XR Demonstrator for Care at Home

Bachelor Thesis

Creative Technology

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Abstract

This project explores the development of an augmented reality (AR) application designed to assist stroke patients using wheelchairs and their families. The app provides users (stroke patients using wheelchairs and their families) with guidance and experiments to arrange furniture and medical equipment in an AR environment. During the evaluation phase, the AR app is assessed for efficiency, satisfaction, and usability by the System Usability Scale and interviews. The evaluated data is concluded to prove how the AR app is valuable.

Acknowledgment

I would like to express my gratitude to my supervisor, Daniel Saakes, and my critical observer, Wouter Eggink. Their support and feedback bring me diverse insights and improvements for this project. Especially, I want to thank Daniel for taking the time each week to listen to my ideas and provide feedback despite always being busy.

I also would like to thank those who participated in the usability tests and lo-fi tests during this project. Based on their feedback and perspective, I could make a hi-fi prototype and draw interesting conclusions from their evaluation.

Acronyms

FME Furniture and Medical Equipment

AR Augmented Reality

APP Application

LoFi Low Fidelity

HiFi High Fidelity

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1. Introduction

1.1 Background and Problem Statement

Augmented Reality (AR) involves blending digital information seamlessly into the user's real-world environment in real time [1]. In contrast to virtual reality (VR), where users are immersed in a completely artificial environment, AR enables users to experience and interact with their physical surroundings while additional digital content is superimposed onto it [1]. AR is used in many cases, such as games, education, marketing, shopping, design and modeling, sports events, manufacturing, and navigation use in AR [2]. A typical example is Pokemon Go, which is one of the most popular AR games in the world.

Home hospitalization (HaH) can be viewed as a viable alternative to traditional healthcare methods [3]. By establishing a care environment equivalent to a hospital within the patient's home, HaH proves beneficial for managing chronic illnesses. This approach not only enhances patients' and caregivers' satisfaction but also contributes to improving patient's quality of life while simultaneously reducing healthcare costs [3]. Approximately 4.5 million patients receive home healthcare in the United States every year [4]. Moreover, approximately 90% of adults aged 65 and older would prefer to stay in their homes rather than move to a nursing home or assisted living facility [4], meaning many patients prefer to receive healthcare services in their own homes.

Diverse medical equipment and stable arrangements are required in homes in order to receive home health care. However, many patients do not know about the medical equipment or information about arrangements. Normally, medical equipment is big and an obstacle in homes, so patients could get hurt by it.

AR apps can assist patients by providing guidance and enabling users to arrange in an AR environment. Therefore, in this project, an AR app will be developed and evaluated by users to assess how much efficiency, usability, and satisfaction the app has. An AR application emerges as a solution to how the AR application would operate and is shown as an example in ***Figure 1***. The term 'patient' has a broad range, so stroke patients using wheelchairs and their families will be focused as target users in this project.

1.2 Goal

There is an existing AR for interior design, which is not used for an app but is used for interior design [5]. The purpose and the goal of this AR are analogous to the project. An AR app for this project is to provide safety guidance and allow users (stroke patients using wheelchairs and their families) to interact in an AR environment. Therefore, users do not have to waste time using the app and safely arrange FME by receiving guidance from the app.

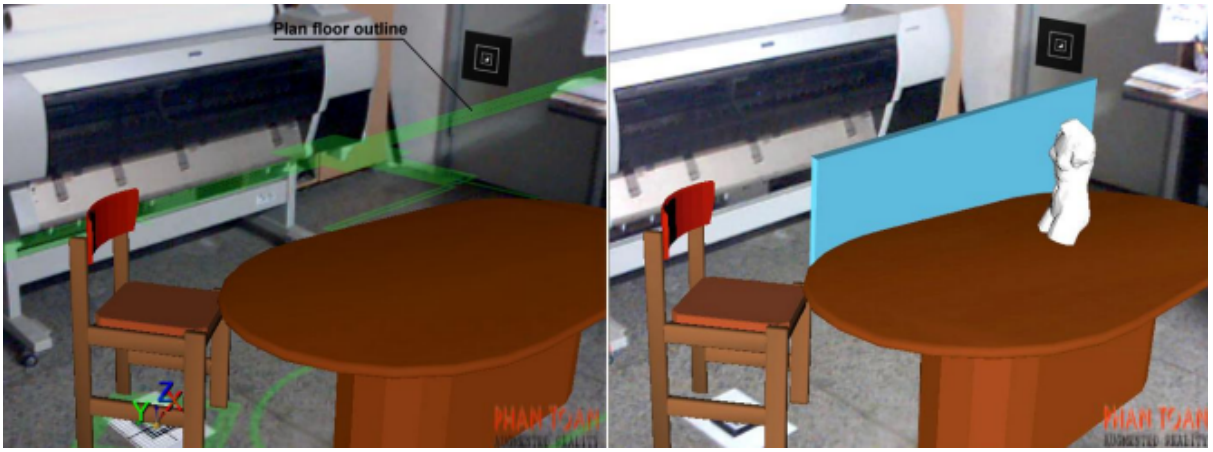

Figure 1. Furniture moves with different angles in AR interior design interface [5]

1.3 Research Questions

Research questions will be described as follows:

Main research question:

- How can an app support the modification of the interior design of a home environment for a person recovering from a stroke?

The design of the app is aimed at the goal of the project, which is for users to have convenience and save time in arranging FME. Considering this question, the factors have to need are described as follows:

1. User Experience: User experience is essentially optimized based on an understanding of how users interact with the app.

2. User Requirement: User requirement identifies what functionalities users have used in other similar apps.

3. Usability: Usability enables users to navigate how easy it is to use the app, and it ensures the app is efficient.

4. Visual Design: Visual design gives users the appropriate impression and appeals to users.

5. Accessibility: Accessibility allows the app to be accessible to all users.

6. Functionality: Functions are effectively implemented in the app and ensure that all users can easily understand and utilize the functions.

Sub-research question:

- Which medical equipment is needed at home for people who experienced stroke and their caregivers?
- What information and experience can be effectively delivered by an AR app to users?
- Which technical methods can be implemented within AR for medical equipment arrangement?

Sub-research questions are required to build the app. What room is FME placed in and what medical equipment is needed are the required considerations because the 3D FME models have to be collected for building the app, and where the FME is placed depends on the layout of the room, such as the living room and the bedroom. The factors contributing to users need to include interface design, 3D models for furniture and medical equipment, customization options, and feedback from users on the arrangement process.

2. Background Research

2.1 Literature Research

In this section, various kinds of literature are explored to collect information about AR and medical equipment for the project. The state of the research topic and field are assessed, and connections with existing research are established in order to generate ideas for the best research directions. This chapter provides the methods that existed and were assessed, and it will conclude with the directions that might be best for this project.

2.1.1 Devices for stroke patients

This article observes and summarizes diverse articles regarding what devices are needed for stroke patients. It divides devices into six categories: 1. Games 2. Telerehabilitation 3. Robotic devices 4. Virtual reality 5. Sensors 6. Tablets. Games do not directly assist stroke habilitation, but games can integrate other exercises for the combination of fun and training movement, such as Wii Sport, Kinect, and ArmeoSenso 53 [13], [16], [17]. Telerehabilitation's technical functionalities are typically accomplished through video conferencing, allowing therapists to observe patients' movements during rehabilitation tasks [13]. Robotic devices are one of the representative methods for telerehabilitation and training. They utilize an exoskeleton approach to assist the movement of hands, wrists, and arms for stroke patients struggling with movement, and representative robotic devices are robotic arms, robotic, and exoskeleton systems [13], [14], [15]. Virtual reality supports patients in a safe and controlled environment to practice activities without concerning mistakes, providing feedback that can be applied in real life [13], [18]. Sensors analyze and measure patient's movements and actions to provide feedback [13]. The ArmeoSensor system has three sensors: acceleration, angular velocity, and magnetic field, which are three dimensions used to measure patients' movement [19]. Motion sensors and physiological sensors measure body temperature, respiratory rate, pulse rate, blood pressure, etc [20]. Tablets include iPads and tablet PCs and are used for therapy and exercises [21] [22]. Tablets support patients in training with exercises and let them move their hands and fingers with the Ball Funnel system [22].

2.1.2 Medical devices at home

To design FME, the medical devices required at home have to be collected and investigated. What fundamental medical equipment is needed at home for patients has to be taken into account, as well as what medical equipment is required for stroke patients in home healthcare. Fundamental monitoring and diagnostic devices are available in the home, and most medical equipment like those are necessary for diagnosis, such as thermometers, weight scales, blood pressure monitors, glucometers, pulse oximeters, and peak flow meters [7].

Figure 2. The first piece of equipment is a blood pressure monitor, and the second is a stethoscope [7]

As described above in ***Figure 2***, portable medical equipment is a fundamental requirement for patients. Furthermore, medical devices do not require specialized performance, which patients can handle with them. The equipment provides patients with primary data through simple diagnosis.

2.1.3 The design of an adaptive healing room for stroke patients

This article illustrates how stroke patients' rooms have to be designed. The designed room is called the adaptive healing room, and it has four following concepts: Artificial Sky (AS), Patient Wall (PW), Adaptive Daily Rhythm Atmosphere (ADRA), and Adaptable Stimulus Dosage (ASD) [12]. The four following concepts are described as follows:

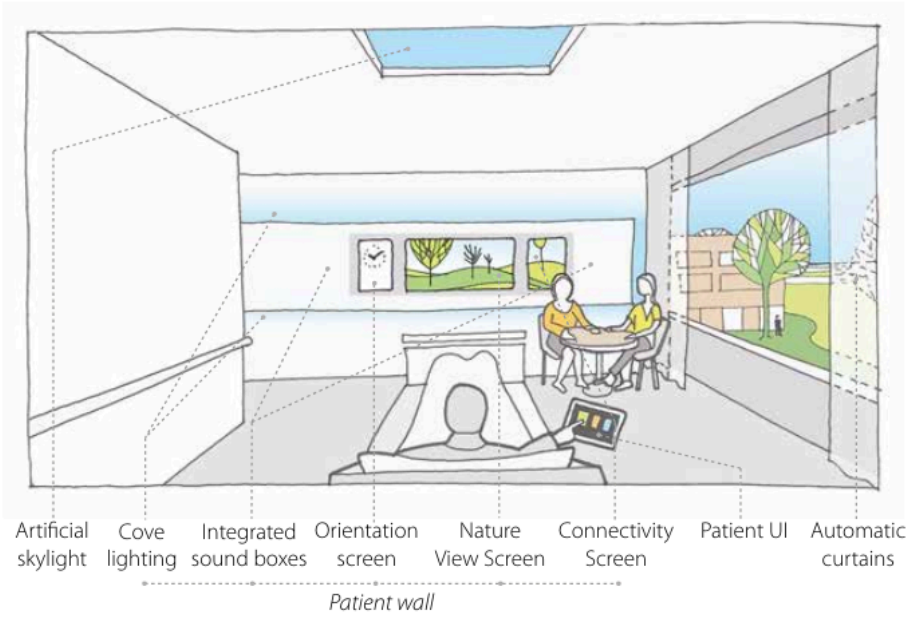

Figure 3. Adaptive Healing Room [12]

The Artificial Sky displays supplementary sunny white light and blue sky views in the ceiling so that patients feel comfortable and relaxed staying in the room, and the white light and the blue sky views provide a bright feeling and the impression of daylight in the room [12].

Figure 4. Artificial Sky [12]

Patient Wall (PW) is designed for all electronic devices that patients need in the room and contains two RGB light coves, two sound boxes, and three multi-media screens [12]. PW considers four aspects to be designed: Positioning, Symmetric position of screens, Clutter-free for low stimulus, and Easy mounting [12].

- Positioning: It is positioned on the wall to bump wheelchairs and beds and clean the top part of PW.

- Symmetric position of screens: Visual scanning training is a well-known therapy for patients with visual neglect, in which therapists encourage patients to explore neglected visual fields.

- Clutter-free for low stimulus: The screens display with switchable glass and a white display background for minimal contrast.

- Easy mounting: The PW uses one plug and one network connection.

Multi-media screens have the nature view screen (NVS), the orientation screen (OS), and the connectivity screen (CS) [12].

- Orientation Screen (OS): The intension of OS is to display a digital or analog clock, the date, a welcoming word.

- Connectivity Screen (CS): It displays pictures of patients' families and friends. The patients can select a picture they prefer to see and zoom in and out of it.

- Nature View Screen (NVS): It displays videos and pictures of nature on the screen during the day so that the patients can relax in the room.

The Adaptive daily Rhythm atmosphere (ADRA) assists the patient's daily routine by creating multisensory environments using light, audio, and video adjustments, and ADRA will generate different multisensory atmospheres for different phases [12]. The eight phases are illustrated as follows [12]:

1. Waking up
2. Breakfast
3. Clinical care
4. Lunch
5. Rest
6. Visitors
7. Going to Bed
8. Sleep

Patient User Interface (UI) provides different services to control the patient wall. The patients can change the theme of the nature view, the color of the wall [12], and the pictures on the patient wall, which do not require significant movement.

Figure 5. Patient UI: displays home page, settings view, theme view, and connectivity view [12]

2.2 State of Art

In this section, some articles are referred to improve and develop this project. These articles describe how AR is built into the mobile app and how to design furniture in the app, which are closely related to this project. Furthermore, they explain diverse methods and system architecture to create apps, so they should be mentioned in this section.

2.2.1 Interior Design with Augmented Reality

Poudel et al. [8] focus on seven goals: selecting furniture from a menu, placing furniture by tapping on the screen, removing rendered furniture, changing the material of rendered furniture, moving the location of furniture, taking a picture of the current environment, and loading 3D models from local storage. In other words, selecting, moving, placing, changing, and removing models and taking pictures are the app's core requirements for the project.
The Android version implements the app using marker-less AR, and the Google ArCore platform is compatible with the software. To save pictures of arranging furniture in the app, an interface to local storage is required, and it receives and exports data of 3D models such as pictures and saved screenshots.

