



TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING

**DEVELOPMENT OF MULTI-PLATFORM AVATARS
DT IMMERSIVE VR INTERFACES FOR INDUSTRY
4.0 OPERATOR PERFORMANCE AND WELLBEING
MONITORING AND ASSESSMENT**

MASTER THESIS

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Tallinn 2022

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THESIS TASK

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Thesis topic:

Development of multi-platform avatars DT immersive VR interfaces for industry 4.0 operator performance and wellbeing monitoring and assessment

Thesis main objectives:

1. Investigate how the industry 4.0 represents a great opportunity for workers to become part of the intelligent system
2. Acquire information regarding to the virtual prototypes in the market like this project.
3. Implementation and improvement of game UI design in Unity
4. Develop the back-end part of the video game by elaborating a user registration system and online player information.
5. Integrate different interactions to the Avatars in the Multiplayer Platform with Meta SDQ
6. Research, select and adapt the necessary data storage techniques adapted to unity to perform a KPI analysis Detection of parameters and evaluation of KPI´s related to the user: Evaluation of well-being, efficiency, and safety
7. Conclusions, together with the proposal of new lines of research.

Thesis tasks and time schedule:

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1.	Learning to use the Unity environment and its different functionalities and Meta SDK Environments	31/03/2022
2.	Unity Implementation	1/05/2022
2.1	Improvement of User Interface	7/04/2022
2.2	Creation of registration System	17/04/2022
2.3	Development of avatar interactions	10/05/2022
2.3.1	Create a multiplayer system	1/05/2022
2.3.2	Create a functional Chat	1/05/2022
2.3.3	Create a system that evaluates the KPIs	15/05/2022
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ABSTRACT:

As part of the MARM curriculum subject of digitalization, the world of virtual reality (VR) together with the powerful world of video games and the future potentials that these offers were discovered. Besides, I was able to cooperate in one of the IVAR Laboratory projects led by Vladimir Kuts. For the opportunity given to me to collaborate in the TalTech Metaverse project, I am very grateful for all that they have supported me and for all that I have learned.

This project aims to implement an at educational gamification application in the Unity development environment. The Metaverse in the video game has been implemented with an educational approach for a possible future output to a virtual world of the TalTech University. Its development was done following the agile methodology. The thesis covers the development process from the conception of the implementation of avatar interactions and User Interface (UI) to the completion of a KPIs (Key Performance Indicators) analysis of the Metaverse. The project has been realized within the framework of the future digitization of the university.

The project, titled Metaverse of TalTech, is a multiplayer educational video game for all students, professors and staff of the university and can be accessed via VR glasses or desktop computer. It is a prototype of a multiplayer game that has a registration system that had been created through the PlayFab server. The registration system has an easy and user-friendly registration process for including the registration of new users, password change, password forgotten recovery. It also has a system for creating or joining rooms. On the other hand. Furthermore, when a new user creates an avatar through the registration system, its characteristics of the avatar are automatically saved for future login and thus saving crucial activity data from the past interactions. And finally, the application allows users can communicate with each through a chat API (Application Programming Interface) system using the ViVox software to offer a more realistic and real-time feel of interactions.

Keywords: Gamification, Unity, Metaverse, API, KPIs.

LIST OF ABBREVIATIONS AND SYMBOLS

API: Application Programming Interface.

AR: Augmented Reality

AWS: Amazon Web Services

CCU: Concurrent Users

DT: Digital Twin(s)

IDE: An integrated development environment.

IM: Instant Messaging.

IoT: Internet of things.

KETs: Key Enabling Technologies.

KPIs: Key Performance Indicator.

MR: Mixed Reality.

PUN: Photon Unity Networking.

RPC: Research, Protect and Contain.

UCC: Unified Communications and Collaboration.

UI: User Interface.

UML: Unified Modeling Language

VR: Virtual Reality

1 INTRODUCTION

1.1 Background

Nowadays, the fourth industrial revolution is a reality all over the planet. The physical world is growing alongside the virtual one. Concepts such as the Internet of Things (IoT), a term that first appeared as far back as 1999, can now be found not only in industry, but in a large number of applications, connecting everyday objects with the Internet, and contributing to the interaction between virtual and real domain.

Internet of things and services enable cyber physical systems in making this connection possible and allow an increasing number of industries to improve their production efficiency handling, and error prevention. This is what is known today as "Smart manufacturing". (González et al., 2021)

Following through this line of continuous evolution and development of all these technologies, the VR connects this physical space with the virtual one, which is one of the keys to Industry 4.0. (González et al., 2021)

Industry 4.0 is a revolution that focuses on adoption of new intelligent technologies that are integrated into organizations, people and assets, for the progressive automation of the production process. These include additive manufacturing, collaborative robotics, production planning tools, artificial vision, VR, gamification, process simulation, operational intelligence, IoT and the so-called KETs (Key Enabling Technologies). (Francisco and Fandiño, 2019)

This paradigm is continuously evolving towards the integration of a human perspective in the modern productions systems digital tools. This is known as Industry 5.0. (Taiz et al., 2015)

The growth of XR in recent years, together with the growth of Industry 4.0, has led to its incorporation into our daily lives. VR, Augmented Reality (AR) and Mixed Reality (MR) can be very useful and have great potential in the educative environment, since in education children learn by playing and experimenting. (Castro Hernández and González, 2021)

Immersive XR experiences, for instance, are becoming increasingly popular in education as advanced UI design continues to emerge. In contrast to conventional 2D desktop GUIs, 3D environments, along with new forms of interaction, are opening possibilities while exposing new design considerations. Forward-looking perceptual technologies, such as head-, eye- and hand-tracking devices, are available for this purpose. To deliver this functionality effectively, however, these technologies must be robust, accurate and energy-efficient.

As part of the continuous evolution and development of all these technologies, one of the tools to connect the physical space with the virtual one, which is one of the keys to Industry 4.0, is the digital twin (DT). (González et al., 2021) By integrating the physical space and the virtual space, through the adoption of advanced IoT solutions, a DT can obtain a large amount of data that can be processed through advanced analytics. These results can then be used to improve product or process development in the physical space (figure 1). (Qi and Tao, 2018).

This master's thesis is based on the development of an educational multiplayer VR game called Metaverse TalTech. In work proposes the implementation of an advanced the UI has been implemented, including humanoid avatars and interactions in a multiplayer platform. Most importantly the applications allow for the collection and analysis of the KPIs of the Metaverse TalTech focusing on the paradigm of the industry 5.0 and human in the DT loop. This work unites video games in VR with the design of advanced interfaces focused on visualization and communication and shows all the potential that XR can have in the future in education and industry.

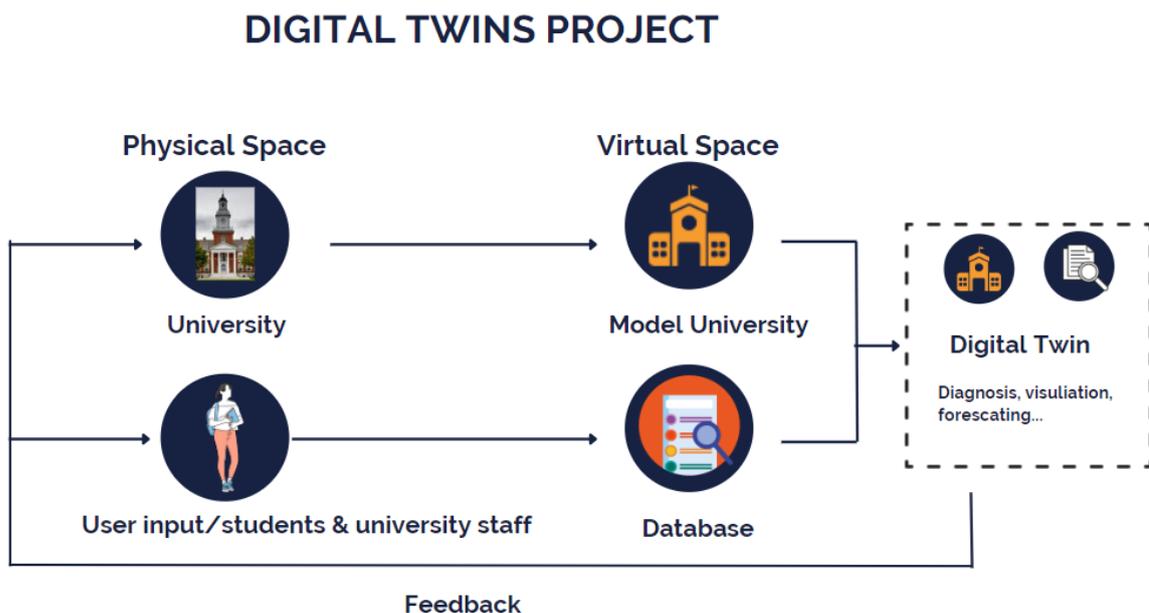


Figure 1: Model of a DT adaptation proposed of the project

1.2 Market Research

An extensive market research has been conducted in order to understand what types of applications, having similar characteristics, are already available and what are the gaps that we can fill with this work.

In 2003 Second Life was recognized as the most powerful and forward-looking virtual world. It reached 1 million users. This game had all the features that a virtual world should have avatars, communication tools, ways to sculpt the environment and even its own currency convertible to dollars. (Rosedale, 2022)

The trouble that many users faced was the emptiness of the experience as they found no motivation within the world and no repercussions in the physical world. This made the virtual world of this game focus more and more on primitive and "empty" instincts such as consumerism. (Grandury González, Jara Vera and Sánchez Ávila, 2022).

Decentraland is a virtual world in development in 2015. This application grants users full ownership of their creations and acquisitions. This idea motivates the user to actively participate in the community and create content as it is solely theirs and can be transferable and exchanged for money in the physical world. This innovative concept of virtual ownership is only possible through the use of Blockchain technology, which was implemented in the most advanced virtual world projects since its emergence. (Esteban Ordano, 2019)

AWS (Amazon Web Services) Cloud Quest is it a videogame created by Amazon that allows players go through a virtual city in which they have to solve technological problems using the cloud. It is an educational and sales tool to teach people how to use its cloud services and boost its Amazon Web Services (AWS) platform, the most widely used globally in its sector. (Amazon Web Services, Inc., 2022)

In addition to this, in October 2021, Facebook Inc, performed a rebranding that would be able to represent the entire range of activities of the company. The company name was therefore changed into "Metaverse": a virtual world in which people from all over the world will be able to meet to carry out different activities, such as shopping, working and playing. This Metaverse will be more than VR and its market value will be superior to the technologies known to date. (Lenis, 2022)

VRChat is a free multiplayer VR video game, in which the player can create his character and interact with other players each others virtual world. This game is compatible with HTC Vive, Oculus Rift and Windows Mixed Reality VR glasses. Players can easily create their own worlds in which they can interact with each other through virtual avatars. It

enables players the ability to create or import 3D models of characters from various franchises and adopt them as their personal avatars. (VRChat, 2022)

The SandBox is a play-to-earn game that combines blockchain, DeFi and NFT technology in a 3D world. The players can create and customize their games, avatars and other digital assets here through the free design tools offered by the platform. Virtual assets can be monetized as NFT and sold for SAND tokens on The Sandbox marketplace. (Planeta NFT, 2022)

Finally, AltspaceVR is a game implemented as a collaborative partnership with different companies such as Samsung and HTC. It is a social platform allowing people to interact with each other within the framework of VR. Within this virtual space, attendees can play interactive games and attend free live events in VR.

Market Research	Multiplayer	VR	Interaction with avatars	Educational	Year founded	Users
Second Life	✓	✗	✓	✗	2003	1.000.000
Decentraland	✓	✗	✓	✗	2015	800.000
AWS Cloud Quest	✓	✗	✓	✓	2022	recently launched
Metaverse of Facebook	✓	✓	✓	✗	2022	recently launched
VR Chat	✓	✓	✓	✗	2017	1,2 M
The SandBox	✓	✓	✓	✗	2012	2 M
AltspaceVR	✓	✓	✓	✗	2015	5000
Metaverse TalTech	✓	✓	✓	✓	-	-

Figure 2: Market Research of the project

In the figure 2, the previously explained applications and their main functionalities are summarized. The TalTech metaverse contains all these features in addition to the simulation of human presence in the industry, and the few gap-as illustrated in this figure are what shall be covered in this master's thesis.

1.3 Objectives

One of the objectives is to provide a global vision of the XR focusing on video games in the field of education, VR and DT. The purpose is to analyze the future of these fields in relation to Industry 4.0 and the paradigm of industry 5.0 together with the advanced design of interfaces and interaction methods.

The objective of this project is to realize a functional prototype of a VR video game in the field of education coupled with an advanced interface design. In addition, to accomplish a unique point of view in linking video games with VR to cover the gap in which humans collaborate with machines.

To do so we include in the gamification environment some advanced methods to track user presence and evaluate KPIs focusing on user interaction and well-being.

2 TECHNOLOGY USED. HARDWARE & SOFTWARE

This section provides information about the most important tools that have been used in this project.

Unity has been used for the implementation of the main technical part in the project. Additionally, a series of different packages and software has been integrated to create different components included in this work. To build the chat-box, Vivox Unity integration was used. Photon Unity Networking (PUN) was selected to create the room system, and PlayFab SDK was used for the registration system and the saving of different characteristics of the avatars the author used. Besides, the said design programs, the design of interfaces tools such as Photoshop were used, essentially in creating buttons and their animations. The required hardware equipment is shown in Figure 3. In the next paragraphs the programs and tools used in the project are explained in more detail.

