DEPARTMENT OF INFORMATICS

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Thesis type Bachelor's Thesis in Informatics: Games Engineering

# Conceptioning and prototyping of a mixed realities dungeon crawler

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# Konzeptionierung und Prototyping eines Mixed Realities Dungeon Crawler

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I confirm that this thesis type bachelor's thesis in informatics: games engineering is my own work and I have documented all sources and material used.

Munich, 15.11.2018 Dennis Assmann

# Acknowledgments

First, I want to thank my flat mates and friends Carl Jonas Böker and Matthias Puchstein who stuck with my though these challenging times. Thanks to my brother, who helped me out, and his daughter, who amused me greatly. Also, a special thank you at Alexandra Klisch for checking my thesis and generally being a good person.

# Abstract

The topic of this bachelor thesis is the development and feasibility of a mixed realities dungeon crawler. First the hard- and software was chosen. Then three prototypes were developed. These prototypes test different approaches to the problems of developing and dealing with the chosen configuration and a virtual game.

# Kurzfassung

Diese Bachelorarbeit befasst sich mit der Entwicklung und Machbarkeit eines Mixed Realities Dungeon Crawler. Zuerst wird die Hard- und Software gewählt und dann drei Prototypen entwickelt. In diesen Prototypen werden verschiedene Lösungsansätze für die Probleme bei der Entwicklung und dem Umgang mit der gewählten Konfiguration und einem virtuellen Spiel getestet.

# Contents

# 1. Introduction

The goal was to create a highly immersive mixed realities game with real life movement and a very natural control scheme. Likewise, it should be a framework for future studies and theses. The basic idea was that a user can create a dungeon everywhere they want if there is enough space,so that it is possible to move around freely without colliding with a real obstacle. For that the following is needed:
1. A virtual reality Headset to simulate the game.
2. The possibility to track the player and his hands.
3. Threat detection, so that a player is not in danger while walking around.
These are the ideas how these requirements could be reached:
1. Using a smartphone and some virtual reality goggles.
This has the advantage that it is affordable for everyone because most people have access to smart devices. But the down side is that a mobile phone does not have the performance capability necessary to too render an immersive game and there is no virtual reality headset for mobile phones.
2. The Hololens system from Microsoft is able to render virtual objects in a real-world setting. But it is also very see through, thereby not immersive enough and not able to generate a widespread virtual world. And there is no control mechanism or tracking included, in the way it is needed.
3. A combination of the HTC Vive and the ZED Mini looked promising.The Vive seemed to be a good solution to simulate a virtual world and the ZED mini could be used in game to scan for real world threats or obstacles and add them to the game view. Additionally, both were at hand in the game's laboratory. That the Vive had its own controllers is another advantage. So, it was decided to use this combination as hardware setup.
Some research revealed that the Vive controllers are not able to use their full potential out of range of their basis station, but they could still be used in a minor way. To balance this out the Myo controllers were used. These track arm movements without the need of a special basis station.
It was decided that the test location for the game was the games laboratory and the adjacent corridor. This would result in some problems later. Using the unreal engine was a personal choice, because my skills are more versed in unreal then in Unity, both are supported by Stereolabs. A negative point in this choice was that nobody else in the department is familiar with the unreal engine.

## 1.1. Related work

There is already a game center named “The void”[1] in different parts of the world. use a mixture of a special headset and a vest to simulate a highly realistic and versatile virtual world. As this game needs a special location it is not feasible for a greater usage.
Another example for a good implementation of virtual reality is the game Pavlov VR[2]. The interaction options are very intuitive and realistic. The downside is that a player has to teleport their character through the game as movement.
One of the best dungeon crawlers is the game "Legend of Grimrock"[3]. It is a turn based non-virtual reality game, that captures the spirit of dungeon crawling perfectly.
The bachelor thesis "HoloRPG - Implementation of a Role-Playing Game in Augmented Reality with the Microsoft Hololens"[4] from Mohamed Ben Jazia is a good source to see the possibilities of the Hololens.

# 2. Definitions

In this chapter the terms, programs and hardware which are used inside the project are explained.