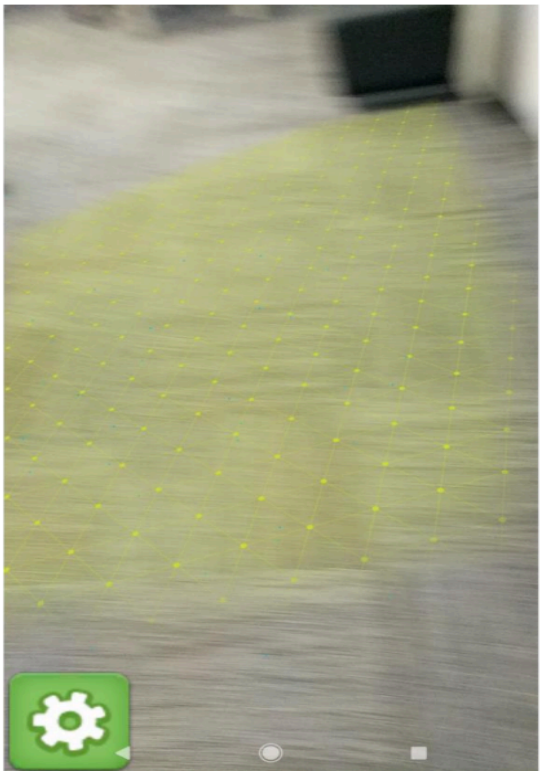

Figure 6. The app renders a plane on the ground [8].

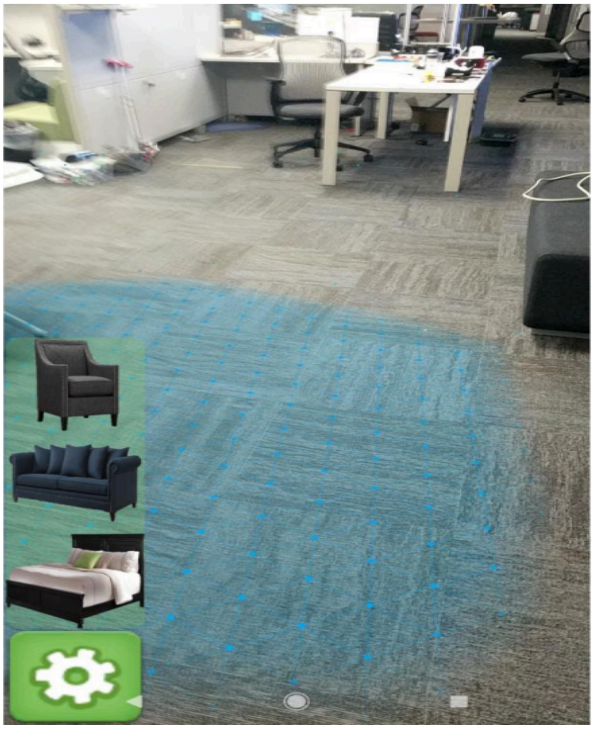

Figure 7. Slider menu for selecting furniture [8]

Figure 8. Rendering furniture in the app [8]

The app is implemented by scanning and rendering the plane, and users can place furniture on the rendered plane. Above are pictures of how it works exactly. The app has essential functions that users need to arrange furniture. The slider menu is an impressive idea, as it does not occupy much space in the app.

2.2.2 Developing Markerless Augmented Reality for Furniture Mobile Application

Ravel et al. [9] used the ARCore SDK by Google in order to create an AR app. The ARCore SDK has three features, motion tracking, environmental understanding, and light estimation, which are used to create AR. It will describe what these three features are for below [9].

- Motion tracking: The framework uses simultaneous localization and mapping (SLAM) to understand device positioning. Feature points extracted from camera images assist in computing the changes as the device moves. These feature points are used to place 3D objects as anchors.

- Environmental understanding: The framework learns the environment, identifies feature points, and detects planes like walls, tables, and slopes. It creates feature points using motion tracking and enables object placement on recognized planes.

- Light estimation: The framework enables lighting adjustments and color correction for 3D objects based on camera-captured images, ensuring realism in dark environments.

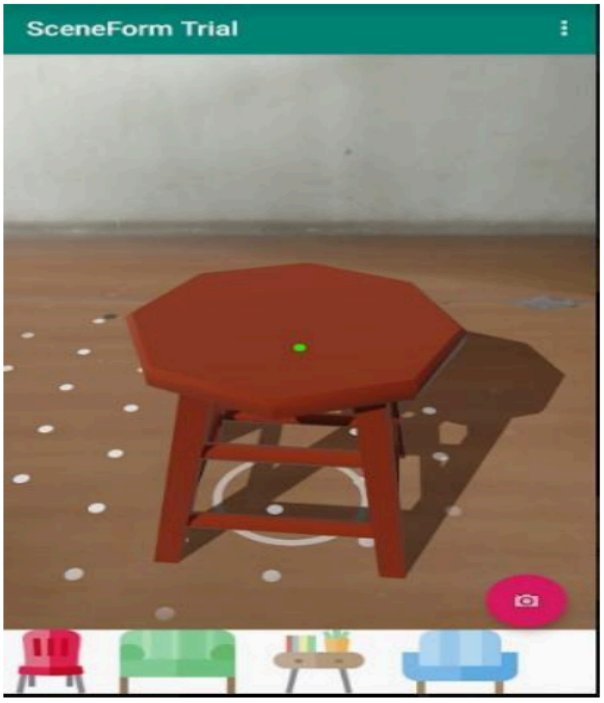

Figure 9. The app renders a plane on the ground and creates a table on the plane [9]

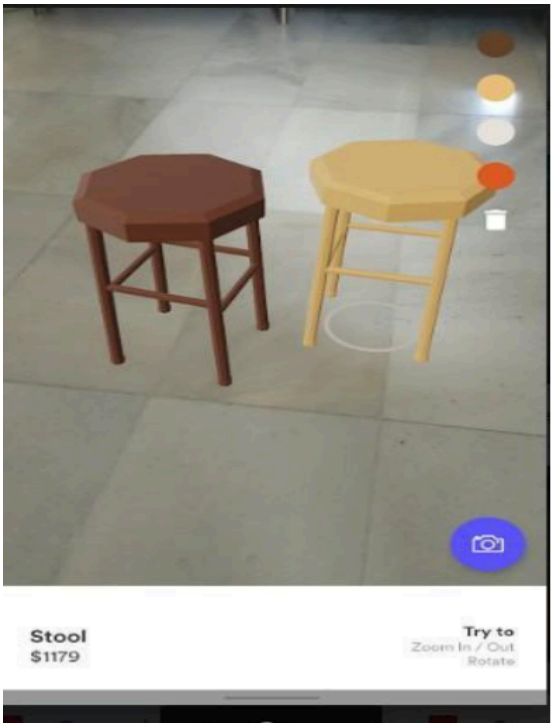

Figure 10. Another table was placed, and its color was changed [9]

After users search and select the furniture they prefer, they are able to place the furniture in a size and color that is satisfying so that users can arrange furniture and select the best furniture for their house. Nevertheless, the final purpose of this project is to emphasize not

only activating online shopping through AR but also providing interaction between products and the natural environment by providing commercial products in the app.

2.2.3 An Augmented Reality Design Tool to Guide Furniture Arrangement at Home

Chuhan et al. [10] built the AR app in the project, which arranges furniture for the guide, and the main goal of the app is to arrange furniture by guiding and assisting users. The app supports users by selecting diverse types of 3D models of furniture, superimposing the desired furniture onto a physical environment, adjusting the 3D model's size and direction, and learning how a specific Feng Shui principle can be applied in arranging the selected furniture to arrange furniture with the best way [10]. The Feng Shui principle is known to support designers to design better use of their living spaces [11]. The app used to be developed by Apple's ARKit 5 software, which is compatible with augmented reality on mobile devices.

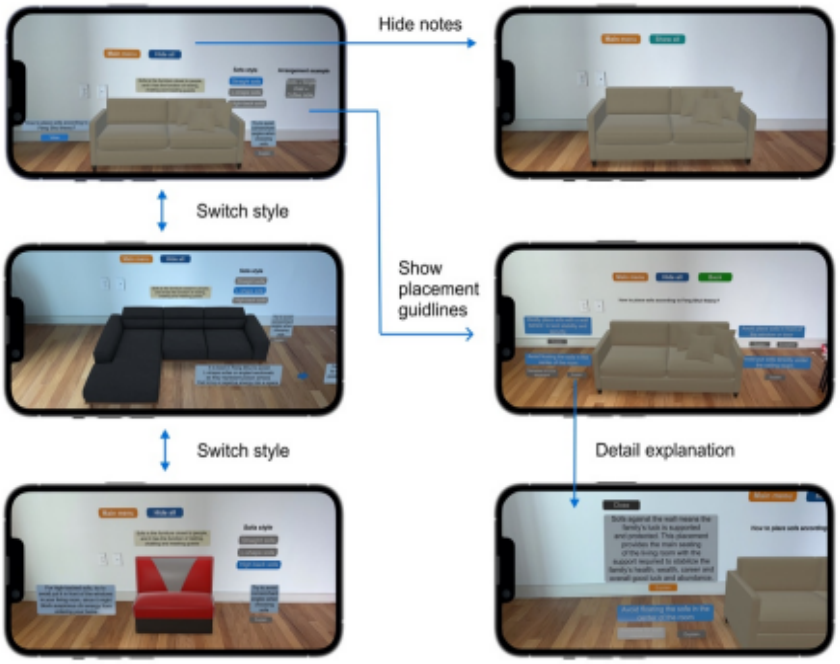

Figure 11. Visualization of different types of sofas and interfaces [10]

As shown in Figure 8 above, diverse interfaces are displayed, and guidelines for arranging furniture according to Feng Shui principles in interfaces are included so that users can easily understand how it works. The app has a 'hide all' button where users can view the entire

space again without arranging furniture and a ‘tool’ button to freely size and rotate the furniture they want in the AR mode.

2.2.4 Digitization of Industrial Business Processes in AR

The app in this article was developed with the firefighter equipment manufacturer to enhance assembly quality and reduce errors. It displays firefighting equipment virtually on mobile devices. It visualizes the final assembly state for fire departments during the sales phase, preventing misunderstandings in requirements management and identifying change requests early in product planning [6]. The app's options are essential requirements for users. The options provide users with the best way and show them various methods for arrangements, such as recording and dragging examples. The app is developed by two software, Vuforia SDK and Unity 3D Engine, which are used for the app's implementation. Vuforia SDK detects the target models with 3D CAD models of the target objects so that the app visualizes the objects that are static and stable, and Unity3D Engine designs and implements the user experience (UX) in the app. Fahmi [6] built an AR for the digitization of industrial business processes and demonstrated functions in the AR user interface, Model recognition and tracking, Tree View, Overlay 3D Model, Animation, loading technical documents, and playing videos. These functions will be described [6] in detail below.

- Model recognition and tracking: The function aligns the AR's camera with a real-life rescue platform using a 2D drawing. It overlays a virtual 3D model onto the physical object for uninterrupted tracking as users move around.

- Tree view: The function organizes optional equipment into categories, such as safety and camera systems, in order to simplify navigation through the virtual catalog.

- Overlay 3D Model: The function displays the selected component's virtual 3D models onto the fundamental structure to apply collision prevention rules and allow multi-perspective model checks.

- Animation: The function animates selected components in the tree view, demonstrating their natural movement in 3D space.

- Load of technical documents: The function loads and opens technical documents as PDFs to save time during the configuration process and to prevent mistakes from using incorrect data.

- Play of videos: The function loads and plays videos demonstrating equipment used during a rescue operation and providing crucial support for making decisions.

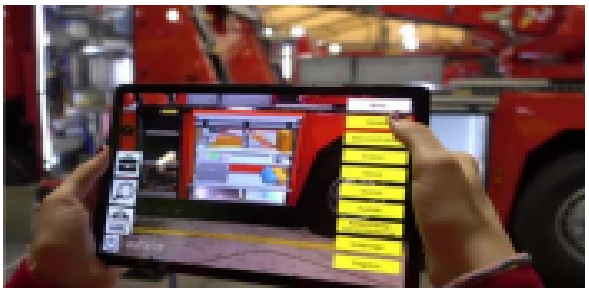

Figure 12. Visualization of virtual data of fire fighting equipment [6]

2.3 Discussion

Diverse articles were explored to review similar works in this session. Unfortunately, the articles that were explored illustrated the AR apps for furniture arrangement and not provide guidacne for safety. Articles on medical equipment arrangements can not be found. But, the articles demonstrate how to design the apps for any arrangement and what functionalities are required for users in the app.

Most AR uses the ARCore platform to create augmented reality in mobile devices and implements diverse interfaces that include scaling, rotating, selecting different types of furniture, setting up a slider menu, and so on. Diverse equipment, such as patient user interface, and artifical skylight is explored in the research. Furthermore, other medical equipment such as MRIs, and mechanical ventilators, and medical rooms are explored during a field trip to the Medtech Center at the University of Twente.

The main target group in this project will be stroke patients and their families. Scenarios will be generated to illustrate the purpose of the app's use in **section 5.3.1**.

3. Methods and techniques

3.1 Design Process

The Creative Technology Design Process (CTDP) is created by Mader and Eggink [23], as shown in ***Figure 13***. CTDP consists of four phases: ideation, specification, realization, and evaluation. The ideation phase generates diverse ideas and finalizes the final idea. The specification phase explores solutions in the early prototype from the user experience in order to resolve the faults and make it into a final prototype. In the realization phase, it is possible to go back to the previous stage if the wrong decision has been made. The evaluation phase identifies the desired prototype that is suitable for the requirement in the ideation phase.