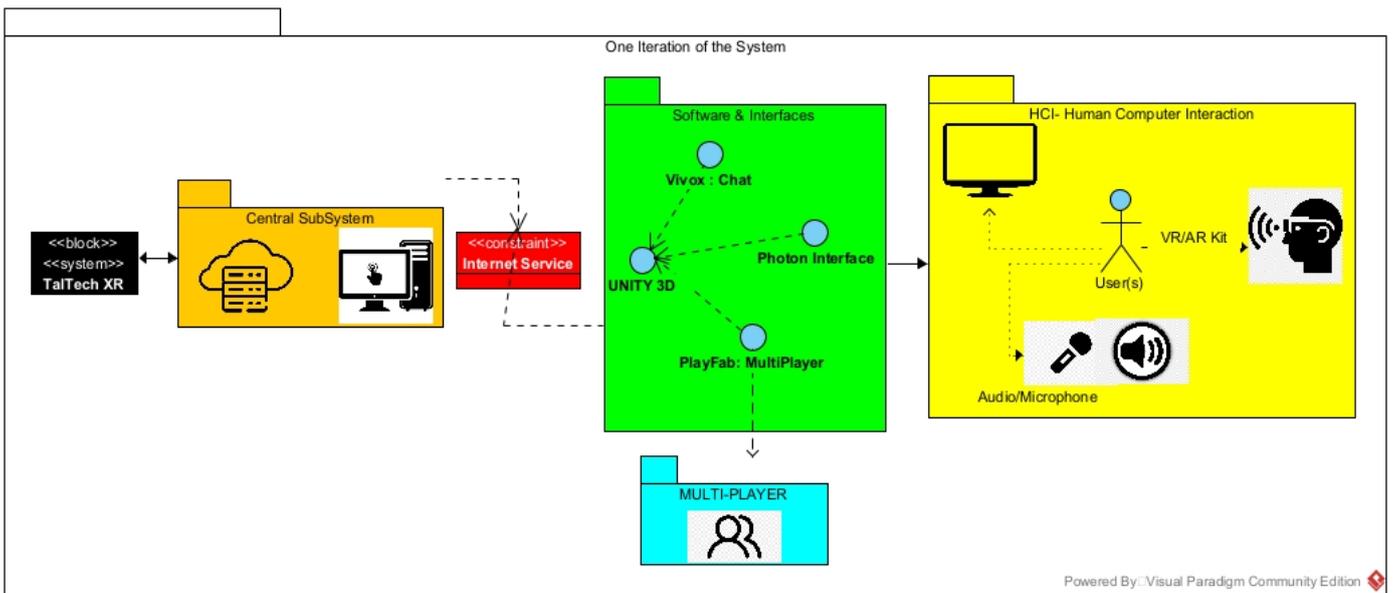


Figure 3: Hardware and software development tools

2.1 Software Tools

As already mentioned, Unity Engine was used to implement the entire project and integrate other SDKs. Unity is a multiplatform graphics engine created by Unity Technologies with the goal of allowing anyone to create attractive 3D environments. This software is free for students and can be used on Microsoft Windows, OS X, and Linux operative systems allowing the development of applications aimed at Windows,

OS X, Linux, Xbox 360, PlayStation 3, PlayStation Vita, Wii, Wii U, iOS, Android, and Windows Phone. (Guamán Cocha, 2016)

Nowadays, videogame development technology is seeing the highest growth rate, especially 2D game development has been made much easier. More than 500 million people are currently playing games developed using Unity 3D. In fact, Unity 3D is used to create the majority of the best 3D games for Android and iOS such as Pokemon Go, Inside and Crossy Road. (Arroyo et al., 2017)

Unity 3D is currently quite popular among game developers, and it is well ahead of the other similar mobile game development technologies. Unity is also a software making immense headway in usage in VR applications. (Arroyo et al., 2017)

One of the biggest advantages of this software is that it allows to develop games for many platforms. Through the compatibility of this software, it has been feasible to implement in this project a functional chat prototype with Vivox and a registration system with PlayFab. Unity package manager allows users to download different packages that can then be imported into their project. A single package can contain different functionalities and resources (e.g. scripts, audios, animations), providing features that can be necessary in the project. The packages provide new functionalities to be able to work with new platforms such as PlayFab, Vivox or Photon.

Unity uses Direct3D (on Windows), OpenGL (on Mac and Linux), OpenGL ES (on Android and iOS), and proprietary interfaces (Wii). It has support for bump mapping, reflection mapping, parallax mapping, space screen ambient occlusion (SSAO), dynamic shadows using shadow maps, render-to-texture, and full-screen post-processing effects.

(Guamán Cocha, 2016)

Unity VR is a unity 3D VR module and adds the ability to target VR devices directly from Unity without the need for external plugins. It provides a base API and feature set with the goal of future compatibility for devices and software. (Unity Technologies, 2016)

Oculus Quest headset has been used in this work. The application can be experienced in first person making use of immersive visualization hardware (Oculus headset) or as a third person through a desktop-based application.

The user can play anywhere with just a VR headset and controllers. (www.oculus.com, 2022).

In addition to this, Meta Avatars SDK has also been utilized in this project to provide user-created Meta Avatars to drive social presence and immersion in VR. The avatars' realistic postures can be inferred from the Oculus headset and Touch controllers through powerful body tracking, giving users a sense of themselves in a virtual world.

(www.oculus.com, 2022) Thanks to these packages installed from the Unity Asset Store it has been possible to implement this project and make a multiplayer game in VR.

The Visual Studio development environment has been used for creating code for this project. This tool facilitates the development since it uses intelligence to autocomplete the code and obtain documentation.

Adobe Photoshop, developed by Adobe Systems Incorporated, is a tool for editing and retouching images and graphics. It has been decided to use Photoshop as an editor for each of the sprites used within the game, such as the design of the chat bubbles and the male and female buttons within the 2D game. (Adobe, 2019) (Ferrer, 2020) This tool has been employed to develop certain designs that have been subsequently integrated into the project such as different buttons and visual assets that will later be implemented in the chat.

Azure PlayFab, owned by Microsoft, is a back-end platform that allows to work with online functionalities in video games. PlayFab offers multiplayer, matchmaking, data management, real-time analytics, leaderboards and statistics, online communities, and chat service statistics among other functionalities. (Ferrer, 2020)

Microsoft Azure Playfab platform was chosen for the scope of this project as it offers a limited but sufficient duration of free service that meets the needs arising during development, facilitating the implementation of online features such as registration and login of accounts in the cloud as well as storage and management of internal data of the game. Likewise, it allows the use of its dedicated servers up to a maximum of 750 operating hours. (<https://playfab.com/>, 2022)

As for this project, it has been used to store user registration information (email, password, username) and the characteristics of the avatars chosen by the players.

Vivox was used to realize the chat functionalities. Its main function is to take advantage of an is to provide an easy-to-implement voice and text chat service to create immersive multiplayer experiences and boost both player engagement and retention rates.

Vivox is highly reliable, scalable and vastly optimized, allowing more resources to be allocated to other game features. It has been used in leading multiplayer game titles such as VALORANT, PUBG, League of Legends and Rainbow Six Siege which are leaders in the gaming industry. (Unity, 2019)

Photon has been used for the realization of the project to make a multiplayer game implementing the multiplayer functionality in this project. These servers have an application called Photon Server installed. Photon PUN is free up to 20 Concurrent Users

(CCU), and if you exceed the limit, new users will not be able to connect. and a limit of 500 messages per Room (game) However, this limit can be bypassed by using the paid version of PUN, which it is scalable can be scaled to support more users. (www.photonengine.com, 2022)

PUN (Photon Unity Networking) is a framework that has scripts that make it easy to program multiplayer video games. It is a Unity package for multiplayer games. It provides authentication options, matchmaking, and fast reliable in-game communication through Exit Games Photon backend.

Finally, Visual Paradigm has been employed to create activity, hardware, and software diagrams. Visual Paradigm is a UML CASE tool that supports UML 2, SysML and Object Management Group business process modeling notation. In addition to modeling support, it provides reporting and code engineering capabilities. (Visual-paradigm.com, 2019).

2.2 Hardware Tools

The hardware components necessary for the development of the project include a personal computer, a screen or auxiliary monitor, internet connection, keyboard, mouse and equipment to run the VR game including the set of Oculus Meta Quest 2.

The minimum requirements for VR game development for the computer hardware are:

- GPU: Nvidia RTX 3070
- CPU: Ryzen 5800x or Intel i9 9900.
- RAM: 16 GB

3 GAME ENGINE IMPLEMENTATION

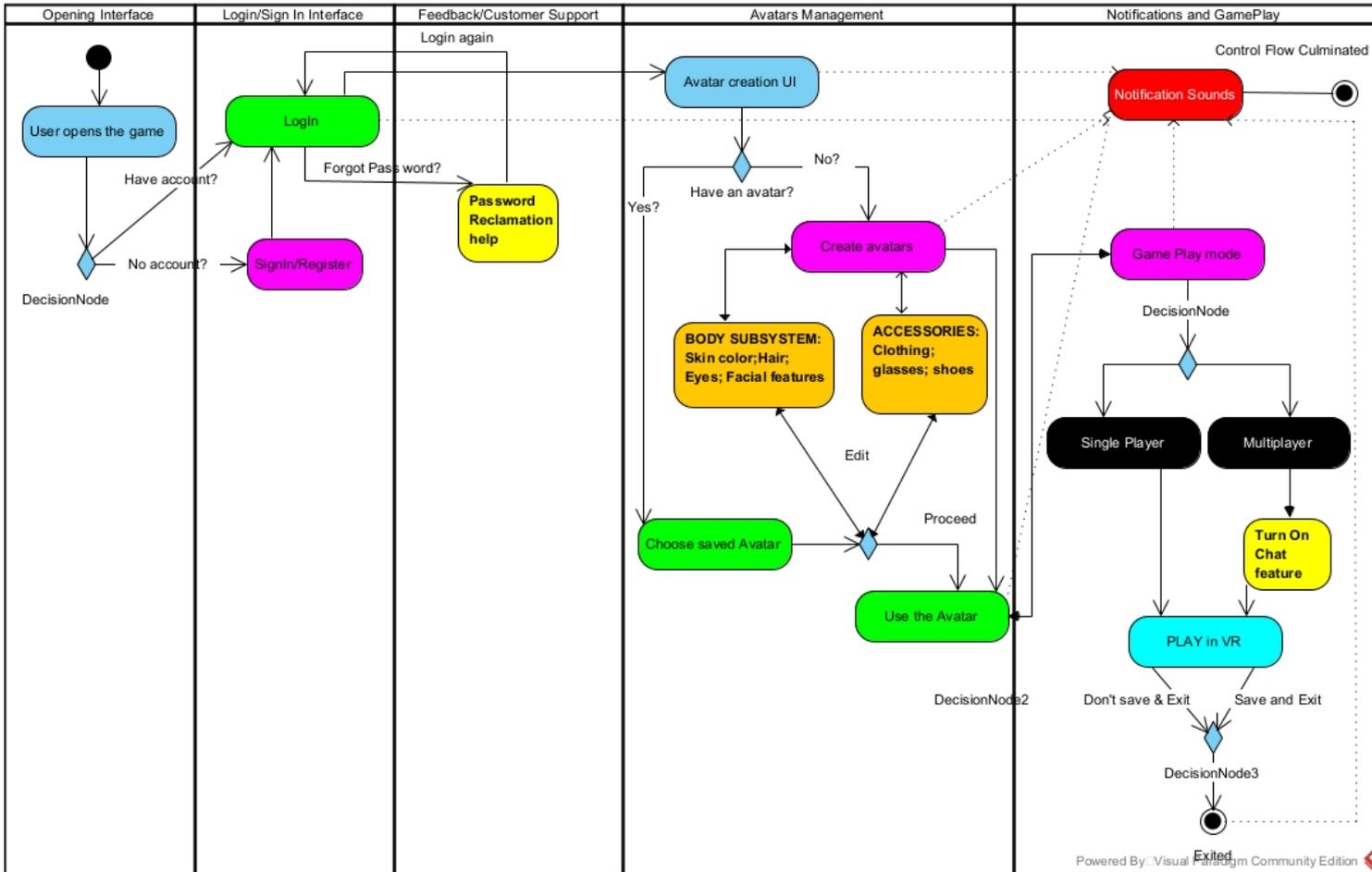


Figure 4: Activity diagram of the project

The TalTech metaverse project has been undertaken using the Unity tool as described in the section 3. The project is composed of four parts:

- The user registration system developed using PlayFab
- -The UI design improvement
- -The development of avatar interactions in which a multiplayer system has been created and a chat where players can communicate the development of avatar interactions
- These interactions included a multiplayer system developed by Photon and a chat development using Vivox

In the figure 4 there is an activity diagram explaining the logic of the project that has been conducted. First, the user registers, then logs in and, in case he/she does not remember the password, he/she uses the "Forgot password" button. Afterwards, the

user customizes his or her avatar, then proceeds to choose to create a room or join a room through the multiplayer system that was implemented. Finally, the creator of the room allows him or her to play and eventually proceeds to start the game.

The system is composed of different panels that are divided into the registration system and the multiplayer system. Thus, for the design of the different panels, to ensure a uniform design in harmony with the colors of the university, different matching colors of the university have been used for all panels, including the logo of Tallinn University of Technology. Besides, the semi-transparent floating panel where the different avatar designs appear was integrated and it had been used as a base for the registration panels and multiplayer panels (Figure 5).

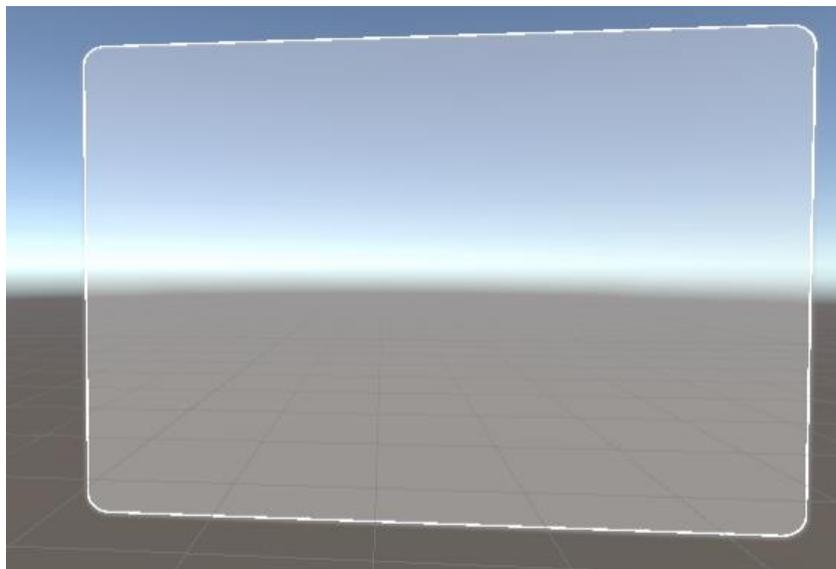


Figure 5: Semitransparent Panel of the Registration System

All project panel buttons generate a sound message on the user click on the interface buttons. Consequently, the user will have a complete experience and will easily know that they have successfully completed the action of clicking on the button (figure 6).

