PREMIERE
Performing arts in a new era

D4.3 – 3D Modelling and editing v1

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PREMIERE

Performing arts in a new era: AI and XR tools for better understanding, preservation, enjoyment and accessibility

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Executive Summary

This deliverable represents a comprehensive documentation of the progress made in the fields of 3D human avatar modelling and scene editing within the scope of our PREMIERE project. This document synthesizes the outputs of Tasks T4.3 and T4.4, illustrating the technological synergy between creating animated virtual humans and crafting interactive virtual environments for performance arts. It integrates innovative technologies to establish a robust framework for VR applications.

Task T4.3 addresses the process of creating and animating human avatars and explores the latest in pose-based and volumetric capture methods, along with advanced facial animation techniques. The deliverable evaluates various software solutions to create virtual human avatars, including Epic's Metahumans, Character Creator, and ReadyPlayerMe, providing a comparative analysis of these tools, detailing their strengths and limitations within the context of VR.

Task T4.4 delves into the creation of a user-centric 3D scene editing and modelling interface, designed to empower performance creators with the ability to shape virtual environments for arts performances. This tool, pivotal for hosting live performances (T6.2) and rehearsals within VR (T6.3), will serve as an integral component of the 3D Virtual Theater (T5.3) and integrate seamlessly with the PREMIERE Content Management System (CMS), enriching use cases 2 and 3 of the project. In addition, the interface will support USD for universal compatibility, ensuring a cohesive and versatile experience across the entire PREMIERE ecosystem.

Task T4.4 focuses on providing an interface that will allow creators to:

- Select from PREMIERE template scenes.
- Import their own scenes.
- Customize a scene by adding and modifying models and characteristics such as lighting.
- Integrate multiple views by adding and customizing multiple cameras.
- Review an environment with other creators in VR.
- Load and save customized scenes.

We will build an interface that will support users in building environments to host physical performances and rehearsals in virtual spaces. It will also provide creators with an interface in which to experiment with transferring a performance in a virtual environment and with the making of a virtual scene as part of the creative process. This tool will have the potential to find applications in different areas of the creative industry (dance, theater), bridging the divide between VR technologies and physical expressions of art, and connecting physical performances with the virtual world by enhancing the creative process with elements from digital technologies.

This executive summary reflects our commitment to providing functional interfaces that enable creators to both construct and animate human avatars, as well as to design and customize 3D scenes effectively. *D4.3 - 3D Modelling and Editing (v1)* captures our efforts to connect virtual and physical performance arts. By utilizing VR technologies, the tools facilitate the creative process, enabling artists to enhance their creative output with digital capabilities. This document not only records the development and integration of a human avatar creator and a 3D Scene Editing and Modelling Interface for the Virtual Theater but also lays the groundwork for future technological advancements in the fusion of art and technology.

Acronyms and abbreviations

Acronym	Abbreviation
USD	Universal Scene Description
UI	User Interface
VR	Virtual Reality
CMS	Content Management System
API	Application Programming Interface
SMPL	Skinned Multi-Person Linear
GLSL	OpenGL Shading Language
HLSL	High Level Shader Language
IK	Inverse Kinematics
BVH	Bounding Volume Hierarchy

1. Introduction

The goal of this introduction is to set the context for the deliverable, ensuring a clear understanding of its objectives and the comprehensive nature of the content that follows. *D4.3 - 3D Modelling and Editing (v1),* consolidates the results from tasks T4.3 and T4.4, offering a detailed account of the progress in virtual human avatar creation and 3D scene editing for virtual reality (VR) environments. It details the techniques and technologies essential for constructing digital avatars and settings that facilitate the virtual representation of live performances and rehearsals.

Section 3 addresses the development of 3D human avatar modelling from Task T4.3. It explores various modelling techniques for creating virtual human avatars and animation techniques such as pose-based and volumetric capture, alongside facial animation, to achieve realistic avatar animations suitable for VR. The section also evaluates different software solutions like Metahumans, Character Creator and ReadyPlayer.Me, discussing their features, ease of use, and how well they can be integrated into other platforms such as our 3D Virtual Theater.

Task T4.4, covered in Section 4, is centered on developing a 3D scene editing and modelling interface, enabling users to design and modify virtual environments. The interface's features and integration with the 3D Virtual Theater are aligned with the project's user requirements and use cases, which are outlined in Section 2.

The document is structured to clearly present the information. It starts with user requirements in Section 2, goes into avatar modelling technologies in Section 3, and then covers the scene editing interface in Section 4. Section 5 discusses the integration of these tools with other PREMIERE components, while Section **Error! Reference source not found.** outlines the workflow and technological challenges for creating these tools.

Concluding the deliverable, Section 7 provides a summary of the document and outlook on the implications and future development for the 3D avatar and scene modelling tools that will be implemented and integrated in the 3D Virtual Theater.

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2. Use Cases and User Requirements

There are two use cases in the PREMIERE project that are most relevant to the 3D Human Avatar Modelling (T4.3) and the 3D Scene Editing and Modelling tool (T4.4):

Use Case 2 (T6.3) – Live performance enhanced with VR technologies: This use case focuses on the enhancement of live performances that take place in physical venues, with the use of XR technologies. The performance will take place both in the physical venue and will also be transferred in a virtual environment with the use of motion capture and human avatars, where remote audiences will be able to view the performance using VR headsets.

Use Case 3 (T6.4) – Actor/Dancer Virtual Co-creation Performance: This use case will be applied in two different scenarios:

- Students will be able to attend virtual classes with an instructor in a remote location. The participants will see their human avatars performing in the virtual environment, and the instructor will provide feedback to the student.
- Performers and creators will be able to stage a performance rehearsal in a virtual space. Performers will practice in a reconstructed virtual stage, and co-creators will be able to experiment with different elements of the performance (e.g. light, sound, visualisations).

For Use Case 4, the 3D Human Avatar Modelling (T4.3) will be necessary but not as relevant as in the other two cases.

The requirements for avatar and scene modeling (T4.3 and T4.4) are gathered in Table 1 from the deliverable D2.1 – User Requirements from WP2.

RQ#	Description	Use case
RQ8.1	Accurate reconstruction and modelling of movement in human avatars based on performers' pose and motion analysis.	2, 3
RQ8.2	3D scene modelling and reconstruction of stage and props.	2, 3
RQ8.3	Mapping of real stage with virtual stage.	2

Table 1. Requirements for avatar and scene modelling. Source from D2.1-User requirements from WP2.

2.1. 3D Human Avatar Modelling – User Stories and Specific Requirements

In Table 2, we have all the User Stories for the three use cases that involve modelling 3D Human Avatars task (T4.3). During the first few months of the project, the consortium met several times and a few documents were exchanged in order to define both the user stories and the functional requirements of the project. The user requirements are documented in D2.1- User Requirements v1 and will later be revised in D2.2. A user story can be used to describe how different types of users could potentially use the Virtual Theatre (through goals) whereas the functional requirements explain what needs to be achieved to successfully reach these goals; this document focuses on the 3D world functional requirements with respect to the scene and the avatars.

User Story	Functional Requirements
Use Case 2 (live performance)	
Performing artists	
As a performer, I would like to perform on a virtual stage.	Create, import, and render performer's avatar in real time.

As a dancer, I want to have clear communication with another performer if I am wearing a VR headset, with the ability to see each other's whole bodies while we are sharing the same space.	Rendering several performer's human avatars in real time.
Use Case 3 (co-creation and rehearsing)	
Artistic creation - production	
As a choreographer/theatre director, I want to be able to see the performing stage with all the performers and objects from various angles.	Render performer's avatar.
As a choreographer, I want performers to have the ability to see and hear each other and their whole bodies.	Render of performer's human avatars in real time.
As a choreographer, I want to verify the dancers' accuracy of body postures.	Render performer's avatar. Proper accuracy in avatar rigging.
As a producer, I want dancers and choreographers to be able to send movement data and receive feedback orally during the creative process.	Render performer's avatar.
As a producer, I want the full cast of a performance, along with the directors, producers, choreographers, stage designers, etc., to be able to observe a rehearsal at the same time and regardless of any accessibility constraints.	
As a producer, I want rehearsals to be recorded to allow for a performer to later play it back and rehearse on their own.	
As a producer, I want the position, body shape, and expressions of a performer to be clearly conveyed to other performers in real time. At the same time, when performers at remote locations touch one another, haptic feedback should also be provided to signify the interaction.	Render of performer's human avatars in real time. Facial animations of the avatars in real time. Proper accuracy in avatar rigging.
Cultural and Creative industries	
As a dance company, we want to enable simultaneous rehearsals in two different spaces without diminishing but enhancing the physical experience.	Render performer's avatars.
Performing artists	
As an actor/dancer, I want to be able to see in real-time what my co-performers are performing, including their motions, gestures, and expressions, even if they are located somewhere else.	Render of performer's human avatars in real time. Facial animations of the avatars in real time. Proper avatar rigging.
As an actor/dancer, I want to be able to practice my performance using a recorded (non-live) performance of my co-creators.	Render co-creator human avatars. Create, import and render the actor/dancer human avatar.
As a dancer, to co-create or rehearse with a dancer who is not in the same physical space, I want to experience that we are together in real time.	Render two performers' avatars from different locations in real time.
As an actor, I would like to be able to perform alongside remote actors(s).	Render performers' avatar and avatars from remote actors.
Teachers - Students	
As an instructor, I want to be able to hear students and see their whole bodies.	Rendering of students' human avatars in real time.
As an instructor, I want to verify the students' accuracy of body postures.	Render students' avatars.
Use Case 4 (creation)	
Artistic creation - production	
As a choreographer, I want to explore abstractions of movements of the physical body in virtual space	Create Non-Realistic 3D Models of Performers.
As a costume designer, I want to create virtual costumes that enhance the movements of the performers.	Create synthetic virtual costumes for the performer's avatars.
Students - scholars	
As a dance teacher, I want to verify the dancers' accuracy of body postures.	Render performer's avatar.

