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How to design an artistic narrative virtual reality experience based on sign language poetry

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ABSTRACT

This thesis discusses the design and the implementation of a virtual reality experience based on a sign language poem. Over the last decade, considerable progress has been noted in the development of Human-computer interaction field in both science and art. Significant technological advancement has been also made in virtual reality and motion capture systems as the equipment becomes even more affordable in consumer level. This thesis is based on the context of time-based narrative in virtual reality. A virtual performer avatar narrates a sign language poem in its original form and the virtual environment is constructed and deconstructed according to his/her hand gestures. The user is immersed into that virtual environment where they can feel their presence in the story or embody themselves into the virtual narrator. Motion capture, virtual reality, storytelling and sign language poetry are the key elements contribute all-together to the implementation of this user experience. The description of this pipeline design is the answer to the question of the title.

RÉSUMÉ

Ce mémoire aborde la conception et la mise en œuvre d'une expérience de réalité virtuelle basée sur un poème en langue des signes. Au cours de la dernière décennie, des progrès considérables ont été enregistrés dans le développement du domaine de l'interaction homme-machine, tant en science qu'en art. D'importants progrès technologiques ont également été réalisés dans les systèmes de réalité virtuelle et de capture de mouvement à mesure que l'équipement devient encore plus abordable au niveau du consommateur. Ce mémoire s'appuie sur le contexte de la narration temporelle en réalité virtuelle. Un avatar performeur virtuel récite un poème en langue des signes et l'environnement virtuel est composé et décomposé en fonction de ses gestes de la main. L'utilisateur est immergé dans cet environnement virtuel où il peut sentir sa présence dans l'histoire ou s'incarner dans le narrateur virtuel. La capture de mouvements, la réalité virtuelle, la narration et la poésie en langage des signes sont les éléments clés qui contribuent tous ensemble à la mise en œuvre de cette expérience utilisateur. La description de cette conception du pipeline est la réponse à la question du titre.

[DVD Cover]

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CONTENTS

PROLOGUE

The present master thesis has been conducted at the INREV laboratory at the department of Arts et Technologies of the Université Paris 8. The duration of the process until the completion was one academic year.

1. INTRODUCTION

1.1 Thesis Objective

The objective of this master thesis is to experiment on particular storytelling narratives combined with virtual reality and motion capture. Most of the focus will be given to sign language poetry. This project describes the design and development of a virtual reality experience that visualizes specific segments of a sign language poem and the user can experience it as a spectator by being in the virtual environment that is constructed according to the corresponding description of an avatar's signs that has the role of the virtual sign language poetry performer. This application also aims to immerse the user into a virtual environment, enabling them to live a reality different from ours. It's important to disclaim that this "other" reality is not supposed to replace our reality, or our natural way of living but to have an opportunity to be present in an extraordinary environment that we would not have the chance to simulate with another physical way.

This application is addressed to both deaf and hearing people. For the former, it can totally enhance their experience at maximum level since they can already comprehend the original meaning of the sign language poem. For the latter, and specifically the ones who don't have knowledge of ASL[1], they can immerse themselves to a depth where they can appreciate the sign language poem a lot more than just relying on the narrator that translates it in spoken language.

This VR experience is based on a time-based narrative. In other words, there is a specific scenario and series of events that happen through the pass of time. The user begins the experience by standing in front of the virtual sign language performer avatar and he/she can move freely while the series of events are happening without affecting their continuation. The user, as a spectator can observe the whole virtual environment that is constructed according to the avatar's hand gestures and he/she also has the ability to embody him/herself into the avatar. The virtual environment always depicts an avatar that performs the sign language poem and along with it through the time, the rest of the environment and characters are constructed and deconstructed. The design is based on digital storytelling techniques and guidelines for immersive virtual reality experiences, accompanied by the Human Machine Interaction Intelligence Principles.

1.2 Motivations

The motivations that led me to the elaboration of this dissertation are the following:

It is a fact that we live in a time when Human-Computer Interaction has made tremendous steps in both research and industry. The design and implementation of user interfaces is an integral part of any information system. Until recently, high-end equipment such as virtual reality kits and motion capture systems were accessible only to industrial studios and research centers. Over the years, the cost of sensors is decreasing, making the recording systems more available than before. This has given many people the opportunity to include research on these technologies, possibly combining them with others, and finally to harness them by implementing interaction systems and user experiences that contribute to the evolution of Human-Machine Communication.

The combination of Sign Language poetry and virtual reality is still at an early state of progress. That intrigued me to extend this domain and discover the possibilities of creative content that can occur by mixing these two fields. Despite the fact that the Sign Language Poetry is analog-based and Virtual Reality is digital-based, they have a lot of characteristics in common such as storytelling, filmlike techniques of expression and 3D visualizations (yes, the signs are performed in our physical space, thus they are three-dimensional visualizations). Therefore, I am amazed that this mix of fields is still nearly unexplored.

Lastly, I highly interested in comprehending the body movement and in general the biomechanics. Applying motion capture to sign language is also a fascinating topic to be occupied with. When I was conducting the motion capture session with sign language, I was not considering that at that moment the suit captured just movement data, but actual samples of a language that are saved in a digital form of movement, which is surprisingly the original form instead of a written text or a recorded voice message. That made me think that capturing sign language is also a way of preservation of cultural

[1] American Sign Language

heritage, because the language is preserved in its most original form which is animated movement that can be observed in 3D.

1.3 Thesis Structure

Chapter 1 summarizes below the contents of the following chapters:
Chapter 2 informs about the state-of-arts of the topics that are combined to accomplish this project. It introduces us to Storytelling and its derivatives and to Sign Language Poetry. Also, it describes the term of virtual reality and its characteristics and gives a historical overview of the ancestors of motion capture and the evolution of technology over the years. In addition, there are references to projects that are related with the prementioned state-of-art topics. At the end, it reports the principal rules of User Experience Usability. Also, it includes modern Motion Capture methods and their applications in various fields.
Chapter 3 describes the pipeline of the design and explains the technical methods and technologies that have been applied for the implementation of the VR experience.
In **Chapter 4** there is a review of the whole process and a conclusion to possible answers to my research questions. At the end, I make a reference to my plans for future extensions of the project.

2. THEORETICAL BACKGROUND

2.1 Introduction

In this chapter, a review is made on the history and the progression of Storytelling. After that, we introduce sign language poetry and its characteristics. Later, we proceed into virtual reality and the variety of its subcategories. Finally, a review is also conducted on motion capture, the origins and its current state-of-art. This theoretical background shares with the readers the research that I conducted before and during the design and implementation of the project. It also prepares them to get a first "taste" of what domains of expertise they should expect before they get deeper into the design and implementation process that are more technical.

2.2 Storytelling

Storytelling is the interactive art of using words and actions to represent the elements and images of a story in a way that trigger the imagination of the listener (Figure 1). Also, narration or storytelling is the art of telling stories to a common audience, with the aim of passing important messages. The first appearance of this technique dates back to the beginning of humankind, and historically it is the first attempt to make a story orally. According to Joseph Campell [25], the first form of storytelling are the myths, stories told by our ancestors to record and convey important happenings and events of the time to the younger generations. Typically, the content of myths was intended to glorify a hero, emphasize important events, or highlight patterns of human behavior. For many cultures of mankind, developed at different times, narrative was a form of communication and a means of teaching to younger generations. However, beyond the transfer of knowledge, cultural values, attitudes and values, narrative is used by people in their effort to harmonize with the environment and to understand human existence. Primarily, narrative has been used as a recreational medium that stimulates interest, and activates the audience. However, despite its entertaining role, narrative has been widely applied to education as a primary means of education in various educational systems and that has been a major evolution in educational research. The narrative, first appeared in the form of oral speech, was enriched with body expressions and gestures. However, one of the early stages of storytelling can be found in the form of drawings in cave walls. Later, with the appearance of written speech, the events began to be recorded and transmitted from generation to generation through stories, the most widely known form of narration. Over the years, as well as human progress, the stories began to become more and more visualized in the form of photographs represented in materials such as canvas, wood or metal and later recorded in the form of films in digital format.

Figure 1[2] How Storytelling affects the brain

[2] Image from Matteo Sciutteri: https://gamedevelopment.tutsplus.com/articles/interactive-storytelling-part-1--cms-30015

Prerequisites for successful use of Digital Storytelling as a learning strategy
According to Robin and Pierson [23], digital narrative can be used as a learning strategy at all levels of education. However, in order to develop the ability to produce digital narratives, an appropriate teaching approach is required. The digital narrative must meet the following conditions so that it can be used effectively and successfully in education:

- Key question: The digital narrative should include key questions that attract the attention and interest of the listener and which should be answered at the end of the story.
- Visual Angle: The digital narrative should clearly summarize the main point of history and the perspective from which it is presented.
- Emotion: Digital narratives should convey and "awaken" feelings to the listener. Through emotions (e.g. love, anger) the listener is watching more actively narrative.
- Sound: The words accompanying the visualization of the digital storytelling must be carefully selected to help the listener easily understand the story.
- Music: Music chosen to accompany the episodes of a digital narrative should enhance the audience's emotional load to the desired result.
- Evolution rate: The pace at which history evolves is critical in keeping the audience's interest. A story in which events evolve very quickly can tire the listener who cannot follow the plot and link the information he receives. Conversely, an evolving story repels the audience's interest. The rate of evolution of digital narratives should vary depending on the messages being transmitted each time. More specifically, the rhythm of the story should vary depending on the choice of visualization and sound support of each episode in order to effectively transmit the messages.
- Content Economy: Digital stories should be carefully structured to maintain a balanced use of audio and visual data for the transmission of messages.

Digital narrative can be used at all levels of education, including adult education and lifelong learning, in all disciplines and can be combined with many other learning strategies such as role playing [24]. Finally, in order for this strategy to be effectively implemented, it should begin with the reaction of learners to a stimulating experience and end with the sharing of digital narratives among learners and their commentary.

2.2.1 Action-based Narrative

Action-based narrative is synonym to interactive storytelling and is a form of digital narrative where the storyline is not predetermined. It is a narrative technique, sometimes used in literature, film, hypertext websites and other narratives, where events are portrayed, for example, out of chronological order or in other ways where the narrative does not follow the direct causality pattern of the events featured, such as parallel distinctive plot lines, dream immersions or narrating another story inside the main plot-line. It is often used to mimic the structure and recall of human memory, but has been applied for other reasons as well. It is worth to be noted that the intent of combining interactivity and storytelling in not something new. It is deeply rooted in our cultural DNA varying from the earliest forms of drama to videogames. This temptation is not a collective decision made by a community of storytellers but it has been born by new audience's behaviors in an accelerating and overly connected world.
It has to be noted that the intent of combining interactivity and storytelling has not been spawned by the Internet alone. It is deeply rooted in our cultural DNA, from the earliest forms of theater to videos games.
Neither has it been a collective decision made by a hypothetical assembly of all storytellers. This temptation has been driven by new audience's behaviors in an accelerating and overly connected world.
An example of the involved action-based narrative are the interactive films. Bandersnatch is a standalone episode of the series "Black Mirror" that gives to the viewer the choices during the movie and according to their option there are alternative endings. I manage to do a flowchart (Figure 1) to analyze which choices were important for the change of the history and which ones just for decoration.

Both of them are useful though, because humans need the illusion of choice. Also, I even counted the endings and I found the same outcome for different in-between choices. Another example in literature is where the subject of the narrative is non-orientable surfaces (mainly Moebius strips), or where the narrative itself takes the shape of a moebius strip.

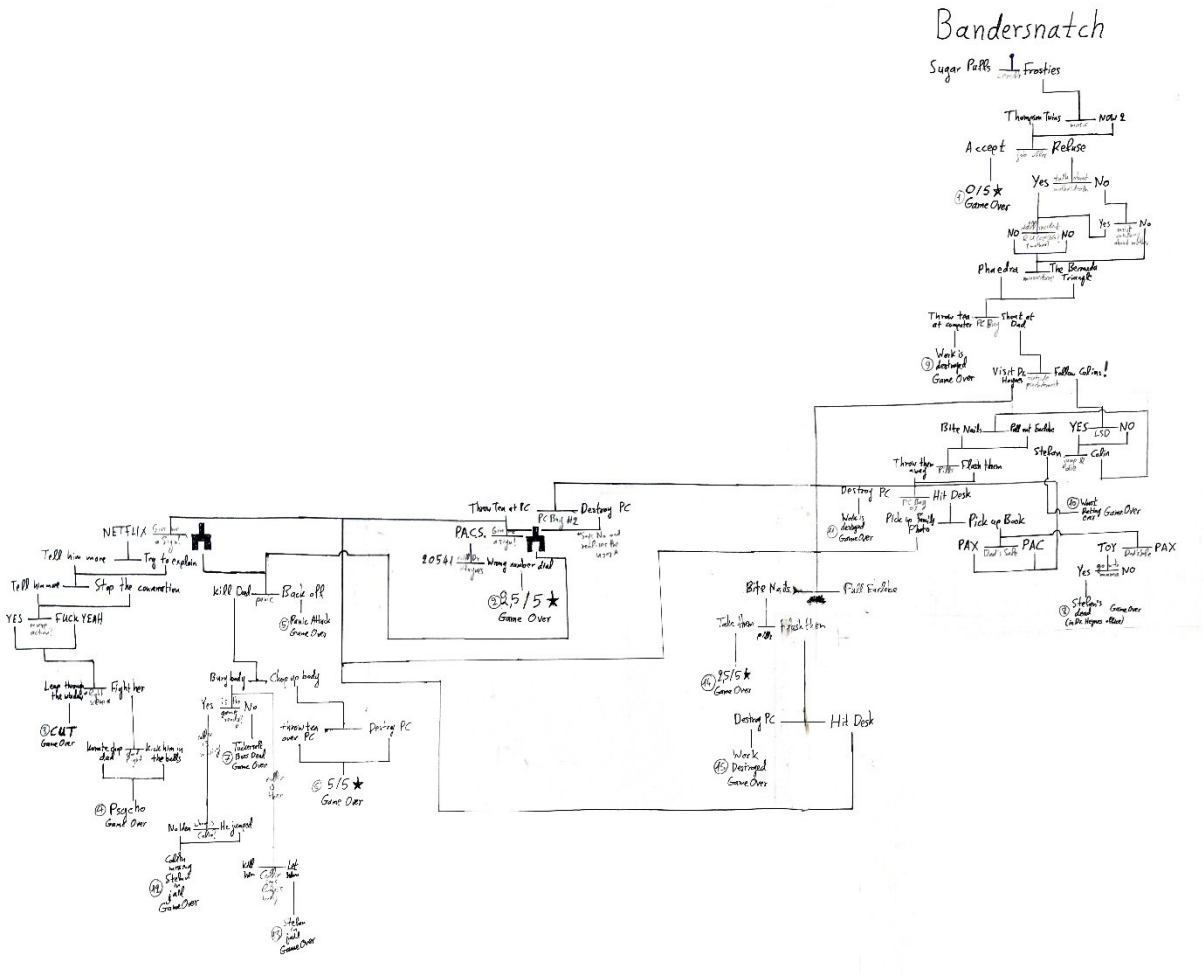

Figure 2 Bandersnatch Flowchart

2.2.2 Time-based Narrative

Narrative can be defined as "a chain of events in cause-effect relationships in time and space." It typically begins with one situation and afterwards a series of changes occur according to a pattern of cause and effect. When we are watching a film, we try to connect the events to make sense of what is happening, to see a line of cause and effect. Even if there is no obvious connection, we still try to make one. Creating narrative in virtual reality is similar to filmography. We act as directors and can create a mood or atmosphere by choosing certain shots -in our case certain actions in the virtual space- in a certain order, to build an image in our minds. We automatically link what is happening between two shots (actions) because it is the same thing that happens in real life. Also, the plot of a narrative does not always show us events in chronological order, as if they happened in real life. There are three distinctions of time within a narrative.

- Screen (Experience) Duration: the time duration of the vr experience
- Plot duration: the length of time of the plot that unfolds
- Story Duration: the length of time that is covered by the story

Space is important in a film because the location is usually quite important. The plot sometimes leads us to infer "other" story space, which we may never see. For example, we know a character has gone off on holiday, but we do not see this "space". Screen space selects portions of plot space to show us, just as it selects certain time events and leaves others out. The decisions that are made in terms of film space need to be examined.

2.3 Sign Language Poetry

Poetry is a form of literary art in the language, whether spoken, written, or signed. Poetry uses various devices and elements, such as resemblance, rhythm, transport, alteration and naming. Poetry often depends a lot on images and transport. In this sense, poetry and sign language are somehow a natural complementarity. Merging them is a magic of poetry in imagery.
Sign language poetry [28] is the ultimate form of aesthetic signing, where the form of the language that is used is as important -or more- as the message. Like every poetry in any language, sign language poetry is a means of expressing ideas unusually distinctly, through an enhanced language of "art." It uses specific linguistic ways to maximize the significance of the poem, just like with oral language poetry. However, the linguistic devices are rather different from the alliteration and rhymes that are familiar to most audiences. The images and metaphors that are used in sign language poems may also differ from those in poems of the spoken language. In general, the basic idea of maximizing the message through a specially enhanced language is the same in poetry in all languages, whether spoken or signed.

"Speech (and writing) have distanced themselves from the iconic - it is by association, not depiction, that we find speech poetry evocative; it can elicit moods and images, but it cannot portray them (except through "accidental" ideophones and onomatopoeia). Sign retains a direct power of portrayal that has no analogue in, cannot be translated into, the language of speech; on the other hand, it makes less use of metaphor."

-- Sacks, Oliver. *Seeing Voices: A Journey into the World of the Deaf*, p 120.

ASL poetry and storytelling have been passed from generation to generation until the emergence of video technology in the 1970s. Since then, works have been published in ASL poetry. Dr. Clayton Valli [29], the American progenitor of ASL poetry, began his research into ASL poetry in the 1980s.
The translation of an ASL poem into English is often discouraged or sometimes not possible due to the natural complexity that handshape, spatial location and movement express. In general, no interpretation can convey a sign language poem fully. Sing language poetry can be better appreciated by its first-hand experience.
According to Sutton-Spence in order to appreciate poetry to the fullest, a reader may take into consideration at least three basic aspects: the form and content of the poem, the social and historical context of it and the poet's knowledge and beliefs. For some critics and analysts, text has the highest priority and in many cases a text can be analyzed in depth without external references. However, it may also be useful to know the social and historical context in which a poem was created in order to appreciate the choice of a certain metaphor or the attitude of the poet for a particular topic. Comprehending the experience of the poet's deaf community can often increase our appreciation for language poetry. There is no doubt that knowing about a poet's life, the facts and experiences that shaped his/her poetic production can also assist on understanding even better some poems. When somebody is studying poetry of sign language, it is important to keep in mind that the deaf people compose and perform it. Their life experiences differ a lot from hearing people who live among them and this will be showed in their poems.

