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Original Article

Development of 3D Avatars for Inclusive Metaverse: Impact on Student Identity and Satisfaction using Agile Methodology, VRChat Platform, and Oculus Quest 2

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Abstract *- The metaverse is a virtual space for innovative research and the convergence of various lines of inquiry. Its evolution is related to Industry 4.0 and IoT and is projected to reach 1.7 billion users. However, the student community does not identify with the metaverse, which generates a lack of awareness of its utilities. The objective of this article is to develop 3D avatars for use and inclusion in the metaverse and measure their impact on variables such as identity and satisfaction. The methodology used was Top-Down, an agile methodology that allowed for continuous feedback and regression of processes from each of the methodological steps. Two 3D avatars were designed and modeled in Blender and Unity for the identity of students at the University of Sciences and Humanities, a platform was found in the metaverse for the avatars, and they were loaded onto it. The results indicate that the avatars were successfully tested using the Meta Quest 2 virtual reality goggles. A positive response was obtained in both the quantitative and qualitative survey, yielding an 81.8% acceptance rate for the style and identity towards UCH students. The adopted agile methodology and the VRChat platform were beneficial for the development of the avatars, and it was concluded that this platform is the most suitable for future research in the metaverse, building on the present research for subsequent projects.*

Keywords *- Metaverse, Avatar 3D, Top Down, Meta Quest 2, VRChat, Identity.*

1. Introduction

In recent years, we have witnessed rapid advancement in technology and the way we interact with it [1]. Industry 4.0 is generating a technological revolution radically transforming production and manufacturing [2], [3]. Through automation, artificial intelligence, the Internet of Things (IoT) [4], [5] and data analytics, Industry 4.0 is driving the digitization of industrial and educational operations, making it possible to optimize the efficiency of a digital universe called the metaverse [6][7], quality up to personalization in production.

According to the CEO of META in 2021, he indicates that by 2023, 1.7 billion users will be reached within the metaverse [8], allowing users to interact, communicate and explore together in a new way to connect and experience the digital world [9]. On the other hand, NASA has been involved in this field since 1990 with The Virtual Interface Environment Workstation (VIEW) project [10], which was used for various astronaut simulations and opened new horizons, such as those of the metaverse.

In Peru, there are proposals to involve the metaverse and virtual environments, but the results are not what was planned [11]. In addition, the COVID-19 pandemic triggered the development of various applications within virtual reality [12], [13]. Medical developments such as simulations of therapies and rehabilitation due to the immobilization of society [14] are precedents that the metaverse is getting closer to us than we think.

A fascinating feature of the metaverse is the creation of avatars [6], [14], digital representations of ourselves that allow us to interact and participate in this new reality. Avatars give us the ability to personalize our appearance and how we present ourselves in this digital environment [15]–[18].

Given the problem of scarce information about the metaverse, its productive development, the low identity of the student community within the metaverse, and the satisfaction of their avatars. It will be seeking how to find a level of relationship and identity between the virtual world and the real world. Thus, it opens the way to a novel line of research for

the solution of problems [19]; given the problem of the scarcity of information about the metaverse and its productive development, it will be seeking how to find a level of relationship and identity between the virtual world and the real world. Thus, opening the way to a novel line of research for the solution of problems [20].

The study's main objective is to develop 2 avatars for the use and application of future research in virtual reality and the metaverse that will allow us to identify our future results with a proper assimilation of the real and virtual world. Thus, the first step will be implementing a virtual reality system and simulation of various branches such as health, engineering applications or lines of research of the University of Sciences and Humanities. Thus, bridging the metaverse's existing information gap and scientific research's main benefits.

The rest of the manuscript is organized as follows: section 2 will look at the methodology used for the creation of the avatar, section 3 will describe one by one the steps applied during the modelling and design of the avatar, section 4 will detail the results obtained, section 5 will describe the discussions and drawbacks encountered during the modelling of the avatar, and finally section 6 will illustrate the conclusions and future work of the research.

2. Estate of the Art

The creation of avatars is essential in the metaverse, allowing us to be part of an online community in an innovative way [21], [22]. For example, in [23], with the scarce creation of VR (Virtual Reality) content in Arabic culture. 32 interviews were conducted with Arabian culture subject matter experts and psychologists to develop guidelines and promote a standard for Arabian avatars. As a result, they based a guideline on stereotypes such as skin colour, eye colour, hair, and cultural clothing. They conclude with the description of avatars with psychological constructs and referents with design guidelines appropriate for Arab culture.

Similarly, in [24], faced with the need for identity with avatars in the virtual world, a dual approach to creating photorealistic avatars is presented. High-cost and low-cost methods for the three-dimensional reconstruction of virtual humans by means of photogrammetry and template fitting were compared.

On the one hand, the high-cost method produced results in approximately 10 minutes and the low-cost method in an average time of 25 minutes. He concludes that low-cost methods are a suitable alternative, given the current consumer VR devices. These investigations are important for successful performance before developing a virtual reality avatar [53]. VR environments should also be considered, as mentioned in [26], who, faced with the need for a physical working environment and the design of a VR studio, propose a workflow with environmental factors necessary to design virtual environments. In which they conclude with the high need for information on decisions to create virtual environments that do not stagnate as pilots and go public for various platforms.

On the other hand, in [27], faced with the need to obtain results in robot tests for space missions, they describe their experiment as the remote operation of a rover in various weather situations. They develop a robotic avatar with a set of requirements for planetary exploration. This projected development for MARC II tested communication protocols such as the Tracking and Data Relay Satellite System and the European IP Communication Laptop, among others. They conclude that the use of a robotic avatar is highly important for simulation, robot testing and haptic systems.

Furthermore, the creation of avatars is also involved in the medical field, as in [28] the face of a lack of understanding of the symptoms of acute coronary syndrome may delay seeking medical treatment. They designed an avatar for identifying and guiding this syndrome, evaluated 70 patients with coronary syndrome using Tobit's growth curve, and obtained that, thanks to the use of an avatar, about 94.2% completed the guidance. As in [29], with the same methodology but applied to heart attacks, showed that using avatars is more than important for the information and support of health services.

Finally, in [30], in the face of certain proposals for the representation of man in the metaverse, they study the various methods for designing avatars in the Telexistence system, for they studied 6 designs such as photorealistic, hologram, cartoon style, shadow, robotic and Furry style. These were evaluated by 16 assistants in VR and AR (Augmented Reality) environments [31]. They concluded that the most suitable models are photorealistic for VR and holographic for AR.

