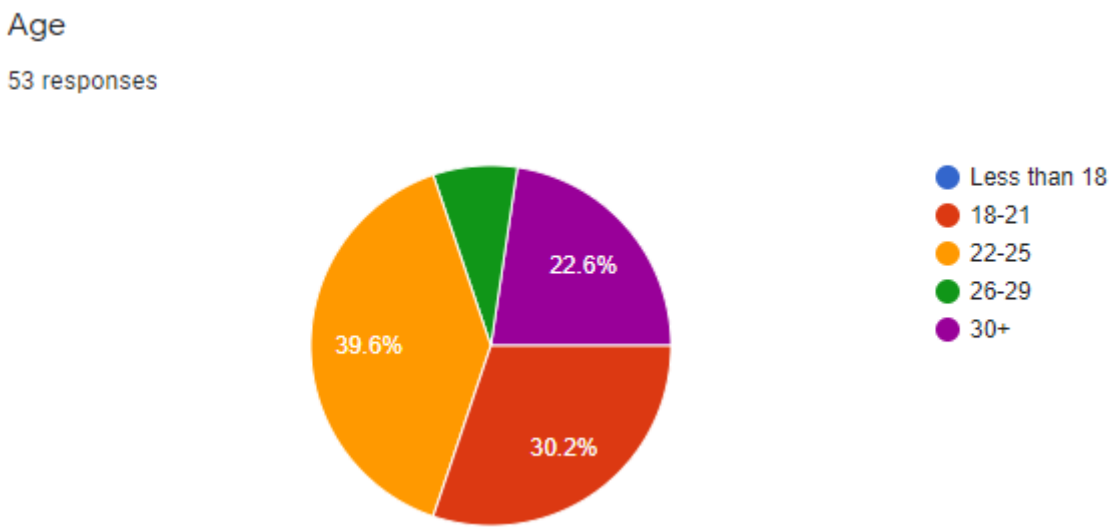


Figure 4.2.6 Question 1

Figure 4.2.6 shows the age demographic of the participants. We asked this question to make sure that the results represented a general audience.

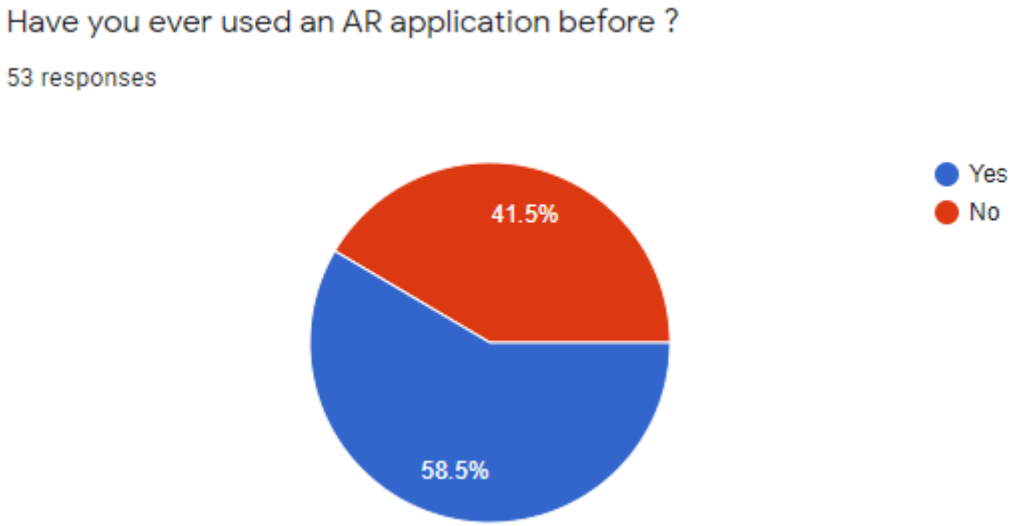


Figure 4.2.7 Question 2

Figure 4.2.7 shows that 58.5% of the participants have used an AR application.

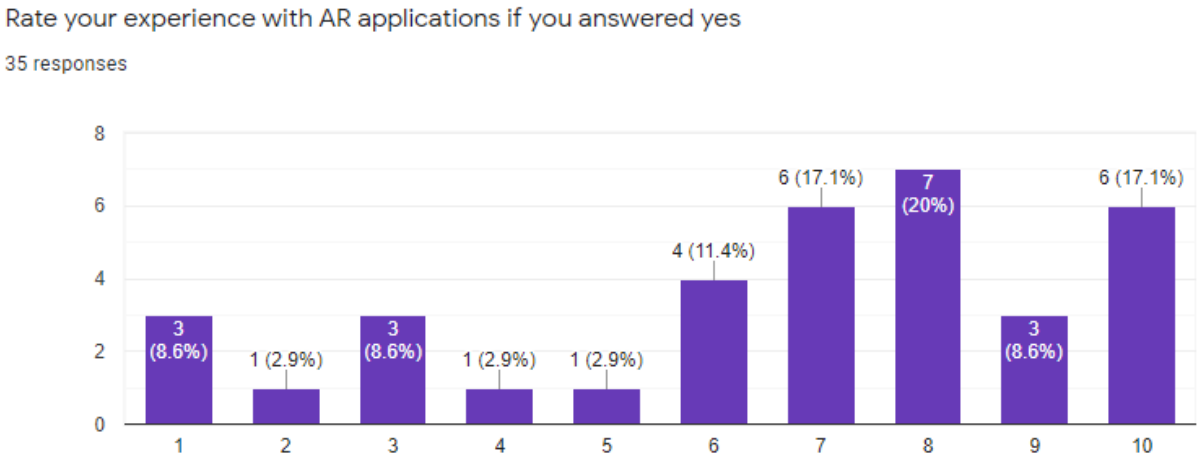


Figure 4.2.8 Question 3

Figure 4.2.8 shows the satisfaction level of the participants that used an AR application before. 74.2% of the participants gave a rating of 6 or higher which indicates that they had a good experience with AR applications.

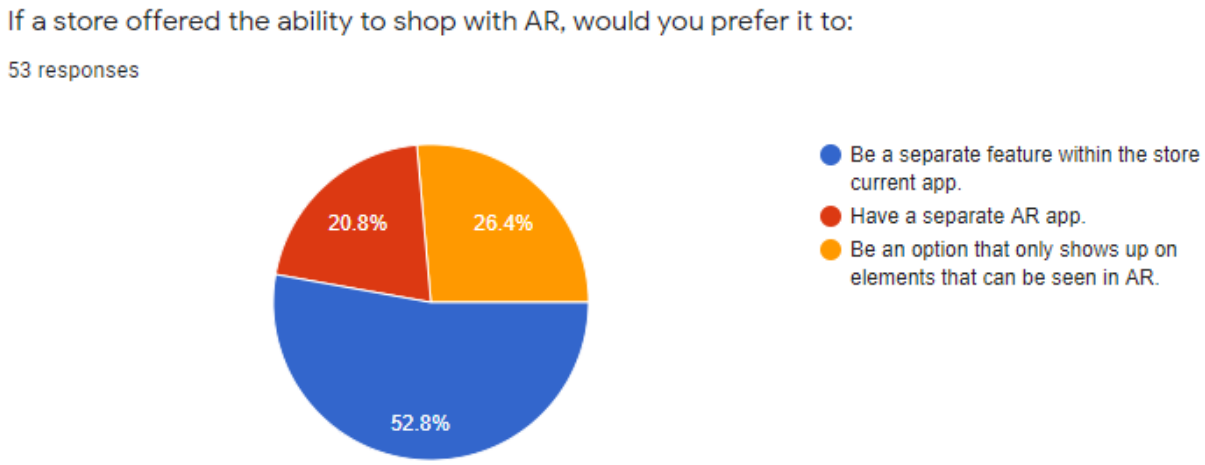


Figure 4.2.9 Question 4

Figure 4.2.9 shows the participant's opinion regarding how to implement AR in an e-commerce application. 52.8% of the participants think it's better to add it a separate feature to the existing application, 26.4% thinks it should be an option that only appears on items that can be viewed in AR, while the other 20.8% thinks that it should have a separate application.

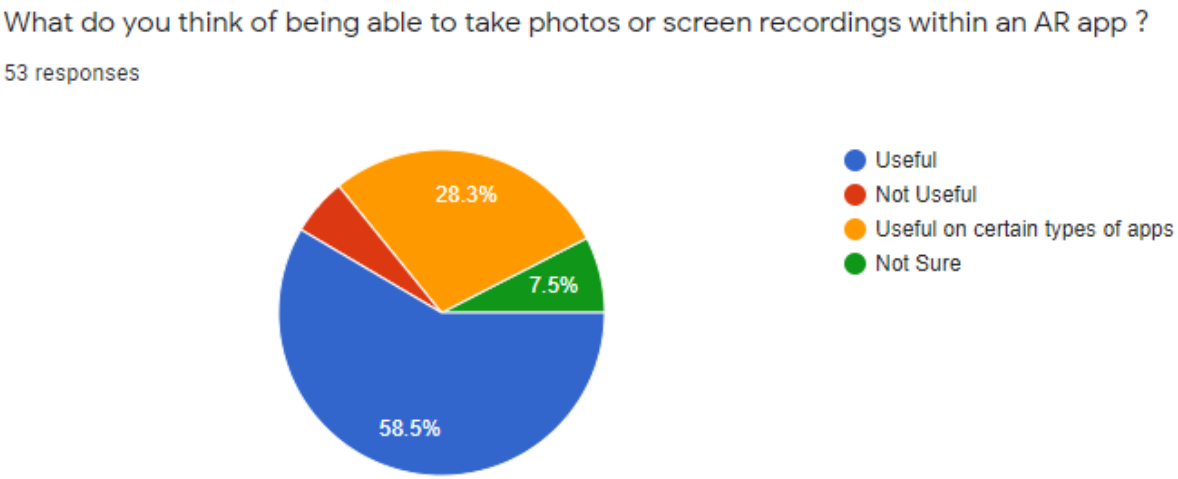


Figure 4.2.10 Question 5

Figure 4.2.10 shows what the participants think of a feature that allows you to record a video or take pictures of the AR scene including the virtual objects. 58.5% thinks that it's a useful feature, 28.3% thinks that it's only useful in certain types of applications, 7.5% are not sure, while the rest think it's not useful at all.

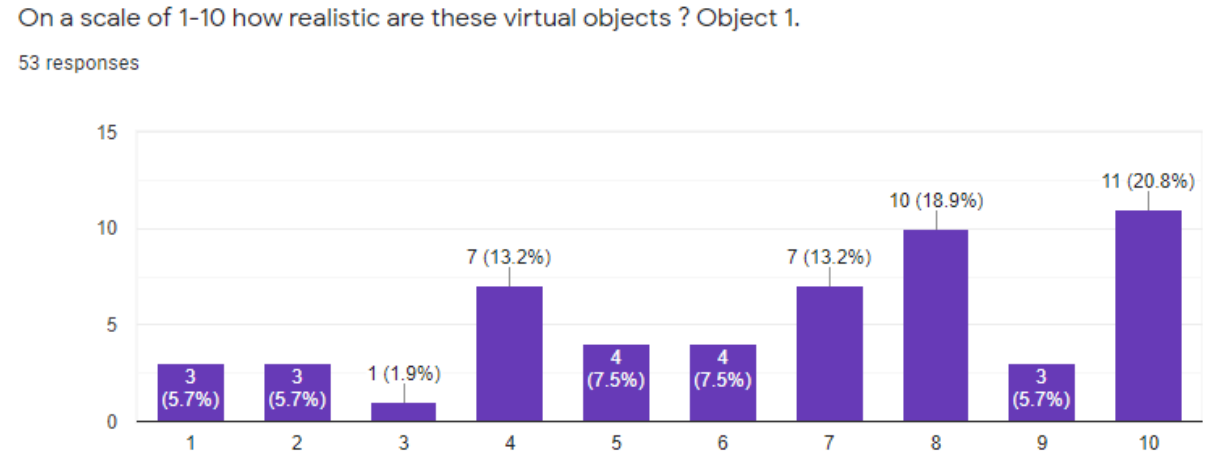


Figure 4.2.11 Chair

Object 2.

53 responses

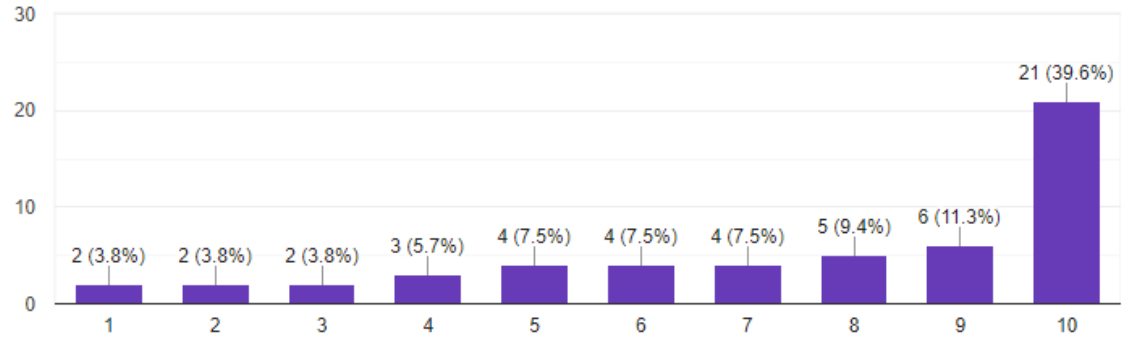


Figure 4.2.12 Carpet

Object 3.