2.4 Virtual Reality

2.4.1 The term

The term virtual reality was first mentioned by Frenchman Antonín Arto in 1932, in his essay titled “Le Théâtre Alchimique” [19], and in 1938 at “Le Théâtre et son Double”, where he referred to the theater as one virtual reality ("la réalite virtuelle"). [20] The term "virtual", from the mid-1400s, has the definition of "being something in the sensation or effect, but not in reality."[21] In 1989, the term was restored in its technological sense by the American writer and pioneer of virtual reality, Jarron Leyner. He is the founder of VPL Research, which developed some of the first systems in the 1980s. He defined virtual reality as an "interactive, three-dimensional, computer-based environment that can be submerged." In 2003, writer William R. Sherman and researcher Alan B. Craig defined virtual reality as a medium consisting of "interactive computer simulations that "sense" the position and actions of the

user, and replace or augment the feedback to one or more senses, giving the feeling of spiritual immersion or presence in simulation (a virtual world). "

2.4.2 Immersive virtual reality

Initially developed by the video game and movie industry, immersive virtual reality has expanded its field of action. It is increasingly used for educational, professional, or commercial purposes. With sometimes surprising applications. Behind this scholarly term lies the ultimate in video games; the dream of every gamer. That of an interactive computer simulation of a new kind, thanks to which its user can literally immerse themselves physically and mentally in a 3D environment. The player interacts directly with the virtual world. As if he left reality for a few moments, to integrate in a world of fiction. In addition to video games, it is not surprising that today immersive virtual reality is increasingly used in the audiovisual industry, as well as for the realization of artistic performances, of course, the stronger the sense of reality in the virtual world, the more intensive the experience.
Researchers have even determined that there are six immersion categories. To accumulate them, the immersive virtual reality program must be able to stimulate multiple senses, including sight, hearing, and touch. The equipment has also evolved in recent years. Oculus Rift is the first immersive virtual reality headset to be put into circulation, starting in 2013. It is now a pioneer alongside the innovations presented at the CES 2019, the global showcase for high-tech innovations, which was held in early January in Las Vegas. The Taiwanese HTC company has unveiled the HTC Vive Pro Eye, a virtual reality headset equipped with an eye tracking system, which tracks the movement of the eyes of the user. The Chinese Pico was not left out, with the G2 4K standalone headset, which has a resolution twice as high as that of its direct competitor, the Facebook Oculus Go.

2.4.3 Virtual Reality Categories

Videogames: The first use that comes to mind for virtual reality is video games, of course! The innovative side of the concept is inevitably a discovery: we have fun, we have fun with. The library of available applications is largely filled with games. For example, Superhot VR [40] is the virtual reality version of the successful indie game Superhot and sets the player in a minimalistic environment, taking out hostile attackers that are trying to kill them. When the user is immobile, the time proceeds extremely slow and they move, the time resumes to the normal state

Real Estate VR tours [41]: It is easy to understand the interest of real estate professionals to appropriate technologies close to virtual reality: imagine visiting multiple properties from a VR station (in store for example), or even from home. This would be in many cases an interesting way to save time. For a first visit, such a device would offer a real advantage.
Vocational training in virtual reality: Training in handling or preparing to deal with situations is expensive for companies and it is sometimes difficult to easily recreate real-life situations off the field. Theoretical courses are useful but not necessarily sufficient. Thus, virtual reality could become an additional step in the training of technical or advanced personnel in delicate or rare conditions, or both. Learn to drive, identify places. Not long ago, a surgical operation was broadcasted in virtual reality on the internet. Even if it was only broadcasting and not "participation", it is a step forward that is made. Finally, why could we not train people to give the rules of the road test via a VR experience? It would be very feasible to recreate an environment where the user would be in the driver's seat:

1. Does the passenger have his seat belt?
2. Is the blind spot free?
3. Do I have good vision on the back of my vehicle thanks to my mirrors?

All these situations can easily be transcribed in virtual reality scenarios.
History Reconstitution / Cultural Heritage: Relive historical scenes from the heart of the action, or from new points of view: the enrichment of content via virtual reality makes these immersions possible. Let's Imagine ourselves alongside Napoleon during the great battles, in the terrible trenches of Verdun, or present at Louis XIV's table during his meals: the possible scenes are endless, the reconstructions of our History would be enriched. Virtual reality applications with historical dimensions are starting to emerge, it is already possible to go to feudal Japan with the **Edo VR** [42] application.
Virtual furnishing: Thanks to virtual reality, a person has the ability to already have visited their next apartment, which is under construction. In the **IKEA VR** experience the user can be in their virtual

kitchen (where the physical place is still under construction) and interact with the objects in it, to evaluate their choice.

Virtual reality for therapeutic purposes in the field of medicine: Virtual reality can be used to deal more effectively with anxiety or nervousness problems. Also, it works as a remedy for claustrophobia as well as acrophobia, the extreme and irrational fear of heights belonging to a specific type of phobia (such as suspension bridges). Research is being carried out at the same time to fight against tobacco addiction, in the context of schizophrenia, or even to fight against paranoid syndrome. These designs are, however, still to this day in the research stage. Another example is, **A Walk through Dementia** [44], a virtual reality application that allows you to get into the shoes of a person suffering from Alzheimer's disease. Finally, virtual reality is used to change the hospital experience [45], particularly to reduce patient anxiety and thus reduce hospitalization time.

Multi-dimensional attractions [46]: You may have recently fallen on advertising campaigns or videos mixing virtual reality with real thrilling attractions. This mix between real and virtual offers multiple benefits. The sensations are real: accelerations, fast heartbeat, wind against the face, inner part of the ear that detects when we are really upside down, etc. Perfectly wired to a virtual course diffused in the HMD, the protagonists can thus find themselves in a universe completely fantastic or enriched by the virtual one, while being subject to the thrills that provide a route of Big Eight. Another advantage: the attractions can be renewed by modifying only the virtual part. For the same course of real rails, thrill seekers can participate in spaceship fighters, or being on the back of dragons. Technically, everyone on the same car could even choose their own universe.

Army and Virtual Reality: Army corps are often the first ones when it comes to new technologies. Virtual reality is no exception. The applications that are to be soon developed will certainly be very seriously considered in the short term. Piloting, training, remote interventions, ground identification or training. In parallel, the police have begun to equip themselves too, for example in solving crime scenes by using virtual reality to help witnesses recall details from the incidents.

2.5 Motion Capture

Motion capture is the procedure of translating human movement information into digital data that can be used in mediums such as movies and videogames. It includes applications in various domains: from medicine, robotics, sports analysis to military use. Nowadays motion capture can be observed most often in blockbuster movies where actors perform by wearing motion capture equipment in order to record subtle expressions and lifelike body movements. Mocap is playing a significant role in the game and video industry since it’s a very demanding work of bringing CGI characters to life.

How does it feel to be a mocap performer?

The visualization of movement and action are inextricably linked, including the cerebral cortex [11]. When somebody thinks on doing an action, for example, lifting one hand or walking straight, activates the cerebral cortex directly. Our imagination allows us to mentally remember and project our planned moves. In fact, visualization of the movement alters the way the brain networks are organized, creating more links between different areas of the brain. It stimulates areas of the brain involved in the rehearsal process of a movement. These are mainly located in the anterior brain which prepares body and brain for action to move efficiently.

Even observing others in action, it "preheats" brain activity and helps us to understand what we want to do and how to combine our actions with those around us. Over time, our mind learns the routine of the movements, allowing these actions to be more automated and synchronized. All these features affect the motion capture performer and assist them embody themselves as best as possible into their role - playing character.

Figure 3 Andy Serkis on War For The Planet Of The Apes

"I had a very strange experience recently came back to New Zealand and I was doing pickups, literally within two or three weeks, for Tintin, Rise of the Apes and then doing Gollum. It was an incredible thing, because I was just wearing the same performance-capture suit and they were just hanging different character rigs on me and I was getting into character. In terms of the technology, it allows less interference between the actor and the performance."

-Andy Serkis

2.5.1 Historic Note

The use of motion capture for character movement on the computer is relatively new, started in the late 1970s and has become widespread in recent years. Nevertheless, the idea of copying human motion for animated character is not new. In 1915, Max Fleischer invented the rotoscope or roto, a device consisting of a film projector and easel to achieve realistic animation in the "Out of the Inkwell" series.

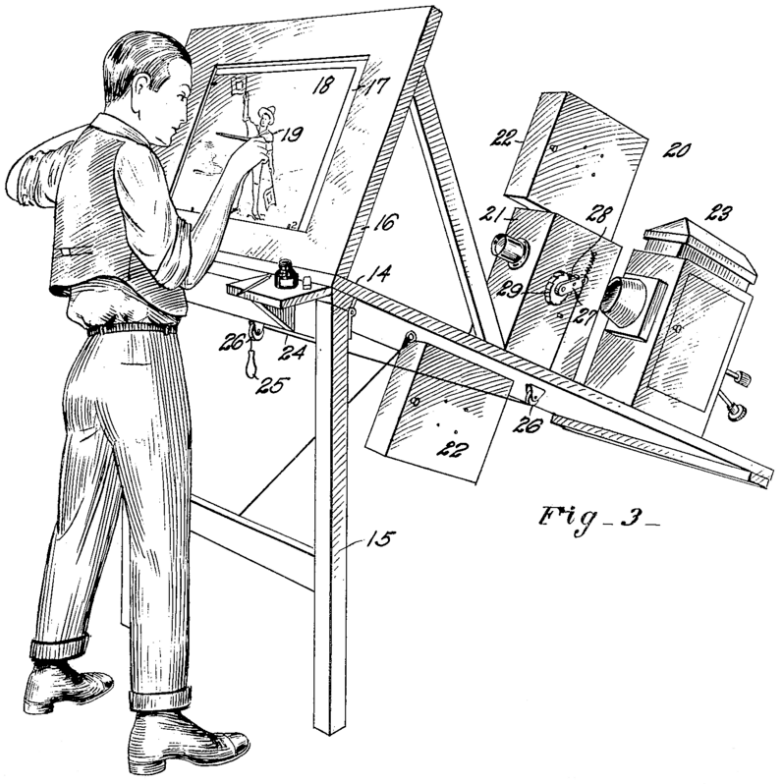

Figure 4 Prototype design of Fleischer prototype

Similarly, Disney Studios, for the film "Snow White", traced the same way to the actors who played the same scenes. Since then, the rotogravure method has been successfully used for human characters. In the late 1970s, when animation was made possible, animators adopted traditional techniques, including the roto rotor. In the New York Computer Institute's Technology Institute, Rebecca Allen used a special mirror to superimpose video cassettes from real dancers on the computer screen in order to portray a computer-generated character as a dancer for The Catherine Wheel "directed by choreographer Twyla Tharp. The computer used the postures ("poses") to produce a smooth display. The rotogravure method is by no means an automatic process, and application to the above-mentioned project helped to implement keyframes in a few frames by automating the process somewhat. The roto can therefore be considered as a "primitive" form and precursor of motion recording, where the movement is partially recorded "manually".
Below is a list of tasks - milestones in the automated recording process [6]:

- ***1980 – 1983: Simon Fraser University - Goniometers***
- ***1982 – 1983: MIT – Graphical Marionette***
- ***1988: deGraf/Wahrman – Mike the Talking Head***
- ***1989: Kleiser – Walczak – Dozo***
- ***1991: Videosystem – Mat the Ghost***
- ***1992: SimGraphics – Mario***
- ***1992: Brad deGraf – Alive***
- ***1993: Acclaim***
- ***1993: Jurassic Park***
- ***End of the 90s: Titanic, The Mummy, The Matrix etc***

2.5.2 Motion Capture Technologies

In the **electromagnetic motion capture,** there are transmitters that install magnetic fields within the space. The outfit includes sensors attached to the basic body joints of the user that they define the position and orientation of the point to which they are attached and all together determine the position and orientation of the individual person. The information on each sensor is transmitted wired or wirelessly. The advantages of this technology are that it can afford 6 degrees of body freedom (DoF) and each sensor is identified separately. Therefore, the occlusion problem is solved. The drawbacks are the limited range and the noise in the information that is likely to cause variations in the movement of the avatar in relation to the real human position. In addition, another disadvantage is the high cost of the sensors. It is important to note that if the recording environment space is properly prepared, then no post-processing is required for the movement data that was retrieved in the mocap session. Finally, the electromagnetic motion capture was popular in the past mainly for digital animation. This technology is used by Ascension.
In **electromechanical motion recording** the mocap performer wears an exoskeleton consisting of rigid bars connected to potentiometers. The main advantages of this equipment are the real-time recording, the high precision that it attributes to the movement of the avatar, its low cost and its autonomy. Just like in the previous technology, here also, each sensor has its own identity. So, knowing each sensor's position, there is no possibility of blocking the projection of one part of the skeleton from another. On the other hand, the fact that this equipment is an exoskeleton with rigid bars, limits the user's freedom of movement. This technology is mainly used for stop-motion animation. Animazoo is one of the companies that use electromechanical motion recording.
Inertial motion recording includes inertial gyroscopes in the user's mocap suit. The benefits of this technology are real-time recording, autonomy, individual sensor recognition, and zero occlusion. However, the features that really make it stand out from the previous technologies are its portability

and the ability to participate in a motion capture session with multiple multiple performers. The main disadvantage is the difficulty of detecting the position in a global coordinate system, thus limiting the movement of the avatar. In some suits of this technology, it is possible to use hybrid systems. The user can attach each sensor individually to any part of his body in order to conduct a recording. In that way the personalized skeleton is displayed on the computer. The companies that use inertial motion capture are Xsens, Noitom, Synertial, Rokoko and Shadow.

Optical Motion capture is currently the most popular motion capture method. A Special space setup is necessary. The active space is surrounded by constant high-resolution cameras that point to the user. The user wears a suit on which special sensors are attached. These sensors are usually LED or highly reflective stickers (or markers). The cameras are specially calibrated to detect these signs and receive in total the necessary information to form the skeleton of the avatar. The main advantage is that this method is easily customizable. In other words, once the active space with the cameras is set up, multiple users, props and animals can participate to be recorded. Of course, this activity is feasible provided that each object and subject is equipped with a special sensor suit. On the other hand, there are several obstacles such as limited recording volume, small dynamic range and special lighting that is necessary in order to distinguish the markers. Finally, the most important disadvantage is the difficulty of matching the markers to the points of the skeleton that is going to be depicted. Due to an occlusion issue, some markers may be overshadowed by another member of the body, and as a result their position is not clearly visible to be able to contribute to the correct definition of the skeleton during processing.

In marker-free motion capture, only customized (calibrated) cameras are used. On the other hand, there is a database with body-type templates, so the user can be properly identified and depicted with a single detailed scan. Since we are talking about scanning, it is worth mentioning that the user is imprinted whole with their clothes. Using this method, is possible to visualize deformations like hair, clothing, fat etc. However, this recording method is not yet ready for reliable development, because it often fails to portray properly the user and the situation becomes irreversible, which means that the scanning process has to be rerun from scratch.

2.5.3 Motion Capture Applications

In the recent years, apart from medicine, military and entertainment, a lot of motion capture applications have been encountered in many other domains as well. This technology is used in sports to analyze and enhance the performance of athletes in order to prevent injuries. Designers use mocap to understand movements, barriers and interactions of users with environments, aiming at designing better interactive experiences. Engineers are using motion capture to analyze the human movement that will assist them design robotic movement with a humanlike pace. Motion analysts, dance historians, and teachers use motion capture to archive and study kinesiology of dancers and actors.

Here are some of the more typical examples grouped in the prementioned areas:

Video Games: The continuous advancement in the graphics quality of video games triggers even higher demands on CG (Computer Generated) character movement. Creating predefined moves (e.g. walking, jumping, running, etc.) with motion capture in actors' studios is now a necessary part of implementing a video game. More specifically:

- *GTA V [48]*: Action and Open World game. Every move that CG characters reproduce across the map has been created with motion capture.

  Sample: https://www.youtube.com/watch?v=jE_QjOM810c

- Watchdogs: Action and Open World game. It is distinguished for the most realistic movements ranging from violence to acrobatics and parkour. All these moves have been made with motion capture with stuntmen. Note that a very realistic interaction of CG character fabrics has been achieved on their movement.

  Sample: https://www.youtube.com/watch?v=XDXxx1y3-IQ

- For Honor: Multiplayer action game. It stands out for the combat movements with historical weapons. Movements vary from heavy, technical, fast to slow. The recording has been completed by using props that represent the actor's weapon.

  Sample: https://www.youtube.com/watch?v=rvZs-a6SgLw

- FIFA: Sports game. It is famous for the reliable depiction of football moves. The recording is done with professional football players. Some of them have a very unique way of shooting dribbling the ball, so their presence in the mocap session is essential for the best possible result.

  Sample: https://www.youtube.com/watch?v=Rpr1SIvL4Gg

- *Some honorable references to video games with impressive motion capture:*

  Assassin's Creed, NBA 2K, Batman: Arkham Origins, The Last of us, Beyond: Two Souls, Uncharted 4, The Witcher 3

Cinema:

• Lord of the Rings: Fantasy / Adventure. It is famous for one of the most fantastic characters - Gollum - who has been performed exceptionally by Andy Serkis.
Sample: https://www.youtube.com/watch?v=w_Z7YUyCEGE

- Avatar: Fantasy / Adventure Movie. The whole movie is a masterpiece of animation as it introduced a new revolutionary method of motion capture.

  Sample: https://www.youtube.com/watch?v=0J1JzYPjcj0

- Planet of the Apes: Action / Adventure Movie. It stands out for the CG characters -the monkeys- that come in contact with people. Also, the shots have been done in environment with unfavorable conditions for motion capture (outdoors with sunlight). This work has been accomplished by Weta Digital using different mocap suits and thus an alternative way of capturing the movement. Specifically, they switched from passive to active motion capture.

  Sample: https://www.youtube.com/watch?v=4NU9ikjqjC0

- Pirates of the Caribbean: Fantasy / Adventure Movie. It is famous for the villain character - Davey Jones - that looks like a humanoid octopus. The detail in the movement of the tentacles is fascinating, and all of them are amazingly synced together with the movement of the computer-generated character (Computer Generated or CG character).

