

Personal Augmented Reality Interior Design Assistant (PARIDA)

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A thesis submitted to Auckland University of Technology in partial fulfilment of the
requirements of the degree of Master of Creative Technologies (MCT)

2021

Auckland University of Technology

Faculty of Design and Creative Technologies

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ABSTRACT

Personal Augmented Reality Interior Design Assistant (PARIDA) – a guided interior designing application with the help of Augmented Reality (AR).

The interaction between the person living in a space and the building is the basis of interior design. Colour selection, door handle choice, look and feel of areas where people touch/interact, general traffic in the house, light, and airflow, and even acoustic conditions are all factors to consider. An interior designer is trained to take all of these factors into account including the overall layout and size of the home when designing a suitable interior space for the people who will be living there. However, not everyone can afford an interior designer, and it is impractical to bring in and experiment with various types of home décor before finalising on a suitable one. This is where computer graphics can be useful. Recent advances in 3D computer graphics technology, such as Augmented Reality (AR) and Virtual Reality (VR), can be useful as a pre-visualisation tool for architecture and interior design. An AR app that runs on a mobile device is portable and does not require any additional hardware. Although there are a variety of AR applications aimed at interior design, a feature review revealed that those applications have little to no guidance system to assist the user in making decisions. PARIDA is an augmented reality application that aims to fill this gap by guiding a novice user through the process of designing high-quality interiors. Professional interior designers may find it useful to easily prototype their designs and make accurate judgments before installation. Home décor stores may find it useful to assist their customers in determining which product will best suit their needs.

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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ACKNOWLEDGMENTS

I wish to express sincere appreciation to my supervisors Dr. Stefan Marks and Assoc. Prof. Ann Morrison for their guidance in developing the application and the preparation of this manuscript. In addition, special thanks to Dr. Zarqa Shaheen whose familiarity with the needs and ideas of the research was helpful during the early programming phase of this undertaking. Thanks also to the members of the AUT Design School for their valuable input.

GLOSSARY OF TERMS

AR – Augmented Reality

VR – Virtual Reality

OS – Operating System

Polygon – A closed, two-dimensional flat shape, which has straight sides and multiple angles

Mesh – A 3D mesh is the structural build of a 3D model consisting of polygons. 3D meshes use reference points in X, Y and Z axes to define shapes with height, width and depth.

Low poly – A polygon mesh in 3D computer graphics that has a relatively small number of polygons

High poly – A polygon mesh in 3D computer graphics that has a relatively large number of polygons

UVs/UV – U and V are the coordinates in 2D space assigned for texturing a 3D model

Décor – The furnishing and decoration of a room.

SDK – (Software Development Kit) software tools and programs used by developers to create applications for specific platforms.

App – Software application

1 INTRODUCTION

1.1 INTERIOR DESIGN

I often get drawn to the pictures in interior design magazines and try to use that as an inspiration to design my own home. But I fail miserably most of the time to replicate the same design that I saw in the magazine. Even if I buy the same furniture, it might look very different, and I often wondered: why? This is because it is not just that piece of furniture that gives the overall feel. Many factors come into play for a successful design such as the size of the room, lighting, the colour of the background wall, any other decorative elements that were present in the room, etc. To incorporate all these elements in our design is impractical. I realised my mistake when I read more about interior design and watched a lot of home decoration videos. In search of a solution that could help people from all walks of life to enjoy living in a professionally designed interior, I decided to embark my research based on the following question:

To what extent can a guided Augmented Reality application help a novice to design interiors to a professional standard?

Interior design is a fascinating field that has the ability to elevate your mental health with the colours and the way objects are arranged in your room (Cooper et al., 2010). Even though it is akin to an art and not everybody can be as creative and artistic as a professional interior designer, there are many rules that can be followed, and a good interior can be achieved. Picking the right colours depending on the size of the room, how much natural light gets in are some of the factors (Bellia et al., 2017). Several applications are already on the market focusing on this area which is just an internet search away. Dulux ‘Paint Colour Visualiser’ is one such application where one can upload a photo of a room and try out different colours from their colour pallet (Dulux - Paint Colour Visualizer, n.d.). Patterns are another important part which is often ignored by people other than professionals. The pattern we choose for our room influences the appearance of how tall and how wide the room is (von

Castell et al., 2020). Lighting is the next important part of interior design. Different types of lighting should be used for different purpose to illuminate the room. Lighting is also capable of affecting the mental well-being of a person (Grimaldi, 2008). Selecting furniture and the layout of furniture in a room is another step in interior design, which requires the consideration of several factors. The size of the furniture, the fabric texture and patterns, the style are some of the deciding factors. But the general arrangement of furniture in the room also plays an important role in making the maximum use of the furniture and its visual appeal. For an interior designer it will not be a difficult task to determine the type of furniture that suits the space. But how can a novice decide on selecting and arranging furniture for their space? Most of the time, their decision comes from the inspirations from interior design magazines, television shows and YouTube videos. This is where real life situations are often ignored, and people end up making wrong decisions. The concern of wrong decision-making could happen over other aspects of interior design like, selection of paint colour, decorative items, curtain patterns and length etc. In these situations, a guidance from an experienced person or an interior design software could be helpful for people to select appropriate colour, pattern, furniture, décor etc. One of the drawbacks of guidance using a software or a professional is that the designs planned might not be of the type, the client desired for. Presenting a 3D model of the designs to the client will help to overcome this problem to some extent. But lack of a contextual view of the design in the real space could still create problems. This is where use of Augmented Reality (AR) and Virtual Reality (VR) can be helpful.

1.2 A SUITABLE TECHNOLOGY

Deciding on a technology to develop an application is an important part as it involves considering various factors such as the target user, target hardware, ease of development, ease of availability, cost etc. This study is in search of a solution for common public to do interior designing in a cost-effective way and at the same time it is easily accessible. A lot of technologies and devices are available to develop AR and VR applications. VR provides a completely immersive experience to the user so that the user can experience the environment as if they are inside it. VR requires a headset to be worn and this can often incur

additional cost. One major problem in interior design scenario is that, since the whole environment is virtual, the user does not get a view of how the virtual objects look in the real world. Augmented reality is able to overcome this problem as it superimposes 3D images over the real images and provides the user a simulated view. Augmented reality can be run on smart phones and does not require any additional hardware. In 18 advanced economies in the world, an average of 76% of people use smartphones and worldwide, more than 2.5 billion people use smart phones (Silver, 2019). The quality of hardware, advancement in technologies, availability of high-quality cameras and popularity and its versatility makes smartphone a perfect hardware choice for this research and project.

Latest AR technologies use the information from the mobile camera and motions sensors to create immersive interactions. Apple created an AR development platform called ARKit in 2017 and a year later, Google created their platform called ARCore. Vuforia is another toolkit for AR, developed in 2017 (*Vuforia Engine*, 2021) and later acquired by PTC. Along with a Software Development Kit (SDK) for AR development, a Game Engine is required that can handle all 3D models, textures and lighting. Unity 3D and Unreal Engine are two of the most popular and best game engines (Christopoulou & Xinogalos, 2017). Unreal Engine comes with ARCore and ARKit for developing AR applications. In Unity 3D, the AR Foundation package provides an abstraction layer for ARCore and ARKit, combining their key features with specific Unity elements to enable developers to create stable applications across both hardware platforms. Developers may use this tool to combine all of these functions into a single workflow. This gives the convenience of developing only one code base while combining the best of both ARCore and ARKit. The Unity document website has a lot of information about the AR Foundation. A wide global community of Unity developers is also available to assist through official forums to trouble shoot (Technologies, 2021). The availability of tools in Unity like 3D models, texturing and lighting tools is an added advantage. Considering all these factors, it was decided to develop the application using AR Foundation and Unity game engine.

2 LITERATURE REVIEW

2.1 INTERIOR DESIGNING AND HUMAN PSYCHOLOGY

Interior spaces and human psychology are closely intertwined. On the basis of their personal desire and needs, humans change their environment and often this change is directly influenced by the world they live in. (Marzieh & Alireza, 2011) These factors need to be considered in the creation of architectural spaces. Since human activity is carried out in specified spaces, physical spaces need to be constructed based on the behaviour and characteristics of individuals living in those spaces. In their study, Marzieh and Alireza conclude that the collaboration of researchers in different areas of behavioural science plays an important role in creating a good design for architectural spaces. This is often due to the fact that those who study behavioural science understand how to effectively communicate with people and pass on the information to the architects.

In another study by Hamdy and Mahmoud (2017), focusing on architectural elements that affect human psychology and behaviour, the authors state that the extend to the relationship interior architecture and human psychology is very broad. In the end, the success of developing interior architectural design with active psychological conception is determined by how the design satisfies consumer beliefs, desires, expectations and satisfactions.

Clear evidences were found in a longitudinal study reviewing 280 academic articles on the relationship between physical environment and its direct and indirect effects on learning, mental health, employment, learning disabilities and mental capital (Cooper et al., 2010). Some of the main findings of the review are the factors contributing through sensory stimulation that affects mental wellbeing. Noise and light are critical factors, as is the quality of the overall build materials. These affect our visual and tactile senses as well as our sense of safety. The review also finds that access to natural objects in the physical environment such as plants and windows with a view is also a contributing factor. The study also recommends that designers and developers should refer to the evidence in the research when designing and maintaining environments for a better mental wellbeing of people using it.

Physical environments not only include interior spaces of both workplace and home, but also comprise of public places, neighbourhoods, apartment living, attached homes and detached homes. In a study by Smith et al. (2012), focusing on the relation of different types of architecture and mental wellbeing, the authors argue that wellbeing is shaped by our physical environment, which is an extension of who we are as individuals. The study urges interior architects to use their own knowledge and expertise along with the evidence in the research and address these diverse requirements of people.

In a study conducted in Turkish houses (Ayalp, 2012), it was revealed that adopting a common format for designing interiors is not a feasible solution. Interior spaces are a reflection of the people living in it. The reflection of personal, social, and cultural identities in these places directly affects human views of the space in which they reside, work, or spend time. It is agreeable that places mirror the main characteristics of our identity. "There is a complex interaction between a person and a space. The person defines the space, the space defines the person; the person gives meaning to the space, the space gives meaning to the person. In other words, there is a complex and bilateral interaction between the person and the space in its cultural, psychological, economic and physical dimensions".

Based on the previously mentioned studies it is evident that interior spaces contribute considerably to mental well-being of people living in those spaces. Studies also suggest that interior designers and architects must keep in mind the relation between interiors and mental well-being when planning a space. As suggested in earlier research, since interior spaces reflect the person living in it, it is important that the designing is carried out to cater the specific needs and interests of the individual using the space.

2.2 TECHNOLOGIES IN INTERIOR DESIGN

Advancement in computer graphics has impacted in every field of human life and interior designing is no exception to it. New and advanced software is used by interior designers to visualise, prototype and design interior spaces. AutoCAD LT, Sketchup Pro, Turbo CAD are some of the popular software packages that professionals use to visualise their designs

(O'Neill, 2020). Accessibility of such software for common public and its ease of use is what makes interior designing more democratic.

AutoCAD LT and Turbo CAD are both focusing on professional designers and architects as potential users since their software is comprehensive and enable users to work out great level of details. The wide range of tools and features and a professional looking interface with numerous tools and buttons may be overwhelming to a novice. A large selection of tutorials, educational materials and educational license are available for both applications, which indicates that these applications are not suitable for someone new to interior designing. A simple to use, easily available web-based application or a Virtual Reality enabled application or an Augmented Reality enabled application could be a better option for occasional users or a one-time user who wants to design their house without much training and practice.

Home styler is one such web-based software that is intuitive and cost effective. (Homestyler, 2021) Users can build their home using their floor planning feature and can decorate it by choosing furniture from over 200 real furniture brands from their available list. The website also offers views in 2D and 3D. Home styler comes as a mobile application as well which can be downloaded from google play store for free. The mobile application lets the user to take a photo of the environment and then paint over it and place furniture in the space. The downside of the application is that it does not use Augmented Reality and the user cannot get the experience of seeing the designs from different angles in the real world to get a better perspective.

SketchUp is another web-based 3D software which has comprehensive tools for modelling and designing house. A free version is available for hobbyists, whereas the paid version comes with more advanced tools for professionals (3D Modeling Software Pricing, 2020). Even though it is easy to learn and has simple tools, it provides no suggestions about interior designing. The user should have prior knowledge about designing and the software acts only as a tool.

Another web-based software is Floorplanner which is simpler than AutoCAD LT and Turbo CAD in terms of the user interface and features. The manufacturer also provides a free

version and a paid version (Floorplanner, 2021). This software has tools specifically to build rooms and provide a wide range of furniture to add into the room and view the room in 3D. But again, the software provides no design guidance.

Planner 5D is a cross-platform tool with a vast collection of furniture and prebuild design plans. This software provides the option of viewing the designs in virtual reality on mobile phones (Planner5D, 2021). The advantage of using a web-based system is that it is potentially easier to use with a big screen, but one disadvantage is that a user has to visualise the design in their room and make a rough guess about how it suits the space.

Instead of providing suggestions to the user, there are automated systems developed to place furniture using interior design guidelines. One such system is developed by Merrell et al. (2011) (Interactive furniture layout) which offers an interactive framework for furniture layout that supports users by recommending furniture placement suggestions that are based on guidelines for interior design. The framework helps users to implement the layout with the help of a custom-made function. This system populates the room with a set of furniture in the catalogue and presents it to the user on a computer screen. One limitation of this system is that the user has to reimagine them in the real space. The colour and feel of that furniture in the physical space can be different from what you see in computer screen and in real life.

From Table 1, it is clear that these systems are a suitable option for those who can visualise the design that was seen on a computer screen into the real world. A professional can judge the difference between how a piece of furniture looks on screen and how it fits in the real environment. Using a web based or desktop application thus becomes more suitable for a professional interior designer or people with an intermediate level of knowledge and experience in designing.

	Software						
Features	Autocad LT	CAD	Home styler	Sketchup	Floor Planner	Planner 5D	Interactive furniture layout
License	Paid	Paid	Free	Free	Free	Free	Unavailable
Ease of use	Professionals	Professionals	Beginners	Beginners	Beginners	Beginners	Beginners
Web based	-	-	✓	✓	✓	✓	-
Implementing VR	-	-	✓	✓	✓	✓	-
Implementing AR	-	-	✓	✓	-	-	-
Standalone Desktop	✓	✓	-	-	-	✓	✓
Models Available	-	-	✓	✓	✓	✓	✓
Object colour change	-	-	-	-	-	✓	-
Automatic placement	-	-	-	-	-	-	✓
Placement suggestion	-	-	-	-	-	-	✓
Design style selection	-	-	-	-	-	-	-

Table 1: Software comparison table

2.3 VIRTUAL REALITY IN INTERIOR DESIGN

Virtual reality provides a completely immersive experience to the user. This technology is a good option for users to visualise an environment that is not present in real life of that is yet to be build. Thus, using virtual reality for visualising interior designs is a good option. There are several studies that explore the use of VR in interior design. One such study by (Li, 2016) examines a web based technology in interior design. The author implemented a multitude of ways to design interiors including painting, furniture placement and textures and colour selection. The three aspects of the virtual reality design process are: (1) 3D modelling, (2) 3D display, and (3) interactive implementation. The system also provides some interior decoration impact sketches to display the efficacy of proposed interior design process. The

study concludes with the finding that some designs had a good quality output in colour selection and furniture placement.

A virtual reality system was created in response to a survey conducted in Seoul, among architects and their clients, with the goal of providing a true sense of being inside the building under construction (Racz & Zilizi, 2018). As a result, users can get a better sense of the space, scale, and atmosphere of the building before it is completed. The emphasis was on a realistic visual experience to have a true understanding of the building's emotional impact and the ability to interpret the various interior design variations. The researchers were able to make a real sense of atmosphere that influence client's feelings and customers were able to better imagine the interiors and size of the building. This study was more focused on visualising interiors of buildings under construction and the designing was carried out by the professional designers. The VR system was used only at the end to confirm that the look and feel of the building is up to the expectation of the clients.

A user oriented decision support system was developed to design interiors using VR by Juan et al. (2019). The system provides users with different "spatial layouts" from which the user can select one. The system then generates a "spatial scene" layout based on the chosen style and produces the best preliminary solution within a small decoration budget. Finally, the overall colour scheme and pattern are fine-tuned for consistency. This system tries to automate a considerable amount of work by doing the layout and calibrating the colour tones and patterns.

Artificial intelligence is also used with VR in interior designing to make the decision making process easier (Meng et al., 2018). First the user draws a basic layout of the space they want to decide and then the system provides some basic function such as furniture placement, furniture conversion, material conversion, and light switch. Researchers used AI to train using the pictures provided to select right textures. This AI based system is more advanced than those systems which use just VR to visualise the designs. It supports the users with the help of AI to create texture using images provided. The authors claim to have created a better system that is scalable because of the use of AI and that provides the user with a satisfactory result in home interior designing.

A web based Mixed Reality tool was developed for virtual home staging to be used by real estate agents to visually present ideas to potential clients, giving property owners confidence in how interior spaces will appear after they are furnished (Vazquez et al., 2021). This system first requires 3D capturing of the interior and then converting into a 3D world, followed by placing virtual objects in it. The 3D capture of the spaces is done using a mobile camera which makes the process simple and requires no additional hardware. Once a 3D capture is created, the models are optimised and then the user can add objects into the 3D world virtually. The system creates high quality 3D renders using a remote rendering service that has the advantage of providing high quality realistic lighting. This is because the environment and the placed objects are all 3D models and reside on one 3D space. The bounce light from the environment can provide added realism to the virtual objects placed. Another advantage of this system is that it is web based and does not need installation of any application to the user's mobile phone. It is a convenient option for one-time users or occasional users. However, the system requires installation of the Matterport capture app to 3D capture the interior spaces. The system has interior design features and provides a wide range of furniture from an external source. Even though it is aimed to help non-designers, there is not much guidance provided by the system.