Table 2. User Stories and Functional Requirements related to 3D Human Avatar Modelling task (T4.3).

According to the requirement *RQ8.1* (see Table 1), the movements of the virtual human avatars will be very important to have an immersive XR experience. In the case of using pose-based models (see Section 3.2.1 for more details), we will need to make sure that the mesh of the performer's avatars will deform properly to achieve the desired accuracy of the movements.

From the user stories in Table 2, the avatars must be **rendered in real-time** with **accurate rigging** to ensure precise portrayal of **body postures** and **expressions.** This is essential for performers in live performances (Use Case 2) and for those rehearsing or co-creating remotely (Use Case 3). Accuracy of the pose movements are required for dance performances and realistic **facial animations** for theatre performances.

The integration of **virtual costumes** is also a requirement for the dance-based artistic creation environment (Use Case 4) to enhance the movements of the performers. Furthermore, there is a requirement for **non-realistic 3D models of performers** to facilitate the study and presentation of movement, serving a range of creative and educational purposes.

Non-realistic 3D models in dance and theatre may be preferred for their ability to simplify and abstract movement, focus on choreography, promote inclusivity by representing diverse identities, body types and abilities. Technically simpler and more flexible, they transcend the limitations of human anatomy, offering creative freedom and exploration beyond realism.Based on the user stories, there is no explicit requirement for creating realistic or look-like avatars of performers. Such avatars, while visually appealing, come with higher computational demands and pose challenges in integration with platforms like our 3D Virtual Theatre. Additionally, ethical considerations must be taken into account. However, we have not dismissed the idea entirely. We have explored and compared various avatar creation options to make an informed decision aligned with our final requirements (more details in Section 3, we explore different software solutions in Section 3.3).

2.2. 3D Scene Editing and Modelling tool – User Stories and Specific Requirements

For the implementation of use cases 2 and 3, there is a requirement to construct a virtual environment (which we will refer to as "scene"), in which the data (motion capture data, human avatars, advanced visualizations etc.) of the performance or rehearsal will be projected. For the producing team's creative process to be extended into the virtual version of the performance, the PREMIERE consortium will provide creators with control over the design of the virtual scene, through the 3D Scene Editing and Modelling tool.

More specific user requirements for the 3D Scene Editing and Modelling tool were collected in WP2 (D2.1 – User Requirements) in the form of user stories and were then mapped to functional requirements for the 3D Scene Editing and Modelling tool:

User Story	Functional Requirements
Performers would like to have the opportunity to perform in imaginary virtual environments.	Importing or building 3D virtual scenes.
Creators, specifically choreographers, would like to explore different spatial situations, such as switching the position of the ground and the sky.	• Add models and assets to a scene • Move/rotate/scale assets
Remote audiences would like to be able to see a virtual reconstruction of the physical venue where a performance is taking place.	3D scene modelling and reconstruction of stage and props.
Performance creators would like to be able to select and customise multiple virtual environments and scenes.	Provide multiple scene templates.

Spectators, as well as performance creators would like to be able to view a performance or rehearsal from various perspectives.	Add cameras in the scene and provide multi-views.
As a creator, I want to be able to view a scene from different angles while designing it.	• Navigating around the scene • Fly-mode
As a creator, I want to be able to review and edit a scene in VR.	VR mode with editing capabilities.

Table 3. User Stories and Functional Requirements related to 3D Scene Editing and Modelling tool task (T4.4).

To stay within the scope of the project, the tool will be available to users to create and customize a scene only in advance of a performance or rehearsal. The creators will not be able to edit the scene in real time (while the performance or rehearsal is happening). In addition, there won't be concurrent multi-user editing functionalities, meaning only one user at a time will be able to make changes to the scene.

3. 3D Human Avatar Modelling

In the realm of computer graphics, different representations of users and AI agents are possible, from simplistic and cartoonish forms to realistic human figures and even fantastical beings conceived by our imagination. This deliverable, however, will focus primarily on anthropomorphically correct digital human representations, known as humanoid avatars.

These human avatars are distinguished by two main aspects: *morphology* and *behavior*. Morphology pertains to the avatar's physical form and the structural design of its 3D model, while behavior is about the range of movements the model can execute. Designing, creating, and animating avatars for VR applications are crucial aspects since they can greatly influence the level of immersion and, in the context of PREMIERE, affect the experience for both the performers and the audience.

Animating virtual humans in digital environments involves various technological methods. For instance, pose-based models utilize kinematic chains (essentially the character's skeleton) to animate the character (or the character's skin) often using motion capture data. An alternative method involves volumetric capture, which seeks to record a person's entire form and movement using multiple cameras. For facial animation, a common technique combines mesh morphing with computer vision. Each of these methods has its own set of benefits and drawbacks in terms of accuracy, computational demands, hardware and software requirements, adaptability, and crucially, the ability to expressively portray characters.

Both aspects that define an avatar – morphology and behavior – are crucial, yet depending on the type of performance, our focus may shift towards one over the other. For instance, in theatrical performances, precise facial animations are essential to convey the actors' expressions to the audience. Conversely, in dance performances, the accuracy of bodily movements takes precedence. Furthermore, in certain performances, the attire of the artists plays a significant role. Depending on the context, different techniques will be required to achieve the desired outcomes.

In the following subsections, we will delve deeper into the processes of modeling and animating human avatars for virtual environments, along with the technologies involved in this process (Sections 3.1 and 3.2). The advantages and disadvantages of these technologies will be discussed in Section 3.2.4. Following that, Section 3.3 will explore software solutions for avatar creation and the pros and cons of using each of them. In Section Error! Reference source not found. we will provide fundamental criteria in selecting avatar modelling technologies for our specific needs.

3.1. Humanoid Avatars creation

As highlighted in the introduction (Section 3), creating a humanoid avatar involves two key steps: developing the 3D mesh (morphology/appearance) of the avatar and enabling movement within this mesh. The initial stage is crafting the 3D model of the avatar. Following this, we must equip the mesh with the capability to move and deform accurately. This is primarily achieved through rigging processes and blendshapes (pose-based models). Alternatively, volumetric capture techniques offer another approach. With these, we can simultaneously capture both the avatar's model and its movements. However, to enhance performance, it is often necessary to transfer this detailed model onto a simpler, lower-resolution version. For increased control, this simplified model is then rigged, allowing for movement manipulation via virtual bones.

In Section 3.2, we will delve more deeply into the technologies used for animating virtual human avatars. **Error! Reference source not found.Error! Reference source not found.** provides an overview of the pipeline for creating humanoid rigged avatars, used in major libraries and software for avatar creation and animation in virtual environments[12].

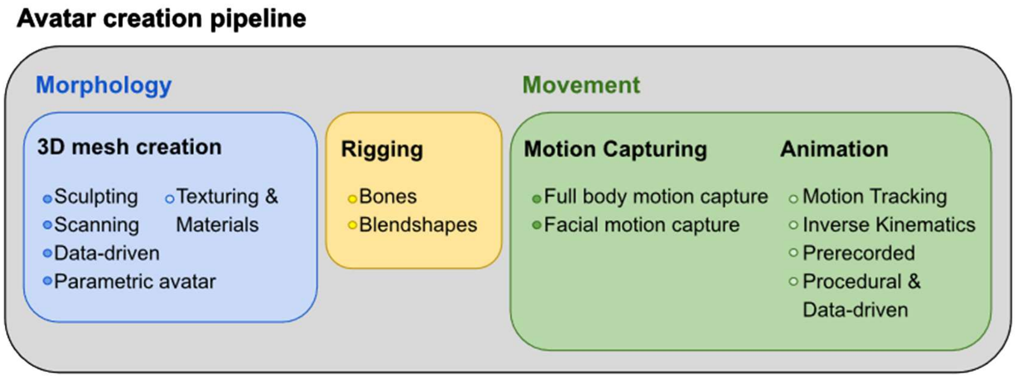

Figure 1. Avatar creation pipeline of humanoid rigged avatars used in main libraries and software available solutions[12].