## 2.1. Dungeon

A dungeon in the terms it is used here is a combination of natural and man-made structures, which are mostly underground. It has its own flora and fauna. In most fantasy settings it is a mixture of challenges for heroes, home for monsters and a treasure vault. Originally it meant "an underground prison, especially in a castle".[5] It changed with the spread of the fantasy pen and paper role play game "Dungeons and Dragons".

Figure 2.1.: A typical dungeon map[6]. Created for a role playing game.

## 2.2. Dungeon crawler

In a classic fantasy setting a dungeon crawler is a role-playing game in which the player explores a dungeon. There are different challenges, like combat, traps and puzzles but also rewards, mostly in the form of experience and loot. However, there are various other genres

which focus on other themes, respectively. This term was also primarily characterized by "Dungeons and Dragons" and its co-creator Gary Gygax [7].

## 2.3. Mixed reality

"MR merges both realms, real and virtual, into a new environment"[8]. This means to create a mixed reality you have to use real objects and virtual objects and combine them to a new experience. There are two main sub parts of mixed reality, augmented reality and augmented virtuality. Both enhance their main features with minor features of the respective other, i.e. mixed reality is a fusion of several features.

## 2.4. Motion sickness aka virtual reality sickness

A lot of early virtual reality games had the problem of motion sickness. It emerges, if there is a difference between motion that is seen and motion that a player feels. Motion sickness can also occur "when detectable lags are present"[9]. Motion sickness includes nausea,disorientation and in extreme cases throwing up.

## 2.5. HTC Vive

The HTC Vive[10] is a combination of hardware developed by HTC and used in Steam, Valves game platform. It is using a headset to simulate a virtual world, a pair of controllers to interact with it and a pair of stations to track the position of the controllers. There are some extensions for more options, and even a wireless solution, the Vive pro.


Figure 2.2.: The Vive headset.[11]

## 2.6. Myo armband

Manufactured by Thalmic Labs, the Myo armband is able to recognize gestures and hand motions. It is worn on a users forearm and allows a natural interaction in games. It is also used in the field of robotic to operate robots and even allows to control prosthetics for disabled users.

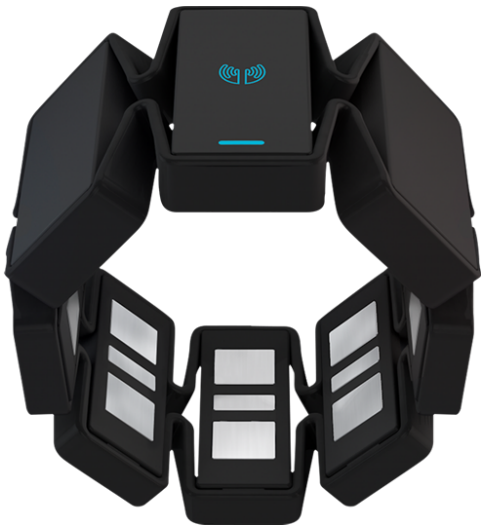

Figure 2.3.: Picture of the Myo[12].

## 2.7. Leap Motion Controller

The Leap motion controller[13] tracks a players hands and their movements. It does not need any handheld controllers and is directly embedded in the headset. It is developed by Leap Motion.

Figure 2.4.: Tracking hands with Leap[14]

## 2.8. ZED Mini

The ZED Mini[15] is a stereoscopic camera with a 110 grad field of view. Its features include a gyroscope and accelerometer. With these it is possible to track its position and scan an environment up to 20 meters. The ZED Mini is compatible with the Oculus Rift and the HTC Vive. It is built and supported by Stereolabs.

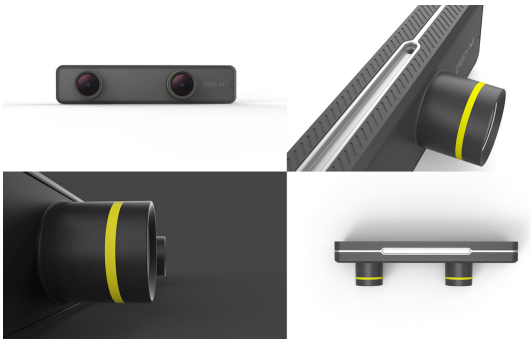

Figure 2.5.: ZED Mini[16]. This component is to be clipped on a VR-headset.