In summary, avatars play a crucial role in the metaverse, as they allow users to participate in online communities in innovative ways. Researchers have explored various aspects of avatar creation, such as creating guidelines and standards for avatars to represent cultural identities accurately. These guidelines consider factors such as skin color, eyes, hair, and cultural clothing. In addition, researchers have compared high- and low-cost methods for creating photorealistic avatars and concluded that low-cost methods are more suitable for consumer VR devices. The importance of virtual environments and the need for information to create them has also been highlighted.

Additionally, avatars have been used in medical contexts to guide patients and provide them with information about symptoms. All of this allows us to develop and focus our research with a clear and direct vision towards the identity of avatars in university students and faculty.

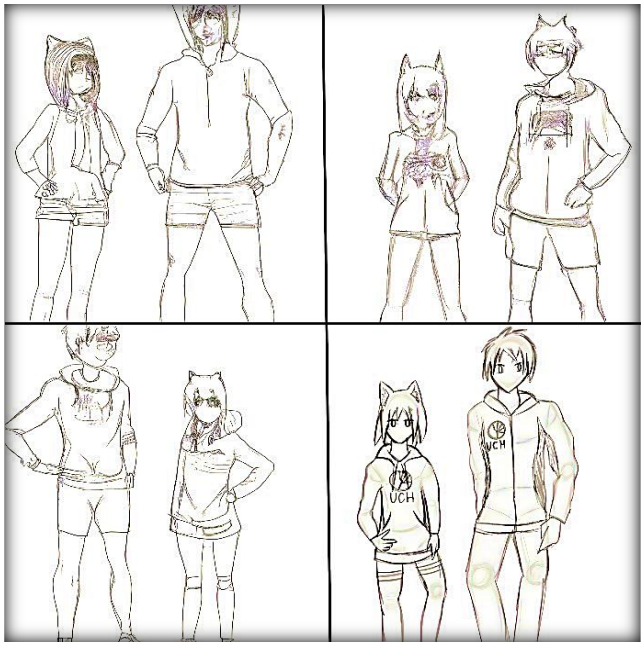

Fig. 1 Sketch of avatar. (Male and Female)

3. Materials and Methods

In this research, the Top-Down methodology was proposed, which, due to its design steps with a tendency to modifications and corrections, allows a great development of the avatar design.

3.1. Initial Design

Following the steps of the Top-Down methodology, we start with the development of a draft avatar prototype with projections such as height standard and stereotype, to be further improved and used as a guide for the subsequent concepts [32], [33] Furthermore, the Top-Down methodology emphasizes the vision of the initial model and projection of the prototype throughout the development of the research.

3.2. Planning and Requirements

It is necessary to know the target audience of the prototype, choose the area of work and mention how it takes advantage of all the factors [33]. To do this, a planning and sequence of required steps is made. In addition, a series of tasks are created and rigorously fulfilled, where the level of difficulty of each of them is to be understood.

As part of the requirements, the search for a platform where the creation of the character and interaction with other users can be achieved is proposed. As mentioned in the objective of this research, this platform must have support and accessibility for virtual reality glasses. Likewise, the virtual reality goggles must have a haptic system [52] capable of virtually replicating the movement of hands and head.

3.3. Implementation of the Model

In this phase, strategies for designing the logical and structural body of the avatar must be established. It should be composed in the search for the appropriate tools for each stage mentioned in the requirements that were established during the previous phase. On the other hand, each advanced stage must be accompanied by a review and evidence gathering.

3.4. Abstraction

This stage verifies the steps and aspects that were concluded, where validation or first tests are carried out [33], as well as proposing any improvements or changes to the platform. Also, this stage will allow us to go back to previous stages and a possible total restructuring of the avatar.

3.5. Manifestation and Documentation

The finalization of the manuscript is subject to a review by a specialist. This will be followed by the drafting of the manuscript, in addition to finding new proposals for improving the prototype, thanks to the literature review, which is an important part of this stage.

4. Modeling and Design of Avatars in the Metaverse

Following the methodological steps for the avatar's design, we start with a sketch in Fig.1, which is based on the marketing area, considering factors such as facial features and identification of the students with the university. The ethnological features of the average Peruvian student between the ages of 18 and 25 are considered, considering a height of 165cm for women and 175cm for men [35].

4.1. Blender

Blender is a free three-dimensional graphics software for creating 3D models [36], textures, animations, water and skin simulations, video and image editing, and 3D applications. It runs on several operating systems comparable to high-end programs such as Softimage XSI, 3DS Max, and Maya. Blender has proven efficient and accurate in creating and measuring samples in scientific studies and has been used by other research teams consistently [37]. As part of the methodological steps, the present program is chosen for the 3D modelling of the avatar.

4.2. Unity

Unity is a widely used platform for developing 3D and 2D video games and interactive content [38]. It allows the creation of games, virtual reality (VR), augmented reality (AR) applications and other interactive content for various platforms, such as PCs, consoles, and mobile devices [39], [40] with its integrated development environment (IDE) and tools for immersive experiences. Unity is a popular choice among developers and content creators in the metaverse [41], [42].

4.3. VRChat

VRChat is a VR platform that allows users to interact in online virtual worlds. Compatible with various VR devices, such as MetaQuest, HTC Vive and Valve Index [43], [44], as well as a desktop version. Users can create avatars, socialize,

play games, participate in events and explore community-created virtual worlds. VRChat is notable for its focus on social interaction and creativity [45], which makes it popular for social encounters, role-playing games, and events in the virtual world.

This creation of avatars is linked to certain requirements indicated in Table1, where we highlight the use of the Unity 2019.4.31.f1 version, which has many compatibilities in libraries, Shaders, textures, and direct compatibility with the blender. On the other hand, the use of the VRCHAT platform allows the integration of Open Sound Control (OSC) communication protocols, which through its open-source libraries, allow the addition of objects and animations to the avatars within the platform, these being controlled from outside the game.