3.1.1. Morphology of Humanoid Avatars

3.1.1.1. 3D Modelling

In 3D avatar modeling, the mesh is constructed from digital geometric primitives defined by vertices, shaping the avatar's final form. This 3D mesh can be created from scratch or modified from a base avatar, using various methods:

1. Sculpting: Manual deformation of primitives and vertices to achieve the desired shape, using tools like ZBrush[3], Blender[4], Maya[5], or 3ds Max[6]. This method, while flexible, can be time-intensive and artistically demanding.
2. Scanning: A quicker alternative, this method captures the physical topology of a model through imaging techniques (RGB and Depth cameras), converting surface information into digital 3D geometry. Techniques include optical laser-based range scanners, structured light scanners, LiDAR scanners, structure's IR sensors and multi-view stereo. Scanning techniques can be used as well for capturing not only the shape but also the movement of a person (see Section 3.2.2 for more detail).
3. Parametric Avatars: This approach uses adjustable parameters on avatars, often based on images or scans, to model a real person with reduced effort. Most used

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[1] Original information from: Gonzalez-Franco, M., Ofek, E., Pan, Y., Antley, A., Steed, A., Spanlang, B., ... & Lanier, J. (2020). The rocketbox library and the utility of freely available rigged avatars. Frontiers in virtual reality, 1, 20. https://doi.org/10.3389/frvir.2020.561558

[2] Image from: Álvarez de la Campa Crespo, M. (2023). Construction and technological development of immersive virtual reality for pain therapy. Doctoral dissertation, Department of Computer Sciences (CS).

[3] https://www.maxon.net/es/zbrush

[4] https://www.blender.org/

[5] https://www.autodesk.es/products/maya

[6] https://www.autodesk.es/products/3ds-max

avatar model representation in research is the Skinned Multi-Person Linear model (SMPL)[7]. Software solutions for creating human avatars from parametric avatars are Epic's Metahumans[8], Character Creator[9] and ReadyPlayer.Me[10].

4. **Advanced Techniques and Neural Networks:** Recent advances involve deep learning methods and neural networks for creating detailed avatars, including faces, clothes, and rigging from single images. Most of these techniques use the SMPL avatar representation. We can as well extract the motion from these methods.
5. **Retopology:** This involves optimizing the high poly model for the intended application, creating a low poly version for efficient rendering and animation. Really important for VR applications since the performance is critical.

3.1.1.2. Appearance / Texturing and Coloring

In 3D avatar modeling, texturing involves applying bitmap images to the model's surface, while materials define optical properties like color and shine. The process relies on UV mapping, where 3D surfaces are mapped to 2D textures, a procedure known as UV unwrapping.

Texture baking transfers details from high-resolution models to more efficient low-resolution versions. This step is critical for balancing detailed visual information with performance efficiency. Texturing can be complex, often requiring the combination of multiple images to achieve a cohesive appearance.

Shaders, essential for rendering, are scripts calculating each pixel's color based on light and material properties. They vary by environment, with popular shading languages including GLSL, HLSL, and Apple's Metal Shading Language. Physically Based Rendering techniques use a combination of different textures to make a surface look more realistic (see Figure 2

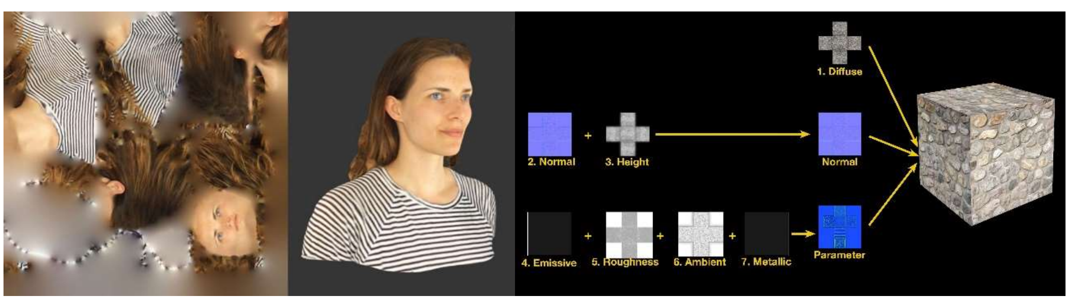

Figure 2: The texture on the left can be applied on a 3D mesh to give color[11]. A combination of different textures such as normal, metallic, and specular maps can be used to add more detail on 3D models[12].

3.1.2. Movement of Humanoid Avatars

In avatar creation, after modeling, we focus on rigging and animation to give avatars movement. Rigging involves adding a skeleton to the mesh, allowing each bone to control

[7] https://smpl.is.tue.mpg.de/
[8] https://www.unrealengine.com/en-US/metahuman
[9] https://www.reallusion.com/character-creator
[10] https://readyplayer.me
[11] Image from: https://3dscanexpert.com/tips/3d-scan-uv-texture-remap-c4d/
[12] Image from: http://www.doug56.net/PBRMaterials/

specific mesh regions, complemented by blendshapes for detailed surface deformations like facial expressions.

For animating 3D characters, methods range from keyframe animation, where animators manipulate frames as in traditional cartoons, to using motion capture data or physics engines for dynamic effects like cloth or hair animation. Real-time control, such as in VR, often uses motion capture systems or inverse kinematics (IK) for parts not directly tracked. We will explore in more detail the technologies for animating virtual human avatars in Section 3.2.

3.1.2.1. Rigging

The rigging technique enables realistic movement and deformation of 3D characters or objects. It involves the use of a hierarchical skeleton structure and associated control mechanisms to animate the model, as we discussed in deliverable *D2.5 - Performance Capture and Storing Protocols*.

As we exposed in the previous deliverable D2.5, we require several components to generate skeletal animations: Skeleton Structure (Rig), Vertices and Weights (Skinning), Joint Rotation and Translation, and Inverse Kinematics (IK). In a BVH file, we can store the hierarchy and motion of the avatar (see **Error! Reference source not found.**). But for storing finger movements and facial expressions, other file formats like FBX or C3D may be more appropriate. Another way to represent and store the motion of the avatar is to use the SMPL or SMPL-X formats, which is commonly used in research, especially with Computer Vision techniques.

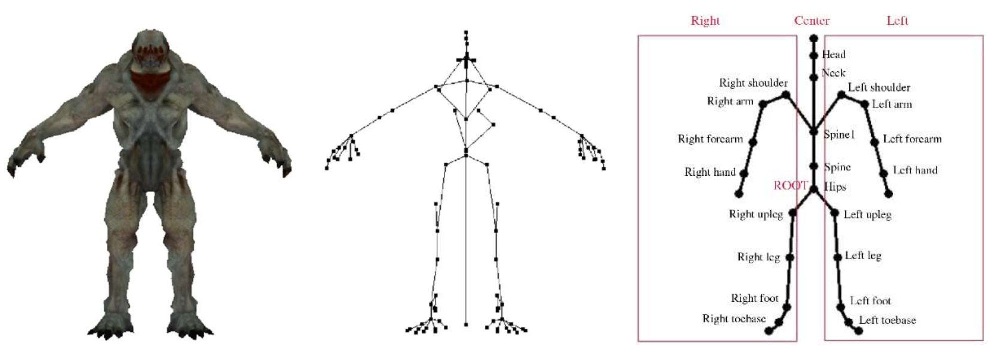

Figure 3. A character and its skeletal rig. Image on the right shows the common BVH hierarchy. Image from deliverable D2.5.

3.1.2.2. Blendshapes

To animate surface details, for example in an avatar, using a skeletal animation approach would turn it into a complex project. We can use different approaches to the basic bone structure, such as morph targets or blendshapes (see Figure 4), which is a vertex animation approach.

In the scenario of facial animation, a set of blendshapes (key facial expressions) are used to form a linear space of facial expressions[13]. Blendshapes allow animators to interpolate between a set of predefined shapes or poses to achieve a wide range of facial expressions

[13] Guenter, B., Grimm, C., Wood, D., Malvar, H., & Pighin, F. (1998, July). Making faces. In Proceedings of the 25th annual conference on Computer graphics and interactive techniques (pp. 55-66). https://doi.org/10.1145/280814.280822

and shapes. Then, face animation is constructed as a linear combination of blendshapes, which can be considered the units of facial expressions; these are shapes that approximate facial muscle actions or FACS[14] (Facial Action Coding System) motions.

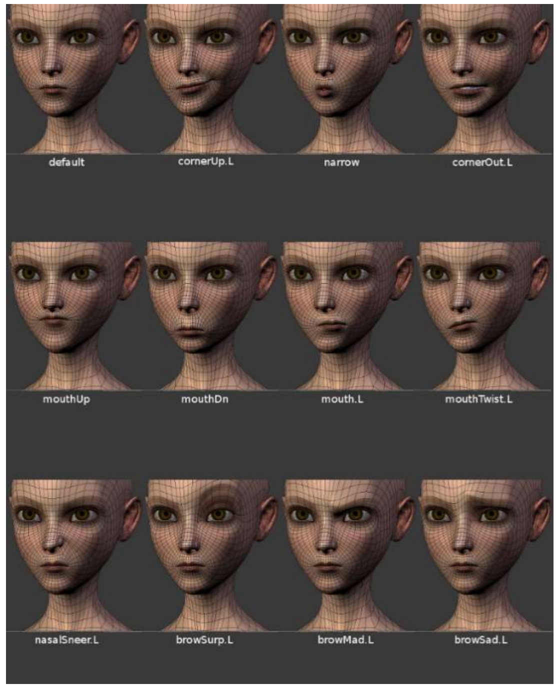

Figure 4. Facial blendshapes from the Blender Foundation Open-Source movie Durian. Image from deliverable D2.5..

3.2. Technologies for Animating Virtual Humans

As mentioned in the introduction of Section 0, there are several techniques to animate virtual human avatars. For example, we can use a skeletal structure or pose-based models (Section 3.2.1). Alternatively, we can directly capture the entire body and movement of a person using volumetric capture approaches (Section 3.2.2). Moreover, we will explore facial animation techniques (Section 3.2.3) and we will discuss the pros and cons of using each of the technologies (Section 3.2.4).