53 responses

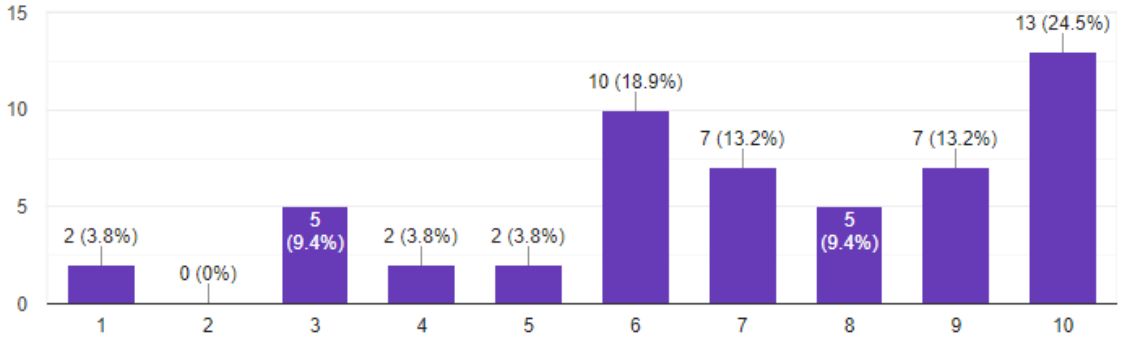


Figure 4.2.13 Sofa

Object 4.

53 responses

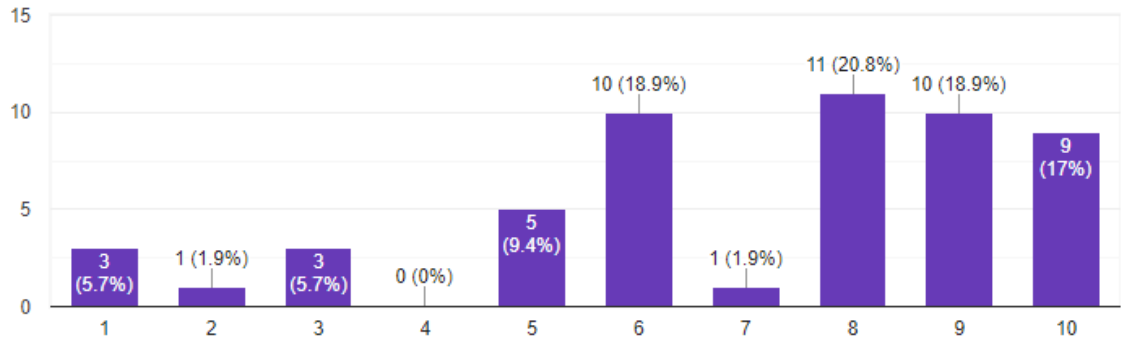
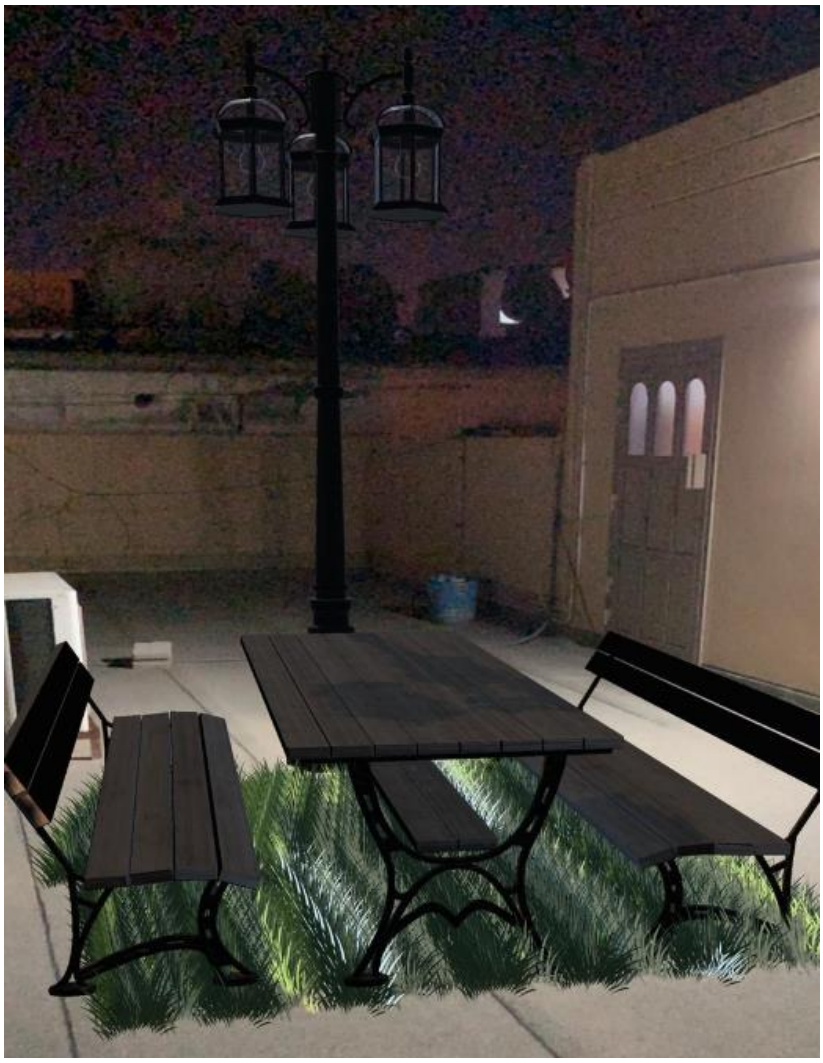


Figure 4.2.14 Table



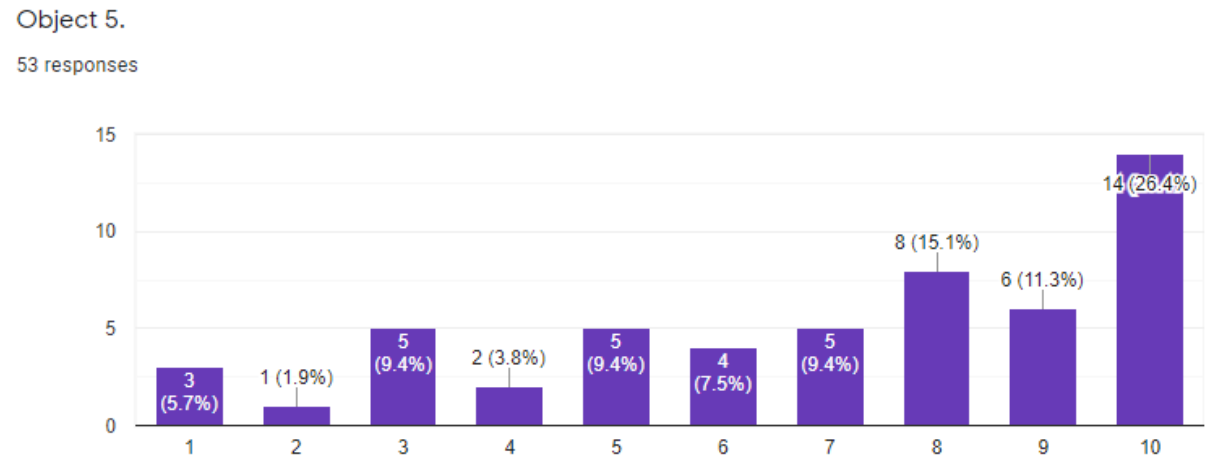


Figure 4.2.15 Garden

Figures 4.2.11- 4.2.15 shows some of the objects we will use in our application. Most of the participants responded positively to the quality of the objects as seen in the scores.

4.3 System Requirement

System requirements are the functionalities that must be available in the system to be built and the restraints on how the system should operate are defined as requirements that can be functional or non-functional requirements.

4.3.1. Functional Requirements

Functional requirements define the functions of the system and its components. A function is described as a set of inputs, the behavior, and outputs.

Our application consists of three main components divided into smaller functions. An Augmented Reality component that allows users to place virtual objects in real-world, a 3D Builder component that provides a virtual environment for users to build full houses from scratch and a shop component that allows users to purchase plants and furniture.

Below we will list the functional requirements for these components:

1- AR, 3D Builder, and Shop common functionalities:
   - FR-01: Browse objects: The user must be able to browse through the available objects.
   - FR-02: Add to cart: The user must be able to add objects to the shopping cart.

2- Shop:
   - FR-03: Purchase: The user must be able to purchase any product via credit card.
   - FR-04: Object page: The user must be able to view the object page containing all details about it.
   - FR-05: View in AR: The user must be able to click a button in the object page to view it in AR.

3- Augmented Reality:
   - FR-06: Detect surfaces: The user must be able to detect horizontal e.g. floor and vertical surfaces e.g. walls and be able to disable detection.
   - FR-07: Object info: The user must be able to view and disable the placed object details above it (name, price, and size).
   - FR-08: Take picture: The user must be able to take a picture of the AR session.
   - FR-09: Pause & Resume: The user must be able to pause and resume the AR session.

4- 3D Builder:

- FR-10: Build a house: The user must be able to place walls, floor, and ceiling to build a house.
- FR-11: Change building material: The user must be able to change the walls, floor, and ceiling color and building material (wood, bricks, etc.).
- FR-12: Save & Load: The user must be able to save and load his designs.
- FR-13: View in AR: The user must be able to view his full design in AR.

5- AR & 3D Builder common functionalities:

- FR-14: Place object: The user must be able to select and place objects in the scene.
- FR-15: Manipulate object: The user must be able to move, rotate, and delete the placed objects.
- FR-16: Reset scene: The user must be able to reset the session and delete all placed objects.
- FR-17: Change Quality: The user must be able to change the quality of the placed objects to match his device capabilities.

FR-01	**Browse objects**
Description	The user must be able to browse through the available objects.
Activities	• The system must display the available objects and plants in the form of categories (chairs, tables, plants, etc.).

Source of requirement	Observation
Priority	High

Table 4.3.1 Browse Objects Function

FR-06	**Detect Surfaces**
Description	The user must be able to detect horizontal e.g. floor and vertical surfaces e.g. walls and be able to disable detection.
Activities	• The system must detect the area the user scanned with his phone and identify horizontal surfaces like floors and vertical surfaces like walls. • The system must be able to distinguish between horizontal and vertical surfaces since some objects are meant only to be placed in horizontal surfaces, such as carpets and chairs, some other types of objects are meant only to be placed on vertical surfaces, such as paintings and lamps.
Source of requirement	Observation
Priority	High

Table 4.3.2 Detect Surfaces Function

FR-14	**Place Object**
Description	The user must be able to select and place an object in the scene.
Activities	• The system must allow users to select an object from the inventory. • The system must place the selected object based on the user tap position.

Source of requirement	Observation
Priority	High

Table 4.3.3 Place Object Function

FR-15	**Manipulate Object**
Description	The user must be able to move, rotate, and delete the placed object.
Activities	• The system must recognize user gestures (tap, drag, twist). • The system must allow the user to move (drag), rotate (twist) the selected object based on his gesture. • The system must display a button above the object to allow users to delete it. • The system must remove the placed object if the button is clicked.
Source of requirement	Observation
Priority	High

Table 4.3.4 Manipulate Object Function

FR-16	**Reset Scene**
Description	The user must be able to reset the session and delete all placed objects.
Activities	• The system must display a button to allow users to reset the scene. • The system must delete all placed objects when the button is clicked.

Source of requirement	Observation
Priority	High

Table 4.3.5 Reset Scene Function

4.3.2. Non-Functional Requirements

Non-Functional Requirement describes how a system behaves. It also defines the limits and constraints of the system. Moreover, non-functional requirements specify the quality attributes of the system. There are many non-functional requirements such as Availability, Reliability, Recoverability, Maintainability, and more. The non-functional requirements of the system are the following:

- **Usability:** The system should be easy to use. The simplicity and clarity of its interface make it a user-friendly system.
- **Efficiency:** The system must be time-efficient. It should be built in a way that will avoid slowing it down.
- **Performance:** The system must perform well and fast
- **Flexibility:** The system must be able to increase the number of its functions to adapt to any changes that happen in the future.
- **Reusability:** The system should have the ability to store some of its building blocks in a library so that other systems and products can also use them.
- **Reliability:** The system must operate in a user-acceptable manner and preserve its performance over time.
- **Availability:** The system must always be available for the users.
- **Portability:** The system must have the ability to run across multiple platforms and operating systems.
- **Maintainability:** The system should be easy to modify and repair to adapt to any situation or a changing technological environment.
- **Robustness:** The system should be able to prevent and deal with errors.

Chapter 5
System Design

5.1 Introduction

After identifying the system requirements, we will now move on to the Design phase. The purpose of this phase is to draw a general outline of how the user interface will appear like after development, along with its features, the functionalities of the buttons, and also the general structure of the system to improve the understanding of the system we will develop using Unified Modeling Language (UML).

5.2 Card-Based Prototype (pseudo design)

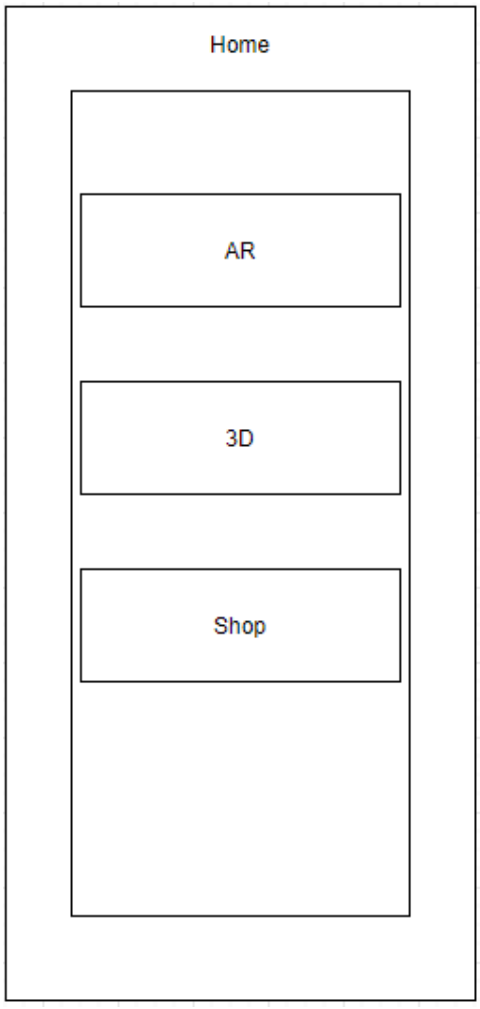


Figure 5.2.1 Home Screen

Figure 5.2.1 shows the first screen that will show when opening the application. It contains buttons to navigate to each feature in the app.

