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DEVELOPMENT OF A VR GAME FOR MEKTORY DEMO ROOM

Bachelor's thesis

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MÄNGU ARENDAMINE MEKTORY VR DEMOALA JAOKS

Bakalaurusetöö

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Tallinn 2018

Author's declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

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Abstract

There were two main purposes of a bachelor's work. First one was to investigate the current state of the virtual reality technologies and provide a survey of the areas where VR applications are being used as well as attitude towards them. Second one was to develop a maximally interesting and comfortable in use VR game with "shooter" elements for Mektory demo room, thus trying to increase tourists' and MEKTORY Business and Innovation Centre visitors' interest in this particular topic.

The game was successfully created in game engine Unreal Engine 4 for HTC Vive virtual reality headset developed by HTC and Valve Corporation.

This thesis is written in English and is 29 pages long, including 5 chapters and 44 figures.

Annotatsioon

Mängu arendamine Mektory VR demoala jaoks

Käesolevas töös oli kaks peamist eesmärki. Esimene neist oli uurida virtuaalse reaalsuse tehnoloogiate praegust olukorda ja anda ülevaadet valdkondadest, kus VR rakendusi kasutatakse. Teine eesmärk oli välja töötada maksimaalselt huvitav ja mugav VR-mäng "shooter" elementidega Mektori demo-ruumiks, püüdes sellega suurendada MEKTORY äri- ja innovatsioonikeskuse külastajate huvi selle konkreetse teema vastu.

Virtuaalne reaalsus on arvuti abil loodud kolmemõõtmelise kujutise või keskkonna simulatsioon, mida võib mõjutada isik, kes kasutab eriotstarbelisi elektroonilisi seadmeid, nagu näiteks ekraaniga VR prillid või sensoriga varustatud kindad.

Virtuaalne reaalsus on viimastel aastatel domineerinud tehnilisi ajakirju, võimalusega oma kasutajaid virtuaalses, kuid turvalises maailmas, kinni hoida. Mängude valdkond on VR üks tuntumaid rakendusi, kuid selle potentsiaal ei peatu seal. VR tehnoloogiaid kasutatakse nii sõjalise valdkonnas, tervishoiu valdkonnas, äri valdkonnas, inseneri valdkonnas, kultuuripärandi valdkonnas, kui ka paljudes teises valdkonnades.

Mäng oli edukalt loodud mängukonsooliga Unreal Engine 4.18.3, HTC Vive virtuaalse reaalsuse prillide jaoks, mis on välja töödud HTC ja Valve Corporation firmadega. See bakalauruse töö mäng on teise tudengi töö jätkamine.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 29 leheküljel, 5 peatükki ja 44 joonist.

List of abbreviations and terms

DPI	*Dots per inch*
TUT	Tallinn University of Technology
VR	Virtual Reality
UE4	Unreal Engine 4

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1 Introduction

In recent years, the development of information technology has made it possible to create technical and psychological phenomena, which in popular and scientific literature have been called "virtual reality", "imaginary reality" and "VR systems". The evolution of programming techniques, the rapid growth of semiconductor chip performance, the development of special means of transmitting information to a person, and better feedback for every user — all this created a new quality of perception and experience, commonly known as virtual reality.

The popularity of VR both in Estonia and in the world is still at a rather low level comparing to other technology forms, such as personal computers, but it is gradually growing with the improvement of VR devices and the increase of good products. For example, Estonian VR startup Wolfprint 3D said it has raised over $500,000 of seed investment through its equity crowdfunding campaign on Seedinvest to strengthen its product and to expands its business in the United States [1]. Furthermore, according to a new report conducted by Grand View Research Inc, the global virtual reality (VR) market is expected to reach USD 48.5 billion by 2025 [2].

The objectives of a bachelor's work were:

- Investigate the current state of the art of Virtual Reality applications and provide a survey of the areas where it is used. We also sought to investigate the changing attitude towards VR in every possible aspect.

- Develop a maximally interesting and comfortable for use VR game with "shooter" elements for Mektory demo room, thus giving tourists and MEKTORY Business and Innovation Centre visitors a chance to get experience of virtual reality and maybe increasing their interest in this specific topic.

2 Virtual Reality

2.1 What is VR

Virtual reality (VR) is the use of modern computer technologies to create scenarios that simulates real life experience. The meaning of virtual reality can be simply understood, from the definitions of "virtual" and "reality". The meaning of "virtual" is functional emulation and reality is everything that we can see and feel as human beings. From here "virtual reality" basically means functional emulation of world. This human-made world can be similar to the real world or it can be fictional, creating an experience that is impossible to get anywhere else [3].

Virtual reality in technical terms is less sophisticated and is more straightforward. VR meaning given by Oxford dictionary is "the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors" [4].

The purpose of VR is to allow its user to experience and manipulate the environment as if it were the real world. Virtual reality should not be confused with ordinary 3-D programs like those that are found in computer games, where you can manipulate the world through a model or an avatar, rather than personally becoming part of the game.

2.2 How is VR achieved

There is a big range of items that are used for stimulating all our senses to create the maximally realistic illusion of reality thereby achieving VR, such as headsets, special gloves, headphones, omnidirectional treadmills etc.

This is more difficult than it may seem because our senses became more complex and evolved to provide us with a fully synchronised experience of our surroundings. If there are distractions in the experience, either of physical or cognitive nature, person will

notice. These problems can divide authentic and pleasant virtual reality from unreal or unpleasant one.

What is truly needed for VR is good combination of software, hardware and sensory synchronicity and when it is achieved adds something what is known as a "sense of presence". It is where the user really feels like he is present in that specific environment. The main components that are needed for that particular effect are headset, head tracking and motion tracking.

2.2.1 Headset

The goal of a headset is to create what seems to be maximally realistic, life size, 3D virtual environment provided separately for each eye. Whatever way one looks, the screen will always follow the motion being mounted to one's head. Holding up ordinary headset just like Google Cardboard even without audio or hand tracking, ideally can be enough to immerse you into a half-made virtual world.

2.2.2 Head tracking

Head tracking is a function given by a VR headset, that holds the picture in front of a user while he is moving his head in different directions, such as up, down side to side or even angling his head. One of the best suitable concepts that can easily explain that is called the six degrees of freedom (6DoF), which refers to the freedom of movement of a rigid body in 3D space. Essentially, the head is free to move in three perpendicular axes, this combined with rotation around these axes, often terms as the pitch, yaw, and roll.

There are a many different internal components which can be used for a head-tracking, but the main are: a gyroscope, an accelerometer and a magnetometer. In addition, some companies, like Sony PlayStation VR, also use LEDs dotted around the headset and external camera which is constantly monitoring those LED's locations to provide 360-degree head tracking [5].

2.2.3 Motion tracking

Motion tracking, the process of digitising your body and hands movements for more realistic experience, is incredibly important for virtual reality. Without that, user would

be limited and closed in the virtual world, unable to move, and explore. Being able to engage and interact with the virtual world and everything that world contains the moment user pulls on his VR headset – is crucial to the creation of an immersive experience.

There are a few options to track user's movements, and these are generally categorized as optical and non-optical tracking.

The optical methods applied for motion tracking use cameras to follow and track transportations of a user. Meanwhile, non-optical tracking exploits sensors that can be installed in hardware or attached to the body [6].

2.3 Applications of Virtual Reality

Mainly people associate term "virtual reality" only with gaming, as it is the most common usage of this technology, but there are a whole host of other uses for VR – many of which are more beneficial, profitable and valuable in real world.

2.3.1 Military

The army was one of the first departments that adopted virtual reality for its personal uses and who knows how VR would look like if army had not invested billions of dollars into it from the very beginning. With their financial help were constructed and built first effective headsets, also known as HMDs. Even today, the number of virtual reality projects for the military is increasing, and by 2025 it is even expected to generate a significant $1.79 billion in revenues [7].

Virtual reality has been used by the military for training purposes in three main services — army, navy and air force. This is particularly useful for training soldiers for different combat situations or other dangerous cases where they have to learn how to react in a best suitable and fast manner.

A virtual reality simulation gives them such an opportunity but without the risk of death or a serious injury. Training particular scenarios, for example engagement with an enemy, has been proven to be safer and less costly than traditional training methods.

It can also be used for training – pilots (simulation of various regular and abnormal situations during the flight), drivers (preparation for the management of various vehicles

on simulators), military physicians (visualization is provided, and the technique is sharpened), mechanics (help in repairing equipment), paratroopers (necessary sequence of actions, visualization).

2.3.2 Healthcare

Virtual reality systems can be and are already effectively used in medicine. The doctor's perception of three-dimensional information about the patient (tomography, three-dimensional data of X-ray machines, ultrasound, etc.) allows to significantly improve the quality of medical work [8]. Interactive models and reconstruction of organs are used for training and designing surgical operations.

Using specialized software, physicians can develop models of individual protheses based on patient scanning.

The creation of training simulators based on virtual reality technologies allows to significantly improve the quality of medical practices, reduce their costs and decrease number of possible medical errors.