Table 1. VRChat avatar requeriment

Basic Requirements	
Unity	Version 2019.4.31f1
SDK	VRCSDK3
Prefab	3d FBX model
Textures	Non-maximum textures at 1024dpi
Shaders	Integrated or third party
Dynamic Bones	Physbone recommended
Verified account	USER rank to upload an avatar

4.4. MetaQuest2

Table 2. Meta Quest 2 Specifications

Processor	Snapdragon XR2
OS	Android dedicated to META
Ram	6Gb
Resolution	1,920 x 1,832 per eye
Refresh rate	72Hz
Wireless connectivity	Wifi 6 and Bluetooth 5.1
Sound	3D
Storage	128/256Gb
Weight	503grams
DoF[a] input	3DoF[a]
DoF[a] output	3DoF[a]
Tracking	Camera and 2 remotes
Battery	3640mAh lithium-ion with 14Wh

a. DoF: Degrees-of-Freedom

Fig. 2 MetaQuest2 components

It is a standalone VR system with viewfinder, motion tracking and handheld controllers. It offers wireless virtual reality experiences with popular games and applications [46]. Table II specifies the main features of the device, highlighting the 3-dimensional degrees of freedom, which translates into full head tracking and 2 controllers for hand position Fig.2. On the other hand, the resolution of this device implies a greater immersion than other types of visors that require a higher cost to reach this quality [47]– [49].

Meta Quest 2 also has the advantage of being used as a VR viewer on the computer, leaving all the graphical load to the computer's processor and graphics card.

For the execution of this research, we will use both modes of the virtual reality glasses; on the one hand, the Standalone mode, which has compatibility with the VRChat platform and the Desktop mode through the Link cable, you can access all the features of VRChat-PC [46] and the capabilities of MetaQuest2.

4.5. Design Process

Having defined the requirements as part of the methodology, we proceed to plan. The beginning of a sketch is paramount, and it was decided for a general model with a vision of comfort and identity, which is why the block diagram in Fig.3 specifies the order of work. The conversion and configuration process are important to highlight the addition of the minimum libraries, shaders and physics to upload an avatar on the VRChat platform.

In addition, this working block diagram will be executed in a double way since, as this avatar development is aimed at a diverse use in other lines of research, it must include both male and female genders in accordance with the identity item explained in the first point of the methodology.

5. Results

As part of the results and following the workflow, we started with the 3D modelling of the sketch through a blender; the incorporation of a framework or skeleton is crucial for the export to Unity (Fig.4). The modelling should be done for both genders, and no importance was given to a model size at this stage as scalability can be regulated later.