  Sample: https://youtu.be/51Ffh2nbHnE?t=1m26s

- Rogue One: a Star Wars story: Fantasy / Adventure Movie. ILM is famous for its amazing effects, including motion capture. This particular film featured the portrayal of an android character - the K-2SO - performed by an actor who, apart from the Mocap suit, he wore a special equipment on the legs and arms to provide a reference for the size of the CG character. The actor has a height of 1.83m while the computer designed character is 2.16m.

  Sample: https://www.youtube.com/watch?v=luXr18cC9N4

- Warcraft: Fantasy / Adventure Movie. Special emphasis was placed on motion capture, because of the large set of CG characters - the Orcs -. There were also many close-up shots of long duration and that demanded even more delicate work on their visualization and movement.

  Sample: https://www.youtube.com/watch?v=NUm_tGQuNdk

- We mention some notable movies due to amazing motion capture:

  The Hobbit (Smaug), Teenage Mutant Ninja Turtles (turtles), Polar Express (all the characters), Avengers (Hulk), Christmas Carol (all the characters), Ted (Ted)

Medicine:

- Gexfix: Orthopedics. Artanim created 3D imaging with motion capture (mocap) that presents a variety of external orthopedic stabilizers of the company. The illustration shows the possible moves the patient can make for each product that is attached to it.

  Sample: https://www.youtube.com/watch?v=oyNcDRcBrtU

Sports:

- Indiana University Health: Athletes benefit from running a motion analysis on their training or rehabilitation. The university records and analyzes motion with high-speed cameras, electromyographs, and force-measuring boards to the ground. All together provide an overall

picture of the biomechanics of the body. Thus, a 3D model of the athlete's body is made in motion and clinical diagnoses and tips are provided to optimize performance and prevent injuries.

Sample: https://www.youtube.com/watch?v=ywt8yluW1nU

- Nebraska Athletic Performance Lab: The lab conducts 3D motion analysis with the Nebraska track and field team to improve athletes' performance.

  Sample: https://www.youtube.com/watch?v=XmGPjIHJfps

- Swimming: Qualisys, in collaboration with Sweden's national bathing team, combines a standard and underwater recording system that can be used in swimmer motion analysis. The aim is to study the biomechanics of the swimmer's body.

  Sample: https://www.youtube.com/watch?v=qtXz6qocciM

Mechanical Engineering:

- Freedspace/Tracklab: They conduct studies on the contribution of traffic recording in engineering such as the prototyping of ergonomic developments in cars (starting with Formula 1), analysis of working conditions of employees for health, risk prevention and planned synchronized movement of multiple drones in space, taking into account possible intermediate objects.

  Sample: https://www.youtube.com/watch?v=S5pu9VWJv-c

- Vicon: These systems provide high-precision virtual prototyping and virtual product tools in the engineering market.

  Sample: https://www.youtube.com/watch?v=eFbV_hyrJp0

Robotics:

- Nonami Group, Chiba University: They implement the grouping of information using multiple quad-copters. Their position and height during their flight is recorded by cameras to avoid collisions.

  Sample: https://www.youtube.com/watch?v=8bMhEMGS5OA

2.6 Related Projects & Applications

- **Notes on Blindness (**Figure 5**):** The feature film Notes on Blindness, written and directed by Peter Middleton & James Spinney, is based on the diary audio of John Hull, professor of theology and writer, who became blind in 1983 after several decades of visual deterioration. In the continuity of the Emmy Award-winning eponymous short film, Notes on Blindness, director's first feature film, uses John Hull's audio recordings and invites the viewer to a poetic and intimate narrative of his journey from loss to rebirth through acceptance. To complete these incredibly rich sound archives, the directors recorded more than twenty hours of interviews with John and his wife, Marilyn. The combination of these interviews and the original diaries form a poignant narrative where the couple confides on thirty years of life. The film also finds its singularity in the use of the lip sync process, thus combining original recordings with scenes performed by actors. This innovative creative approach reinforces the scope of the film and transports the viewer into an inner journey into the experience of blindness. Notes on Blindness is also an interactive experience in virtual reality accompanying the eponymous documentary feature film. Also based on John Hull's original recordings, this six-chapter experiment uses virtual reality technology and gameplay mechanics to immerse the user in the cognitive and emotional experience of blindness. Each scene refers to a moment, a memory and a specific place addressed in John Hull's diary. Together they constitute a deeply immersive experience in a real-time 3D animation environment magnified by binaural audio spatialization. Developed on Unity.

- **Sensations of Sound:** This application explores what it actually means to hear and how music feels for the profoundly deaf. Artists and storytellers can help us move beyond our own imaginations and allow us to feel an approximation of someone else's reality. "'Sensations of Sound' tells such a powerful story that simply couldn't have been captured in such an intimate way through a more traditional medium," adds Szczupak. "We're honored to be a part of bringing Rachel's story to life for such a fundamentally personal experience."
- **Seeing AI:** This application narrates the world around the user. It is Designed for the blind and low vision community. This ongoing research project harnesses the power of AI to open up the visual world and describe text, objects and nearby people. The application also assists the user to recognize short text as soon as it is in front of the camera, the camera reads it out loud. It provides audio guidance to capture a printed page, and recognizes the text, along with its original formatting. It captures people's faces so the user can recognize them, and get an estimation about their age, gender, and emotions. It recognizes currency notes and identifies colors. It Reads handwritten text. At the end, it generates an audible tone that corresponds to the brightness in the surroundings.
- **The giant [56]:** A linear storytelling VR experience. The fact that they have chosen to use an ancient narrative this is what makes this technological piece of art so successful. According to the authors, "[myths] seemed modern in how quickly they gave a narrative - you have to ask yourself whether the old oral narrative traditions [are in fact] similar to the newest online storytelling style." "The Giant," relying on a narrative style in which an impartial narrator clearly indicates the most basic points of a chart, the viewer is left to rely on the vividly edited video environment to fill the gaps.
- **Dökk [57]:** ("Darkness" in Icelandic) is the new media performance with fuse* and the natural evolution of Ljós ('light'). Dökk is a journey to a sequence of digital landscapes, where the perception of space and time varies. Dökk's scenography is designed to offer a sense of deep interdependence between the user and the world around him. In order to represent this concept, a system was created that processes real-time data from biometrics and motion sensors (worn by the performer and placed on stage) as well as social data that is streamed from the social networks. This data contributes to modifying the digital and audio performance scenarios: whenever a performance is happening, the system analyzes in real time the messages shared by people from all over the world on social networks, implying their emotional state through a sentiment analysis algorithm. This data, along with the interpreter's biometric data, make the performance different each time it is happening.
- **Choreomorphy [58]:** Choreomorphy is inspired by the Greek words "choros" = "χορός" = dance and "morphe" = "μορφή" = shape. Visual metaphors, such as the notion of transformation, and visual imagery are widely applied in various movement and dance practices, education, and artistic creation. Motion capture and comprehensive movement representation technologies are used in this field. Choreomorphy is a system for a whole-body interactive experience, using Motion Capture, that allows the users to experiment with different body and movement visualizations in real-time. The system offers a variety of avatars, visualizations of movement and virtual environments that can be easily modified through an intuitive user interface. The motivation of designing this system is the exploration of different avatars as "digital selves" and the reflection on the impact of seeing one's own body as an avatar that can vary in shape, size, gender and human or non-human characteristics, while dancing and improvising. Choreomorphy is compatible with different inertial motion systems and can be also used as a Mixed Reality experience where the user acts as spectator and watches pre-recorded choreographies in 3D volumes in space, but can also interact in the visualizations of the avatars through a floating GUI with simple gestures or voice commands. The 3D representations and interactions are constantly updated through an explorative co-design process with dance artists and professionals in different sessions and venues.

- **3D In Motion (3DIM):** The Artanim Foundation and the MINTLab Lab have implemented a real-time recording, imaging and sound recording system. It is compatible with a wide variety of motion capture systems such as Kinect, Xsens, Vicon and other. This context is about the scene of the show and real-time shows. It is used in DJ events, dance performances and other artistic works. Multiple persons can be involved to interact with.

  Sample: https://www.youtube.com/watch?v=yUXyxlG-tbg

- **Holoportation:** The Microsoft research team [15] presents a far-reaching system for telepresence in augmented and virtual reality. This system demonstrates 3D real-time reconstruction of people, furniture and objects using a set of new depth cameras. These 3D models can be transmitted to remote users. This allows users who wear Augmented and Virtual Reality glasses to view, listen and interact with remote 3D participants as if they were in the same physical space.

  Sample: https://www.youtube.com/watch?v=7d59O6cfaM0&t=6s

- **Hypnoid:** Suguru Goto [9] presents a motion capture system where the dancer's movement is transferred to an avatar in the virtual space. The avatar moves according to the dancer's movement and at the same time produces pictures and sounds in real time. The basic performance is dance, but it could also be music. Physical movement can act as a virtual musical instrument and produce images at the same time. Consequently, one move can produce multiple elements. The title "Hypnoid" is a state of hypnosis and refers to the stage that most likely occurs in someone who is in the phase just before sleeping but still keeps consciousness. Although this exists in the present, real space, it can also be associated with the so-called "virtual space," which ultimately makes it different from Augmented Reality.

  Sample: https://www.youtube.com/watch?v=Hij-4DV4J2E

- **Motion and Shape capture (MoSh):** The Max Planck Institute [12] presents a new method that replaces the skeleton with a 3D parametric model. Given a set of marks, MoSH evaluates the locations of the scars at the same time in a trial 3D model, assesses the shape of the body and regains the modular posture of the body. Leaving the shape of the body to vary over time, MoSh is capable of recording the modular movement of soft tissue.

  Sample: https://www.youtube.com/watch?v=GdRcJz_xK_8

- **Moss [59]:** It is a VR videogame featuring a cute mouse that only squeaks, however it communicates with the player in sign language.

Figure 5 Notes on Blindness

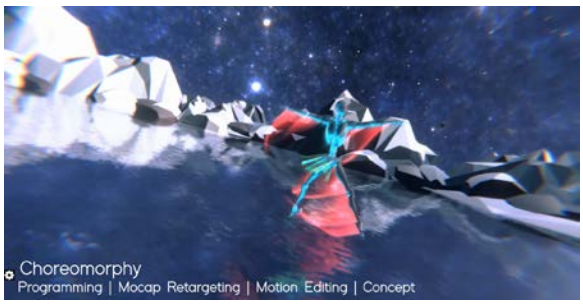

Figure 6 Choreomorphy

2.7 User Experience Usability

2.7.1 Heuristics

The design of easy-to-use interactive systems is an important part of human-computer communications science. This ensures quality communication between the user and the interface and thus the "experience" of interacting with the interactive system.

Figure 7 Goals of User Experience

The purpose of non-application-friendly interfaces is to provide users with user-friendly tools at both visible and distinctive points that do not interfere with their visual field. Of particular importance is the rapid access to the interface. According to Scott Rogers [16], the user should never press a button more than three times to reach any setting window because he does not want to spend all his time by pressing buttons until he makes the desired setting and then to press another button to return to the game screen that is supposedly not the focus of the user's attention, there is still a problem. Nielsen [26] [28] , Schneiderman [27] [29] and Tognazzini [30] constructed the 10 Usability Heuristics and 8 Golden Rules of Interface Design.

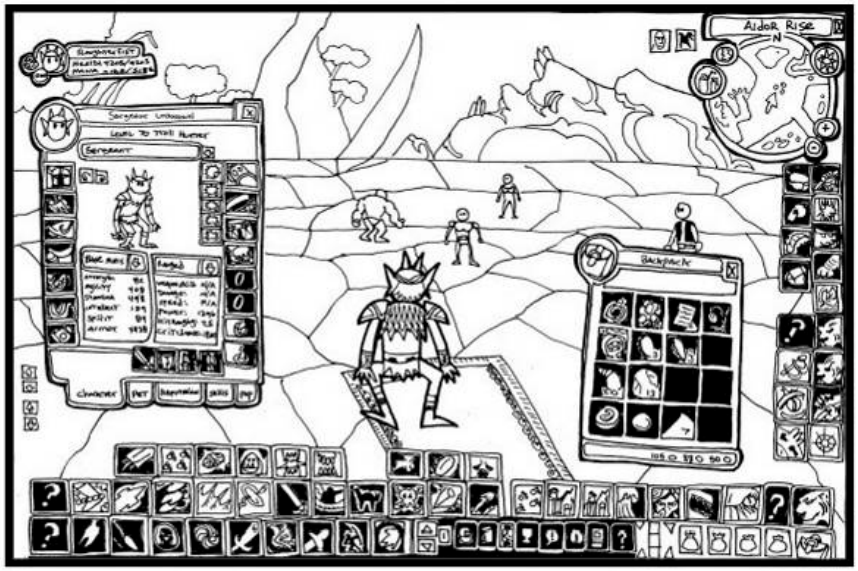

Figure 8[3] Interface with scattered buttons on the bulk of the screen, turning it into "claustrophobic"

[3] Picture from Scott Rogers's book "Level Up! The Guide to Great Video Game Design "

2.7.2 Immersion

Immersive Virtual Reality is an interactive 3D computer simulation that immerses a person completely in a virtual environment so that they have a sense of real presence in the virtual world. This is made possible by stimulating several senses of the user such as sight, hearing and touch. **Immersion** or **immersive state** is a psychological state where the subject ceases to be aware of his own physical state. It is frequently accompanied by an intense concentration, a disturbed notion of time and reality. The term is widely used in computing, virtual reality, and video games (such as MMORPGs), but may be misused as a buzzword. In this case, its meaning is intentionally vague, but remains appreciated for its particularly captivating connotation.
In the field of virtual reality, immersive systems are also used to immerse the user in a familiar environment, either for distraction or for training purposes - to instill reflexes that will then be used in a real case, or to reconstruct remotely a real system on which one can thus operate by remote control. The attractions of Poitiers Futuroscope or piloting drones by immersion in a virtual cockpit, are examples. The degree of immersion is determined by the concordance of the sensations with those to which the user is accustomed and by the adequacy of the different senses between them (for example the touch and the sight). According to the authors, immersion can be distinguished into several categories. Staffan Björk and Jussi Holopainen, in Patterns in Game Design, divide immersion into 6 categories: sensorimotor, cognitive, emotional, spatial, psychological, sensory. Ernest Adams, author and consultant in game design, distinguishes only the first three but names them respectively tactical immersion, strategic immersion, narrative immersion. The concept of immersion has been criticized by several researchers, including Gregory Chatonsky. [22]

2.8 Research Questions

After conducting research on the theoretical background knowledge that is related with the tools that we are going to use for the design of the VR experience, I stated the following “problematiques”:

- How is virtual reality and sign language poetry related to each other?
- Does the artistic visualization of sign language poetry in VR enhance the way that the spectator appreciates and experiences it?
- Can different aesthetics affect the user in their experience with the narrative?
- Does the time-based narrative in virtual reality have a strong impact on the user?

3. DESIGN & IMPLEMENTATION

3.1 Introduction

In this chapter we will describe the pipeline of the design and implementation of the VR Experience. We introduce the tools (hardware and software) that have been used to the completion of the project. Then we describe the different states of implementation that have been accompanied by the background knowledge that we have already analyzed in chapter 2. Then we jump into the technical part where we show some examples in implementing some aesthetics with visual scripting and the visualization of the sign language poem content.

3.2 Technologies

3.2.1 Perception Neuron

Perception Neuron is an inexpensive inertial motion capture suit. It has been used in many fields such as videogames, filmmaking, visual effects and sports analysis. One of its major advantages is that it is lightweight, so it allows the performers to be flexible wherever they are. The modular system is based on IMU (Inertial Measurement Unit) sensors composed of a 3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer. These tiny wireless sensors that are called Neurons, are placed on the talent's body and altogether they connect to a hub. The hub is in turn connected to a computer via wifi or usb. The combination of the pre-mentioned hardware features of the sensors and complex algorithms such as proprietary Embedded Data Fusion, Human Body Dynamics and Physical Engine algorithms convert movement into digital motion data. Also is pretty straightforward to set up and nearly plug 'n' play without a lot of troubleshooting. On the other hand, the sensors are pretty sensitive and there is a high risk of malfunction if there are strong electromagnetic fields nearby. In addition, extreme angular motions or metallic surfaces can affect the sensor data acquisition. The suit unit outputs data at 60fps or 120fps. The data stream is channeled to the hub where it can then be transferred to a computer via WIFI, via USB or recorded onboard using the built-in micro-SD slot.

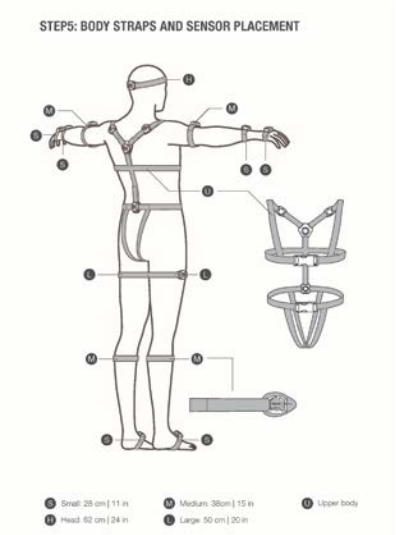

Figure 9 Perception Neuron Suit

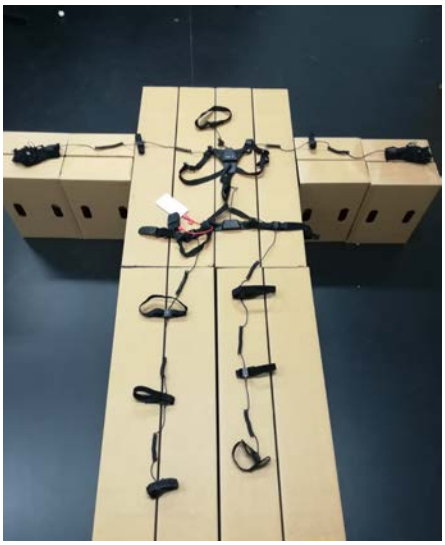

Figure 10 Perception Neuron Suit

3.2.2 Axis

Axis Neuron is the in-house software by Noitom that is delivered with Perception Neurons and is designed to manage and calibrate the mocap suit as well as performing basic motion capture. The main operation of this software is to connect the suit for calibration and manage the system, as well as recording and exporting data files for manipulation in most professional 3D, previz and game development tools. Perception Neuron is considered a dedicated professional tool for film makers, video game developers, visual effects professionals, biomechanics researchers, sports and medical analysts, and virtual reality enthusiasts. It is considered as a flexible and affordable platform to experiment with. One of the most important features of AXIS Neuron is the ability to stream BVH data stream and also export the data file to FBX for use in software programs such as Motionbuilder. Also, Axis offers the possibility of recording up to 120 fps, which is extracted in BVH file format [4]. This type of motion file is widely used, from 2008 onwards, in software for motion imaging. Renowned for its hierarchical structure that makes it more legible than other motion files.