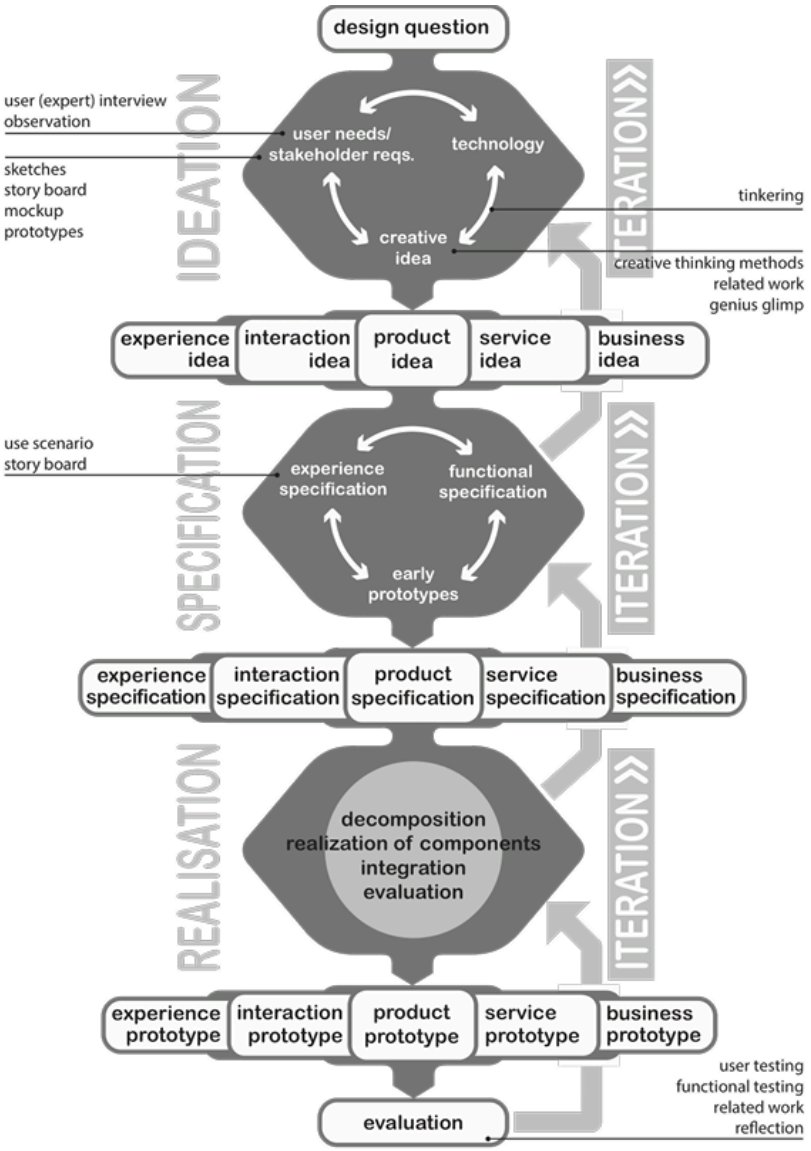

Figure 13. Creative Technology Design Process

3.1.1 Ideation

The ideation phase assists in generating creative ideas, requirements, and technologies. In this phase, requirements need to be identified to determine exactly what stakeholders need in the project, and these requirements are analyzed. The stakeholders are analyzed, how the stakeholders impact the project, and the interest power grid in ***Figure 14*** supports to distinguish them [24]. In the ideation phase, it is important to generate and develop ideas, and several stages are required to go further: brainstorming, idea selection, concept development, visualization, user feedback collection, and experimentation and validation. Diverse ideas are generated and filtered to select the best ideas, and the selected ideas develop the concepts. A prototype is created based on the concepts and ideas to be tested by users, and the prototype is improved by the feedback to be the final prototype.

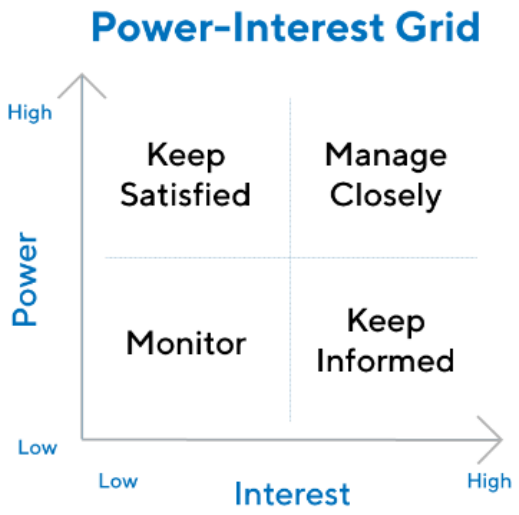

Figure 14. Interest Power Grid [24]

3.1.2 Specification

In this stage, a lo-fi prototype will be created based on the concepts and ideas. In my project, the lo-fi prototype is the AR app designed by the IKEA-place app [25]. The lo-fi prototype collects feedback from user experience, and final requirements are defined. The list of the final requirements is analyzed using the MoSCoW method. The MoSCoW method has four

categories: Must, Should, Could, and Won't [26]. The Must category includes requirements that are necessary for the project. The Should category has requirements that are important to the project, but they are not essential, which means the project still functions if the requirements are removed [26]. The Could category describes the requirements in the Could category that have a small impact on the project [26]. The Won't category shows the requirements are not required in the project.

3.1.3 Realization

In the realization phase, if the current decision is wrong, it is possible to go back to the previous phase, ideation, or specification to generate new ideas or improvements. The final decision is finalized with the cycling steps, and it creates a hi-fi prototype. The hi-fi prototype will contain diverse functionalities that users need, and this phase will review how the hi-fi prototype is designed and visualized in detail.

3.1.4 Evaluation

The evaluation phase processes the usability test to test the effectiveness of the hi-fi prototype, and this phase identifies how the prototype has been appropriately developed based on the target users. During the interview, the consent form will be provided to participants, and the participants will be informed of appropriate instructions for conducting the usability test. The participants will be asked essential questions for interviews, and the prototype will be assessed anonymously by the SUS (System Usability Scale) regarding the project.

4. Ideation

4.1 Stakeholders

4.1.1 Stakeholders analysis

Stakeholder	Power	Interest
Designer	**High**	**High**
Supervisors	**High**	**High**
Stroke Patient	**Low**	**High**
Patient's Families	**Low**	**High**

Table 1. Stakeholders identification

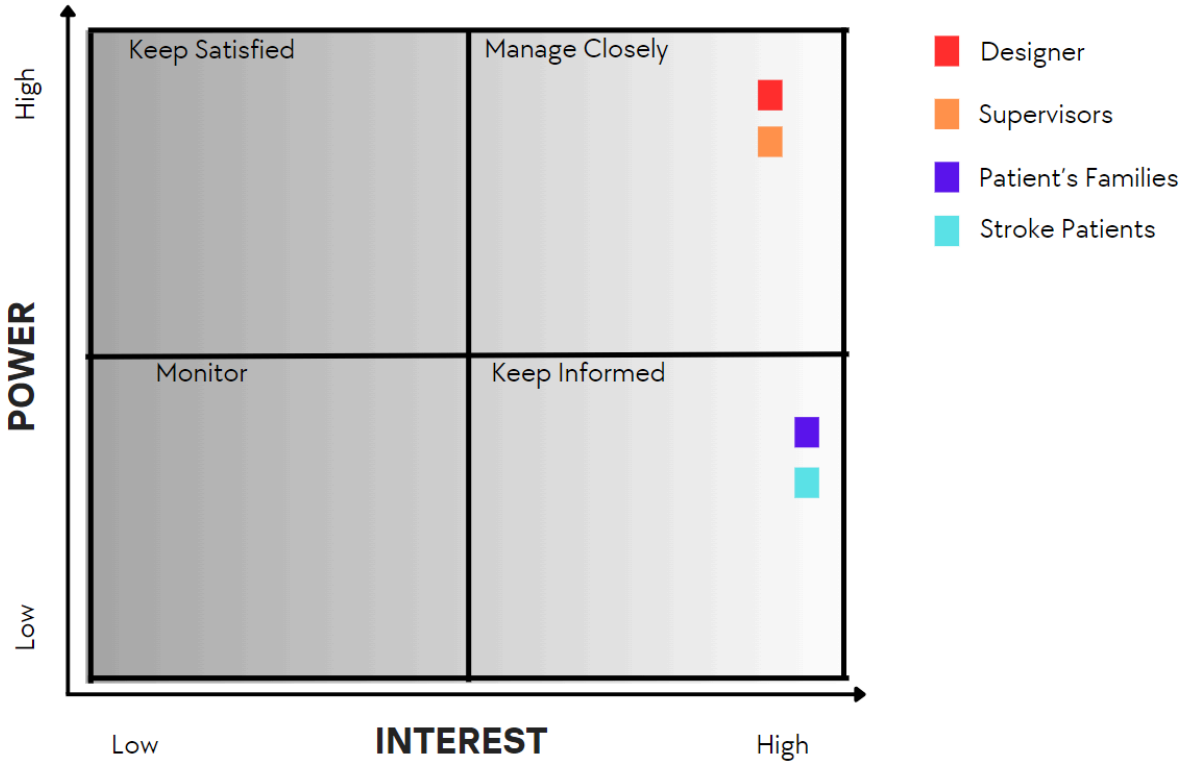

Figure 15. Power-Interest Grid for Stakeholders

The designer, Seokho, designs and develops the AR app during the project, and the AR app is created through feedback from the supervisors and final ideas. The designer creates the app incorporating necessary functionalities to ensure accurate implementation and user experience. The supervisors are Wouter Eggink, who gives feedback to the designer on this project, and Daniel Saakes, who guides the designer on how the project should proceed. Stroke patients and their families are the most important key stakeholders in this project, and they are the users who use the app.

4.2 Functional Ideas

To design the app, it has to consider how it supports the modification of interior design for the users and how the app has to be understandable. It is necessary to generate ideas about what AR app functionalities are required and how the app is designed to enable users to utilize the app in various ways and with convenience. Various functionalities and designs are investigated, and the necessary ones will be selected to be included in the final idea, and the final ideas will design the app.

4.2.1 Selection Menu

The menu option will be an essential functionality in the app so that users can select the desired objects and place them in appropriate positions. The selection menu obstructs the screen while users use the app, potentially interfering with equipment arrangement.

4.2.2 Video Recording

Video recording could be useful when the users want to save the arranged scene in the app so that they can reuse the sources next time. However, if the recording video is leaked on the Internet or public, it could become a privacy issue. So, this functionality needs to be evaluated and considered more whether it is included in the app.

4.2.3 Screenshot

Screenshots can also save the user's work. However, the pictures might contain the user's personal data, which could become a privacy issue. This functionality also needs to be considered when the video recording is implemented in the app.

4.2.4 Search Function

Search functionality is mainly used when users input initial consonants or one or two words, and the app will find the objects they are looking for. Therefore, it helps users find the objects they are looking for and prevents them from wasting time.

4.2.5 Adding desired objects

If the app does not have the objects the users are looking for, they can add the extra objects they want. The added objects are saved in the app and can be used again. The app should connect to the Internet to add this functionality so that the users can search for the wanted objects on the Internet and add them to the app.

4.2.6 Design desired objects

The app provides a design tool so users can design any preferred equipment. The designed equipment can be placed to arrange and save the design in the app. However, it is likely not to be significantly beneficial, as there is no expected larger user base.

4.2.7 Caution Notification

Caution notifications help users avoid danger when placing equipment or ensure interior design at home. Users may not be aware of the risks when arranging equipment, so caution notifications can prevent them.

4.2.8 Authority

The AR app provides authority to minimize privacy issues. Authority can restrict access to personal information such as user location, contacts, photos, camera, microphone, and other device functionalities. This is an essential factor to enhance user privacy and security. Recording video and screenshot functionalities can work safely with the authority. So, if users permit the authority, they can use the camera function in the app.

4.2.9. Scaling Function

Scaling objects is essential for resizing big or small objects in the app. It assists users in easily arranging objects and enables users to resize objects. However, furniture and medical equipment need to be arranged in the app in a real size, so this function might not be necessary.

4.2.10 Dragging Function

Dragging objects is also essential for moving objects in the app, and it supports users in controlling them. Users can select desired objects in the selection menu, drag them onto the screen, and place them. So, this functionality must be enabled in the app.

4.2.11 Guidance

The AR app provides diverse guidance for users. If users are in their bedrooms, they are informed on how to arrange and what risks they need to be aware of. The app will enable the guidance app to provide information to users.

4.2.12 Evaluation of Functional Ideas

Category	Functional Ideas
Must	**Selection Menu**
Could	**Video Recording**
Could	**Screenshot**
Could	**Search Function**
Could	**Adding desired objects**
Could	**Design desired objects**
Should	**Caution Notification**
Could	**Authority**
Should	**Scaling Function**
Must	**Dragging Function**
Must	**Guidance**

Table 2. Functional Requirements

Functional requirements are evaluated based on the Moscow method, and this table describes what functions are required and recommended. Selection Menu and Dragging functions must be needed in the app so that users can select objects that they want to spawn and place the spawned objects where they want to place. A scaling function should be required for most apps. However, it is not required because the objects with the real size will be spawned in the app. Screenshots, search functionality, adding desired objects, video recording, design of desired objects, and authority are recommended, but they are not necessarily required for this project. Guidance must be added to the app so that the app can provide diverse guidance to users.

4.3 Final Idea

Section 4.2 discusses various ideas, and now, essential functionalities are filtered to be used in the design of the AR app and how to design the AR app. Three scenarios are generated to show how users are likely to use the app, and these scenarios will be illustrated in more detail in the Specification phase. The scenario helps to determine what app design would be suitable and how users easily understand the usage of the app. Furthermore, one can brainstorm what functionalities would be beneficial for the app and target users through the scenarios. Therefore, the two required functionalities are selected: the selection menu and the dragging option in this phase. The selection menu and dragging objects are essential tools for the app in which the selection menu supports display objects that users should use to arrange. The dragging option enables users to control objects they will arrange for so they can drag them easily and place them wherever they want. The figures below will show how to design and use the app. After the lo-fi tests in the specification phase, the final functional and non-functional requirements will be generated to create the hi-fi prototype.

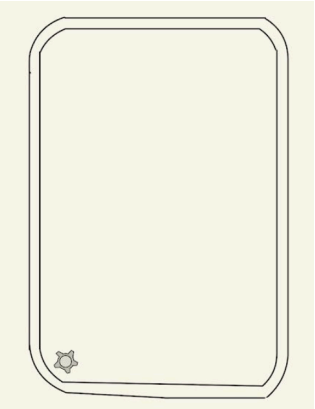

Figure 16. The initial screen when the app has opened

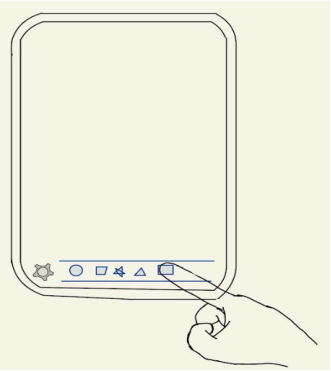

Figure 17. Selection Menu

A slider menu is on the below screen, and users can select preferred objects.

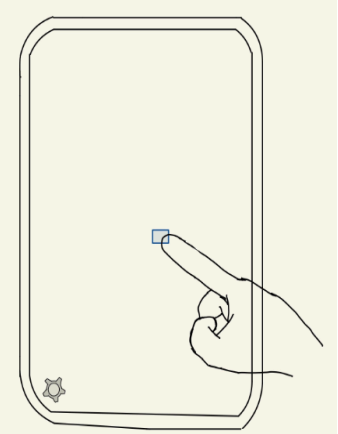

Figure 18. Dragging

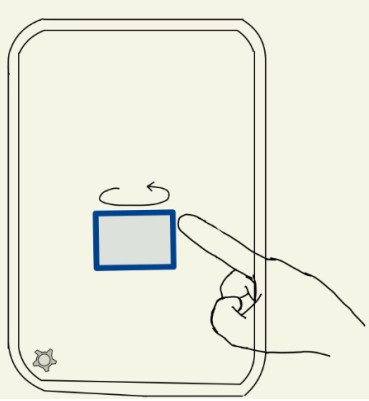

Figure 19. Controlling an object

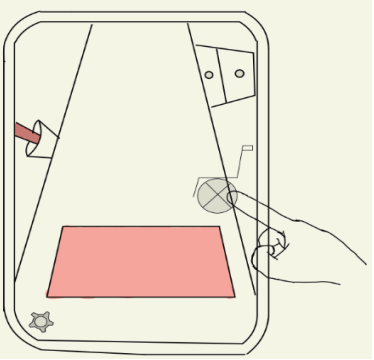

Figure 20. An object is placed in the appropriate position

5. Specification

5.1 Lo-fi prototype

A lo-fi prototype is made using a game engine named Unity to improve and filter necessary and unnecessary functions and finalize a hi-fi prototype. The lo-fi prototype enables objects to spawn as soon as users touch the screen, and they can touch, move, and drag objects spawned on the screen, as shown below in ***Figure 21***.