3.2.1. Pose-Based Models

Pose-based models rely on a digital skeleton to define the movement of the avatar. Each 'bone' in the skeleton influences certain vertices of the mesh, and animators can create movement by adjusting the bones' positions and rotations through keyframing or applying motion capture data. This technique is instrumental for animations where precision and control over the individual parts of the model are necessary. These pose-based systems allow for intricate animations, such as a character playing a piano or performing complex hand

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[14] Ekman, P., & Friesen, W. V. (1976). Measuring facial movement. Environmental psychology and nonverbal behavior, 1, 56-75. https://doi.org/10.1007/BF01115465

gestures. In deliverable D2.5, we already explored several mocap technologies that allow animating virtual human avatars from the input data in real-time and offline.

Additionally, on top of the pose-based models, blendshapes (which is a vertex-based model) are employed to animate finer details, like facial expressions, enhancing the avatar's lifelike qualities.

Several methods exist for animating virtual avatars using pose-based models. Pre-made animations offer ready-to-use movements, while motion capture systems provide a way to record and apply potentially in real-time human movements to the avatar (see deliverable *D2.5 - Performance Capture and Storing Protocols* for more information about mocap technologies). For parts of the avatar not directly captured, techniques like Inverse Kinematics (IK) help estimate their movements. This is particularly relevant in virtual reality, where users might control avatars with their own movements. While comprehensive motion capture systems capture all joint movements, simpler systems might only track key areas like the head and hands, requiring algorithms to estimate the rest of the body's movements.

Motion tracking in VR can be achieved with systems like Optitrack[15] or Vicon[16] for optical motion capture, or Xsens[17] and Rokoko[18] for inertial systems. However, the complexity and the price of these systems can be an impediment for consumer VR applications. More affordable VR systems, such as Meta Quest[19], typically track the head and hands only, sometimes supplemented with additional sensors for more comprehensive body tracking. The level of tracking accuracy can impact the user's sense of embodiment within the virtual environment.Prerecorded animations are another option, though they can be less suitable for VR environments where real-time body movement is essential. These animations, however, can be beneficial in specific scenarios, such as prerecorded performances. Procedural animations, driven by code rather than pre-set keyframes, offer a alternative for creating animations on the fly. Techniques like physics simulation and neural-network-based models are explored for creating more varied and realistic movements. However, it is important to ensure that these generated animations are realistic and natural to maintain immersion in virtual reality experiences.

3.2.2. Volumetric Capture Approaches

Volumetric capture represents a more holistic approach not only for obtaining the 3D mesh of a person (as mentioned in Section 0) but also for animating virtual humans. It involves capturing a person's movement in three dimensions using an array of cameras to record the action from multiple angles. This data is then processed to create a detailed 3D model that includes the nuances of the person's movement and shape. Unlike pose-based models, volumetric capture can record the additional aspects of the performance, capturing the subtleties of clothing movement and facial expressions. This method is particularly advantageous for creating highly realistic animations for virtual reality applications, where an immersive and lifelike experience is paramount. As previously discussed in Section 0, we

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15 https://optitrack.com/
16 https://www.vicon.com/
17 https://www.movella.com/products/xsens
18 https://www.rokoko.com
19 https://www.meta.com/quest/

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have outlined technologies that are adept at capturing both the movement and form of a person or object.

3.2.3. Facial Capture Techniques

Primary facial capture techniques involve the use of optical motion capture equipment that requires markers, exemplified by systems like Optitrack's Expression[20], or systems that do not use markers, instead relying on cameras paired with computer vision software to track facial movements. Additionally, Faceware[21] offers a commercial solution for facial motion capture that can be synchronized with full-body motion capture through Motion LIVE for iClone, facilitating the concurrent recording of facial, bodily, and hand movements. Moreover, another solution is Live Link Face Motion Capture technology which can be integrated into Unreal Engine[22].

3.2.4. Advantages and Disadvantages of Animation Technologies

When animating virtual human avatars, each technology has its own set of strengths and limitations. Understanding these can help in selecting the most appropriate method for specific applications.

Pose-Based Models:

- Advantages:
  - Precise Control: Allows for detailed manipulation of movements and poses, which is crucial for choreographed performances.
  - Customization: Suitable for creating specific animations that aren't achievable through generic methods.
  - Integration with Motion Capture: Enhances realism by applying real human movements to the avatar.
- Disadvantages:
  - Potential for Unnatural Movements: Especially in complex movements or when using IK for untracked joints.

Volumetric Capture Approaches:

- Advantages:
  - Realism: Captures nuanced movements and expressions, offering a highly realistic output. Excellent for capturing the full essence of a performance, including the movements of costumes.
  - Immersion: Ideal for VR applications where lifelike experiences are crucial.

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20 https://optitrack.com/software/expression/
21 https://facewaretech.com/
22 https://dev.epicgames.com/community/learning/tutorials/lEYe/unreal-engine-facial-capture-with-live-link

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- Disadvantages:
  - Equipment and Cost: Requires a significant investment in camera arrays and processing power.
  - Limited Flexibility: Once captured, modifying the animations can be challenging.
  - Space Requirements: Needs a controlled environment with sufficient space for setup.

Facial Capture Techniques:

- Advantages:
  - Detailed Expressions: Capable of capturing subtle facial movements for realistic animations. Critical in theatre where emotive expressions are key.
  - Integration with Body Motion: Systems like Faceware provide synchronized facial and body animations.
- Disadvantages:
  - Marker-Based Limitations: Systems requiring markers can be intrusive and limit natural performance.
  - Dependence on Equipment: Quality and realism depend on the sophistication of the capture technology.

Ultimately, the best technology will depend on the specific requirements of the performance, including factors like the complexity of movements, the need for facial expressions, the spatial dynamics of the performance, and the intended platform for showcasing the performance (live, broadcast, virtual reality, etc.).

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3.3. Software Solutions for Avatar Creation

3.3.1. Epic's Metahumans

Epic's Metahumans[23] is a free virtual human creator dedicated to the Unreal Engine, featuring a lot of dedicated control parameters to customize the avatars, although it is heavy in terms of system resource requirements. The visuals in Figure 5 illustrate the interface of

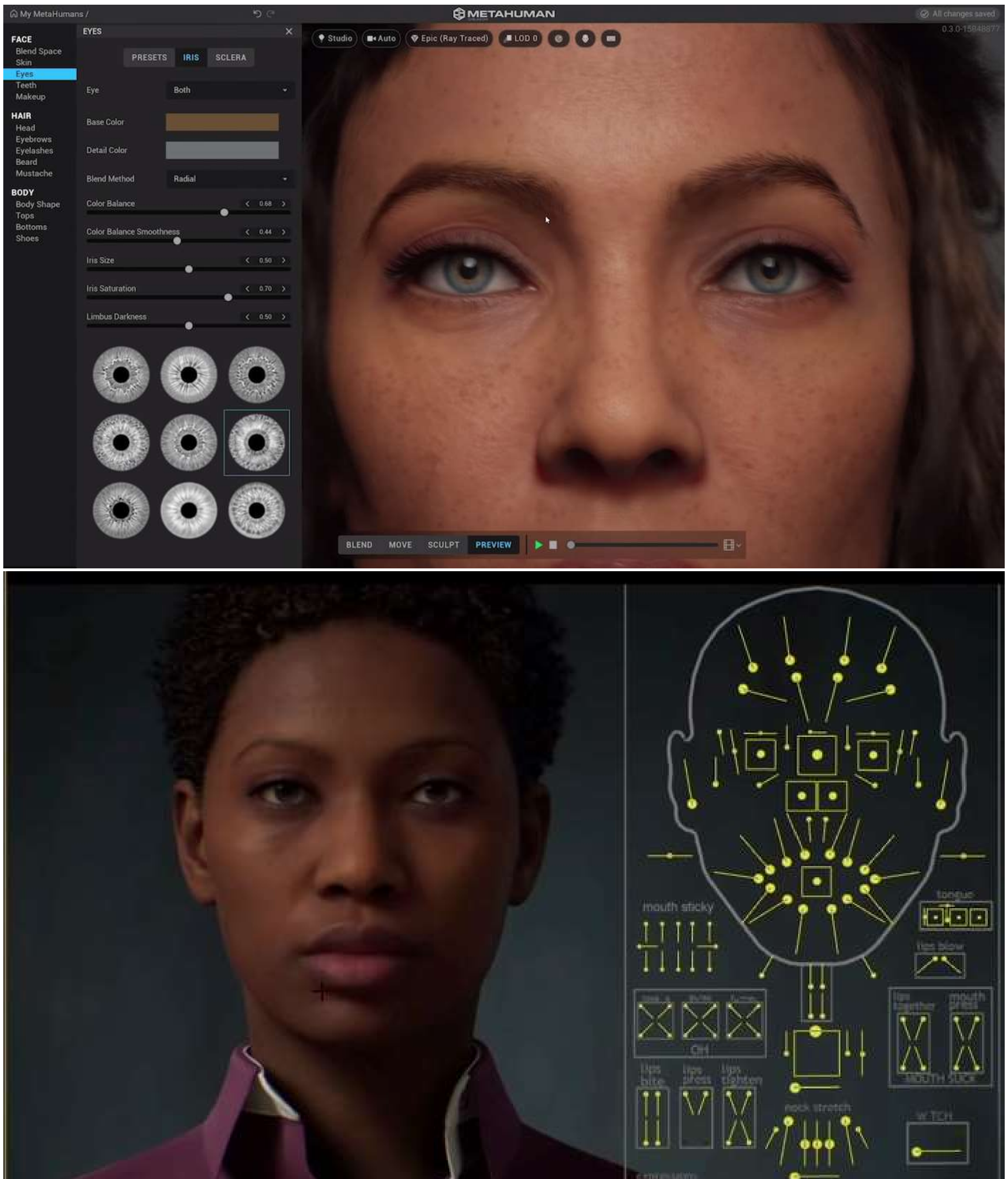

Figure 5. Interface of Metahuman creator.