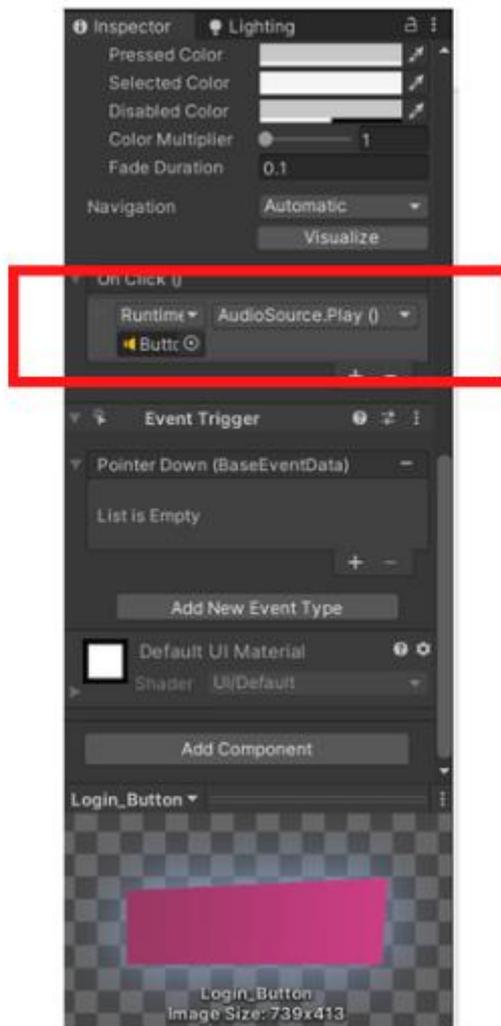


Figure 6: Sound Effect Added to the LogIn Button

In addition to this, an animation was added to the registration panels and the multiplatform panel to enhance communication with the user and improve user experience. A quick view of the laboratory was included to let users know that they are about to enter the specific scenario (figure 7). This view is animated and turns 360 degrees to show the environments and contained features.

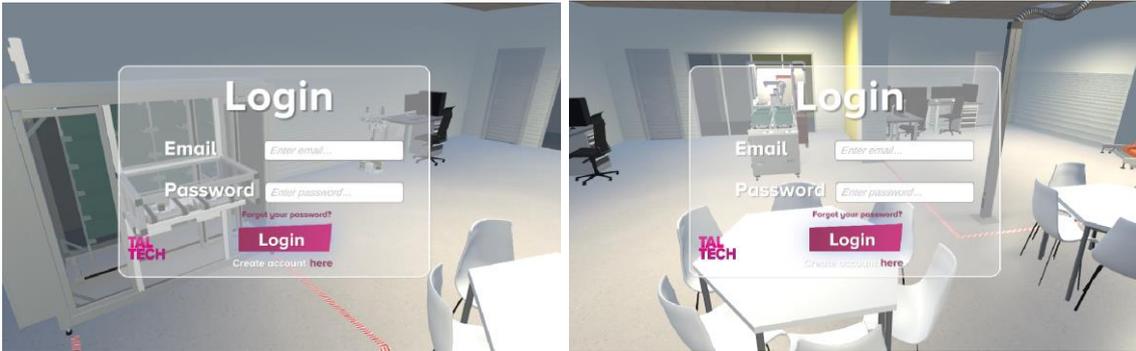


Figure 7: Vision of the laboratory in the LogIn Panel

3.1 Registration System

To create and design the registration system inspiration was sought from other registration systems previously realized in professional software such as Microsoft Outlook (figure 8).

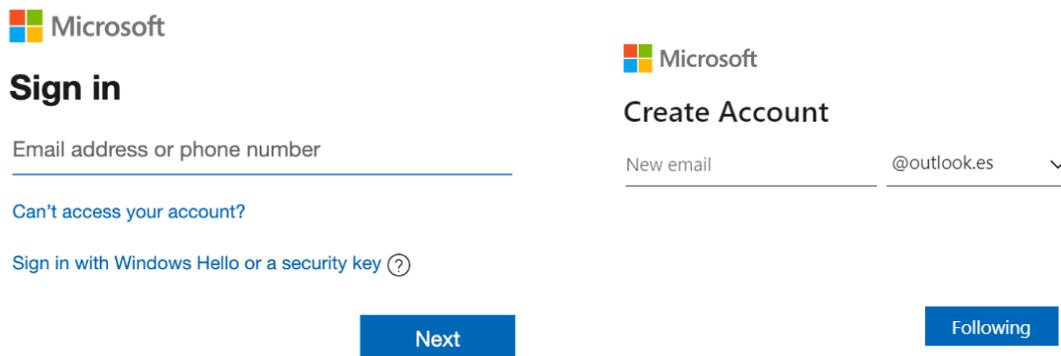


Figure 8: Registration System of Microsoft Outlook (www.microsoft.com, 2022)

The proposed registration system is divided into 3 parts:

- **LogIn Panel:** this allows the user to enter the game with his username and password (figure 9).
- **Registration Panel:** this panel allows the user to register with his username, email, and password (figure 10).

- **Password Recovery Panel:** if the user forgets his password, there is an option to create a new one provided by this panel (figure 11).

Additionally, if the user enters his credentials incorrectly, an error message will be displayed in the game (figure 12).

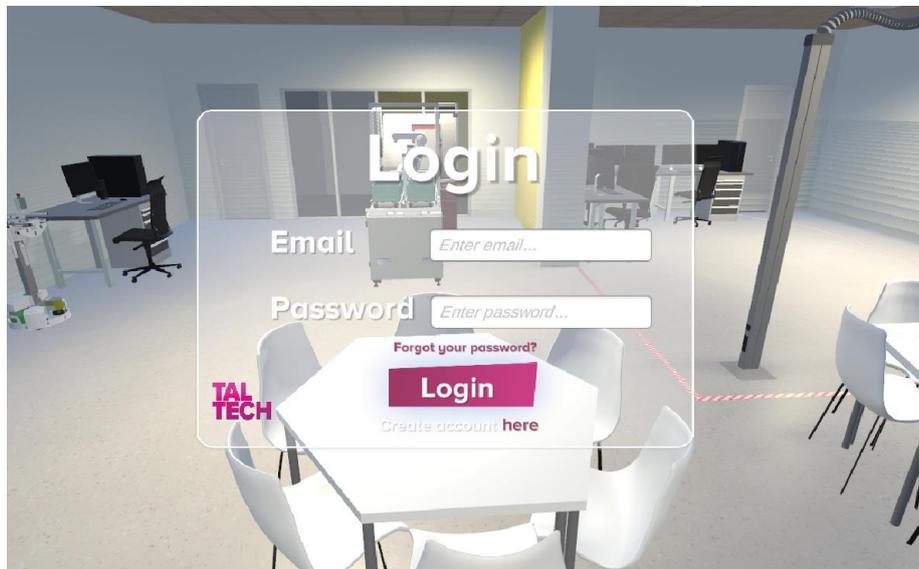


Figure 9: LogIn panel

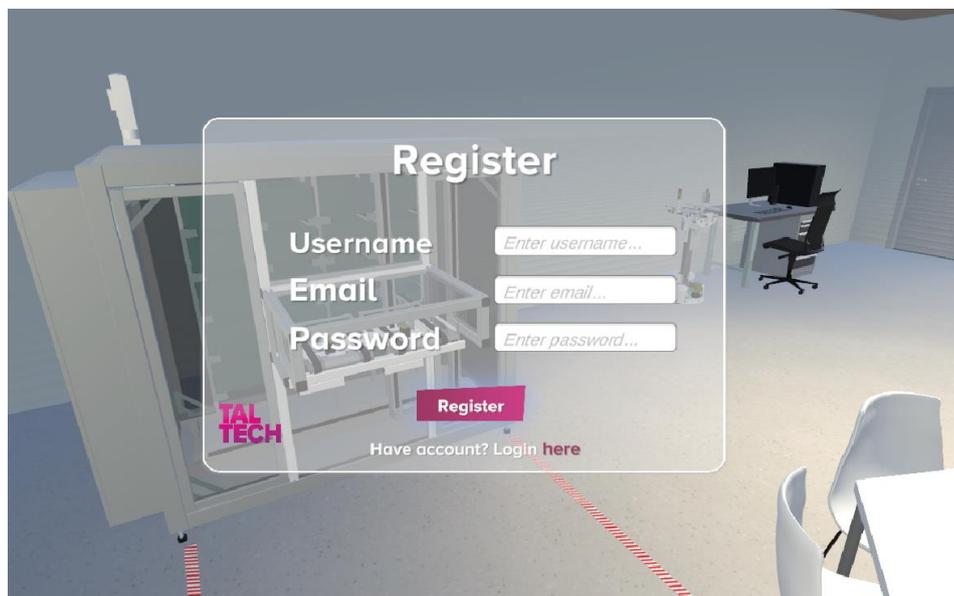


Figure 10: Registration Panel

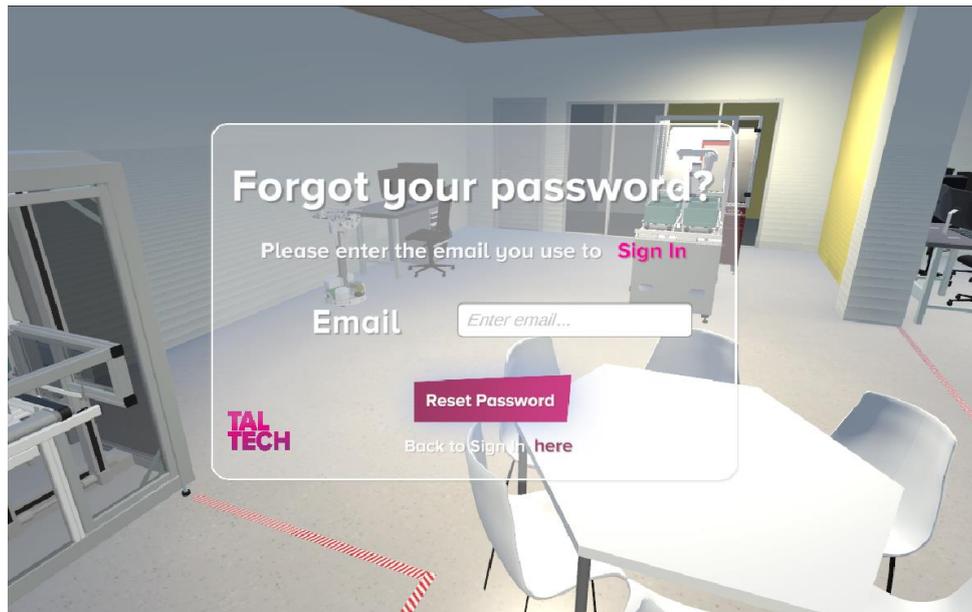


Figure 11: Password Recovery Panel

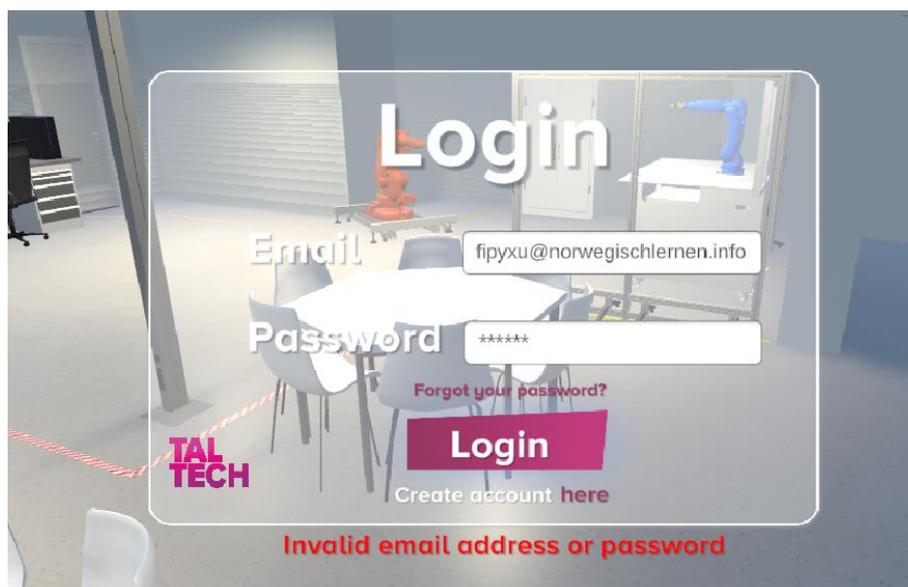


Figure 12: Error message in the player LogIn Panel

3.1.1 LogIn Panel

The registration system was created in the form of a login panel. For the user to access the game and log in, they will have to enter their email and the corresponding password of their choice and click on the LogIn button.

To avoid having similar usernames, it was decided to choose to register and log in with a unique email address and password. The LogIn panel is divided into 6 elements (figure 13):



Figure 13: Elements of the LogIn Panel.

1. Panel Title

2. Email and Password:

- **Email:** By clicking on the enter email text, users are able to insert their email address.
- **Password:** The password is encrypted automatically by PlayFab to maintain the visual privacy of the users.

3. Forgot your password button: The "Forgot your password?" text links the user to the dedicated panel allowing password renewal.

4. LogIn button: When users have inserted their credentials, they can proceed by clicking on the LogIn button. This leads them to the Interface panel where they can customize their avatar.

5. Create Account button: By clicking on the button "Here" the user can create a new account and register in the system.

6. Taltech Logo.

3.1.2 Registration Panel

After creating the LogIn panel, the following task consisted in implementing the registration panel. This allows the users to register to the system with their username, email and password.

There are 7 elements in the LogIn panel (figure 14):

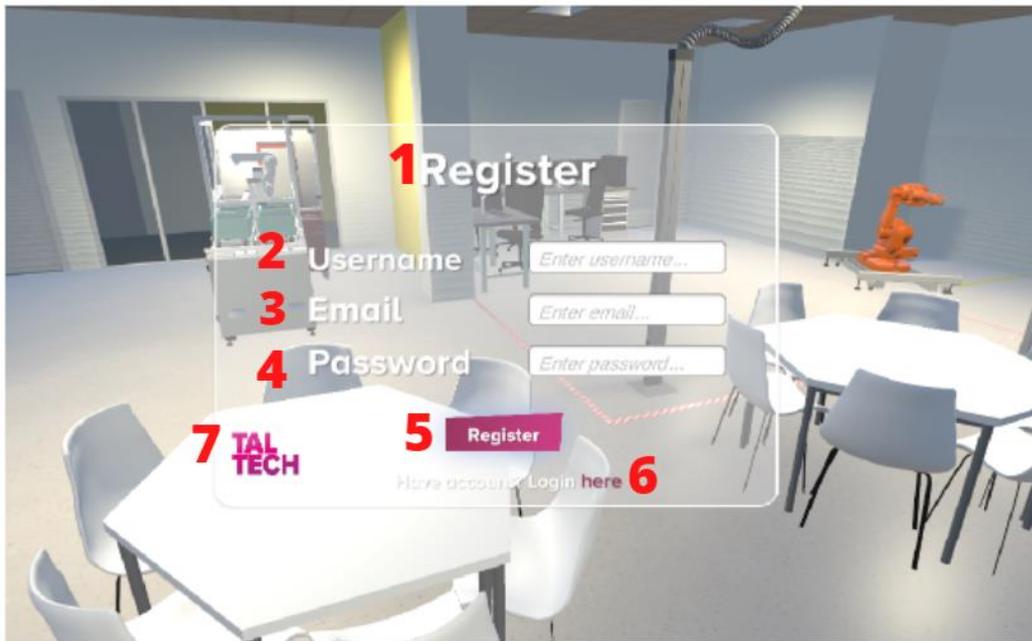


Figure 14: Elements of the Registration Panel

- 1. Panel Title**
- 2. Username**
- 3. Email**
- 4. Password:** The password will be encrypted.
- 5. Register Button:** The user when it is finished registering clicks and registers.
- 6. Have account? Login here button:** The user can click the here button to return to the LogIn panel.
- 7. TalTech logo.**

3.1.3 Forgot Password Panel

While observing other registration systems that had a recovery panel, it was noticed that these systems had a password recovery panel. So, one was created in the project.