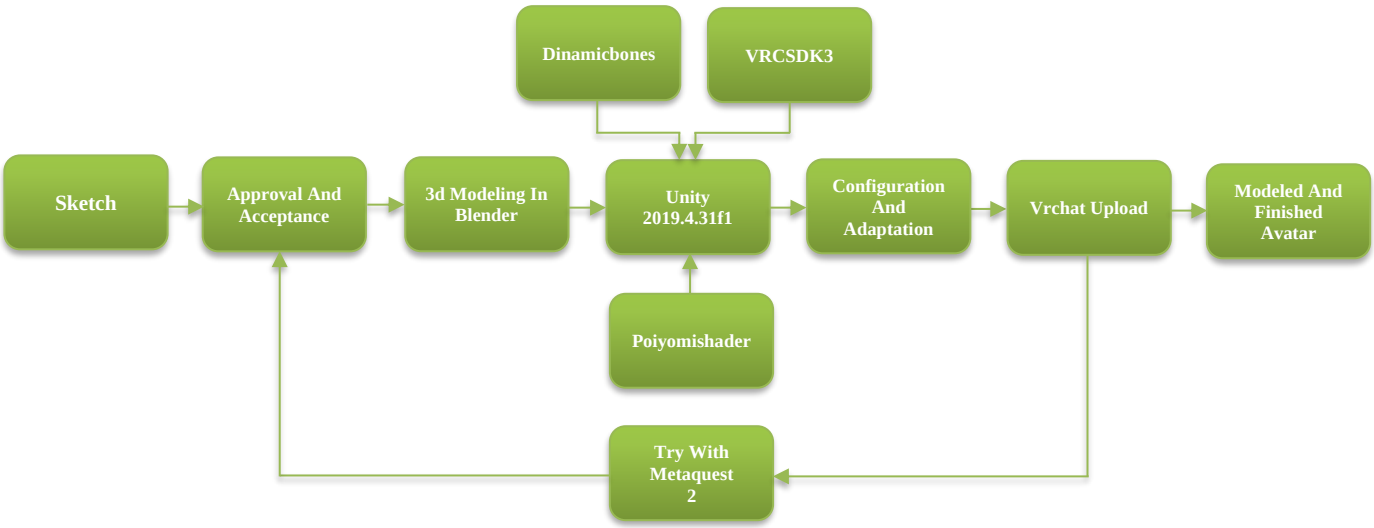

Fig. 3 Block Diagram

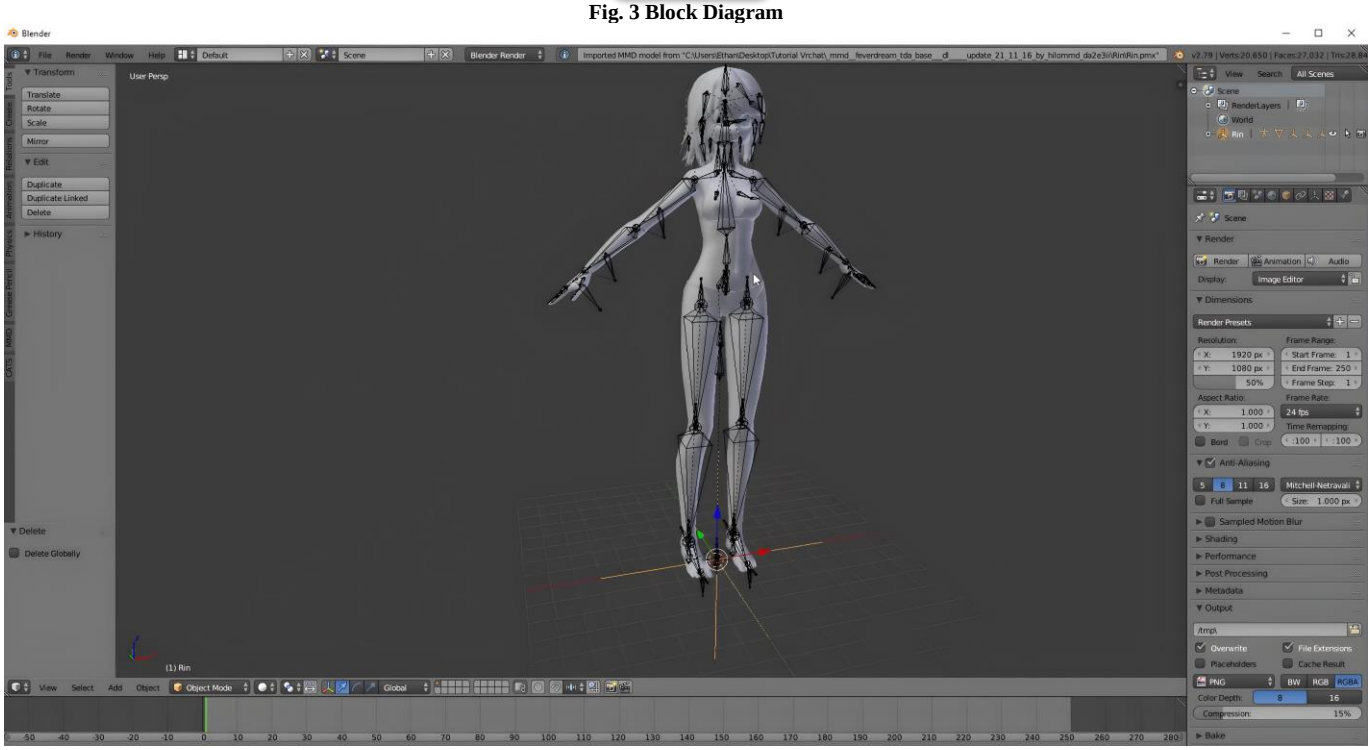

Fig. 4 Avatar design in blender

The polygon limitation is important as VRChat is restricted to 5000 polygons for mobile (MetaQuest2) and 20000 for Desktop users. These limitations also allow for greater immersion fluidity in terms of frames per second (FPS) and transmission quality between the glasses and the platform rendering.

Consequently, textures were created in both avatars, female and male. This led to an addition in both avatars, such as coats, because we wanted to generate an identity in the avatars. According to [23], baggy clothing allows a quicker adaptation between the user and the avatar. In addition, the logo of the University of Sciences and Humanities, its representative colors and details such as hair, skin and clothing colors, in general, were incorporated. The next step was to export the avatars from Blender to Unity, with previous preparation by both programs.

On the one hand, the blender was configured in .fbx export format, rooting the texture and material files. On the other hand, unity was configured in the 2019.4.31f1 version, installing the VRCSDK3 downloaded from the VRChat documentation, the physics by DynamicBones purchased in the Unity shop and adding a free shader PoiyomiToon v7.3.

Finally, the export of all files was done with some detail as the incompatibility of materials and their respective correction by the PoiyomiToon shader.

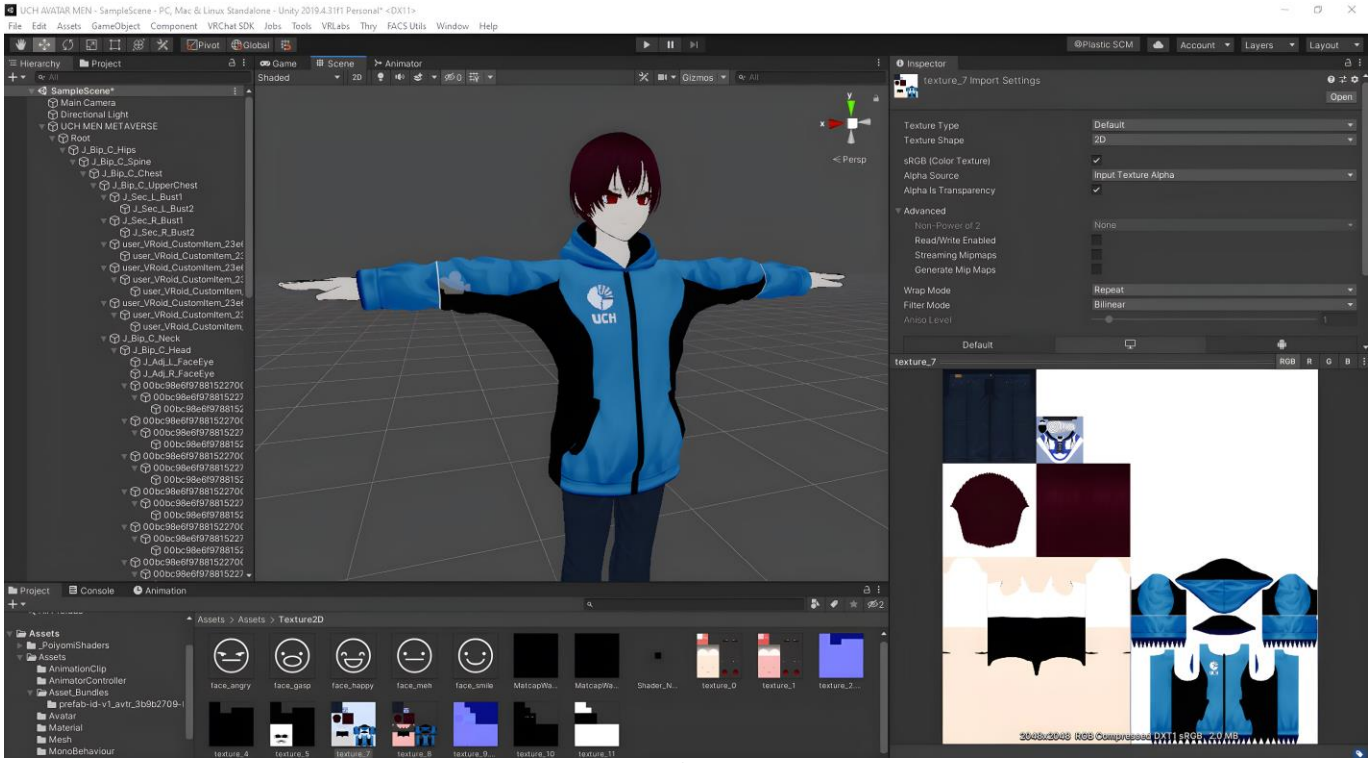

Fig. 5 Hierarchy of bones and textures

Fig.5 shows the export result, with the verification of textures and the respective bones for the haptic synchronization between the MetaQuest2 glasses. In the same way, the female avatar was exported, with the difference that the latter, having fewer polygons, presented fewer incompatibilities.

In addition, the existing textures can be modified in unity itself, and no regression to blender was necessary for editing. On the other hand, these textures correspond to a material modified by the Shaders (PoiyomiToon), which allows a varied configuration of contrast, rendering, compression, and overlay effects compatible with the VRChat platform. PoiyomiToon also allows a lighting configuration executed by its own script that helps the university logo to be displayed in any circumstance.

This shader is free to use; however, it has a paid version called PoiyomiPro, which is necessary to mention since both options were considered when choosing a shader and the free one was chosen.