23 https://www.unrealengine.com/en-US/metahuman

the Metahuman creator, showcasing the detailed customization of human face characteristics.

This tool is characterized by its comprehensive facial and body rigging systems and its diverse array of head designs, while offering simpler options for body shapes and clothing that can be modified externally. The tool is noted for its utility in creating avatars, allowing for the importation of an individual's facial features. The procedure involves generating a 3D model of a person's head through photogrammetry, followed by a cleanup of the model in 3D editing software. Further steps include adjusting the textures and removing unnecessary elements such as hair. The cleaned model is then brought into Unreal Engine to define facial landmarks, and subsequently into the Metahuman creator for final editing, resulting in realistic human avatars (see Figure 6).

Figure 6. Metahuman avatar results.

3.3.2. Character Creator by Reallusion

Character Creator[24] is a cost-effective commercial product designed for creating virtual characters. It stands out for its dedicated plugin that facilitates seamless integration with Unreal Engine, enabling users to bring their characters to life within a powerful real-time environment. Additionally, the software provides flexibility by allowing the export of characters to numerous Digital Content Creation tools (DCCs) like ZBrush, Blender, 3DS Max, Maya, and Cinema 4D.

Using Headshot 2[25], a plugin for Character Creator, you can transform a 3D scan into a digital twin. This technology not only preserves the intricate details from the original 3D scans but also simplifies the texture baking process, resulting in highly realistic and lifelike character models (see Figure 7).

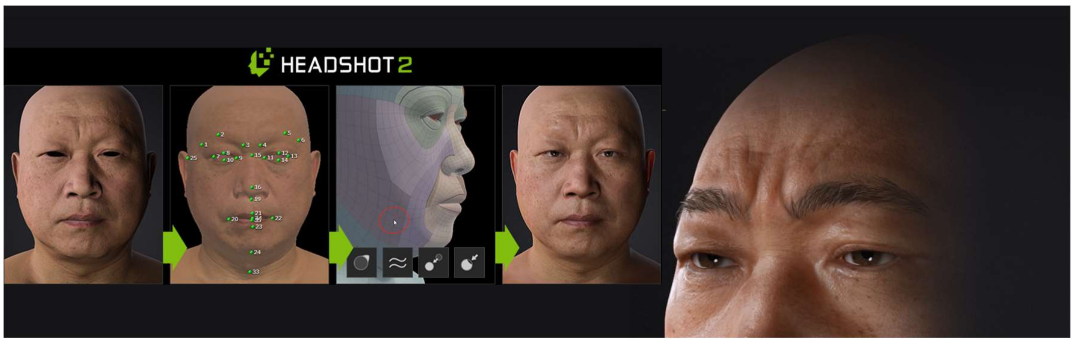

Figure 7. Image illustrates 4 stages of Headshot 2 and the result of a digital twin from a 3D scan.

[24] https://www.reallusion.com/character-creator/
[25] https://www.reallusion.com/character-creator/headshot/

Furthermore, Character Creator boasts the ability to quickly generate detailed faces from photographs in minutes. This is particularly beneficial for users looking to create characters with a specific look or to replicate real-world individuals accurately (see Figure 8).

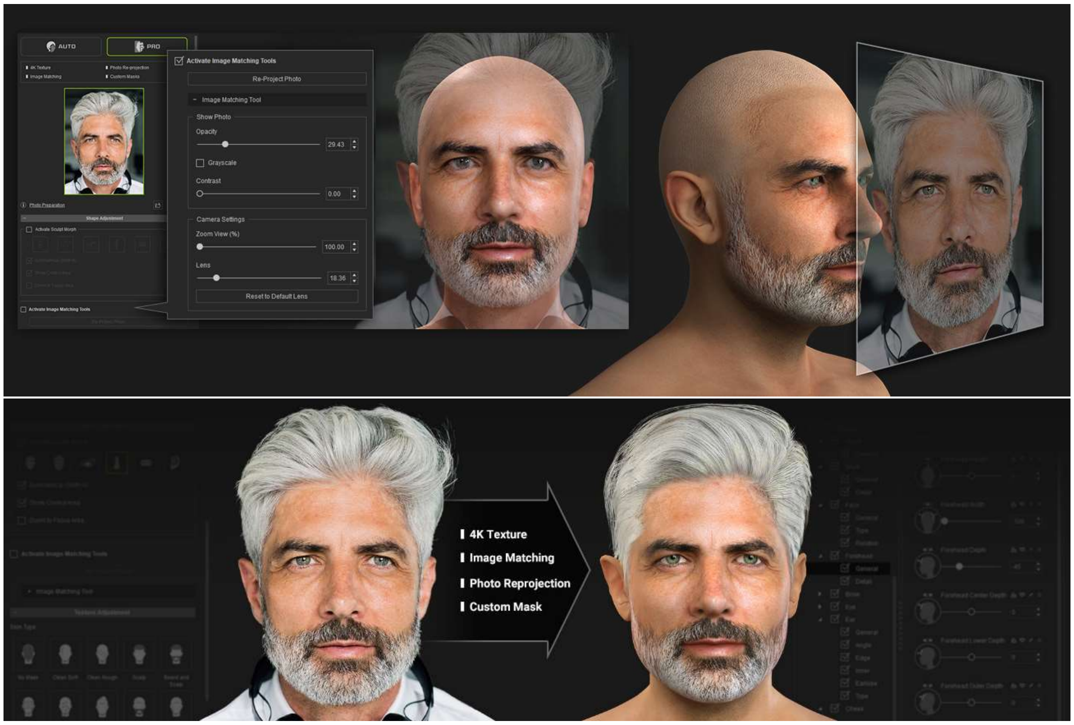

Figure 8. Headshot 2 generates 3D digital humans with detailed faces from single pictures.

Lastly, there is full support of Character Creator within Unreal Engine. The software offers a a range of specialized shaders for various components such as skin, eyes, hair, and teeth, enhancing the visual fidelity of characters and ensuring that avatars look as realistic as possible within the VR environment (see 9).

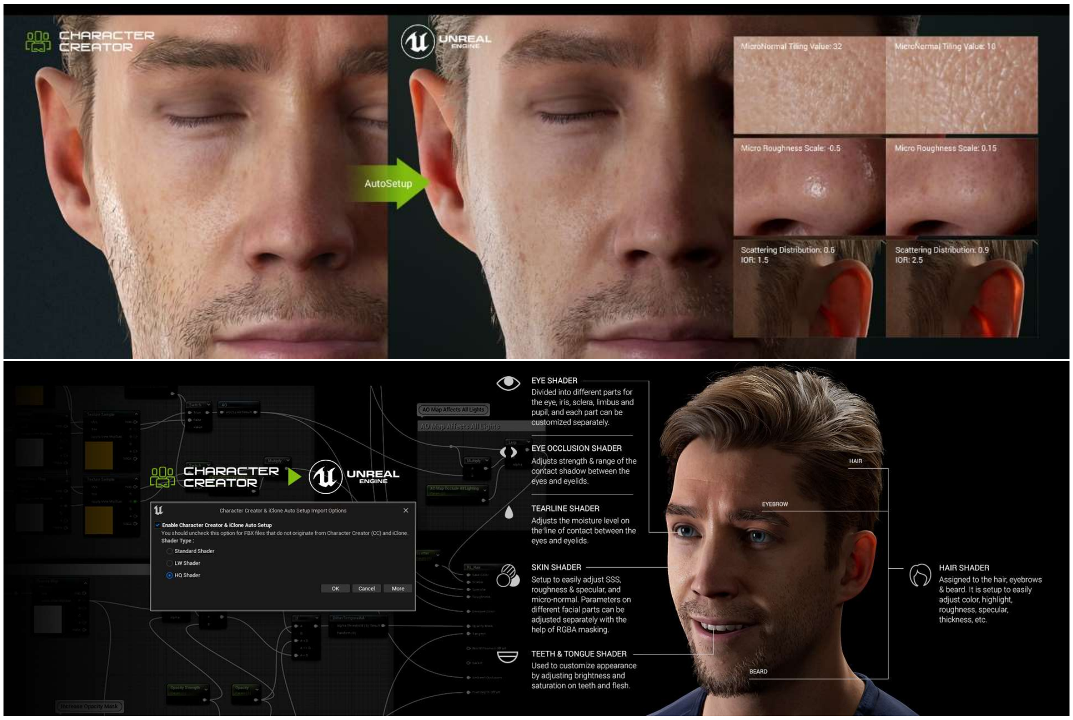

Figure 9. Full support of Character Creator within Unreal.