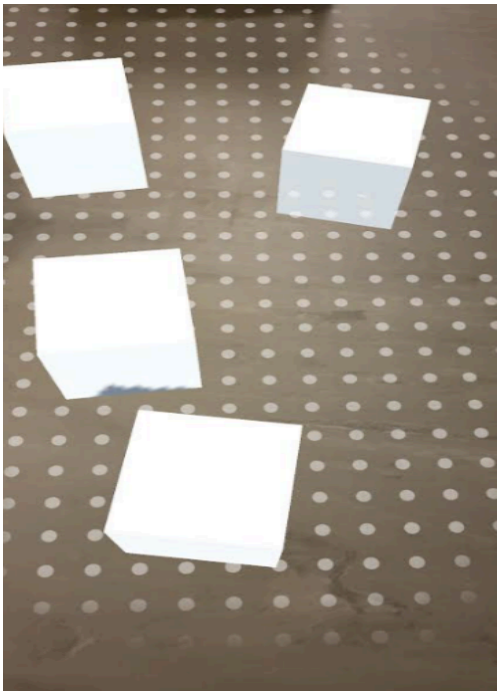

Figure 21. Lofi-prototype

The lo-fi app contains a few functions that detect planes, spawn objects, and move and rotate objects. The functions will be described in more detail below.

Functions	Description
Detecting Plane	**The app scans real floors and makes planes to let objects spawn on**
Spawning Objects	**An object is spawned when a user touches a part**

Rotating and Moving Objects	**An object on touch can be moved and rotated by the user's fingers**

Table 3. Lo-fi app's functions

5.2 Lo-fi Test

The lo-fi tests are required to improve the final prototype. The test identifies where the prototype has errors and provides suggestions and feedback for improvement. It is planned that participants are stroke patients for the target group. Unfortunately, it is difficult to recruit stroke patients, so normal people conduct the test. The test does not take over 20 minutes and is anonymously conducted. Participants can be recorded if they allow video recording during the test, and they can skip any questions if they do not want to answer. During the lo-fi test, participants use the app and are asked questions about the prototype. A protocol is generated for the Lo-fi test, which is described below.

Protocol on the Lo-fi test:

1. Introduce the test
2. Guide what the app is for
3. Let participants use the app
4. Ask some questions about the app for improvements

1) Male/Female? Age?

2) Do you understand how the app works?

3) Do you think you don't have any inconvenience to control objects in the app?

4) Could you easily recognize it as an object?

5) What was the inconvenience for the app?

6) What was the satisfaction of the app?

7) What functionality is useful for the app? (extra functionalities like camera option)

8) Do you think this app will be useful for patients with the purpose of the app?

9) Do you have any ideas for adding medical equipment for patients? (extra medical equipment at home)

10) Do you have any other suggestions for improving the app?

The semi-structured interviews are appropriate for asking participants more specific and deep questions [27]. So, participants can be asked extra questions that are not on the given questionnaire list.

5.2.1 Result of the Lo-fi test

Questions	#1	#2	#3
Age? Male/Female?	26, male	25, male	24, female
Do you understand how the app works?	Easy to understand.	Yes.	Easy to understand.
Do you think you don't have any inconvenience to control objects in the app?	It seems like it is a rotation issue.	Objects don't seem to be in the right place on the y-axis.	It is hard to control rotation.
Could you easily recognize it as an object?	Yes.	Yes.	Easy to understand.
What was the inconvenience for the app?	It is hard to recognize a grid on a plane.	Difficult to see objects on the Y-axis.	Objects spawned on different heights. Did not understand why it is limited the number of fixed objects.

What was the satisfaction of the app?	It is useful for the purpose of an arrangement.	It was easy to control on move and rotation.	It was easy to recognize which objects were fixed with color change.
What functionality is useful for the app? (extra functionalities like camera option)	Scaling and customizing will be useful to the app.	It will be useful if an object is placed over the wall, and a collider of the object turns red to show the space is unavailable.	I would like to be able to place objects more precisely rather than by estimation. A manual is needed.
Do you think this app will be useful for patients with the purpose of the app?	I estimate that it is going to be useful for them.	That is going to be useful for them.	That is going to be useful for them.
Do you have any ideas for adding medical equipment for patients? (extra medical equipment at home)	I would say medical beds, intravenous, and oxygen masks.	I would say supports, helmets, handles, and cushions.	I have no idea.
Do you have any other suggestions for improving the app?	I would like to add extra model tools, scan real objects with a camera, and use them as an object.	The y-axis has to be defined so that objects are placed in the right place.	I would say that to add more models, the selected objects should contain four arrows on the left, right, up, and down so that they can be placed precisely, and a category is required to hide the visualizing

			buttons on the screen. You can add an opening button, which helps other buttons hide and reveal because the buttons interrupt the screen as obstacles.

Table 4. Questionnaire for Lo-fi Test

5.2.2 Evaluation of Lo-fi Test

During the test, participants were observed in terms of how they acted and used the app. The three participants provided functional and non-functional feedback during the lo-fi tests with interviews. They all easily understood how to use the app and recognized spawned objects at the beginning of the tests. Moreover, they are satisfied with the purpose of the app and the app. However, there are a lot of requirements for improvement. Two out of three participants complained about rotation in which objects rotated faster than normal. Each participant had a different method of rotating objects in which one participant rotated objects with two fingers in one hand, and the other participants rotated them with one finger in each hand. So, participants feel inconvenienced by the fast speed of rotating objects depending on their rotation method. Participants recognized that some objects spawned at different heights for some errors, making it difficult to recognize precisely where the objects were placed. All participants especially require objects to be placed at the correct height accurately. They also mentioned that it would be helpful if there were a change in the object's color to indicate when part of the object is placed in an invalid position. An opening button can be added to hide and reveal other buttons, preventing them from obstructing the screen. The most impressive improvement was adding a manual so that users unfamiliar with AR apps could easily understand what functions are for and how to use AR apps. Even users familiar with AR apps could get more information from a manual. Furthermore, users can get information from instructions with information buttons, which the buttons provide users with what an object is, what size of an object is, and what cautions they need to be careful. From the lo-fi tests, a stage has been reached where it can be further refined how information can be easily conveyed to users and how the app can be made easier to understand.

5.3 Personas

Personas explain how the scenarios, ***Figure 24, Figure 25,*** and ***Figure 26***, work. There are two personas, Jack and Walter, described in detail below. A high school student is familiar with using AR apps because he has been learning about AR and VR through social media and school. On the other hand, an elder man is unfamiliar with AR, so he struggles with AR apps.

Figure 22. Jack [30]

Jack, 17 years old, lives in Enschede. He is a high school student and a stroke patient. He arrives home from school daily, rides his wheelchair by the front door, and gets safely in his room.

Figure 23. Walter [30]

Walter, 70, lives in Enschede and is a stroke patient. Every day, he comes home after going for a walk, rides his wheelchair in the front door, and goes to the bathroom to wash his hands. He then goes to the kitchen and sits to read the newspaper.

5.3.1 Scenarios

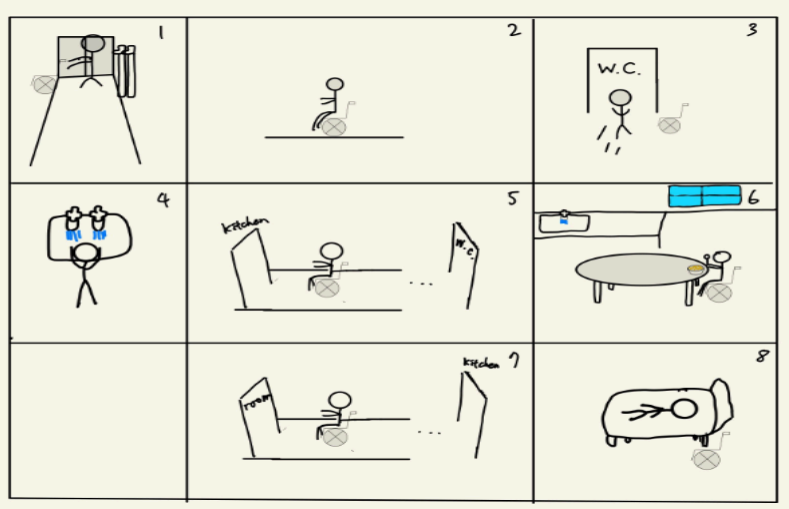

Figure 24. Scenario 1

A scenario, ***Figure 24***, is created as a routine for a patient that describes a patient arriving home, taking his/her own wheelchair, and moving from the front door to his/her own bed. So, the app will be implemented, what functions the app requires, and how the app has to be designed based on the scenario. In order to build the app, the app should support users in arranging furniture, equipment, and wheelchairs in a safe space. Moreover, the app provides guidance so that users are aware of risks and methods of arrangement.

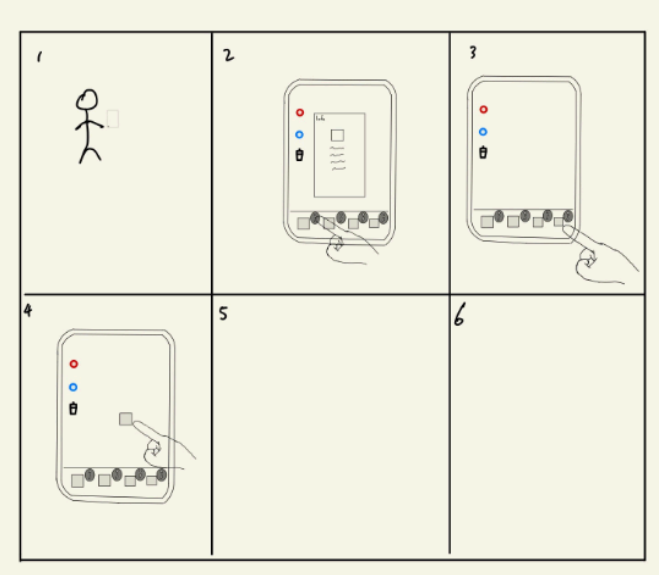

Figure 25. Scenario 2 for Jack

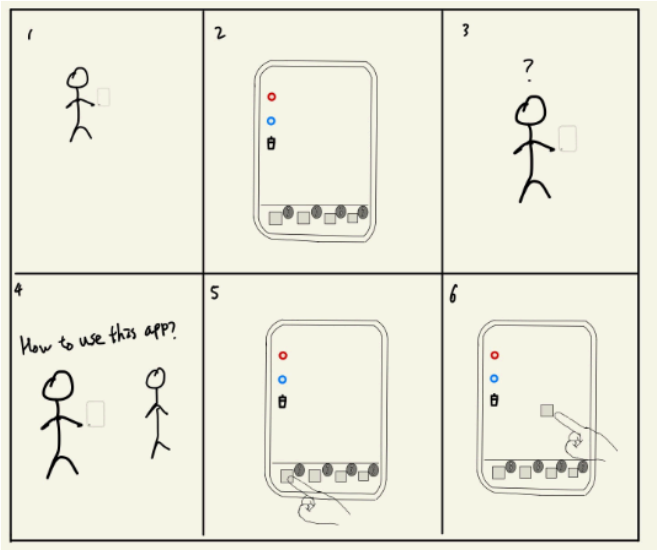

Figure 26. Scenario 3 for Walter

Figure 25 demonstrates Jack using the app well since he is familiar with AR apps and understands them quickly. So, he utilizes all buttons to arrange objects and does not have much inconvenience when using the app. On the other hand, ***Figure 26*** illustrates a different case with Walter, who struggles with using the app. He needs help to recognize what the app is for and how to use the app at the beginning of using the app. He needs a lot of time to understand and learn how to use the app and needs assistance to ask for help. Therefore, users might not know about AR apps and may not have used them before. Therefore, the app for this project requires a manual and instructions for introduction, even if they have used AR apps.

5.3.2 Interaction Personas and Scenario

Combining a scenario and personas from different age groups provides insights into app design considerations. It assists in identifying factors for designing and improving an app accordingly. It's important to consider how different age groups interact with technology, their preferences, useability challenges, and accessibility needs.

5.3.3 Target Groups

Diverse age groups can use AR apps, and many users use them for various purposes. However, AR apps require hand control so that users can control them. It is still essential to know what the AR app for this study is for and who it is for.

The main target group for this project is stroke patients using wheelchairs and their families in diverse age groups.

AR apps have reasonable and understandable functions, which must be recognizable by visualizing common icons for diverse age groups. It is difficult for old users and users who have not used AR apps to understand how to use AR apps and their functions if there are no instructions for using AR apps. Therefore, it is essential to design the AR app for this project to provide standard visualizations for stroke patients in diverse age groups. Otherwise, users struggle to use the app as potential design pitfalls [32].

5.4 Functional and Non-Functional Requirements For Hi-fi Prototype

The final prototype's functional and non-functional requirements are identified as final ideas, and the requirements are assessed through lo-fi tests and chapters 4 and 5.

5.4.1 Functional Requirements

Category	Functional Requirement	Description
Must	**Selection Menu**	**It provides diverse objects for selection**
Could	**Video Recording**	**It provides saving scenes that users want to save**
Could	**Screenshot**	**It also provides saving scenes that users want to save**

Could	**Search Function**	**It is connected online and provides diverse objects users are looking for**
Could	**Adding desired objects**	**It allows users to add extra objects to the selection menu**
Could	**Design desired objects**	**Users can design objects that they want to add**
Should	**Caution Notification**	**The app notices cautions to users for danger**
Could	**Authority**	**The app asks users for permission to connect to the camera**
Should	**Scaling Function**	**Users can scale objects**
Must	**Dragging Function**	**Users can drag spawned objects**
Must	**Guidance**	**The app guides users with safety and layout**
Could	**Notification**	**It is for unavailable space in objects, so if an object is placed in unavailable space, the part of the object in unavailable space changes another color for noticing.**
Must	**Spatial Recognition**	**When a user touches an object, the object shows its collider to arrange in a suitable space**

Table 5. Functional Requirements

Table 5 illustrates the functional requirements for building the final prototype, which are assessed using the MoSCoW method. The functional requirements are described in **Table 5** through feedback in the lo-fi test, and the ideation phase determines which requirements must, should, or could be needed.