The forgot your password panel consists of 7 elements (figure 15).

1. Panel Title

2. Please enter the email text

3. Email: The user is required to enter his email in order to retrieve his password.

4. Reset Password button: The Reset Password button is used to reset the password.

5. Back to SigIn and here button: The here button to return to the SignIn panel.

6. TalTech Logo

The forgot your password panel primary function is to send an email to the user in order to recover the user's account and create a new password. In the figure 16 it shows an example of a password recovery email.

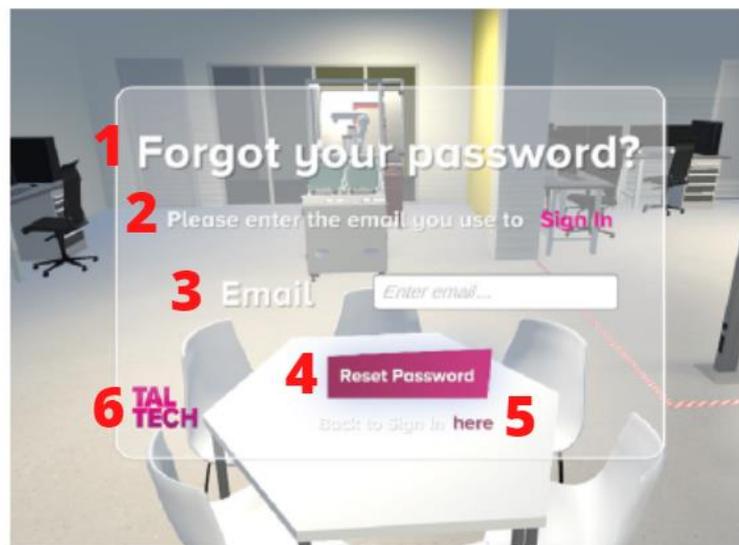


Figure 15: Main Elements of the Password Recovery Panel

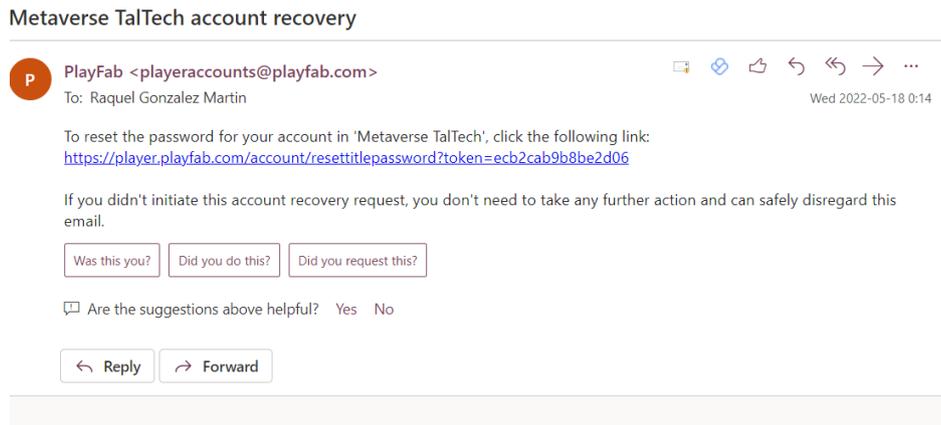


Figure 16: Forgot Password Email Example

3.1.4 Development of the Back-End with Azure PlayFab

The back-end has been implemented in the cloud through Azure PlayFab. The back-end represents the persistence layer and is where the user data is stored to maintain consistency between different uses of the application. This is especially important for the metaverse because if it did not exist, the game would become repetitive, and players would get tired of it. (Ferrer, 2020)

In the case of the registration system, the Azure PlayFab server has also been used to store the login data of the users. The PlayFab manager saves an instance of login data when the user is logged in (figure 17).

My Game Studio | Upgrade account | RA

Metaverse TalTech | Players | Segments | Shared Group Data

Development 3 / 100K

Players | 3 total players | New player | Search Tips

Query: Most recent logins | Search players | Clear | Search

ID	Last login	Created	Country	VTD
6E614862E72220B fipyxu	May 14, 2022 5:50 PM	51 days ago	Estonia	\$0.00
64C5659CABD4A8A3 requxiwa	May 13, 2022 12:29 PM	52 days ago	Estonia	\$0.00
ADBC8DBB99E7E5F9 mokelo5863	Mar 25, 2022 11:43 AM	52 days ago	Estonia	\$0.00

Figure 17: Players Login Data PlayFab Register System Metaverse TalTech

It is possible to view the PlayFab application and investigate the login information of the players. The PlayFab manager provides the access to the PlayFab website. On the PlayFab website, the login credentials are required to access and manage the users and data stored in the application.

The players' IDs can be seen together with their usernames, their last logins, and the country from which they have logged in. This information can be extracted and used in the future and be used for statistics analysis on the use of the application. Figure 18 shows all Logins of all players in the last 30 days including date, platform, IP address, city and country.

50 logins in the last 30 days

Date	Platform	Source	IP address	City	Country
5/16/2022 5:49 PM	PlayFab	PlayFab	46.131.38.215	Tallinn	EE
5/13/2022 12:29 PM	PlayFab	PlayFab	46.131.38.215	Tallinn	EE
5/8/2022 9:42 AM	PlayFab	PlayFab	84.78.242.180	Madrid	ES
5/8/2022 9:35 AM	PlayFab	PlayFab	84.78.242.180	Madrid	ES
5/2/2022 4:35 PM	PlayFab	PlayFab	46.25.187.205	Madrid	ES
4/29/2022 9:37 AM	PlayFab	PlayFab	95.61.205.93	Madrid	ES
4/28/2022 5:06 PM	PlayFab	PlayFab	90.167.203.101	Madrid	ES
4/28/2022 5:03 PM	PlayFab	PlayFab	90.167.203.101	Madrid	ES
4/28/2022 4:59 PM	PlayFab	PlayFab	90.167.203.101	Madrid	ES
4/28/2022 4:41 PM	PlayFab	PlayFab	90.167.202.252	Madrid	ES
4/28/2022 4:36 PM	PlayFab	PlayFab	90.167.202.252	Madrid	ES
4/28/2022 4:31 PM	PlayFab	PlayFab	90.167.202.252	Madrid	ES

Figure 18: Logs in the last 30 days PlayFab Metaverse TalTech

Moreover, each user can save the characteristics of their avatars, both male and female (figure 19). As a result, when the user accesses the login screen, it will be registered and all the features of the user's avatar will be saved, too. Thank to this the users of the video game have a satisfactory experience (see appendices 1,2,3,4).

PLAYER DATA

Remove Tail display

<input type="checkbox"/>	Key	Value	Permissions
<input type="checkbox"/>	FemaleCharacter	{"hair":0,"shirt":-1,"pants":-1,"shoes":-1,"beard":-1,"eyesColor":{"r":0.16} JSON	Private
<input type="checkbox"/>	Hi	Welcome to the Metaverse	Public
<input type="checkbox"/>	MaleCharacter	{"hair":13,"shirt":11,"pants":6,"shoes":2,"beard":5,"eyesColor":{"r":0.22} JSON	Private
<input type="checkbox"/>			Public

READ ONLY DATA

Figure 19: Player avatar data stored in PlayFab

3.2 Improvement of User Interface

Before Metaverse integration, an analysis of the existing interface and functions was conducted. One of the limitations of the original UI was usability, intuitiveness of the functions and lack of feedback. When the user interacted to the interface elements, the elements did not react or provide any visual or audio feedback. For example, if you selected one of the avatar's hair types, you could not see the differences between hair types or facial features. It was decided to make an investigation of how an interface was developed, what the basic principles of a UI, the differences between a basic interface and a more complex one.

The interface (figure 20) is divided into 5 clear elements that will be explained below:

- 1. Side Menu:** The customizable avatar design features bars can be seen here: There are 7 features: skin color, eyes color, hair, beard, shirt, pants and shoes.
- 2. Central Menu:** It is a semitransparent panel with the subcategories of the features eligible for the customizable avatar design: It has two buttons reset and play.
- 3. Welcome text:** "Welcome to the metaverse + username. Now it's time to create your avatar!"
- 4. Switchable male or female avatar button.**
- 5. View of the avatar.** The user can choose the corresponding avatar characteristics according to the user's preferences.

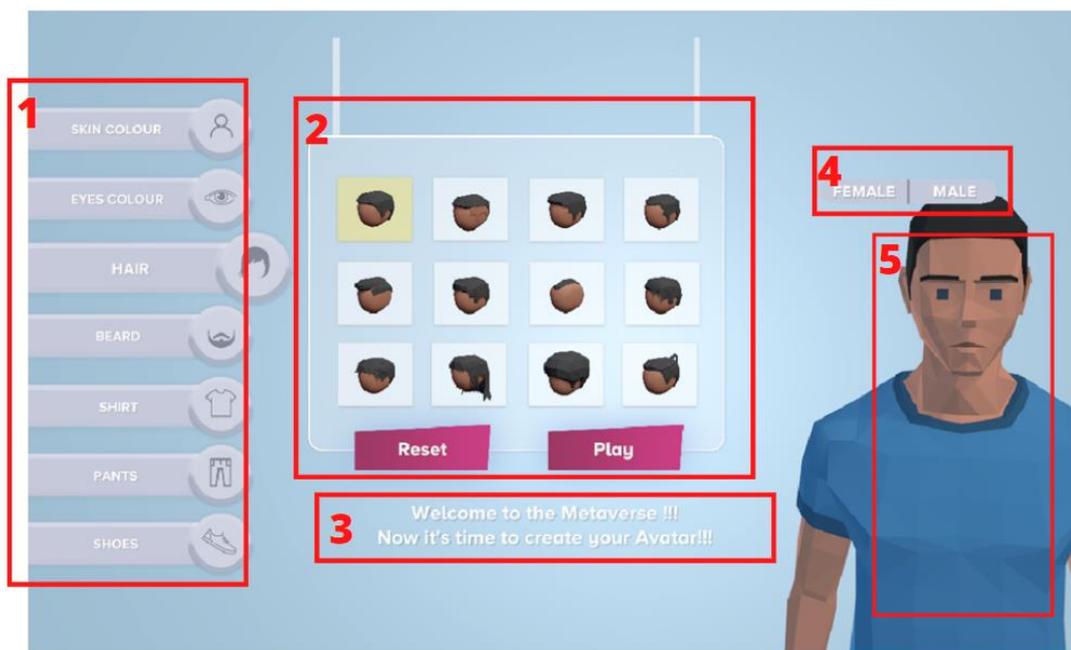


Figure 20: Main elements of the UI

Several improvements were made to the UI and presented in the following sections.

3.2.1 Selection Of Subcategories

At the time of selecting one of the subcategories such as hair types, the user did not know if he had made that selection or not.

The first thing that was implemented was a menu controller that would mark the selected modifier. For this reason, when the player selects a type of hair, that element changes the background to yellow and changes the scale to give a better visual cue. In addition to this, when clicked on the subcategory, an animation is produced in which the hair type becomes bigger/enhanced to provide easier visualization (figure 21).



Figure 21: Hair type selected on the left and on the right when the user is clicking on the UI

Additionally, when the mouse is over the subcategories, the background does not change color to yellow, however, the hair type does become wider relative to the neighboring icons (Figure 22).

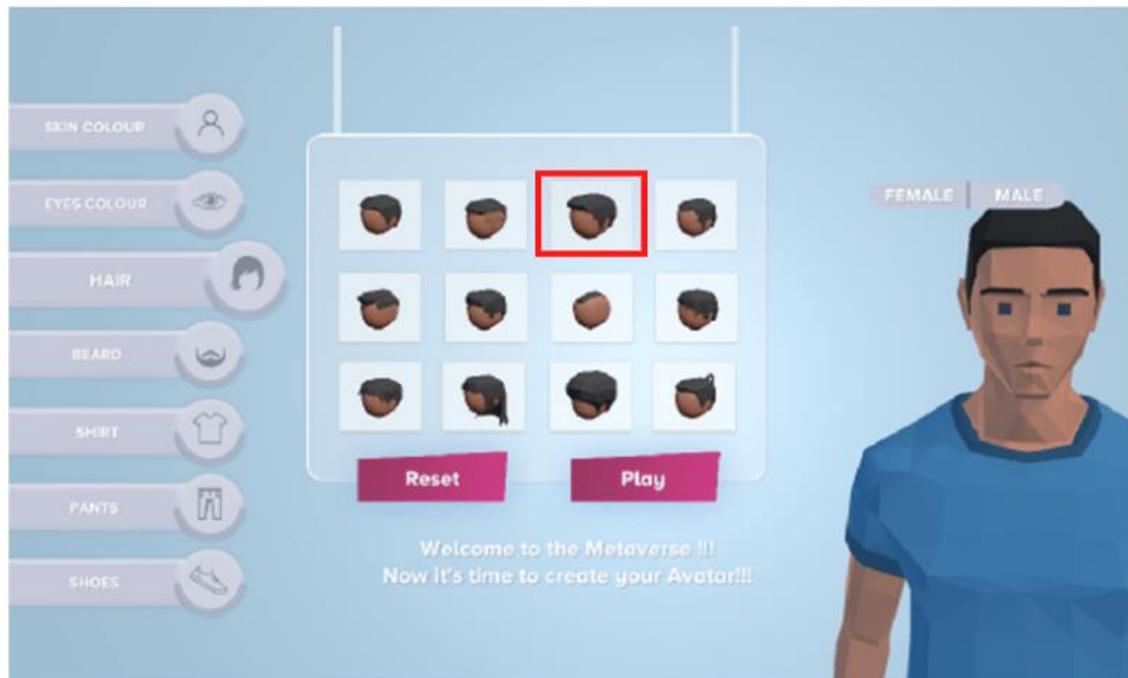


Figure 22: Subcategory when mouse is over without clicking

In Figure 22 it is possible to see how the scale of the menu items changes when the mouse pointer is hovered over them. This allows the user to see where the said item is located and what type of hair or subcategory was selected.