3.3.3. ReadyPlayerMe

ReadyPlayerMe[26] offers a unique platform for creating non-photorealistic, lightweight avatars suited for virtual environments. Users can easily generate a digital representation of themselves by uploading a photo through the platform's website. This process personalizes the avatar, moving away from anonymity by reflecting the user's real-world appearance. ReadyPlayerMe also provides an API that allows for seamless integration of these avatars into popular game development environments like Unreal Engine and Unity. This integration capability facilitates the use of custom avatars across various applications, making ReadyPlayerMe a versatile tool for developers and users alike in the creation of personalized virtual identities (see Figure 10).

[26] https://readyplayer.me/avatar

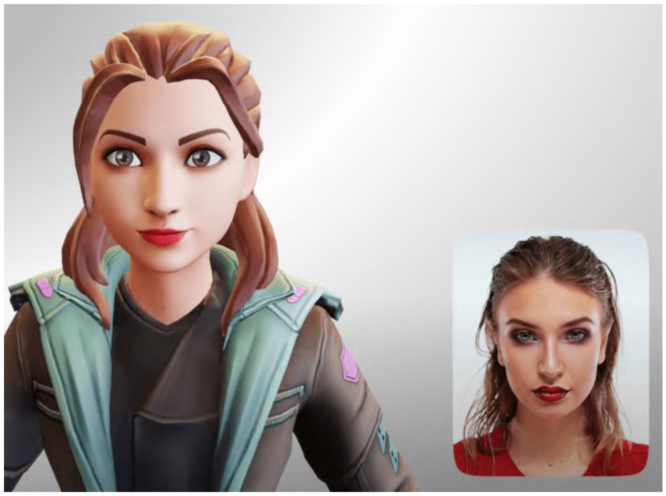

Figure 10. Virtual human avatar from a single frontal face picture.
Source: https://readyplayer.me/vrchat

3.3.4. Software Solutions Comparison

In comparing software solutions for avatar creation, a range of features must be considered. These features include realism, in-engine editing, performance, effort, and the ability to create a clone of oneself.

Epic's Metahumans: This high-fidelity avatar creation tool excels in realism, offering a vast array of customization options for facial and body features. However, its detailed control parameters and high-quality output come with significant demands on system resources. Metahumans perform best when used in a tethered environment, with limitations in lighting and rendering more than one character at high quality -.

Character Creator by Reallusion: Positioned as a cost-effective solution. It supports various DCC tools and facilitates the creation of lifelike avatars from 3D scans or photographs with moderate effort. The tool also offers full support within Unreal Engine, providing specialized shaders for enhanced visual fidelity.

ReadyPlayerMe: This platform is ideal for creating non-photorealistic, lightweight avatars. It simplifies avatar creation, allowing users to upload photos and quickly generate avatars with a decent level of realism. ReadyPlayerMe avatars are optimized for performance in XR environments and offer an API for easy integration with Unreal and Unity, suitable for unthethered VR applications.

When selecting a software solution for avatar creation, the decision will depend on the specific needs of the project. Metahumans might be chosen for projects requiring the highest level of realism and detail, while Character Creator serves well for those who need a balance between realism and system performance. ReadyPlayerMe is the go-to for quick creation and integration of avatars that are less resource-intensive, making it suitable for a wide range of applications, especially when working with unthethered systems where performance is a key concern.

In **Error! Reference source not found.**, we compare the different digital human representations including abstract characters such as SMPL-X format.

Feature	Abstract Characters (including SMPL-X)	Ready-Player Me	Character Creator	Metahumans
Realism		*	***	****
In Engine Editing	***	***	* (Materials)	* (Materials)
Performance (XR)	***	***	**	*
Effort	*	**	**	**
Clone yourself			***	****

Table 4. Comparison of different virtual human models for XR environments.

3.4. Fundamental Criteria in selecting Avatar Modelling technologies

When selecting technologies for avatar modeling, several fundamental criteria need to be considered to ensure the avatars meet the intended purpose and quality standards. These criteria include the realism of the avatars, performance in extended reality (XR) environments, the resemblance to real individuals, the effort required, the choice between in-engine editing versus external tools, and ethical considerations.

3.4.1. Realistic vs Non-realistic avatars

The choice between realistic and non-realistic avatars depends on the application's goals. Realistic avatars, which mimic human appearance and behavior closely, are essential in simulations where realistic human interaction is needed. In contrast, non-realistic or stylized avatars are suitable for more artistic or abstract applications, where creative expression is prioritized over realism.

3.4.2. Performance (XR)

Performance in extended reality (XR) encompasses the avatar's responsiveness and resource efficiency in virtual and extended reality environments. High-performance avatars should maintain fluid motion and accurate interaction without overburdening the system's processing capabilities, ensuring a seamless user experience.

3.4.3. Look-alike avatars

Creating look-alike avatars involves replicating the physical features of real individuals. This is crucial in applications like virtual meetings or simulations where representing actual participants enhances the experience. The technology chosen should accurately capture and render facial features, body shapes, and even expressions.

3.4.4. Effort

The effort involved in avatar creation includes the time, skill level, and resources required. Technologies that offer templates, easy-to-use interfaces, and automated features can significantly reduce the effort, making avatar creation accessible to non-experts, whereas more complex systems might offer greater customization at the cost of increased effort.

3.4.5. In Engine editing vs external tool

Deciding between in-engine editing and using external tools for avatar modeling depends on the specific needs of the project. In-engine editing allows for real-time adjustments within the virtual environment, beneficial for immediate feedback and integration. External tools, however, might offer more advanced features and precision, suitable for detailed modeling work.

3.4.6. Ethical considerations

Ethical considerations in avatar modeling involve respecting privacy, avoiding misrepresentation, and ensuring diversity and inclusivity. Technologies should not allow for the unauthorized use of personal likenesses, should avoid perpetuating stereotypes, and need to offer diverse options to represent various demographics respectfully.

4. Design of the 3D Scene Editing and Modelling Interface

4.1. A streamlined solution for the creation of 3D virtual scenes

In the fields of animation and film there is a plethora of software tools for the creation of 3D models and scenes. However, in the case of PREMIERE, we want to develop a tool for 3D scene modelling and editing that more specifically addresses the needs of the performing arts sector. As XR technologies are not yet widely used in the performing arts, there is still a lack of expertise and resources in employing 3D modelling and VR technologies among creatives in theater and dance, especially in smaller theater and dance companies.

Larger theater companies internationally, such as the National Theater in London, are already creating immersive theater performances using VR and AR technologies. However, in these cases, they cooperate with professional technical teams that have the expertise to create virtual environments for performances.

One of the PREMIERE project's aims is to make the use of XR technologies in the performing arts more accessible to creators. Therefore, as part of T4.4, the consortium will create and provide basic scene templates to the creators according to the design of the project's use cases. In addition, the functionalities and features of the tool will be tailored to the needs of the performance creators, for example providing the capability of changing the lights of the environment or adding multiple cameras and views for the spectators. The interface will be simple and user-friendly, so that even if there is no expertise in the use of 3D modelling technologies, the users will be able to customize the scene templates for use in a performance or rehearsal.

Finally, the 3D scene modelling and editing tool will be integrated with the other PREMIERE components, so that the virtual environments created within the tool will automatically be loaded into a virtual performance setting, along with the rest of the elements of the performance (human avatars, motion capture data, advanced visualizations etc). Therefore, the tool will fill in the gap of 3D modelling expertise required to create virtual environments to host performances enhanced with XR technologies.

4.2. Technical Implementation

The 3D scene editing and modeling tool will be developed using Unreal Engine 5.3, which will be used for the implementation of most of the PREMIERE components. The scene editing tool will be launched from the 3D virtual theater, with its full editing functionalities available in desktop mode, and some of its functionalities adapted for VR mode, using a VR headset and controllers.

An important element of the 3D scene editing tool's implementation will be the integration of USD, an open-source software toolset which enables the interchange of elemental assets (e.g. models) across applications and offers a way to "describe" a scene, assembling and organizing its elements into a unified, editable format. Integrating USD in the development of the 3D scene editing tool offers the following advantages:

- Users will be able to load their own 3D scenes into PREMIERE and edit them with the 3D scene editing tool.
- Users will be able to import their own 3D models into the scene.
- Compatibility across PREMIERE's different components (e.g. saving a customized scene in the 3D editing tool and loading it in the 3D virtual theater for a performance).

This means that creators have the flexibility to design their own scenes and models using external software, and then use PREMIERE's tools to enhance their design, as well as collaborate with their co-creators on the same assets and scenes.

USD also comes with an API that can be accessed within Unreal Engine using C++ or Python, to implement more specialized functionalities, which we will also use as part of the tool's implementation.

4.3. Features and Functionalities

In this section we describe the features and functionalities that the 3D Scene Editing and Modelling Interface will provide, along with initial technical specifications. First drafts of the user interface design for the tool are also shown in the figures that follow. There will be a main menu with the generic features of the tool, such as adding an asset and saving the scene, as well as asset specific menus, offering different options for models, cameras and light sources (**Error! Reference source not found.**).