## 2.9. ZEDfu

ZEDfu[17] is part of the ZED Mini installation. It is a program used to scan an area and create a mesh of it.

## 2.10. Mesh

"A mesh is a collection of vertices, edges, and faces that describe the shape of a 3D object"[18] Meshes are used in 3D programs like Blender or Maya to develop object and even whole worlds. Game engines use these objects and simulate physics with them, so a player can interact with them.

## 2.11. Blender

Blender[19] is a free 3D graphic suite to develop 3D objects and animate these. Blender is developed by the Blender Foundation.

## 2.12. Unreal Engine

The unreal engine[20] is a free game development kit. It has a high graphic standard and allows to develop triple A game titles. It features an easy integration of most new game technologies and is continiuously developed to be up to date.

## 2.13. A concept of a dungeon crawler

A dungeon crawler in a fantasy setting should contain certain elements:
1. It should be more than one room, else it is not really a dungeon.
2. There should be at least one fight and one trap to interact.
3. To reward players a dungeon should have a possibility to give them loot.

# 3. Game concepts

Different features were used to test and solve problems. On one side it should be an immersive experience that is intuitive to use on the other hand the game should be safe to use.

## 3.1. Doorway/Hidden Door

Figure 3.1.: Open doorway.

When the player changed from inside the room to the corridor, there needed to be a door. First, a virtual doorway was created that was closed but later it was changed to be open, because it did not fit with the real-world door and there was the danger, that the player would walk into it. With an already opened virtual door the ZED Mini shows the real-world door. Further improvement of this concept can be made through an algorithm which can recognize the position of the real door and sets the virtual one accordingly. But that would be out of scope for this bachelor thesis.
On the other side of the doorway, inside the corridor the now open door was hidden behind a wall. Through this the idea of a hidden passage was tested. The player can still see the

light from the start room shining through the wall, so they know where the doorway should be. Also, the virtual wall does not clip to the real one. So, if a player walks through it, they should not collide with a closed door or in that case with a wall. The concept of walking through virtual walls inspired a completely new project idea.

## 3.2. Monster

Figure 3.2.: Monster in relaxed stance.

As there should be combat in a dungeon crawler, there should be an enemy. For that a prefabricated hero/monster from the game Paragon[21] was used and customized. It has a small attack animation and is destroyed on contact. There is no heads-up display in the game, so there is no indication of damage done to the player. This should be added later, for a more challenging experience. Due to the tracking of the ZED Mini it is possible to evade contact with the monster and let it stand there. The concept of evasion was included to test the natural movement of this setup.

## 3.3. Trap

Another obstacle in a dungeon is a trap. There are a lot of different types of traps. A pressure plate trap is used, which is triggered, when something moves on top of it. In this case the player gets showered in a red light, symbolizing a magic attack. As with the monster it is possible to prevent activating it through evasive movement. If the player kneels and interacts with the trap, they can disable it. In that case it is no longer possible to activate it.

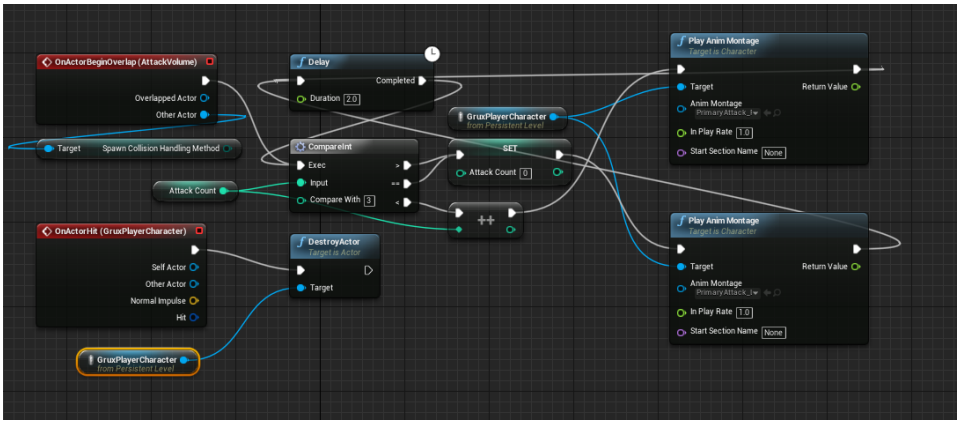


Figure 3.3.: Blueprint code for the attack animation.