VR applications are being developed to assess the risk of developing Posttraumatic stress disorder following trauma, and mental resilience training aimed at preventing PTSD in active duty soldiers and other high-risk groups. Furthermore, virtual reality exposure-based therapy is now being commonly used for the treatment of PTSD [9].

Finally, VR technologies are used for the social adaptation of autistics [10]. This disorder manifests itself in different ways, and in many cases it's not easy for autistics to face with the rules and characteristics of human society and the world around them, but with the help of VR, they can painlessly outplay different situations, seeing how to behave better in those or other situations.

2.3.3 Business

Virtual reality is being used in a number of ways by the business community which include:

Demonstration of VR-technologies in ATL (above-the-line)- or digital-advertising [11]. It is relatively rarely used, mainly to demonstrate the "innovation" of the product or

business. Another scheme of use is calling in to an offline visit to the office, attracting customers to get the VR experience offline.

BTL (below-the-line) communications and direct sales. It is widely used in various businesses for demonstration of the product at exhibitions, sales offices and other passable by many people places.

Communication within the business. It is widely used for joint design, other remote interaction, training of specialists, repair and maintenance of equipment and other tasks. This is an extremely promising area because of the relative cheapness of VR devices compared to specialized training stands and in the context of business costs for these specific tasks [12].

The VR technologies allow to validate the performance of the workstations designed in a virtual scenario, where it is possible to simulate manual tasks and evaluate ergonomic indexes, which the design in based on [13]. This approach benefits the companies, in terms of costs and time, and allows optimizing the assembly line design and related workplaces, by improving workers' benefits.

2.3.4 Engineering

Virtual reality engineering primarily consists of 3D modelling tools and visualisation techniques, which gives engineers an opportunity to see and work on their project in 3D and what enables them to gain a better understanding of how everything in their product works, thus giving ability to spot any problems and weaknesses or possible dangers right before real life implementation [14].

One of the examples, where can be seen engineering implemented into virtual reality is Balfour Beatty Rail, a rail infrastructure contractor who uses this inside their design process [15]. It is being used for many main activities like: planning, prototyping and construction purposes, what really helps with project realisation.

Another example is car manufacturers, who prototyping their product in VR during the design process. This enables them to produce and work on multiple versions of a product. This makes the creation of a physical prototype unnecessary before primary testing, what reduces expenses and make the development stage much faster. A great example of that

can be seen at the JLR Virtual Reality Centre in the UK, who uses advanced tracking and projection facilities, what helps to design the next generation of Land Rovers.

2.3.5 Heritage

Virtual reality now can be used to save historical heritage, for example online museums and historical settings or visitor centres [16]. These settings employ interaction as a means of communicating information to the general public in new and exciting ways.

Interactive exhibitions are particularly appealing to children [17]. Children are often not interested in history, because it is not that easy to attract them to a museum or gallery as children often see that as a boring experience. But with the modern interactive technologies such as VR can change that perception and show young audience the broad experience of history and science.

3 UNREAL ENGINE

Starting its march in 1998, Unreal Engine differed from its competitors in several innovations, and some of them were ahead of their time.

Written in C ++, the engine allows you to create games for most operating systems and platforms: Microsoft Windows, Linux, Mac OS and Mac OS X, Xbox consoles, Xbox 360, PlayStation 2, PlayStation Portable, PlayStation 3, Wii, Dreamcast and Nintendo GameCube. In December 2010, Mark Rein demonstrated the work of the engine Unreal Engine 3 on iPod Touch and iPhone 3GS. In March 2010, the work of the engine was demonstrated on the communicator Palm Pre, based on the mobile platform webOS.

To simplify the porting, the engine uses a modular system of dependent components: it supports various rendering systems including Direct3D, OpenGL, audio playback, text voice playback, speech recognition for Xbox360, PlayStation 3, Nintendo Wii, network modules and supports various input devices.

On August 18, 2005, Epic Games Vice President Mark Rein said that Unreal Engine 4 has been in development for two years and its target platforms are personal computers and consoles of the 8th generation, and the only person who has been working on the engine is Tim Sweeney [18]. Sweeney himself at GDC 2006 announced that the development of the fourth Unreal Engine will not begin before 2008, since UE3 will be relevant until 2010. On October 9, 2008, at the TGS, the Square Enix development team reported that they "saw the next Unreal Engine 4" and "cannot wait for the opportunity to work with it." Earlier, Square Enix released The Last Remnant and "did not encounter problems when working with Unreal Engine 3". Presentation of the technical demonstration of Unreal Engine 4 was held on E3 2012 on June 7.

March 19, 2014 Unreal Engine 4 began its free distribution for all comers with a subscription of $19 per month. The source code is also laid out on the GitHub repository. Epic Games initially did not plan to support the 7th generation of consoles (PS3, XBOX360 and Wii U) taking a course solely on the "next gen" and PC.

As in the case of its predecessors, Unreal Engine 4 not only introduced something new, but also displayed already existing quality of graphics to a new level. One of the most important features is that the engine itself is convenient and simplifies life of the

developer. Take for example Blueprint, a scripting system that has been simplified to a regular menu and where you can create logical links between events - this means that script writers do not need special knowledge of programming languages to work with the script engine system. At its core, Blueprint is an assembly of components that forms a complex object in the game world. You can edit this assembly using the Blueprint Editor. The assembly behaviour is controlled by the C ++ class and the graph editor. Together they complement each other.

4 Development of a VR Experience for MEKTORY VR Demo Room

For the basis of this work was taken the graduation work of the student Martin Luik with the theme of the work "Kolmemõõtmelise maailma loomine virtuaalprillidele" [19]. In his work, Martin created 3d projection of space with small planet and comets flying around it. The main task of my bachelor's thesis was to add to VR world created by Martin a game with elements of a contemporary "shooter"-type game.

4.1 Materials

First of all, were created three additional materials for main models that would be created in the next step.
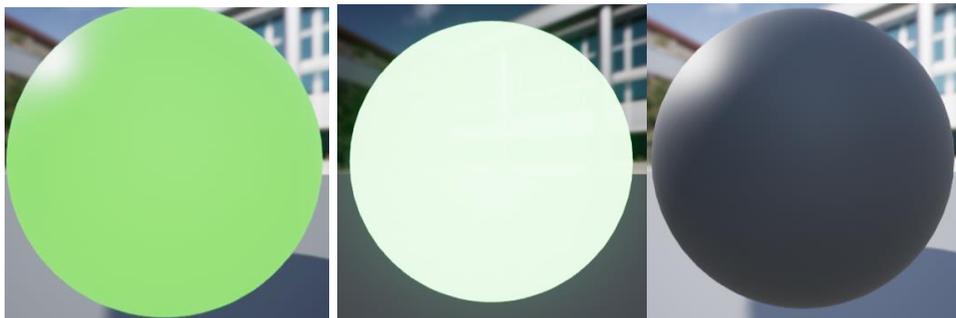
Figure 1. Additional materials created for the project.
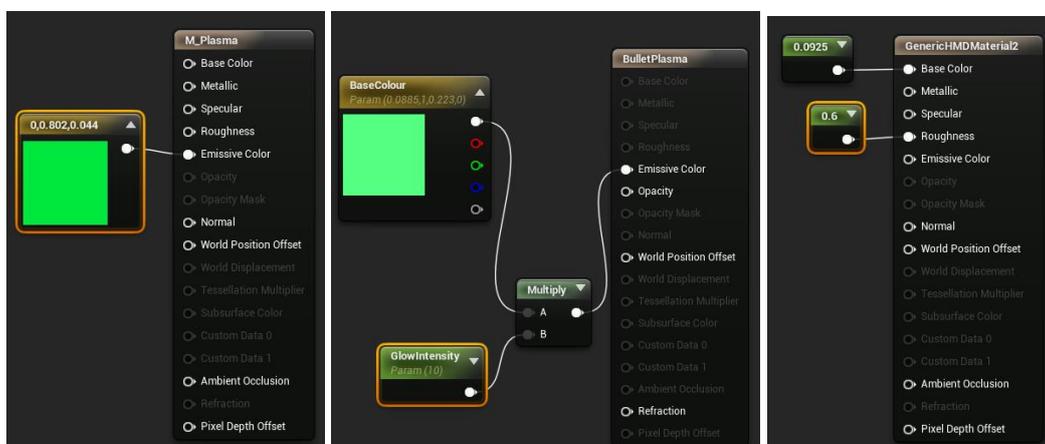
Figure 2. Additional materials' statistics.

4.2 Models

Two main models, pistol [20] and enemy Character [21], were downloaded and then imported to the Unreal Engine. After arranging materials to the models, the following result was obtained.

Figure 3. Model of a pistol with chosen materials.

Figure 4. Model of an enemy with chosen materials.