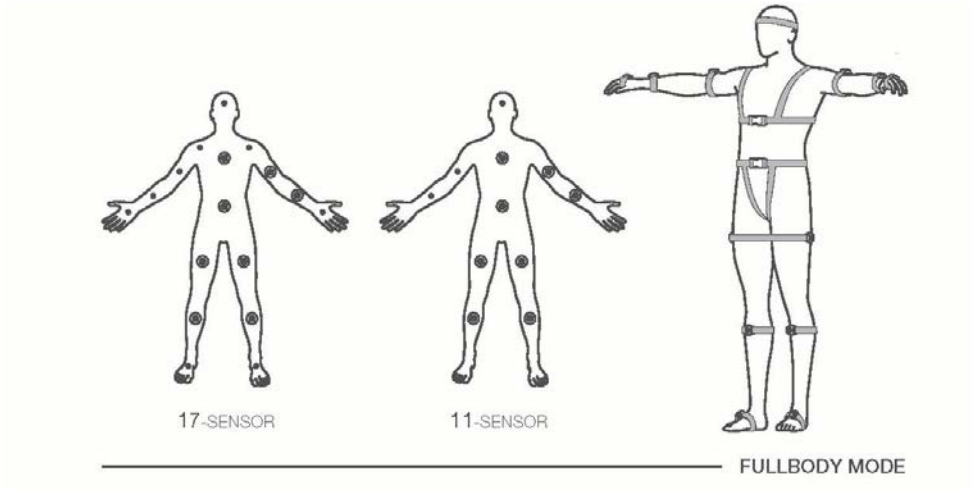

Figure 11 Fullbody Perception Neuron

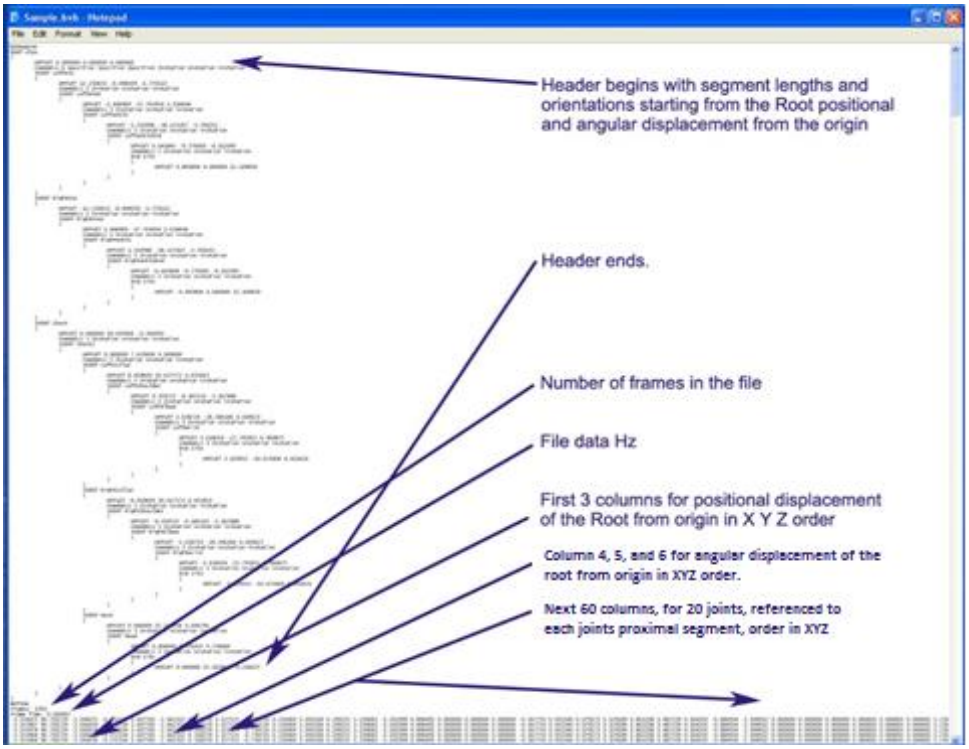

Figure 12 Sample bvh motion file with the hierarchical structure structure.

3.2.3 Unreal Engine

Unreal Engine[4] is a video game engine developed by Epic Games. The Unreal Engine is programmed in C ++ and in a scripting language, called "UnrealScript", used for 90% of the code related to the gameplay of Unreal Tournament15. The engine uses an object-oriented design, which allows it to be extremely modular. The interfaces of the different sub-parts of the code are clearly defined, the developers can work on one of them without it affecting the rest of the game. It also allowed to isolate the code related to the platforms. in separate software libraries, making it easy to port the game to other platforms. Finally, this modularity is found in the scripting language of the game engine. All elements of the game, such as weapons or objects, are defined independently. Programmers can therefore add or modify these elements without affecting the source code. This object-oriented design coupled with the Unreal level editor makes the Unreal Engine a powerful system for creating new games or game changes using it. Big part of the code has been designed to make the game attractive to programmers and artists in the mod community. The Unreal Engine focuses on subtractive CSG (solid geometry) unlike the Quake engine, which is based on additive geometry. In summary, to build a universe in the Quake engine, the elements are added to the void (much like building a house by adding bricks). In the Unreal Engine, the world is full at the beginning and the designer digs into it to create his universe. This offers the possibility to the designer of the unreal engine to use "portals" to partition his world in very distinct closed zones and thus offers the engine the possibility thanks to the PVS (potential visibility sets) to display only the visible part Unreal engine could offer intricate interiors and rich exteriors while delivering impressive performance for the time. For the "sky", Epic adopted the Skybox system: a common process today to represent the sky in real-time 3D. Unreal Engine is for PlayStation, Nintendo 64, PlayStation 2, and Dreamcast consoles and PCs from the late 1990s.

Blueprints: The **Blueprints Visual Scripting** system in Unreal Engine is a complete gameplay scripting system based on the concept of using a node-based interface to create gameplay elements from within Unreal Editor. As with many common scripting languages, it is used to define object-oriented (OO) classes or objects in the engine. As you use UE4, you'll often find that objects defined using Blueprint are colloquially referred to as just "Blueprints." This system is extremely flexible and powerful as it provides the ability for designers to use virtually the full range of concepts and tools generally only available to programmers. In addition, Blueprint-specific markup available in Unreal Engine's C++ implementation enables programmers to create baseline systems that can be extended by designers.

Materials: These assets are applied to the 3D mesh in order to control their visual look in the scene. Through the material we can define the color, the shininess, the transparency etc. They are also used to calculate how light interacts with the surface of the object that they belong to. For these calculations a variety of textures, property settings and math expressions are used input stream to the Material.

File type compatibility: Unreal Engine offers built-in support for importing and exporting FBX files. These FBX-based workflows are optimized to support game requirements, which tend to be focused on working with individual objects. Datasmith, by contrast, brings in entire scenes, potentially containing thousands of objects, each with its materials, pivots, scale, hierarchy, and metadata, from a wide range of sources. However, you should feel free to use the FBX import pipeline if it suits your needs. For example, you might use it to import pieces of additional set dressing that you'll use to augment your Datasmith content in your Unreal Level.

Marketplace[5]: The purpose of the Marketplace is to provide high quality content to Unreal Engine developers for their commercial projects or educational purposes, and the aim of these guidelines is to make obtaining and distributing great Unreal Engine content easy and beneficial for everyone. Although we'll always do our best to work with publishers to resolve any issues, products may be rejected at any time for failure to meet criteria outlined in these guidelines.

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[4] https://www.unrealengine.com/en-US/what-is-unreal-engine-4

[5] https://www.unrealengine.com/marketplace/en-US/store

3.2.4 Autodesk Motionbuilder

Motionbuilder [6] is 3D Character Animation software developed by Autodesk. Used for virtual production, motion capture and keyframe animation. So far, it has been used to convert unsupported format of some 3D models to Unity-supported FBX [3] interoperable configuration and many other software. In case future predefined animations are introduced to the application (for example, to show some technical motion) then Motionbuilder will be used to adapt the models to this animation. Animation can be retrieved from an earlier motion recording session with the application or recovered from the Wholodance online platform that contains a huge variety of dance moves and choreographies.

3.2.5 Blender

Blender is a 3D graphics designer, free software and distributed by the GNU General Public License [2]. It is used for modeling, rigging, water simulations, animation, rendering, nonlinear editing and for creating interactive 3D applications such as video games. It is available for all major operating systems such as Microsoft Windows Linux and Mac OS X. Solaris is also supported [3]. Blender features advanced animation tools, various character and character design tools for character, hardware creation tools as well as Python programming language for internal scripting.

3.3 Intensif

The "Intensif" project is a 3-week intensive course of the ATI department that happens at the end of the first semester and we must work as groups to complete a project in the pre-mentioned time period. That project has to be connected with the topic of the thesis of each member of the team. For me it played an important role in the completion of this thesis, because it trained me to get confident in developing content in Unreal Engine. Before the intensive course I had bare knowledge of this game engine, because I had experience only in Unity. Moreover, the first experiments of the project have been done in Unity but I was not satisfied with the aesthetic result (**Figure 18**). In the first semester I was more focused on the research part and motion capture session so I still had time to change platform for the implementation. Unreal attracted me more than Unity not only because it was something to explore but also it contains characteristics that I found superior. Even though it's more complex and the frustrating to begin, I really appreciated visual scripting, the polished look of the shadows and the accuracy and smoothness of the lighting.

During those three weeks of "intensif" I managed to get comfortable with Unreal Engine and eventually we created a Horror VR experience. Obviously, the content has nothing to do with the current project, but the pipeline of design and implementation for which I was responsible to, it was similar to the current project. Both projects have a time-based narrative storytelling. Everything is happening through the pass of time and the user does not have the ability to take action to change the ending. However, the difference is that in the current project the narration is already there, but in the horror one I contributed to fabricating the scenario (**Figure 14**). Both projects contain motion capture animation, which means that also all the steps are included (recording, retargeting, cleanup, test in the engine, motion editing). One of the differences here is that in the horror project I was also the performer. My role was to perform different kinds of movement of a monster (eating, running, turning, attacking) (**Figure 16**)(**Figure 17**). Another difference between the current experience and the horror one is that in the in the second one the user cannot move freely because there is a fixed path of movement for the camera, but they can interact with the environment with a virtual smartphone that is used as flashlight in order to illuminate the dark virtual environment. The user can hold it and move it with one of the motion controllers that they are holding (**Figure 15**)(**Figure 18**). On the other hand, in the sign language poetry experience the user can roam freely in the virtual environment as if they were in "god mode" but there is no interaction with the motion controllers at all.

[6] http://www.autodesk.com/products/motionbuilder/overview

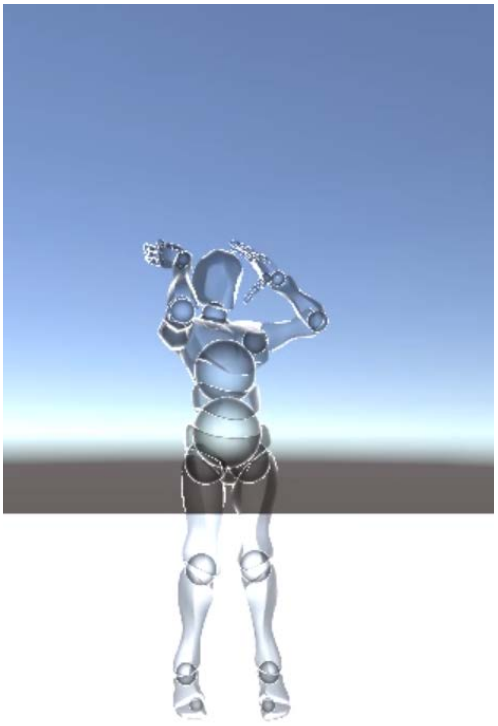


Figure 13 Sign Language poetry prototype on Unity

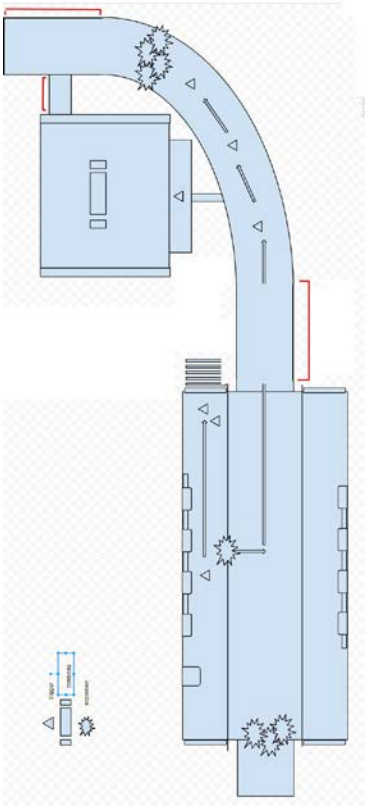


Figure 14 Draft design of the horror level

Figure 15 Interaction with the environment with flashlight I

Figure 16 mocap on running

Figure 17 mocap on turning

Figure 18 Interaction with the environment with flashlight II

3.4 Design

3.4.1 Original Sign Language Performance

Collaborating with Julie Chateauvert [52](Figure 20) , we chose one of the most famous poems of Peter Cook [53] (Figure 19) , which has the title "*Old Wise Corn"*. We watched multiple times one of his performances on the specific poem in order for me to comprehend as much as possible the content and the structure of the poem in order to visualize it in the VR experience in the most efficient way. The sign language performance of Peter Cook is accompanied by the narration of Kenny Lerner who describes in spoken language the poem. Therefore, after watching the performance several times I wrote down the description of the narrator in the form of a scenario by adding comments about the movement and the signs of the performer for each action. Afterwards, I divided the poem into parts for the motion capture recording that have the potential of being well visualized at the final VR experience.
Chosen sample from the poem "old wise corn":

A. *This brown seed will become a star*
he throws it up, repelling, exploding in the sky, a star
a white seed exploding
a black seed becomes an Olympic golden metal spangled
black power salute then explodes in the sky, a star

B. *the Orion plugs out his sole eye*
and throws it down, down, down
towards the canoer's chest cavity
expands with heat
the warmth flows from his heart το his head

Description:

A. *This brown seed will become a star*
The performer takes from the wise corn a brown seed

he throws it up, repelling, exploding in the sky, a star
he throws the seed towards the constellation of Orion -> the seed gets repelled by Orion -> the seed explodes in the sky and becomes a star

a white seed exploding
the performer takes from the wise corn a white seed and throws it in the sky -> the seed explodes and becomes a star

a black seed becomes an Olympic golden metal spangled
the performer takes from the wise corn a black seed -> he throws it in the sky -> the seed transforms into an Olympic golden medal

black power salute then explodes in the sky, a star
1968 Olympics Black Power salute -> the golden medal transforms into a star

B. *the Orion plugs out his sole eye*
Orion takes off his helmet -> fire steam comes out of his cheek -> he plugs out his eye with fire trails coming out of it

and throws it down, down, down
He throws it -> the eye falls as a comet

towards the canoer's chest cavity
the canoer stops paddling and watches the comet coming

expands with heat
the warmth flows from his heart το his head
the comet reaches the chest of the canoer

Figure 19 Peter Cook performing "old wise corn”

Figure 20 Julie Chateauvert performing "old wise corn" in mocap session with perception Neuron suit

Before the motion capture session begins, I set up the Perception Neuron’s sensors, calibrated the system on Julie Chateauvert who was the mocap performer and we took the necessary measures to reassure the quality of the mocap recording such as turning off unnecessary wireless networks and turn away metallic surfaces from the performance space. Afterwards, we began the mocap session for each individual part that we chose. For the sake of dissemination and organization I also set up a video camera to record the whole mocap session and afterwards I filed each video capture with its corresponding mocap recording to use it as reference/cue for comments that we did during the session in order to confirm if something went right or wrong. During the motion capture session Julie Chateauvert is imitating the performance of Peter Cook and the data of her movement is streamed and visualized to an avatar in Axis software. Through this s/w the motion files are saved in raw file format and we can later export them in other file formats such as bvh and fbx. After the session I reviewed all the recordings and chose the ones with the highest movement quality and probability to be fixed later in the cleanup process. At the end, we completed the session with a total of 14 recordings: 9 recordings for the part A, where the 4 have been rejected at once and 5 for the part B.

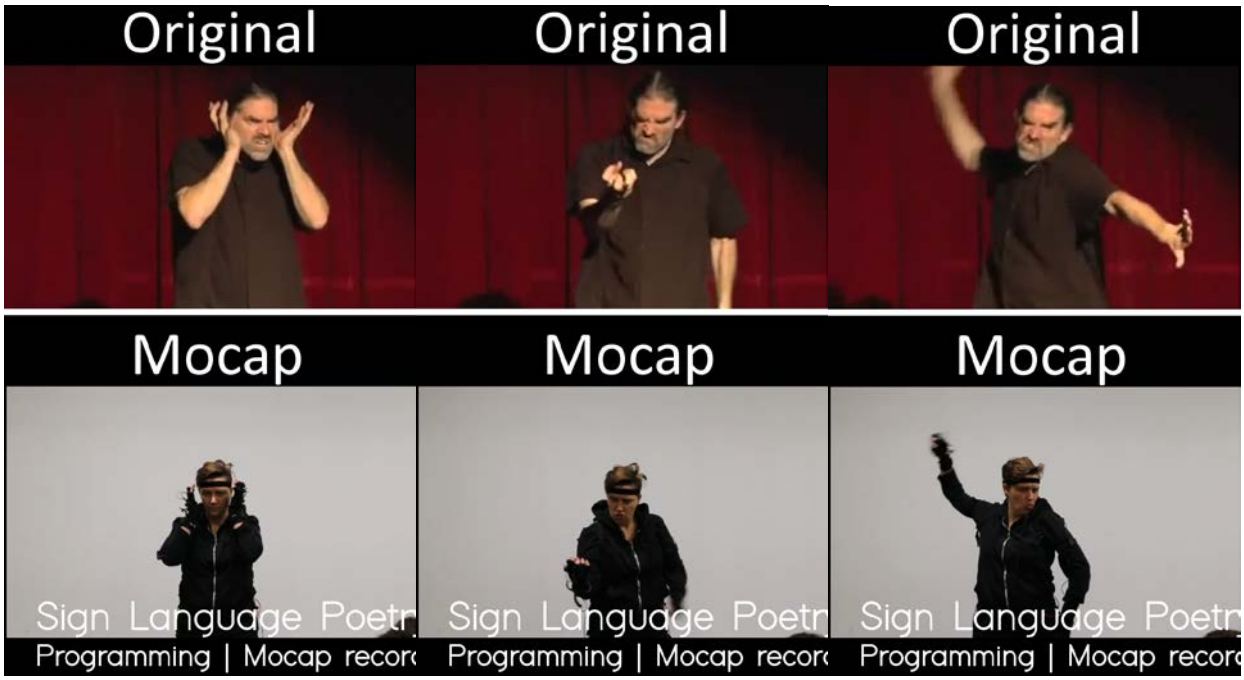


Figure 21 Mocap | Original samples

3.4.2 Retargeting and Cleanup

The outcome of the recording session grants us with a motion capture file in bvh format, which is basically the movement visualized in a skeleton. The **retargeting** procedure is mandatory since I need to map this movement into a specific avatar that will be used in the VR experience. After having chosen the 3d mesh of my avatar I had to make sure that it fills certain conditions before I proceed to the retargeting and cleanup process. These are:

- **The 3d model needs to be already rigged**.
- **The 3d model needs to be already skinned.**
- **The skeleton structure of the chosen 3d model has to match with the bone hierarchy of the motion data files**.