5.2.1. AR

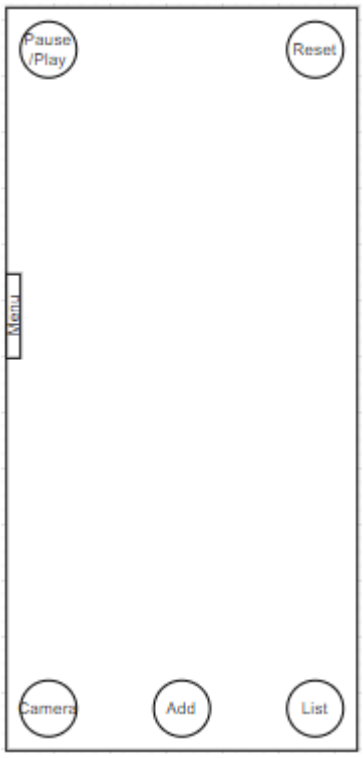


Figure 5.2.2 AR Home Screen

Figure 5.2.2 shows the AR feature Home Screen.

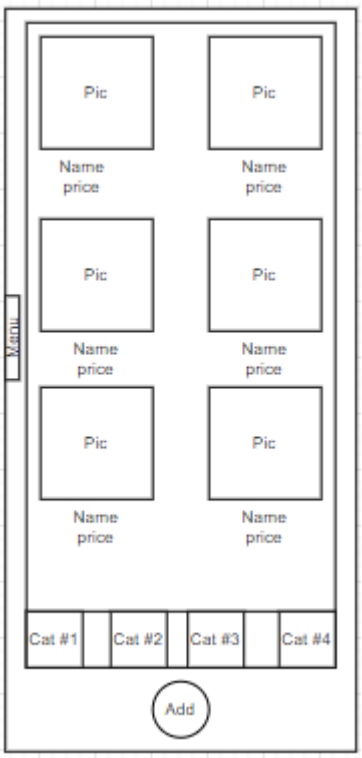


Figure 5.2.3 AR Inventory

Figure 5.2.3 shows the items inventory in the AR Scene.

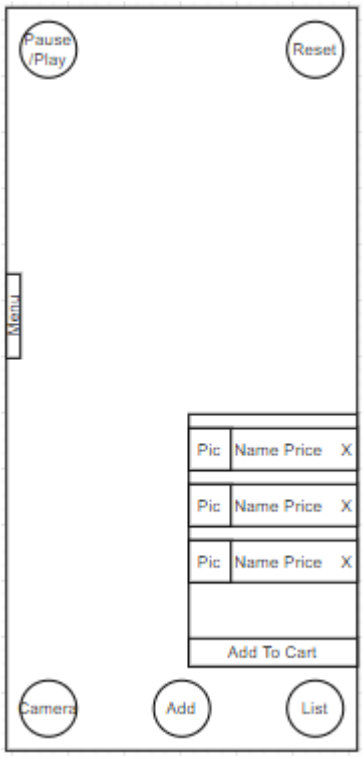


Figure 5.2.4 AR Items List

Figure 5.2.4 shows a temporary list that will contain the items the user added to the scene and is considering buying them.

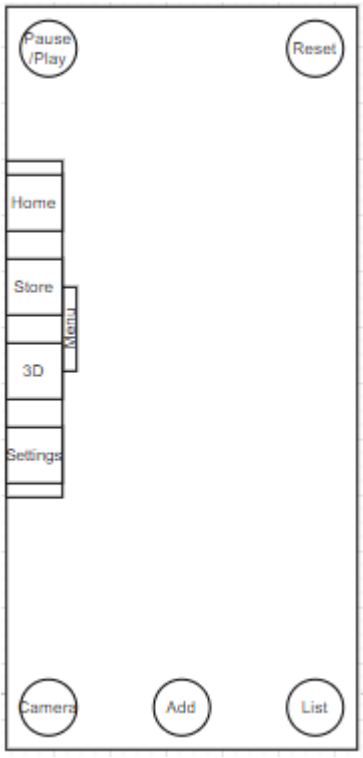


Figure 5.2.5 AR Side Menu

Figure 5.2.5 shows the Side Menu of the AR scene. It contains navigation and settings buttons.

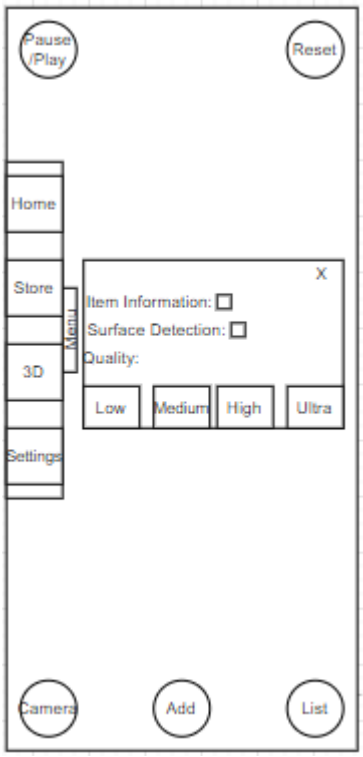


Figure 5.2.6 AR Settings

Figure 5.2.6 shows the settings menu of the AR scene. It contains options to disable/enable surface detection, disable/enable item information, and change the quality of the objects.

5.2.2. Shop

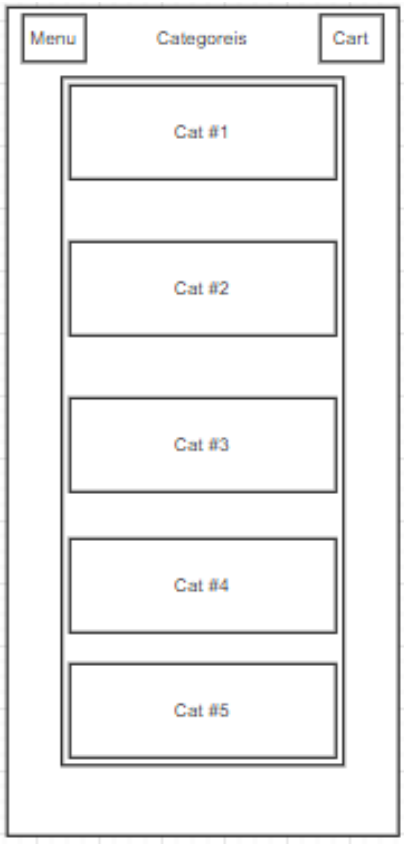


Figure 5.2.7 Catagories

Figure 5.2.7 shows the categories page. It contains a list of available categories, a side menu button, and a cart button.

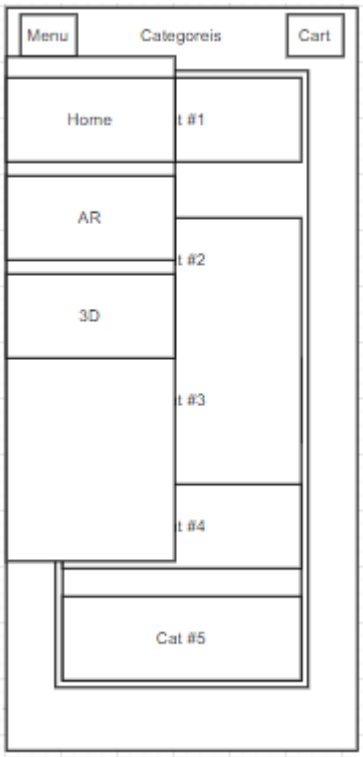


Figure 5.2.8 Shop Side Menu

Figure 5.2.8 shows the side menu of the shop scene. It contains navigation buttons for other scenes.

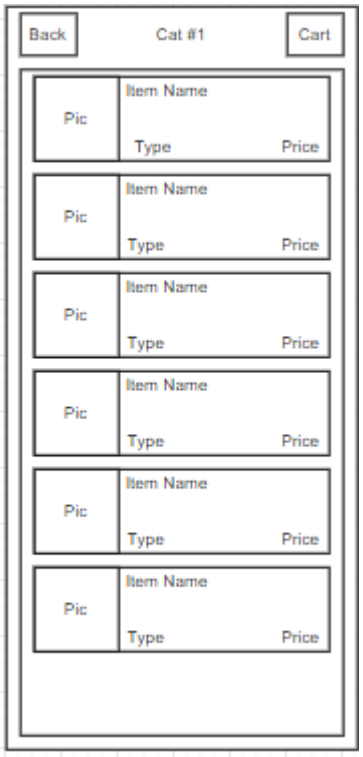


Figure 5.2.9 Sample Category

Figure 5.2.9 shows how each category will look like.

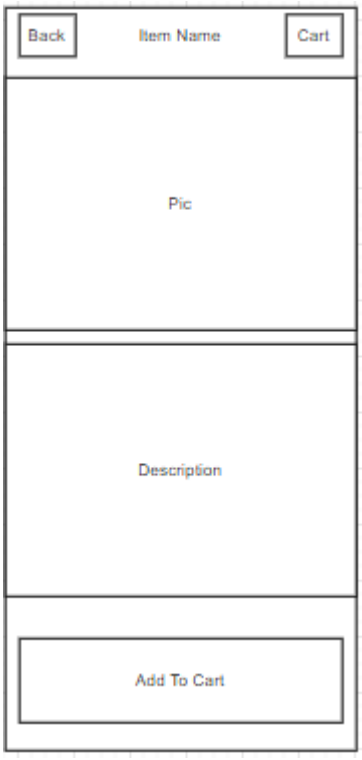


Figure 5.2.10 Item Page

Figure 5.2.10 shows the item page.

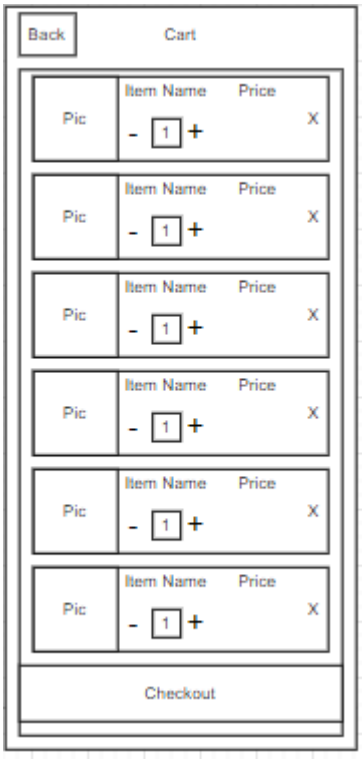


Figure 5.2.11 Shopping Cart

Figure 5.2.11 shows the shopping cart.

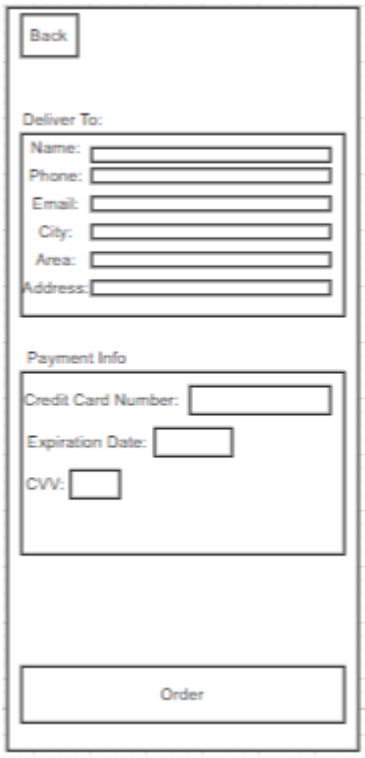


Figure 5.2.12 Checkout Page

Figure 5.2.12 shows the checkout page.

5.2.3. 3D Builder

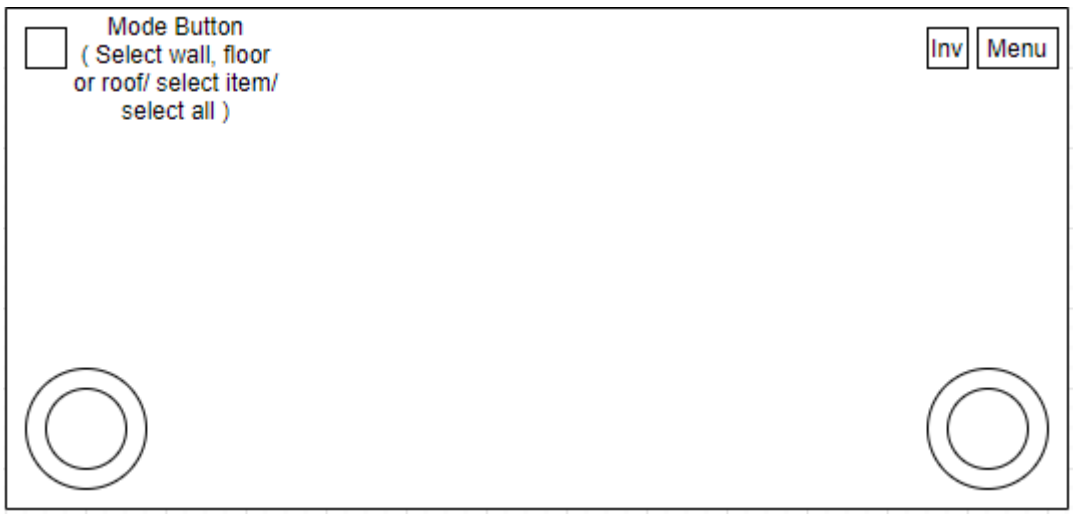


Figure 5.2.13 3D Builder Home

Figure 5.2.13 shows the home screen of the 3D Builder scene. The two circles at the bottom are joysticks to move the scene camera.