4.3.1. Scene Management

- **Create a new scene from scene template:** The user will be able to select a ready-made scene from a list of scene templates. The scene will be selected either from the 3D virtual theater, which will launch the scene in the 3D scene editing tool, or from the tool directly.
- **Create a new scene from scene import:** The user will be able to import a scene (in USD format) that was modelled using 3rd party software and customize it.
- **Load a scene:** The user will be able to load a scene they were previously working on from the 3D Virtual Theater.
- **Save a scene:** The user will be able to save a scene with the customisations they made (organized in a USD format).

4.3.2. Assets

- **Add a model/asset from templates:**

PREMIERE will provide a list of assets from which the user will be able to select and add in the scene. The collection of assets will be stored in a remote server along with a JSON meta file (Figure 11) outlining the files' hierarchy. The meta file will be read by the tool to construct the endpoints in real time and populate the library of assets, as well as retrieve and load the selected asset in the scene locally.

```
{
    "objects":[
        "Bottle",
        "DustPan",
        "Broom"
    ],
    "furniture":[
        "Chair",
        "Table"
    ]
}
```


Figure 11 Example JSON file with storing hierarchy of assets.

The PREMIERE team will be able to update the asset collection online, eliminating the need for client-side updates of the scene editing tool. Assets will be separated into several categories, such as objects, furniture, nature, and other relevant categories which will be decided according to user requirements. All the assets that will be part of the 3D model collection of the 3D scene editing tool will be either created by the PREMIERE team, or open-source assets.

The assets can be stored in the CMS or in a separate remote server that will communicate with the CMS. The data for each asset will be organized in a folder including the model in USD format, as well as a thumbnail image for the asset list. The tool will also feature a search bar to browse through the asset library. The user will be able to drag an asset from the list and drop it in any location in the scene (Figure 12**Error! Reference source not found.**).

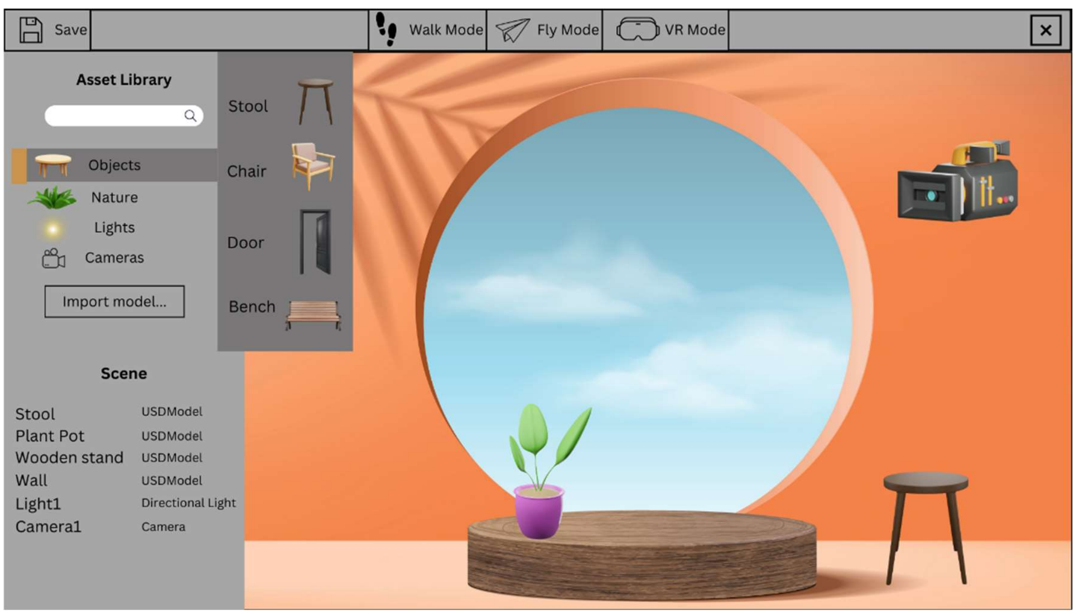

Figure 12 3D Scene Editing Tool Asset List

Import a new model/asset: The user will be able to load their own 3D models, provided they are in USD format.

Move/rotate/scale/delete a model: Every existing model in the scene will have a translation/rotation/scale gizmo which the user will be able to use to move the model in a different position, rotate it locally and scale it. They will also be able to change these properties from a window in the user interface (Figure 13).

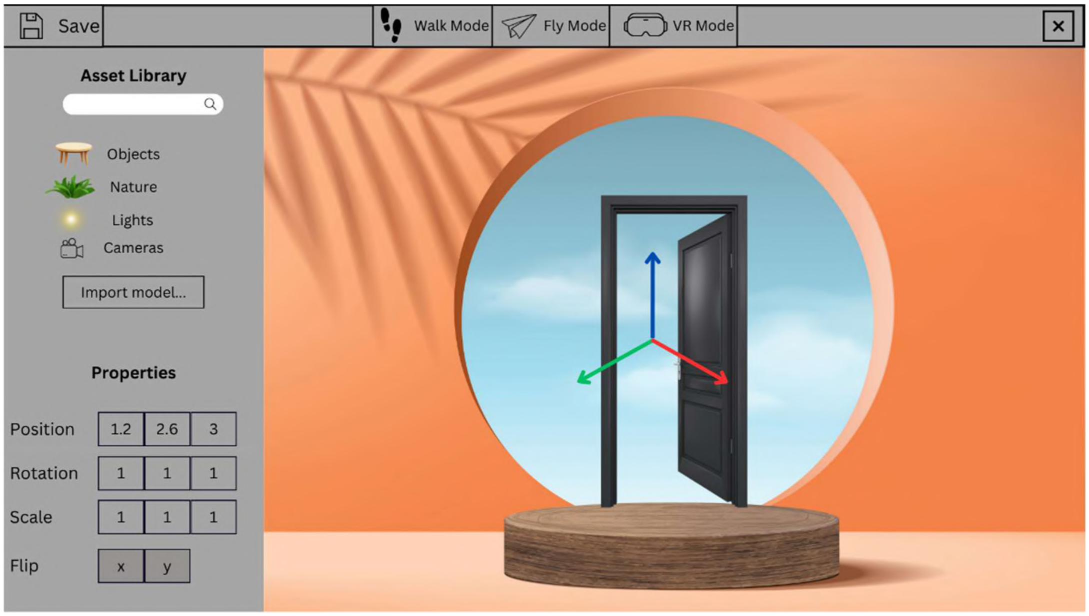

Figure 13 Transforming a model's properties (move, rotate, scale, delete)

4.3.3. Lighting

- **Add a light source:** The user will be able to add multiple light sources to the scene.
- **Modify/delete a light source:** Modify the light source's position and direction, change its intensity and colour, or delete it from the scene.

4.3.4. Cameras and Multi-views

- **Add a camera:** The creator will be able to add cameras in different positions to provide multiple views to spectators during a performance.
- **Modify/delete a camera:** Change the camera's position, direction and depth, or remove it from the scene.

One point that remains to be decided is how multi-views will be managed. One option we will consider is for the 3D scene editing tool to expose to the 3D virtual theater a list of the cameras in the scene (when the user saves the scene). Creators will then be able to manage the viewpoints of the performance from the 3D virtual theater as part of the performance's set-up. Multi-views may be implemented in the following ways:

1. The director/creators of the performance specify the timeline of the camera views during the performance, so that the camera changes at specific moments of the performance.
2. An interface is provided to the user in the 3D Virtual Theater from which they will be able to switch their perspective as they like.
3. A combination of the above options.

4.3.5. Navigation

While the user is editing the scene, they will be able to move around to review the scene from different vantage points. There will be simple movement (walking), rotation and zoom functionalities, as well as fly mode. The user will be able to switch between walking and fly modes. These functionalities will be mapped on mouse and keyboard buttons for the desktop mode, and on controller buttons for the VR mode.

4.3.6. VR Mode

Users will be able to use the 3D scene modelling and editing tool both on their desktop setup, as well as through a VR headset. Offering a VR view is essential, as creators will be able to review how their virtual environment will be perceived by remote spectators using headsets during a performance. It is also a useful feature for the creators to have access to the VR view while in the process of creating and customizing it. In addition, many of the editing features will be available in VR mode, so that users can make changes while viewing the scene in VR, using the headset's controllers.

4.3.7. Access and Permissions

Any individual creator with a user account in the 3D Virtual Theater will be able to use the 3D Scene Editing Interface to create and customize their own scenes. However, in the case of theater and dance companies, where a group of creators and producers will be working together to customize a scene for a performance, there has to be a group admin who will grant access to the group members to edit a scene using the tool. As was briefly mentioned in Section 2, only one user at a time will be able to edit a scene, holding a lock to the file while doing so. Other group members will be able to see the changes and make further customizations after the user saves it.

5. Integration with PREMIERE components

5.1. 3D Virtual Theater

5.1.1. 3D Human Avatar Modelling

The integration of virtual human avatars within the 3D Virtual Theater varies based on the chosen creation technology. Using tools like Epic's Metahumans or Character Creator, we need to create the avatars externally and then import them into the virtual environment. On the other hand, for non-realistic avatars, ReadyPlayer.Me's API enables an in-world integrated interface for designing and customizing avatars directly within the 3D Virtual Theater.

5.1.2. 3D Scene Editing and Modelling Interface

Users will be able to launch the 3D Scene Editing and Modelling tool through the 3D Virtual Theater. The tool will be either wrapped as a standalone tool in the implementation of the 3D Virtual Theater or will be developed as a part of it.