2.4 AUGMENTED REALITY IN INTERIOR DESIGN

While VR provides a completely immersive experience where the user is transported into the virtual world, it often lacks in providing a contextual view. Augmented reality on the other hand superimposes 3D objects on real world which gives the user a better understanding of the object's size and feel. Augmented reality is used in interior design to help users to better visualise and understand the changes that are going to be implemented. When users need to make choices from a wide variety of options it is easy to select objects that do not fit together well. In situations like this it is better to use technologies like AR and make an informed decision. Arranging furniture in the real world is tiring and time consuming. Using a glitch free AR system will be very helpful since the user can try multiple styles and combination of furniture with smooth system. Since there is no stress in moving heavy and bulky furniture in a virtual world there is more opportunity for the user to discover

a suitable arrangement. AR could reduce the cost of interior design by reducing the amount of time and resources invested on each project and making successful design more accessible to a broader audience (Sandu & Scarlat, 2018).

One of the promising works in using AR in interior design is from Kán et al. (2021). The authors use separate algorithms to place objects automatically in the space considering parameters such as room type, type of objects placed, room style, colour etc. The system takes inputs from the user about the types of furniture the user likes and then provide a selection from a list of furniture. This way only that furniture that suits the style selected by the user will be placed in the world. Another great feature used is the storage of all 3D models on a server. This helps reduce the application size on the mobile device and makes the system scalable to the growing list of furniture. To automatically place furniture in the world, the application first scans the world and places objects according to an algorithm. To avoid placing multiple furniture in the same room, the software uses an object avoidance system with a list of which objects can be placed next to a particular piece of furniture. One drawback of this system is it takes away the liberty of the user to place whatever furniture that they want. Another limitation of the work is that the room scanning, and placement calculation works only on rectangle shaped rooms. The rules generated in the app could also take away the ability of the user to create extreme designs. In the expert study, professional designers had only binary options to comment on the design that if the design was sensible or not. They were not able to gauge how good or how much the designs were adhering to the principles of interior design.

2.5 APPS ON THE MARKET

Smartphones have been used by corporates as enterprise devices since 1993. But a more affordable version for the general public was developed by Apple in 2006 (Sarwar & Soomro, 2013). In 2008, Google introduced its operating system (OS) for smart phones called Android. While Apple's OS was available only in iPhones, Google's Android was made openly available to other smartphone manufacturers and soon became very popular (Rhine, 2017). Since then, millions of mobile applications were developed for various purposes (Mobile App Download and Usage Statistics, 2021). Finding an application for a

specific task is only a few Google searches away. Using the right key words and searching with broad as well as specific terms will yield all the results needed. For this project, the terms ‘interior design’, ‘AR’, ‘interior design augmented reality’, ‘home designer’, ‘AR interior designer’, were used. Searching with each key word gave around 200 results on average. Out of those results only those apps are picked that provides either guidance, use AR, incorporates real world visuals or some form of interactivity.

Out of the several AR applications developed in the domain of interior design, the most popular one is IKEA place. It is developed by IKEA systems primarily to try out their products using AR before purchasing them (IKEA Place, 2017). The app provides 3D models of their products in actual size for users to virtually place them in their home and get the look and feel of the product if it is place in their homes. The app has focus on promoting their new products and offers. IKEA place is a good option for people who want to virtually see a product in their room before buying. A user can add as many as furniture in their home and fully design it, but the app does not offer any guidelines to the user about design styles.

Room (Room – 3D, AR & VR Platform, 2021) is an AR app for interior designing which has features to virtually place an object in real world, move, rotate, and resize it. The app can bring objects to life using AR and it can create 3D Models using a VR Showroom feature. The app also provides a 3D walk-through in prebuild rooms. With the app, a user can build their own virtual reality environment with wallpapers, furniture, carpets, and other decorative objects. There is an extensive database from where various 3D objects could be downloaded and viewed in VR or AR. 3D modelling is another feature Room offers. It is also possible to upload own models to the application. This app was developed as a marketing piece of the company with the same name. Since the models are on a server to download, the application is light to run and install. A scaling feature of 3D objects is not present in this application which is a good thing for AR apps in interior designing as it can create confusion to the user about the size of objects. Apart from that, there is not much focus and guidance provided for interior designing.

Gazzda is an AR application similar to IKEA Place which lets the user virtually place Gazzda furniture in an interior space (Gazzda, 2020). With the app, a user can browse the list of

available products and select one and virtually place it in the room, move and rotate the product, and choose different sizes, materials and colours of the furniture. The app also has features to share the design with friends or save it for later. It also provides information about the nearest dealer and sends enquiries about any product. As the application is designed for a furniture company to promote their products, the features in the app are more inclined to the interior design and visualisation purpose. However, the app seems to focus more on product marketing with features such as light estimation for a true to life appearance in the real world and provides information about dimensions and price and there is little guidance on how and where to place the objects.

Myty AR is similar to the earlier mentioned app Room, but has an inspiration feature, where the user can search through a variety of interior design photos with “get the look” information (Myty AR, 2020). The search result will help the user to find their favourite style, colours and more information. The app calls their Augmented Reality concept “play and decorate” where a user can test furniture products in their home, position the furniture by moving and rotating to find perfect position, try new wall colours, create new room from an existing one to get idea for redecoration, detect existing furniture to find new, better models from their catalogue. Finally, it provides the feature for sharing the picture of the design with friends. As this app is not developed by any specific company like IKEA or Gazzda, it provides 3D models of a range of furniture manufacturers. The app provides a categorised list of furniture depending on its maker and provides price information as well. As a guidance to interior designing this app provides features to browse through inspiration images. But the app provides no suggestion in the AR part on how and where to place furniture.

Design Home is a calming and entertaining game that helps users to experience the life of an interior designer (Design Home, 2021). The design challenge feature in the app helps the user to improve their decorating skills and enables access to a wide range of furniture and decor brands to create 3D spaces. Users can unlock more features to bring a dream home to life, and gain access to bathrooms, kitchens, and other customisation choices. It is fast and entertaining, and users are able to engage with a lively artistic community while learning

about various décor trends, enhancing design skills and providing inspiration that they can use in their everyday life. Even though the app does not use AR, it provides games to help and guide users to decorate a room. The app provides some hints on what object to place where with colour coding. Some of the pieces are not compulsory to add to the space but it gives the user a perspective on how the room would look with and without small decorative items. If the game could have incorporated Augmented Reality as well to the application, then users could get a clearer picture of how their room would look if properly interior designed.

A simple AR application that can place virtual objects in real world is something that an average user will be easily drawn to. Home AR Designer is one such application (Home AR Designer, 2018). This is an app that uses AR and high-quality configurable furniture 3D models for home renovation. The developer of the software claims to provide users the best home design experience using high-quality 3D models. Colours and fabrics of the furniture can be changed, and furniture and accessories can be placed anywhere in the interior space. Designs can be shared with friends for their comments. The simplicity of this application and easy to use menu is what makes this different from other. There is a variety of furniture to choose from and all models are stored in the application. This lets the user place the objects as soon as they select a furniture with no waiting time to download a model. On the other hand, the models are downloaded with the app which increases the download size and time significantly compared to the other apps where the models are stored on a server. Absence of a free scaling tool for the models ensures that the user will see objects with proper size, but a lack of a guidance in interior designing is a drawback.

Homer - AR Furniture and Interior Visualiser is an AR application that lets the user select from a variety of brands and groups, place the products on the floor and walls, change their height, location, and orientation with swipe and zoom gestures, and design a home space with several products (Homer - AR Furniture And Interior Visualizer, 2021). Users can not only capture photographs but also record videos of their designs and share them with friends and family. With cloud technology, users can upload and download any product from anywhere. Another interesting feature in the application is the option to view the furniture

in 3D before placing them in the world. Along with the move and rotate option of the placed 3D object, they can also be scaled. This is not a good option as it can confuse the user to judge the size. Lack of guidance on interior designing is another downside of the app.

Home styler is another interior designing app which lets the user create do-it-yourself (DIY) design projects, save them and share them with friends, family members and home design professionals (Homestyler, 2021). Users can build their own interior design profile and get likes, comments and followers. A photo of the room can be uploaded or the user can use one of the many templates provided. Users can check the scale of three-dimensional furniture and check how they fit in the floor plan. Designs can be created with thousands of home furniture, art accessories, decorations, and lighting fixtures from different furniture stores like IKEA, Target, Crate & Barrel, Pier 1, etc. Designs can be published and shared on social. However, virtual placing of 3D objects in the real-world using AR is not implemented. As recommendations the app provides information about latest trends, different styles, and useful tips from home design community. The app takes a photo of the space and then the user has to place a vertical and horizontal grid in the photo taken, matching the edges of the room. The 3D objects are then placed on the grid which give the illusion of virtually placing them in the real world, but users cannot actually walk around the object to view it from different angles.

Floor plan home improvement in AR is a comprehensive application to draw floor plans of a house by just using a mobile phone (*Floor Plan - Home Improvements in AR-Wodomo3D*, 2021). The floor plan creation algorithm scans the room using different techniques and creates a floor plan of the house. After that, the user can remove or add walls and see how the result looks. The user can paint the walls with different colours. The walls can be made thicker or thinner and inclined ceilings can also be created. A small 3D version of the house can also be viewed to better understand the structure. This application creates a structure and floor plan of a house and then lets the user design the interior by painting the walls and even adding and removing walls. This feature is not available in other applications as they are not creating the structure of the room. Apart from this unique feature, the application provides

no other tool to design the interiors. Bigger projects might find this useful step to interior designing but not so much for beginners or one-time users.

The AR Furniture app is an augmented reality technology designed to help retailers sell their goods online (AR Furniture – Apps on Google Play, 2020). The app has functions and features that are intended to address some of the most common user concerns, such as choosing a colour or style of furniture, such as couches, tables, lamps, and kitchen appliances, that complements an existing décor or design. The challenges of putting 3D content into real-world spaces, such as ensuring the object size are sensible, speeding tracking to minimise lag, realism, and colour accuracy, are all put to the test in the development of this framework. The majority of users are now conscious that augmented reality can be used to browse for furniture. This is also valid when it comes to home décor and refrigerator purchases. This application is intended to assist the consumer in determining whether or not a certain piece of furniture or appliance will still fit well in their room. Customers can prevent making errors and returning products by using the 3D furniture and appliance preview. Customers may also experiment with various combinations in their rooms using this tool. The application provides features to move and rotate the objects, but the scaling feature is not recommended for interior design purpose. Along with it, the absence of a guidance system makes this app less suitable for interior designing.

2.6 SUMMARY AND RESEARCH GAP

Several applications created for interior designing were tried and tested before starting my research (Table 2). That include those which use Augmented Reality and those which do not. There are many applications that teach interior design or provide a lot of information about interior design and there are some that search and find interior designers in the nearby places. Those applications that do not let the user do interior designs are not listed in my research as my primary aim is to develop an application that gives user ability to design their interiors and show a virtual representation of the design they make. While reviewing, it was found that there are several applications that were created to assist user to design interiors without the help of an interior design professional. But how much is this achieved is what I had to investigate and for that I had to have a broad view of their features, availability, cost,

and user friendliness. All applications provided a realistic view of the 3D objects in the real world. All of them had good light estimation and it blends well in the real world. Most of them provide a wide range of furniture categorised into sections so that the user can easily choose one by going into the category and select one and then place in the world virtually. They could be moved and rotated so that the user can place in the exact position they want. Some of the applications allow the user to change the dimensions of the furniture using the ‘pinch zoom’ gesture in the screen. Unlike clothes, furniture does not come in different size, so this feature is counterproductive as it gives wrong perception of size of the objects. Only a few of the application provided features to change the colour of the furniture. Some had wall paint colour changing feature and gave colour suggestions. But none of them provided a guidance system to give users suggestions on where to place and what objects to place. An overview of the applications that I reviewed is listed below.

	Products									
Features	IKEA	Room	Gazzda	Myty AR	Design Home	Home AR Designer	HomerAR Furniture	Home styler	Floor plan Home Improvement	AR Furniture
Price	Free	Free	Free	Free	Free	Free	Free	Free	Free	Free
Rating on Google	4.6	2.5	4.1	3.7	4.2	3.0	Not avail able	3.9	3.3	Not availa ble
Available on Android	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
Available on Apple	✓	-	✓	✓	✓	-	-	✓	-	-
Uses AR	✓	✓	✓	✓	-	✓	✓	-	✓	✓
Models on cloud	✓	✓	✓	-	-	-	✓	-	-	✓
Object placement	✓	✓	✓	✓	-	✓	✓	✓	-	✓
Object colour change	-	-	-	-	-	✓	-	-	-	-
Automatic placement	-	-	-	-	-	-	-	-	-	-
Placement suggestion	-	-	-	-	✓	-	-	-	-	-
Wall paint	-	-	-	-	✓	-	-	✓	✓	-
Design style selection	-	-	-	✓	-	-	-	✓	-	-

Table 2: Mobile app comparison

In search for an appropriate technology to use in interior design which can be used by beginners or novice, several factors have to be taken into account. It should be user friendly, intuitive, have good graphics and use cutting edge technology to provide real time feedback to the user. Several applications available on the market that provide 3D models of variety of furniture and uses technologies like VR and AR. Those that use AR provide a contextual view of the objects in real world. Other than Home Design providing placement suggestion for furniture, none of the available smart phone applications using AR provide a guidance to the user on interior design. Some of the web-based applications and research projects completely automates the process taking out the decision-making freedom from the user. This is the area where PARIDA is focusing, where a guidance is provided to the user in a step-by-step procedure, where to place furniture and what to place first but at the same time not taking out the freedom of the user.

3 RESEARCH DESIGN

3.1 APPROACH

A visual overview of my research framework is shown in Figure 1. Based on the literature review and application search conducted on an assisted system for interior designing, it is evident that there is room for development of a cost effective and easy to use application. This research is exploring the possibility of a guided AR system that can provide a cost effective and easy to use application for interior designing. Primary data is collected after user testing to gauge the usability and advantages of using such system. Secondary data from the previous research is not helpful in this research as the data heavily depends on the application and its features and limitations. The new application developed should not be limiting the users too much in creating a design like in the research done by Kán et al. (2021), but rather provide a guidance system. Past research reviewed in this thesis applied a hybrid method combining qualitative analysis as well as quantitative analysis. A similar method is adopted for this research as a detailed analysis of the effectiveness of the application in helping the user to create a quality design. The primary data collected in the research is also used to analyse if the application and the system is useful to a wider range of users. A conclusion is drawn based on a survey from the users after using the application and a review of the designs created by the users. The design reviews are done by a professional or an experienced interior designer.

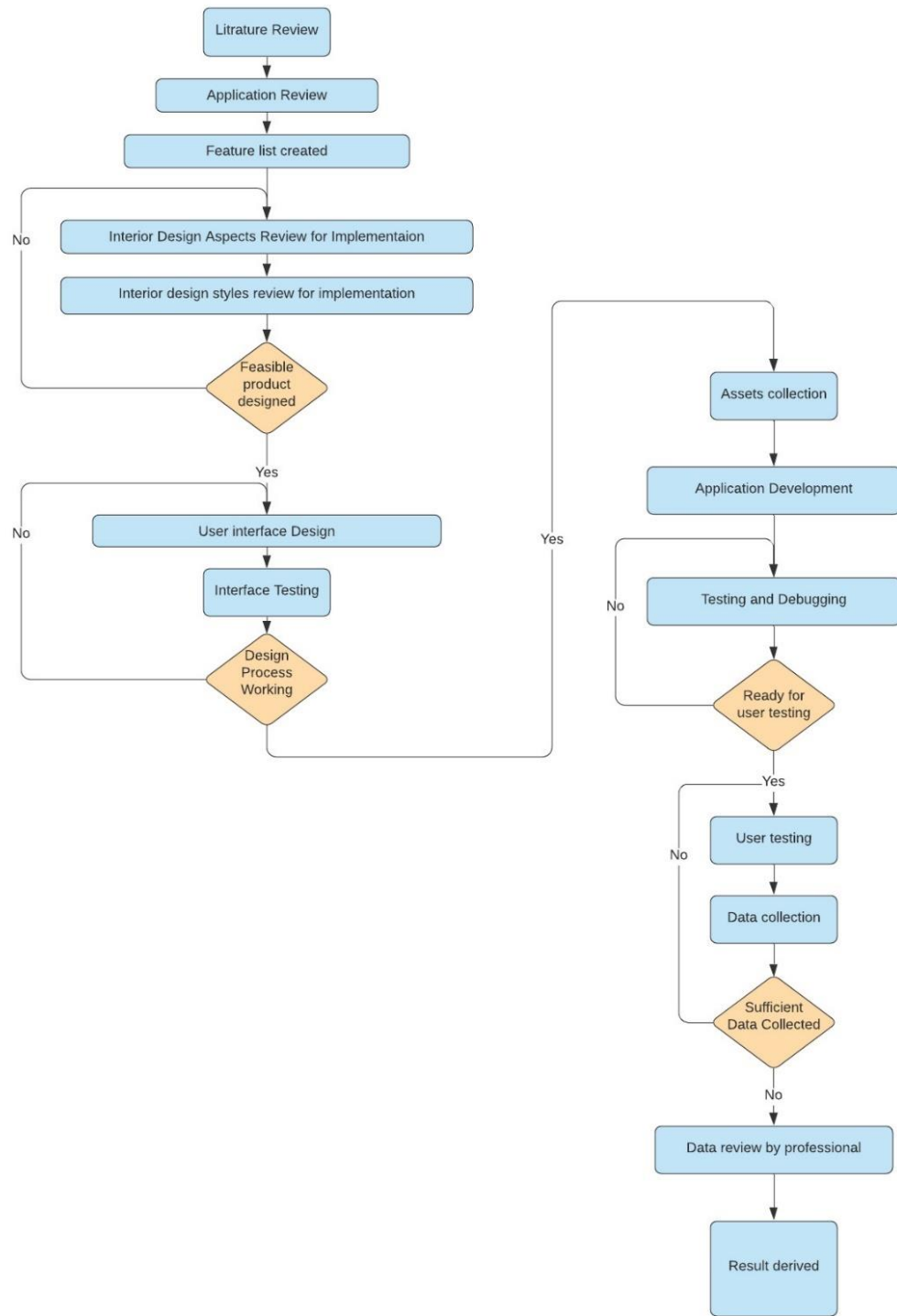


Figure 1: Research Framework

3.2 METHODS

3.2.1 Participants

The developed application is intended to be used by novices as well as professionals, but the primary aim is to empower the novice to design quality interiors. To measure the extent to which the application is helpful in guiding a user to design interiors, it is important that the users do not have prior knowledge about interior designing. If the application was tested by professionals, then they would likely use their own knowledge and might consciously or subconsciously ignore the guidelines provided by the application. Results created would not reflect exact measure of how effective the suggestions were, and qualitative feedback would also likely not reflect the original aim if there were professionals or experienced designers testing this application. Users with a general knowledge of room layout or interior styles may also pose the risk of skewing the results. So, selecting the users was an important step in getting the right results for the research. Proper measures have to be taken to exclude participants who have a prior knowledge or aptitude towards designing. Therefore, participants were first asked a series of questions to make sure they are new to interior designing. The questionnaire also makes sure that they are not formally educated in interior designing in general so that people with a creative aptitude and any kind of designing skills are excluded. They can answer only ‘yes’ or ‘no’ so that people with any level of designing skill can be excluded (see Table 3).