3.2.2 Zoom Camera in The Categories

In order to make the UI more dynamic it was decided to implement the view of the avatar from different perspectives. If the user was going to select features related to the face, it will make a zoom in. If the user was going to select the features related to the body, it will zoom out. In that way, the user could see the character from different perspectives.

- **Zoom In:** It produces a zoom focused on the avatar's face in skin color, eyes color, hair and beard. (Figure 23)
- **Zoom Out:** It produces a zoom out from the avatar's face so the avatar's whole body can be seen with the categories of: Shirt, Pants and Shoes. (Figure 24)

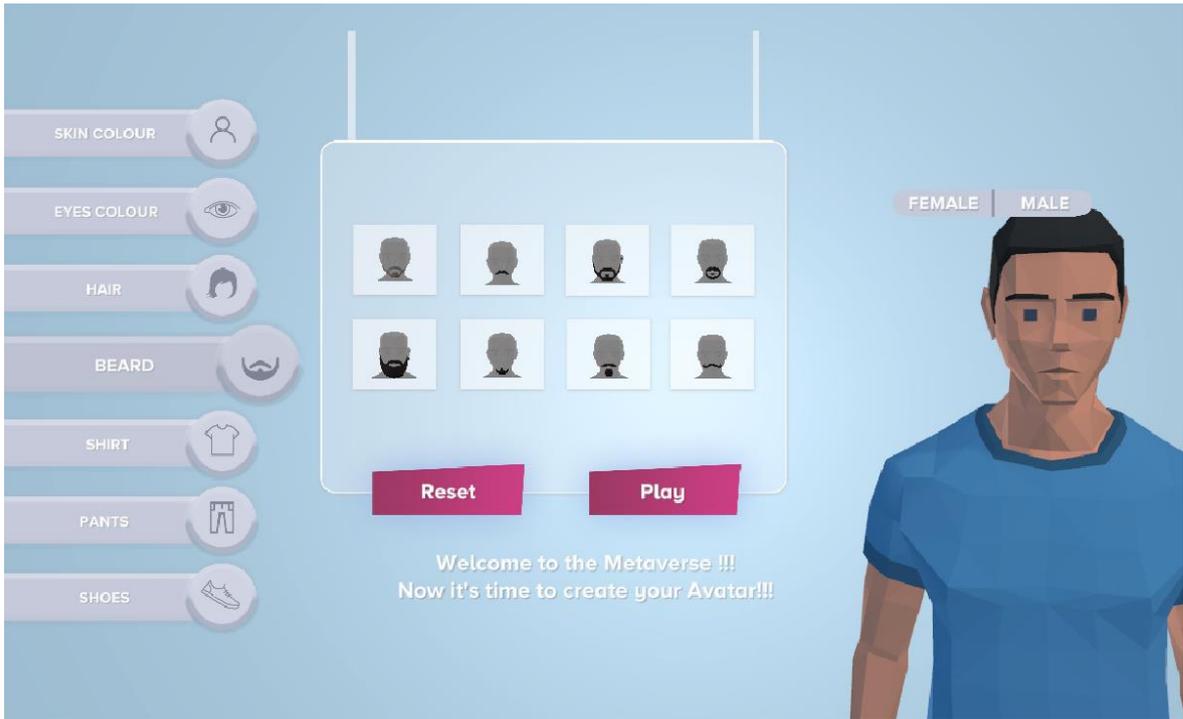


Figure 23: Zoom In in the UI

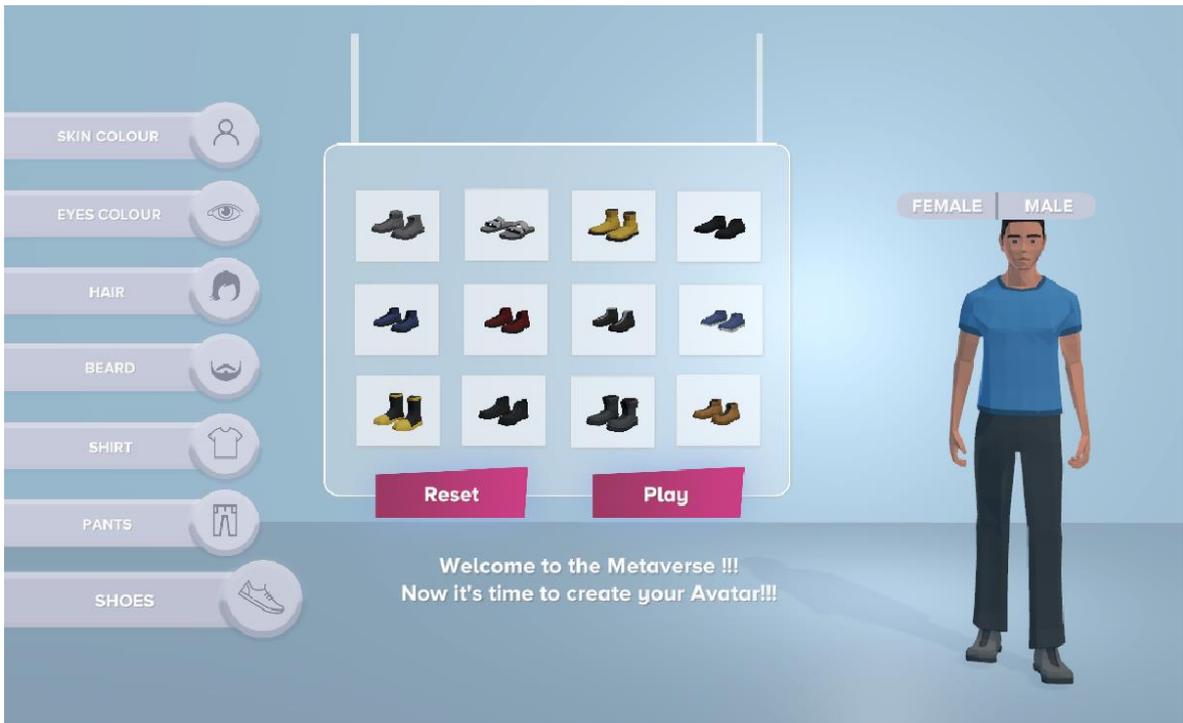


Figure 24: Zoom Out in the UI

3.2.3 Female/Male Button

A change that was implemented was the female and male button to improve the dynamics of the previous one. A new design was implemented using Photoshop. In the figure 25, the design that was initially in the project is shown.



Figure 25: Initial design of the button in the Project

Initially two designs were made with Photoshop to match the rest of the UI. One for the female button and other for the male button (figure 26). Nevertheless, a second layout of the buttons was created to achieve a better quality and to provide a more intuitive experience for the user (figure 27).



Figure 26: Design I of Female and Male button

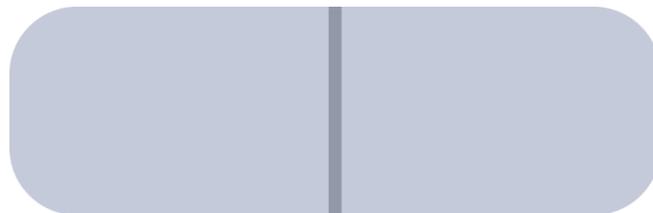


Figure 27: Design II of Female and Male button

Besides, when the female or male button is selected, its color would switch from gray to black letting the user know when he/she has selected one or the other (figure 28).

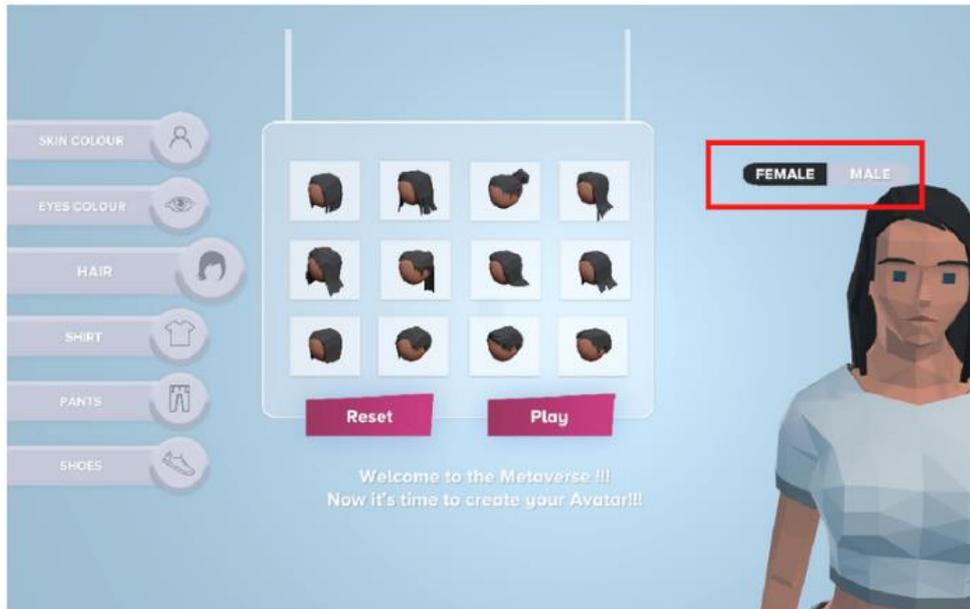


Figure 28: Female Button selected

3.2.4 Category Side Menu

Another part of the UI that had weak feedback was the side menu on the left side, where the users could see all the different features to customize their avatar. The major problem was that the user had to look at the content of this category to know which option was selected. As a solution to this issue, the category element would be moved to the right when a user clicked on it to select the category (figure 29).

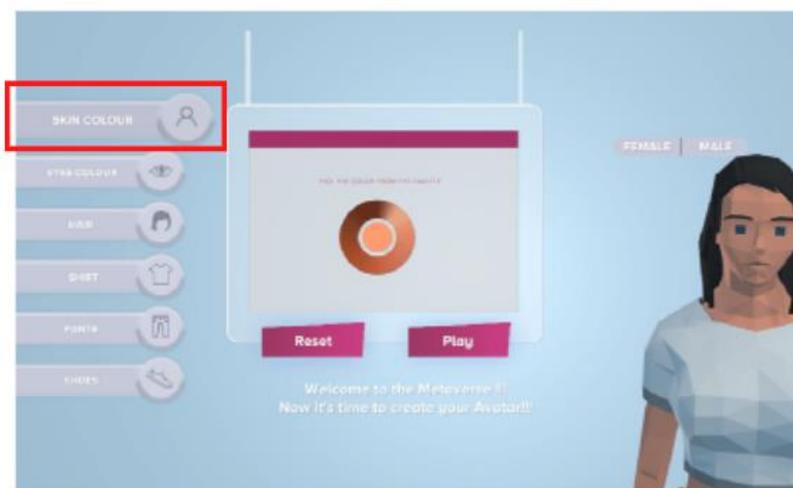


Figure 29: Skin color selected in the side menu

3.2.5 Welcome Text

After the Login system was implemented, it was decided to incorporate a welcome message for the user. This message is automatically updated based on the user's name to improve the user's experience and make it more personal (figure 30).

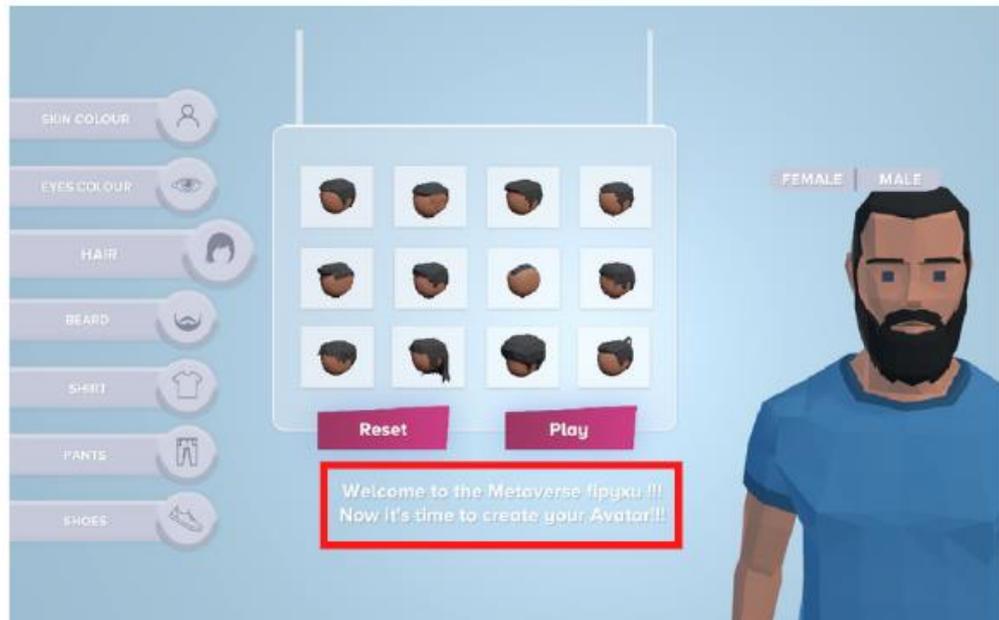


Figure 30: Welcome text in the UI

3.2.6 Reset And Play Button

Another Ui improvement provides a reset button allowing the custom avatar to return to the initial state. The Figure 31 shows the initial state of the avatar after the reset button is pressed and Figure 32 shows the state of the avatar when the user is customizing it.