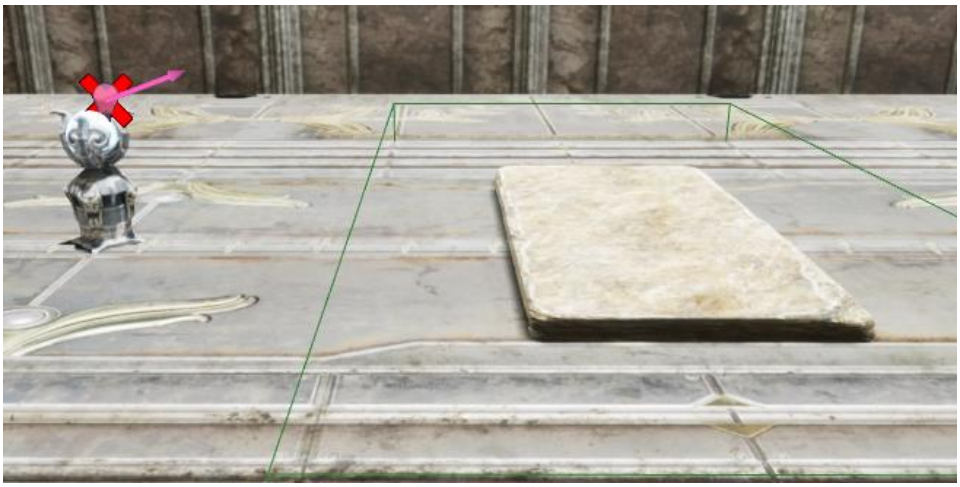

Figure 3.4.: Side view of the pressure plate and magic light emitter.

## 3.4. Elevator

To prevent motion sickness there had to be a way to move between different levels without showing a movement in which the player is not involved. Ideas for this were a magic teleporter or an elevator. Watching people on YouTube play virtual reality games and feeling rather ill and disoriented by magic teleportation, it was decided to use an elevator. Inside of it is a button. If pressed, the screen went black for a second and then the player stands in a new level inside the elevator. This has also the benefit, that the players position is known.