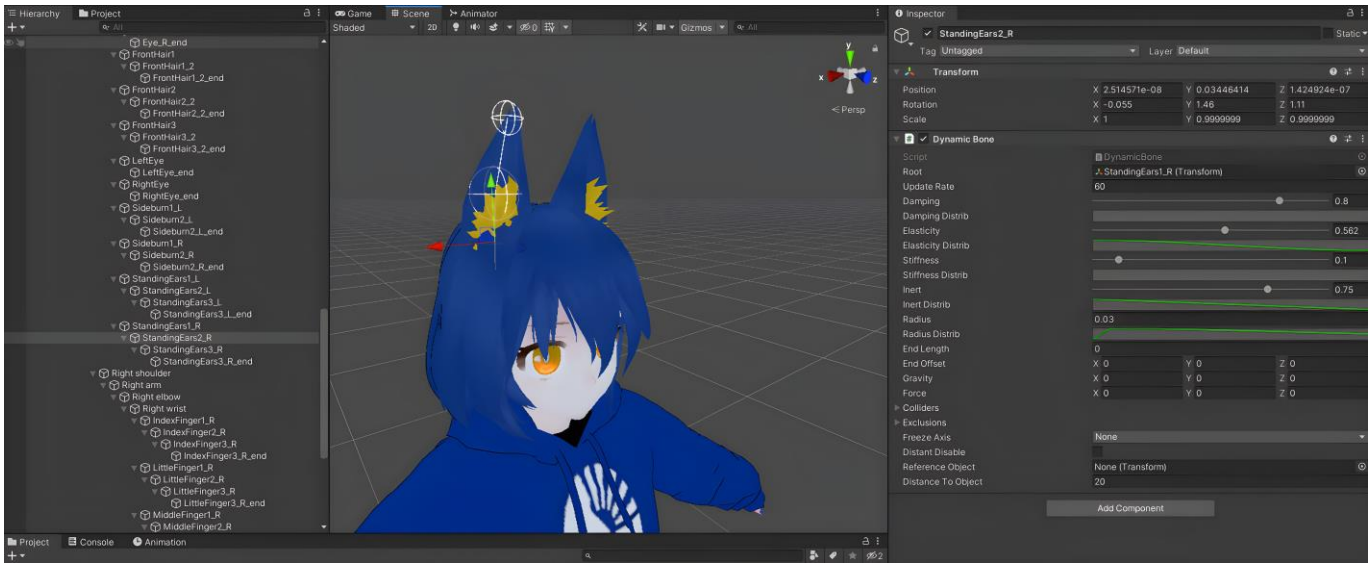

Fig. 6 Dynamic bones

Next, we proceeded to add and configure the physics and joints using DynamicBones, in which a parent bone is selected as a fixed point and the child bones to which gravity physics is applied. In Fig.6, we can see how the physics of the ears were added to the female avatar; with the addition of collision and elasticity within VRChat, it will be possible to interact with this object. The DynamicBones also allowed for additional realism to be given to the avatar regarding the modified parts' indirect movement in relation to the movements indicated by the user via the controls or the coordinates provided by the VR goggles.