During the retargeting procedure each bone of the motion data file has to be matched with the corresponding bone of the 3d model. The result of this method is that the 3d model performs the same movement as the motion data file. This procedure can be applied to other models too, which means that the motion data can be retargeted to another compatible 3d model. Essentially, retargeting is the activity of transferring the motion data from a 3d model to another that act as vessels of movement.

A successful retargeting does not mean that the animation will be correct. There are many parameters that can cause loss of quality of the mocap animation such as using a very particular shape of a 3d model. Glitches in the animation can occur during the recording due to inefficient calibration of the motion capture suit or external factors that can affect the sensors such as strong electromagnetic fields (e.g. room with many wi-fi networks) or exposing the motion capture suit very close to metallic surfaces. Thus, **Cleanup** is the step where these issues can be eventually fixed. It's a time-consuming and delicate process where I have to fix the movement of the bones of the 3d model manually. Since the subject of the VR experience is sign language, I focused on reassuring the quality of the hand gestures. Therefore, the primary objective of the cleanup was to scan through all the frames of the mocap recording, detect where there are issues such as one hand getting inside the body of the 3d model and keyframe their position. This editing has been done by using the Motionbuilder IK/FK Control Rig [34], which is basically an IK/FK rig and it consists of two sets of controllers that are driving the hierarchy of the skeleton. In addition, the forwards kinematics skeleton is the one that the geometry of the 3d mesh is bounded to and the Inverse Kinematics is a set of controllers. In the Control Rig there are switches that allow us to decide which one of rig elements (IK or FK) is going to be driving the bound skeleton and thus we can edit the motion in that way.

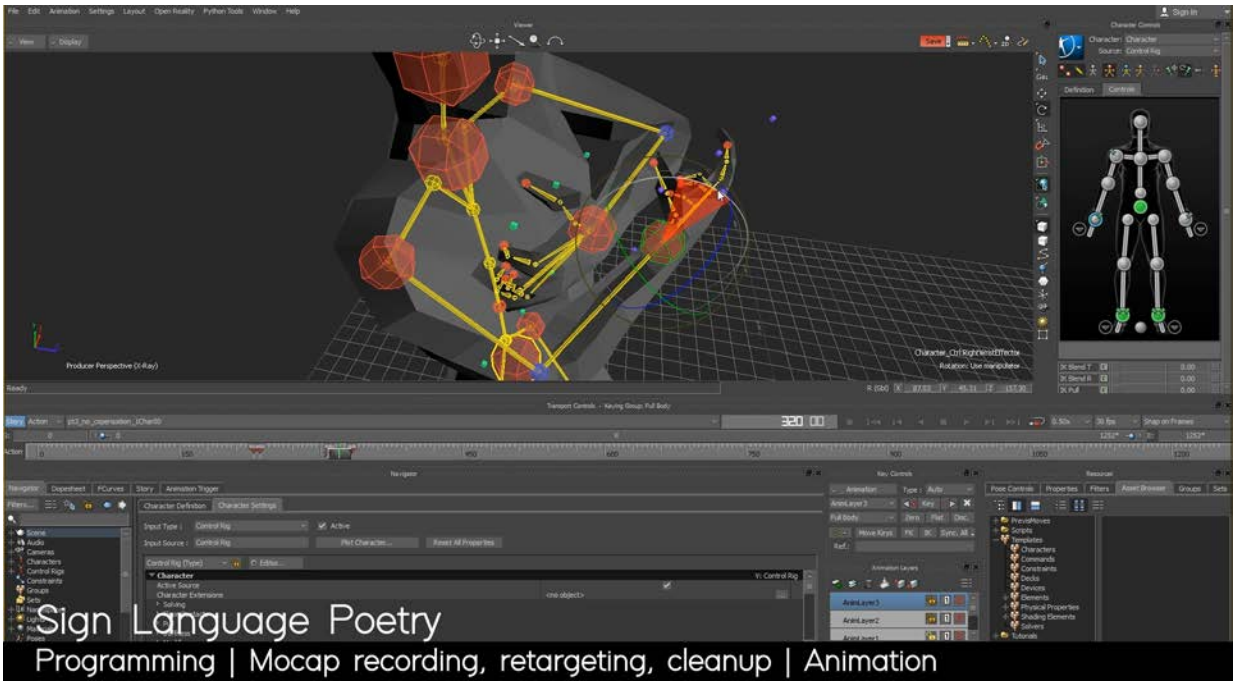


Figure 22 Cleanup process in Motionbuilder

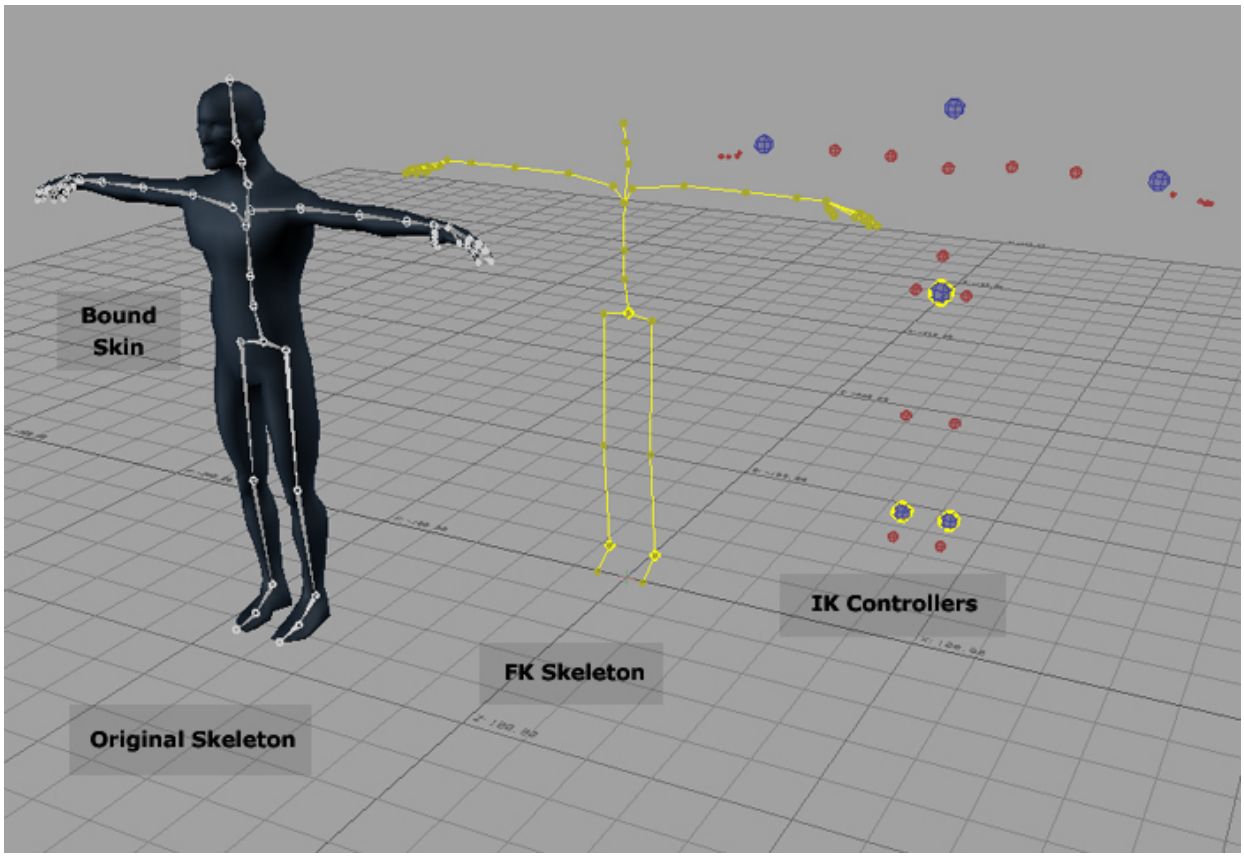


Figure 23 Motionbuilder IK/FK Control Rig

3.5 Implementation

3.5.1 Import into the Game Engine

Once the mocap animations passed the quality assurance, I exported them from Motionbuilder in fbx file format and imported them into the Unreal Engine, where the VR implementation and animation level sequence took place. This step was crucial, because there is often the risk of compatibility issues that may occur when a file type is passed from one platform to another one. To confirm the compatibility I had to check through the animator editor of UE4 if the imported animation is exactly the same as the one from Motionbuilder. The most common issue that we meet are animation glitches. This usually happens when the skeleton of a 3d model has a different name convention from the default one of Unreal Engine. So, the most common solution is to create a skeleton profile for the imported 3d model -that contains the mocap animation- and correspond its bones name convention with the one of Unreal Engine's default skeleton. During the development, the functionality of the application is a top priority. It is important to develop the basic mechanics that we need for the VR experience before we proceed to the aesthetics and animation part of the VR experience. Thanks to Unreal Engine's plugin that enables VR, there are few things that we have to configure in order to make our application VR-ready (Figure 17). Once we are in the development part, it is recommended to set some basic actions that make the experience less frustrating. These basic command actions are:

- Button for restarting the experience. If the user demands to re-watch the narration of the poem, they can restart it. However, if the narration ends, the virtual environment is still preserved until further command.
- Button for changing the camera angle view. I set a number of cameras around the environment in order to enable the user to "teleport" around the environment, because it is bigger than the actual physical the is available for the user. Also, if somebody is curious about the VR experience and does not have an VR kit, they can enjoy the different points of view with this action.
- Button for pausing the experience. Sometimes, the storytelling can be very fast for somebody and the quantity of information might overwhelm them, so a small break does the trick.

3.5.2 Avatar

One of the most basic questions when it comes to animating movement is how an avatar looks like and how its features reflect an image related to a practice of the movement or the general context. For the sign language VR experience, I made sure to use an avatar where the movement of its upper body and its hand gestures are clear. Even though it is a fact that the face expressions also play an important role in sign language, I decided to use a 3d model without facial expressions in order to give a more protagonist role to the visualizations of the environment that they are actually depicting both the hand gestures and the facial expressions of the sign language performer. For the sake of maintaining the chosen synthwave/vaporwave aesthetics that I chose to apply in the virtual environment and also optimizing the application, the 3d model is low-poly. After importing it into Unreal Engine I finalized its visual look by creating and applying materials into it. A **Material** is an asset that can be applied to a mesh to control the visual look of the scene. In more technical terms, A **material** specifies how an object responds to light. When light from the scene hits the surface, its material is used to calculate how that light interacts with that surface. These calculations are done using incoming data that acts as input stream to the Material from a variety of images (textures) and math expressions, as well as from various property settings inherent to the Material itself. The most common parameters are:

- Kd: Diffuse response to light
- Ks: Specular response to light
- Ns: "Shininess"
- Map Kd: Texture

I conducted experimentations with semi-transparent, Perlin or Simplex noise and flat shaders to apply to my avatar's material. With the semi-transparent and emissive shaders the fingers of the avatar were not enough visible, hence they broke the fundamental rule of the vr experience -maintaining the hand gestures as clear as possible- so I rejected them. Also Perlin or Simplex noise shaders despite their compatibility in respecting the aesthetic consistency and the finger clarity, they are more expensive algorithmically. As a result, I used flat shader, which fulfill all the conditions. Also, I used the wireframe shader for the Avatar that acts as Orion.

Table 1 Candidate shaders for the avatar

Shader	Finger clarity	efficiency	Aesthetically consistent
Semi-transparent	-	+	+
Perlin Noise	+	-	-
Simplex Noise	+	-	-
Emissive	-	+	+
Wireframe	+	+	+
Flat	+	+	+

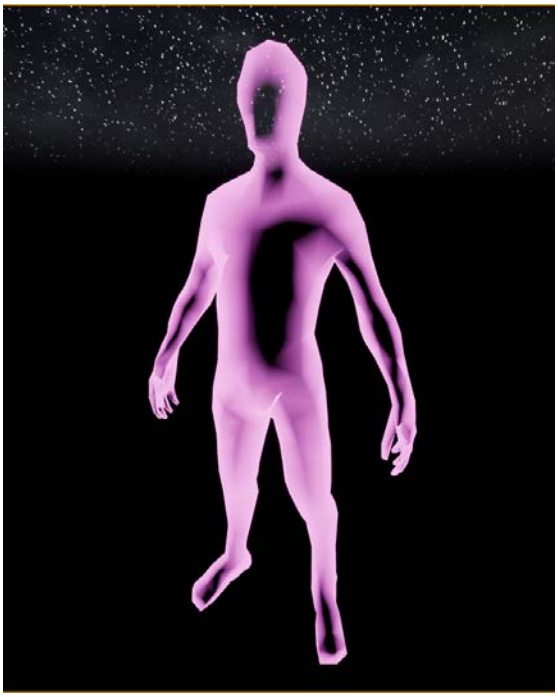


Figure 24 Semi-Transparent

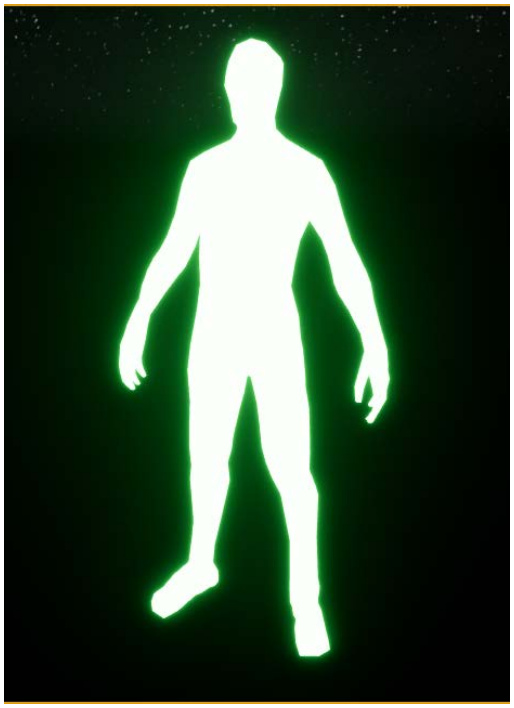


Figure 25 Emissive

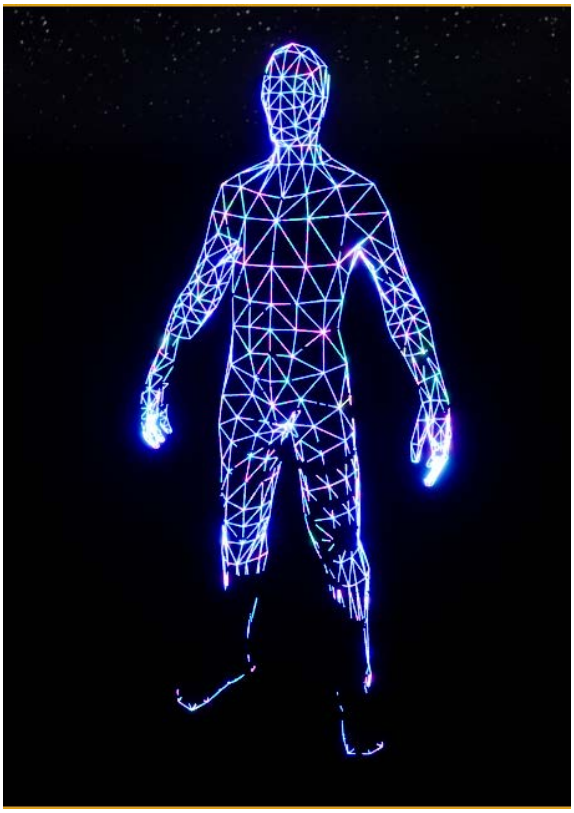


Figure 26 Wireframe

Figure 27 Flat

The flat shader material is implemented in the following way:

- The flat shaded normal are calculated from the world position of the rendered pixel
- DDX and DDY are HLSL[37] functions that give approximate screen-space derivative of the value that we request. The most common use is to compute our own mip-map, that can be passed into the texture sample node.
- The cross product of DDX and DDY [39] from the world position of gives the normal direction of each polygon. (Figure 28)

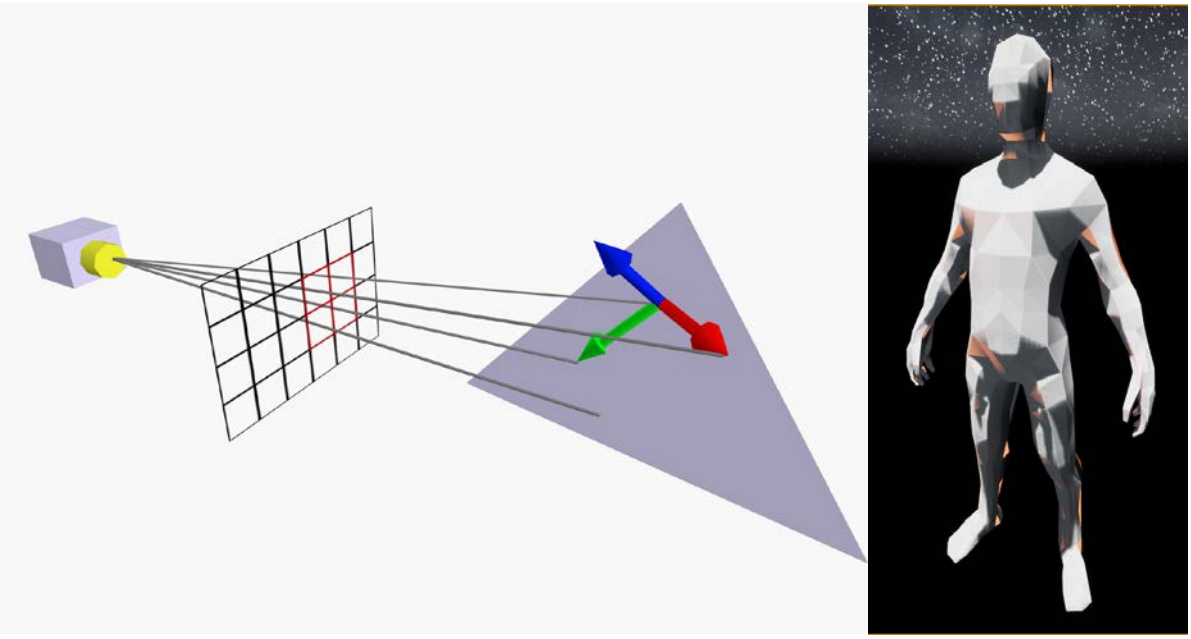


Figure 28[7] shader derivative functions

3.5.3 Sequencer Animation

The Sequence Editor within Unreal Engine 4 is a cinematic editing tool. It allows users to add Tracks that can modify certain properties of Actors in a level through the pass of time or in specific moments. In our case this tool is suitable because our project is based on time-based storytelling, therefore the signs and gestures of the virtual performer lead the series of events that happen through the pass of time. During the narration, the sign language performer can construct an environment, roam around it, change the world scale (for example he/she "zooms" from human scale level to molecular), trigger events and change point of views of the entities that participate in the poem, deconstruct the environment and reconstruct a new one and so on until the end. Thus, through the sequence editor I visualized all the actions of the performer into the virtual environment. When we open the Sequencer Editor in Unreal Engine, a timeline window appears, where I added all the objects of the scene that I wanted to manipulate. The virtual performer avatar one of the scene actors that remain in the view for the whole experience, since it is the main core of the experience. For example, in the case of the first verse of the part B of the prementioned poem (3.5.1), a second avatar that represents the constellation of Orion is keyframed to appear in the corresponding moment when the virtual performer performs the related sign about him. In Addition, A boulder element appears in the location where the eye of the Orion should be and is keyframed to follow his hand in order to create the illusion of being thrown away (thus visualizing the second verse). In general, I have keyframed transform, rotation, visibility and personalized parameters of the objects that are included in the scene.