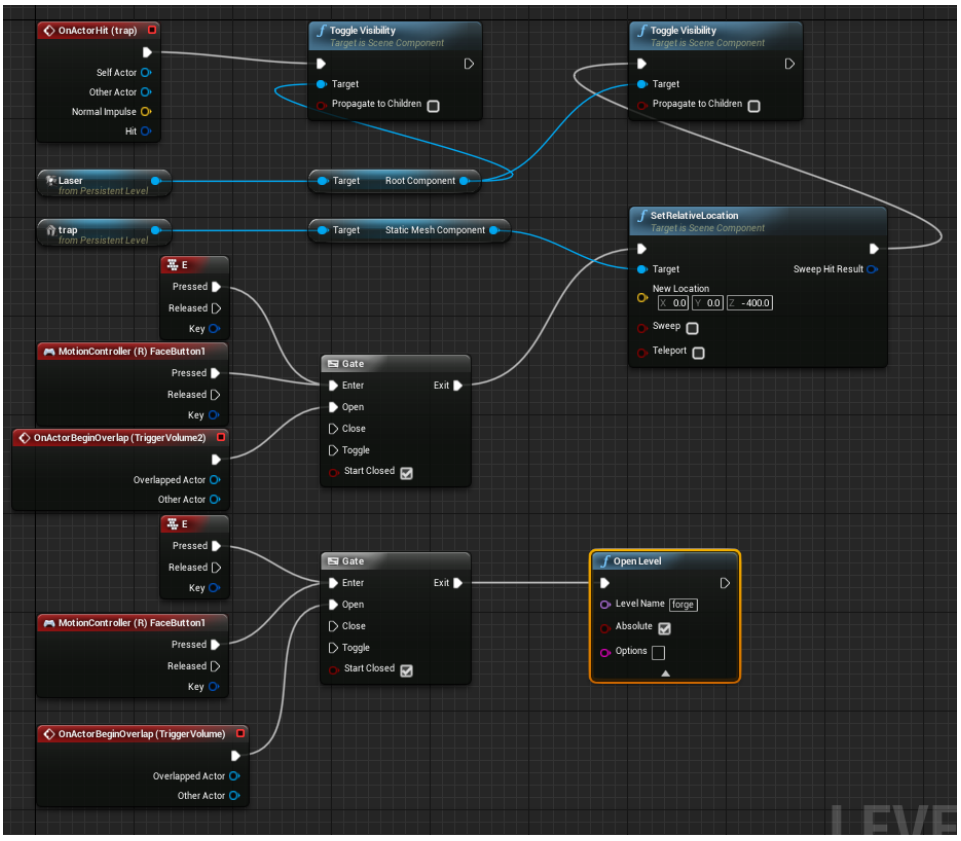


Figure 3.5.: The script to interact with the trap and the elevator.

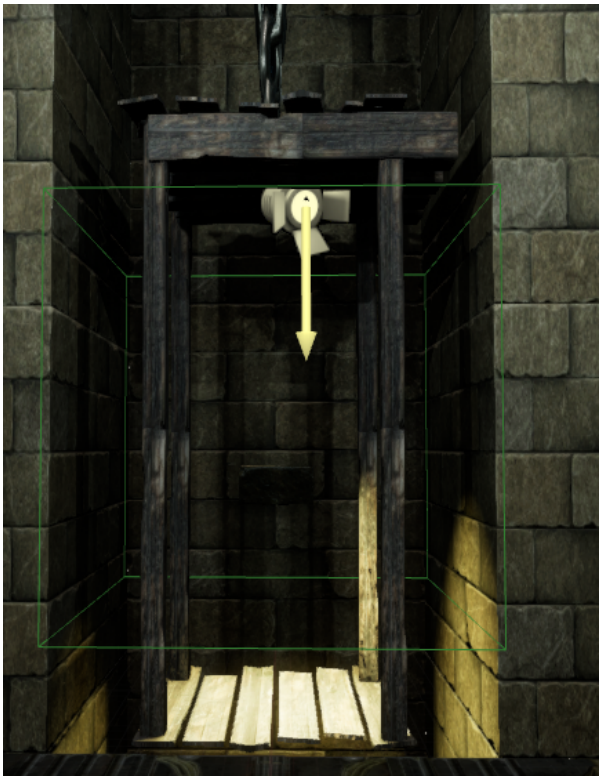

Figure 3.6.: Elevator in the first level.

## 3.5. Chest

A way to reward the player is with loot. That is why there should be treasure chests in a dungeon. The chest is not functional. The plan was that a player can open it and find new equipment inside of it.

## 3.6. Windows

The second levels purpose was to see, if it is possible to simulate a great open virtual space inside a much smaller real space. Hence, windows were integrated. These have a view of a bigger enclosure. Regrettably the threat detection averts this and shows the real walls instead. A possibility to avert this problem could be to create a trigger zone around the windows and to deactivate the ZED Mini in these zones. For that to work safely we must be sure, that there is no hazard there. On the other side of the windows is an open space. This is even more complicated to simulate without deactivating the camera. Else the player only sees the real walls.

Figure 3.7.: Chest above a lava river.

Figure 3.8.: Windows to a inaccessible room.

## 3.7. Threat detection

The player should be able to see everything that is not part of the simulated world. This breaks immersion for the player but is better than to jeopardize their wellbeing. As such,