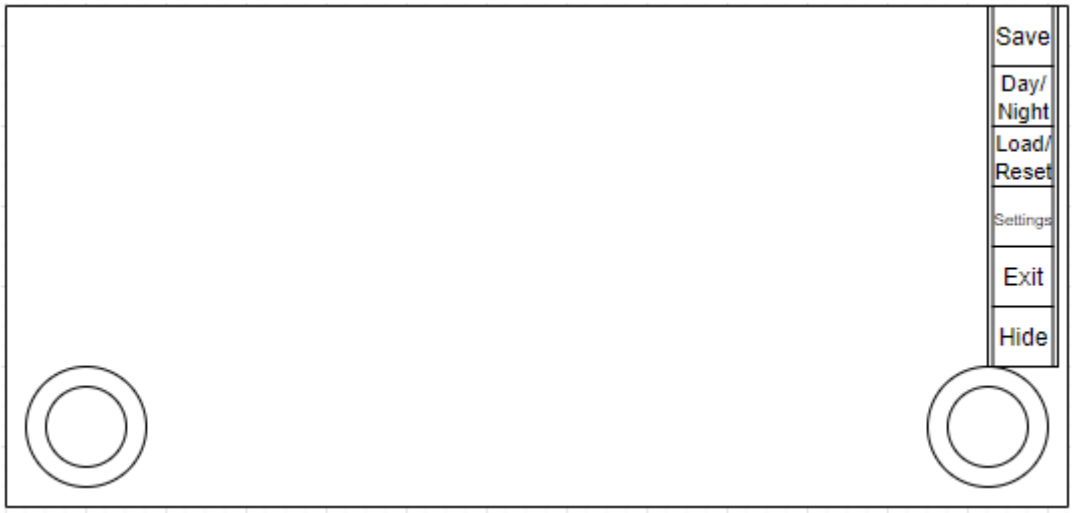


Figure 5.2.14 3D Side Menu

Figure 5.2.14 shows the side menu of the 3D Builder scene.

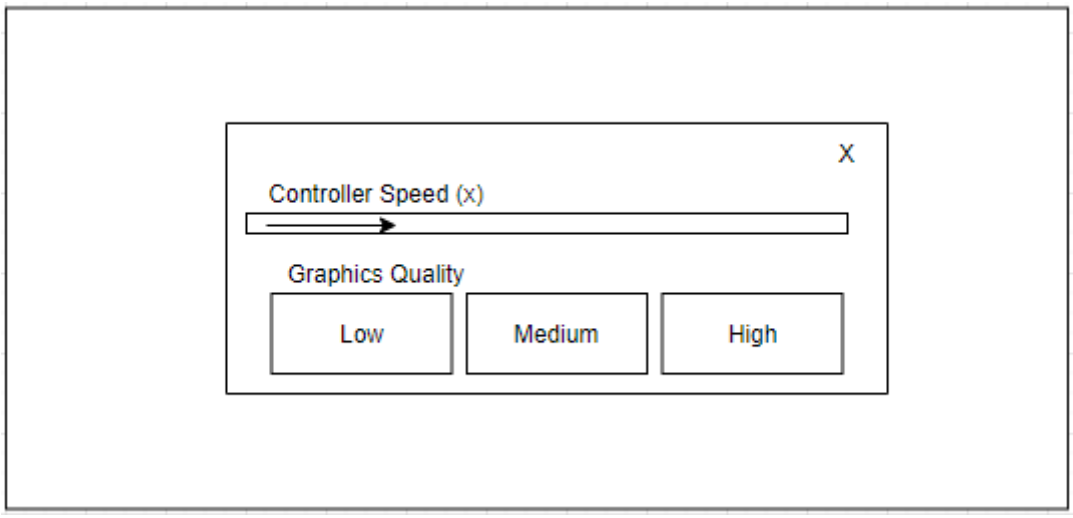


Figure 5.2.15 3D Builder Settings

Figure 5.2.15 shows the settings panel of the 3D Builder Scene.

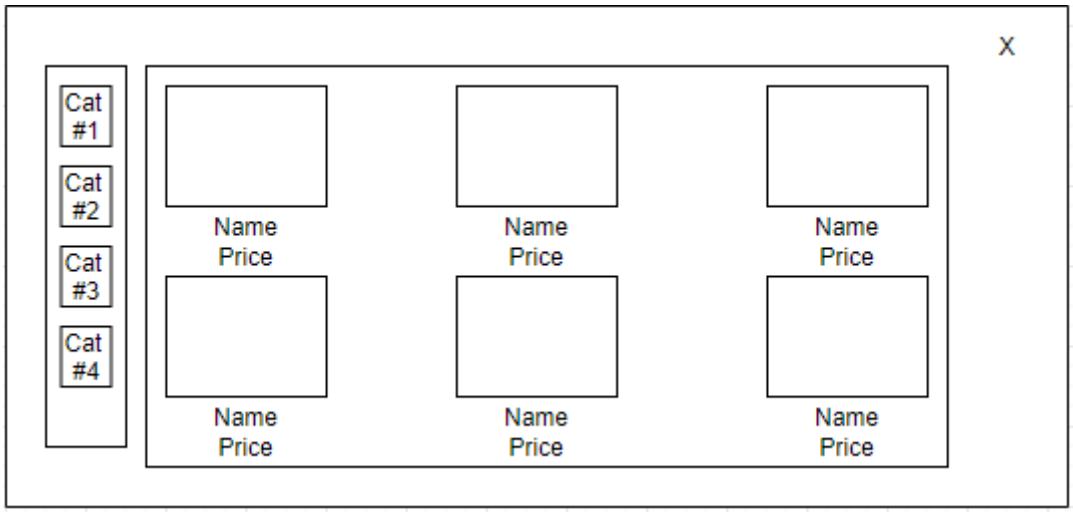


Figure 5.2.16 3D Builder Inventory

Figure 5.2.16 shows the inventory of the 3D builder Scene.

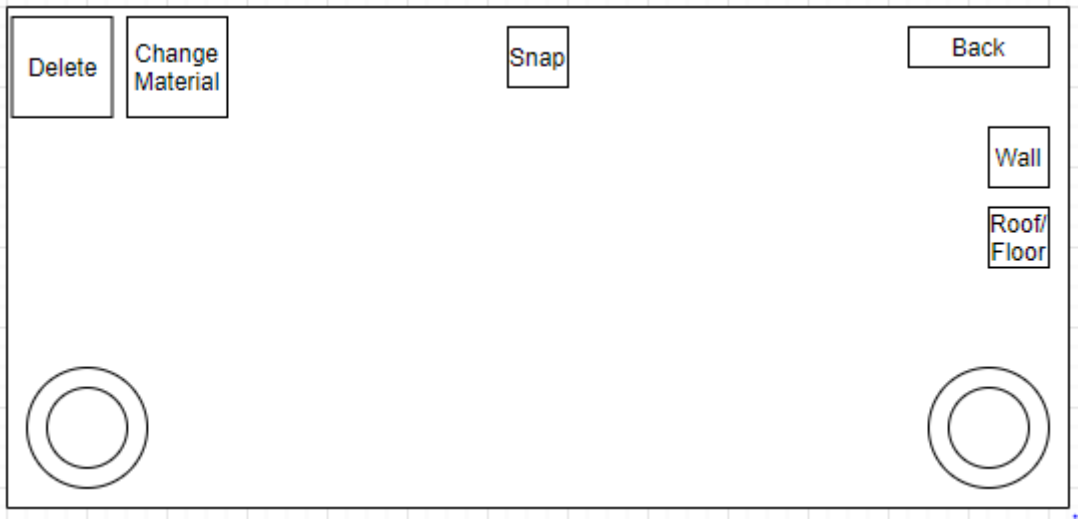


Figure 5.2.17 Building Object Selected

Figure 5.2.17 shows the screen that shows when a building block is chosen (walls, floors, roofs).

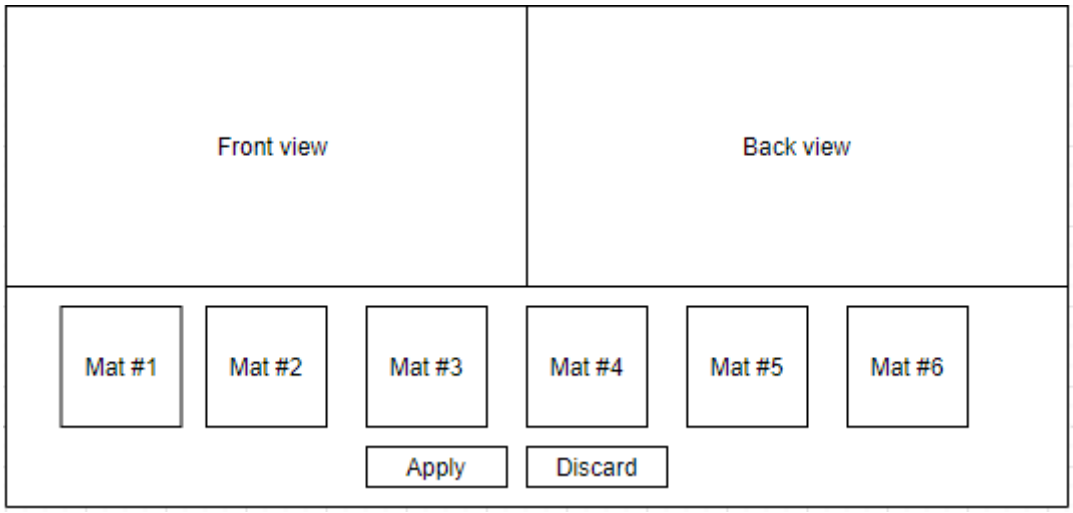


Figure 5.2.18 Material Change

Figure 5.2.18 shows the change material panel. The user changes only change the material of a building block (walls, floors, roofs).

5.3 Unified Modeling Language (UML)

Unified Modeling Language (UML) is a standardized modeling language enabling developers to specify, visualize, construct, and document artifacts of a software system.

5.3.1. Use Cases

Use case diagrams are used to show the usage requirements for a system. UML Use Cases are used for actual development to provide significantly more value because they describe the core of the requirements.
Use case diagrams depict:

- **Use cases**. A use case depicts the sequence of actions that provides something of measurable value to an actor. It is shown by a horizontal ellipse.

Figure 5.3.1 Use Case

- **Actors**. An actor is a person, organization, or external system that plays a role in one or more interactions with your system. Actors are drawn as stick figures.

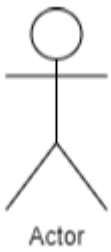


Figure 5.3.2 Actor

- **Associations**. Associations between actors and use cases are shown in use case diagrams by solid lines. An association exists whenever an actor is involved with an interaction described by a use case. Associations are modeled as lines connecting use cases and actors.

Figure 5.3.3 Associations

- **Include.** Sometimes a use case is necessary for another use case to be utilized. This case is linked by a dotted arrow from the dependent use-case to the depended

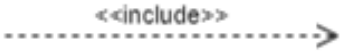


Figure 5.3.4 Include

- **Extend.** Occasionally, A uses case is optional, in utilization, while another Use case is operating. The extend relation is shown by a dotted arrow from the optional use case towards the main use case.

Figure 5.3.5 Extend

5.3.1.1 AR

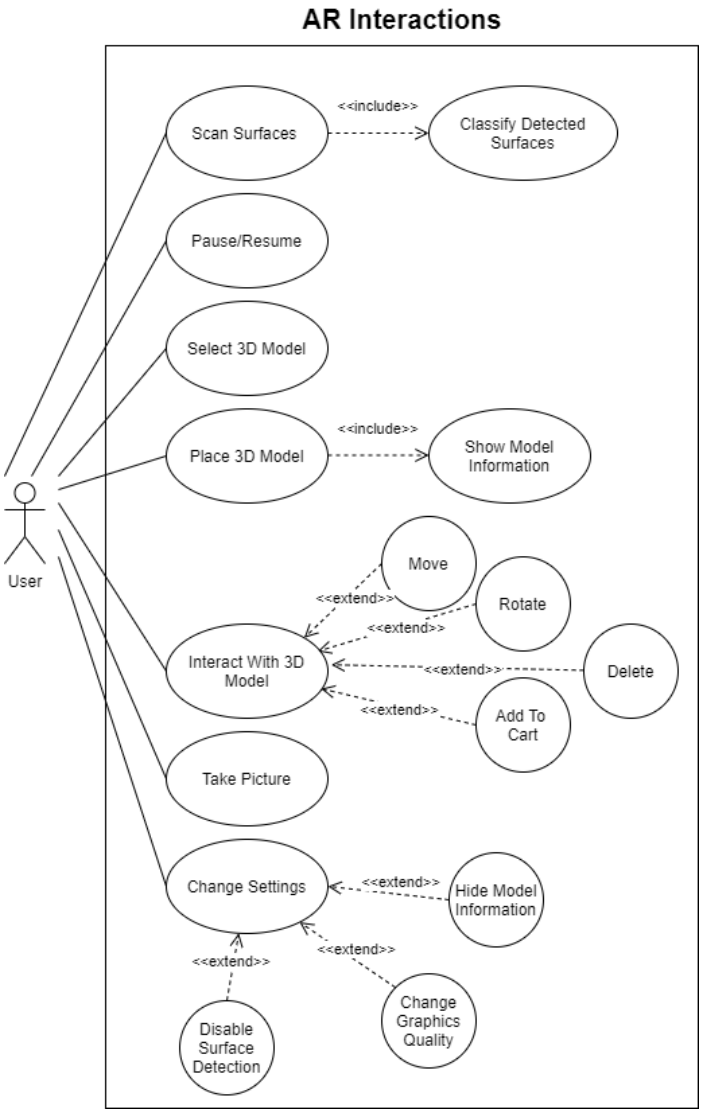


Figure 5.3.6 Use Case 1

Scan Surfaces: The user scans the area with his device and the detected surfaces are classified into horizontal and vertical surfaces. This important because some models can only be placed on horizontal surfaces eg. Chairs and other models can only be placed on vertical surfaces eg. Paintings.

Pause/Resume: The user can pause the screen which means that the camera will freeze on the last frame before pausing creating a still image that the user can still place models in and interact with them. He can then resume the screen.

Select 3D Model: The user selects the model he's interested in from a list.

Place 3D Model: The user taps on the device screen to place the selected model. Information about the placed model will appear above it (Name, Price, and Dimensions).

Interact With 3D Model: The user can select and move, rotate, delete, or add the selected model to cart.

Take Picture: The user can take a picture of the scene including the placed models and excluding the user interface.

Change Settings: The user can hide the placed models information, disable/enable surface detection, and change the graphics quality of the placed objects.