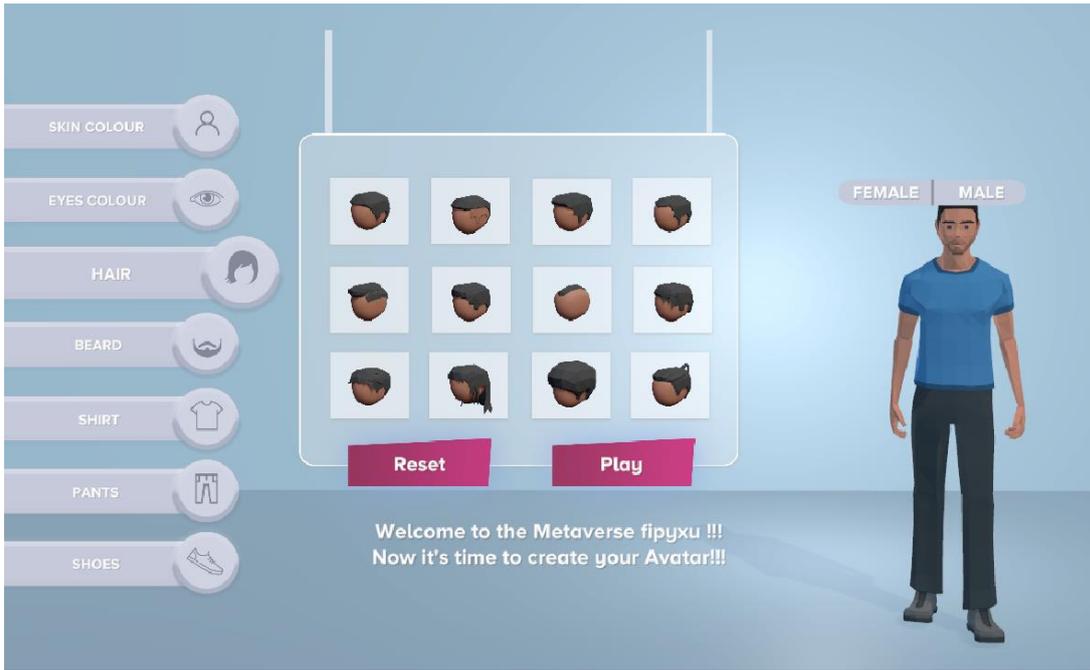


Figure 31: Initial State of the avatar when reset button is pressed

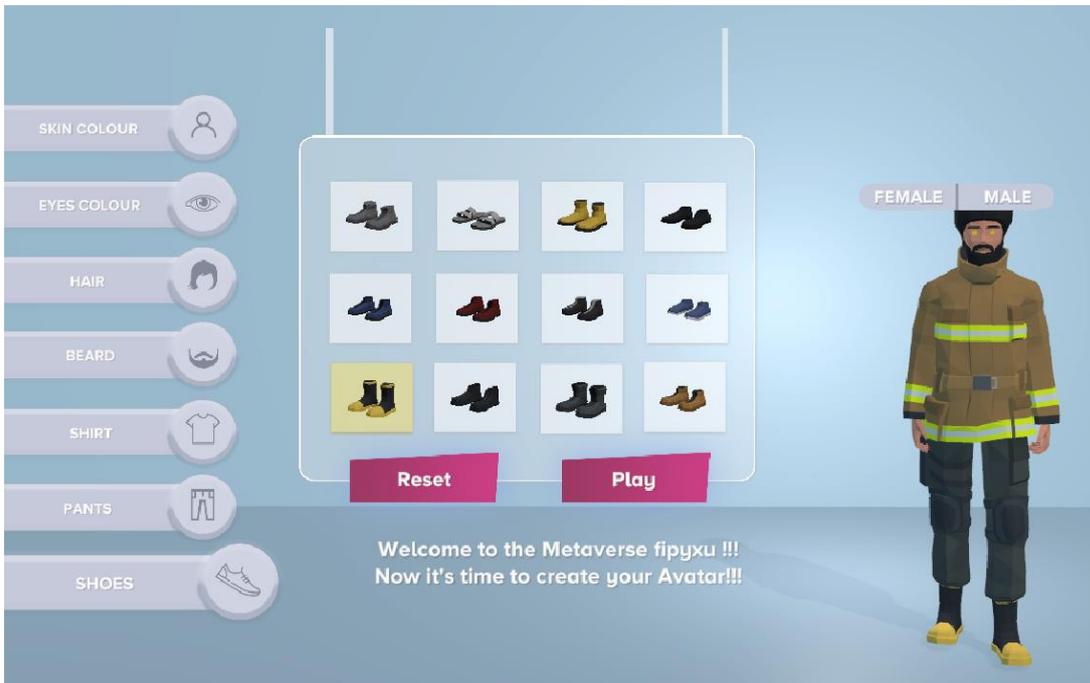


Figure 32: Final State of the avatar when the user is customized

3.3 Development of Avatar Interactions

3.3.1 Create And Join Rooms and Multiplayer Platform.

The improvement of the UI and the registration system was followed by the creation of a multiplayer platform for users to create or join rooms. The design of this feature was inspired by games, such as Among Us, adopting Photon (Figure 33).

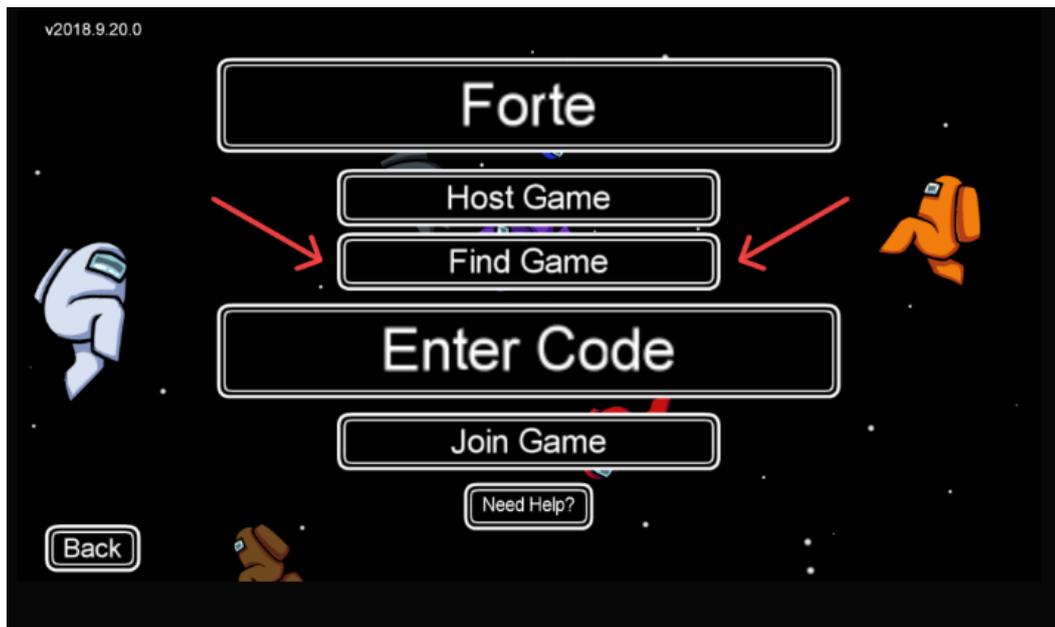


Figure 33: Among Us Multiplayer Platform (Alexander and Tate, 2022)

The “create and join room” panel uses the APIs and Photon servers to create an application Lobby. All users will be able to create a room with the name they prefer by giving a name to the room and clicking on create. Other users can join the room with the name given by the room creator and click join.

Whenever the users are in a room, a list of names is displayed and synchronized via RPCs (Research, Project and Contain). An RPC is a message that running a method played remotely in the room that the user connects to. In addition, RPC can include parameters such as an int or a string. For example, if we want to provide information about the color of the avatar's clothes, we pass an int with the ID of the color and, in the other user's game, the avatar's clothes will be updated.

When a room is created and joined by others the creator will click on the start button and automatically go to a loading panel.

Each player is provided with a *PhotonView*, which is a component that allows to synchronize different parameters (figure 34):

- **Position** of the avatar in the world
- **Rotation** of the avatar in the world
- **Scale** of the avatar in the world

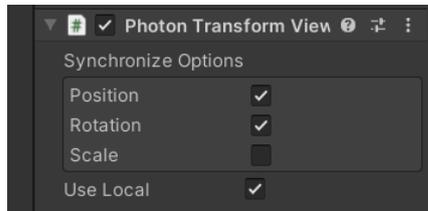


Figure 34: Photon View Transform parameters

Each avatar is assigned a unique ID and the *PhotonView* could observe other components such as: Rigid Body View to synchronize the avatar's physics and the animator view to synchronize animations, such as the avatar's movements (figure 35). Furthermore, a network controller assigns the spawn point of each avatar. A spawn point is the position where the player's avatar is spawned. Also, the network controller is responsible for removing the players offline. (Appendices 5, and 6)

The multiplayer function is composed by 3 different panels. The "create and join room" panel, the "waiting" panel and the "loading" panel.

In the multiplayer panel, the user will decide whether to create a room or join one with the code provided by the creator. After this the creator and the guest will both access to the waiting panel. The creator will have access to the "start playing" button once all invited users joined the room. Subsequently, they will proceed to the loading panel and lastly, they will enter the laboratory scene.

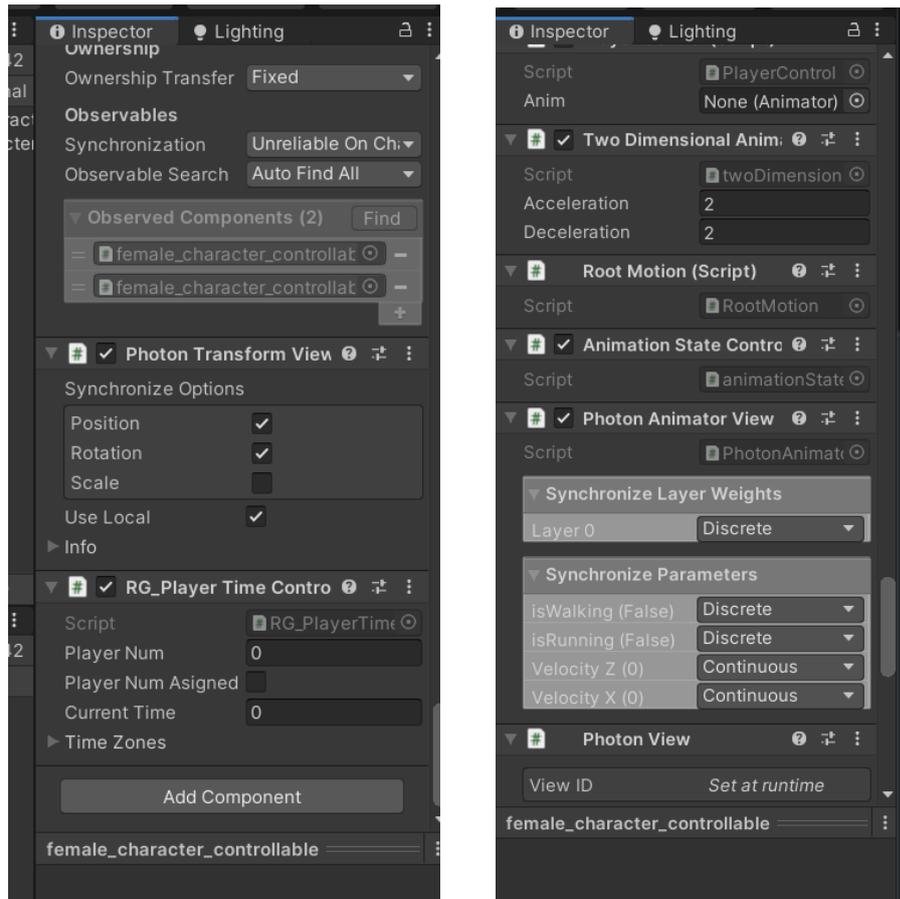


Figure 35: Photon View components

3.3.1.1 Multiplayer Panel

The multiplayer panel (figure 36) was composed of 5 elements:

1. Panel title

2. Room Name: The creator is required to provide the name of the room. The guests who want to join must type the name of the room provided by the creator.

3.Create Button: The create button indicates to the room creator that he/she has to click on it to create the room. The text is encrypted.

4. Join Button: The join button indicates to the users that when they have the code that the creator tells them, they can proceed to click Join.

5.TalTech Logo

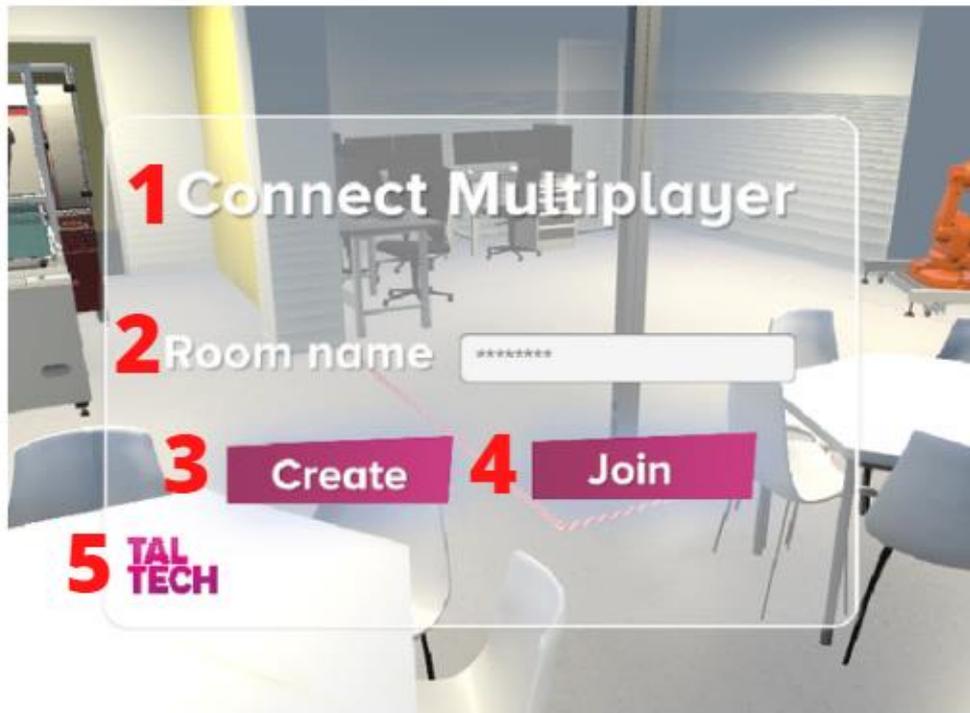


Figure 36: Elements of the Multiplayer Panel

3.3.1.2 Player Waiting Panel

The Next panel to be made consisted of the players waiting panel.

The Player Waiting panel includes 4 elements:

1. Panel Title

2. Users-name waiting

3. Start Game Button: The Start Game button enables the room creator to click on the button when all players joined the room

4. TalTech Logo

The player waiting panel is composed of two panels:

-Room creator panel: If the user creates the room the user will be able to have the access to press the Start Game button at his own choice (figure 37).

-Panel of the room guest: If the user joins the room as a guest, this user will not have access to the Start button (figure 38).



Figure 37: Creator Room Panel



Figure 38: Guest Room Panel

3.3.1.3 Loading Panel

Ultimately, when the users have successfully joined or created the room, they will be moved to a loading panel which will subsequently bring them to the laboratory scene after loading completion.