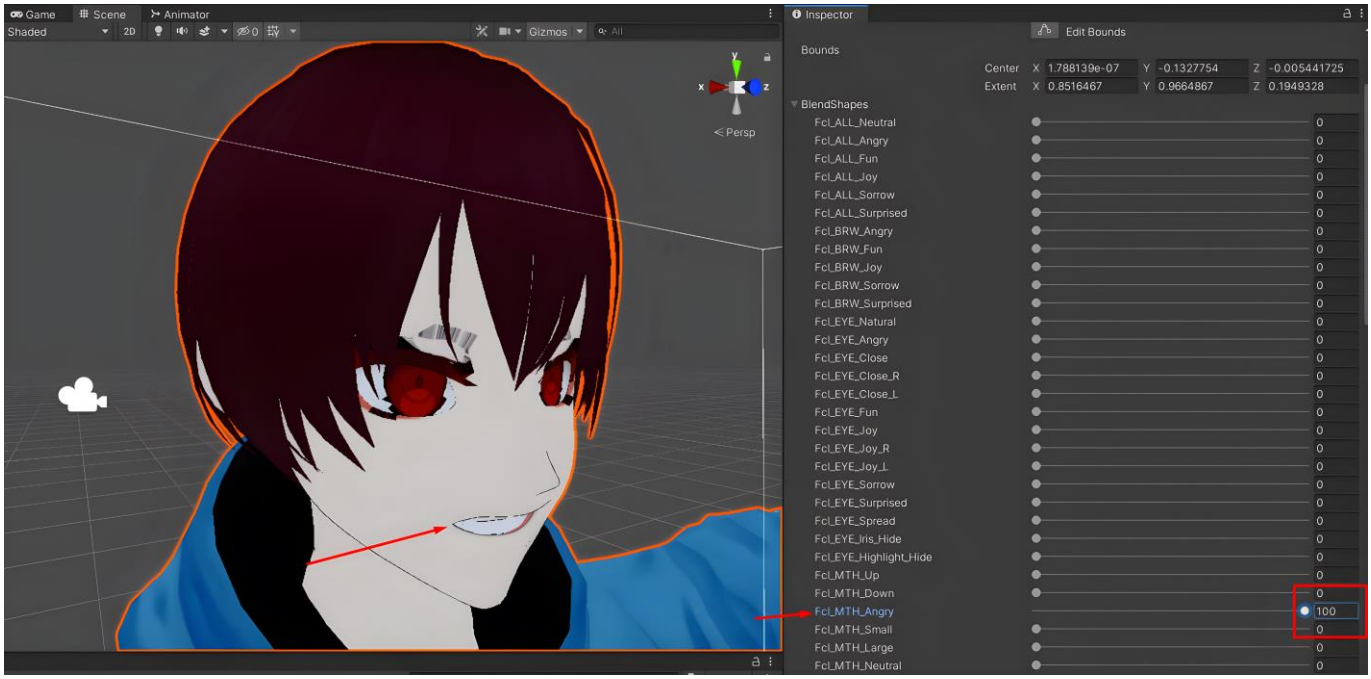

Fig. 7 Setting of facial gestures

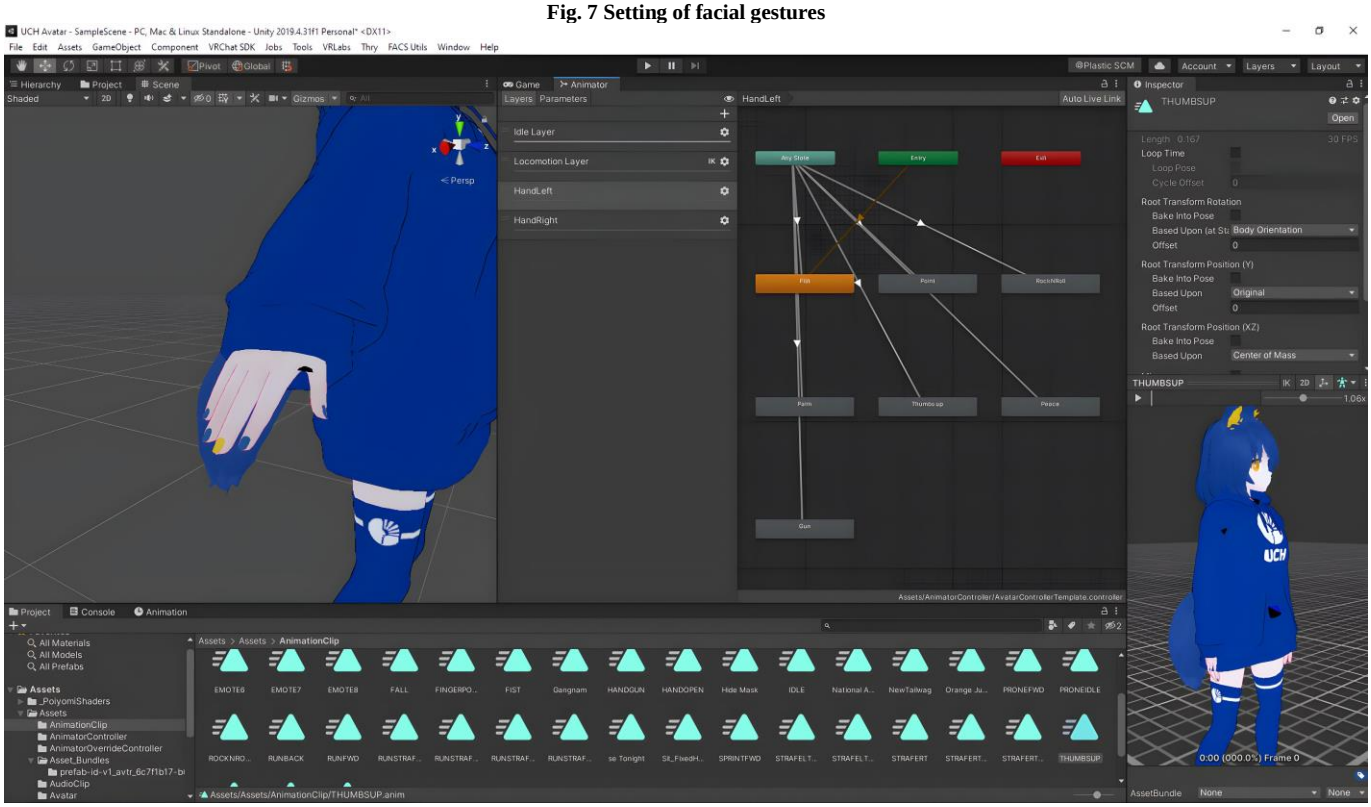

Fig. 8 Gesture layer programming

Once this configuration was finished, the facial features were configured, which are easily accessible in a configuration thanks to the Blender extension that articulates the avatar's face for movements such as the eyes, mouth, and eyebrows.

These gestures are also stored as animations that are then added and synchronized with the hand gestures. In Fig.7, you can see that the settings can vary between 0 and 100, which results in a more realistic movement. The same applies to the female avatar in development.

Unity through the VRSDK3 gives us the tools and models as far as hand movement is concerned. The HandsLayer is a universal configuration that fits all humanoid-based models, which was added to both avatars with some margin of error but not affecting gameplay.

The rooting of these two animations was then merged, using the Animator tool to create the respective layers and variables, which the VRCSDK3 extension will use to synchronize the MetaQuest2 controller signals with the avatar (Fig. 8).

These allow for 6 different hand positions, the point, rock and roll, peace, thumbs up, gun, and palm positions. These positions were merged with facial gestures such as smile, surprise, scared, salute, wink, and sleep. The first position is considered neutral because of the non-usability of the controller, so the neutral face gesture is merged with it.

The configuration is stored as an AnimatorController, which we will call FxLayer, for synchronization between the variables and the PlayableLayers needed for each Avatar configuration. The variables nested in this animation merge must correspond to a sequence given by VRChat itself, which can be found in the VRCSDK3 documentation.

The same is shown in Fig.8, where an Anystate is highlighted in which the FIST hand gesture is merged and so on with each animation.

Next, we proceeded to verify the avatar, running a preview that was built into unity. The result was successful, and then we proceeded to configure the VRCDescriptor extension as a requisite step to upload the avatar in VRCHAT.

As seen in Fig.9, the ViewPosition values must be configured for the position of the camera that the avatar will have as PointView. It is recommended to put it between the eyes, followed by the Lypsinc, which allows the movement of the lips when a person speaks within the VRChat platform; followed by the PlayableLayer as the FX layer, Hands layer, and Locomotion layer that allows naturalization of the avatar.

In this part of the design, it was verified and taken into consideration Emotes configuration, a part that is predefined by VRCSDK3. You can add dances or elaborate animations; however, for practical use, it was decided not to put this option since the avatar must be compatible with both platforms as it is MetaQuest2 and Desktop.

Finally, having configured the requirements for the Avatar load, we proceeded to compile the avatar. For this, as required by the VRCHAT requirements, we need an account with a minimum level of USER. Then, we verify the optimized level in Fig.10(a) included in the VRCSDK3 and verify any error, like the incompatibility of some external elements with the VRChat platform.