[7] Left image taken from Giuseppe Portelli: http://www.aclockworkberry.com/shader-derivative-functions/

Figure 29 Sequencer editor Mode: "*towards the canoer's chest cavity*" verse

Figure 30 Play Mode: *"towards the canoer's chest cavity"* verse

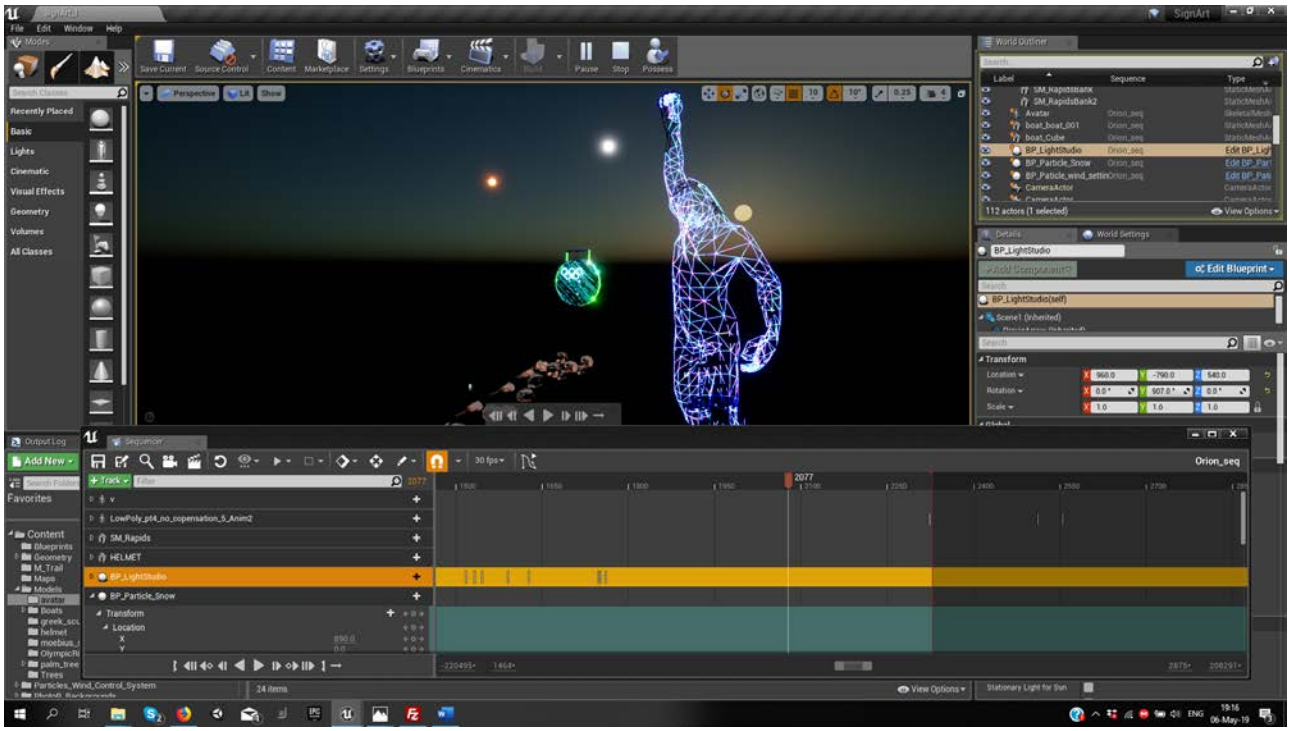


Figure 31 Sequence editor Mode: *"black power salute then explodes in the sky, a star"* verse

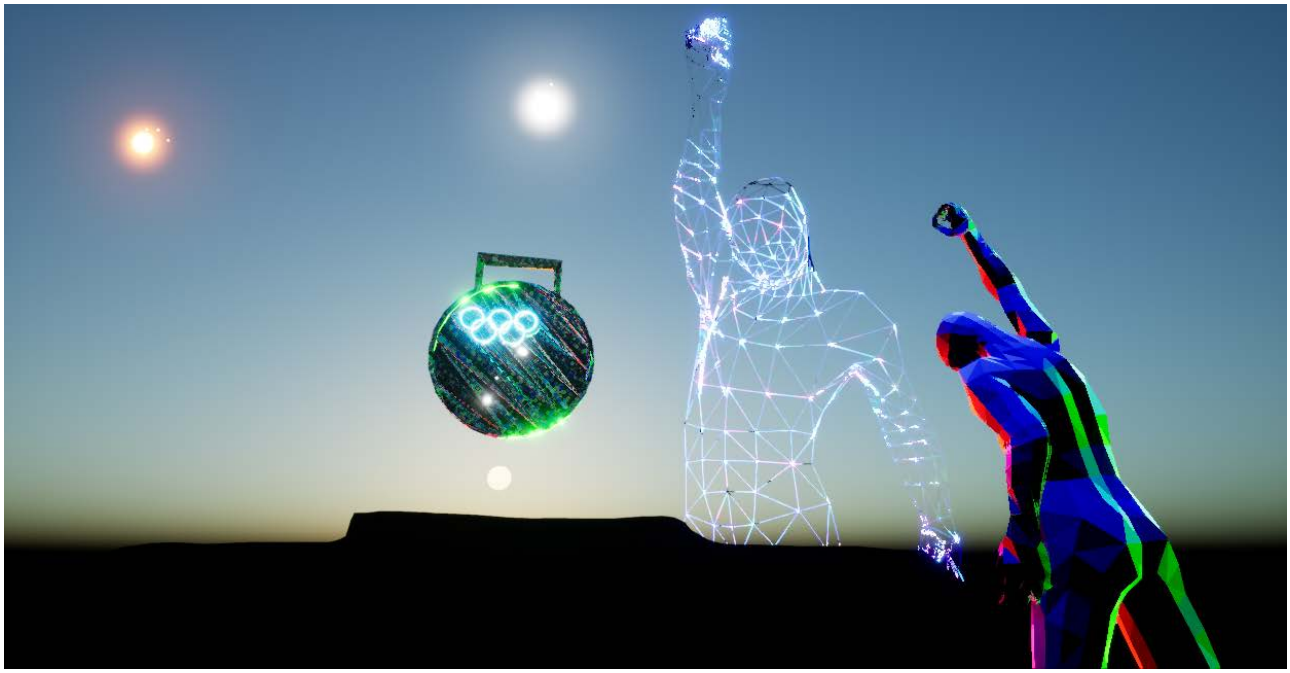
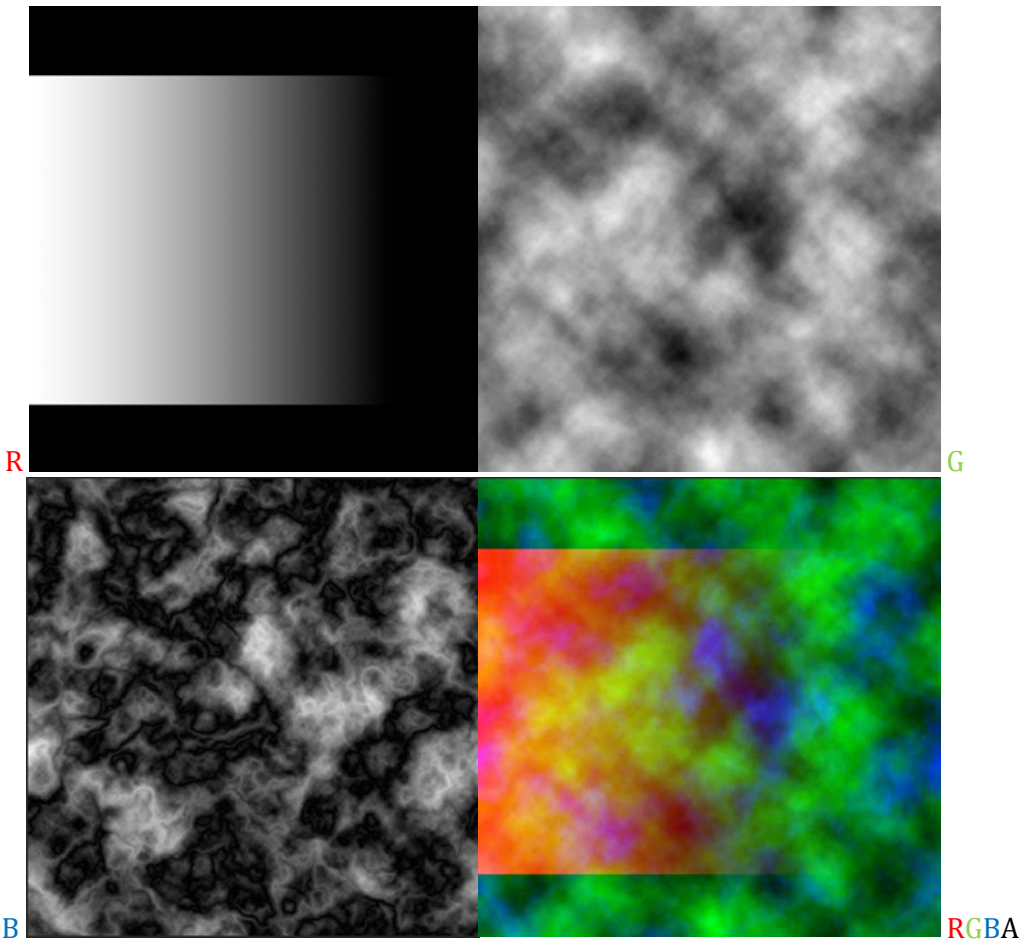


Figure 32 Play Mode*: "black power salute then explodes in the sky, a star"* verse

3.5.4 Visual Effects

Visual effects play an important role in nearly every content that is related with graphics. For this experience there are also used visual effects to emphasize specific moments and of course beautify the virtual environment. In Unreal Engine, the visual effects vary from objects in the scene such as atmospheric fog, particle systems, blueprint materials to camera post processing effects. It is also a fact that Virtual reality experiences are applications that demand a lot of processing power. Even with a high-end computer there might be performance issues that lower the framerate of the execution of the application, making it hard for the user to experience it. It is important before the developer reaches this point, that they should already have decided to set an equilibrium between the amount of visual effects and performance, and if something needs to be sacrifice it's better to strive to the latter one. For this project I used the following three types of particle systems:

- **Fire** that has been used as trail of the comet (the eye of Orion that is thrown towards the canoer). This asset can be found in the starter content of UE 4.20
- **Snow Particles**, that with some modifications in the directionality, density and particle size they seem like space dust. This asset can also be found in the starter pack of UE 4.20
- **Light Particles** [36] that have been used as motion trails for the wise corn seeds (part A in 3.5.1). This visual effect is a particle system that consists of 5 emitters, that each one of them has a blueprint material. The blueprint Material is responsible for the complexity in color and patterns of the final trail structure. Firstly, I created a texture that contains a different pattern for every channel (RGBA). Therefore, after importing that texture into the blueprint material I applied expressions independently to every channel (for example panning the UV texture coordinates of the green channel) and then blended them all-together to the final result. (Figure 29)(Figure 30)Afterwards, I created the particle system consisting of five (5) emitters where the three (3) of them are responsible for the ribbon shape of the trail (Figure 31) and the rest of them for the core shape (Figure 32). The different colors of the ribbon emitter also determine the color and animation pattern of the material because of its multichannel configuration.