4.3 Widgets

For game purposes were created 9 widgets, which were later used for showing main information about the game to every user, such as score, time left for the end of the game, seconds until the game will start and also buttons for starting and restarting the game.
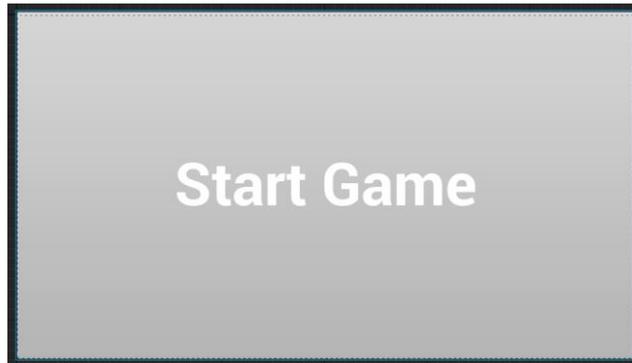
Figure 5. Start Game widget.
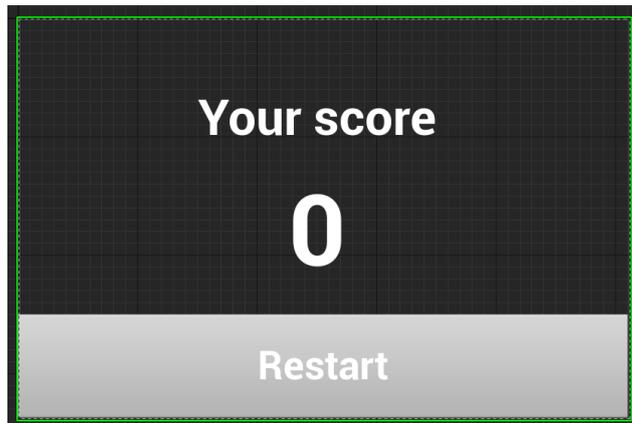
Figure 6. End of the game widget, containing score and restart button.
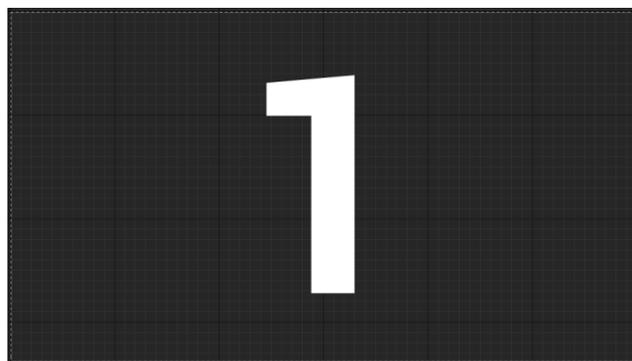
Figure 7. Count down widget (1 second until the game start).

4.4 Particles

During this work were used 2 particle effects, but only one of them were created additionally, one was already given by Unreal Engine 4. For the game was made green sparkles particle that was later used, when projectiles hit enemies and has the name "P_Laser_Sparkles".

As the base of "P_Laser_Sparkles" were used start UE4 particle "P_Sparks", where were changed such elements as: spawn rate, initial size, initial rotation, initial velocity, colour and colour over time.

Figure 8. Particle effect showing green sparkles.

4.5 Actors

"An Actor is any object that can be placed into a level. Actors are a generic Class that support 3D transformations such as translation, rotation, and scale. Actors can be created and destroyed through gameplay code" [22].

During this bachelor's thesis were created 2 main Actors "projectile" and "Menu".

4.5.1 Projectile

The next step was to create a projectile that can be shot from the pistol. For that task was created an Actor class to where were then added such components as: sphere collision, mesh, point light and projectile movement.

Figure 9. Projectile components

Figure 10. Projectile view with sphere collision and point light.

Sphere collision which in project was named "ProjectileCollision" is being used for detecting an overlapment of a projectile with different dynamic objects, such as "Menu" and enemies. So, collision preset should be put an "OverlapAllDynamic".
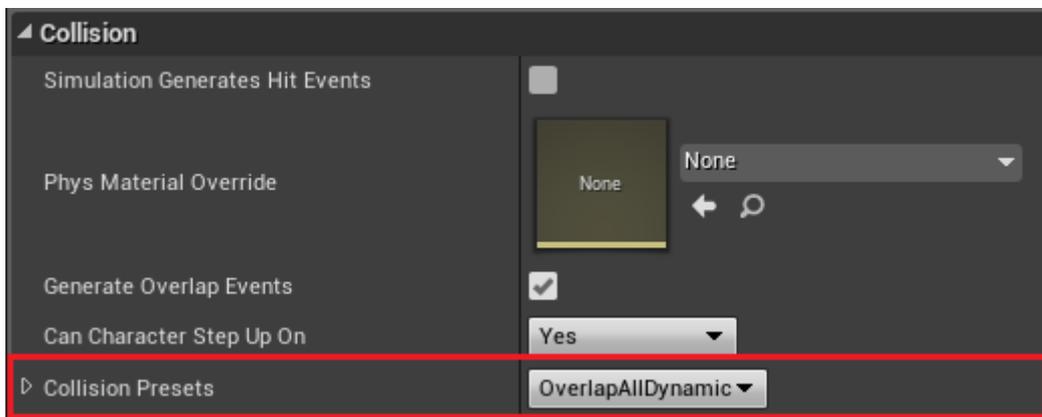
Figure 11. Projectile sphere's collision presets.

Mesh here named as "LaserMesh" is a simple spheric mesh that as a material uses "BulletPlasma" material created earlier. Also, it has collision preset too. It's needed for pushing other dynamic objects located on the map, like rocks or statues, so collision presset should be "BlockAllDynamic"
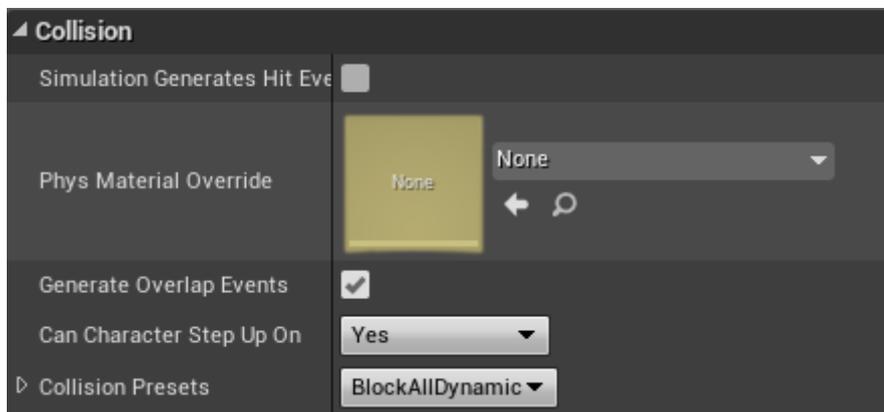
Figure 12. Projectile mesh's collision presets.

Point light here named as "LaserLight" is being used to produce light over the projectile, so it can be better seen and was more realistic. When point light is created there should be chosen suitable light intensity, its colour and attenuation radius. For this exact project intensity was put 500, attenuation radius 200 and colour was maximally close to the bullets colour.
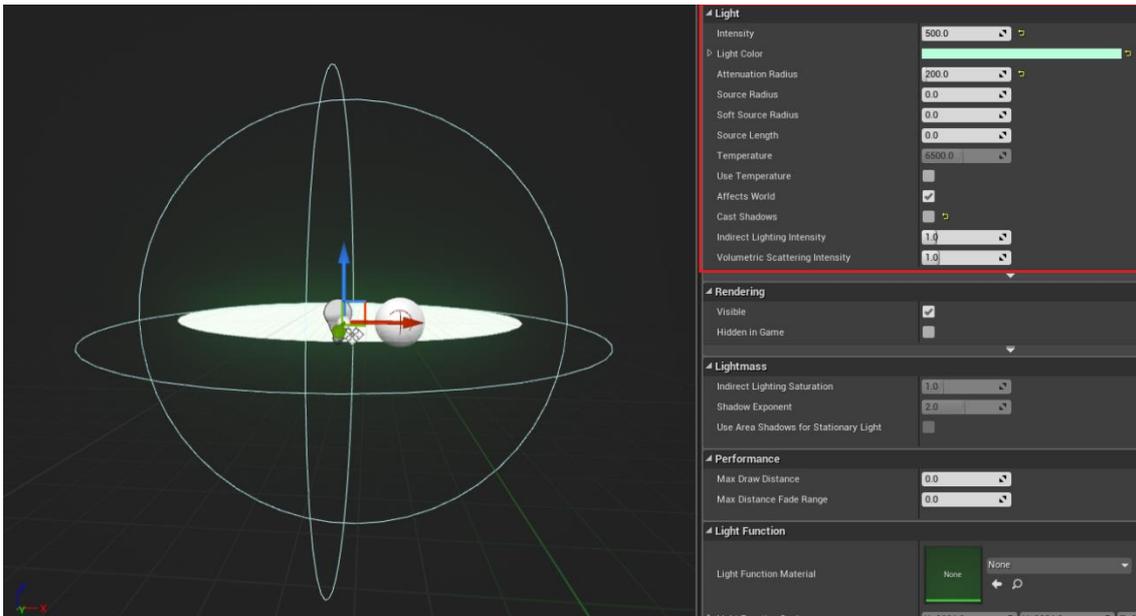
Figure 13. Projectile point light's parameters.