5.4.2 Non-Functional Requirements

Category	Non-Functional Requirement
Must	**Manual Text**
Must	**Information Instruction Text**
Should	**Diverse objects have to be added.**

Table 6. Non-functional requirements

Table 6 illustrates the non-functional requirements, which require untechnical parts. Information instructions and a manual for the AR app are mainly needed so that users can easily understand without assistance. These are for users unfamiliar with AR apps and those who have not used AR apps. Moreover, these provide information on what functions the app has.

Considering both the functional and non-functional requirements, it has been decided that all non-functional requirements, the selection menu, dragging, guidance, and spatial recognition in functional requirements will be included in the final prototype. These selected requirements are essential for designing the final prototype, provide guidance, and are sufficient for a basic AR app to function.

6. Realisation

In the realisation chapter, the final prototype for this project will be described and implemented, containing the requirements discussed in the Specification phase. The AR app is implemented by a Game Engine named Unity, and it demonstrates the following aspects: UI, Guidance, Software, Hardware, Objects in Hierarchy, and Scenes in Unity. Implementing an AR app involves two methods: Android and iOS. The app for this project is implemented using the Android version.

6.1 Flowchart

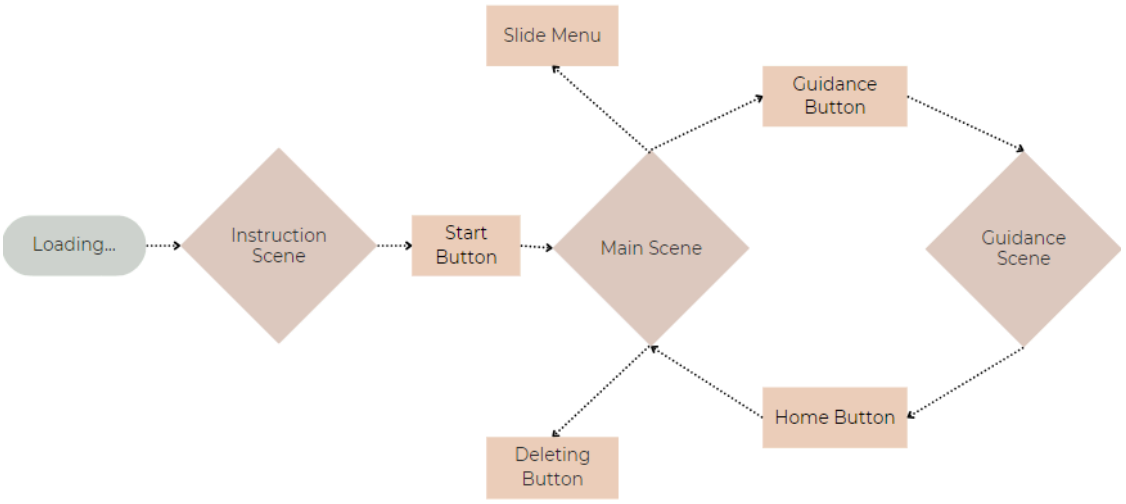

Figure 27. Flowchart in hi-fi prototype

6.2 Hardware

6.2.1 Phone

Figure 28. Galaxy S9 Plus [34]

Galaxy S9 Plus is used for this project's hardware. This mobile phone receives data from Unity and displays an AR screen.

6.3 Software

6.3.1 Unity

Unity is game engine software used for development and interactive content. It uses C# as its primary scripting language, allowing developers to program game logic and object behaviors. Unity has a powerful physics engine for implementing realistic physical effects like gravity. Moreover, Unity has tools for developing AR and VR content, supporting platforms like ARCore and ARKit.

Figure 29. Unity [31]

6.3.2 Blender

Blender is a free and open-source 3D creation for modeling, sculpting, animation, simulation, rendering, and motion tracking.

Figure 30. Blender [28]

6.4 Implementation

This section describes the setup for the hi-fi prototype in detail below in the subsections. The final prototype is built based on the discussions in Chapters 4 and 5. The prototype is an AR app that provides guidance and assists users in safely arranging furniture and medical equipment. The first scene in the prototype shows a loading, which the prototype activates. The second scene shows short instructions on the usage of the prototype. Users can start using the prototype by pressing the start button in the center of the screen, and the app transitions to the main scene. Lastly, there is a guidance button in the main scene to transition to the guidance scene, in which users can be informed of diverse guidance with the two buttons, a bedroom button, and a kitchen button. The two buttons provide four categories of guidance for each room.

6.4.1 Loading Scene

This scene helps users recognize that the prototype starts loading. It contains a slider bar that visualizes a loading bar in the app in the first scene.

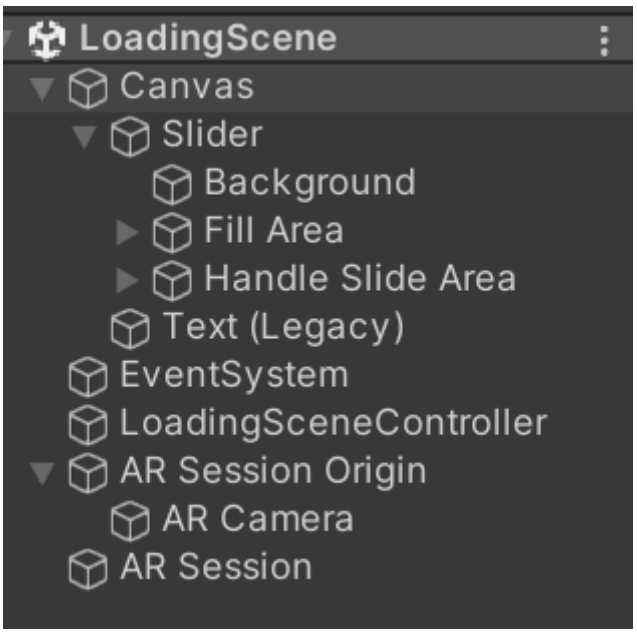

Figure 31. Hierarchy in Loading Scene

Figure 31 shows the objects added to this scene. Canvas and EventSystem are for sliders, LoadingSceneController contains a LoadingSceneController script, and AR Session Origin and AR Session support the AR environment in the scene.

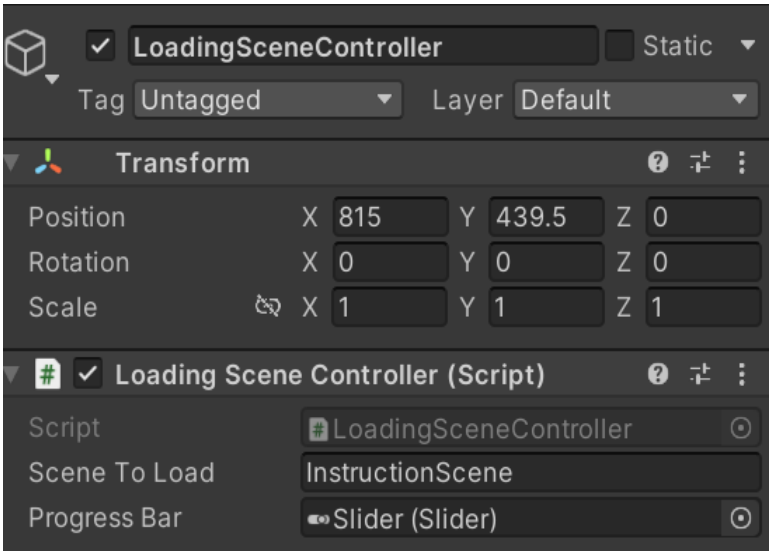

Figure 32. Loading Scene Controller Script

Figure 32 requires one scene to transition to the next scene and a slider for connection. So, when the slider shows finishing loading, the next scene, the Instruction Scene, is loaded.

The loading scene controller is a script that transitions to the next scene, the Instruction Scene, as soon as the loading is complete.

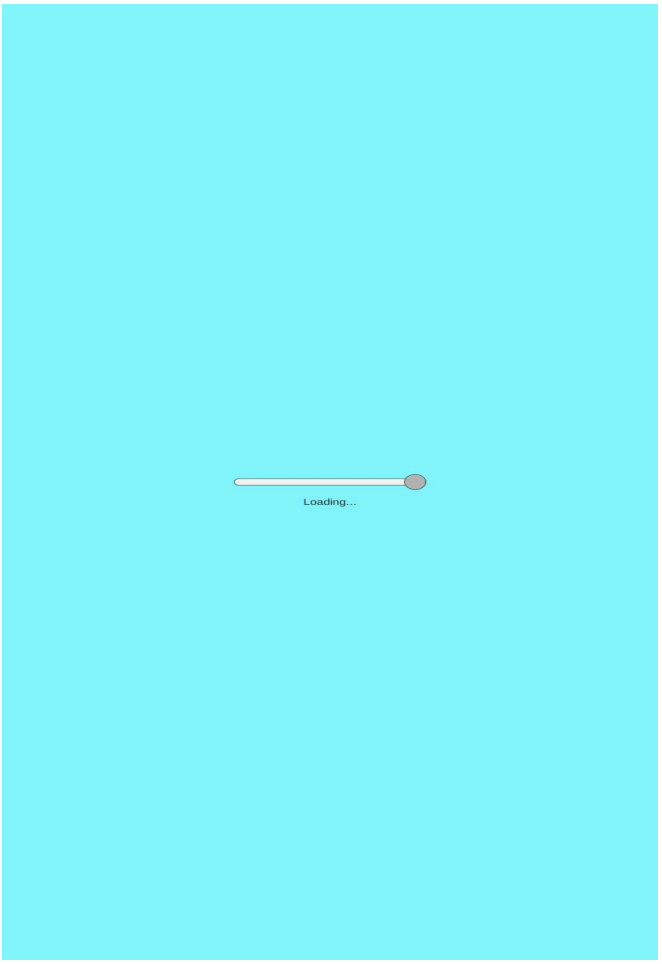

Figure 33. The screen of the loading scene in the prototype

6.4.2 Instruction Scene

The instruction scene helps users to understand how to use the prototype before they start to use it.

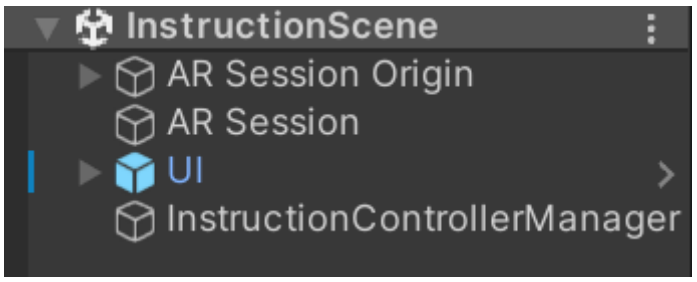

Figure 34. Hierarchy in Instruction Scene

The UI contains buttons and a slider menu for the main scene, which is the screen where users can use all functions. The main scene will be followed in more detail in **section 6.4.3**.

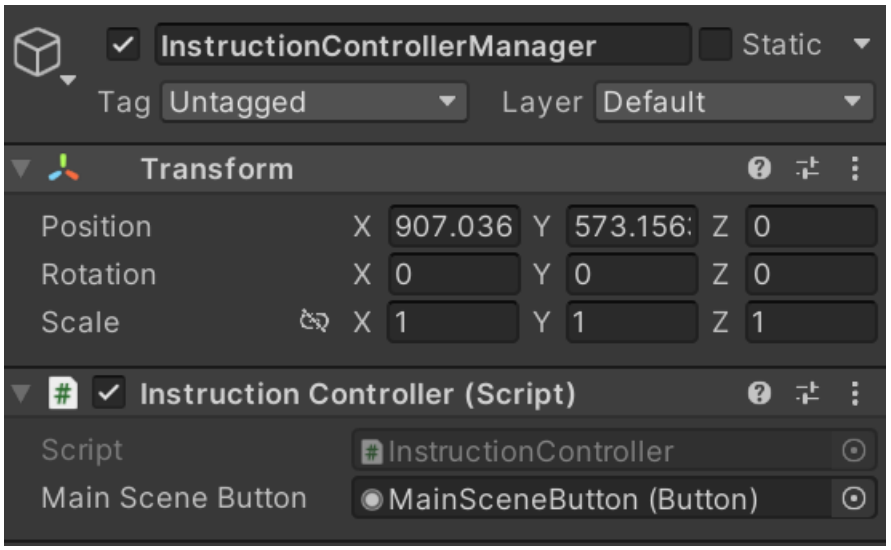

Figure 35. Instruction Controller Script

The instruction controller script enables users to transition to the next scene, Main Scene when they press the start button in the center of the screen.

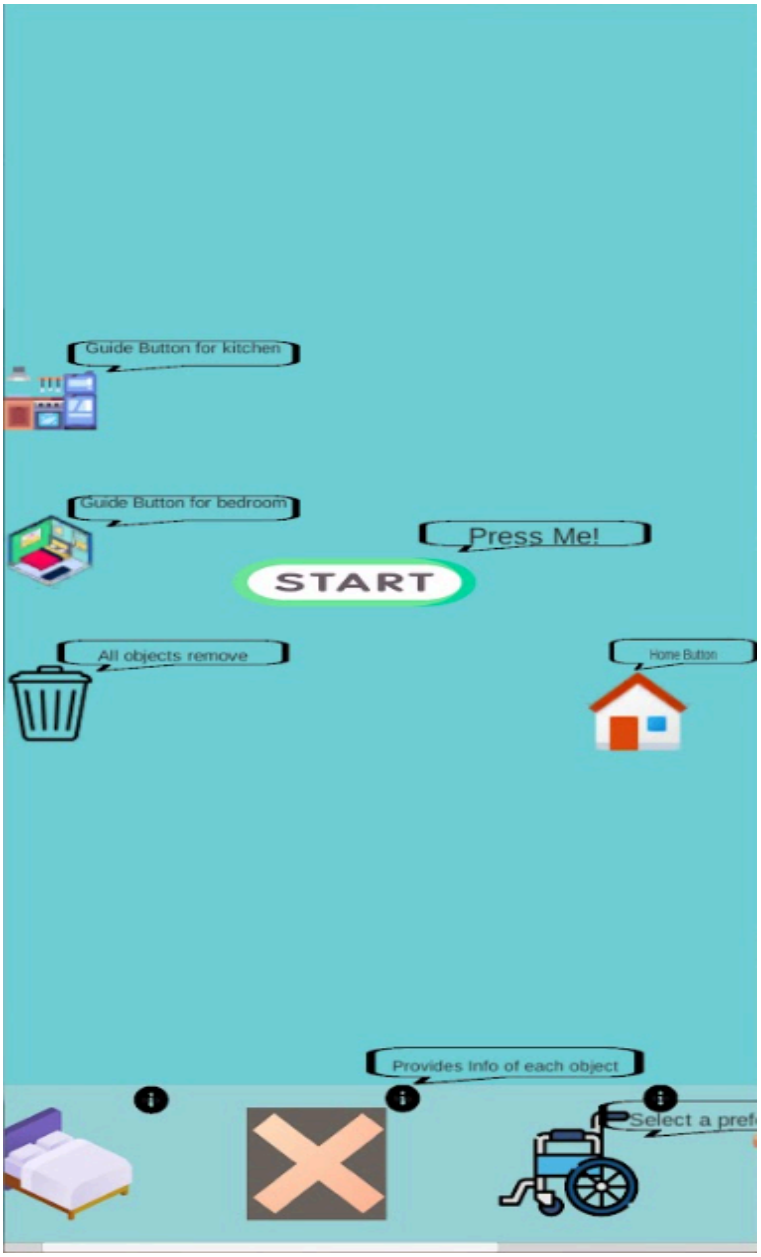

Figure 36. The screen of the instruction scene in the prototype

Speech bubbles for instruction are displayed next to each UI. Users can easily understand what buttons are for, and after understanding the prototype's usage, they can press the start button in the center of the screen to start the prototype. The icon of the start button is from the website [31].