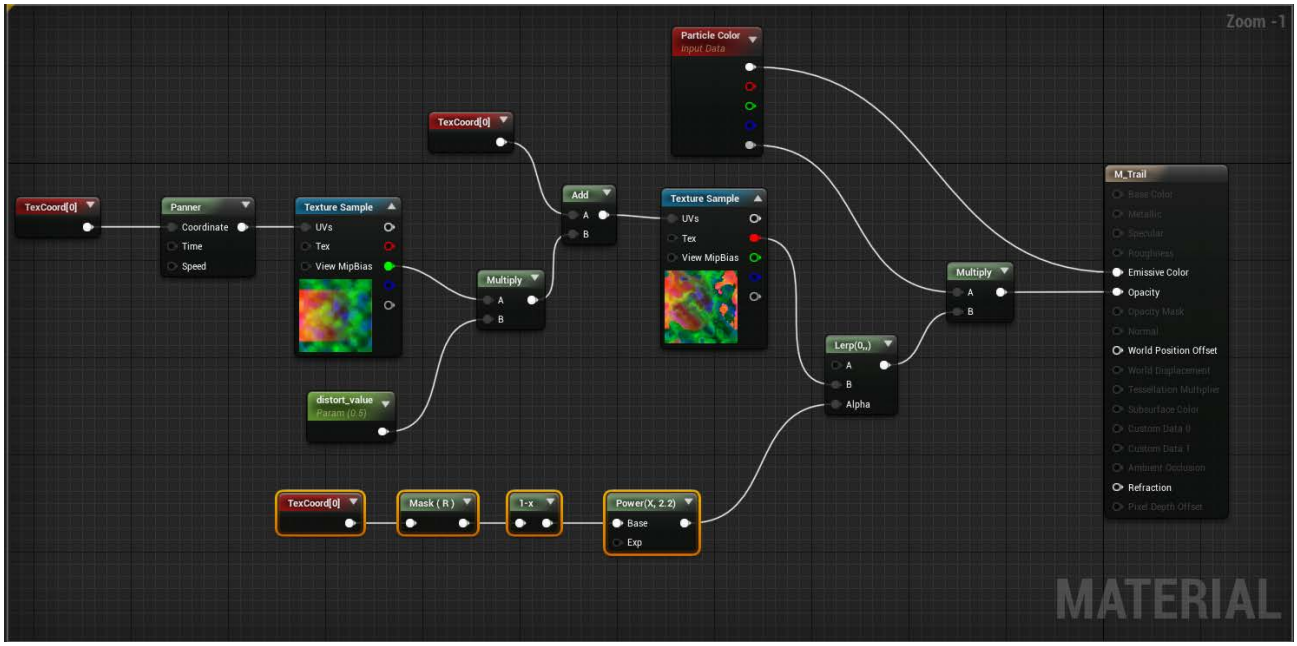


Figure 33 Implementation of the light trail material

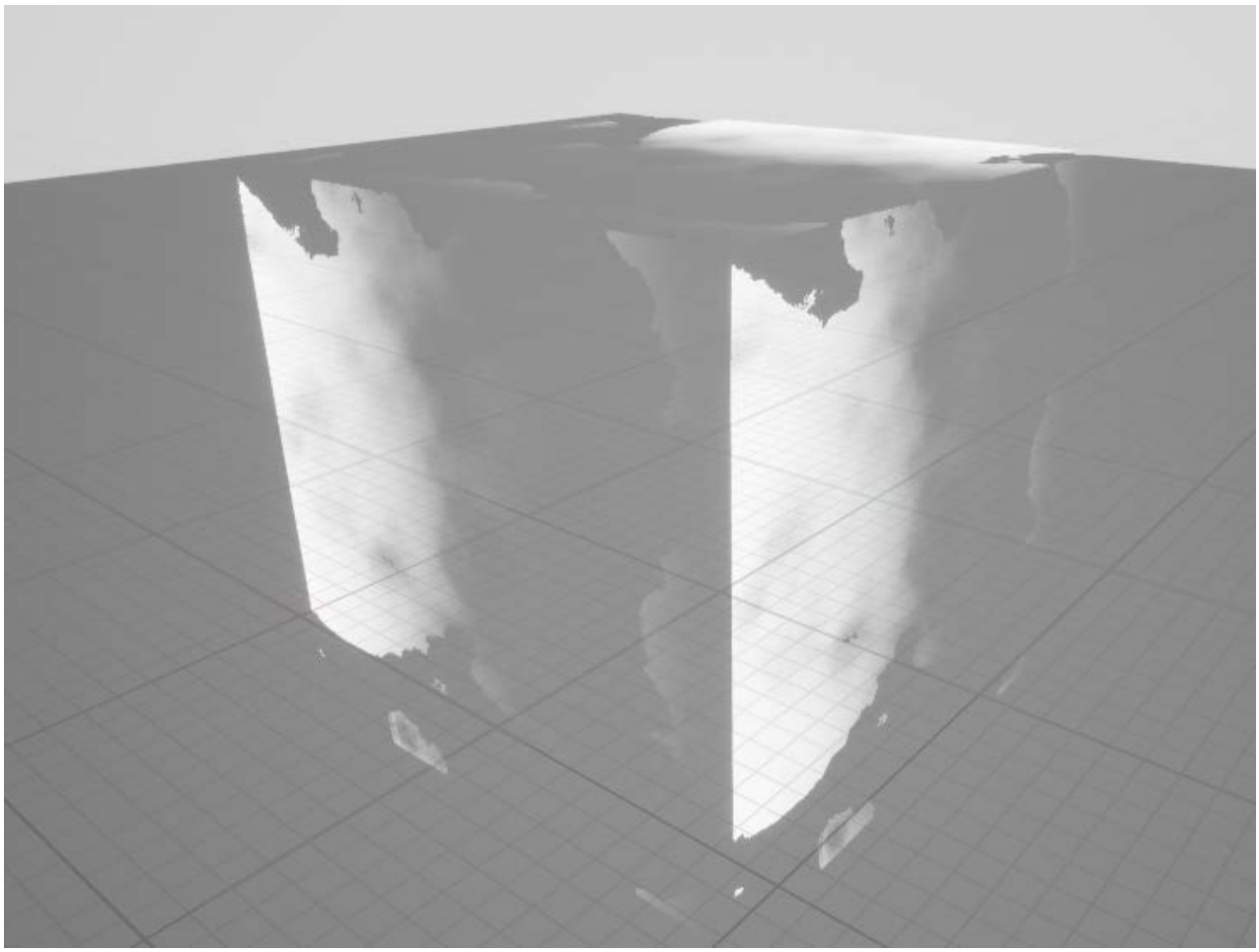


Figure 34 Light trail material

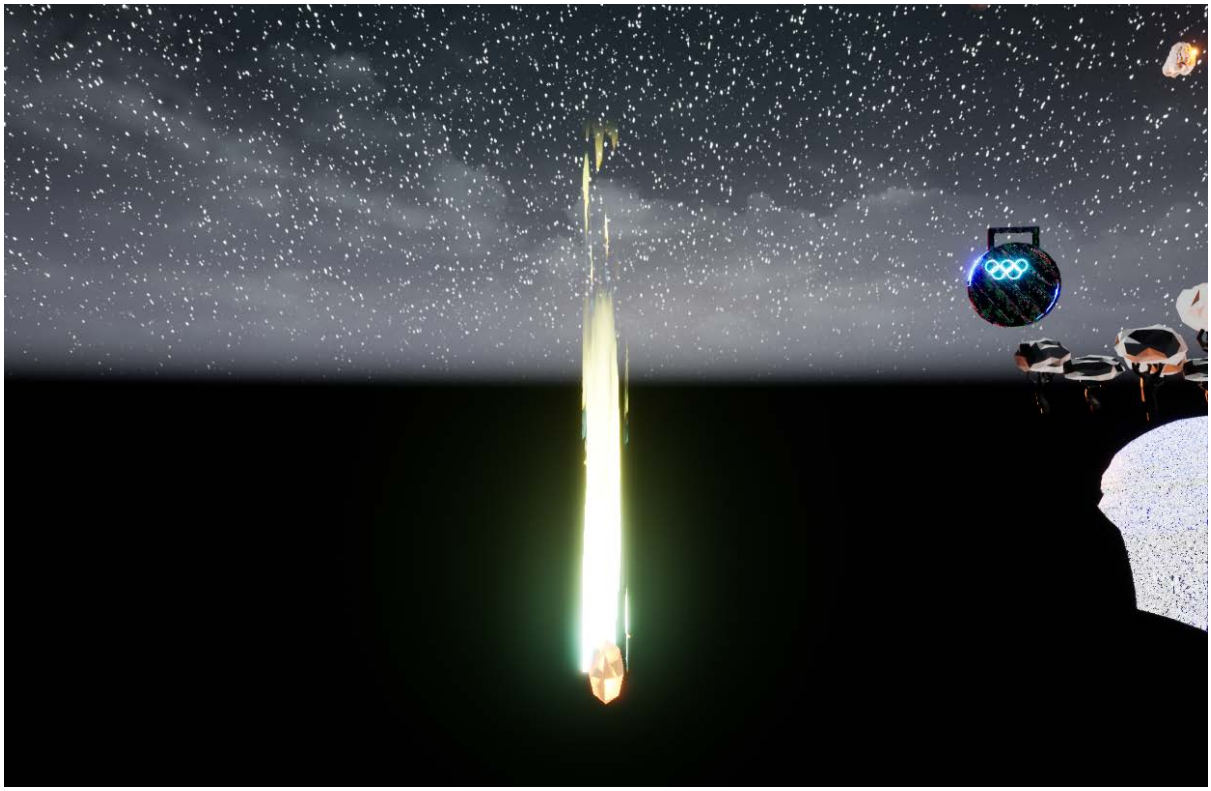


Figure 35 Ribbon shape emitters

Figure 36 Core shape emitters

4. CONCLUSIONS AND FUTURE WORK

4.1 Review

In the above chapters we described a pipeline that guides us on what knowledge we should collect before we begin a storytelling project either it is an interactive one or linear. Afterwards, we are shown how to convert sign language poetry data from analogic to digital from scratch. And later on, we are shown some examples on how to deal with the aesthetic part with the usage of blueprints. At the end, there are noted the possible issues and troubleshooting in order to complete the project.

Figure 37 Play Mode: *"he throws it up, repelling, exploding in the sky, a star"* verse

4.2 Conclusions

- How is virtual reality and sign language poetry related to each other?
- Does the artistic visualization of sign language poetry in VR enhance the way that the spectator appreciates and experiences it?
- Can different aesthetics affect the user in their experience with the narrative?
- Does the time-based narrative in virtual reality have a strong impact on the user?

The embodiment through this immersive technology allows the users to experience a story like no other medium before. It not just storytelling, it can be considered as storyliving. Concerning the relation between VR and ASL Poetry, a user who understands ASL understands differently the poem from someone who does not know the language and listens only to the narrator who uses the spoken language. I have observed that during the sign language poetry performance, I didn't recognize enough signs but I observed hand and upper body gestures accompanied by facial expressions where a person who does not have knowledge of ASL can comprehend a significant percentage amount because of the context of the movement but it is not enough to have the same point of view with somebody who knows the language. Also, the vocal narration that is translated has significant differences from the original content or it can lack content because a movement can be done quicker and at the same time describe more things Therefore, the vocal narrator tries to keep up by retaining the main concept. The visualization of ASL poetry in VR is the medium that brings these two groups of people closer in terms of assisting the second group approach the level of appreciating a poem in its original form without translating it. This VR experience is a proof that the hearing world does not have to assimilate every time the deaf community. Sign language is also root language with many varieties (for example French sign language is different from American sign language) and translating it into other languages can cause loss of information, thus loss of the actual experience. You might think that the visualization in the VR

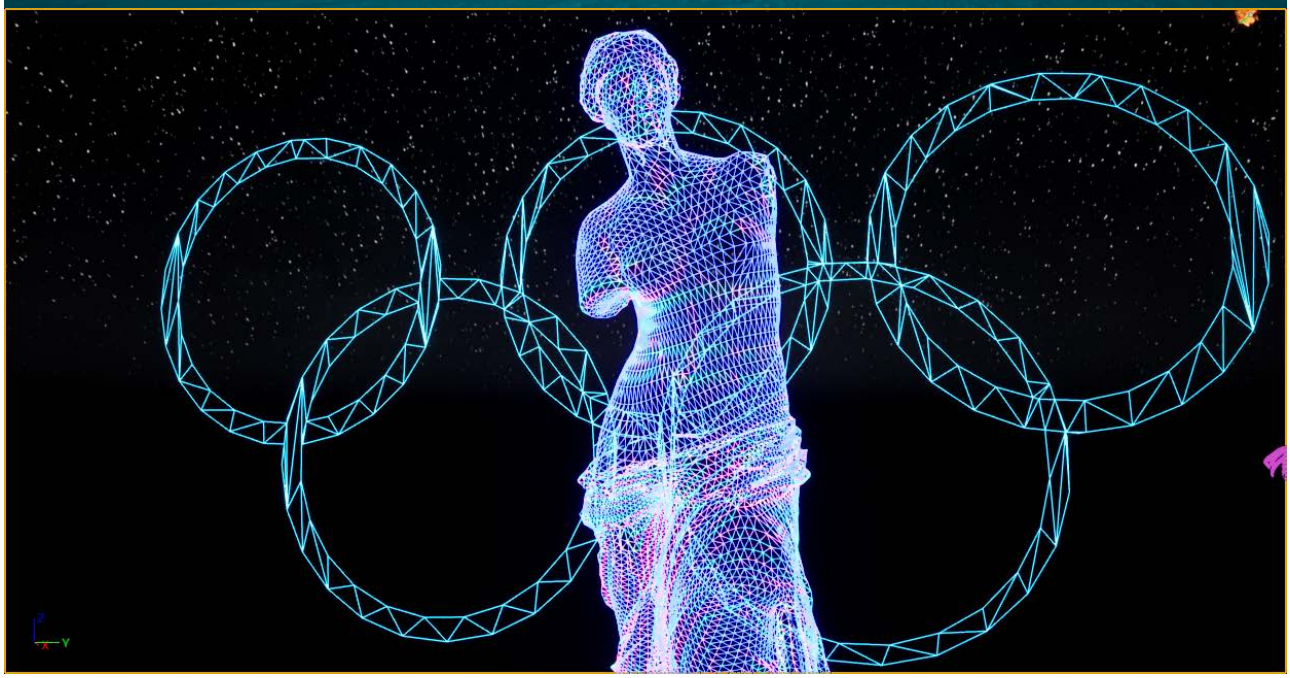
experience it is also kind of a translation, an iconic one. It is true, but in this case, due to the fact that we translate analog image to digital image, and also the work is done frame by frame, or let's say better gesture by gesture, there is full synchronization between the visualizations and the hand gestures.
At the End, concerning the time-based narrative there are two important values that have to be always fulfilled for the user. Impact and presence. These are, whether the user is a part of the world or not or whether if they have impact on it or not. They can be full spectators (ghosts) without any impact, not being able to change anything, but they will be privileged observers. They can be observers who are able to change things or not. Or be a character with impact or without. Then, by altering those parameters, they can create different parameters to experience the world.

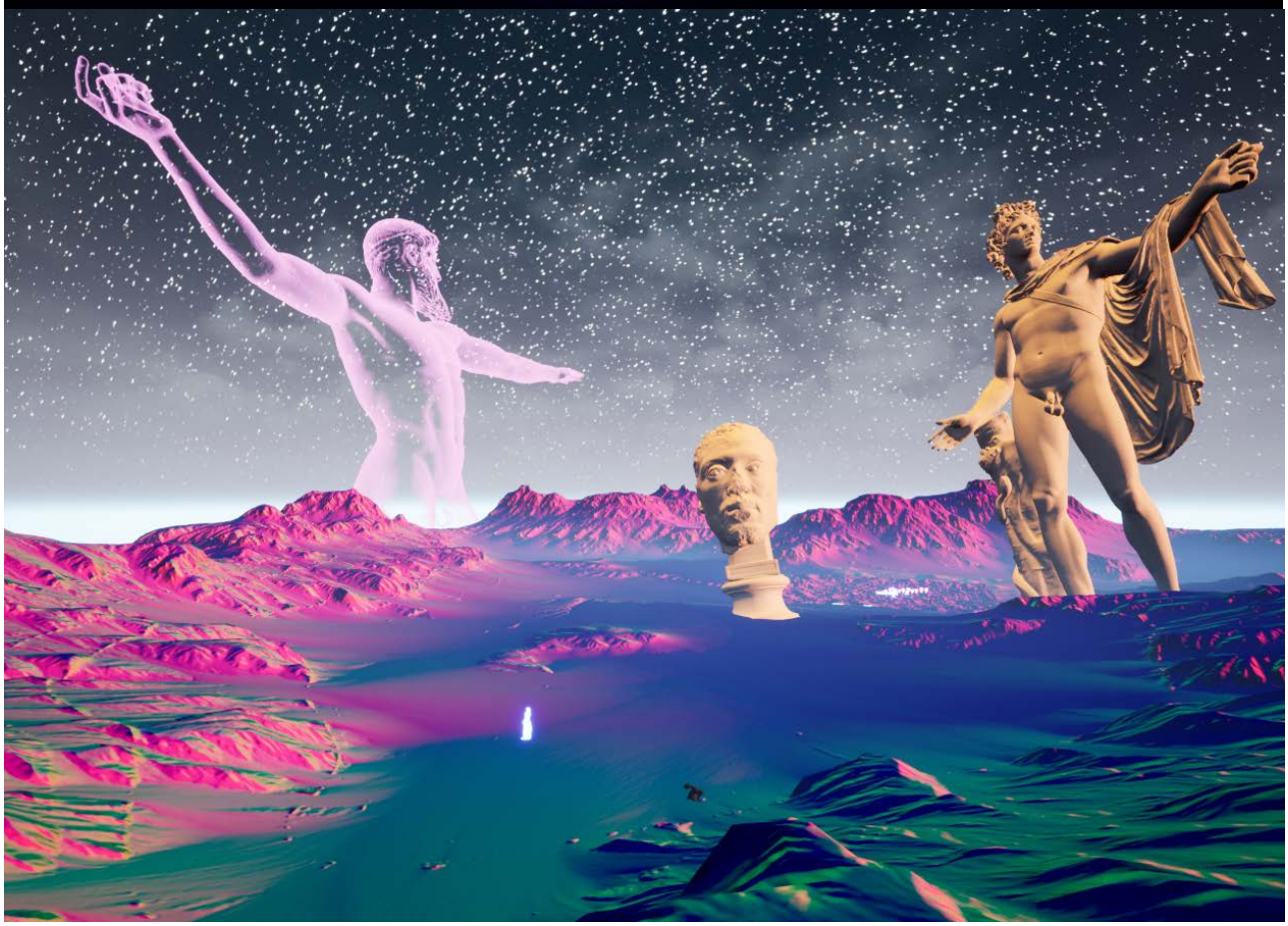
4.3 Research Project

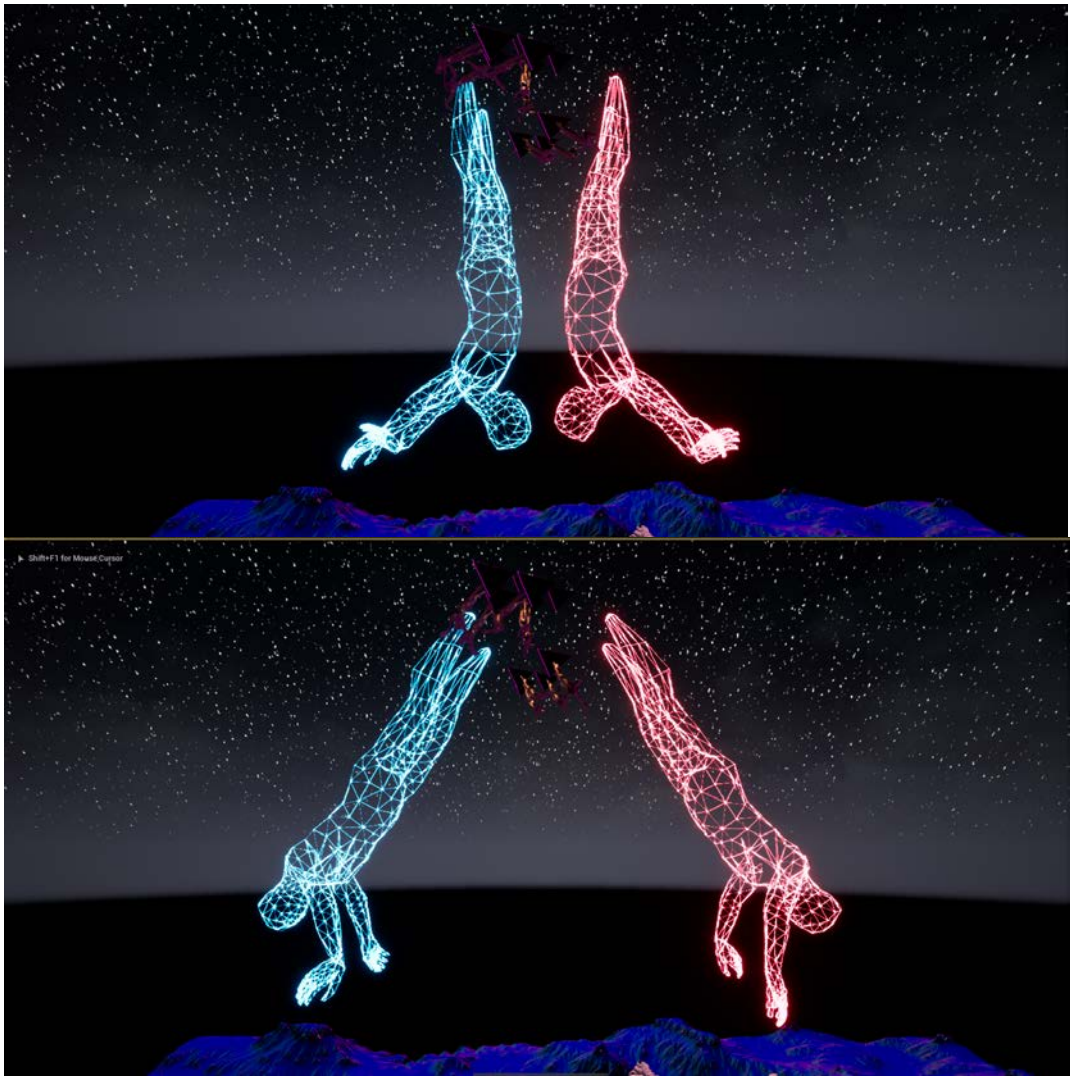
The current VR experience concept is going to be used as prototype application under the research project "traduire la performance performer la traduction" of LABEX Arts-H2H [54].