Projectile movement adds physical rules to our bullet. Here can be chosen bullets speed and because this bullet is laser, so here was also changed projectile gravity scale to 0.
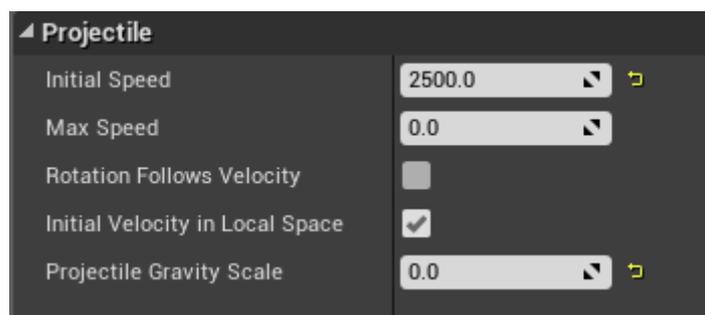
Figure 14. Projectile movement's parameters.

4.5.2 Menu

Next Actor is "Menu" which contains a widget that during the game changes. At first it shows a "Start Game" button, which when being pressed starts a countdown, what is also

a widget located in this Actor. When the game ends "Menu" shows the score and "Restart Game" button.
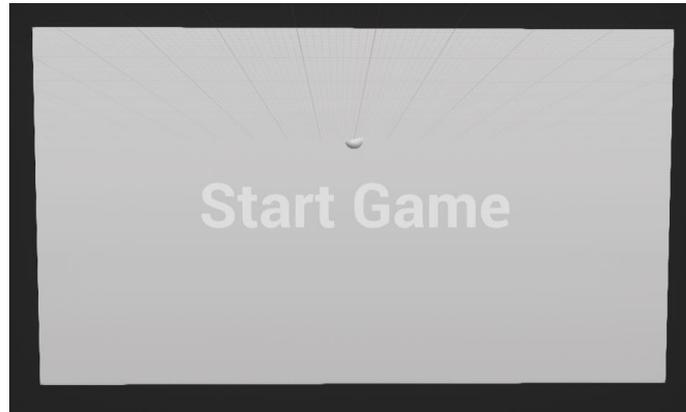
Figure 15. "Menu" Actor within viewport.
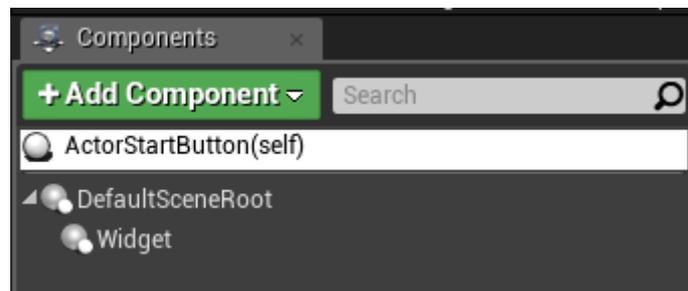
Figure 16. "Menu" Actor's components.

4.6 Pawn

"The Pawn class is the base class of all Actors that can be controlled by players or AI. A Pawn is the physical representation of a player or AI entity within the world. This not only means that the Pawn determines what the player or AI entity looks like visually, but also how it interacts with and within the given world in terms of collisions and other physical interactions" [23].

In this project was used only one pawn, which was user's pawn. There have been added two motion controllers for each of HTC vive controllers and then to each of them were chosen pistol meshes that were made earlier. Then to those controllers were attached widgets showing score and seconds until the game end. Also, to the meshes were added invisible arrows which were later used to get location of pistol barrels to shoot projectiles from there.
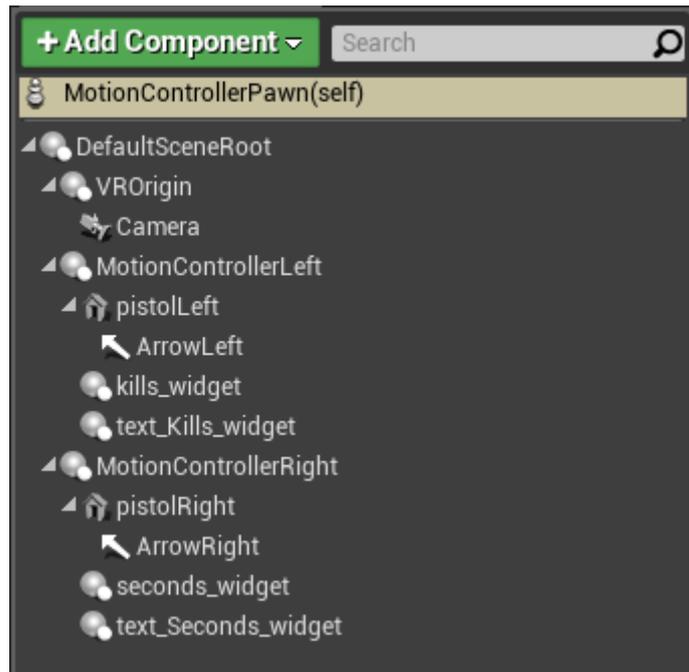
Figure 17. Pawn's components.

Pistol meshes were rotated 37° for better usability of a motion controller and comfortability of a user.
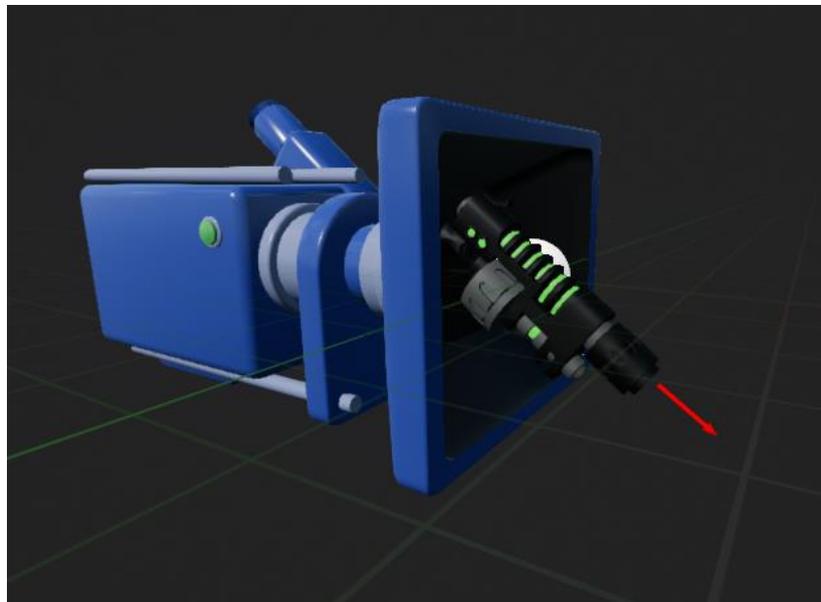
Figure 18. Pistol meshes within Pawn's viewport.

Inside the motion controllers were chosen correct hands.
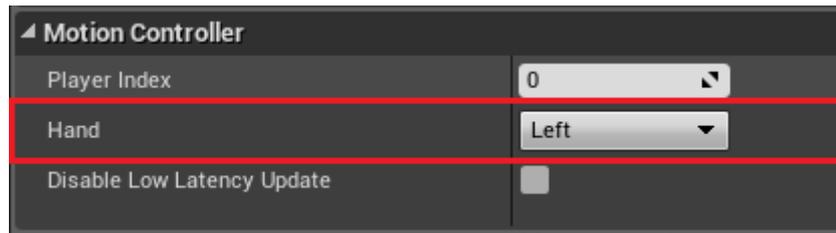
Figure 19. Motion controller's settings (hand selection).

4.7 Character

"With the addition of a "CharacterMovementComponent", a "CapsuleComponent", and a "SkeletalMeshComponent", the Pawn class is extended into the highly-featured Character class. A Character is designed for a vertically-oriented player representation that can walk, run, jump, fly, and swim through the world. This class also contains implementations of basic networking and input models" [24].