The loading panel is divided into only 3 components (figure 56):

1. Panel title

2. Loading bar: The loading bar represents the total load of the game.

3. TalTech Logo

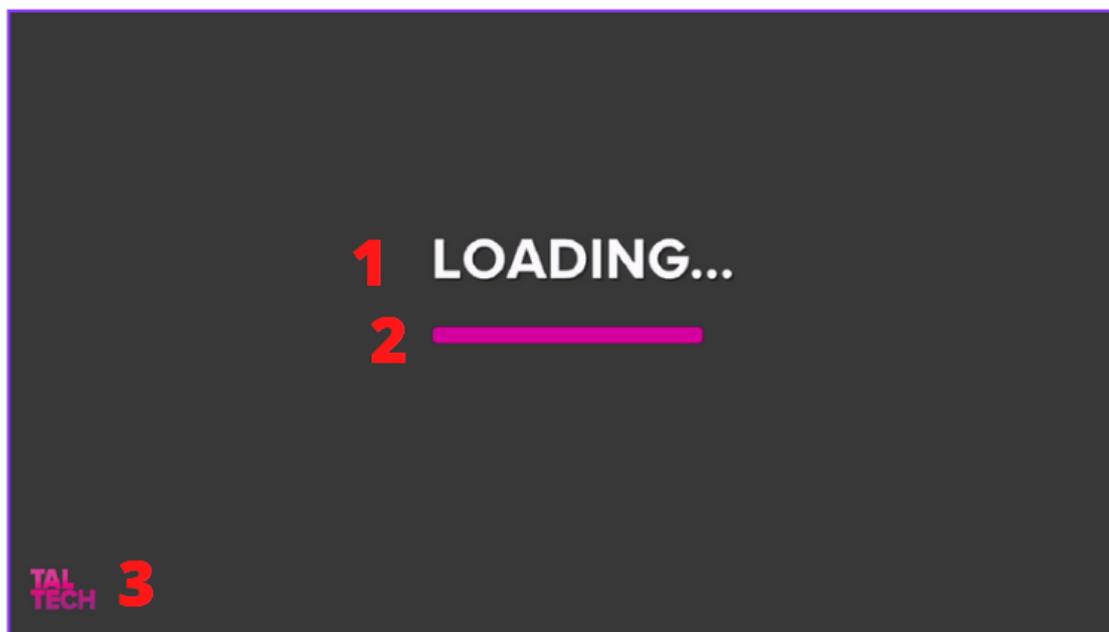


Figure 56: Loading Panel

3.3.2 Additional interactions avatars

Small adjustments have been made to improve the final result of the game. In addition to this, a basic movement has been implemented for the avatars, so that the user can move freely around the laboratory and access the different areas. In the same way, unity Collider Components, which allow to simulate physical interactions between objects, were added to the tables and other objects in the laboratory so that the avatar would collide with them and not pass through the objects themselves. Additionally, the

user is able to take screenshots of the environment by pressing the keyboard space bar (figure 57). These will be saved in a separate folder called metaverse (figure 58).

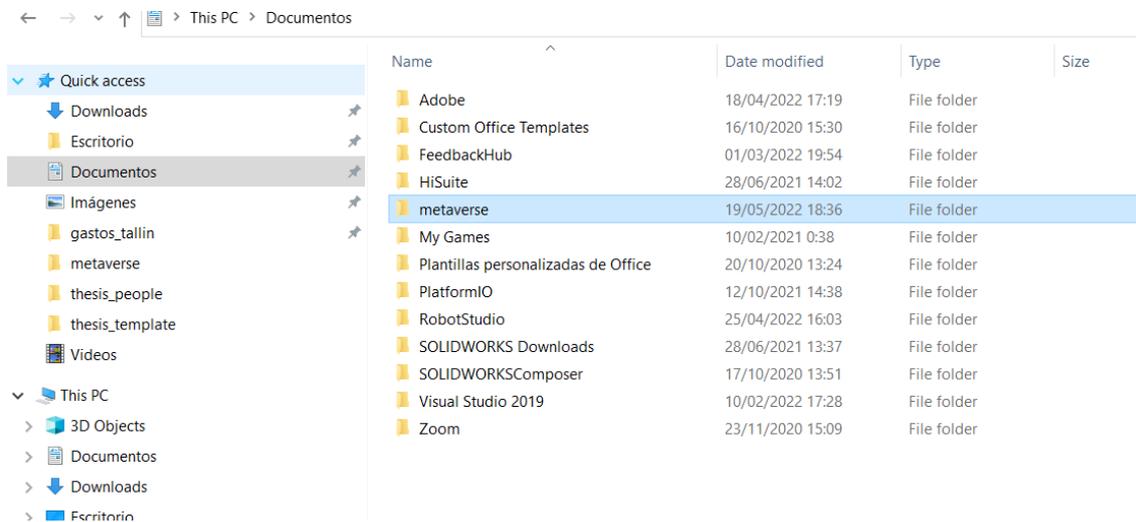


Figure 57: Metaverse Folder



Figure 58: Screenshots in the metaverse folder

3.3.3 Chat

One of the basic needs in a metaverse is the ability for users to communicate with each other. For this reason, a chat was developed by means of Vivox server.

We encountered several problems due to API access. In addition, the learning curve for the implementation of this technology is much longer than PlayFab or Photon, since in order for the system to work properly, it was necessary to use Vivox's own libraries. At the end, browsing through the documentation and looking for other people's implementations, it was possible to have a functional chat.

Other issues were related to users disconnecting abruptly from the chat which caused a failure in the server. Duplicate message would be created after the user started messaging to the server again. This problem was solved by adding a double check when leaving the chat.

The design of the chat bubbles was done using Photoshop. The aim was to differentiate the messages received by the user, the messages sent by the user and the system messages links in other applications such as Facebook or Telegram.

Besides, if tests are made outside the final application, it is necessary to press the escape key to end the communication to the chat.

The chat can receive as many messages as necessary, the space of the main panel of the messages is adaptable and the scroll bar allows the user to scroll through the chat. In addition, the sender and the receiver of the message will be able to see the name of the user with whom they are logged in.

The chat panel is divided into 4 elements (figure 59):

1. Messages: here you can see 3 types of messages.

- **System Messages:** The system sends a welcome message to all users.
- **Transmitter**
- **Receiver**

2. The scroll bar: The scroll bar is automatically lowered as more messages appear in the chat.

3. Messages chat

4. Send button: When the user wants to send a message, he/she clicks on this button.

Additionally, when a user receives a message, a sound is produced to indicate that a message has arrived. Finally, a button has been added to the chat where the user can click to make it appear or disappear (figure 60).

3.4 Areas Times Management. Worker efficiency KPIs simulator.

KPIs are indicators that companies use to measure how successful they are and how close they are to achieving their established goals (Velimirović, Velimirović and Stanković, 2011). Therefore, it enables the company to understand the project's performance by measuring specific data, analyzing it, and optimizing the process to achieve its objectives efficiently.

To work with the data, it should be measured, post-processed for the storage, and further analyzed for purposes from the designated data sources, such as sensors, logs, performance metric counters, and other relevant for one or another project/system design. For the related thesis, the primary focus is to collect data from an educational VR environments and use it as a simulator for worker performance on the manufacturing (in this case lab) shopfloor. In these specifically developed environments, there are several KPI-s to be considered (Belch, 2019):

- **Usage:** Occupation time of the stations. The time one or another station is being occupied/used by the worker.
- **Engagement:** User/Operator/Worker interaction with the surrounding environment.
- **Attention:** The user's head movement and/or eye-tracking for user focus validation.

The main advantage of the developed VR system is the feedback acquired from user engagement while using it. That allows the organization to improve the manufacturing layout design project and adapt it to the users in a very highly effective way based on the data gathered in prior simulation.

In the related thesis, the KPIs are focused on the management point of view, emphasizing the occupation/usage of the stations and the time the avatars (users) are online and virtually "working," considering the paradigm of industry 5.0 -, where the connection between humans and collaborative robots and the work in parallel. This data is being measured by the usage of the unity software, where the whole system scene of the lab has been divided into seven zones (figure 61).

- 1.ABB IRB 160 (Industrial Robot cell)**
- 2.CNC (Material handling cell)**
- 3.Festo System (Mobile robot connected to zone 2 and 6)**
- 4. Motoman GP8 (Industrial Robot Cell)**
- 5. Rest Zone (Restroom for breaks)**
- 6. Storage Block (automated warehouse system)**
- 7. WC (Bathroom)**

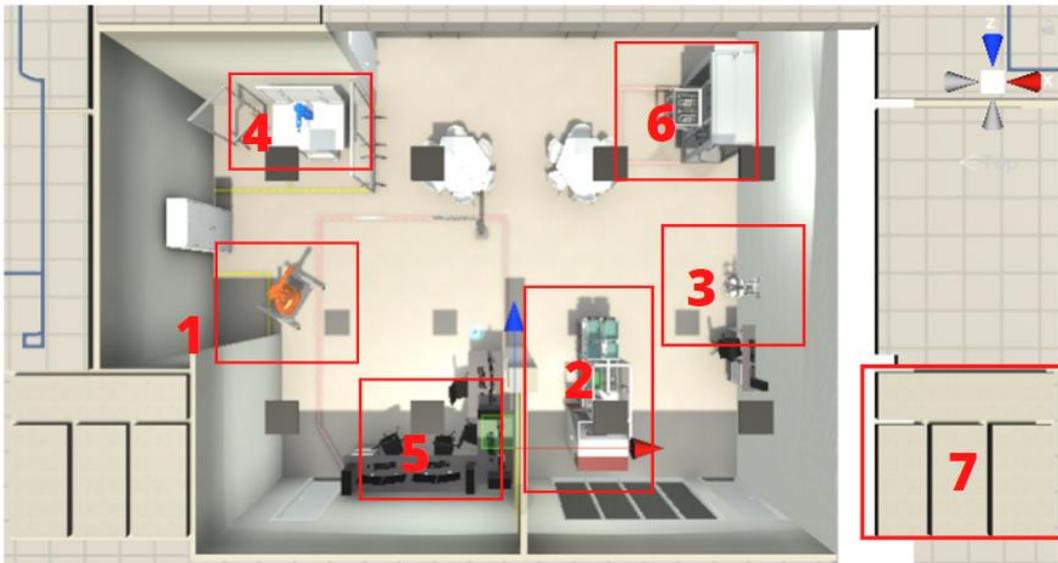


Figure 61: Working zones Areas of the laboratory

To perform the KPI analysis for this project, a virtual trigger has been installed/integrated into each of the zones, so when the avatar (user) crosses cross one of them (the virtual line), a chronometer gets an activation signal and starts storing the

time log of the user presence in that specific zone. All data is being saved to an excel sheet on demand of the simulator user.

When the user presses the activation button ("space" in the related-use case), an Excel file is saved in the Metaverse folder in the computer's documentation folder defined in-prior with all the time logs the user had present in each of the seven zones of the laboratory. In addition, the document is saved with the user's name and the date on which the log file was made (Figure 62). Later, using this data, the KPIs can be set.

Table 1 and Figure 63 show the time logs that the user "fipyxu" has generated in its virtual working time in the metaverse and how much time the user was present in each of the zones.

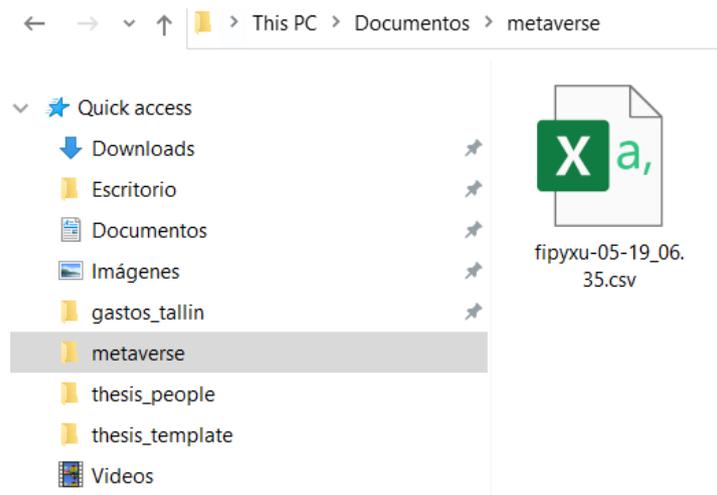


Figure 62: Areas of the laboratory

Table 1: Total time in the areas of the laboratory

Total Time	ABBIRB1600	CNC	FestoSystem	MotomanGP8	RestZone	StorageBlock	WC	Exploring
300,76s	50,34 s	90,98s	71,04s	10,53s	20,11s	15,21s	4,62s	37,93s

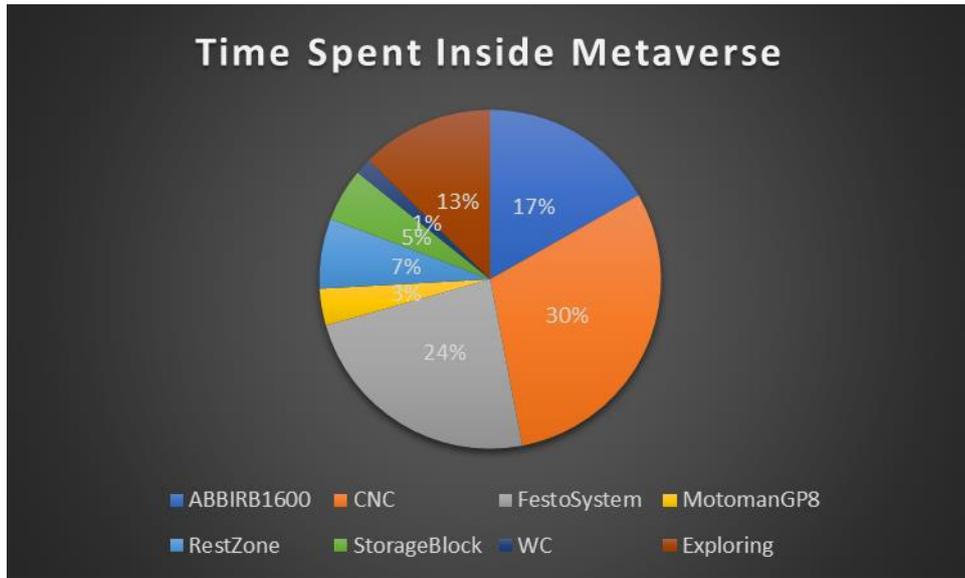


Figure 63: Graph of the time spent in the metaverse

With the obtained data stored in the log file and the user information provided by the PlayFab portal – the project administrator can now define and analyze the following KPIs:

- Usage of the working stations: The organization knows the total time the users spend in each working station. This information allows understanding of the most occupied/used stations and the vice-versa – less occupied/used. With that information, the design project can better use the manufacturing resources in the future.
- Total time inside the metaverse: By measuring the total time a user spends in the metaverse, the administrators will acknowledge if the user quit the virtual simulation fast (due to a technical issue or because being not interested in the experience) or if they stay longer than expected by the use-case scenario.
- Registered users: By using the PlayFab platform, the organization can check the number of registered users and their progression over time. If the number of users grows over time, it will mean the gamified environment experience and the updates are successful. On the opposite side, if the number of users tends

to decrease, the virtual environment should be examined and updated to find the issue preventing its success.