5.3.1.2 3D Builder

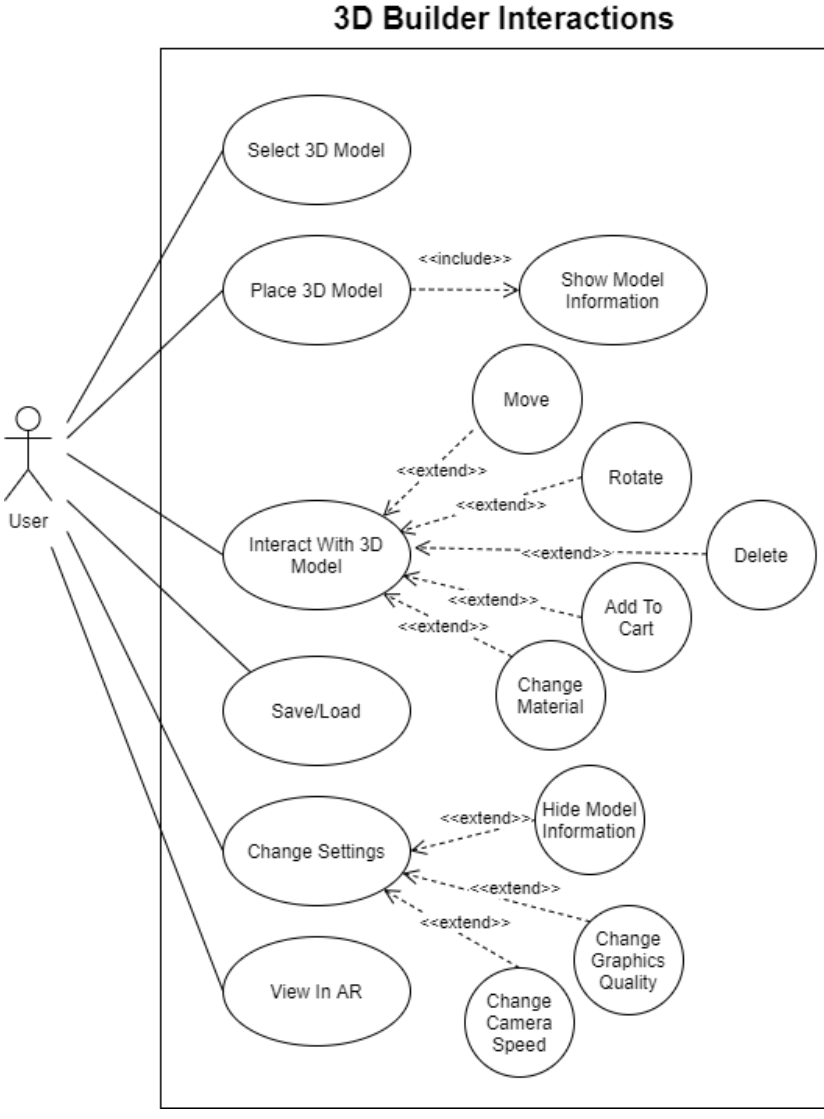


Figure 5.3.7 Use Case 2

Select 3D Model: The user selects the model he's interested in from a list.

Place 3D Model: The user taps on the device screen to place the selected model. Information about the placed model will appear above it (Name, Price, and Dimensions).

Interact With 3D Model: The user can select and move, rotate, delete, or add the selected model to cart. The user can also change the material of the building blocks only (walls, floors, and roofs).

Save/Load: The user can save his designs in a list for later use. He can then select the design he wants to load from the list.

Change Settings: The user can hide the placed models information, control the camera speed, and change the graphics quality of the placed objects.

View In AR: The user can view the full model in AR.

5.3.1.3 Shop

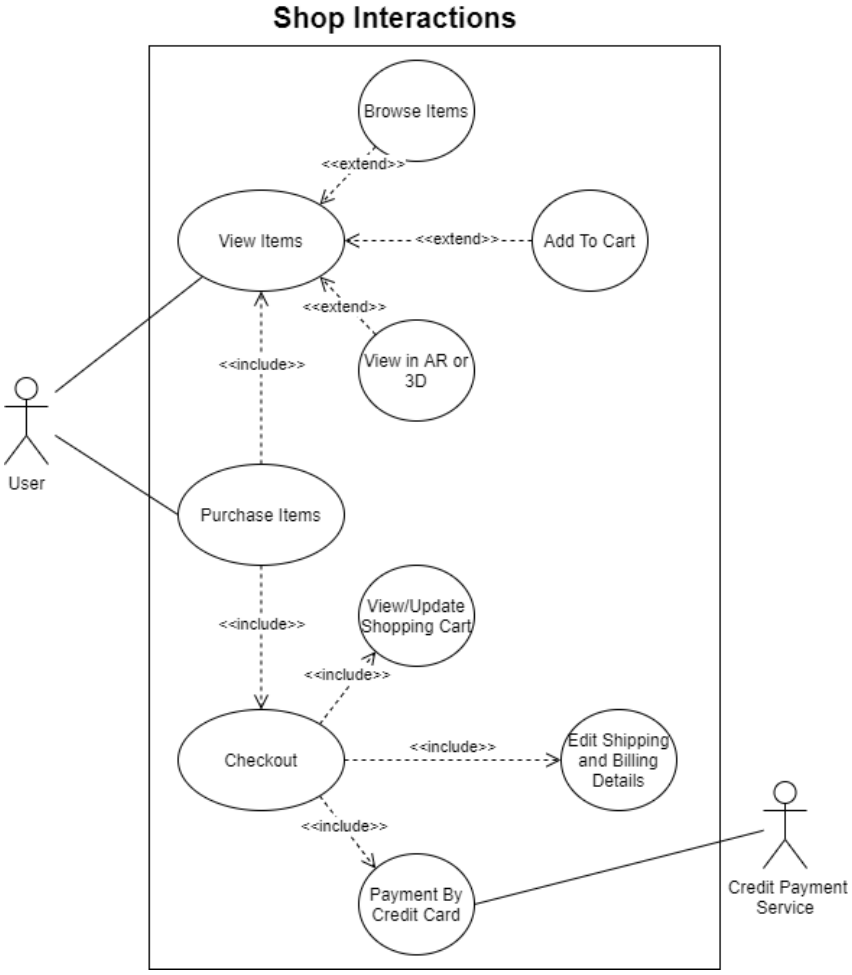


Figure 5.3.8 Use Case 3

View Items: The user can browse the available items and view their information (Picture, Name, Price, and Description). The items are separated into categories. He can also view the

item in AR or 3D. He can then add the items to the shopping cart if he wants. This use case can be used as part of the Purchase Items use case.

Checkout: This is an included use case that can't be used by itself. Its part of the Purchase Items use case. The user can view the shopping cart, edit the quantity of the items, or delete them. He then enters his address and payment details and proceeds to payment.

5.3.2. Sequence Diagrams

Sequence diagrams describe interactions among classes in terms of an exchange of messages over time. They're also called event diagrams. A sequence diagram is a good way to visualize and validate various runtime scenarios.

5.3.2.1 Place Object in AR

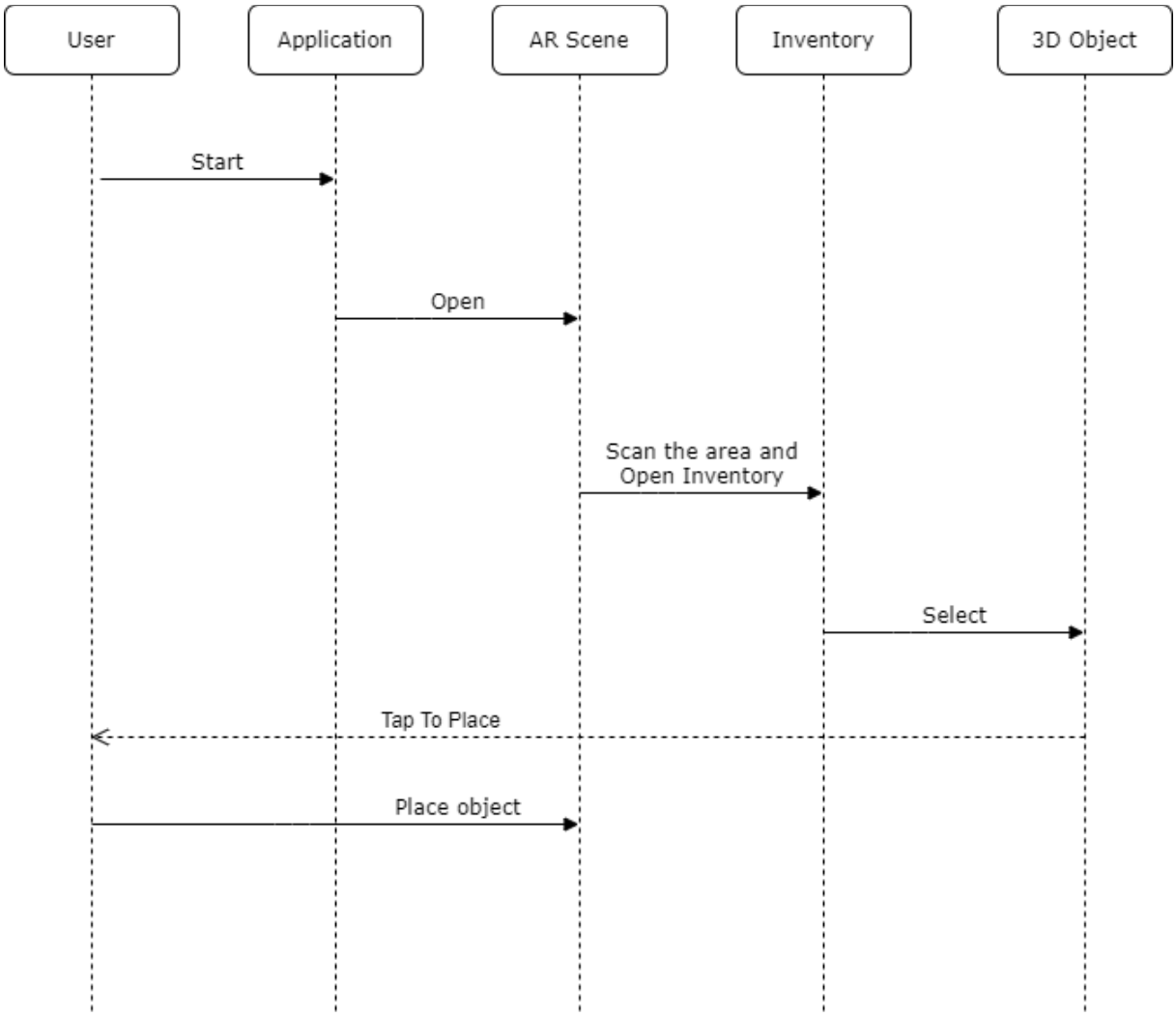


Figure 5.3.9 Sequence Diagram 1

Step 1: The user starts the application.

Step 2: The user opens the AR Scene.

Step 3: The user scans the area and opens the model's inventory.

Step 4: The user selects the model he wants to place.

Step 5: A message will appear asking the user to tap on the desired place to place the model.

Step 6: The user taps on the screen to place the model.

5.3.2.2 View shop item in AR

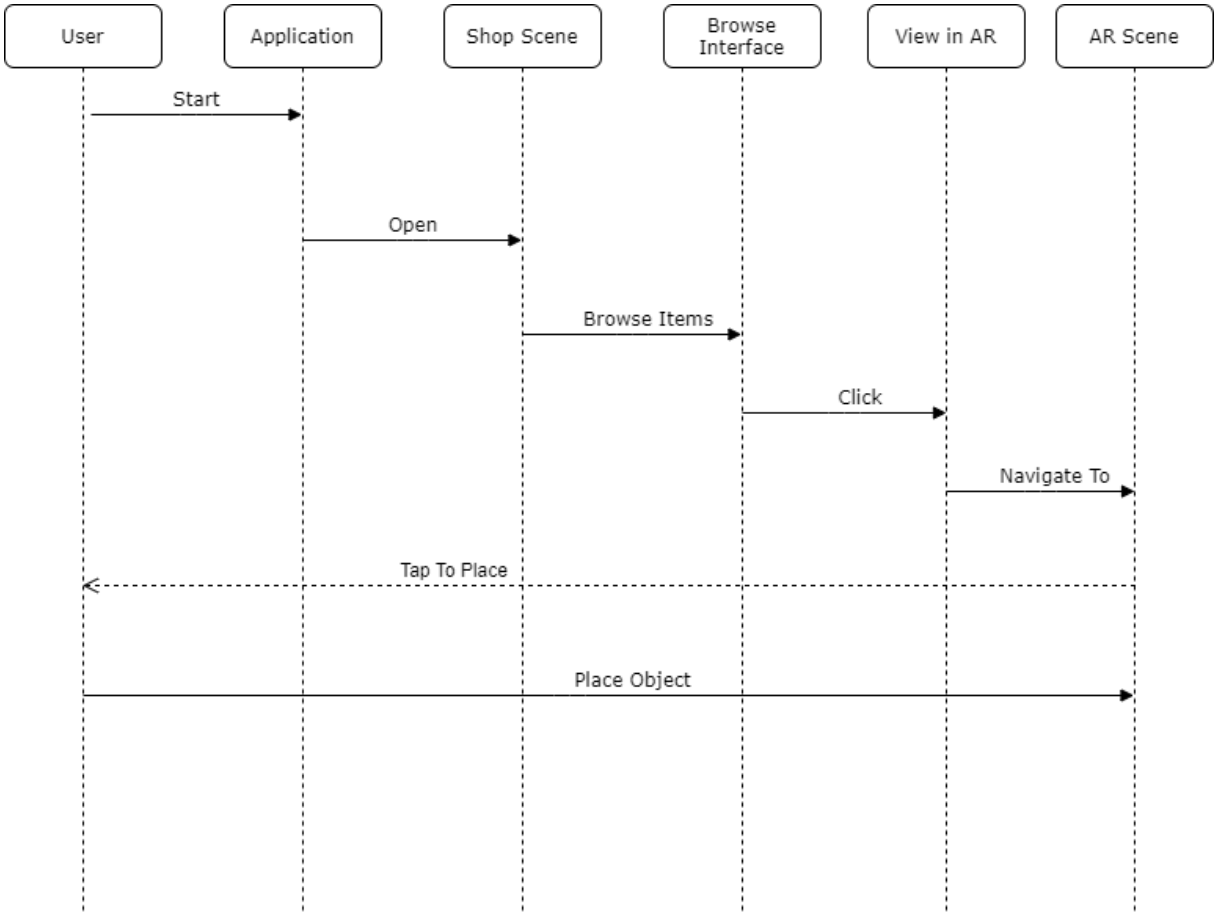


Figure 5.3.10 Sequence Diagram 2

Step 1: The user starts the application.