A new project for a performance or rehearsal will be created in a room of the 3D Virtual Theater. When the user is prompted to create the virtual environment that will host their project, they will be able to either load their own 3D scene, or create a scene based on a PREMIERE template. The 3D Virtual Theater will host this list of templates, and when the user selects one, they will be taken to the 3D scene editing tool where the scene will be loaded. The user will also be able to open a scene from their existing projects. Therefore, as part of this integration, the 3D Virtual Theater will need to hold references to the 3D scenes saved in the CMS by the 3D scene editing tool.

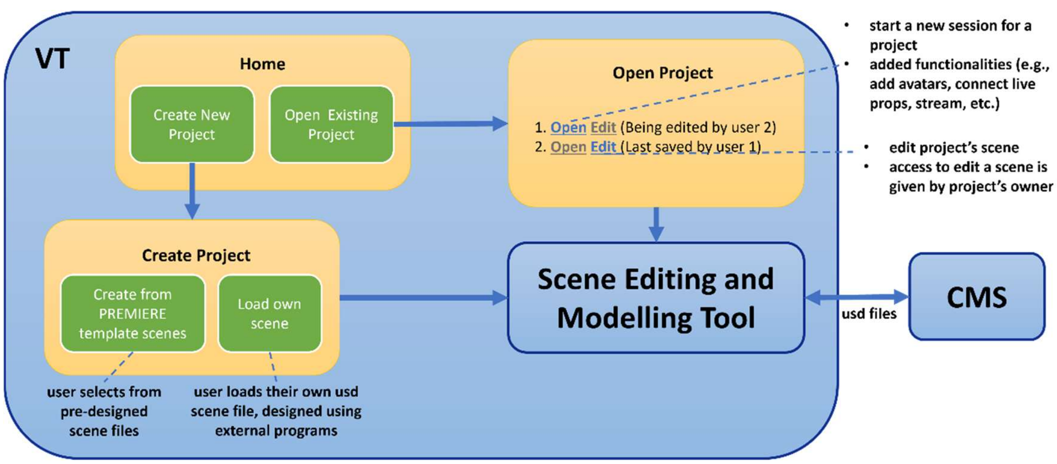

Figure 14 Communication between the 3D Scene Editing Tool, the 3D Virtual Theater and the CMS

5.2. Content Management System (CMS)

5.2.1. 3D Human Avatar Modelling

Our CMS will store a library of predefined avatars for reuse in subsequent performances. It will also archive all avatars created for specific performances, ensuring their availability for future use. Additionally, the CMS will manage custom clothing options that can be applied to various avatars, offering versatile costume choices for new performances.

5.2.2. 3D Scene Editing and Modelling Interface

The CMS will be used by the 3D Scene Editing tool as a storage location for all the assets and information necessary to load, customize, composite, and save a scene. The user will be agnostic to the CMS, as it will be used in the backend of the 3D scene editing tool to retrieve the necessary data. This data will include:

- Composited 3D scenes stored in USD format that can be unwrapped into a scene hierarchy when loaded in the tool.
- A collection of 3D models (in USD format) which will be presented in an asset library to the user, along with their meta data.
- Camera information to be used in the composition of multi-views by the performance creators.
- Meta data on the storage hierarchy of the data stored in the CMS.

All the information in the CMS will be accessed through URL endpoints constructed by the 3D scene editing tool backend, based on the meta data files in the CMS.

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6. Implementation Planning

6.1. 3D Human Avatar Modelling

In the development phase, we aim to leverage cutting-edge technologies for creating and animating avatars that can be integrated into a 3D Virtual Theater environment.

6.1.1. Workflow and Milestones (Roadmap)

Our roadmap to March 2024 involves the following key milestones:

Default Generic Characters: By January 2024, establish a library of generic character models, including androids and various body representations, for immediate use in productions.

Retargeting Tool Development: Develop a tool by the beginning of 2024 that can retarget generated motions from performances to different character models.

Integration Decisions: Depending on the preferred software, decide, after the revision process in March, between high-fidelity avatars from Epic's Metahumans or Character Creator, with an understanding that ethical considerations and model size could present challenges. Alternatively, ReadyPlayer.Me offers a solution for integrating a character creator within the 3D Virtual Theater, targeted for completion by the end of January 2023.

6.1.2. Challenges and Solutions

Several challenges are anticipated during the development phase:

- High-Quality Avatar Management: Managing high-quality Metahumans presents a challenge due to their large file sizes and resource demands. As a solution, we propose optimizing the models or employing more efficient, generic characters when possible. ReadyPlayer.Me can be a solution for this challenge.
- Ethical Concerns: The replication of actors' likenesses using high-fidelity avatars raises ethical questions. If we decide to use look-alike avatars, we will establish clear guidelines and obtain consent for the use of such representations.
- Performance in VR: Ensuring smooth performance in virtual reality, especially with untethered devices, is crucial. We will focus on optimizing avatars for better performance without compromising on quality.
- Integration with Existing Systems: Integrating new avatar creation tools with the current CMS and the 3D Virtual Theater could be complex. We plan to use APIs and dedicated plugins to streamline this process, particularly with ReadyPlayer.Me for non-realistic avatars, aiming for a seamless workflow.
- Documentation and Compliance: Keeping up with the documentation and aligning with the European Union's funded project requirements will be handled with regular updates and reviews of the development process.

6.2. 3D Scene Editing and Modelling Interface

6.2.1. Workflow and Milestones (Roadmap)

The implementation of the 3D Scene Editing Tool can be separated in the following tasks:

1. Designing and developing the user interface
2. Loading a scene from a remote server
3. Saving a scene to a remote server
4. Loading USD assets and meta-data from a remote server
5. Asset manipulation within the scene
6. Compositing a scene from USD components
7. User navigation in the scene
8. User controls for desktop mode
9. User controls for VR mode
10. Adding cameras and multi-views
11. Integration with PREMIERE components

Up to this point of the development cycle, we have completed the feature of loading USD assets and meta-data from a remote server into the scene, as well as parts of user navigation and adding cameras.

Our roadmap to September 2024 (M24) involves the following key milestones:

Scene Management: By January 2024 (M16), establish the functionality of loading a scene file in USD format from a remote server and composing the scene hierarchy into the scene editing interface. Also, the functionality of exporting and saving a scene (again in USD format) to the remote server.

Asset Manipulation: By February 2024 (M17), we will implement the capability for the user to manipulate the properties of assets and models within the scene (position, scale etc).

User Interface and VR mode: By March 2024 (M18), we will have a prototype of the 3D scene editing tool, including a first draft of the user interface and basic user controls in desktop and VR modes.

Cameras, lights and multi-views: By May 2024 (M20), implement the addition of cameras, lights and management of multi-views.

User controls: By July 2024 (M22), complete user controls for desktop mode and for VR mode with editing capabilities through the controllers.

Integration with CMS and the 3D Virtual Theater: By August 2024 (M23), we will complete the integration with the rest of the PREMIERE components.

Testing and piloting: By September 2024 (M24) we will conclude with the tool's testing and piloting, to resolve any issues.

6.2.2. Challenges and Solutions

- USD Integration: One of the challenges in the implementation of the 3D scene editing tool is the integration of the Open USD API with Unreal Engine. Even though Unreal Engine does offer USD related features, most of them are within the engine's editor and are used during development. The functionalities that can be accessed via blueprints or scripts are very limited and there is no access to the functions of the Open USD API. A particular requirement in the PREMIERE project is that we want to manage USD files and scenes at runtime, meaning that we cannot utilize the editor USD functionalities that Unreal Engine offers. Therefore, some development effort will have to go towards the integration of Open USD as an external library, or to find alternative solutions to manage the USD scenes and files.

- User Interface Design: Another challenge is designing the user interface for the 3D scene editing tool's two modes, namely the desktop and VR modes. We have decided that a separate interface will be implemented for each mode, to facilitate user interaction and create an optimal user experience. However, this doubles the development effort for the user interface implementation, something that can be minimized by cooperation among the technical partners of the consortium to reuse elements of user interface design across components of the PREMIERE project.

7. Conclusion

In conclusion, we exposed in this deliverable the 3D Human modeling tools that can be used to create custom avatars for virtual environments, as well as the features of the 3D Scene editing and modelling tool that will be integrated into the 3D Virtual Theater.

The development and integration of avatar technologies into virtual environments have made significant strides. The use of software solutions like Epic's Metahumans, Character Creator, and ReadyPlayer.Me has demonstrated the potential for creating both realistic and stylized representations suited for various applications, from performance arts to interactive virtual realities.

Our planned milestones will guide us in integrating these avatars into the 3D Virtual Theater, with an emphasis on addressing ethical issues alongside technical development. We will face challenges with making everything run smoothly, especially for VR setups that do not use wires, and we will look for ways to make high-quality avatars work without needing too much power.

Regarding the 3D Scene Editing and Modelling tool, we have looked into the motivation for implementing this tool as part of PREMIERE, and how it can increase accessibility in the creation of virtual environments for the performance arts. We have outlined the features and functionalities of the tool, as well as details on the technical implementation and initial drafts of the user interface design. We have set clear milestones that will drive the next steps in the development of the tool.

Finally, we've begun exploring the integration of these tools with other PREMIERE components, specifically focusing on the connection with the 3D Virtual Theater and the CMS.

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