6.4.3 Main Scene

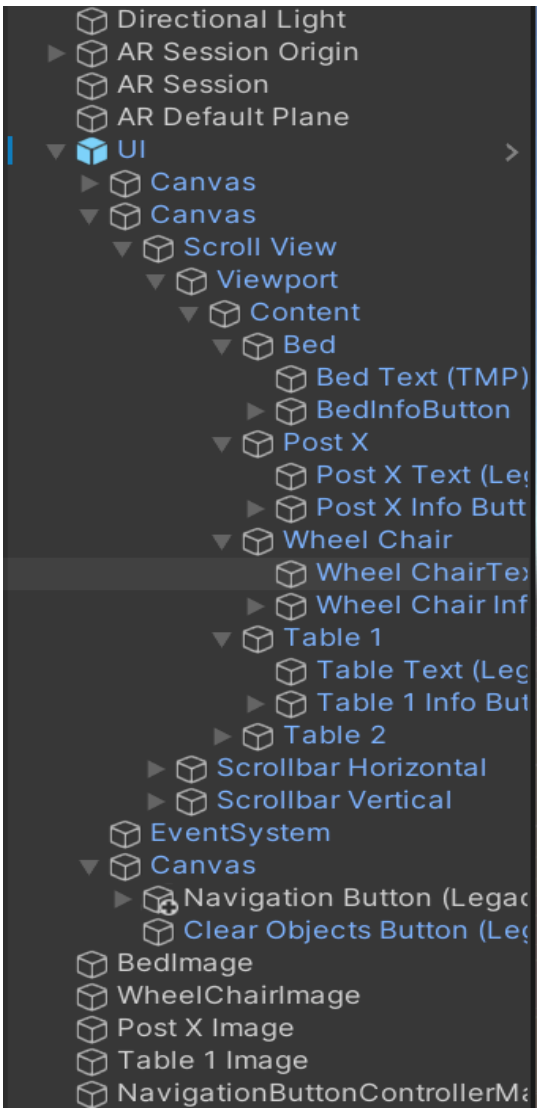

Figure 37. Hierarchy in the main scene

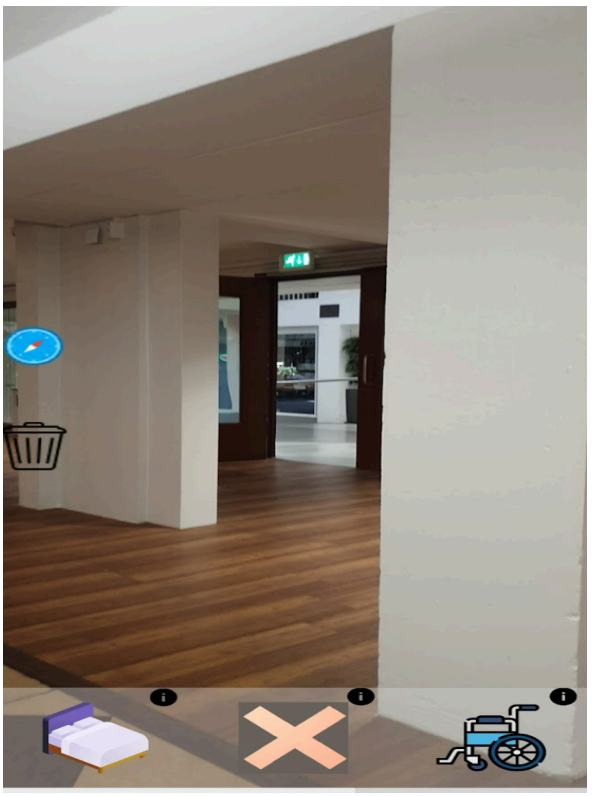

Figure 38. Main Screen

Figure 38 shows the prototype's main screen, which contains a slider menu for selecting objects, information buttons in the slider menu, a guidance button, and a deleting button. Users can arrange and delete objects in this scene. The deleting button removes existing objects on the screen. Users can spawn objects they want in the slider menu. Information buttons show each object's appearance and pop-up images on the screen, as shown below in ***Figure 45*** and ***Figure 46***. These buttons assist users in seeing how the objects look before they try to spawn them. The icons in the slider menu are from the websites [28] [31]. When users press the guidance scene, the main scene transitions to the guidance scene, which will be described in detail in **section 6.4**. The below guidance button controller script in ***Figure 40*** helps transition to the guidance scene when the guidance button is pressed. The object info controller enables an object image to pop up on the screen when the info button is pressed and adjusts the texture if the texture is saved on the script.

Figure 39. Guidance Button [28]

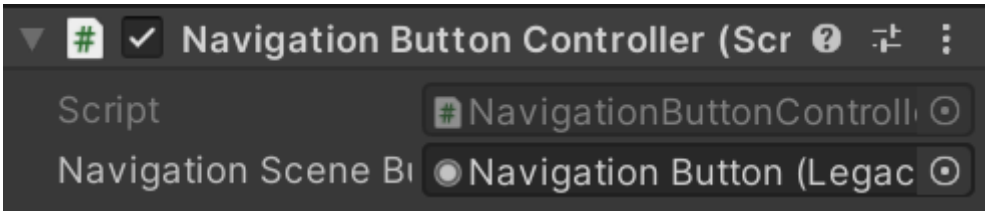

Figure 40. Guidance Button Controller in the guidance button

Figure 41. Info Button [31]

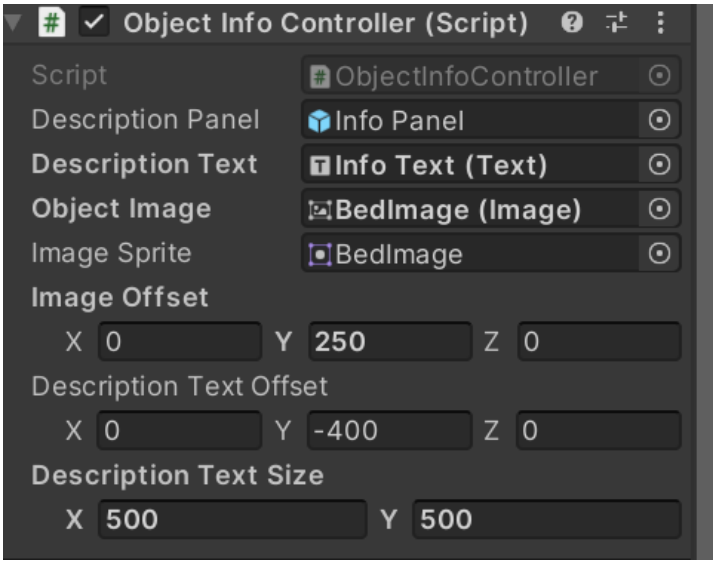

Figure 42. Object Info Controller in all info button

Figure 43. Deleting Button [28]

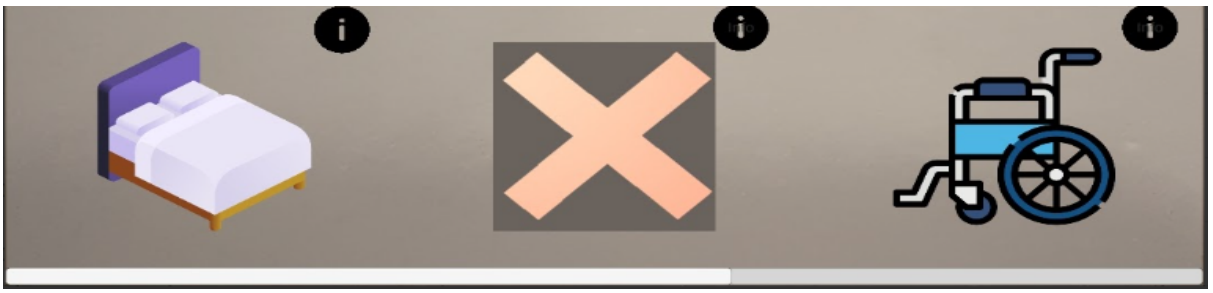

Figure 44. Slider Menu

Figure 45. Info buttons with bed and X for posting

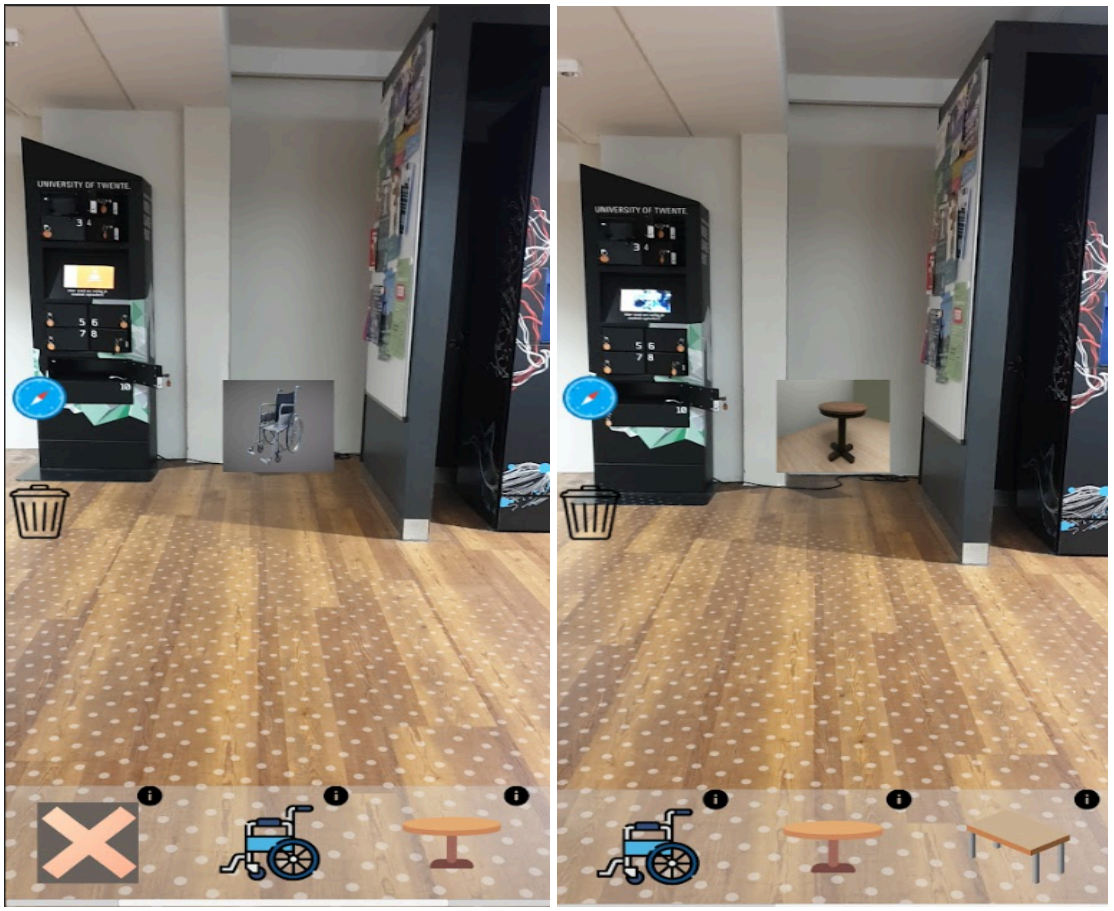

Figure 46. Info Buttons with wheelchair and table

Figure 47. Table and Wheelchair in the slider menu

Figure 48. X for posting and bed

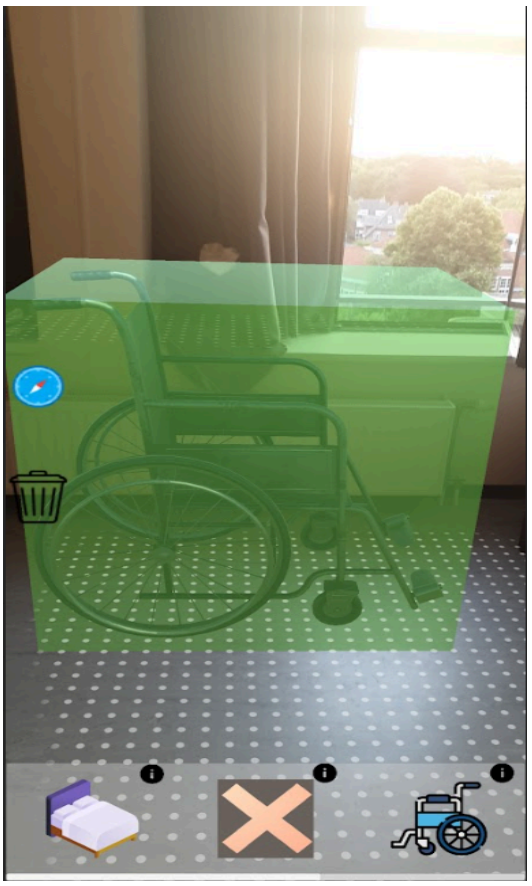

Figure 49. Selected object with touching

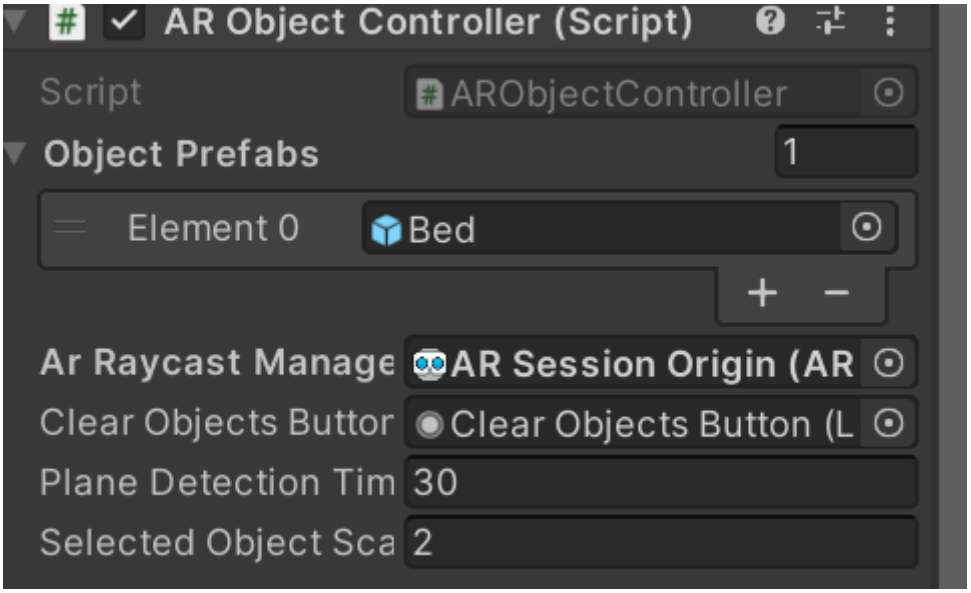

Figure 50. AR Object Controller in all object's prefab and the deleting button

All models and images for each model in Figures 45 and 46, except the X model, come from the asset store [29]. The X model is created in Blender. X is a symbol used to indicate places where space is insufficient, or objects cannot be placed. ***Figure 47*** and ***Figure 48*** show