Eligibility Questionnaire		
Are you younger than 18 years of age?	<input type="checkbox"/> No	<input type="checkbox"/> Yes
Do you have any experience in Interior Designing?	<input type="checkbox"/> No	<input type="checkbox"/> Yes
Do you have any formal education in Interior Designing?	<input type="checkbox"/> No	<input type="checkbox"/> Yes
Do you have any difficulty in using AR application?	<input type="checkbox"/> No	<input type="checkbox"/> Yes
Do you have any difficulty using touch screen mobile phones?	<input type="checkbox"/> No	<input type="checkbox"/> Yes
Do you have any personal interest in the outcome of the research?	<input type="checkbox"/> No	<input type="checkbox"/> Yes

Table 3: Participant Eligibility Questionnaire

3.2.2 Interior Designs

Interior design involves a wide range of decision making such as colours, patterns, lighting, furniture layout, design styles, architecture of the building etc. As developing a comprehensive interior designing application would take a lot of time and resources, the version developed for this study contained only a subset of features. Several factors of interior designing such as colour of walls and the décor, lighting or pattern selections, placement and selection of furniture could be considered, however, this would require scanning the interior space and recognising the interior features. Details such as lighting in the room and finding out the type of curtains suitable would require the calculation or measurement of the amount of light entering the room and the time of day etc. Another aspect that could be implemented is a large range of colours and patterns that can be used in the designs. However, not all colours or patterns are suitable in all situations. Modern style interior designs use plain colours and simple patterns (Bill Ferris, 2021).

One aspect of interior design that was implemented for the purpose of this research is the selection and arrangement of décor. This has the possibility of using the full potential of AR and provides the user more information about the décor that are placed in the room and their size and colour. Apart from picking a favourite furniture from the shop, there are a lot of decisions to be made when selecting and arranging furniture. Different type of furniture belongs to different design styles and express different characteristics to the interiors (Interior Design Project: Furniture Styles | Kanopy, 2009). If decisions are not made carefully then the design might not work. For example, a small room will feel more cramped if the furniture is bulky. The colour of the floor or the carpet has to be taken into consideration when selecting a fabric for furniture. The patterns on the furniture, the colour of the fabric or leather has to be in sync with the floor. The same goes with the colour of the walls or any patterns on the wall. Modern design styles have metal parts, but a traditional style has more wooden parts and engravings on it. Considering all the above factors a further subdivision is made on design details where the focus is on placing the furniture and the relationship between the furniture and its fabric and textures.

There are a lot of design styles available when designing interiors. Traditional, Victorian, Mission, Art Deco/Nouveau, Contemporary, are few of them (Interior Design Project: Furniture Styles | Kanopy, 2009). Furniture also falls into these style categories depending on its finish, fabric and materials used to manufacture it. In this research, two design styles are selected: Bohemian and Modern. These two styles were selected for implementation because they do not have any intersecting elements. The user can try and see the difference in styles easily and will not get confused. In the mobile application, furniture with Bohemian and Modern style designs are available to add to a room. This furniture is modelled and textured based on the design style to place in the real-world using AR application. Furniture belonging to the style mentioned above have unique features. In a Modern design style, the emphasis is on functionality, cleanliness, and the lack of any kind of decoration or detailing.



Figure 2: Modern Style Couch (Pixabay - Living Room, Interior Design, 2021)



Figure 3: Bohemian Couch (Pixabay - Brick Wall, Room, Interior Design, 2021)

Modern Furniture has straight, tidy lines that are reminiscent of 1930s architecture (see Figure 2). Classic interior design is distinguished from contemporary architecture by this testament to the Bauhaus movement's sensibilities and Scandinavian design ideals (see Figure 3). Dark colours, such as blacks, creams, and beiges, are often used in colour palettes. Bohemian style on the other hand uses vivid colours such as greens, pinks, and turquoise on things like furniture, dinnerware, curtains, and rugs. Intricate shapes from nature, and vibrant colours are emphasised in bohemian-style houses, which have a laid-back feel. In reality, both of these elements are often mixed and matched to produce a distinctive and eclectic look. Bohemian style is all about combining interesting colours, trinkets, textures, and different styles of furniture with no intention of copying or adhering to a single theme. A modern sofa with striped upholstery could be paired with an antique velvet ottoman and a

bright-coloured statement chair. Bohemian interiors are so flexible because of the combination of various styles of furniture (Bill Ferris, 2021).

Based on the design styles, PARIDA can provide guidance on selecting different furniture and placing them. As the material on the furniture like the fabric or leather, the patterns on it, the type of wood patterns, all play an important role in the design style careful consideration has to be made in applying or changing the textures of the furniture. The same piece of furniture can be used in two different styles if the patterns or fabric colour matched the theme. This leads to another possibility of allowing the user to change the textures of the fabric on the furniture. The user should be limited in selecting the furniture based on the style they want to follow. This applies to changing the pattern or materials on the furniture. If a user picks a pattern texture for the furniture with vibrant colours it will not be suitable for a modern style interior design. If all or most of the décor belongs to one style, then the design should work. But occasionally mixing one or two elements from different styles is also a good idea. The ultimate power to decide what to use and what not to use on their room should be with the user. The application only provides a guidance to the user and does not take control over the designing process. So, there should be a system in place so that the user can override the guidance system and have full control of the designing.

3.2.3 Development

Several approaches were considered in creating the application depending on design practices. Users should be able to make decisions step by step and finally place the décor in the real world. As the application is intended to guide the users as a personal assistant, developing a menu system was the first step. By navigating through the menu, the system will provide and receive information about the users' design requirements. Designing a kitchen is completely different from designing a living room. Each room has its own separate set of rules. For example, the kitchen requires more task-based areas, different set of furniture and colour schemes, therefore, separate algorithms need to be developed for each room. As a result, the selection of a room is one of the important decisions to make. Picking a style is another important step and the user should be aware of what the features of each design style are. This is where the system will provide some information on what those design styles mean

and what is included and exclude. When one style is finalised then the next step is to place the décor in the room. This is where a layout style must be implemented. Furniture layout design falls under the umbrella of space planning, a sub-field of interior design that deals with the allocation of spatial resources (Kubba, 2003). A good furniture layout must consider both practical and aesthetic aspects. The functional parameters assess how well the architecture facilitates human activities such as interaction, rest, and activity in the room. The aesthetic standards are concerned with how the structure is seen as a visual piece. While the aesthetic aspect is left to the discretion of the user to some extent, there are some guidelines to be followed while arranging furniture. These guidelines are derived from the field of environmental psychology, which investigates how the layout of a room influences human behaviour (Germer & Schwarz, 2009). Conversation and circulation are two things that are influenced by furniture style. The configuration of seating, which must support comfortable eye contact and a regular speech rate, has a significant impact on conversation. When designing a living room, this factor should be considered the most important while in the design of a bedroom, this factor is less important. A focus point is also required for every arrangement. In case of designing a living room, the focus point could be a coffee table, TV or a fireplace. Once a focus point is decided then the other furniture can be placed around it.

Considering all these factors, a menu system was developed to guide a user to arrange the furniture. Depending on the user's choices, the menu will provide appropriate directions on what to do in each step.

3.2.4 Software Design

Creating a menu system was the first step in developing the application. The app will get information on what design style the user is going for. As mentioned earlier, only two styles are provided at this stage: Bohemian and Modern. When a style is selected, a brief description and image of the design style is displayed, and the user needs to confirm to proceed. After selecting a style, the user can pick which room to design. For the purpose of this research, only living room designing is implemented in the application. After selecting the room, the user will be asked to pick a piece of furniture as focus furniture to place in the room first. There are three options provided at this stage: Coffee Table, Bookshelf or TV.

When one type is selected, more options of that piece of furniture are presented to the user. If a coffee table is selected, then different types of coffee tables are presented to choose from. The options will be limited depending on the design style selected earlier in the application. This is done by disabling the furniture pieces that do not match the design style. Instead of completely hiding the furniture, it is kept visible but disabled so that the user will understand what the different styles of furniture are. Once a focus furniture is selected it is then placed in the world virtually. The user can move and rotate the furniture to place in the exact position required. Size of the furniture cannot be changed because unlike clothes, furniture does not come in multiple sizes and it gives the user false sense of size of those furniture pieces. After placing the focus object, the user will be asked to place more furniture around it to create the complete layout of the room. The menu provides options to go back and change the options in case the user changes their mind. But some levels of limitations are given to the user to make sure guidelines are followed. If the user tries to go back in menu without placing a focus object, then a warning message is displayed that the focus object is not actually placed in the world. Each furniture type is categorised and displayed to make the menu more organised. Planning the menu was done using a user interface prototyping tool Fluid UI. Figure 4 depicts the flow of all menu items in the application. Figure 5 and Figure 6 provide a closer look at each of the panels in the menu.

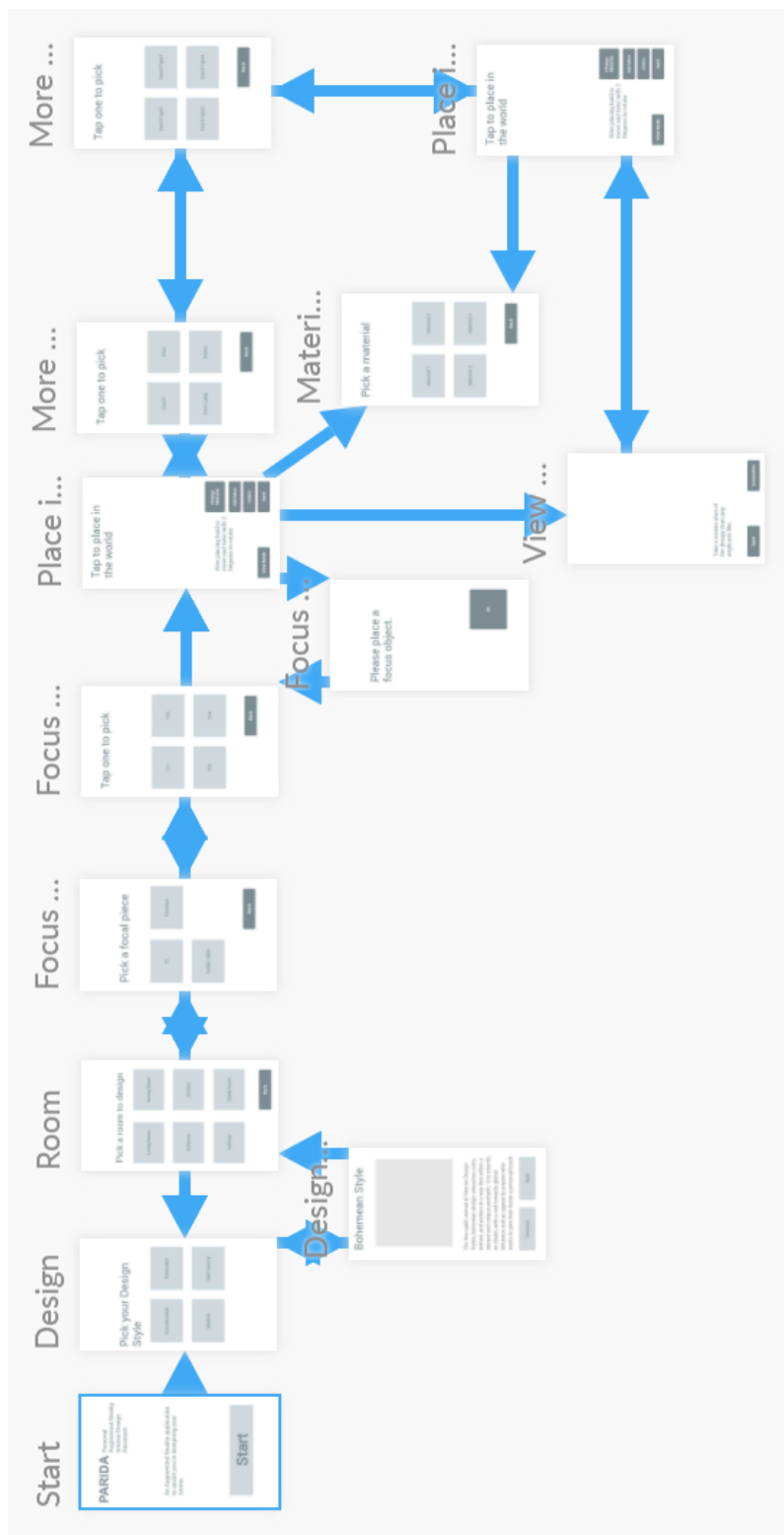


Figure 4: Complete set of menus

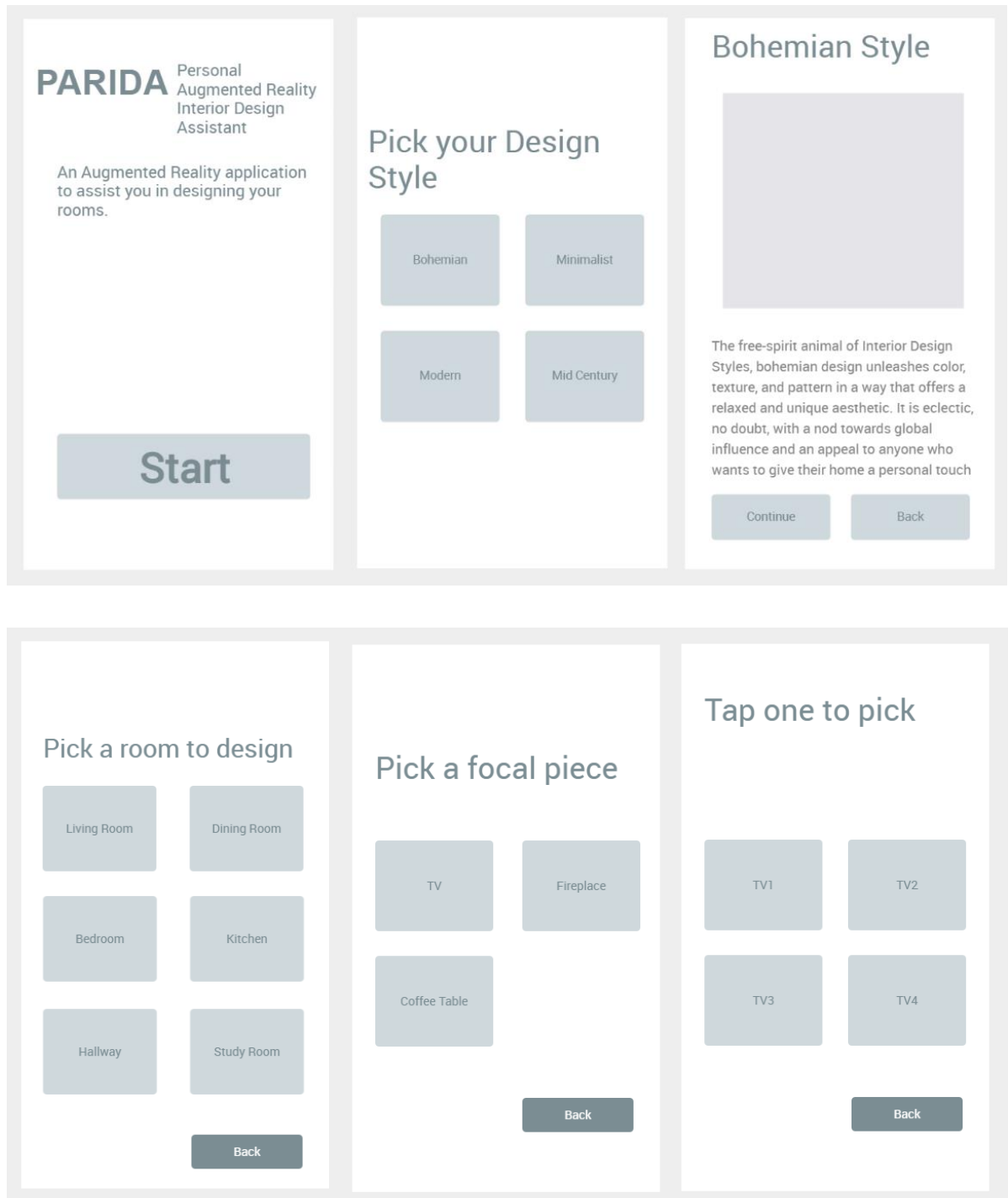


Figure 5: Detailed look at each panel, part 1



Figure 6: Detailed look at each panel, part 2

3.2.5 Models

The menu system gives a structured approach to designing by prompting the user to choose one design style and then follow a procedure for the layout of the furniture. The next big step is modelling the furniture that belong to Bohemian and Modern design styles. There are a lot of sources, free and paid, to download models of home décor. But not every model that is available will be suitable for this research. For example, traditional furniture models have lot of details with intricate shapes carved into it (see Figure 7). There will be curved lines and complex shapes. Downloading these types of models are not helpful as traditional style is not implemented in the application at this stage. Another challenge was the quality of the 3D models that is available from the internet. Most of them had a lot of details added to the mesh which resulted in a high poly mesh and made them unsuitable for a mobile application.