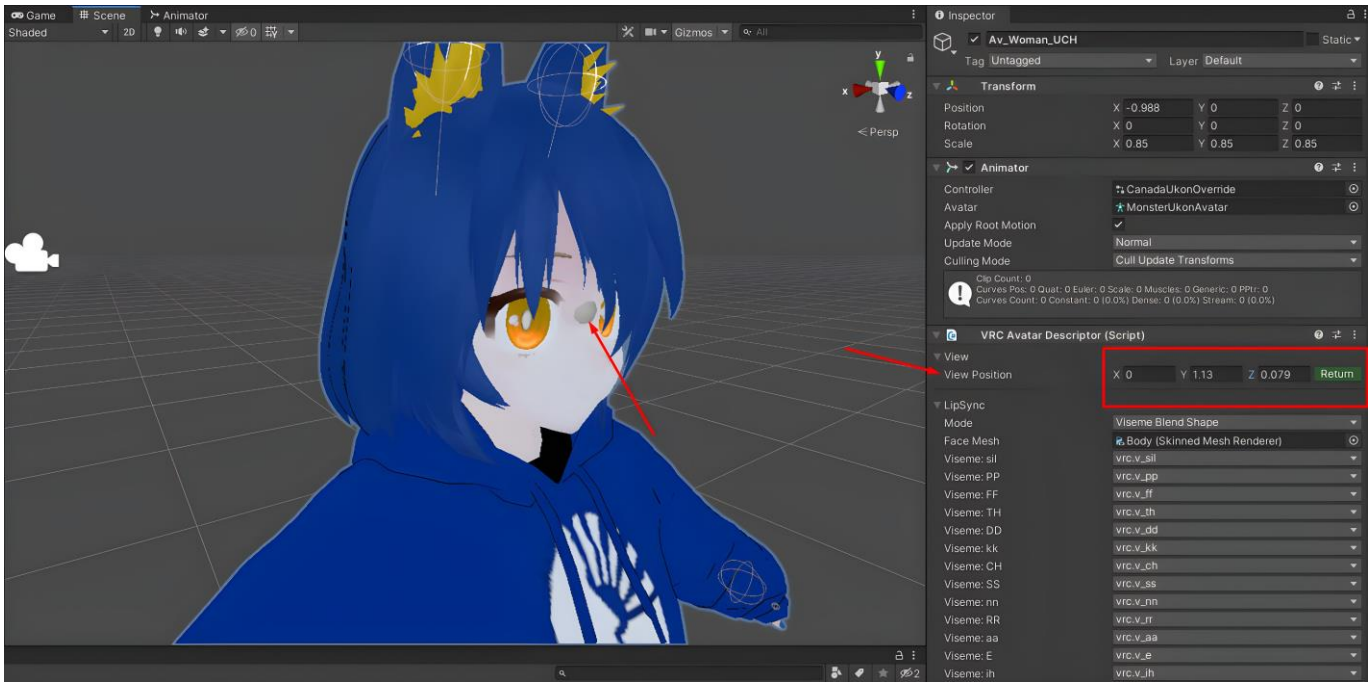

Fig. 9 Avatar descriptor setting

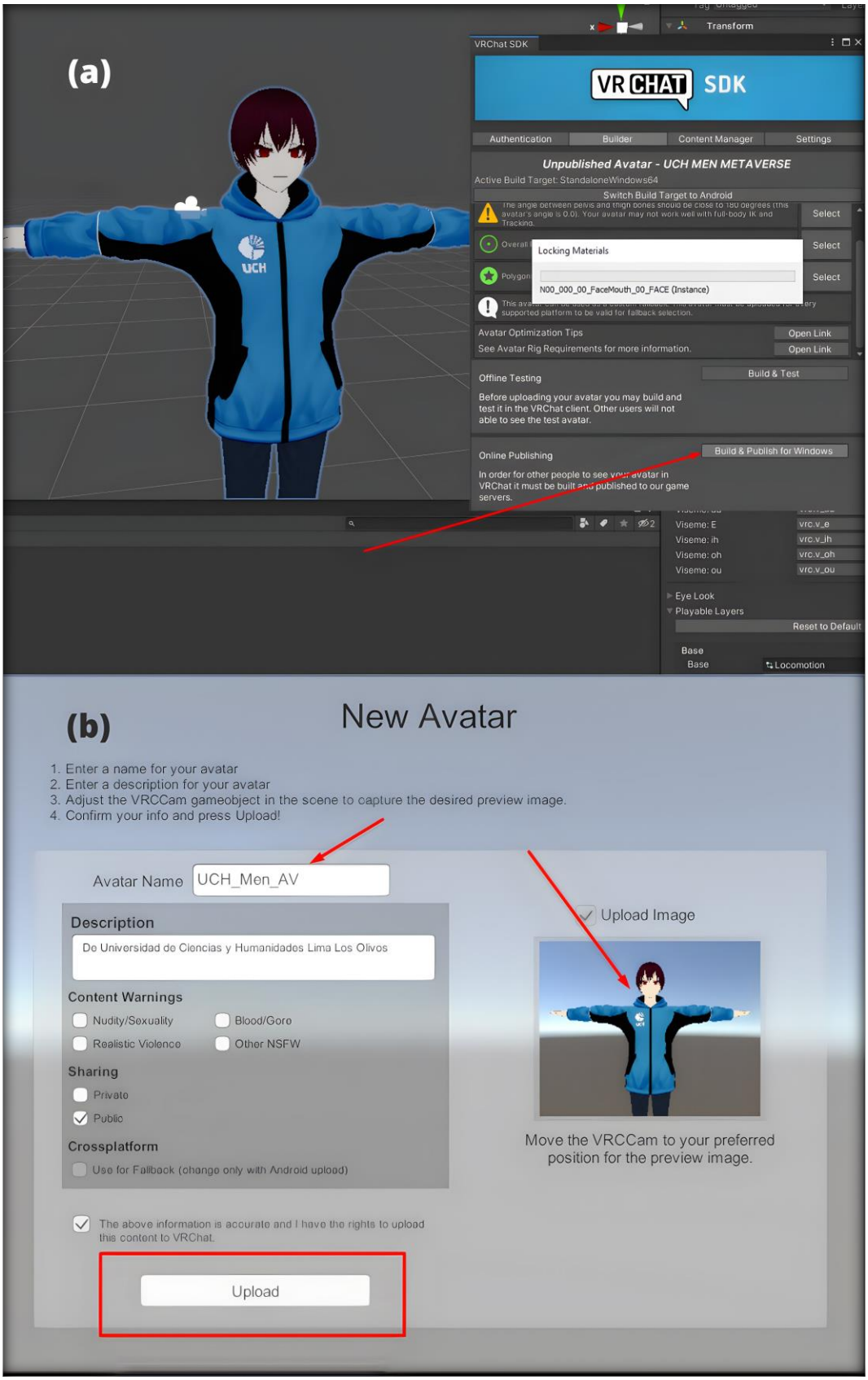

Fig. 10 (a) Testing and verification, (b) Avatar information

In Fig.10(b), the avatar publication was applied, where we were redirected to the avatar data form. In this section, we added information such as avatar name, description, the preview of the avatar and the mode in which you want to upload, where we chose the public mode.