existing objects in the prototype and users can arrange them. ***Figure 49*** illustrates the state when a user touches an object. It not only indicates that the object has been touched but also enables more precise placement using the green collider. The AR object controller in ***Figure 50*** enables objects to be generated at the center of the screen when the object button icon in the slider menu is pressed. The Clear Objects Button in ***Figure 50*** is the deleting button mentioned above.

6.4.4 Guidance Scene

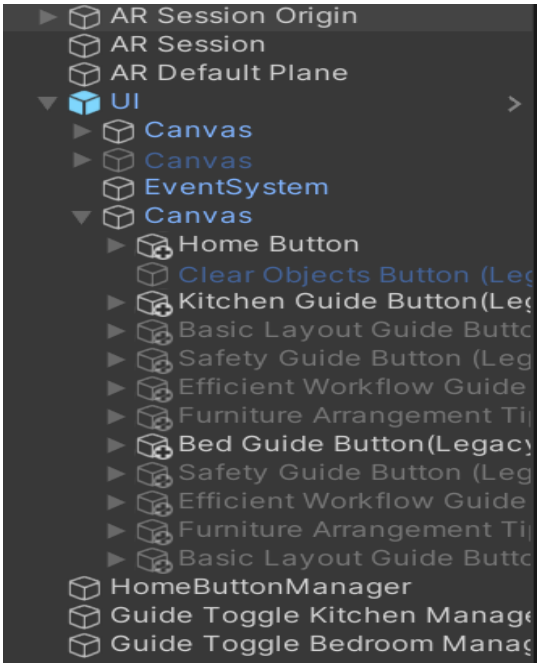

Figure 51. Hierarchy in Guidance Scene

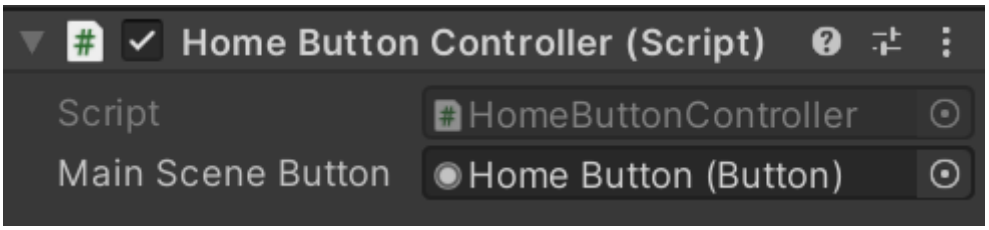

Figure 52. Home Button Controller

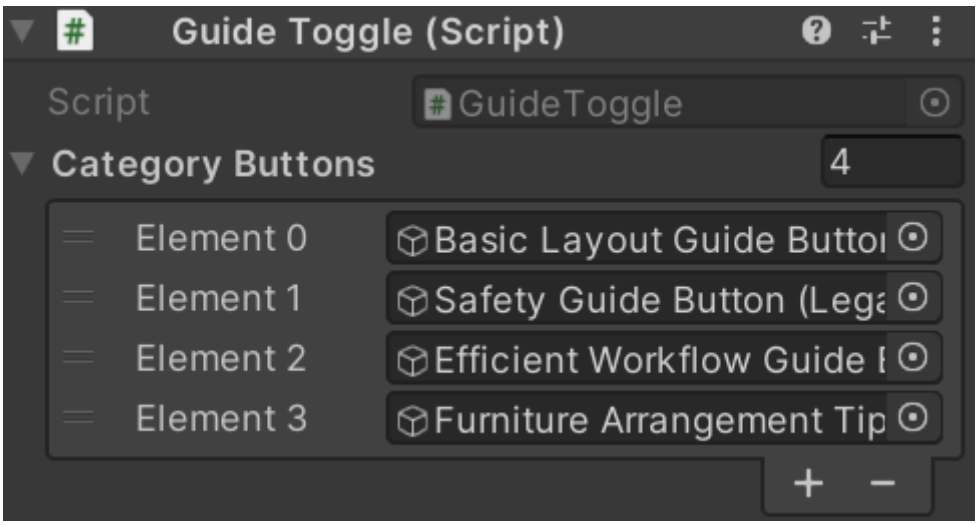

Figure 53. Guide Toggle

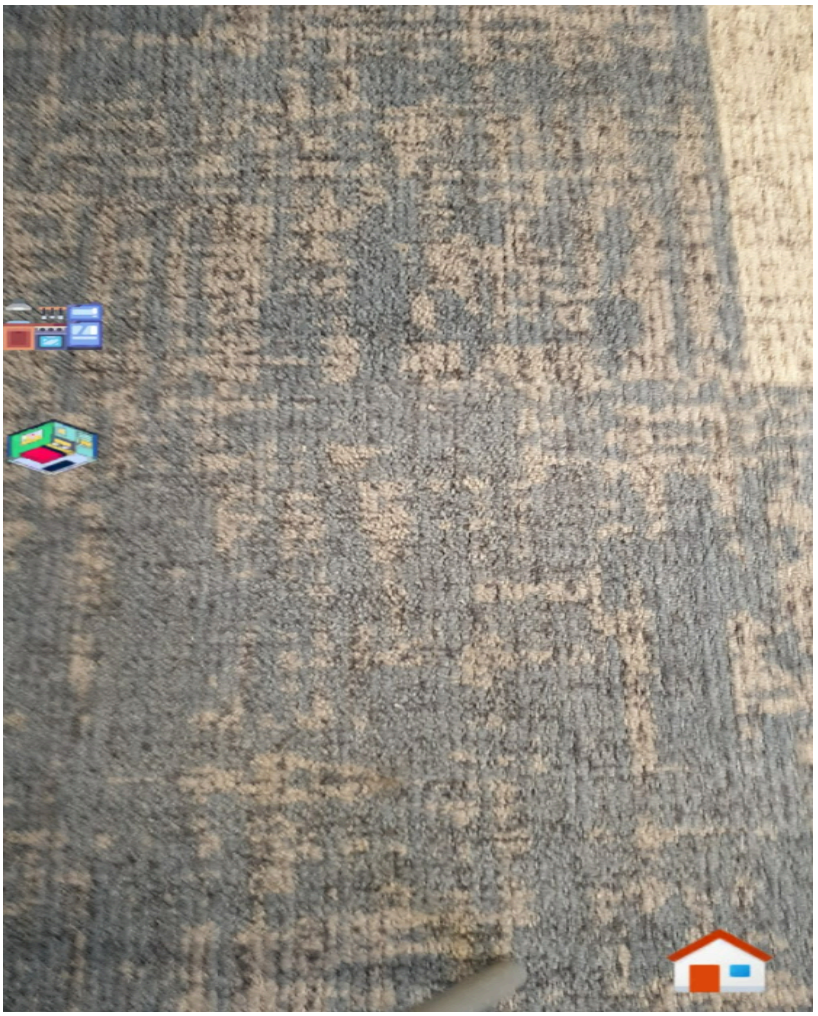

Figure 54. Guidance Scene

Figure 55.Kitchen Guidance Button [28]

Figure 56. Bedroom Guidance Button [28]

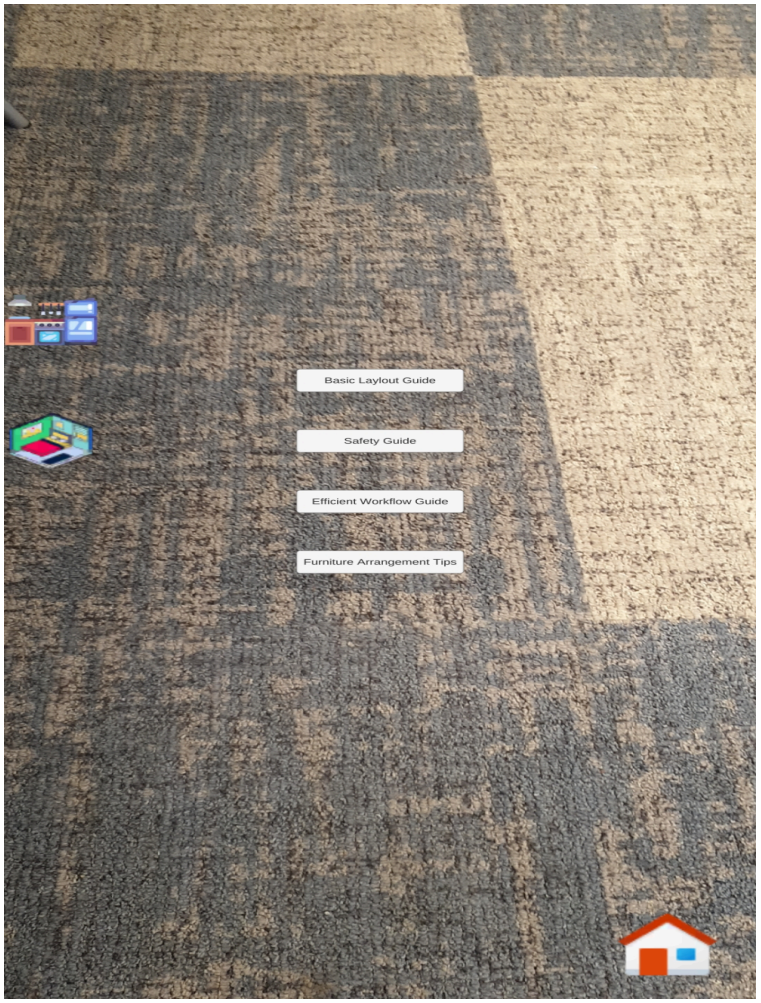

Figure 57. Four categories for guidance in the Bedroom button

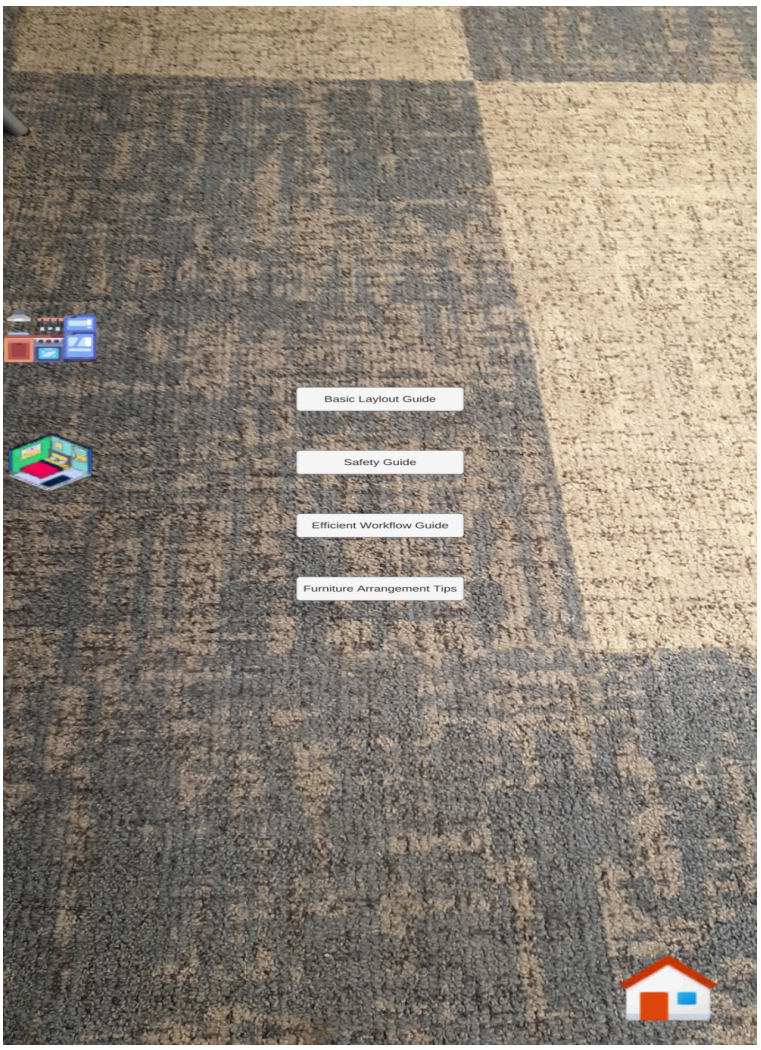

Figure 58. Four categories for guidance in the Kitchen button

Figure 59. Home Button [28]

The home button controller script in ***Figure 52*** is in the Home Button Manager object and is linked to the Home Button, enabling users to return to the main scene when they press it. The guide toggle script in ***Figure 53*** shows the guidance scene and enables the Kitchen and Bedroom guide buttons to pop up four-category guide buttons in the center of the screen when the buttons are pressed. However, the next steps for visualizing information about the

guidance are not implemented after pressing these four guide buttons in this prototype. The Guide Toggle Kitchen Manager and Guide Toggle Bedroom Manager objects contain the Guide Toggle script with four updated elements. ***Figures 55*** and ***56*** illustrate the kitchen and bedroom guidance buttons. If users press one of the buttons, four guidance categories appear in the center of the screen, as shown in ***Figures 57*** and ***58***. Once users have finished using the guidance scene, they can return to the main scene and interact with the home button, as described in ***Figure 59***.