Figure 7: Traditional style chair (Pixabay - Armchair, Chair, Furniture, Seat, 2021)

Suitable types of models for this project will be low poly models which are intended for games and real time graphics. These models will have less vertices and faces. Most of the details will be created using textures. Finding low poly mesh of furniture that are made with modern and bohemian style limited the number of furniture that can be used. To overcome this issue, models that match the design styles were downloaded and then the mesh count was significantly reduced to match the requirement. Maya was the 3D software used to optimise the models. Models needed new UV maps as the mesh edge flow was totally

different from how it was downloaded. A proper UV map was necessary to apply textures properly to the models later in the pipeline. UV map (Figure 11) is a flat image of a 3D model's surface that is used to wrap textures quickly. UV unwrapping is the method of making a UV map. UV unwrapping was also done in Maya. This was an easy method as UV unwrapping is a part of modelling process. In some cases, models were created from scratch because that was easier than reducing the polygon count and removing the details. For example, the model in Figure 8 is basically a set of boxes or cubes arranged to make a couch. It is easier to create the model than reducing the details on it. Since Maya is an industry standard software for modelling and animation there are several tools to carry out these tasks.

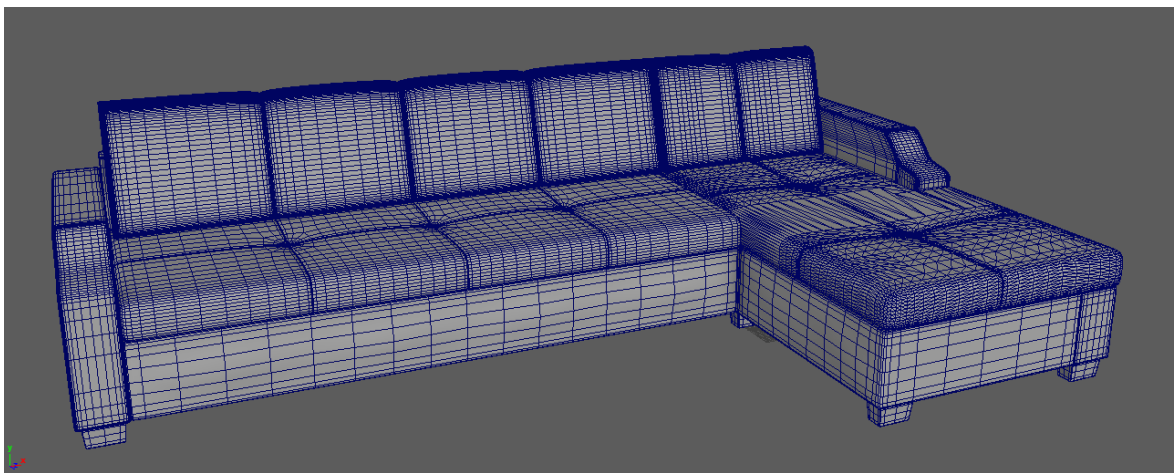


Figure 8: 3D couch with high poly count

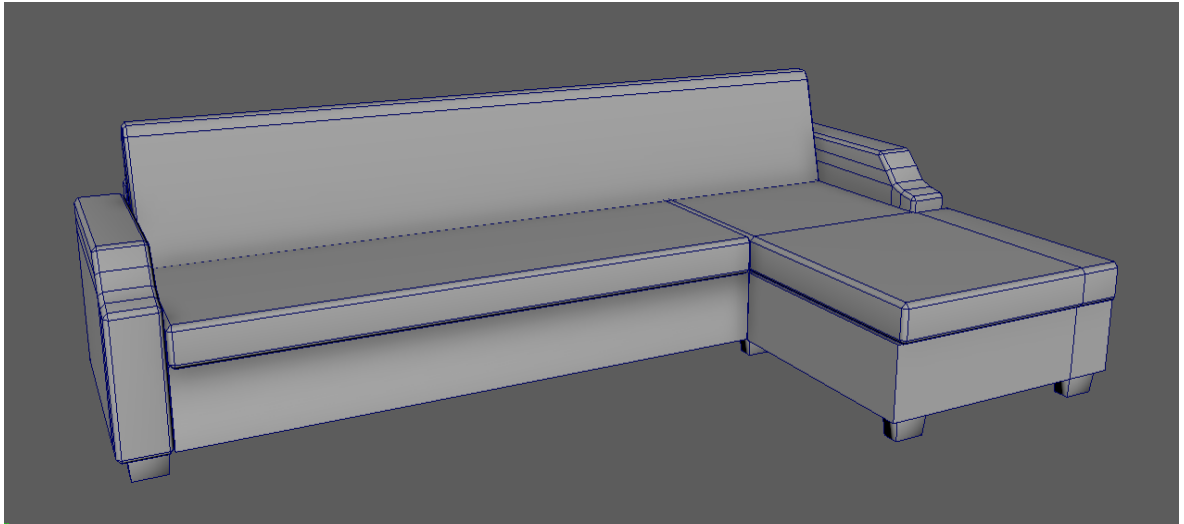


Figure 9: 3D couch with low poly count

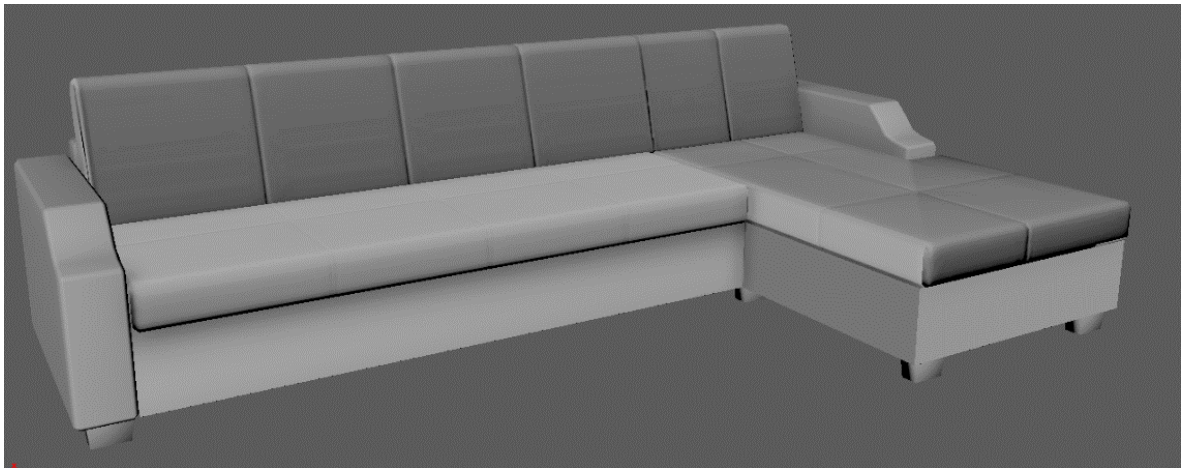


Figure 10: 3D low poly model with normal maps applied

The couch in Figure 8 is modelled with lot of details added into the mesh. This level of detail does not work well in a real time rendering application where the target platform is a mobile device. In Figure 9, the same couch is used to reduce the mesh complexity and make it suitable for using in a mobile device. The lost details can be achieved using a normal map. Normal mapping is a texture mapping technique used for manipulating the way light is bounced off a surface. It is used to add details without using more polygons. Figure 10 shows

the same low poly model but with a normal map applied to it. The details such as the edges of the cushions are not part of the model but provided by the normal map applied to it.

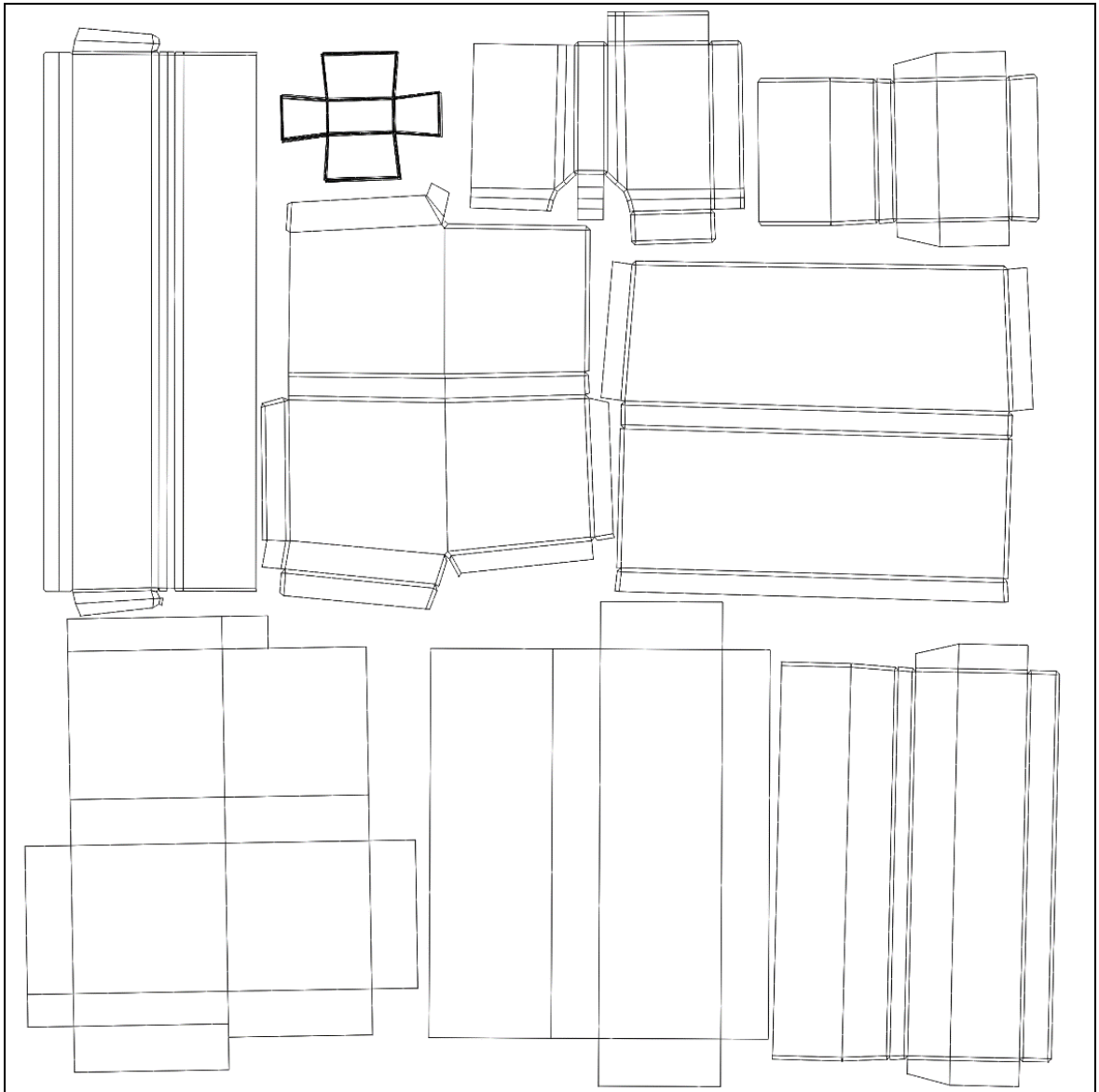


Figure 11: UV layout of the couch model

As there are a lot of 3D models required in the application for designing interiors, optimising each one is an important step. Collectively it improves performance to a great extent, avoids lag while placing and moving the objects and increases user satisfaction. A large set of décor items can be used for designing interiors of a living room. For this research, a few selected

categories are considered to keep the application lite and avoid juggling with a lot of models and textures. Focus of this research is applying interior design guidelines to a user than presenting with a variety of décor options. Some of the furniture that were added in the application are couches, both single seater and double seater, coffee tables, fireplace, some plants, separate chairs, floor lamps and because it is a living room a TV is also added. Each furniture category has separate different models. All models belong to either Modern or Bohemian style or sometimes both styles. Since Bohemian style can incorporate a lot of different style elements some models can be seen under both styles. TV is one such element which needed to be added to both styles. When a user selects one furniture category, for example “Couch”, all types of couches are displayed, and some are kept disabled as mentioned earlier. After picking one type of couch the user can place in the world using Augmented Reality. Once the couch is placed in the world user can further customise it by changing the textures on it.

3.2.6 Textures

Colours and patterns are an import part of interior designing. A particular type of couch will look very different when it is in leather upholstery than when it is in cloth upholstery with distinctive patterns. A user might like a particular model of couch but not the materials used on it. For example, shiny steel legs and frames look very different to a matte black frame. The patterns and finishes on a model can contribute a lot to the visual appeal of the object. That is why a texture changing feature is also implemented in the application. The user can select a furniture and change its texture based on a list of options. These options are a set of textures or materials that is available to apply on a piece of furniture. For example, some of the options on a couch are a beige leather upholstery and black legs, white leather upholstery and metallic legs. The user cannot individually change the finishes on each part of the furniture. This is because furniture is mass produced and there is not much option of customisation. This application is aimed at users who cannot afford to hire an interior designer and furnish their home with customised furniture. People who can afford to buy custom made furniture will most probably be hiring interior designers to design their homes.

The texture changing feature is available for almost all furniture. For that furniture where different textures are not available, the texture change button will be disabled. Even though the textures are displayed as one file or option in the application they are a combination of three different maps. Diffuse map, metal map, and a normal map. A diffuse map shown in Figure 12 (1) gives the colour to the 3D object. It decides what colour is reflected off from the surface of the object. The metal map shown in Figure 12 (2), is a black and white map that tells the render engine which part is metallic and which part is not metallic so that the light reflection is altered according to that. The normal map shown in Figure 12 (3) adds details to the model by changing how light reflects from the surface of the object. This is helpful in adding details such as the texture of the leather or some scratches or imperfections on the surface.

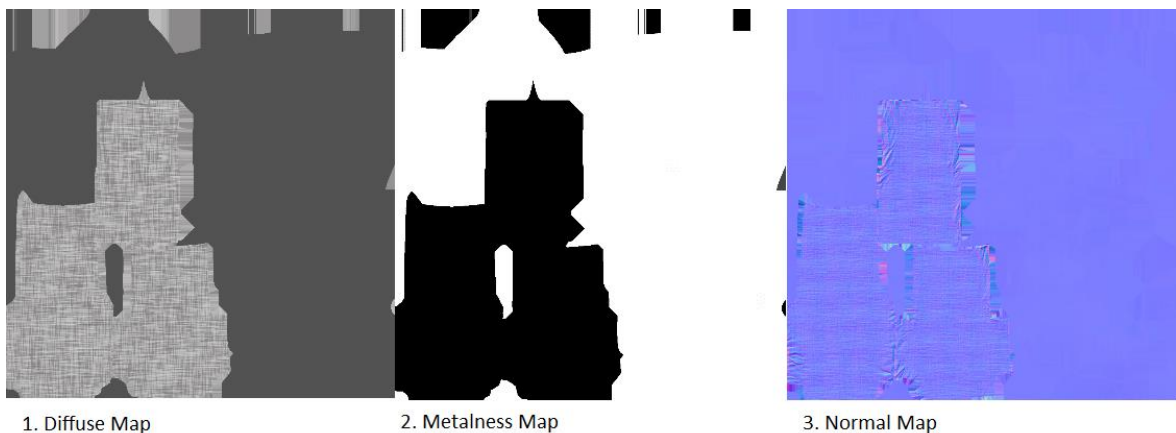


Figure 12: Diffuse Metalness and normal map of the couch

There are several other maps that can be used to add a great level of details to the models. Some of them are specular map, roughness map, occlusion map etc. Specular map is a black and white map that can control the specular reflection of a surface so that a particular area of the model will be reflective while others are not. Roughness is similar but controls the roughness on a particular area of the model. The occlusion map is used to show which parts of the model can be lit with high or low indirect lighting. Ambient illumination and reflections provide indirect lighting, but steep concave sections of surfaces, such as a crack or a fold, will not receive any indirect light. These and several other maps are avoided in the

application so that the models load faster, and the application is not too heavy to run on a mobile device. UV map of the models can be brought into an image editing software like Photoshop to create the maps. But for this project and intuitive texturing application called Substance Painter was used. 3D models created in Maya are UV unwrapped and brought into Substance Painter for texturing. In this software, textures can be directly painted into the 3D model rather than painting on a UV map eliminating a lot of guess work. After painting, Substance Painter exports different maps which can later be applied to the materials in Unity. Materials define how a surface should be rendered, by including references to the Textures it uses, tiling information, Colour tints and more. The available options for a Material depend on which Shader the Material is using. A Shader is a set of code that determines how the game engine represents an object on the computer screen. In this project, the Unity standard shader is used and only texture maps are applied to it.