For an enemy was use a Character component, so it could be moving using "CharacterMovementComponent". As a mesh was chosen "UFO" mesh, created before. Furthermore, were added point light to be better seen in space.
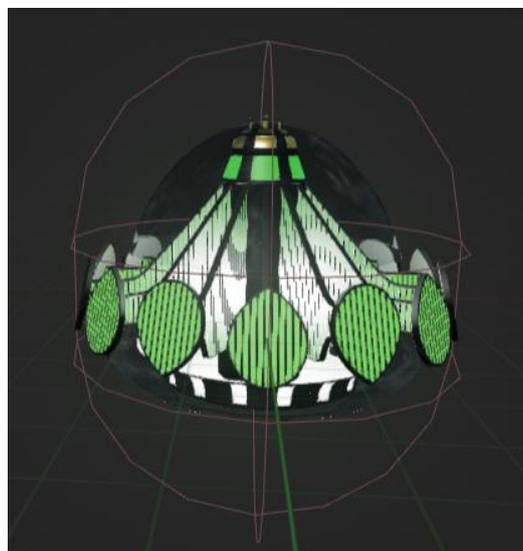
Figure 20. Enemy Character within viewport.
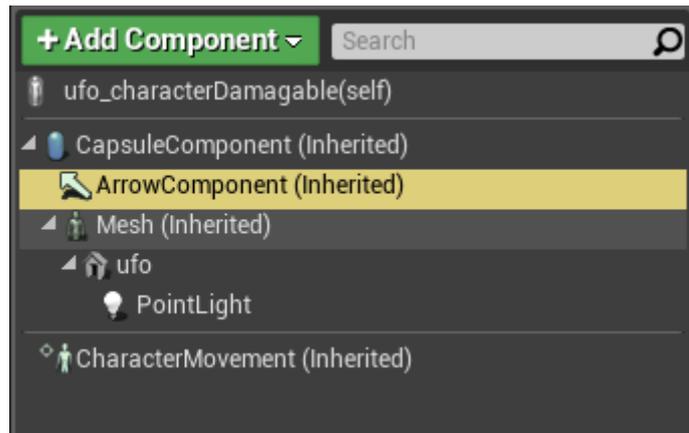
Figure 21. Enemy Character's components.

As a default movement mode was chosen "flying", so it could fly in space. Also, were chosen suitable flying speed, equal to 400.
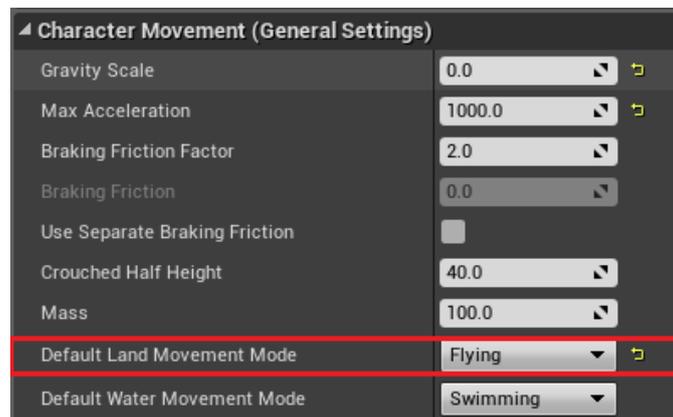
Figure 22. Enemy Character's movement settings (General).
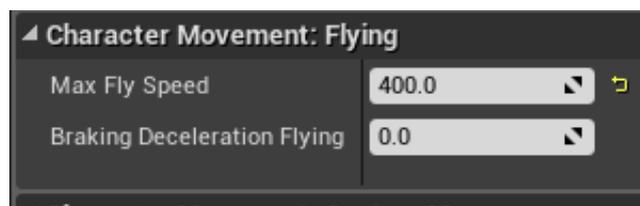
Figure 23. Enemy Character's movement settings (Flying).

Furthermore, were also implemented special interface named "I Damagable" for later work with object interactions.
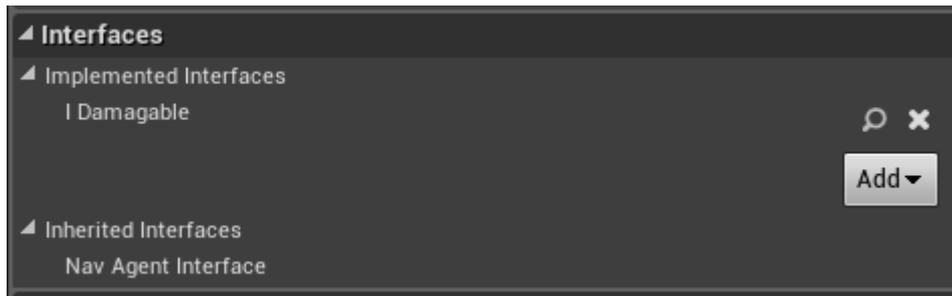
Figure 24. Enemy Character's implemented interfaces.

4.8 Behavior Tree

"Behavior Trees are a powerful and useful tool for creating Artificial Intelligence in UE 4. They are a combination of two asset types: The Blackboard and the Behavior Tree. The Blackboard is the AI's memory. It stores key values for the Behavior Tree to use. The Behavior Tree is the AI's processor. It makes decisions, and then acts according to those particular decisions" [25].

Our blackboard contains two parameters "MoveLocation" and "SelfActor". "MoveLocation" contains random location in reachable distance for enemy where it will move next. "SelfActor" contains enemy Actor.
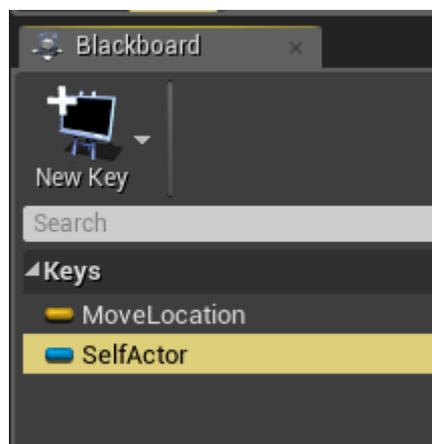
Figure 25. Behavior tree's blackboard.

Behavior Tree contains of "ROOT", "Selector", "Sequence" and two functions "FindRandomLocation" and "Move to". Selector Nodes execute their children from left to right and will stop executing its children when one of their children succeeds. Sequence Nodes execute their children from left to right and will stop executing its

children when one of their children fails. Behavior Tree does a cycle that's chooses random location in reachable distance and then moves to it.
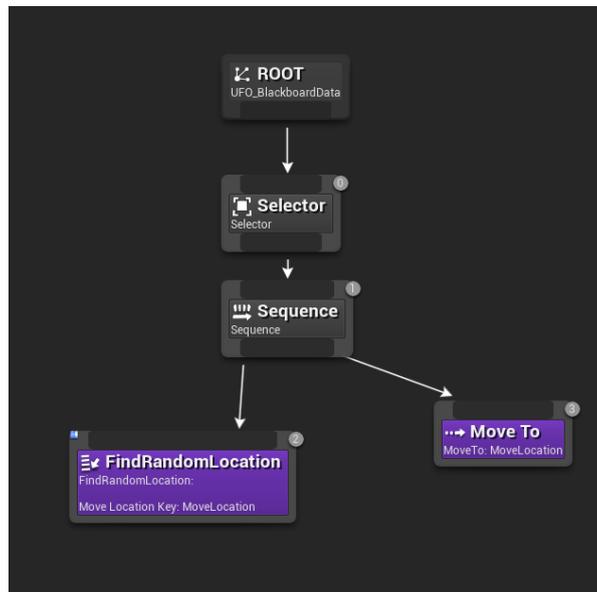

Figure 26. Behavior Tree's structure.

4.9 Events and event dispatchers

"Events are nodes that are called from gameplay code to begin execution of an individual network within the EventGraph. They allow Blueprints to perform a series of actions in response to certain events that occur within the game, such as the game beginning, the level being reset, taking damage, etc. These events can be accessed within Blueprints in order to implement new functionality, override or augment the default functionality" [26].

"By binding one or more events to an Event Dispatcher, you can cause all of those events to fire once the Event Dispatcher is called. These events can be bound within a Blueprint Class, but Event Dispatchers also allow events to be fired within the Level Blueprint" [27].

4.9.1 Projectile Actor

Actor "projectile" has two main events. The first event triggers on the projectile appearance — as the projectile appears starts a countdown from 0 to 3 seconds, when it ends the "projectile" Actor is being destroyed. That is needed to economize data usage and lighten the work of a PC.
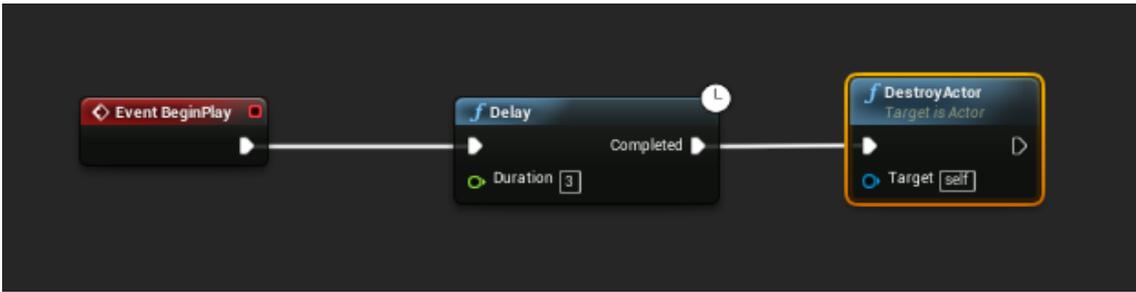
Figure 27. Projectile's event "BeginPlay".