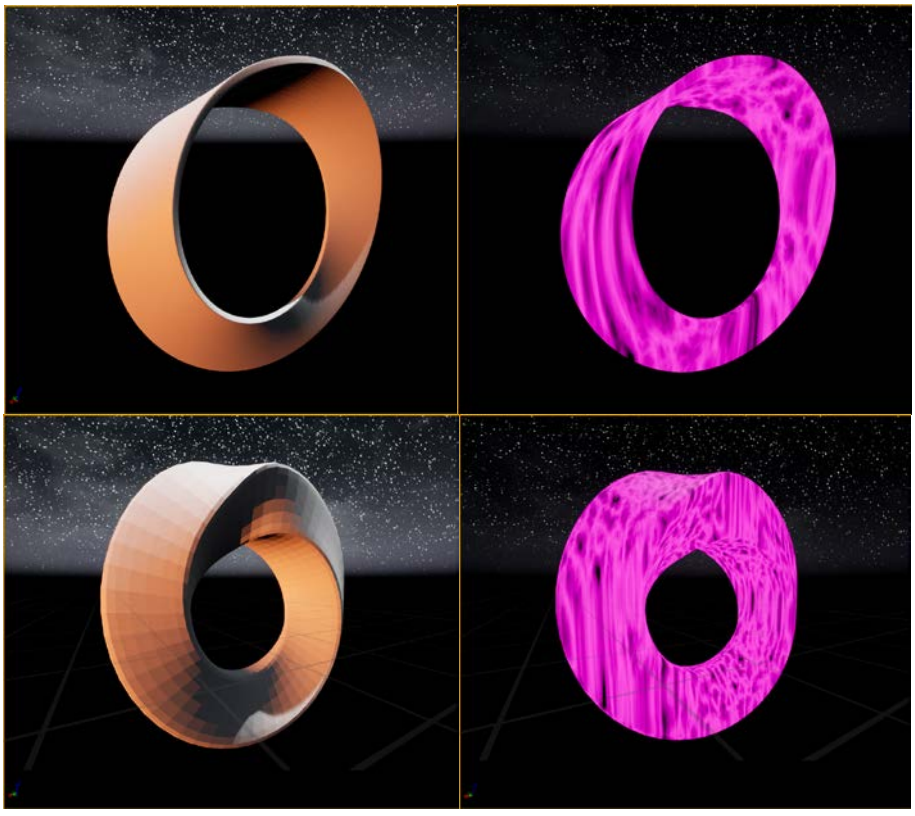
4.4 Future Work

I am highly interested in storytelling with parallel worlds or multidimensional spaces. My plan is to upgrade the VR experience into a moebius-strip narrative VR experience. The user is driving/walking on the non-ending Moebius strip, and on the sides of it there will be gates that lead to other worlds. Each world represents a VR experience, but since we are talking about parallel world timelines it can be a VR experience with same content of another one but with a different outcome, since it's a parallel timeline. In other terms, I am planning to convert the experience to an action-based one even though each individual experience will probably be time-based. The aesthetics stick to the synthwave/vaporwave style.









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TERMINOLOGIES

Term	Description
Accelerometer	device that measures proper acceleration
ddx	hlsl function that returns approximate partial derivative with respect to window-space X
ddy	Hlsl function that returns approximate partial derivative with respect to window-space Y
Game Engine	software-development environment designed for building video games
Gyroscope	device used for measuring or maintaining orientation and angular velocity
Hotkey	Shortcut key
Hub	Device that transfers the motion capture data from the suit to the computer
Immersion	perception of being physically present in a non-physical world
Intuition	ability to acquire knowledge without proof, evidence, or conscious reasoning
Motion Trail	depiction of the distance that a moving object has covered
Occlusion	when one object in a 3D space is blocking another object from view
Procedural	Data that has been created algorithmically
Rigging	*creation of a digital skeleton for a 3D mesh*
Skinning	Attachment of the mesh of a 3D model to the virtual skeleton or the rig
T-Pose	Default pose of a 3d model in the shape of T

ACRONYMS

ASL	American Sign Language
BVH	Biovision file format
CG	Computer Generated
CGI	Computer Generated Imagery
Custom	Customized
DIT	Department of Informatics & Telecommunications
DOF	Degrees of Freedom
FBX	Filmbox file format
FK	Forwards Kinematics
FPS	Frames per Second
GUI	Graphical User Interface
HMD	Head Mount Display
IK	Inverse Kinematics
JIT	Just-In-Time Compilation
Mobu	Motionbuilder
Mocap	Motion Capture
MR	Mixed Reality
PNG	Portable Network Graphics file format
SDK	Software Development Kit
S/W	Software
UE4	Unreal Engine 4
VFX	Visual Effects
VR	Virtual Reality
Wholodance	Whole-Body Interaction Learning for Dance Education
3D	3 Dimensional

APPENDIX I: VISUAL SCRIPTING

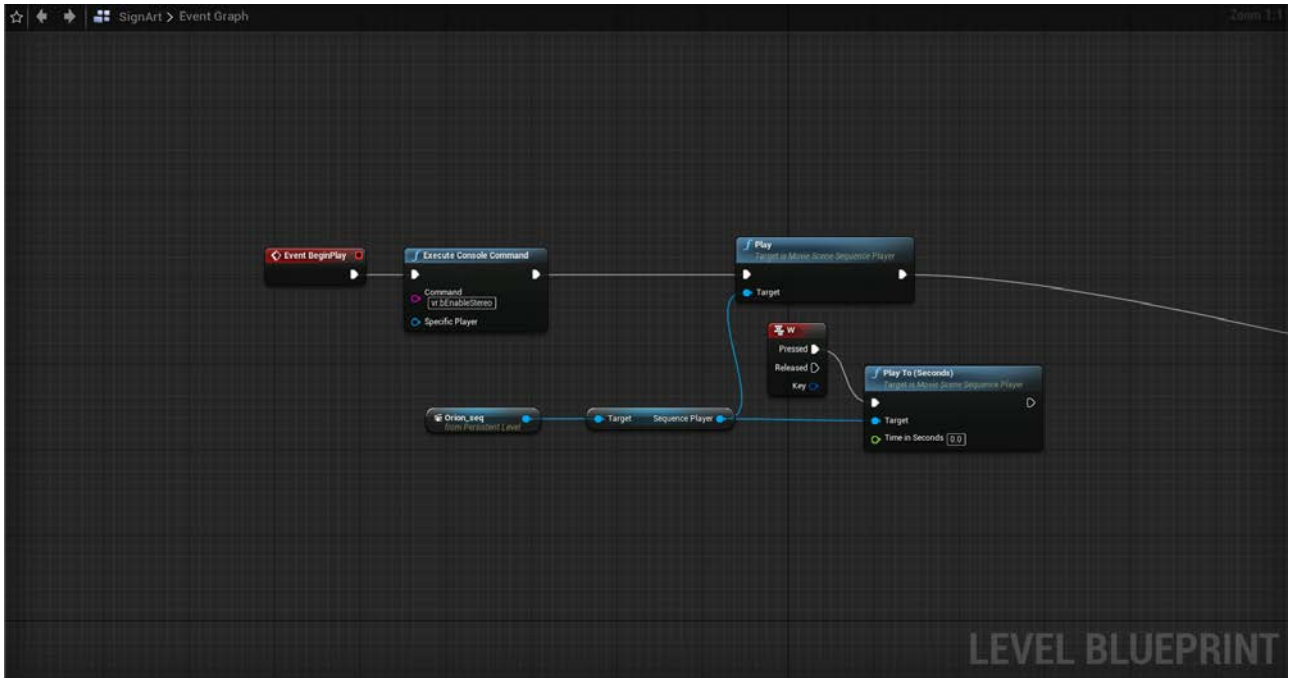

Figure 38 Simple configuration to enable VR

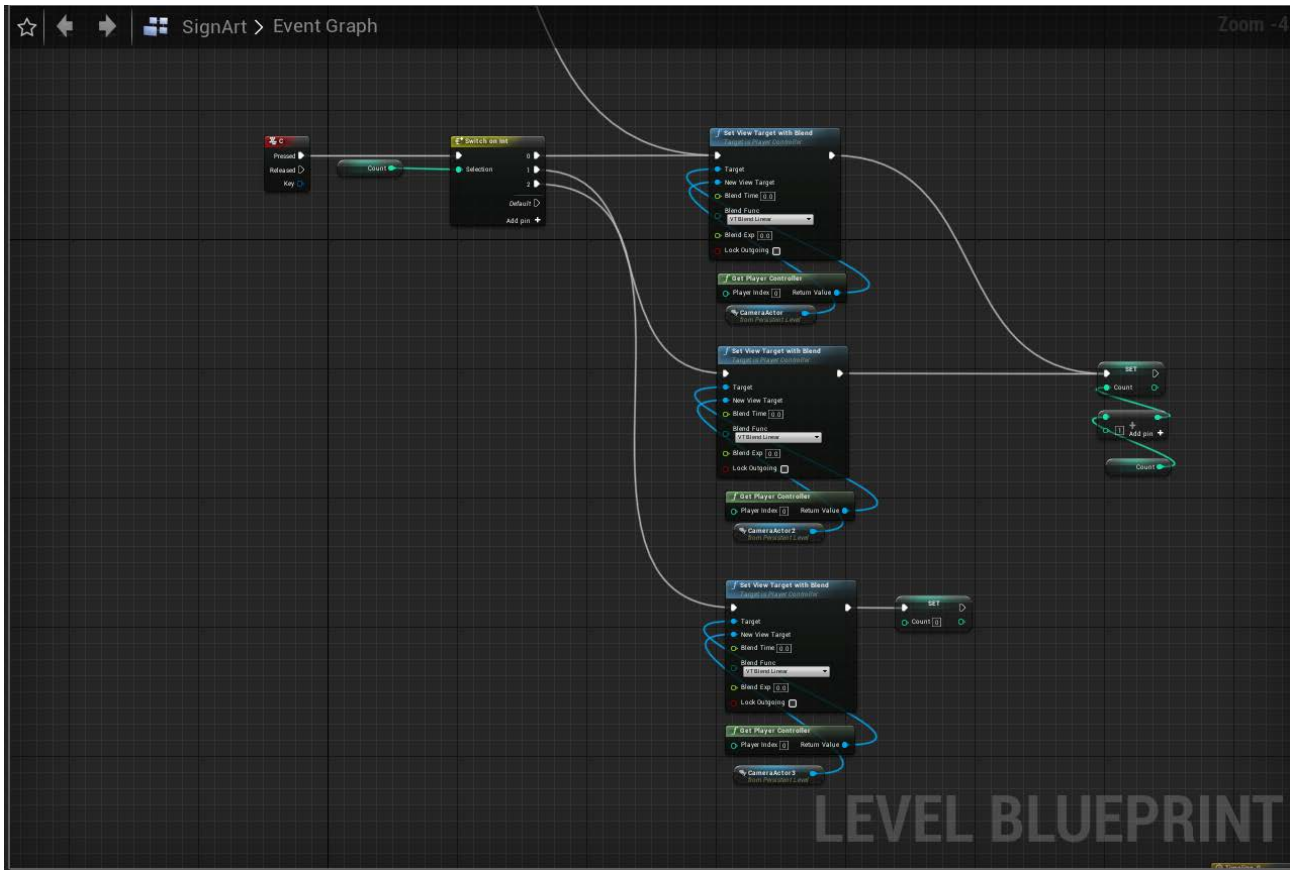

Figure 39 Change of camera angle implementation

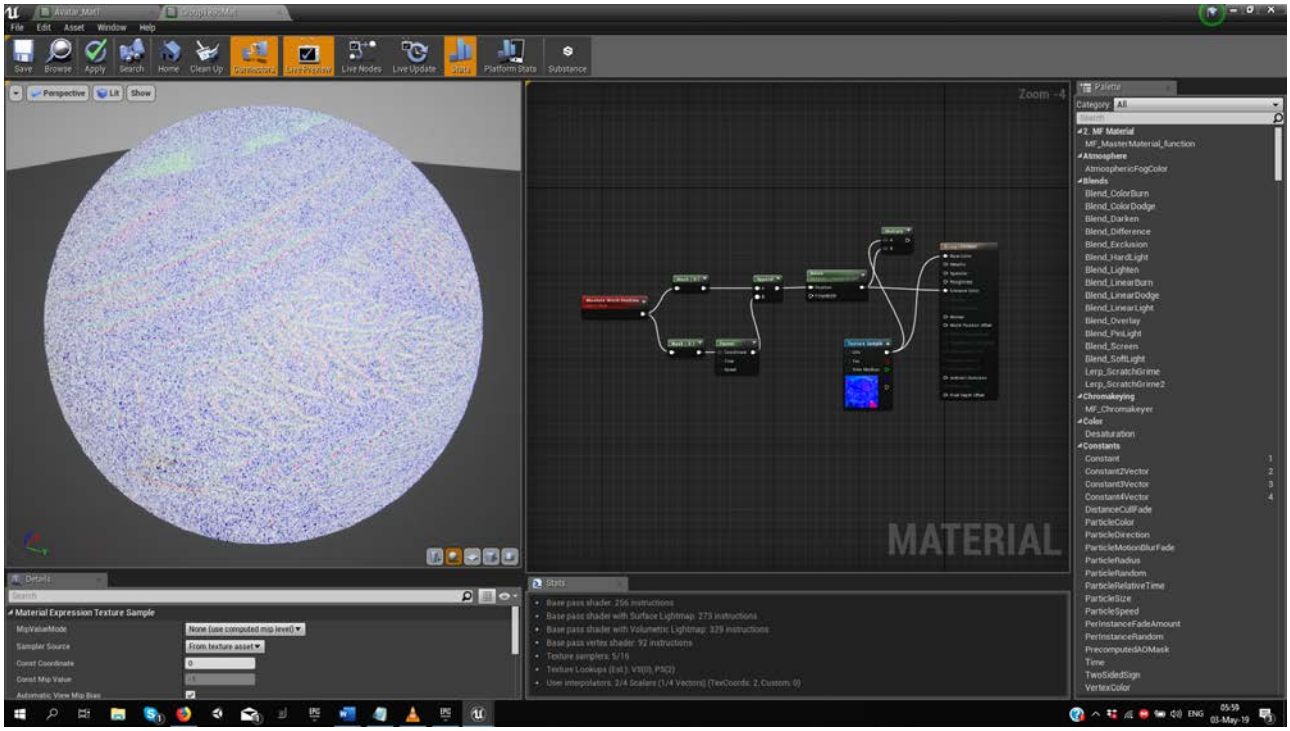

Figure 40 Simplex Noise Material

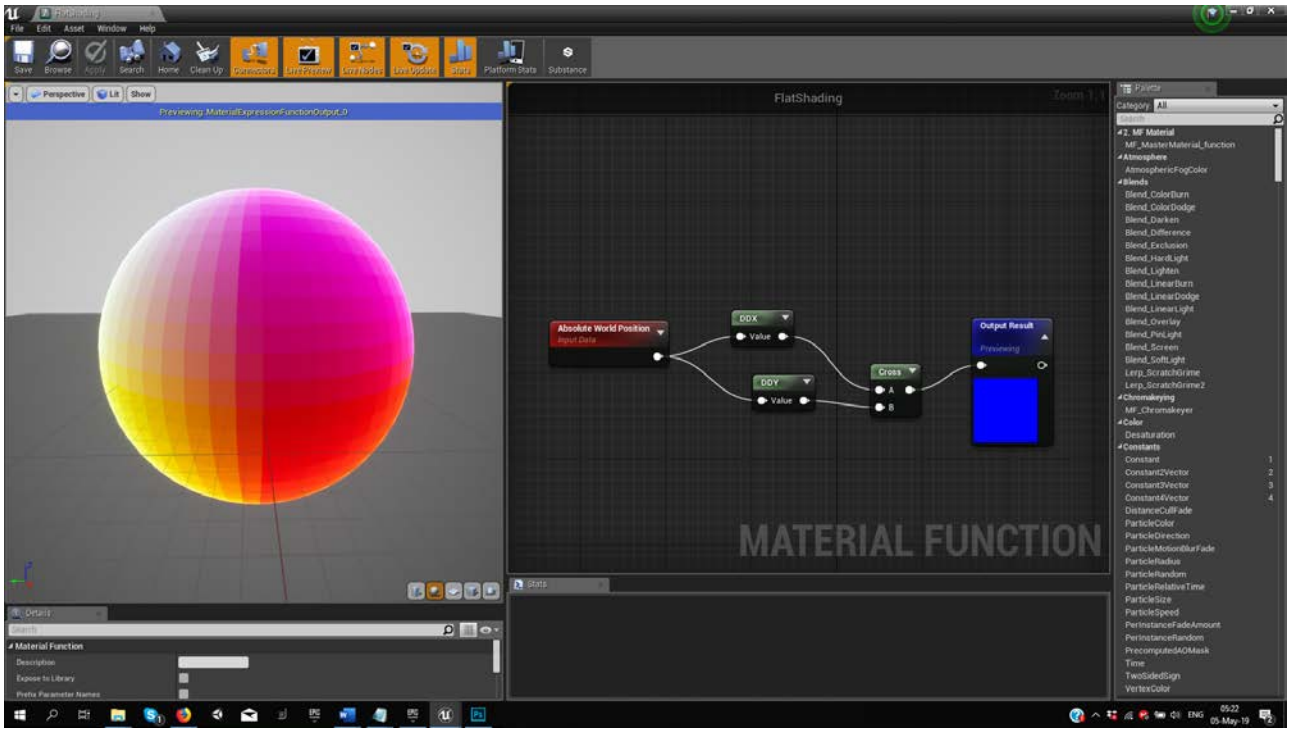

Figure 41 Flat Shader

APPENDIX II: MANUAL

Installation Manual

Minimum system specs:

- **Hardware:**

Table 1 : Hardware specs

OS	Windows 7/8/10
Processor	86 dual-core 2GHz
RAM	300Mb
HDD	600Mb
GPU	OpenGL 4 compatible

- **Equipment: Oculus Rift (Virtual Reality kit)**

Installation process:

1. Connect Oculus Rift to the computer.
2. Make sure that you have already installed the Oculus software.
3. Configure Oculus Rift sensors.
4. Set-up the guardian system.

Execution instructions:

1. Wear your VR HMD.
2. Launch the application.

Instructions for use:

Table 2 : tools

name	description	HOTKEY
Pause	Pause the experience	P
Restart	Restart the experience	R
Camera View	Change camera view	C

ADVICES - TIPS:

Try to walk into the body of the virtual narrator, and when u embody yourself to it, observe its body and it hands.
Once the virtual narrator finishes the performance, he/she remains still. If you are embodied to him/her, take a look at its body. Then take off your HMD and look at your body. Repeat.

APENDIX III: ASL POETRY DEMO PROTOTYPE