3.2.7 Implementation

The Unity 3D game engine was used to develop the application and build to the target hardware. The engine is well equipped to handle 3D models, textures and lighting. Unity uses the C# (C-Sharp) programming language to develop game play logic and interaction. For the implementation of Augmented Reality there are several other technologies available, but for this project, a cross-platform framework of Unity called AR Foundation was used. AR Foundation is an extension of Google's ARCore and uses the same technology used in Google's ARCore and Apple's ARKit. ARCore uses a technique known as simultaneous localisation and mapping (SLAM) to determine where the handset is positioned in relation to the world around it as the user moves it. ARCore uses feature points to compute the change in place by detecting visually distinct features in the captured camera file. To approximate the location and orientation of the camera relative to the environment over time, the visual information is paired with inertial measurements from the device's IMU (Inertial Measurement Units) (Fundamental Concepts | ARCore, 2021).

After scanning the world and creating an understanding of the horizontal surfaces, the next process in implementing AR is to place an object into the world. On a mobile device, the most user-friendly way is to touch the screen and place the object. This can be implemented

in multiple ways. A raytrace function is available in ARCore which projects a ray from where the user touches on the screen into the world. The object could be placed on the point where that ray hits the floor and then adjusted to the exact position. The problem of this approach is that touch is not accurate all the time. A different approach is to do the raycast from the centre of the screen and indicate where the ray is hitting the floor by displaying a crosshair. Once the user finds a suitable location to place the object then a touch anywhere on the screen will place the object on the screen. The user should also be able to move, rotate or delete the object once it is placed. If there are multiple objects placed in the world, the user should be able to select one object and then move it. The crosshair implemented to spawn objects in the world was again used to select objects. Overlap of the crosshair with the 3D objects is detected using Unity's collision detection, and when a collision happens, that object is selected as an actively selected object. Any gesture given to the screen by the user will be applied to that object. When the mobile phone is moved and the crosshair is moved away from the object, the overlapping stops, and the selected object becomes neutral again.

Once an object is selected, a "Delete" Button is enabled on the screen, and by touching that button, the user can delete the selected object. To move the object, the user needs to first select the object using the crosshair and then touch and hold the screen with one finger. Unity will read the touch and hold and if there is no active object, it will assign the position of the touch relative to the world to the position of the object. The user can touch and hold and then move the mobile phone to move the object. The object will stop moving when the user lifts the finger. Rotation is also implemented in similar way but with the touch of two fingers. First the user has to select an object with crosshair, then with the object in selection, the user touches the screen with two fingers and slides around the object. The new rotation of the object is calculated with the direction of the object towards the touch position relative to the world. As the user slides the two fingers around the object, it rotates facing the fingers.

One challenge with this method was that when there are multiple objects present in the world, moving of objects become complex. There is no collision preventing to move one object over or through another object. The user does not have to move one furniture away to move another like in the physical world. In the Augmented Reality world, there are no limitations

of physical space and mass. So, when a user moves one object through another object to the other side of the room, then the crosshair selects both the objects, and they move simultaneously. This problem was solved by limiting only one object to be able to be selected in the system at a time.

Furniture placement functionality is used in two sections in the application. One is when the user selects a piece of furniture as focus object, and another is when adding more and more furniture around the focus object. While adding a focus object there will be only one piece of furniture and there will be less complexity. In the second time use the user will be adding more furniture around the focus object and that is when the user has to deal with multiple objects, by moving and arranging them.

Another important functionality is the material on the furniture. Unity Engine provides a Physically Based Rendering (PBR) shader in order to more accurately simulate realistic lighting scenarios. Several material maps can be used to alter the look of the 3D objects in Unity (Pharr et al., 2018). This feature can be used as an advantage in this project as the change in material can bring a lot of difference in the appearance of a furniture. It also has significance from a design perspective. Furniture with metal frames and legs will be more suitable for Modern style interiors but on the other hand wooden furniture and presence of textures suit more to a Bohemian type of interior. Even though metal and wood are completely different material and has different properties in terms of light reflection and refraction, with the use of PBR material same model can be used for wooden furniture and metal furniture.

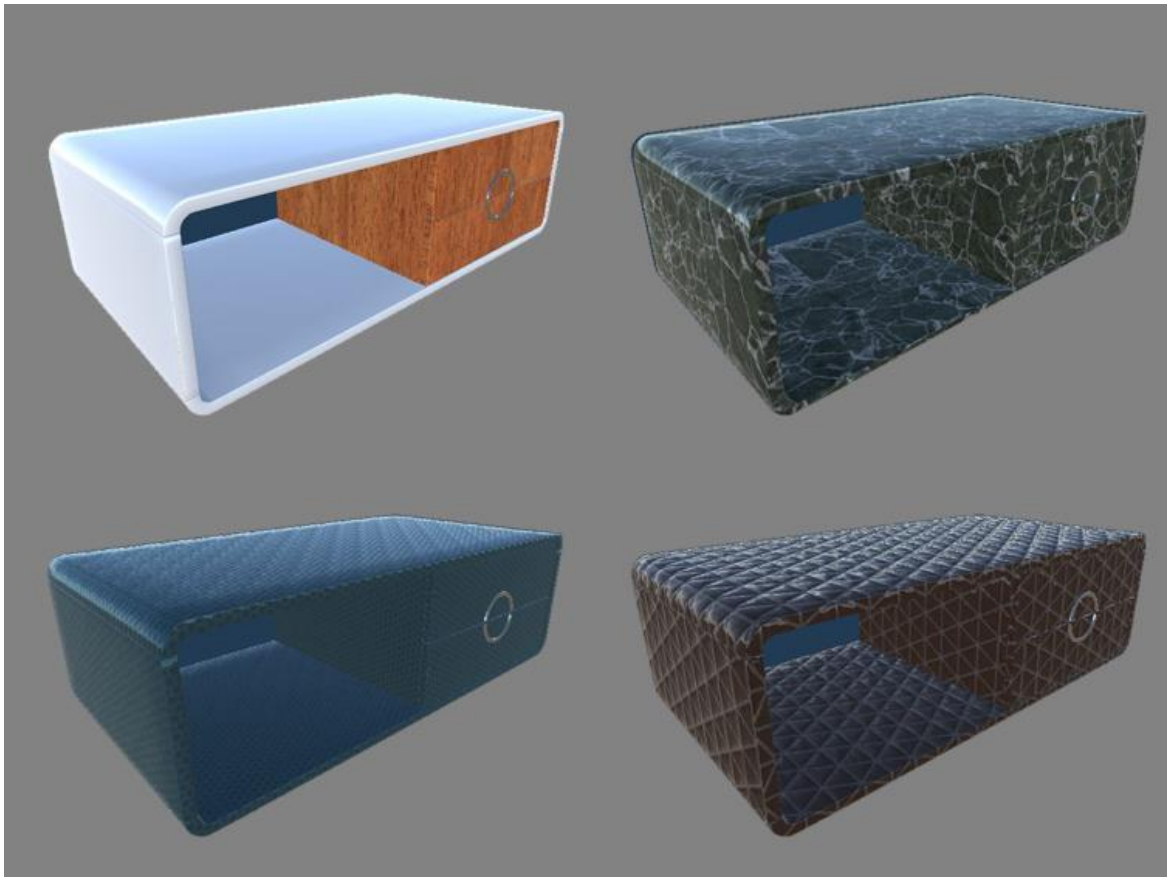


Figure 13: Coffee table model with 4 different materials applied

Figure 13 is a render from Unity of the same model with different materials applied. The coffee table has different appearance in, and the materials also looks different. The image at the bottom right has lot of details like small, bevelled bulges around the model. The light reflection from the model shows the details. The image on the top right has a flat shiny and smooth surface on the outside and wooden drawers in the middle portion. But in reality, the models are the same and it has a flat mesh. The normal map, metal map and the diffuse map are the maps that give this effect to the model. This possibility of giving different appearance to the same model with different materials increases the importance of more than one option of materials for a model. Instead of showing a whole lot of 3D models with different materials applied to it the user will be able to apply different materials to the models. This way a user can make a step-by-step process in designing the interior space. Once a model is chosen it can be placed in a space and then the user can try out different materials. The

application will not restrict the user to change materials in a specific point while using the application. The user could change the material and then place the object or first place the object and then change the material at the end. To implement the texture changing feature another button could be introduced to the user interface. Whenever a furniture or a 3D model is selected, a texture change button will be enabled and when user touches it, all the texture options should appear. But not all objects have a texture option available to it, for example, the TV and the plants. So, a check must be done before displaying the texture option in conjunction with the list of 3D models.

A large list of furniture and an even larger list of materials are required for an application like this to do complete interior designing. In this project, only the living room design feature is implemented and that required 26 models and for each model required an average of three material options. So, a total of 78 materials had to be sorted and arranged for one room. Even though some pieces like the chair and plants can be used in other rooms, there is requirement of a large list of objects and materials. To tackle this problem one database is created in Unity to store the models and another one is created to store all the materials. This will help to store more models and materials in future and make the application scalable. The database initially has a list of categories like TVs, Couches, Chairs, etc. Each element in the category can be expanded like an array and any number of furniture items can be added to it. This system is helpful in displaying a category first to the user and then displaying more items in that category. For example, a user can pick a chair category and then the system will display a range of chairs that can be used in the world. Depending on the design style chosen at the start of the application, some of the items will be disabled. To avoid confusion, a text will be displayed at the bottom which says that those items disabled are not matching with the style. Even though the item is disabled the user will still be able to see the image of the furniture item (Figure 14). This will help the user to get an understanding what is included and excluded under the chosen design style. The disabling of the items in the menu system is done at runtime. To make this happen, design style information is also stored with the model. When an item is spawned in the world, the user is able to change the texture of the model. This texture set is unique to the model because the UV coordinate set of one model

does not match with another model. So, more information is required to store with each model in database. This texture information is stored linking to the texture database.



Figure 14: Furniture selection panel with some buttons disabled

The second database in the application is the material database. This database has a larger file size than the furniture database because each furniture will have more than one material set. Each material requires several texture maps, e.g., diffuse map, normal map, metallic map, with each texture being 1024×1024 pixels in size. Depending on which furniture is selected, the appropriate list of materials has to be retrieved from the database and presented to the user. Just like the furniture, materials of those furniture are also added in the form of an array in Unity. This is beneficial as more materials need to be added in future.

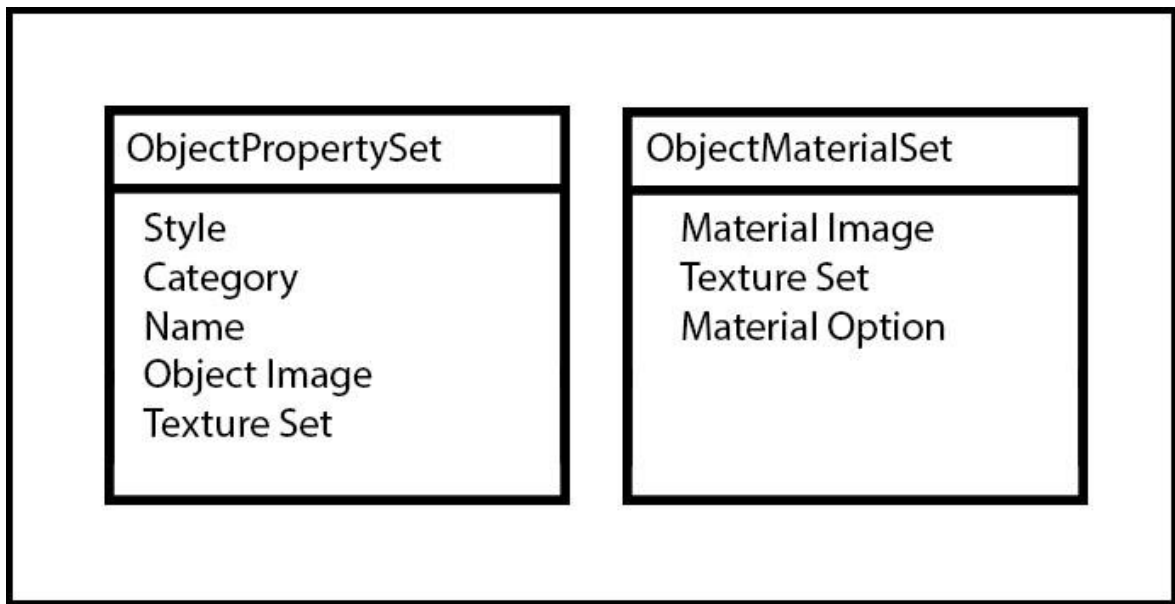


Figure 15: Class names with properties

The next challenge was to find a way to connect the model and its appropriate material sets. Two C# classes `ObjectPropertySet` and `ObjectMaterialSet` helped to overcome this hurdle (Figure 15). The first class, `ObjectPropertySet` holds information about the models or furniture such as what style it belongs to, what category of furniture it belongs to and what material set. When a user selects an interior design style then the application can use the style information from `ObjectPropertySet` to selectively present to the user. The category value holds information about how that particular furniture is categorised. Some of the categories are couch, chair, floor lamp, coffee table etc. The user first selects a category before selecting a furniture to place in the world. While running the application, the user selects a design style first. This is stored in the application. If the user selects the couch category, all furniture pieces that fall under that category will be displayed. The application then loops through the displayed list of couches and disables the buttons of those couches that do not match with the style information in the `ObjectPropertySet`. This class also stores more information like the name of the furniture, the texture set and the image of that furniture. The texture set identifies which texture set or material set is applicable to the object. The object image is used to display on the button so that the user can easily identify. The name information is not used in the application at this stage. This could be useful in

future when displaying more information about a particular piece of furniture such as the name, price, weight, fabric type, frame make and type etc. `ObjectMaterialSet` has a long list of materials of each 3D object. This class is added to the materials in Unity Engine. Along with the list of materials this class also holds information about the texture set name, a material variable and an image of the object in the material. On the object database a subgroup is also stored which contains information about the materials that can be applied on it. This material information is checked against the database of materials. If a match is found, then appropriate set of materials are displayed to the screen. The texture image is used to display on the button in the texture options panel. Depending on how many texture options are provided in the database an image is also provided to show to user how the furniture looks in that texture. A material variable is used to pass information to the buttons (Figure 16).

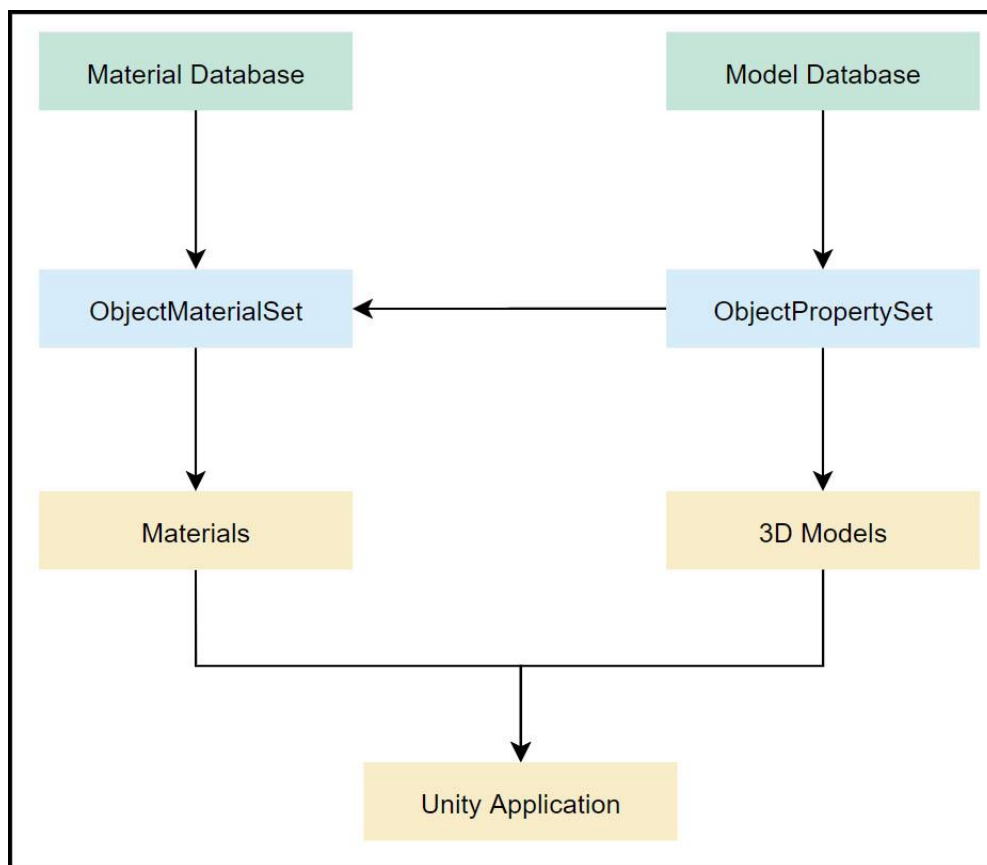


Figure 16: Data flow in the application

3.3 USER TESTING

User testing of this research is designed to find out how efficient a guided AR mobile application will be, to help in designing interior spaces to a professional standard by novice user. The users will only be using the guidance from the application and no other external influences will drive them in creating the design. Due to the practical difficulty of implementing all factors on interior designing only a few of the features such as placing and arranging furniture, applying different materials for furniture are included in the developed application and the testing space is arranged according to the requirements of the application.