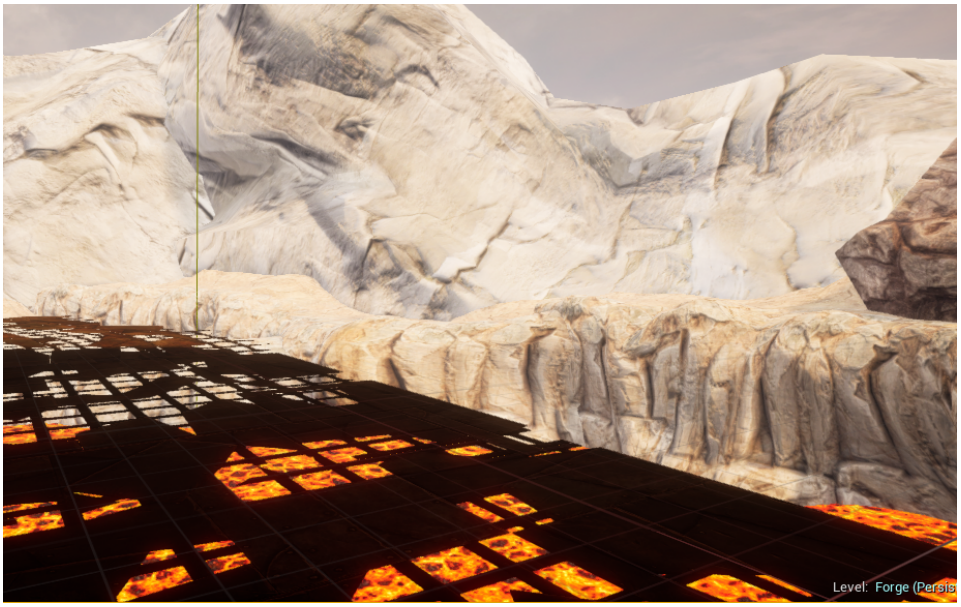


Figure 3.9.: The virtual open space.

they should deal with every simulated obstacle as if it was a real one. Luckily, the ZED Mini automatically shows everything from the real world in the games path. It should be possible to create an even better detection, for moving objects outside the virtual world, but that is outside the scope of this thesis.

## 3.8. Sound

For a better immersion and more fun. This includes gentle background music[22] and some sound effects[23].

## 3.9. Vive controller

In the unreal engine the Vive controller is already implemented. By modifying the MyZED-PlayerPawn the controls were usable and found the correct items to interact with. As the players are moving around a wider space and outside of the Vives base stations, we cannot use their tracking function.

## 3.10. Myo controller

After some code was written for the Myo controller a plugin was found that integrated the Myo functions to the unreal engine. Here the MyZEDPlayerPawn had to be modified, too.

Figure 3.10.: Sword in stone.

## 3.11. Sword

The sword is the latest addition in the last prototype. It is meant for fighting and possible special interactions, like bashing virtual objects or walls. A combination of Vive controller and Myo is used to track it, especially if it is out of range of the camera view. Because of lack of time it is not fully operational. The plan is to add more weapons like a bow, a staff, daggers and even magic to the players repertoire and to use a greater range of control mechanism. Ideas for that include gesture controls for magic and using sensors on real foam weapons for a better immersion.

## 3.12. Leap controls

Another plugin added the leap controls to the unreal engine. There was not enough time to finalize them. A problem with these controls is, that they use an extra sensor attached to the headset and there is no more space.

# 4. Implementation

Before it was possible to build anything, a few different programs had to be installed and compiled . First, the ZED software development kit version 2.0 and CUDA for NVIDIA were needed. After that the special unreal engine for ZED[24] and a Stereolabs plugin. Then a project with the name "Dungeon of TUM" was created. Compiling the engine and the project took an hour each time it had to be installed on a new PC. There were some problems with the provided PCs. Initially the prototypes should be created on a PC specially used for Vive projects and run them on a powerful gaming laptop but the graphic card on this PC did not fulfill the minimum requirement for the ZED Mini, neither did the laptops graphic card. Interestingly, it was possible to run the unfinished levels on the laptop but not on the Vive workstation. There were still multiple error messages and the whole system had to be restarted a few times. The main problem of the laptop was, that it could not rebuild any lighting in unreal engine. A third PC that was specially ordered with a high-end graphic card should have been the solution, but the special unreal engine did not work at all and after some tinkering, it was decided to build everything on my personal PC at home and test it on the laptop. For data transfer and easy access, a git repository was created, but the project files were to big for a noncommercial use of git. In the end a 32 GB USB-stick transferred the data from PC to PC .