Step 2: The user opens the shop scene.

Step 3: The user browses through and selects the item he wants.

Step 4: The user clicks on the view in the AR button.

Step 5: The user is navigated to the AR Scene.

Step 6: A message will appear asking the user to tap on the desired place to place the model.

Step 7: The user taps on the screen to place the model.

Chapter 6
System Implementation

6.1 Introduction

In the previous chapter, we completed the design phase which includes designing the system along with the interface. In this chapter, we will discuss the tools that will be used to develop the system and to design the 3D models that we will use in the application. Along with the development of the system.

6.2 Tools and Softwares' used

One language was used during this phase as well as some software's. A brief explanation will be given about the language and each software and the reason for using them.

6.2.1. Development

Below is a list of all the tools, software's and programming languages used to develop the Application:

1-Visual Studio:

Visual Studio is an IDE developed by Microsoft. It's used to develop websites, mobile apps, web apps, and web services. We used Visual Studio because it supports C# language which is the programming language used by the unity game engine and because it was recommended by unity to be used as an external editor.

2-Xcode:

Xcode is an integrated development environment for macOS containing a suite of software development tools developed by Apple for developing software for macOS, iOS, iPad, watchOS, and tvOS. We used Xcode to build our application into IOS devices.

3-Android Studio:

Android Studio is the official integrated development environment for Google's Android operating system, built on JetBrains' IntelliJ IDEA software and designed specifically for

Android development. It is available for download on Windows, macOS, and Linux based operating systems. We used Android Studio to build our application into Android devices.

4-Unity:

Unity is a cross-platform game engine used to create 2D, 3D, Virtual Reality (VR) and Augmented Reality (AR) games, as well as other types of applications. We chose unity to develop our app because it provides a built-in cross-platform AR development framework called AR Foundation. It uses a language we're familiar with (C#) and because its more suitable for mobile development, whereas Unreal Engine is a little bit heavy for mobile use.

5-AR Foundation:

AR Foundation a cross-platform framework built for AR development that allows developers to deploy their applications across multiple mobiles and wearable AR devices. We used AR Foundation because it contains the core functionalities of both ARKit and ARCore frameworks. This allowed us to build one app that works on both IOS and Android devices.

6-ARKit & ARCore:

ARKit and ARCore Augmented reality frameworks developed by Apple and Google respectively. They use the device camera feedback to add virtual objects to a real-world environment. We used ARKit and ARCore as plugins in unity to be able to use AR Foundation.

7-XR Interaction Toolkit:

XR Interaction Toolkit is a unity package that provides a framework that makes 3D object interactions available from the unity input event system. We used XR Interaction Toolkit for objects manipulation (select, move and rotate) and object information overlay (display information above the object).

8-Universal Rendering Pipeline (URP):

Rendering Pipeline: A rendering pipeline is a set of functions used to process graphics commands on the GPU.

Universal Rendering Pipeline is a unity made customizable rendering pipeline that lets you display high-quality graphics across different platforms ranging from mobile to PC's while

maintaining device performance. We used URP because it's easily customizable and enables us to place high-quality objects without compromising device performance.

This is how a rendering pipeline works in AR Applications:

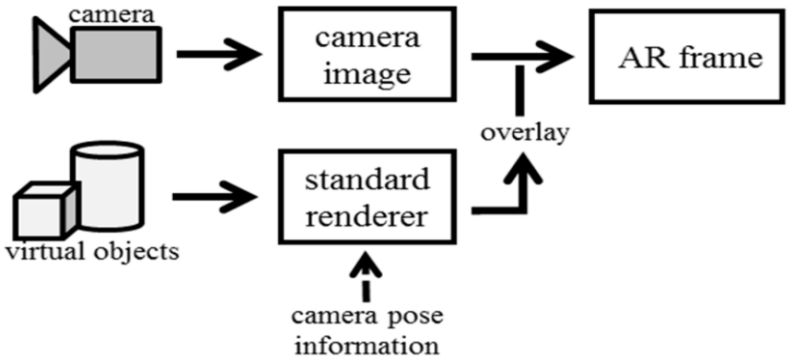


Figure 6.2.1 Rendering Pipeline

9-C#:

C# is a general-purpose programming language developed by Microsoft as part of its .NET imitative. It’s the primary scripting API of the Unity game engine.

10-JSON:

JSON (JavaScript Object Notation) is a lightweight data-interchange format. It’s a syntax used for storing and exchanging data. We used JSON because we needed a way to store some variables that we need to perform some of the app functionalities.

6.2.2. 3D Design

Below is a list of all the tools and software’s used to design and configure the 3D objects used in the Application:

Some important terms:

Vertices: A position (usually in 3D space) along with other information such as color, normal vector, and texture coordinates.

Edges: A connection between two vertices.

Face: A set of closed edges.

Polygons: A set of faces.

Mesh: A mesh is the structural build of a 3D model consisting of polygons.

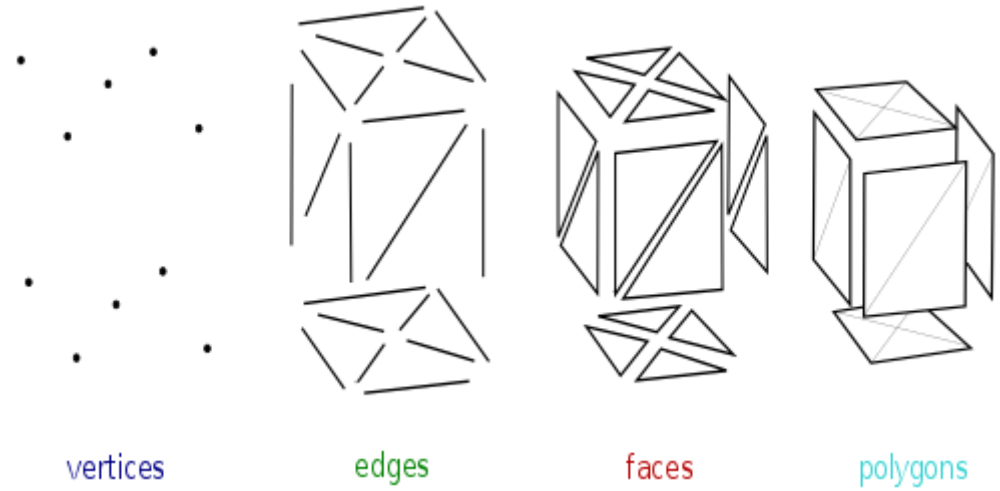


Figure 6.2.2 Mesh Components

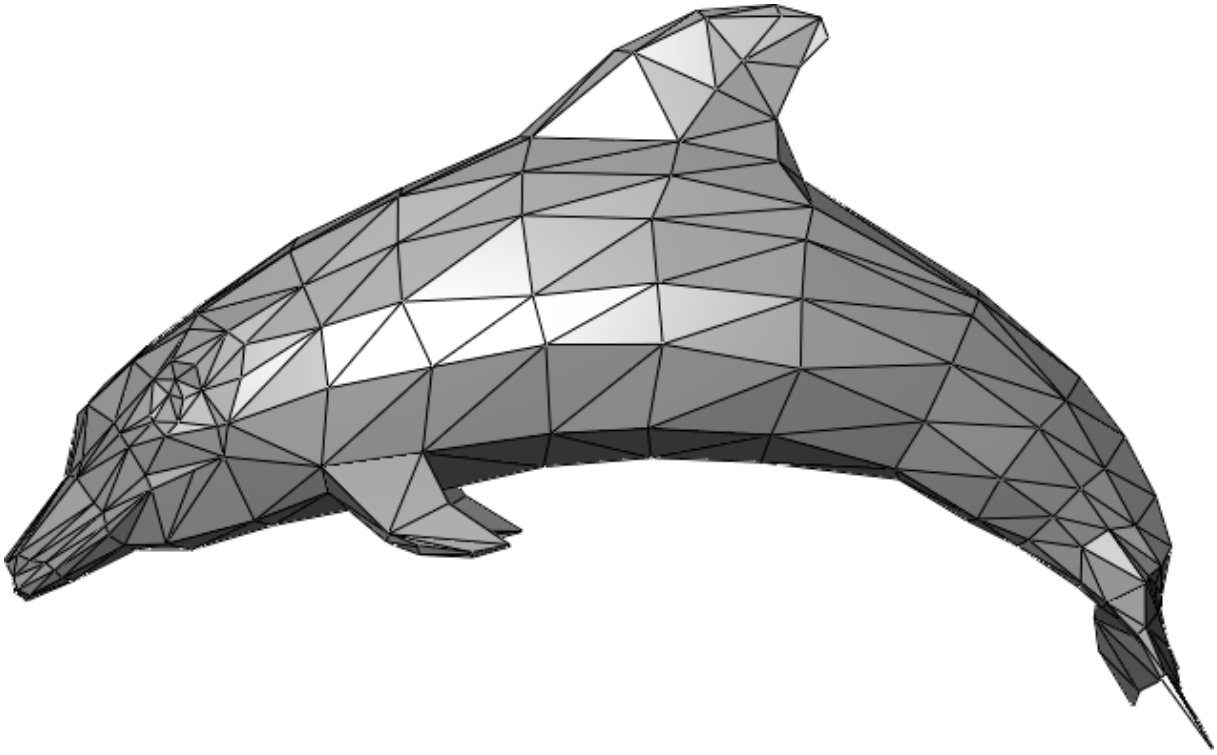


Figure 6.2.3 Sample mesh representing a dolphin

1-Blender:

Blender is a free and open-source 3D creation suite. Some of its functionalities are 3D modeling, animation, and rendering. We used Blender to adjust the sizes of our objects to make them like real objects.

2-Maya:

Maya is a 3D computer animation software that offers powerful modeling, texturing, simulation, and animations tools for artists, modelers, and animators. We used Maya to reduce the number of vertices to make them suitable for mobile devices. Unity recommends no more than 100,000 vertices if the 3D object is meant for mobile devices to maintain performance and to prevent the application from crashing.

3-Substance Painter:

Substance Painter is a 3D painting that allows you to texture and render your 3D models. We used Substance Painter to apply a texture to our 3D objects to make them look as realistic as possible.

6.3 Constructing the User-Interface

We implemented the User Interface almost as designed in the prototype with some modifications.

Some of the guidelines we followed while designing our User Interface:

Recognition over Recall: Users prefer they recognize similarities between the currently used system and anything they know from before.

Using Familiar metaphors: Very simplistic language has been used to indicate each category and function

Clean and Functional: The system should appear neat and performs all the functions

Attractive and pleasurable: The system should be colorful and provide an exciting sensation while being used