3.4 USER TESTING SETUP

User testing was conducted in room 905 of the WG building in AUT Auckland city campus (Figure 17, Figure 18). This was a small room of size 2.8×4.7 meters, normally used as a meeting room by AUT staff and students. An empty room was required for conducting the experiment since the developed application will be used by a potential user to design their empty room. An added advantage to an empty room was that the system will not read desktops or chair surfaces as horizontal planes (floors) and it will not become too complex to run the test. So, all furniture was removed from the room to create an empty space. However, some objects were fixed to the wall such as a whiteboard, a wall hung TV, a dark green colour fabric wall panel and a small cabinet, but they were not interfering with the plane detection of the application. There were no additional markers required for smooth running of the AR application as the textures on the floor were distinctive enough for ARCore to detect the planes. Reflective surfaces might have been a problem and could have required covering up with cloth or paper. But the only reflective surface was the whiteboard on the wall. Since the application was detecting only floor surfaces, the whiteboard was not considered a significant issue.



Figure 17: Room WG905 Photo 1



Figure 18: Room WG905 Photo 2

3.5 INVITEES

Participants were invited by the researcher using flyers advertised on AUT notice boards to come and test the application. Since the application is aimed to empower a novice user to create professional quality interiors the type of participants that test the application was important for this experiment. The participants should not have any prior knowledge about interior designing so that they do not use their knowledge consciously or subconsciously while testing the application. To avoid above mentioned problem, an exclusion criterion was created. This was clearly mentioned in the advertisement flyer (see Appendix 7.57.1) and potential participants who were volunteering were asked to fill out the eligibility form (see Appendix 7.2) to make sure they were not experienced in interior designing. There were 14 participants selected for testing the application after applying the eligibility questionnaire. One participant was not able to attend due to being sick. Participants were predominantly younger people as six out of the 13 participants were aged between 18 – 25 and four were aged between 26 – 35 and only two were aged above 36 years of age (see Figure 19).

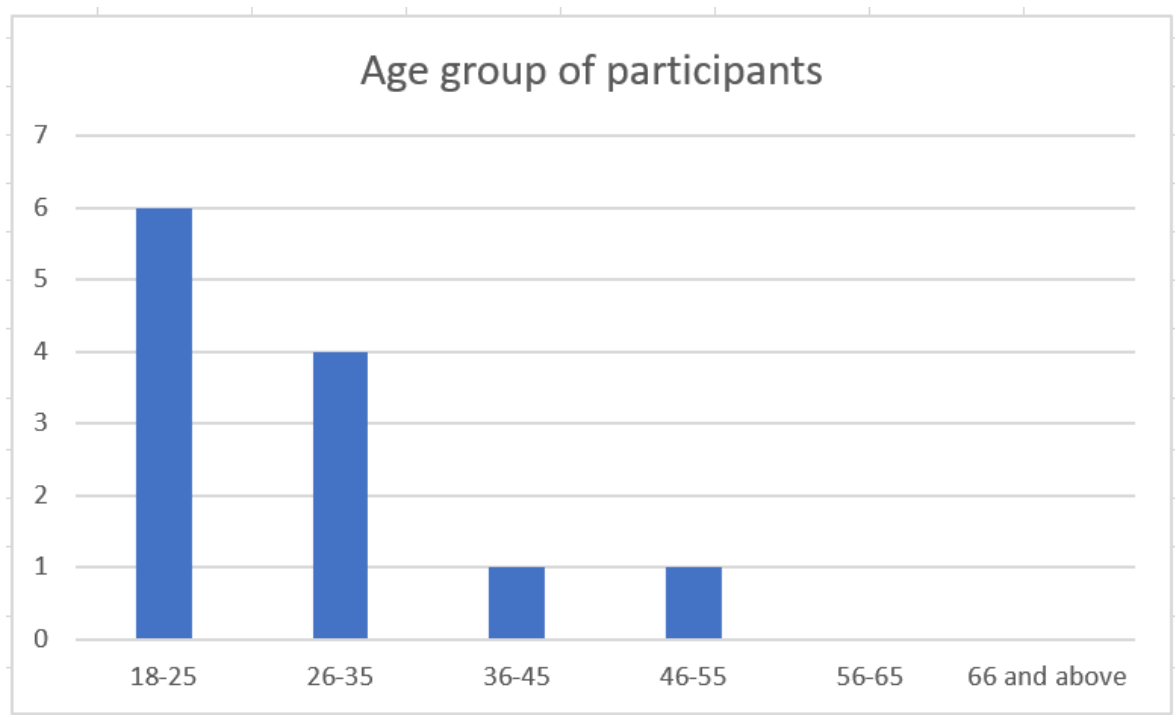


Figure 19: Age group of participants

3.6 TESTING

Room WG905 was booked for two days, and participants were invited by the researcher to test the application in the space. Upon arrival at the testing space, the researcher provided a brief description verbally, about the research and what the user will be doing at the testing, even though it was already mentioned in the information sheet provided to the participants (see Appendix 7.6) prior to the testing. A quick demonstration of the application was also given to the user about the basic operations before the user started testing the application. The participants were then given the mobile phone with the PARIDA app installed in it. Although the participant information sheet estimates roughly ten minutes for the testing of the application, no actual time limit was given to the participants to design the space. As it is a new application, the users needed some time to get familiar with the interface and navigation in the application. Once the participants started to use the application, the researcher did neither interfere nor help. The participants then went on designing the space and once they had finished designing the room, they notified the researcher. The researcher then took screenshot of the designs from the same phone from different angles and then handed over a feedback form (see Appendix 7.3) to the user. Since the users just finished testing the application, they were able to provide valuable feedbacks about the application. The feedback form asked about the usability of the application, efficiency as an interior designing application, whether the experience gave any insight into interior designing etc. The user demographic was also collected in the feedback form such as age group, experience in app development, use of Augmented Reality, familiarity with smartphones etc. There was space provided for explaining what was most difficult in using the application and where can the application be improved. Space for additional comments was provided at the end. The following figures (Figure 20, Figure 21, Figure 22) are some of the designs produced by the participants.



Figure 20: User design 1



Figure 21: User design 2



Figure 22: User design 3

3.7 RESULTS

The participants spent an average of 11.23 minutes (SD=2.42 min, Min=6 min, Max=15 min) (Figure 23).

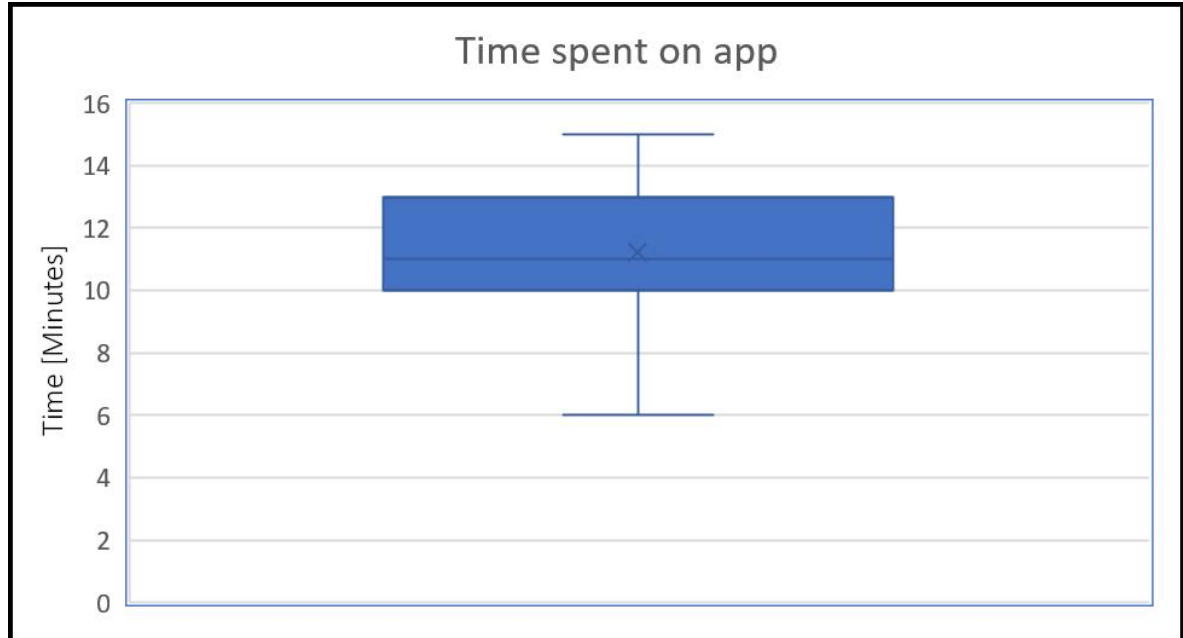


Figure 23: Time spend on app

Many participants struggled to use the application at first but quickly learned to use it. Even after completing the designs, it was observed that some participants were exploring the application and trying out different furniture. Use of an Augmented Reality application was exciting for many people. Even though the technology was familiar to some people, only two have used an app for interior designing prior to this study. The texture changing feature was something that excited some participants.

3.8 UER FEEDBACK

Feedback was collected from all 13 users immediately after the testing to make sure that the participants do not miss any feedback and suggestions they got while using the application. Feedback was provided through a form which had questions about application usability and user demographics and provision for comments. (See Appendix 7.3)

Feedback on the application

- F1. Did you learn anything new about interior design principles?
- F2. What did you learn? (Subjective question)
- F3. Did you make any design decision that you wouldn't do otherwise?
- F4. The app is useful to design interiors. (Strongly disagree to strongly agree)
- F5. The application is user friendly or not
- F6. What can be improved in the app? (Subjective question)
- F7. If released, would you download this app?
- F8. How much would you pay to download this application?

Participant Demographic

- D1. What is your age group?
- D2. Do you use a touch screen smart phone on a daily basis?
- D3. Have you used any Augmented Reality application before?
- D4. Have you used any application for interior designing before?
- D5. Have you hired the services of an interior designer before?
- D6. Have you developed any mobile application?
- D7. Which smart phone do you own?

All participants were smartphone users, so the use of touch screen based mobile application was nothing new to them and it should be inferred that the participants had no difficulty in familiarising with the using of a touch screen interface. This was evident and observed at the time of user testing. Participants easily navigated to the Augmented Reality screen in the

application without any confusion. Nine out of 13 participants have already used an Augmented Reality application. With the above information provided by the participants it is clear that most of the participants were young and not new to the technology and difficulty in using a new system was not an obstacle in the smooth running of the testing. In terms of interior designing, two people have used a mobile application for interior designing. But an interior designing AR application might have been a new experience to the participants. The application is primarily intended to assist users to design interiors. The application shows different furniture of different styles and a method to organise them in a room, and it is highly likely that users may learn some new ideas about interior designing. This can be considered as an advantage of the application.

A positive response was received for the first question which was “did you learn anything new about interior designing?” (Figure 24). One person responded, “a lot” and nine people agreed that they learned “a little”. Only three people responded that they learned nothing.

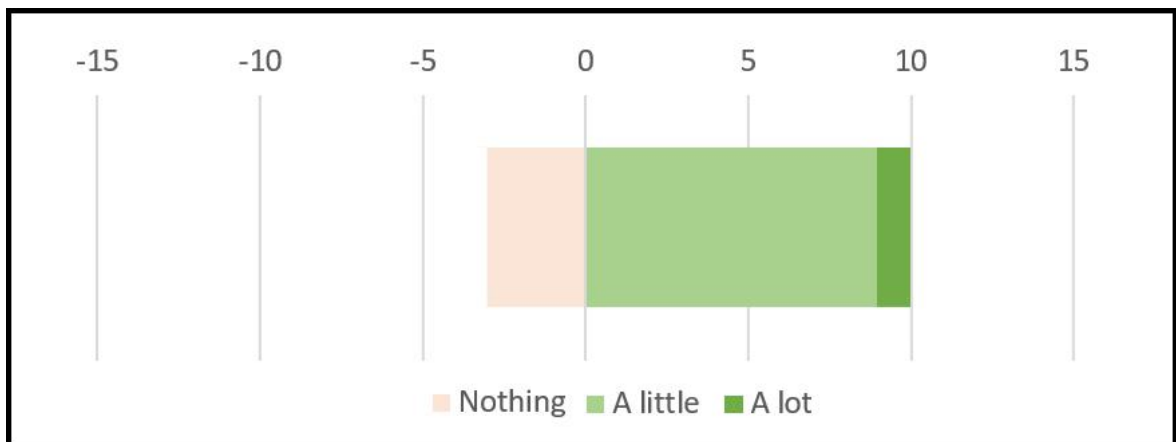


Figure 24: Question F1- did you learn anything new about interior design?

The second question was about the guidance provided by the application that if the participants made any design decisions based only on the suggestions from the application. Only three people responded ‘yes’ to this question and four were unsure about this. Six participants were not sure that the decisions were based on the suggestions from the application (Figure 25).



Figure 25: Question F3 - did you make any decision based on the app?

Response to this question is contrary to the first question because the majority of the participants responded they learned something about interior designing and in the second question their feedback was that their decisions were not made according to the application. Misinterpretation of the question might have been one of the reasons for this contradiction. Even though the participants were not trained or educated in interior designing some might have learned some tips and tricks from videos and magazines.

The fourth question was to gauge how useful the participants felt the application was for interior designing. The choices were: strongly disagree, disagree, not decided, agree and strongly agree. The response to this was mostly positive (Figure 26). 12 of the 13 participants agreed that the application is useful for interior designing and two out of the 12 strongly agree to it.

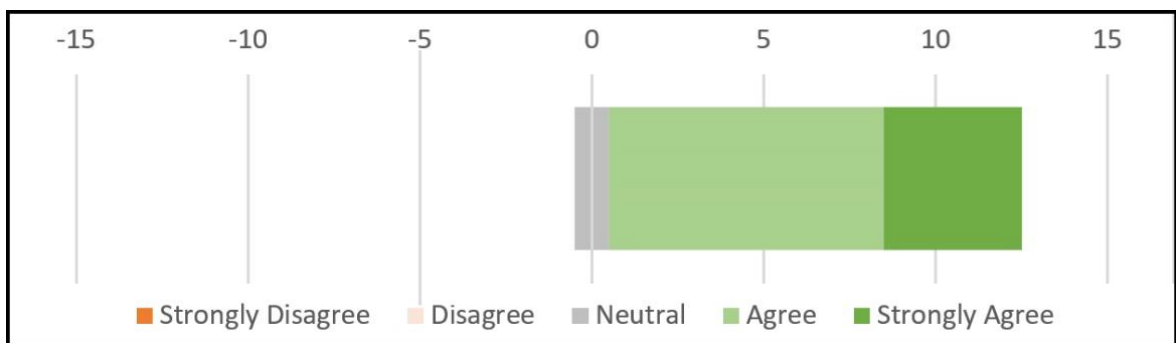


Figure 26: Question F4 - the app is useful for interior design

Use of the AR technology and seeing a virtual furniture in real space and the guidance from the application might have been the reason for a positive response. Many users were seen testing the fidelity of the application by moving the furniture and walking around the virtual object to see it in different angle and to test if it stays in place even if the mobile phone is moved or rotated fast. Even though most of the participants used AR and only two people used an application for interior designing, this might be the first time they realised the possibility of AR in interior design. At the time of testing, many people were seen struggling to properly use the AR part of the application. Placing an object in the exact position they desired, moving and rotating the object precisely finding the exact type of furniture, etc. were the areas that participants struggled with most. Moving and rotating objects were done using different operations. This also caused confusion among the users in the initial stage of using the application.

However, after spending about two to three minutes with the application, participants were observed to gain confidence. This is evident in the response to the fifth question, how user friendly is the application. 12 of the 13 participants responded that the app is ‘somewhat user friendly’ and one person responded the application is intuitive (Figure 27). There was no negative comment for this question.

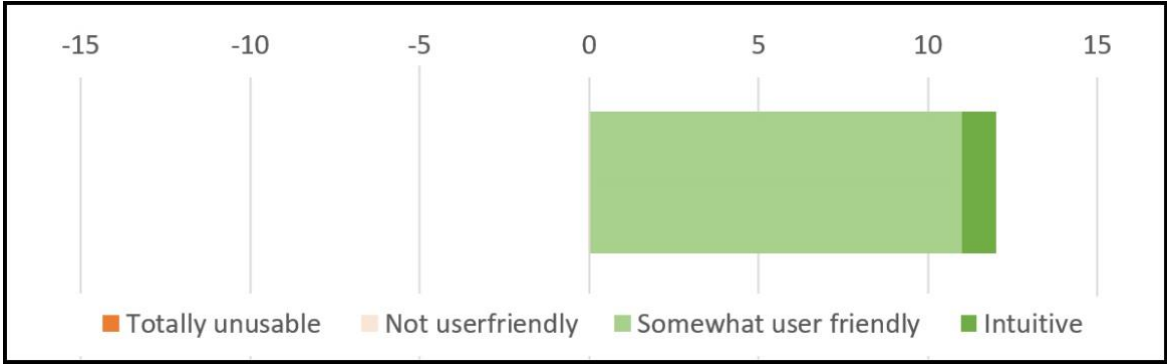


Figure 27: Question F5 - How user friendly is the app?

Ten out of the 13 participants responded ‘yes’ to the seventh question, that if released would they download the application, and only three were unsure about it (Figure 28). To the eighth question, how much they were willing to pay for this application, there was also a positive

response. Nine out of 13 were willing to pay \$1 to \$10 for this application and only three were not willing to pay anything (Figure 29).¹ Responses to the seventh and eighth questions indicate a wider acceptance of the application among the participants of the user testing and willingness to download and use the application in future. These responses also correlate to the responses to the fourth question that if the application is useful in interior designing. The response here was also widely positive.



Figure 28: Question F7 - if released would you download the app?