Finally, the avatar is uploaded, and unity starts understanding all the avatar files in a .vrca format, which is the file compatible with the VRCHAT platform. With all this, the design of the avatar was completed. As a penultimate step of the methodology, a test point was established with various users where the level of identity and the verification of some of the points were evaluated.

The avatar was successfully evaluated with teachers and students from the University of Sciences and Humanities (Fig.11), and positive feedback was given regarding the use of the MetaQuest2 virtual reality glasses.

A hybrid focus survey was conducted, including both quantitative and qualitative questions, to determine the satisfaction level and identity of the 3D avatars.

Fig. 11 Immersive test with teachers

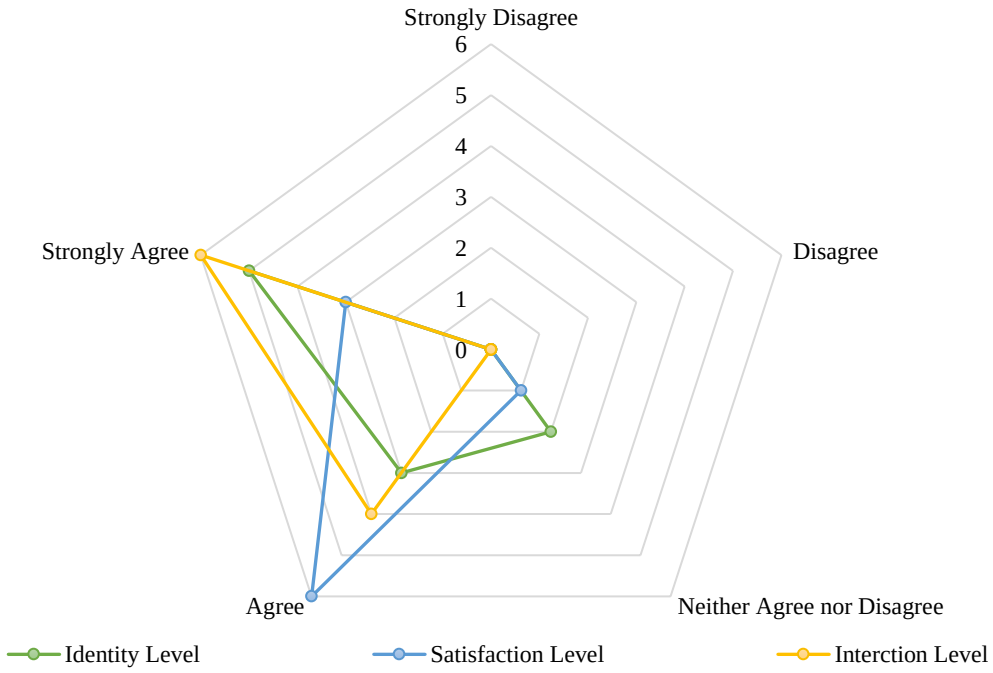

Fig. 12 Likert Satisfaction Chart

Favourable results were obtained, such as high values in the Likert scale for the level of interaction and identity (Fig.12), with 63.6% of respondents indicating that they were very satisfied and 36.4% satisfied. In addition, 81.8% felt that the 3D avatar reflects the students' personal style at UCH. In the qualitative approach, feedback was given regarding the level of personalization the avatars could have, with comments such as "Flying and changing size" or "More variety of clothing" being the most repeated.

6. Discussion and Conclusion

This manuscript presents the modelling and design of avatars for the metaverse with an agile Top-Down methodology which provides flexibility in the face of changes during the development of the creation. The design of avatars with the capacity to generate identity was proposed, which is why it was decided to take characteristic features of each genre and standardize them for university students. However, as mentioned in [23], an age range should be generated to encompass the diverse traits shared by university students fully.

On the other hand, using the MetaQuest2 virtual reality goggles offered us comfort and immersion of a high degree, thanks to its 3 tracking points (heads and both hands). Although there are other devices capable of processing up to 11 tracking points, the MetaQuest2 was able to offer a high degree of immersion and comfort [48], these would not be compatible with the various platforms of the metaverse such as RecRoom, Altspace, or HorizonWorld [43], [50]. In addition, the VRChat platform was the most suitable for creating the avatars as it had the necessary documentation and could include the avatar in the various VRChat worlds.

Regarding the 3D modelling of the avatars, unlike in [24], the result of our modelling in the blender was generated with relative ease and with a high acceptance rate in the same way as in [45], by generating a synchronization between the virtual avatar and the person [51] furthermore, that this synchronization can still be improved by a realistic choice of materials, by using specialized shaders and textures.

In respect of the information and working environment for virtual reality [26], our research agrees and demonstrates that an environment is necessary for the development of diverse lines of research since the metaverse consists of an infinite universe of possibilities. For example, medical simulations [28], [29], spatial and educational simulations, like the conclusions of [27], with the difference that in our research, a platform is used as a future testing environment. Regarding the style of avatar used in the present research, we concluded the same as [30] concerning a full-body avatar. Furthermore, the VRChat platform allows this integration and lends itself to Avatar modifications. However, a disadvantage of this decision is portability with other virtual platforms that do not have a built-in biped system.

While uploading the avatar to the VRChat platform, we noticed that the configuration was only supported for DESKTOP, which meant additional work to reconfigure the whole design and adapt it to the requirements VRChat gave in terms of Quest-compatible avatars. That is why in future modelling, we recommend using tools such as QuestTool, freely available on Github, to ease problems such as large textures, incompatible materials, and excess Physbones of an avatar.

As mentioned above, the results of this work will allow various researchers to know and explore the metaverse with a wide range of possibilities in terms of their lines of research. For this reason, open use of the avatars is invited by finding them on the VRChat platform under the names UCH_Men_AV and UCH_Woman_AV. The avatars are also expected to be used on the standalone platform of MetaQuest2 and VRChat. A high level of acceptance was reached in terms of identity and satisfaction. For future research, we will consider the qualitative results obtained as personalization and varied models to further increase the avatar's identity.

The results of the present research were as expected. As future work, it is planned to implement an augmentation of facial features with which to generate greater empathy when interacting with other users on the platform, on the other hand, also implement a system of individual personalization for each user. Finally, a superior tracking system, commonly known as fullbody-tracking, is expected to be added. This is expected to change the perspective between the user and the various applications given to the avatar.

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