Second task is being triggered when projectile overlaps with any other object. Then it controls if it overlapped an object with interface "I Damagable", if that is true, after that it calls function "Affect Health", located in that enemy Character using interface "I Damagable", that decreases number of life of an enemy by 34 points (maximum health is 100 points). In the end, event spawns particle "P_Laser_Sparkles" and destroys projectile.
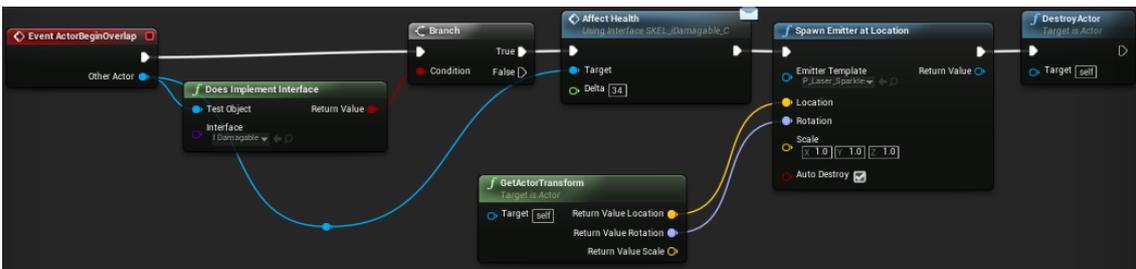

Figure 28. Projectile's event "ActorBeginOverlap".

4.9.2 Enemy Character

Enemy Character contains 1 event "Affect Health", 1 event dispatcher "AddScoreDispatcher" and variable Health component which is a float number equal to the enemy health.
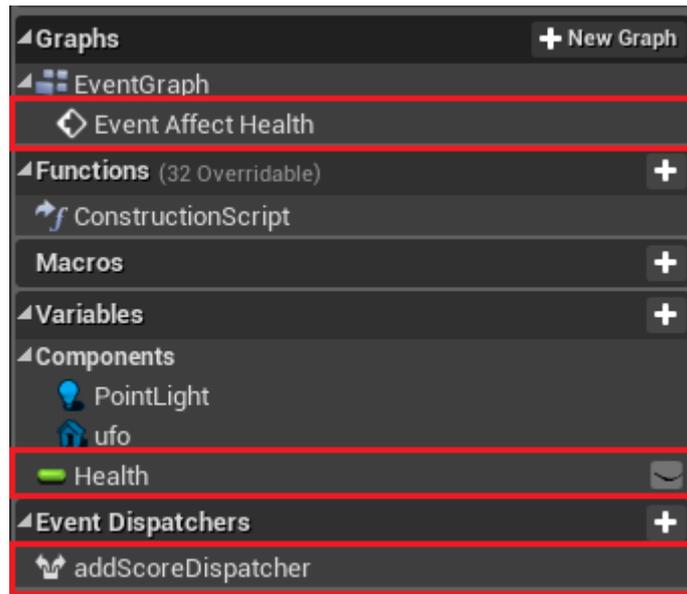
Figure 29. Enemy Character's events, variables, event dispatchers.

Event "Affect Health" takes existing component "health" and subtracts from it given health (here 34) and sets it as a new health value. If health is less or equal to zero, then event calls a dispatcher named "addScoreDispathcer" then spawns particle "P_explosion" and destroys enemy Character. This dispatcher is needed to notify "Menu" blueprint that it should increase score value located there.
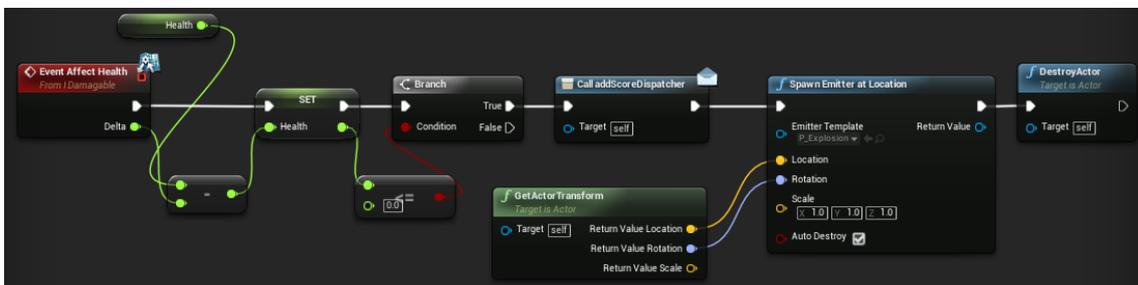

Figure 30. Enemy Character's event "AffectHealth".

4.9.3 MotionControllerPawn

Pawn contains 4 events, but they were all made like pairs for left and right controllers. First pair is being trigger as motion controller button is being triggered. On button pressed it starts function "FireGunRight" or "FireGunLeft" depending on which controller button was pressed, then it starts looping timer for that event again, so player can shoot bullets by holding button, not only by pressing it. On button release that timer is being cleared, so user will stop shooting.
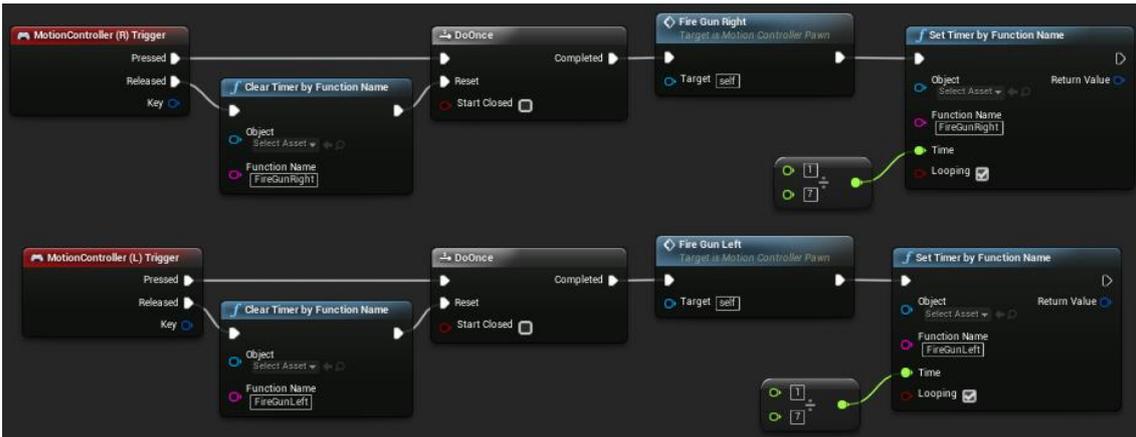
Figure 31. Pawn's events on Trigger button pressed and released.

Second pair ("FireGunLeft" and "FireGunRight") creates haptic effect on the motion controller (vibrations) and then spawns projectile on the location of an arrow. After that it changes material for one part of the pistol to make it more realistic when shooting.
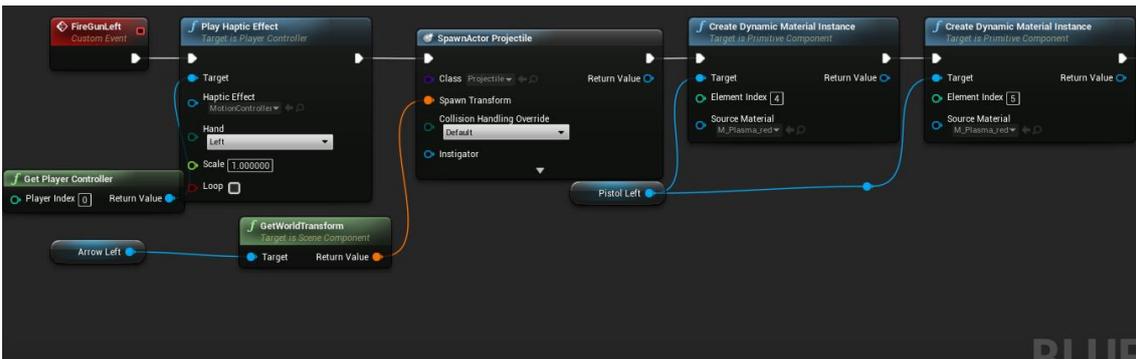
Figure 32. Pawn's event "FireGunLeft" (First part).
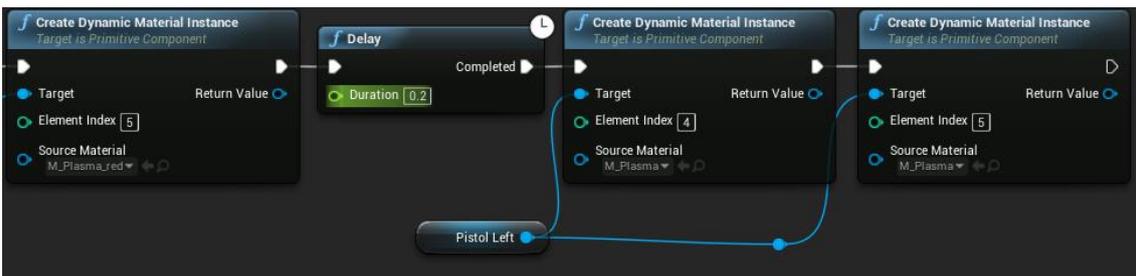
Figure 33. Pawn's event "FireGunLeft" (Second part).