6.3.1. AR

Figure 6.3.1 AR Home

Figure 6.3.2 AR Inventory

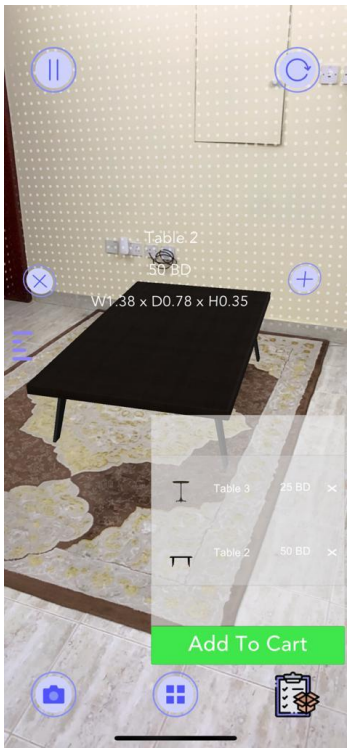


Figure 6.3.3 AR Shopping List

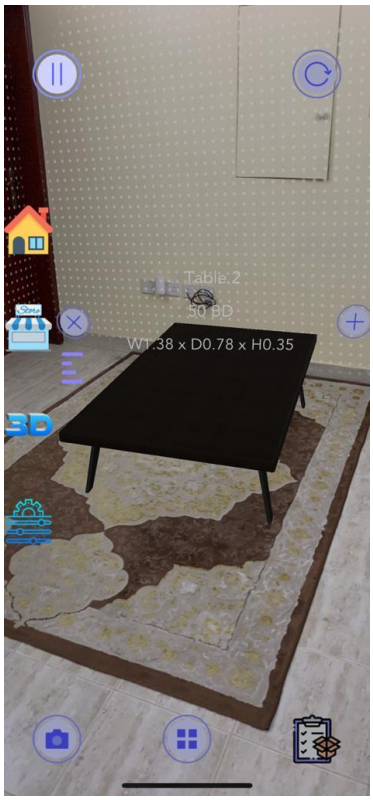


Figure 6.3.4 AR Side Menu

Figure 6.3.5 AR Settings

6.3.2. Shop

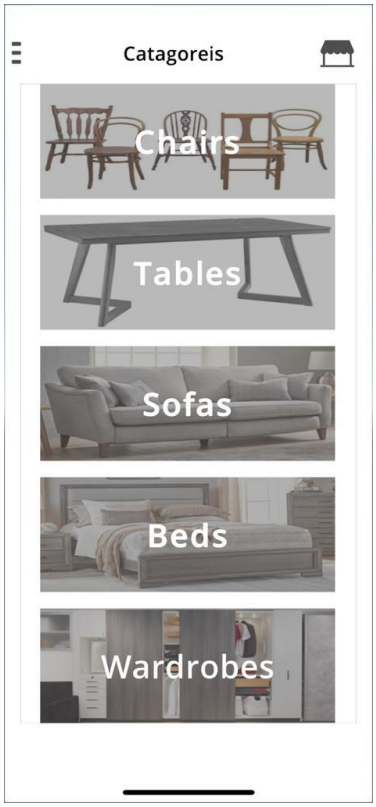


Figure 6.3.6 Categories

Figure 6.3.7 Side Menu

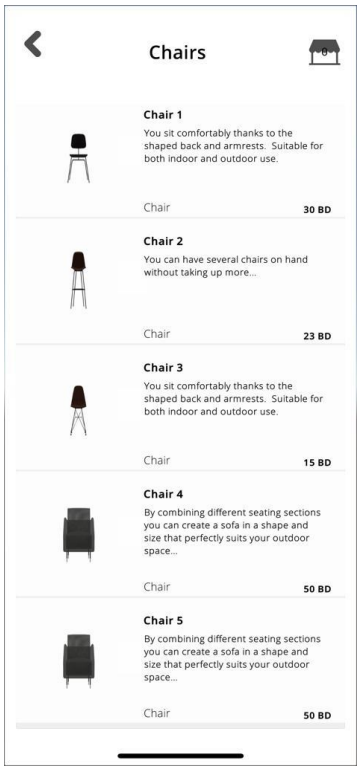


Figure 6.3.8 Category Sample

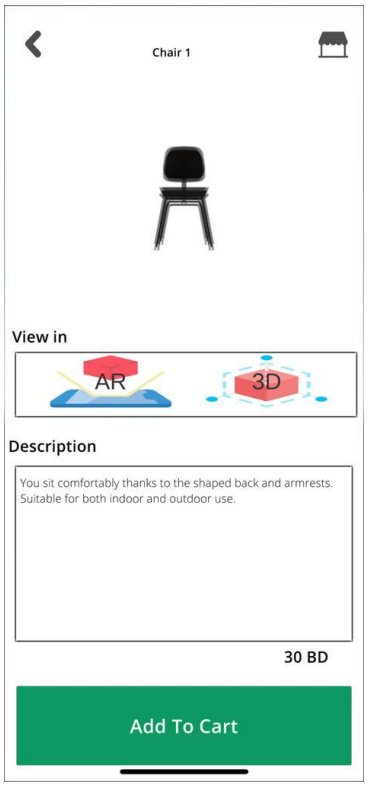


Figure 6.3.9 Item Page

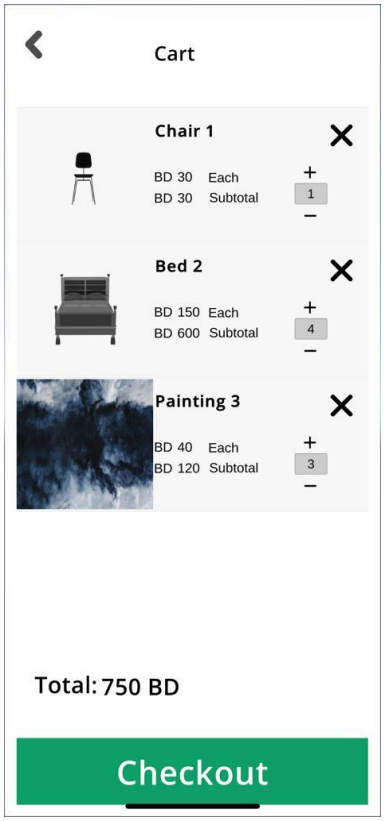


Figure 6.3.10 Cart

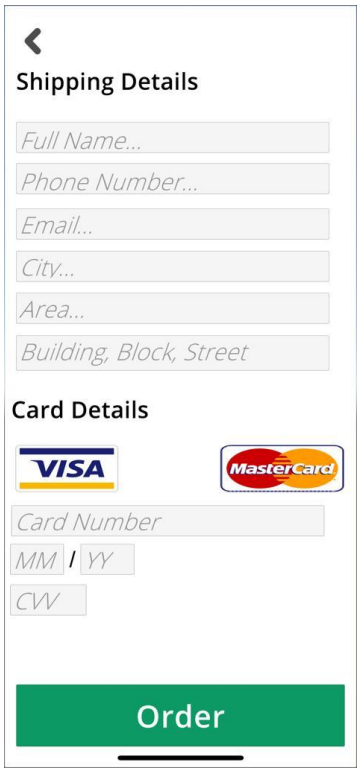


Figure 6.3.11 Checkout

6.3.3. 3D builder

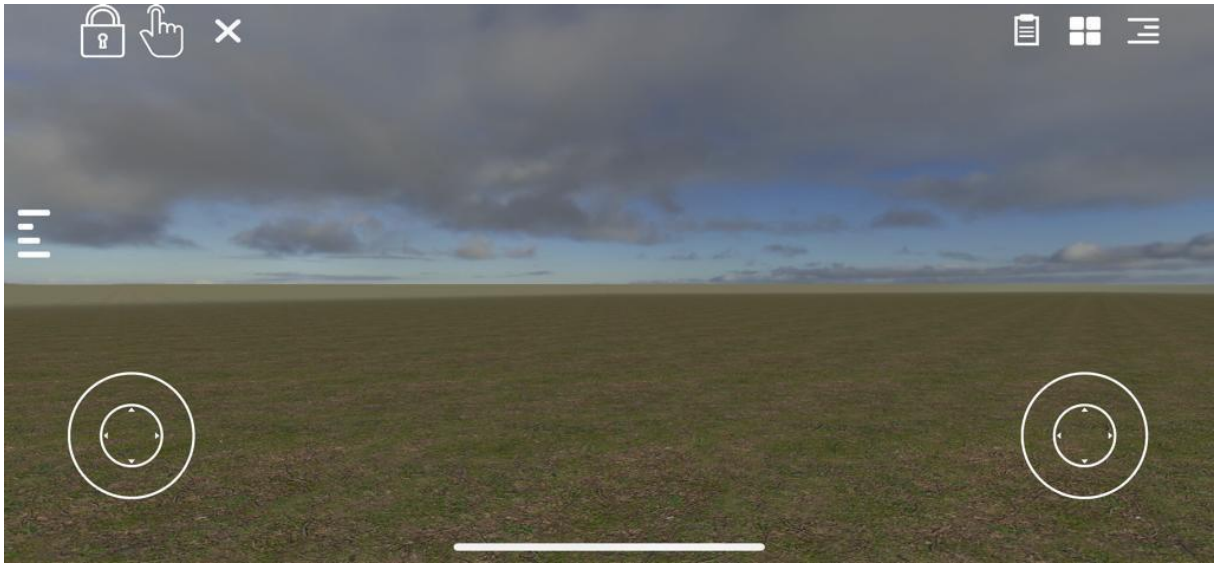


Figure 6.3.12 3D Builder Home

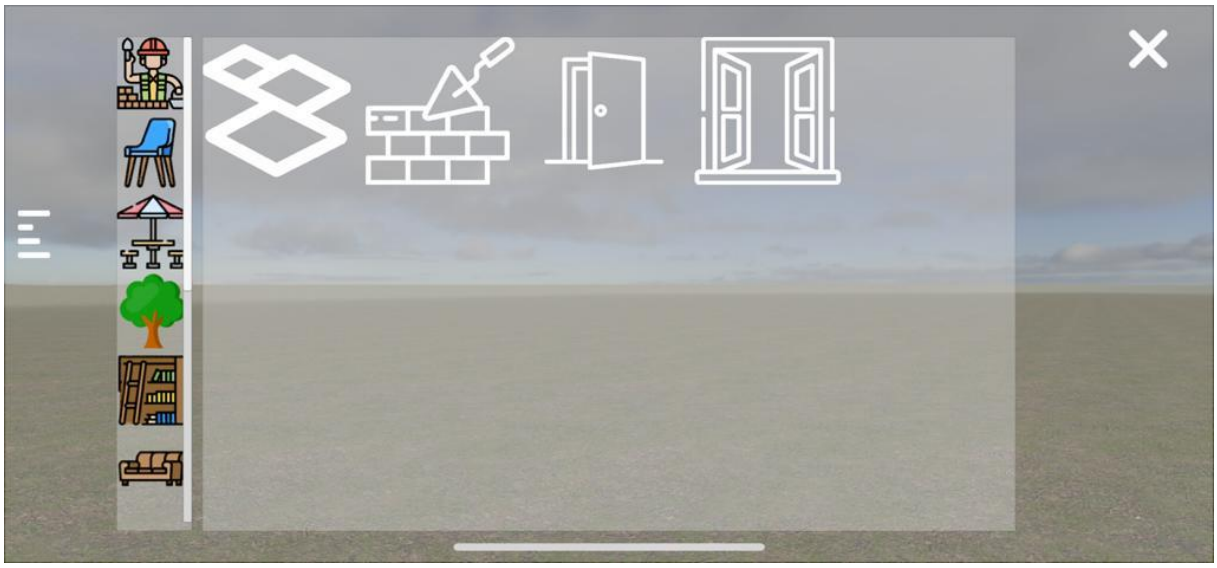


Figure 6.3.13 3D Builder Inventory

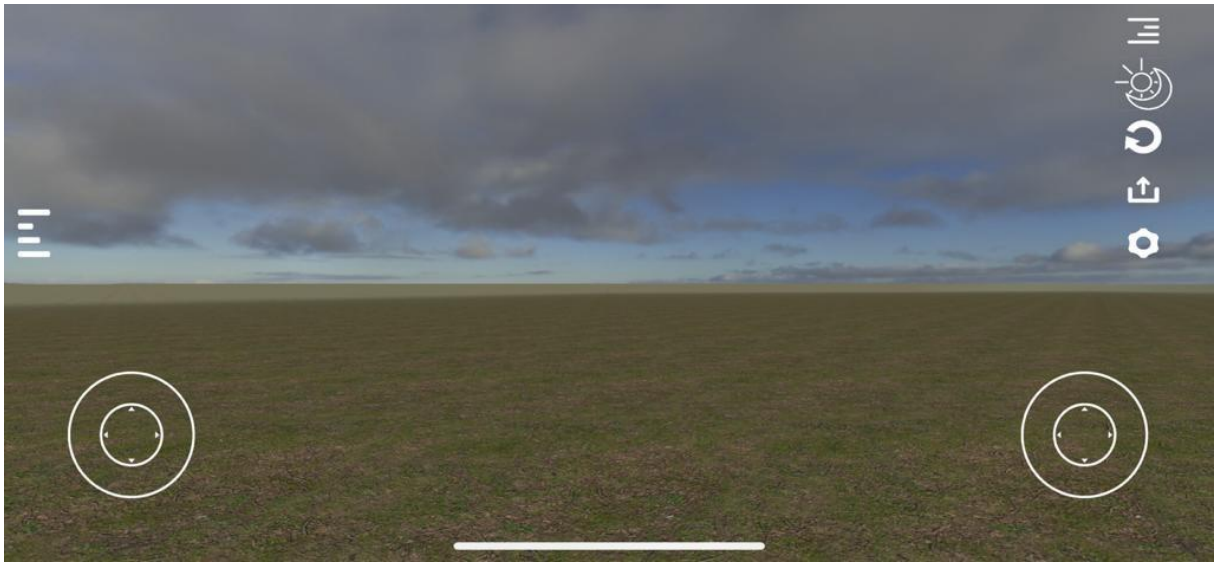


Figure 6.3.14 3D Builder Menu

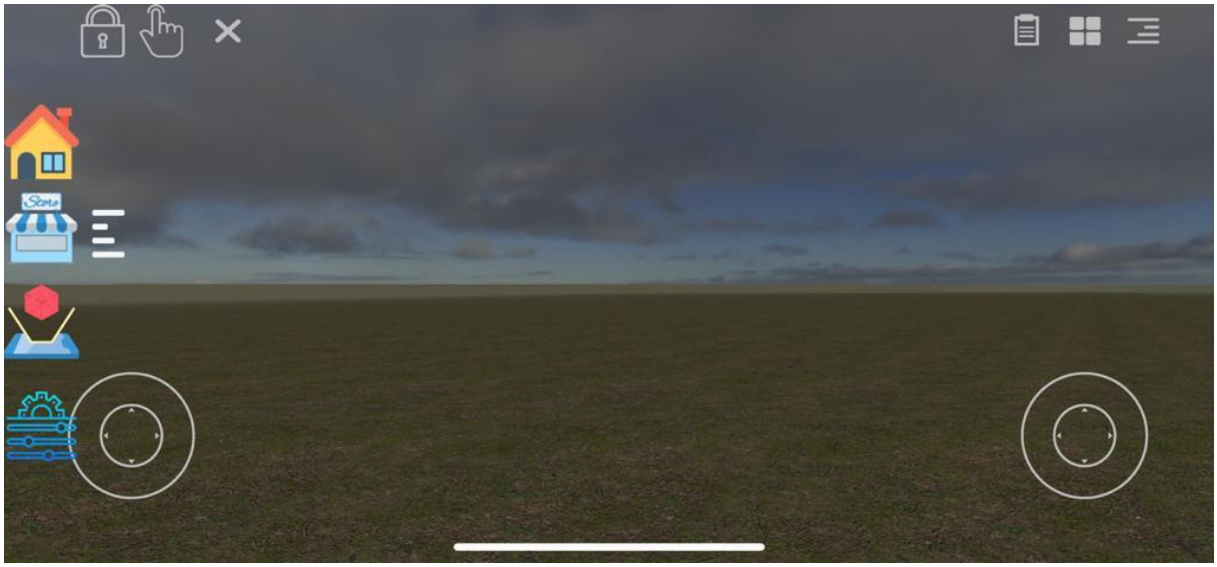


Figure 6.3.15 3D Builder Side Menu

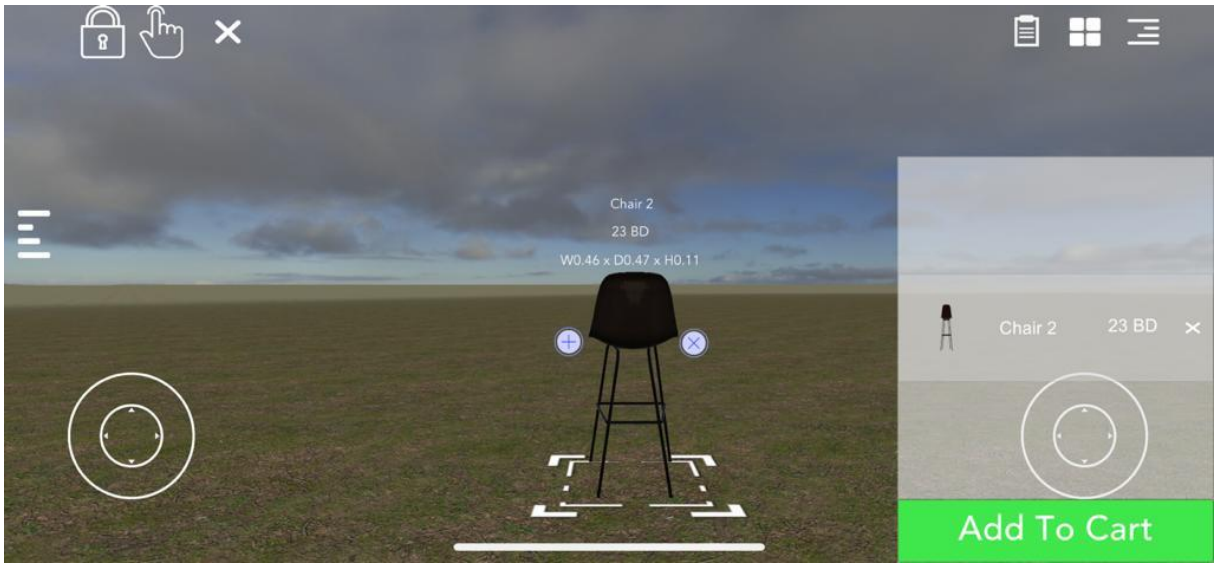


Figure 6.3.16 3D Builder Shopping List

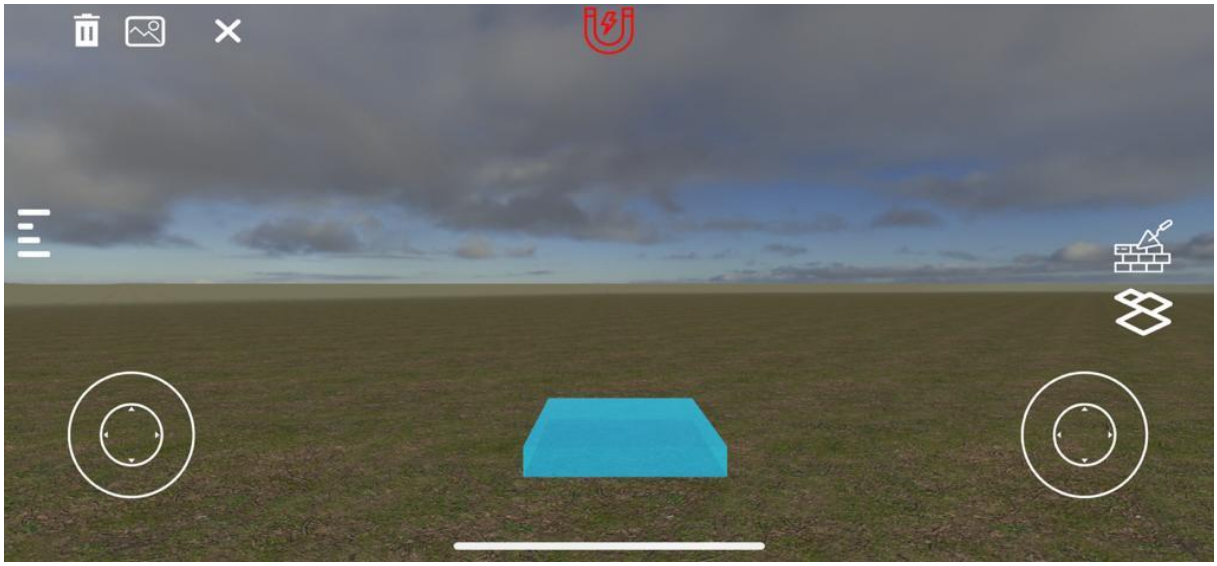


Figure 6.3.17 3D Builder Object Select

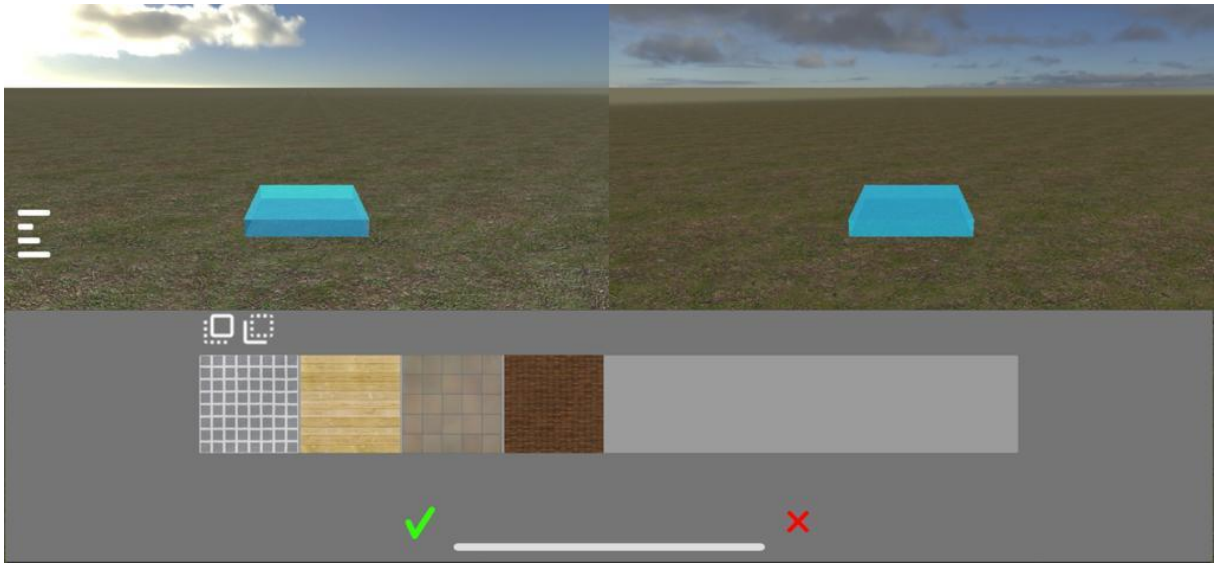


Figure 6.3.18 3D Builder Object Material Change

Figure 6.3.19 3D Builder Settings

Chapter 7
Testing

7.1 Introduction

After the development phase, we now have moved on to the testing phase. Testing the proposed system is an important phase of any model. Most of the bugs and errors in the system can be detected through system testing, which can then be fixed and removed from the system. It is also advisable to let other users test the system, as a different perspective can easily shed light on any errors that might have been missed.

7.2 Types of Testing

1- **Unit Testing:** Unit Testing the level of software testing where individual units/ components of the software are tested. The purpose is to validate that each unit of the software performs as designed.

2- **Integration Testing:** Integration Testing is the level of software testing where individual units are combined and tested as a group. The purpose of this level of testing is to expose faults in the interaction between integrated units.

7.2.1. Unit Testing

7.2.1.1 AR

Test Number	Test Case	Expected Result	Actual Result
1	The user moves his phone around to scan the area and detected surfaces.	A generated mesh will cover the detected surfaces.	A generated mesh covered the detected surfaces.
2	Open inventory and select a 3D object.	A message will appear asking the user to place the selected model.	A message appeared asking the user to place the selected model.

3	Tap to place the 3D object.	The object should appear on the screen.	The object appeared on the screen.
4	Drag to move the 3D object.	The 3D object should follow the user finger movement.	The 3D object follows the user finger movement.
5	Twist to rotate the 3D object	The 3D object should rotate according to the user twist direction.	The object rotated according to the user twist direction.
6	Delete the 3D object.	The 3D object should be removed from the scene.	The 3D object is removed from the scene.
7	Reset scene.	All 3D objects in the scene should be deleted.	All 3D objects in the scene are deleted.
8	Take a picture.	A picture of the scene without the UI should be saved to the gallery.	A picture of the scene without the UI is saved to the gallery.
9	Pause the scene.	The camera should freeze on the last frame before pausing and the user should still be able to place and manipulate 3D objects.	The camera does freeze on the last frame before pausing and the user can still place and manipulate 3D objects.
10	Resume the scene.	The camera should be back to normal.	The camera is back to normal.
11	Disable surface detection.	The device should stop scanning the area.	The device stopped scanning the area.
12	Hide 3D object information.	The information above the 3D objects should disappear.	The information above the 3D objects disappeared.
13	Change 3D object quality.	The quality of the 3D objects should change according to user choice.	The quality of the 3D objects did not change.

Table 7.2.1 AR Unit Testing

7.2.1.2 3D Builder

Test Number	Test Case	Expected Result	Actual Result
1	Open inventory and select a 3D object.	A message will appear asking the user to place the selected model.	A message appeared asking the user to place the selected model.
2	Tap to place the 3D object.	The object should appear on the screen.	The object appeared on the screen.
3	Drag to move the 3D object.	The 3D object should follow the user finger movement.	The 3D object follows the user finger movement.
4	Twist to rotate the 3D object	The 3D object should rotate according to the user twist direction.	The object rotated according to the user twist direction.
5	Delete the 3D object	The 3D object should be removed from the scene.	The 3D object is removed from the scene.
6	Change building blocks (roofs, walls, and floors) material.	The building blocks material should change.	The building blocks material is changed.
7	Save 3D design	The 3D design should be saved in a list.	The 3D design is saved in a list.
8	Load 3D design	The user should be able to view a list of previously saved 3D designs and load the one he wants.	The 3D design is loaded.
9	Hide 3D object information.	The information above the 3D objects should disappear.	The information above the 3D objects disappeared.
10	Change 3D object quality.	The quality of the 3D objects should change according to user choice.	The quality of the 3D objects changed.
11	Change camera movement speed.	The camera speed should be adjusted according to user input.	The camera speed changed according to user input.

12	Reset scene.	All 3D objects in the scene should be deleted.	All 3D objects in the scene are deleted.