7. Evaluation

7.1 Evaluation Method

After implementing the prototype, usability tests should be conducted to identify areas for improvement. The purpose of the usability test is to enhance the user experience, identify problems, evaluate efficiency, measure user satisfaction, and verify the design. The usability tests are conducted individually through a specific protocol: 1). Introduction of the purpose of the study 2). Explanation interface 3). Participants are given an assignment using the prototype 4). They do the assignment 5). Grade SUS (System Usability Scale) 6). Interview. Since this prototype is intended for use at home, the tests are conducted in individual homes.

7.1.1 Protocol

At the beginning of the test, participants sign a consent form and receive a brief information letter about the project and the purpose of the test. Then, they are given an explanation of the prototype. Participants can use all interfaces and place objects as they want while using the prototype. After using the prototype, they rate it using the SUS and provide more detailed feedback through an interview.

7.1.2 System Usability Scale

The SUS (System Usability Scale) is a simple survey tool used to evaluate the usability of a product or system [33]. It features ten items rated on a 5-point scale and can be used across software, hardware, mobile apps, websites, and other systems. The form of the SUS can be found in the appendix 1 [35]. To calculate the SUS, the sum of all points of odd-numbered questions subtracts by 5, and the sum of all points of even-numbered questions subtracts the response score from 25 [33]. The two calculated scores add and multiply the sum by 2.5 to obtain the total score, which ranges from 0 to 100 [33]. An average SUS score is 68, with scores above 70% generally indicating good usability [33].

7.1.3 Interview

After using the prototype, participants submit the SUS questionnaire and conduct a semi-structured interview with four questions. This semi-structured interview is conducted to gather more detailed feedback because the SUS has limitations in data collection. Participants are only required to identify their gender and age for verification purposes. Then, they proceed to test the prototype anonymously. If participants are asked questions difficult to answer and do not want to answer, they can skip to the next question. The questions in the semi-structured interviews can be found in ***section 7.2.2***.

7.1.4 Target Group

The primary target users for testing the prototype are stroke patients who use wheelchairs and their families, and this would provide accurate data. However, due to difficulties in recruiting stroke patients, general students are recruited to conduct the test. Therefore, six general students tested the prototype in this project.

7.2 Results

7.2.1 Graphs

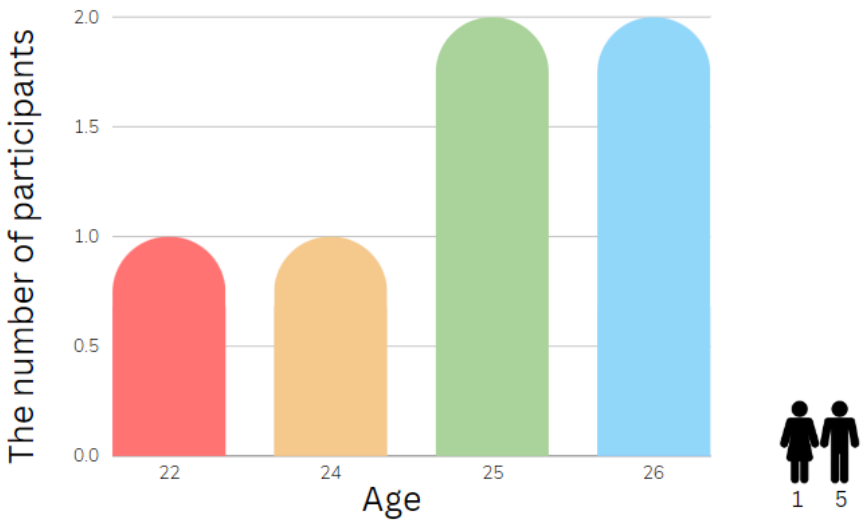

Figure 60. Participants

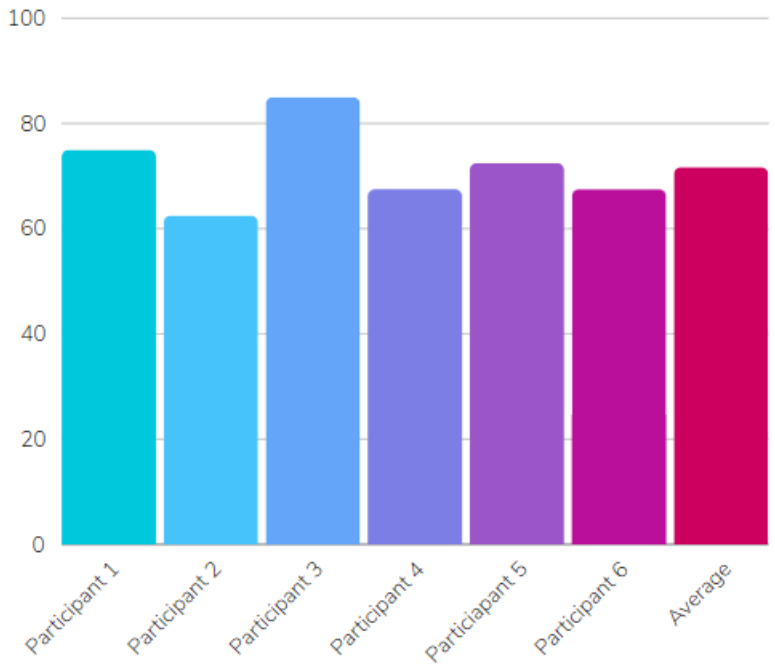

Figure 61. SUS Results

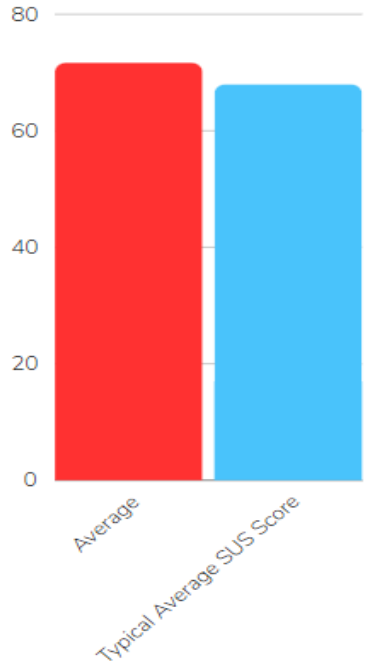

Figure 62. Comparison of the typical average SUS score and the average score of SUS on these tests

Figure 60 shows the demographics of six students who participated in these tests: one female and five males. The participants included one 22-year-old, one 24-year-old, two 25-year-olds, and two 26-year-olds. The SUS results are 75, 62.5, 85, 67.5, 72.5, and 67.5, with an average of 71.7, as shown in ***Figure 61***. As mentioned in **section 7.1.2**, the typical average SUS score is 68. Comparing the typical average SUS score with the average of the usability tests, as shown in ***Figure 62***, the average score from this test is 3.7 points higher, which means that users can interpret that they found the system relatively easy to use and had a satisfactory experience. However, the evaluations identify a lot of improvements through interviews.

7.2.2 Interview Results

All participants were asked the following four questions:

1. What tools are they unnecessarily required?
2. What was the inconsistency in the prototype?
3. What factors like interest or enjoyment contribute to you during the test?
4. What improvements would you like to provide?

The answer to Question Number	Participant 1	Participant 2	Participant 3
1	None	None	I initially didn't understand the icon's meaning when moving to the guide scene.
2	Adjusting the rotation speed is difficult. Button positions in the instruction scene need to be more consistently positioned.	I would like to have various objects in the slider menu, and it would be better if the start button were positioned slightly lower.	I would like to have more objects for medical devices.
3	It was interesting that the prototype detects planes to place objects.	It was impressive that the objects were in their actual size, and they appeared larger when closer and	The objects have the actual size, and it was interesting that the prototype detects planes to place objects.

		smaller when farther away.	
4	I would like to have a button to return to the instruction scene and also a feature for saving data.	The object rotation speed would be slower, and the plane detection would have to be better.	I would like to have a button to return to the instruction scene, and the textures in the scene would be bigger.

The answer to Question Number	Participant 4	Participant 5	Participant 6
1	The information button doesn't have appropriate image sizes and lacks other information, so it has little significance.	I don't think the furniture arrangement tips and efficient guide in the categories are necessary.	It was difficult to perceive the purpose of the object X and the Kitchen's icon.
2	None	I didn't realize the purpose of creating the object X, couldn't quickly perceive if it was a scene transition, and it would be better having more objects available.	None
3	The prototype had good intentions, and it was interesting that I could place objects through the AR app.	It was interesting that I could place objects.	It was impressive that I could place objects and let them move and rotate.
4	The object rotation speed would be slower, and the guidance scene would be implemented more.	It would be better if the objects could be removed one by one. The textures in the guidance scene would be bigger, and the prototype would be good if it had a data file	It would be better to have more medical devices, especially objects that don't have information for general users. When arranging furniture, there is an instruction manual in

		saved.	the information window explaining how to place it, with brief information. After reading this, users create it by pressing the confirm button. I would like to have a button to return to the instruction scene and read it again.

Table 7. Results of the interviews

7.2.3 Conclusion Interview Results

Overall, all participants were proficient in using the prototype from the beginning. It was suggested that if a more diverse range of age groups had been recruited, data from those less familiar with AR app usage could have been collected. All participants answered that they were impressed by the prototype's ability to detect places for object placement and control. During interviews, most participants pointed out issues with button icon recognition and suggested creating a button to return to the instruction scene. Regarding objects, there was a suggestion to add more variety, and some participants commented that object rotation was too fast. In terms of functionality, participants suggested creating a feature to save work data to a file so they could reopen it later for continued work. One of the most notable improvement suggestions was to provide more detailed information in the object information window and add a "create" button within the information window so users could press it to generate objects on the plane.

7.2.4 Discussion Evaluation

The evaluation phase is to collect data and conclude the final result. The test involved using SUS and interviews to assess the prototype. During the tests, an observer who is the designer of the prototype identified that participants did not recognize difficulties with using the prototype. However, the SUS and interviews revealed more detailed errors and areas for improvement. The SUS evaluated the efficiency, satisfaction, and usability of the prototype. However, SUS made it challenging to identify specific areas for improvement, so interviews were conducted to gather more detailed feedback. Moreover, the data was obtained from a

small number of participants, and the tests were not conducted with the exact target group, resulting in less precise data. Nevertheless, significant errors are unlikely since participants tested the prototype from the patients' perspective and evaluated it based on efficiency, satisfaction, and usability. Participants provided valuable feedback on specific areas, such as button placement and interface design. For instance, feedback suggested that the icons were not intuitive and a return button to the instruction scene would enhance usability. Additionally, the object rotation speed was to be slower, and there was a suggestion for a more diverse range of objects.

Reflecting on this test, asking participants about prior experience with AR apps before the interviews could have collected better data. Overall, the usability test is a crucial phase in evaluating the performance and usability of the prototype. Continuous testing and improvements in future phases will help to develop a better prototype.

8. Limitation & Future Work

8.1 Limitation

Limited Target User

The tests were conducted with only six participants, consisting of one female and five males, all within a narrow age range (22-26 years old). The small and homogeneous sample limits the collection of detailed data. The absence of a more diverse participant group, particularly the actual target users such as wheelchair-bound stroke patients, means the data may not accurately reflect the prototype's usability for all intended users.

Limited Scope of Evaluation

The evaluation relied on the SUS and semi-structured interviews. While these methods provided useful feedback, they might not cover all aspects of the prototype's usability. For instance, long-term user engagement and the impact of the prototype on users' daily activities were not assessed. This limited scope might overlook crucial usability issues in practical, long-term use.

UI Design Issues

Several UI design-related issues were identified during the tests. Participants highlighted that the rotation speed of objects was too fast, making it difficult to control. Furthermore, the consistency in button placement within the instruction scene has to be clarified. Some participants initially struggled to understand the meaning of certain icons, such as those used for the transition to the guide scene. These design flaws could hinder the oval user experience and need to be addressed to improve the prototype's usability.

8.2 Future Work

Expanded Participant Diversity

Future studies should aim to include a more diverse participant group, particularly targeting stroke patients who use wheelchairs and other potential users who may have specific accessibility needs.

Comprehensive Usability Assessment

It should consider incorporating methods that assess long-term user engagement and the prototype’s impact on daily activities. This approach would provide a more specific understanding of usability.

UI Design Refinements

It addresses identified UI design issues, such as objects' overly fast rotation speed and button placement inconsistencies. It ensures that icons and guide elements are intuitive and facilitate smooth guidance across different scenes. Testing and refining elements enhance the prototype's user experience and usability. This approach will systematically improve the prototype’s interface, making it more effective in guiding users through various interactions and tasks.

9. Conclusion

The goal of this project is to enable stroke patients to safely arrange medical and household furniture and receive guidance using an AR app. The AR app enables users to pre-arrange various furniture and medical devices in an AR environment, providing guidance to reduce accidents and offering valuable information before actual placement.

Background is conducted to gather insights, which are used during the ideation phase to develop and refine ideas. Lo-fi tests are conducted to identify areas for improvement and detect errors, leading to the development of a hi-fi prototype. Data from lo-fi tests and personas are used in the specification phase to organize and refine ideas. The ideas are collected in the final stage to create the hi-fi prototype.

The evaluation phase includes conducting usability tests to assess the prototype's efficiency, practicality, and user satisfaction with interviews and SUS. Finally, the data collected from these tests are analyzed to describe conclusions.

Appendix 1. SUS Questionnaire

System Usability Scale (SUS) Questionnaire

App Name: AR App for Health Care

Date:

Please rate the following items on a scale from 1 to 5. 1 - Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 - Strongly Agree

1. I think that I would use this app frequently.

   1 2 3 4 5

2. I found the app unnecessarily complex.

   1 2 3 4 5

3. I thought the app was easy to use.

   1 2 3 4 5

4. I think that I would need the support of a technical person to be able to use this app.

   1 2 3 4 5

5. I found the various functions in this app were well integrated.

   1 2 3 4 5

6. I thought there was too much inconsistency in this app.

   1 2 3 4 5

7. I would imagine that most people would learn to use this app very quickly.

   1 2 3 4 5

8. I found the app very cumbersome to use.

1 2 3 4 5

9. I felt very confident using the app.

1 2 3 4 5

10. I needed to learn a lot of things before I could get going with this app.

1 2 3 4 5

Please provide any additional comments:

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