4.9.4 Menu Actor

"Menu" Actor has 6 events, 2 event dispatchers and 2 variable components.
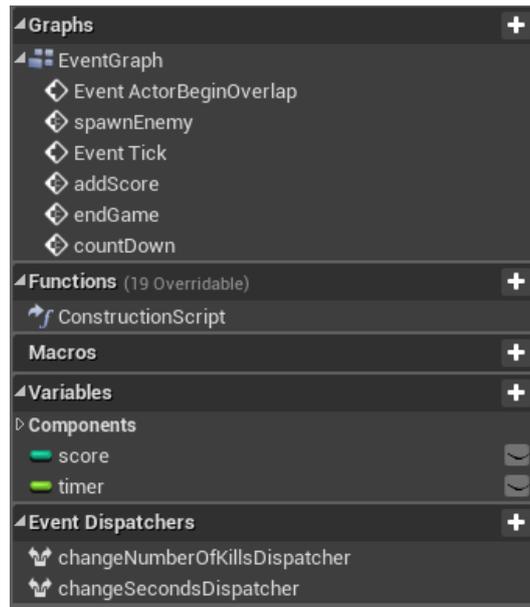
Figure 34. "Menu" Actor's events, variables, event dispatchers.

"SpawnEnemy" event gets location of a "targetPoint" located in enemy spawn zone and from it takes random location in reachable radius from that point and there spawn an enemy Character.
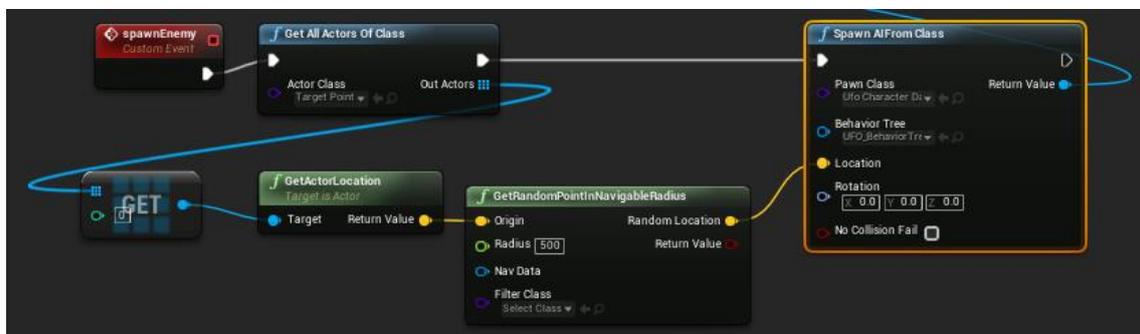
Figure 35. "Menu" Actor's event "spawnEnemy".

"Event Tick" is a simple event that is called on every frame of gameplay. It is bound to "addScoreDispatcher" – dispatcher located in enemy Character. When enemy is being destroyed this dispatcher calls another event located here, it is "addScore" event.

"addScore" event adds to local variable "score" one and then calls "changeNumberOfKills Dispatcher" that in level blueprint changes widget located on the pistol and showing your score.

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Figure 36. "Menu" Actor's events "Event Tick" and "addScore".

"countDown" event changes "Menu" widget to widgets showing numbers from 3 to 1 giving player some time to get ready for the game.
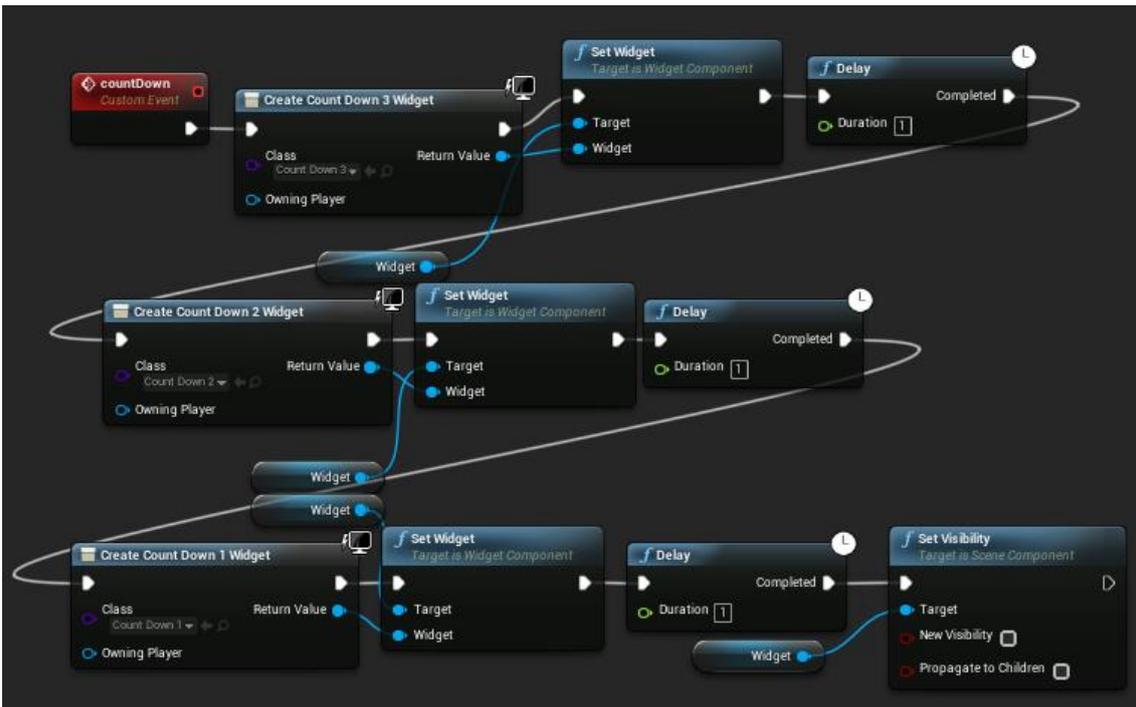
Figure 37. "Menu" Actor's event "countDown".

"endGame" event, as can be seen from the name ends the game. It creates widget that contains user's game score and restart game button. Then it stops spawning enemies, as the game already ended, and no more enemies are needed. After that all already existing enemies are being destroyed and explosion particle effect is being played on their locations. In the end widget becomes affectable and score becomes equal to zero.
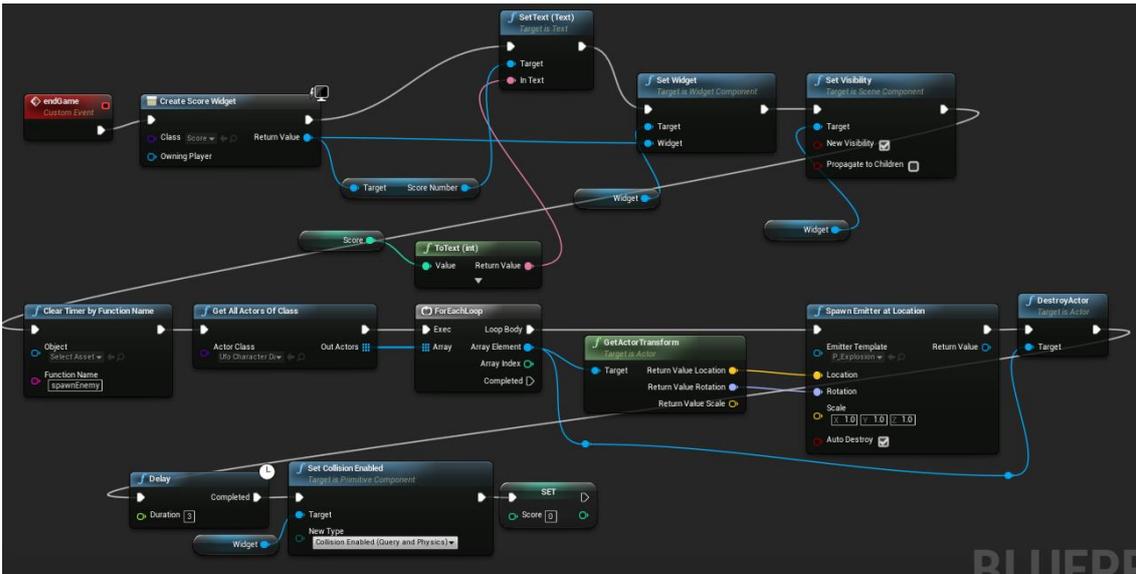
Figure 38. "Menu" Actor's event "endGame".