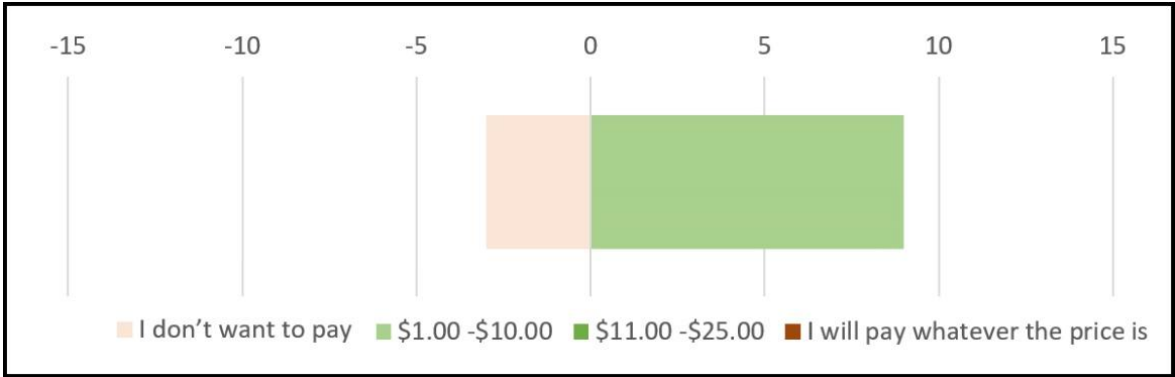


Figure 29: Question F8 - How much would you pay for the app?

¹ As this question was on the other side of the feedback form one of the participants missed to answer it.

Apart from the dichotomous questions and Likert scale questions, users were also invited to provide feedback. The majority of the feedback was on the user experience side of the application. Three users suggested giving live feedback for first time users would be helpful. Implementation of virtual buttons were suggested by one of the users. Right now, the application provides no buttons for rotation and translation. The user needs to slide with two fingers to rotate and touch and hold with one finger and move the mobile phone to move the objects. The application is not providing any feedback on these operations. Another user suggested implementing 'gizmos' like in 3D software to move and rotate object. Precise placing of the furniture was a difficult task, according to a user. To accurately place and rotate the objects, furniture snapping to a grid was also suggested. This should allow the user to rotate an object in specific angles. An 'undo' button was suggested by another user. A plan view was also suggested by the same user to view where the furniture is placed and how far objects are away from each other. One of the challenges faced by users were that how far they can move the object. Sometimes the furniture was moved beyond where the walls are and this was not recognised by the users. This problem of objects moving beyond vertical was addressed by one of the users. They suggested to have a system that blocks the furniture from moving through the walls. One user finds it more intuitive to drag and place objects than touch and place object in the world. One of the users find it more usable when it was in landscape mode. Clicking and selecting a furniture and then moving was a suggestion from one of the users since the user find it really difficult to move objects to place. This suggestion is pointing more towards the user experience in computers.

Another area where the users suggested improvement is in the accuracy of the information and measurements. One user suggested to check the size of some of the models. Another user suggested that even though the application provides some brief description about the interior design styles, it would be good if the application gives some more details and explanation about different types of furniture, their material, who designed those etc. A feature to add more colours were suggested by one user and enquired about any possibility of paint walls and change floor colours and textures. Another user suggested to simply add more colours. Another user suggested to consider the scale of the room and scale of the

furniture and if they all fit in. Mixing of different design styles was a request from one user. They suggested that instead of restricting, the application could just provide suggestions.

Some of the positive feedback from the participants was that they learned about arranging furniture, a way to layout the furniture in a room and that they were able to see how a piece of furniture looks in different colours and materials since it is hard to visualise. Four people said they learned about design styles and furniture styles. For many, using an AR application and placing the objects virtually in a real space was a fun experience.

3.9 PROFESSIONAL REVIEW

The final stage of the testing process was collecting qualitative data from a professional interior designer by reviewing the designs created by the users. Success of the application depends on the quality of designs created by the participants. The researcher is relatively new to interior design field and might not be a best person to judge the designs created by the research participants. So, to gauge the quality of designs, a specialist from the interior design industry who has experience in the field or someone who has a qualification in interior designing would be required. If the reviewer is not connected to the research in any way, then the review would be unbiased and will give the researcher a view of the study from a completely different perspective. Several people were contacted to do the review, but the quantity of work required to complete the review of 13 set of designs (52 images) was a tedious task, which made many professionals reluctant to take the task. A paid review might also create a biased result. Fortunately, the researcher managed to find a designer who has working experience and academic knowledge.

The designer who reviewed the designs is working as a project manager for a construction and interior design company in New Zealand. She has been part of several big and small projects in and around Auckland. She also worked on the interior designing of University of Auckland's city campus. She is also having a Bachelor of Architecture degree from SRM University, India. Reviewing the designs was not an easy task as there were 56 photos, more than 4 photos for each design. The designer was provided with an information sheet (see Appendix 7.4) about what is expected and what to review in the designs. Photos of the empty

room were provided and then the photos of the designs created by each user were provided, categorised in separate folders (Appendix 7.7).

Generally positive feedback was received from the designer in terms of furniture selection and colour of the furniture. Six out of the 13 designs had good selection of furniture. Only three designs have good furniture placement as commented by the designer (see Appendix 7.7).

One of the main negative feedbacks was use of colours. The different furniture in the space had different colours and they were not in sync with other furniture. There were patterns as well that were not matching with the overall appeal of the room. Another area to improve as per the designer was that the space and the use of furniture in it. Some users placed too big furniture to a small space and sometimes users placed very few furniture and the room looked empty and unfinished. Other issues were the size of one furniture not matching with other furniture.

Technical difficulty faced by the users was as issue in reviewing the designs. There was some floating furniture in the designs which made it hard to judge the placement of the furniture in relation to other objects. In one of the designs, all the furniture were floating, making it difficult to judge what the user was trying to achieve in the designs. Another issue was the presence of fixed objects in the room. The room already had a white board and a wall hung TV which interfered with the design and the room. A TV and cabinet placed in front of the wall hung TV was a bad design according to the reviewer. Placement of a big cabinet blocking a white board was also a wrong design decision. These were some technical issues faced during the testing and could be considered not related to the application.

Overall, positive reviews were received from the users as well as the designer about the application. They commented that the application has good potential in interior designing and suggested there is room for improvement. One major concern to consider according to the reviewer was the floating furniture which made the review difficult and spoils the overall design. This will also prevent the user from creating a proper design.

4 DISCUSSION

Feedback collected from the participating users revealed that 92% agreed that the application is useful for interior designing and 77% percent of participants were willing to download the application if released. Even though the application was not primarily intended to educate about interior designing, 77% of participants agreed that they learned something about interior designing. One of the factors where the application has had a negative impact is the lack of a consistent user experience. This might have added some difficulties in using the application among some users and resulted in some negative or neutral feedbacks. When developing an application based on a new concept, where there is not much awareness about the general working, then an intuitive and consistent user experience is an important factor.

4.1 THE RESEARCH

This research is an enquiry about the efficiency of an Augmented Reality mobile application in interior designing without the help of a professional interior designer. Design of the research was to get the application tested with non-professionals and create designs and then get a validation of those designs by a professional interior designer. There were many variables involved in the testing such as the usability of the application, prior knowledge, and experience of the users in using an AR application. The testing conditions also play an important part such as reflective surfaces on walls or the absence of textures on wall and floor that can create difficulty for AR to detect the floor planes accurately. Capturing of the designs created by the users should reflect the whole design elements in the room. If the photos were not able to capture the wide view of the room, then the designer would not be able to judge the designs.

4.2 STRENGTHS

The application acts as a first step towards designing interior spaces by providing a guidance in making the initial steps towards the right direction. Even though the application does not give a comprehensive guide to the whole interior designing process, it will give the user tips and hints on how to approach a design problem and how to start working on finding a solution. It will also give the user some knowledge about the design styles, the types of décor

and ways to arrange them in a room. Layout of furniture is another area on interior design where common people lack knowledge and expertise. This requires the help of or more than one person to try out different layout and is a labour-intensive job. This part of designing is tackled with the application. The selection of a design style and then selection of furniture based on the design styles will give the user an idea about the style of furniture based on its shape and materials. Layout of furniture based on a focus point or object will help the user to easily arrange furniture and other décor in an interior space. Based on the feedback from the users, the application provides a visual cue on how a furniture look in different materials. This will help users to decide on what are the options to consider when picking a piece of furniture.

Implementation of AR technology was a good experience for many users. This opened a new world of possibilities of using AR in not just interior designing, but in other area of study. Selecting a furniture from a magazine or from a website is not as easy as selecting from the application where the user can pick one model and try different materials on it and visualise in the real world. Using the application several times to designing interiors might familiarise the user with the design styles and some of the furniture layout patterns and techniques. Repeated use may also help the user to familiarise themselves with the different types of furniture and which design category it falls into. Thus, finally making a user knowledgeable about interior designing and empower them to design their own interior space without the help of the application is considered the biggest strength of the project.

4.3 LIMITATIONS

Considering how vast the interior designing discipline is, this research and the application has barely scratched the surface. Using the application only gives the user a head start in making some initial decisions, but there are a lot of factors to be taken into account when designing interiors.

One of the major technical problems faced during testing was that the application kept on detecting additional floor planes at different heights. This caused the floating of the furniture. When furniture is placed in the world, the application might detect a plane higher than the

floor plane and place the object on it. The plane detection could be turned off or disabled to prevent this from happening. But this must be manually done, and users were not aware of it. As a result of this some users were unable to design properly using the application those designs were unable to be reviewed.

Another issue found was that people generally do not read instruction that are displayed on the application. In the application, the instructions to the next step in the design process were displayed along with the list of furniture. So, users directly went on to selecting a piece of furniture and start placing in the world rather than read what to do or where to place it. In the designing process implemented in the application the users are required to first select a focus object and then place it in the world. After that, the user should select and add more furniture to place around it. This step-by-step process was not performed by some users because they didn't read the instructions. One way to solve this issue was to display a full screen message to the user so that the user will never miss it. An "OK" button can be presented to the user so that the user goes to next menu only when the button is pressed.

The existing architecture of a building is a crucial element in interior designing. The overall style of the architecture needs to match the elements in the interiors. A modern furniture and design style will not generally match in a traditional style architecture. Another feature to be considered in the architecture is the size of the room. From the designer's comment, some users were not aware of this factor and added more furniture that it can hold from an interior design point of view. Too few furniture items will make a room look empty and too much furniture will make the room look too busy and not so spacious. The shape of the room is also important as some rooms have curved walls and some have irregular shapes.

Colour and materials of the furniture and other décor in the room is also an important factor which was not taken care of in the application. The interior designer who reviewed the designs created by the users mentioned this. Users were using different kind of colours and patterns in the space which were not matching with the overall design. The type of pattern also important in the designs. It gives an illusion of space, and some patterns belongs to different design styles (von Castell et al., 2020). This is again related to the architecture of the space. If the space is small, then the patterns need to be selected according to that. Thick

lines and too many patterns can make the room look even smaller. The architecture style of the room is also another part to be considered when applying patterns to the furniture. A modern space with minimal architectural features should not have furniture with traditional patterns. This combination could be applied if the user is going for a mixed design or Bohemian design style which combines different styles. This brings to the next limitation of the application where the user gets the ability to mix different design styles. At the moment, the application lets the user pick one design and then displays furniture matching that design style. Occasionally mixing one or two items from a different design style gives a fresh look to the space. This is not implemented in the application.

Lighting is another important factor that is not implemented in the application. Lighting affects the appearance of wall colours, furniture colours, spaciousness and a lot more (Bellia et al., 2017). The environment and architecture of the room such as the number of doors, windows, their size, curtains and the windowpane play an important role here. Another limitation is the availability of furniture that is used in the application is the same colour, style and size. A user might get a variety of options to choose from in the application but in real life the options might be limited and when it comes to final installation the designs might differ. One other issue pointed out by the designer who reviewed the designs was that some furniture is too close to the other ones, and it will be difficult to use them in that layout in real life situation. The placement of furniture in relation to others are not tracked in the application. They should be also tracked on how far and close they are placed and their relative sizes since this contribute to the overall visual balance.

4.4 FUTURE WORK

Response from the user testing shows that future scope of an Augmented Reality application for interior designing is promising. Even though there were very few steps implemented in designing it gave users a considerable number of options to design a space. The advantage of using AR helped the users to visualise 3D objects in real space and the suggestions provides a furniture layout style. Only few of the limitations of the research listed above are challenging and the rest of them can be easily overcome.

Future scope of the project lies in implementing more of the interior designing principles. Just like how the selection of furniture is based on the design style chosen by the user, the patterns, colours and materials can also be filtered. Users should be able to apply a certain number of colours depending on the colour theory and the colour of the other objects in the space. Selection of patterns for the furniture should also depend on the same principle. Patterns can be categorised depending on the shapes, colour and style. Including more design styles will make the application comprehensive as well as challenging. This will give more options for users to mix different design styles. The mix of different style elements should not be too much that the final design does not fall into any category and does not reflect any theme. This can be monitored by keeping a count of how many different style elements are mixed in the design. If the mix count is over a certain limit the system can warn the user. The relation between each object placed in the space can also be tracked in the system to get a proper balance visually. For example, a coffee table too close to a couch will hinder the free movement in the area. A proper distance has to be maintained between a TV and the couch in front of it. This can be calculated by the application and notify the user each time an object is placed or moved. Vertical plane detection is completely turned off at this stage of research to keep it simple and concentrate more on furniture layout.

Detecting vertical planes opens up a lot of opportunities for customising and designing the space. Picture frames and photos are an important part of interior designing that can add a lot of visual appeal to the space. Wall hung TV, floating shelves and cupboards are some other elements that can be added to the walls. Each of these elements has its own design styles and has a different impact on the final design. Wall colours and textures are the other important factor which is discussed later in this chapter.

A major feature that needs to be implemented to make the application a comprehensive interior design tool is the reading and analysing of the environment. Interior design has a lot of influence on the architecture of the building. Detecting and understanding of these features are important when selecting the type of furniture, the number of furniture, their colour, patterns on them etc. Size of the room needs to be calculated first to determine how many pieces of furniture fit in the room and how big they can be. Size is also important on selecting

the colours and patterns for the décor. Room size or size of a particular space that a user wants to decorate can be entered into the application either manually or by using the AR technology. The user can measure the area using other means and add that to the application as the first step of the designing process. The other way is scanning the space using AR to determine the floor and walls. This method can be more convenient for a user as they do not have to rely on other tools. Once the area is defined then the calculation of number of furniture and size is just the use of mathematics. Understanding the environment also includes determining the amount of light entering the room and if there is any tint to the light. Light entering the room can have different tint depending on wall paint, time of day and the exterior elements such as trees or other buildings. The amount of light and light tint can alter the colour of the furniture. ARCore has a light estimation feature which can estimate the quality of light entering into a space. The tint of light can be calculated by scanning the room with the camera on the phone. Depending on the light the application can suggest suitable materials for the furniture. Light tint is also depended on the colour of the walls and the colour of the furniture and walls are dependent of each other. So, an option to try different wall colour is an important feature to consider in future. Since ARCore can detect vertical and horizontal planes implementing this feature will not be a difficult task. To change the colour of the walls, a 3D plane can be placed over the walls with a translucent material. Changing the colour of the plane can augment the wall paint changing effect. Detection and consideration of irregular walls and doors and windows on a wall would be a bit more challenging to implement. In these situations, the user could either manually define the walls by drawing them using AR or placing tiles of wall on the vertical plane wherever there is a physical wall. Changing floor colour or material is also a feature to be added in this part. Floor colour can reflect on the objects and the material used determines how much light to reflect off the floor. Tiles with lighter shades reflect more light than a carpet with similar shade. This can affect the colours used on the furniture.

Window coverings are the next important part of interior design and also challenging to implement in the application. Each window covering has its own style and purpose. There are blinds and blackout curtains that can completely block the light coming from outside and there are sheers that allows some light to pass through. There are rolling shades that can be

either blackout or translucent. Each of these window coverings has its own visual appeal but when implemented in AR the application should also mimic the light effect on the space. This is a challenging part to implement as there is no physical object controlling the light getting into the space. Simulating light entering a room can be implemented by reducing the world brightness of the scene in Unity depending on the objects used as window covering.

Implementing the features mentioned above, PARIDA can be developed into a comprehensive interior designing tool that guides the user to design interiors in all aspects.

In addition to removing all the bugs and fixing the UI and UX, there is much potential for future development opportunities in planning stages for this project. If concentrated on a target audience, the application can be customised to cater a specific set of requirements. This idea could be presented to furniture dealers in New Zealand to help their customers choose a suitable set of furniture and try virtually in their homes. The customers do not have to guess how it looks in their room and maybe do not have to get disappointed after buying that piece of furniture. The application could give an idea about the size and fit of the objects in their room, and it can also suggest more furniture that comes as a set along with the chosen one. Customers of home appliance shops can also use this application to see how an appliance like refrigerator, food processor or any other whiteware will look and fit in their home. All these ideas require the basic functionalities developed for this research and some 3D models of the products. Curtain makers could also use this software to show customers the difference between the types of curtains and the colour and material differences. With some additional research and development, the scope of the application could expand to show different paint colours to the customer. The application could be used to design interiors of restaurants, shops or public places. Apart from residential interior designing applications the software could be used by professionals to quickly create multiple prototypes to present to their customers.

5 CONCLUSION

PARIDA is a search for a cost-effective way to empower novices to design interiors to a professional standard. The application was developed to run on a mobile device so that there is no need for special hardware, and that it is portable and accessible to a wider audience. Compared to the available mobile application on the market at the time of the study, this project managed to implement several features into one application and provide foundation stone for a comprehensive interior design software. Table 4 compares the list of features of other applications to PARIDA.