## 4.1. First prototype

The first iteration was a simple level in which it is possible to spawn some virtual objects and test these. It was mainly used to get to know the ZED Mini. The main aspect to test was the depth perception and how these objects interacted with the real world. It showed that, if there was enough space it was possible to create a real looking three-dimensional object with a realistic shadow. For that, the shadow light sources had to be set right. Furthermore, this stage checked if the ZED Minis tracking abilities would be adequate for this project. This was done by taking all equipment and moving around with it while running the game. There where some small adjustments but it looked promising.
The last stage was testing spatial mapping with the ZED-Mini. Using the supplied program ZEDfu it was possible to slowly scan the laboratory and create a mesh. Unfortunately ZEDfu crashed in most cases while scanning or while rendering the mesh. It was a lot more stable to scan in the unreal engine, but challenges here came in the form of the unreal engine first showing the scanned room shifted on the x axis and then the calculated mesh was deleted when the instance was terminated. In the end it was possible to create one good mesh of the

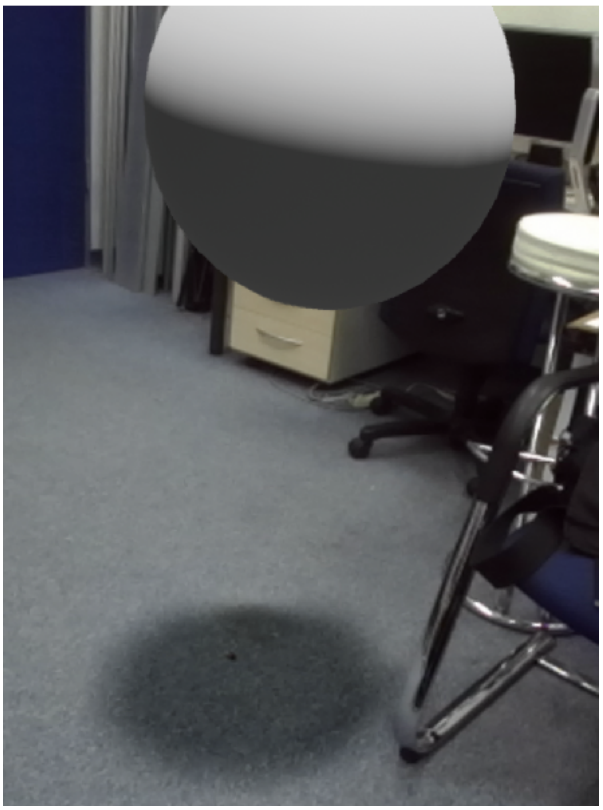

Figure 4.1.: Sphere with its shadow

room and none of the corridor. While working on generating a mesh, there was an update for the ZED software development kit to version 2.5. After installing that update it was no longer possible to compile Dungeon of TUM and the content had to recreated. To avoid further problems like this, the software development kit was not updated later.
At the end of project time the first prototype was used to integrate control mechanism without interfering too much with other systems that are present in the other iterations. Also, this level is small and therefore had a better performance than testing in the other prototypes.

## 4.2. Second prototype

The plan for the second prototype was to use the generated mesh and build a room inside it. The idea was that the player could start anywhere in the room. The ZED Mini then scans the room, checks it against the given mesh, and adjust the virtual world accordingly. A lot of time was invested in this approach, even learning blender was considered and started. The mesh had to be customized to even get it inside of the unreal engine and then it would not let me build anything inside of it. Also did spatial mapping no longer recognize the mesh. Building a good-looking level would have been nearly impossible, because of how it looked inside. One reason why the mesh looked so strange was, that the laboratory was just incommodious.

Figure 4.2.: The created mesh from outside.

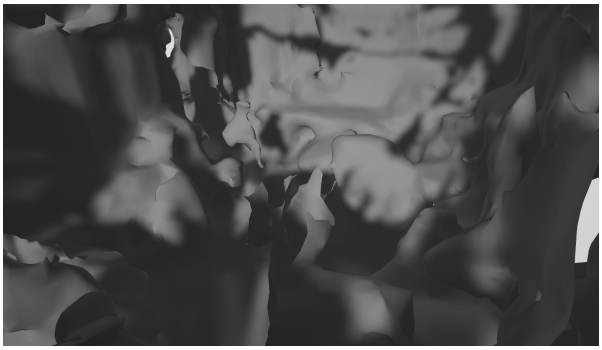

Figure 4.3.: The created mesh from inside.