"ActorBeginOverlap" event plays when dynamic objects like projectiles are overlapping "Menu". First of all, this event set collision of a widget disabled so user cannot use it again, then it starts event "countDown" which was created earlier. Then it calls "changeSecondsDispatcher" that is being listened in level blueprint and writes on pistol seconds until the game end. Hereupon this event starts spawning enemies by calling function "spawnEnemy".
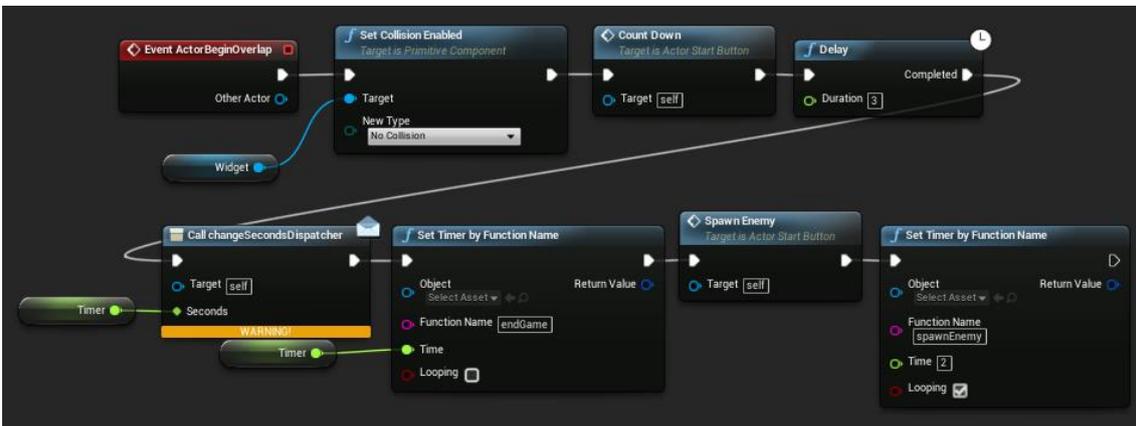
Figure 39. "Menu" Actor's event "ActorBeginOverlap".

4.9.5 Level Blueprint

"A Level Blueprint is a specialized type of Blueprint that acts as a level-wide global event graph. Each level in your project has its own Level Blueprint created by default that can

be edited within the Unreal Editor, however new Level Blueprints cannot be created through the editor interface" [28].

Level blueprint has 4 additional events.

"changeTimer" event changes widget located on the pistol, that shows number of seconds left for the game end. When the timer becomes equal to 0 it clears timer that is calling this event.
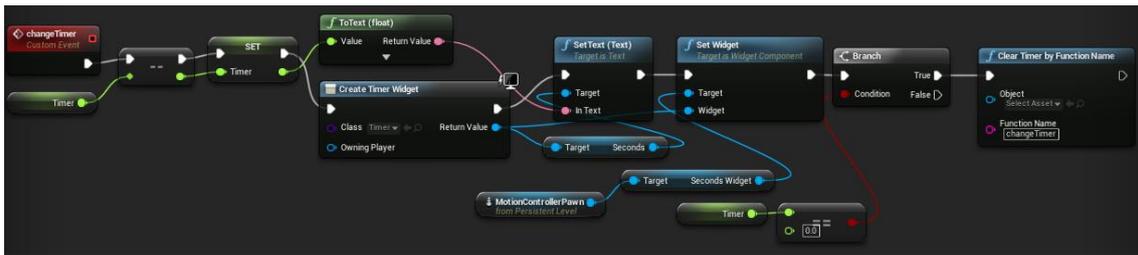
Figure 40. Level blueprint's event "changeTimer".

"changeSecondsDispatcher_Event" when called as input gets the number of seconds the game will last and sets it as a local variable. Then it sets a timer that will call "changeTimer" event every second.

Figure 41. Level blueprint's event "changeSecondsDispatcher_Event".

"changeNumberOfKillsDispatcher_Event" when called as input gets the score of the game at the moment and then changes widget located on the pistol, that shows that score.
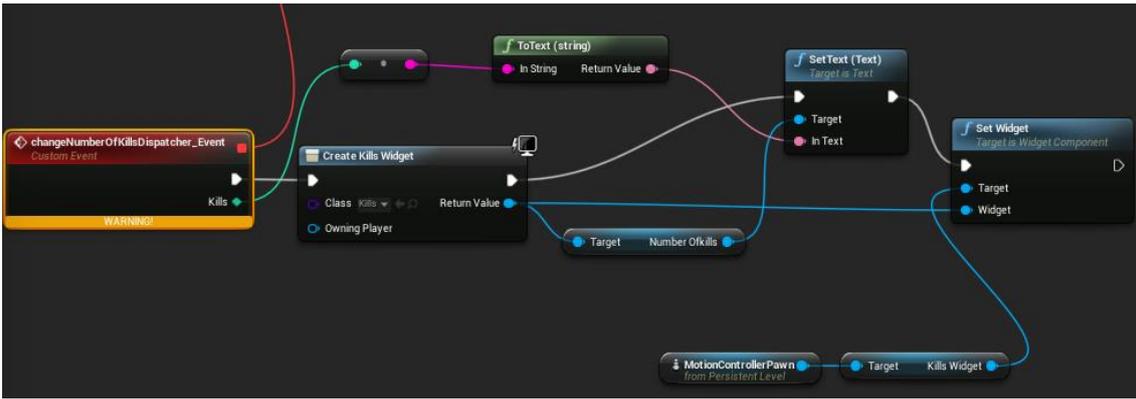
Figure 42. Level blueprint's event "changeNumberOfKillsDispathcer_Event".

"event tick" is bound to "changeNumberOfKillsDispatcher" and also to "changeSecondsDispatcher", so when these dispatchers will activate then level blueprint will catch that and activate functions "changeNumberOfKillsDispatcher_Event" and "changeSecondsDispatcher_Event".
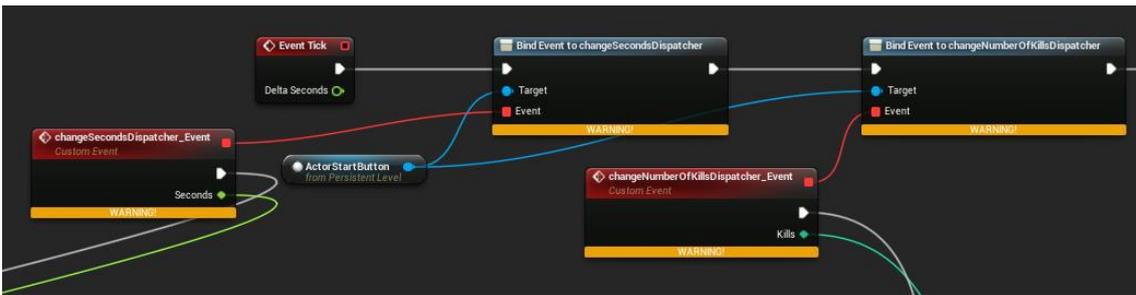
Figure 43. Level blueprint's event "Event Tick".

4.9.6 Behavior Tree

In behavior tree was created one additional function named "FindRandomLocation" that takes location of enemy on chooses random location in reachable radius of an enemy.
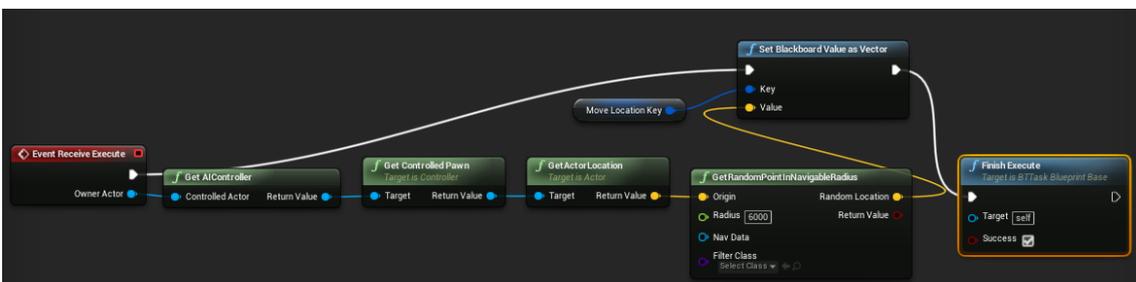
Figure 44. Behavior tree's Receive Execute.

5 Summary

In conclusion, Virtual reality is a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person. What is needed for particularly good VR is the perfect combination of software, hardware and sensory synchronicity. The main components that are needed for that are headset, head tracking and motion tracking.

VR is now gradually growing with the improvement of VR devices and the increase of good products. There is a whole host of uses for VR technologies, it is being applied in military, healthcare, business, engineering, heritage and many more.

The objectives of a bachelor's work were, investigation of the art of Virtual Reality applications and development of a maximally interesting and comfortable for use VR game. All objectives of a bachelor's work were fulfilled, all needed information was successfully obtained, and VR game was created.

Looking forward, the game has room to be developed further, as it can be expanded, there can be added different levels and it can be made more interesting to play.

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