Table 7.2.2 3D Builder Unit Testing

7.2.1.3 Shop

Test Number	Test Case	Expected Result	Actual Result
1	Browse items	The system should display the list of items that are in the selected category.	The system displayed the list of items that are in the selected category.
2	View item page	The system should display a page containing the selected item's full details.	The system displayed a page containing the selected item's full details.
3	Add to cart	The item should be added to the shopping cart.	The item is added to the shopping cart.
4	Edit items quantity in cart	The selected item quantity should change depending on the user input.	The selected item quantity changed depending on the user input.
5	Delete items from cart	The selected item should be removed from the cart.	The selected item is removed from the cart.
6	Checkout	The system should display a message for the completion of the order.	The system displayed a message for the completion of the order.

Table 7.2.3 Shop Unit Testing

7.2.2. Integration Testing

Test Number	Test Case	Expected Result	Actual Result
1	Add to cart from AR	The system should add the items added to list from the AR scene to the shopping cart	The items are added to the cart.
2	Add to cart from 3D Builder	The system should add the items added to list from the 3D scene to the shopping cart	The items are added to the cart.
3	Select an item from the shop and view it in AR.	The system should display the selected item in AR from the shop.	The system displayed the selected item in AR.
4	Select an item from the shop and view it in 3D.	The system should display the selected item in 3D from the shop.	The system displayed the selected item in 3D.
5	View your house design in the 3D builder in AR.	The system should display the house designed in the 3D builder in AR.	The system displayed the house designed in the 3D builder but the furniture location was highly inaccurate.

Table 7.2.4 Integration Testing

7.3 Technical Specifications

Application Size: 320.1 MB

Load Time: 1.1 seconds

CPU Usage: 37%

Memory Usage: 576 MB

Battery Usage (10 min): 4%

Chapter 8
Conclusion and Future Work

8.1 Overview

This chapter summarizes all the work that has been done throughout the project, the project limitations, the scope of our future work, and some concluding remarks.

8.2 Project Outlook

The proposed solution system was achieved through many steps throughout the project. The chapter breakdown below summarizes what has been done in this project to help solve the initial issue.

Chapter 1: Introduction: This chapter included an introduction to the problem and some background information about the usefulness of this project and it included project objectives.

Chapter 2: Literature Review: This chapter included reviews of existing systems similar to the proposed system and a thorough study of their solutions, along with the advantages and disadvantages of each system.

Chapter 3: Project Management: This chapter is mostly going to focus on the management side of the project and will also contain the selected process model and the reason behind its selection. And in addition to that, it will also include a section regarding risk management. And finally, a brief section regarding the project activity plane and which is going to be visualized with a Gnatt chart.

Chapter 4: Requirement collection and Analysis: This chapter is going to be about gathering system requirements through questionnaires and quantitative data analysis. Once the requirements are collected they will be separated into functional and non-functional. In the end, we will break down some of the important functional requirements using structured English.

Chapter 5: Design: This chapter's focus is going to be about designing the system user interface, and the analysis of the requirements collected in chapter 4 using UML use cases and UML Sequence diagrams.

Chapter 6: Implementation: This chapter is going to contain details about the different tools, languages, and software used to develop the system and also the implementation of the user interface designed in chapter 5.

Chapter 7: Testing: This chapter is going to contain the details about the different types of testing that had been done on the system and discuss the findings.

Chapter 8: Conclusion and future work: This chapter is going to be the concluding chapter of the report. It will contain a summary of all the steps done throughout the project, the project limitations, future work, and some concluding remarks.

8.3 Project limitations

- The application requires the room to be empty for perfect surface detection and object placement/manipulation. If the room is filled with furniture the objects may sometime float in the air when the user tries to move them.
- High energy consumption.

8.4 Future Work

- Implement a full shopping experience including the database and login/signup.
- Add persistence AR experience (save/load).
- Allow users to share their sessions live and enable viewers to place and manipulate objects if the user permits them.
- Upload the 3D object to a server instead of storing them in the app.
- Enable users to import their 3D objects.
- Build a website for the 3D builder and shop.
- Implement an AI solution that helps people make better choices when designing their home.
- Add a video recording feature to AR.

8.5 Concluding Remarks

Given the inexperience of the team regarding the technology used in this project, and the time constraints, we were able to develop a fully functioning application that meets the objectives established at the start of the project.

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