- Users logged in: This data is being stored in the PlayFab portal, providing the data of the users are active (online) simultaneously. With this information, the organization can check their users' preferred schedules.

From the data obtained, as represented in the graph in Figure 63, the distribution of the time spent by the avatar is clearly observable. A simulator of the users' times is generated. Through the Excel table (with the obtained data), which is generated automatically by Unity, it is possible to simulate the time spent by each avatar in each zone. The key success indicators would be focused on the total time spent by the avatars in the metaverse, because if the users either spend a very short time in the metaverse or a long time in the metaverse, something unwanted is hindering longer stay by the users inside the program. It could be that either the program does not work properly or is not to the liking of users ergonomically or the users find it difficult to use.

In addition, another indicator of success in the metaverse is the number of users who have logged in, as it also shows the degree of user satisfaction which comes by the metric that more new users are coming in based on recommendations from current users and that those who use it once, do log in again.

4 ECONOMICAL COST ANALYSIS

The budget has been conducted on an annual basis and has been divided into 3 differentiated parts.

- Hardware
- Software
- Development

The hardware budget required the following items (table 2):

- **Meta Quest 2:** A VR headset developed by Facebook Reality Labs. It is needed for testing the game and the updates. The cost will be of the direct purchase 349€. (store.facebook.com, 2022)
- **Personal computer:** It is needed for developing and testing the product and management of the project. The expected life of the computer is 4 years, with a cost of 1000€ and the annual cost will be 250€/yr.
- **Internet connection:** In order to develop an online game and manage the resources, an internet connection is necessary. The price will be of 25€/month and the annual cost will be 300€/yr. (www.telia.ee, 2022)

Table 2: Hardware Budget

Hardware	Direct Purchase	Monthly	Annual
Meta Quest 2 + Controllers	349,00 €	-	-
Personal computer	-	20,83 €	250,00 €
Internet connection	-	25,00 €	300,00 €
TOTAL (€)	349,00 €	45,83 €	550,00 €

The software budget required the following items (table 3):

- **Unity 3D:** It is a cross-platform 3D engine and a user-friendly development environment. For students is free, for private companies will be 377,77€/yr.
- **Photoshop:** It is an image creation, graphic design, and photo editing software. 290,28€/yr.
- **PlayFab:** It is a complete backend platform for live games with managed game services, real-time analytics and LiveOps. It is free up to 100.000 users.

- **Vivox:** It provides managed communication services in the form of integrated voice chat, Instant Messaging (IM) to online games, virtual worlds, and other online communities. Free up to 5.000 users.
- **Photon:** This software solves problems like matchmaking and fast communication with a scalable approach. It is free up to 20 users. For 2.000 is 4.203,84€/yr.
- **Microsoft Office:** Word and Excel for data analysis. The cost will be 69€/yr.
- **Visual paradigm:** It is designed for software development teams to model business information systems and manage development processes. It is free.

Table 3: Software Budget

Software	20 users	2000 users
Unity3D	- €	377,77 €
Photoshop	290,28 €	290,28 €
Playfab	- €	- €
Vivox	- €	- €
Photon	- €	4.203,84 €
Microsoft Office	69,00 €	69,00 €
Visual Paradigm	- €	- €
TOTAL	359,28 €	4.940,89 €

The costs related to the development of the project. Different categories of work will be required:

- **Analyst:** In charge of the Project Analysis phase and in charge of the Project Documentation phase.
- **Designer:** In charge of the Design phase of the project.
- **Programmer:** In charge of the Implementation and Testing phase of the project.

Considering that the planned duration of the project has been approximately 4 months, it has been estimated about 280 total hours.

Table 4: Development Budget

Development	Time	Cost	Total cost
Analyst	10	20€/h	200,00 €
Designer	20	20€/h	400,00 €

Programmer	250	24€/h	6.000,00 €
TOTAL			6.600€

The total budget is the sum of the hardware, software and development budgets.

As can be seen, the budget is divided in 2, one is a total of 7.509,28 € for 20 users at the same time. The next one would be for 2000 simultaneous users which would be 12.090,89 €.

Table 5: Total Annual Costs for 20 users and 2000 users

Annual Cost	20 users	2000 users
Hardware	359,28 €	4.940,89 €
Software	550,00 €	550,00 €
Development	6.600,00 €	6.600,00 €
Total	7.509,28 €	12.090,89 €

CONCLUSION AND FUTURE LINES

This project has allowed getting to know the importance of VR technologies, video games in the field of education and in connection to the industry 4.0 and Industry 5.0 paradigms

Despite the short period of time in which the project has been developed, a completely new software combined with a new programming language has been learned. A functional VR game prototype has been made including a registration system, a multiplayer system, a chat and a KPI analysis focused on VR coupled with Industry 4.0.

Despite several criticalities, especially with the chat development, problems have been always overcome. As a result of this project, a whole new world has opened up for me which it will be continue explored.

As for future lines, a voice chat is to be implemented, as well as the possibility of adding elements such as images or documents to the chat. Additionally, the design of the chat could be improved. This project could be scaled up so that more than 2000 people can be connected at the same time in the multiplayer system with Photon.

In addition to this, it would be interesting to add two extra KPIs.

- The first would be detecting an interaction with any specific machinery in the lab. This would allow knowing where the users have clicked or interacted in in the environments which options of the robot are being used, and how human robot collaboration processed could be made would be more efficient.
- The second KPI is the VR headset, the head-tracking and eye-tracking would deliver vital information about the user experience and how to optimize his educational purpose. When they get distracted, what is the most efficient way of learning and being efficient.

One feature which the author considers to be quite essential in reaping further efficient outcomes from this product would be enhance the tools that would eventually trace and the avatars' behaviors while in the Meta environment. For example, the designers carrying on this product in future could work on mapping where the users went, in which sequence and for which reason. The current designer (author of this thesis) has already incorporated the time-spent data feature. Mapping the operator/user path would allow for reaching a consensus to improve how the real life layout should evolve based on how the users interact with machines in the virtual environment.

This could also lead to conclusions who the users interact with, why and at what time of their stay in each specific room or place. This allows for mapping profiles of the like-minded and most interested students in the real laboratory. This could also be used in gaining insight into future inclinations or skills or interests of prospective students seeking admissions at TalTech.

This proposal sounds intrusive to privacy under various laws, essentially the EU GDPR, hence, it is proposed that any one working on it further seeks out legal guidance on this front, and if possible, prepare a Privacy Consent statement built-in to this product which clearly explains how the users' behavior would be tracked and what would be the limits of the usage of that collected data and its influence regarding decisions taken which could directly or indirectly impact the users' real life.

SUMMARY

The developed project *Metaverse TalTech*, is an educational multiplayer game in VR where the users can see the university in VR. The project is based on the improvement of an existing project through various interactions. In the case of the TalTech Metaverse project, it is a virtual world that supports several users connected at the same time. Each user is in a virtual world that is the TalTech university.

This work focuses on the implementation of avatar interactions in the Metaverse including the improvement of the UI making it easier and more user friendly when using the game. In addition, a registration system has been implemented through PlayFab and a chat where users can communicate through Vivox. Besides, a multiplayer system has been implemented through Photon.

Finally, an analysis of KPIs was done. The occupancy rates and times spent in and around the different areas of the laboratory, is performed to analyze the user behavioral data for future assessments that could culminate into rearranging the floor plan as best suited to the users (students and professors- in real life). For this purpose, the PlayFab server and different tools and techniques in the Unity engine are used, which are specialized in performing the mentioned tasks efficiently.

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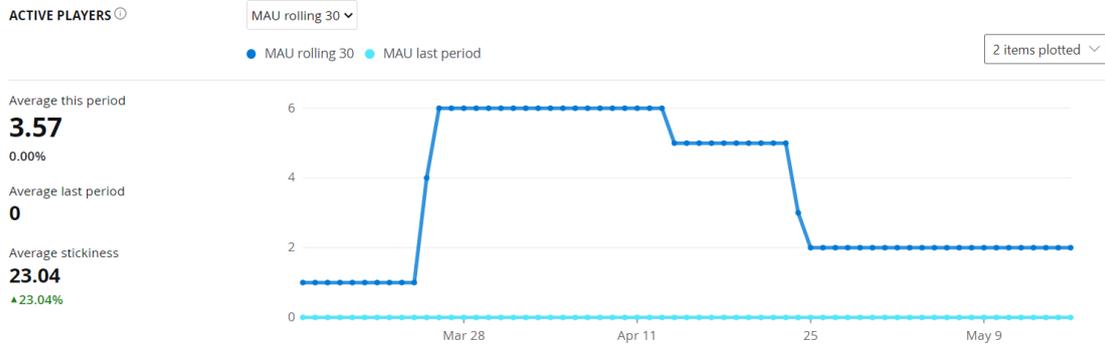
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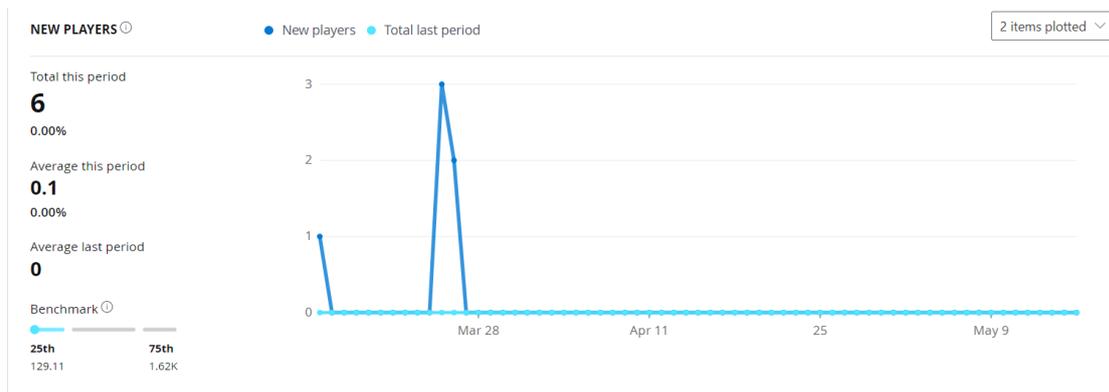
APPENDICES

Appendix 1 PlayFab Active Players Data

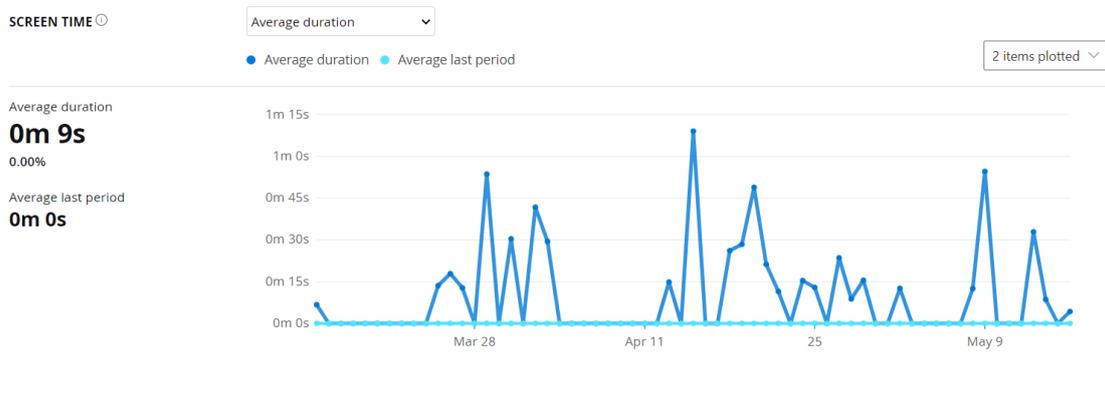
26 week trends



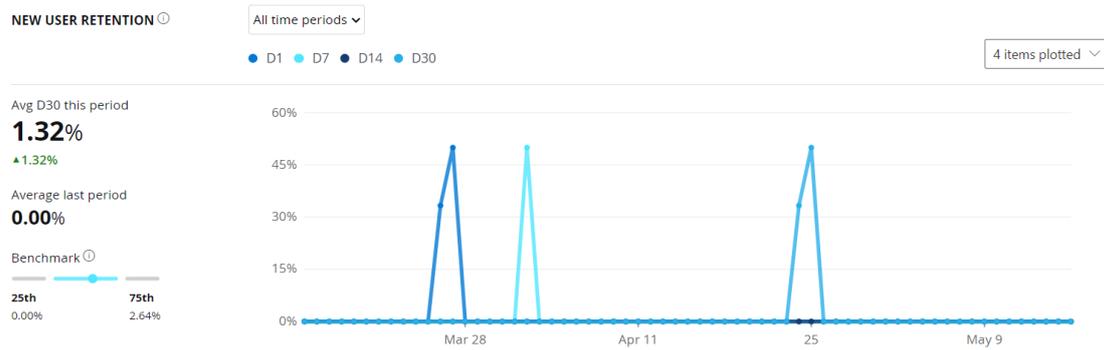
Appendix 2: PlayFab New Players Data



Appendix 3: PlayFab Average Time Players



Appendix 4: PlayFab New User Retention



Appendix 5: Photon Network Create and Join Room Visual Studio c# I

```
65 //joinOrCreatePanel.SetActive(false); desactiva la opcion de unirse
66
67 public void CreateRoom()
68 {
69     PhotonNetwork.CreateRoom(roomInput.text);
70     print("Creating room" + roomInput.text);
71
72     roomPanel.SetActive(true);
73     joinOrCreatePanel.SetActive(false);
74 }
75
76 //
77 public void JoinRoom()
78 {
79     PhotonNetwork.JoinRoom(roomInput.text);
80     print("Joining room" + roomInput.text);
81
82     roomPanel.SetActive(true);
83     joinOrCreatePanel.SetActive(false);
84 }
85
```

Appendix 6: Photon Network Spawn Point Visual Studio c# II

```
28
29 //it is instanced the object in the network. It is launched one. We need to add our player
30 //we create a player in the spawn point position with a rotation looking forward to get the other playe
31 if (PhotonNetwork.InRoom)
32 {
33     print("instantiating player");
34
35     oldPlayerFemale.SetActive(false);
36     oldPlayerMale.SetActive(false);
37
38     PhotonNetwork.Instantiate(playerMale.name, spawnPoint.position, Quaternion.identity);
39 }
40
41
```