	Products										
Features	IKEA	Room	Gazzda	Myty AR	Design Home	Home AR Designer	HomerAR Furniture	Home styler	Floor plan Home Improve	AR Furniture	PARIDA
Price	Free	Free	Free	Free	Free	Free	Free	Free	Free	Free	Free
Rating on Google	4.6	2.5	4.1	3.7	4.2	3.0	Not available	3.9	3.3	Not available	Not Applicable
Available on Android	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Available on Apple	✓	-	✓	✓	✓	-	-	✓	-	-	✓
Uses AR	✓	✓	✓	✓	-	✓	✓	-	✓	✓	✓
Models on cloud	✓	✓	✓	-	-	-	✓	-	-	✓	-
Object placement	✓	✓	✓	✓	-	✓	✓	✓	-	✓	✓
Object colour change	-	-	-	-	-	✓	-	-	-	-	✓
Automatic placement	-	-	-	-	-	-	-	-	-	-	-
Placement suggestion	-	-	-	-	✓	-	-	-	-	-	✓
Wall paint	-	-	-	-	✓	-	-	✓	✓	-	-
Design style selection	-	-	-	✓	-	-	-	✓	-	-	✓

Table 4: PARIDA compared to Apps on market

Automatic placement of furniture, wall painting and models placed on cloud are some of the features missing in PARIDA. Automatic placement is one of the key features to be implemented and it can act as the first step of the design process for users. Once the objects are automatically placed, then the user should be able to move them to arrange to their own interests. Colours of walls are also an integral part of interior design. Room décor colours and wall colours are connected to each other from a design perspective. They contribute to

each other on the appearance of the room. All the above-mentioned points make the wall colour selection feature in the application an important feature to be considered in future development. Integration to cloud will be essential when the selection of furniture and décor grow. Even though all features mentioned in Table 4 are not present in PARIDA, there is no one app that has all the features. Even so, this project managed to implement most of the features that is present in the reviewed applications.

There were several obstacles faced during the development of the application mostly incorporating the principles of interior design into a mobile AR application. Fidelity of placing and moving the furniture was an issue in the application. While testing, some users accidentally moved the furniture they placed earlier, and they had to move it back to correct position. The user experience for moving and rotating objects were different which took time for some users to realise and learn. Plane detection by ARCore was another issue. The application continued to detect planes while it was in use and caused some furniture to float in mid-air. This prevented users from creating proper designs. This issue was also mentioned in the review by the professional designer.

In the testing phase, even with only one of the aspects, furniture selection and arrangement, implemented in the application, 92% of the participants found it useful for designing their homes. Evaluation of designs created by the participants were done by a professional designer. The designs got positive reviews from the professional interior designer on the selection of furniture and its styles. While the application provided guidance to the users, it neither created the designs automatically nor did it limit the user in applying their ideas. This provided the users with a sense of satisfaction and control while designing the space and allowed them to create designs customised to their taste while still adhering to the interior design principles. By implementing more features and aspects of interior design, the application has immense potential to develop into a comprehensive interior design tool and help people to design their interiors to a professional standard inexpensively.

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7 APPENDIX

7.1 PARTICIPANT CONSENT FORM

Consent and Release Form

Project title: Personal Augmented Reality Interior Design Assistant (PARIDA)

Project Supervisor: Dr Stefan Marks and Dr Ann Morrison

Researcher: Ranju Raveendran

- ☐ I have read and understood the information provided about this research project in the Information Sheet dated 13 October 2020.
- ☐ I have had an opportunity to ask questions and to have them answered.
- ☐ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ☐ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ☐ I permit the researcher to use the photographs that are part of this project and any designs from them and any other reproductions or adaptations from them, either complete or in part, alone or in conjunction with any wording and/or drawings solely and exclusively for (a) the researcher's portfolio; and (b) educational exhibition and examination purposes and related design works.
- ☐ I understand that the photographs will be used for academic purposes only and will not be published in any form outside of this project without my written permission.

☐ I understand that any copyright material created by the interior designing sessions is deemed to be owned by Ranju Raveendran and that I do not own copyright of any of the designs.

☐ I agree to take part in this research.

With respect to photos being taken during the study, please select from the options below:

☐ I give permission for photos of me to be taken during the study.

☐ I give permission for photos of me to be taken, but with my face blurred out.

☐ I do not want my photos to be taken during the study.

Participant's signature :

Participant's name :

Would you like to receive a summary of the findings/outcomes of this research? Yes ☐ No ☐

If Yes, please provide your contact details:

.....
.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 13 October 2020
AUTECH Reference number 20/313

Note: The Participant should retain a copy of this form.

7.2 PARTICIPANTS ELIGIBILITY QUESTIONNAIRE

Are you younger than 18 years of age? ☐ Yes ☐ No

Do you have any experience in Interior Designing? ☐ Yes ☐ No

Do you have any formal education in Interior Designing? ☐ Yes ☐ No

Do you have any difficulty in using AR application? ☐ Yes ☐ No

Do you have any difficulty using touch screen mobile phones? ☐ Yes ☐ No

Do you have any personal interest in the outcome of the research? ☐ Yes ☐ No

If you answered 'No' to all the questions above, then you are just the right person I am looking for!

7.3 FEEDBACK ON APP

Did you learn anything new about Interior Design principles?

☐ Nothing

☐ A little

☐ A lot

If you learned something, please specify

--

Did you make any design decision that you wouldn't do otherwise?

☐ Yes

☐ Not sure

☐ No

The app is useful to design interiors.

Strongly Disagree	Disagree	Not decided	Agree	Strongly Agree

The application is...

☐ Totally unusable

☐ Not user friendly

☐ Somewhat user friendly

☐ Intuitive

If you answered “not user friendly/unusable”, what do you think could be improved.

If released, would you download this application?

- ☐ Yes
- ☐ No
- ☐ Not sure

How much would you pay to download this application?

- ☐ I do not want to pay
- ☐ \$1.00 - \$10.00
- ☐ \$11.00 – \$25.00
- ☐ I will pay whatever the cost is

Participant Demographic

What is your age group?

- ☐ 18-25
- ☐ 26-35
- ☐ 36-45
- ☐ 46-55
- ☐ 56-65
- ☐ 66 and above

Do you use a touch screen smart phone on a daily basis?

☐Yes ☐No

Have you used any Augmented Reality mobile application before?

☐Yes ☐No

Have you used any application for interior designing before?

☐Yes ☐No

Have you hired the services of an interior designer before?

☐Yes ☐No

Have you developed any mobile application?

☐Yes ☐No

Which smart phone do you own?

☐ Android

☐ Apple

☐ Not a smart phone user

Any other comments

--

7.4 PROFESSIONAL DESIGNER INFORMATION SHEET

Date Information Sheet Produced: 14/Oct/2020

Project Title: Personal Augmented Reality Interior Design Assistant (PARIDA)

An Invitation

I am Ranju Raveendran, currently working on my Master of Creative Technology at AUT. I am developing an Augmented Reality mobile application as part of my research. I require a participant who is trained and experienced in interior designing to review roughly 20 designs made by some other participants of the same research.

You will be giving comments and reviews on how good the designs are from a professional designer's perspective and how closely they are adhering to the principles and rules of design.

What is the purpose of this research?

The findings of this research may be used for academic publications and presentations.

The purpose of the research is to find out to what extent a guided Augmented Reality application can help a novice to design interiors to a professional standard. The AR application will have a guiding system for the users to suggest different elements to choose from or guide the user where to place them in the space.

You will be evaluating designs made by those participants to find out if the application has served its purpose. The evaluations will focus on the suggestions made by the application and the guidance system in the application and not on the designing skills of the participants.

Am I suitable for this study?

Success of my research and app depends on how good the designs are and how efficient it is to guide a novice to design quality interiors. To gauge these the knowledge and experience of a professional interior designer is necessary.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice) and whether you choose to participate will neither advantage nor disadvantage you. You can withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having removed any data that is identifiable as belonging to you or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

If you agree to participate in the study and I have received the consent form, then I will be sending you roughly 35 designs (depending on how many participants I get for testing the application) to review. Your review will focus on how closely the designs follow the principles and general quality of the designs. Designs will be photos given in digital format which are captured from the app. There will be photos of the same design from a different angle. The time required for reviewing will be agreed with the researcher so that you can do it in your own time and pace. You are welcome to test the app yourself to see how it works and its features. General feedback of the app is highly appreciated.

What are the discomforts and risks?

There are no risks or experience of discomfort anticipated while using this application. You will not be wearing any virtual reality headsets and you will not be using any tools that could harm you. The reviews can be done at place that is comfortable to you and at your comfortable time. Timeframe required to finish the review will also be decided by the you.

What are the benefits?

You will be able to see designs created by those who are completely new to interior designing. Get an insight into how an algorithm can guide in designing. It will be a fun experience using an AR application in interior designing. The results and insights gained from your participation and your feedback will be a valuable addition to the wider body of knowledge around the interior design in general and future improvements of the app specifically.

How will my privacy be protected?

Identity of the participant and the reviews made by the participant will not be disclosed to anybody outside the research. All relevant data will be stored in AUT, School of Future Environments teacher's office in a password protected USB stick. Entrance to the office is regulated through access cards.

What are the costs of participating in this research?

There will be about thirty-five designs to review. A total of maximum ten hours is anticipated for completion of the reviews. This could be done over a period of 2 weeks. A time frame that suits with the schedule of the research can be discussed and agreed with the researcher.

What opportunity do I have to consider this invitation?

You will get at least one week to consider and respond to this invitation.

Will I receive feedback on the results of this research?

If you are interested, a summary of the findings of the overall study can be sent to you.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Stefan Marks by email at *****@aut.ac.nz or by phone on 09 *** ***** ext. *****

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTECH, *ethics@aut.ac.nz* , (+649) 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference.

You are also able to contact the research team as follows:

Researcher Contact Details:

Name: Ranju Raveendran

Email: *****@aut.ac.nz or *****@gmail.com

Project Supervisor Contact Details:

Name: Dr Stefan Marks

Email: *****@aut.ac.nz

Office Phone: 09 *** **** ext. ****

Approved by the Auckland University of Technology Ethics Committee on *13 October 2020*, AUTECH Reference number *20/313*.

Acknowledgement

I confirm that the answers provided above are true to the best of my knowledge.

Participants Signature:

Participants Name:

7.5 INVITATION FLYER



- If you are **not** an Interior Designer
- If you are **not** trained in Interior Designing
- If you are **18** years or older

Then please continue reading...

You are invited to test an Augmented Reality mobile application that is being developed as part of a research project. The App is intended to help users to design interior spaces to a professional standard by providing guidance based on design principles.

What you will do...

- Use a mobile application to design a given space.
- Spend approximately 10-15 minutes using the app.
- Provide feedback (mostly ticking some boxes on a form)

Sound fun?

Please contact Ranju Raveendran using the following email for more information:

*****@autuni.ac.nz

7.6 PARTICIPANT INFORMATION SHEET

Participant Information Sheet

Date Information Sheet Produced:

07/Sept/2020

Project Title

Personal Augmented Reality Interior Design Assistant (PARIDA)

An Invitation

I am Ranju Raveendran, currently working on my Master of Creative Technology at AUT. I am developing an Augmented Reality mobile application as part of my research. I require participants who are **NOT** designers and who **DO NOT** have any qualifications or experience in interior designing.

Approximately 20 minutes will be spent on this study. With the assistance of an AR application, you will design an interior space. You will have a fun experience and hopefully learn a bit about the principles of interior design.

What is the purpose of this research?

The findings of this research may be used for academic publications and presentations.

The purpose of the research is to find out to what extent a guided Augmented Reality application can help a novice to design interiors to a professional standard. The AR application will have a guiding system for the users to suggest different elements to choose from or by guiding the user where to place them in the space. So, it is important that the application will be tested by participants with no experience in designing interiors. Feedback from the participants will be recorded for future improvements of the application.

The designs made by the participants will be evaluated by a professional interior designer to find out if the application has served its purpose. The evaluations will focus on the

suggestions made by the application and the guidance system in the application and not on the designing skills of the participants.

Am I suitable for this study?

This study requires participants with no education or experience with interior designing. This is because the primary aim of my research is to empower non-professionals to design quality interiors. You would require basic understanding of using a touch screen smart phone. Please answer the questionnaire attached to this form to find out if you are suitable for participating in the study. After the selection process is completed the questionnaire, you answered will be destroyed to protect your privacy.

How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice) and whether you choose to participate will neither advantage nor disadvantage you. You can withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having removed any data that is identifiable as belonging to you or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

If you are suitable for participating in the study and I have received the consent form, then I will be sending you information about the date, time, and location of study. This will be in a public place on AUT campus and will be scheduled during office hours. Once you arrive at the location, I will give you a quick verbal explanation of the research and a demonstration of the application. Then you will be asked to design a space using the mobile application. Photos may be taking depending on how you responded to the permission section in the consent form. Afterwards, you will be asked for some feedback about the application and some basic demographic questions about yourself.

What are the discomforts and risks?

There are no risks or experience of discomfort anticipated while using this application. You will not be wearing any virtual reality headsets and you will not be using any tools that could harm you. The study will be conducted at a safe and well-lit location.

What are the benefits?

It will be a fun experience using an AR application and you will learn few tips and tricks in interior designing. You will be able to apply them in arranging your interior space. The results and insights gained from your participation and your feedback will be a valuable addition to the wider body of knowledge around interior design in general and future improvements of the app specifically.

How will my privacy be protected?

Identity of the participants and the photos if taken and designs made by the participants will not be disclosed to anybody outside the research. All relevant data will be stored in AUT, School of Future Environments teacher's office in a password protected USB stick. Entrance to the office is regulated through access cards.

What are the costs of participating in this research?

You will be spending around 20 to 30 minutes for the study including filling the forms, testing the application and providing feedback.

What opportunity do I have to consider this invitation?

You will get at least one week to consider and respond to this invitation.

Will I receive feedback on the results of this research?

If you are interested, a summary of the findings of the overall study can be sent to you.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Stefan Marks by email at *****@aut.ac.nz or by phone on 09 *** **** ext. ****

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTECH, *ethics@aut.ac.nz*, (+649) 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Name: Ranju Raveendran

Email: *****@autuni.ac.nz or *****@gmail.com

Project Supervisor Contact Details:

Name: Dr Stefan Marks

Email: *****

Office Phone: 09 *** **** ext. ****

Approved by the Auckland University of Technology Ethics Committee on *13 October 2020*, AUTECH Reference number *20/313*.

7.7 DESIGNER REVIEW

11/12/21, 9:32 AM

Gmail - Interior Design Review Request



Ranju Raveendran <[REDACTED]@gmail.com>

Interior Design Review Request

3 messages

Ranju Raveendran <[REDACTED]@gmail.com>
To: [REDACTED]@gmail.com

Mon, Jun 7, 2021 at 11:52 PM

Designs.zip

Hi [REDACTED]

Thank you very much for agreeing to review the designs made as part of my research using an Augmented Reality mobile application for Interior Designing. There are 13 sets of designs (4 photos per design, a total of 52 images).

I have attached the photos for you to review also the information sheet and consent form for further details. Please let me know if you have any concerns.

Thanks again,
Ranju

2 attachments

Consent Form Designer .pdf
208K

Information Sheet Designer .pdf
207K

[REDACTED] <[REDACTED]@gmail.com>
To: Ranju Raveendran <[REDACTED]@gmail.com>

Sun, Jun 13, 2021 at 7:55 PM

Hi Ranju

Find enclosed my review comments and signed consent form. Please let me know if you do require any further information.

Most of the images submitted have floating furniture in them, maybe something to look at.

Kind Regards,
[REDACTED]

[Quoted text hidden]

2 attachments

Consent Form Designer - Signed.pdf
216K

Design review notes - Radhika.pdf
80K

Ranju Raveendran <[REDACTED]@gmail.com>
To: [REDACTED] <[REDACTED]@gmail.com>

Mon, Jun 14, 2021 at 3:32 PM

Hi [REDACTED]

Thank you very much for the comments. Those are valuable inputs to my research. I really appreciate it.

Best regards

Ranju

[Quoted text hidden]

<https://mail.google.com/mail/u/0/?ik=bacf400f51&view=pt&search=all&permthid=thread-a%3Ar-3851296491544004497&simpl=msg-a%3Ar-3856...> 1/1

Review of Designs

User 1:

- Too much use of colour for a small space. Could have done with just an accent wall and thinner stripes.
- Different colour finishes to the furniture, dark red couch could have been replaced with a light/pale colour.
- Furniture placement and choice of furniture would have been better.

User 2:

- Floating furniture in one of the photos, furniture placement could have been better.
- Colour of furniture/ finishes could be improved.

User 3:

- The TV cabinet is placed wrong side facing out.
- Furniture placement could have been better – you do not place a cabinet blocking a large whiteboard. Either one could have been smaller.

User 4:

- The wooden cabinet could have been avoided for a small one placed under the white board.
- The back wall TV could have been removed.
- Good furniture choice

User 5:

- Space not utilised well with only a single seater placed.
- Floating furniture's.

User 6:

- Great furniture placement. Good choice of furniture and finishes, though the coffee table could have been subtle.

User 7:

- Great furniture placement.
- The wooden cabinet could have been replaced with a smaller one.

User 8:

- Furnitures are all floating in the images.

User 9:

- Good furniture selection, however, the orientations to be worked on.

User 10:

- Good furniture selection and could have added a couple single seater or another couch.
- Furnitures placed too close to each other.

User 11:

- All furniture's are floating, however, good choice of furniture and colour.

User 12:

- Floating furniture.
- Furniture placements to be worked on, the coffee table is placed away from the couch.
- Space utilisation not done right, only a single seater has been placed.

User 13:

- All furniture's are floating, however, good choice of furniture and colour.