So, a dungeon was built and tested later with the hardware setup. The following features were implemented in this prototype: Doorway/hidden door, monster, trap, elevator and threat detection.
Before working on the prototypes, the unreal marketplace was searched for usable assets. There were a lot of useful assets in the Infinity Blade: and Soul: projects[25][26][27][28][29][30] and also some scripts and plugins.
Because of the nature of the ZED unreal engine none the scripts or plugins from the marketplace could be used. To insert the asset, a new project in another unreal engine had to be created, the asset content had to be installed there and then migrated to the Dungeon of TUM project.
In the building process of this prototype there were some hurdles. The one which took the most time, were the lighting artifacts in the first level. This happened in spaces where no direct lighting was imminent and changed every time, the level was built. Compiling the project to a whole game helped with it, as that calculated the light mass correctly.
Another strange error was in the second level, the starting point. If a player spawn position was added, the camera would jump to a completely different point in the level and could not be moved anymore. Porting the data from my PC to the laptop solved that problem.

Figure 4.4.: Lighting artifact.

Correctly building a game for the ZED Mini was also interesting. The level is generated in all directions from the headset. This means that the floor is dependent from the height of the user. To circumvent that, the player should lay the headset on the floor and start the game then. Furthermore, everything had to be built around the coordinates 0.0.0, because this was set as the starting point for the headset. That meant everything had to be adjusted a few times. Testing the second prototype was difficult because of the sheer mass of errors.
The Vive seemed to have developed a loose connection and would not show anything most of the time, while the ZED Mini must be connected via a USB 3 port. Often it reported that it was not connected to a correct port even when the connection worked before or the ZED Mini lost the connection and did not manage to reconnect. Even if the connection was stable, there were error messages while running the simulating. These included either: “Could not find camera” or “Not enough GPU memory”.
There were some problems due to the narrow space of the starting room. The ZED Mini is great for augmented reality but has its problems with mixed realities. It tries to generate the virtual content without a collision with real objects. As the virtual starter room was tested in the laboratory it showed that it collided everywhere. As result the walls were flickering, and the complete game would jump around trying to avoid obstacles. Lastly, the level was too big. There is an option to scale everything in unreal engine in relation to real measurements, but that did not work. So, every asset had to be adjusted by hand until it fit.

## 4.3. Third prototype

In the final prototype everything learned from the previous ones was used and control mechanism were added, mainly the code for the Vive and Myo controllers. A function to ignore collision in the ZED Mini code was not to be found. Due to that the start room was dropped and the corridor recreated. Now the player starts in the corridor, which is mostly empty of real obstacles. Also, planes were used for walls instead of a volume as planes do not collide as much. It would be advantageous to use the hardware setup outside or in a large open space.
The following features were added in the third prototype: Chest, windows, sound, Vive controller, Myo controller, sword and the plugin for the leap controls.

Figure 4.5.: Corridor

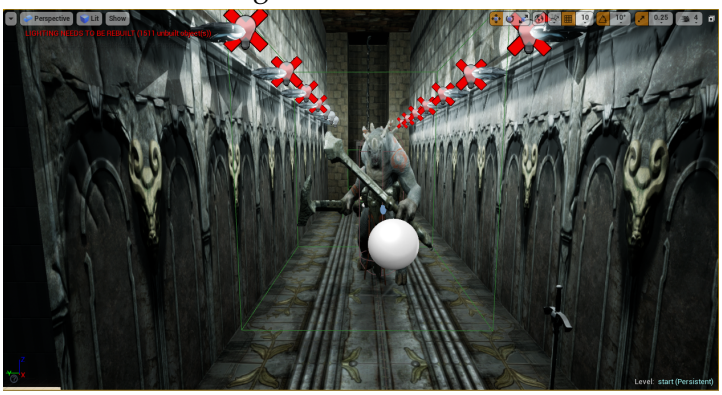

Figure 4.6.: Virtual corridor

## 4.4. Transportation

With the HTC Vive, Myo, ZED Mini and a gaming laptop, a player has to transport a lot of things. To make it more comfortable a system of belts to transport everything was developed. A normal backpack for the laptop could not be used, because it would overheat quickly. Another problem is the lack of access to a Vive pro, which includes a battery pack. So, the player had to carry a long power cable around with them.

Figure 4.7.: Laptop strapped to be worn.

Figure 4.8.: Wearing the setup (right side).

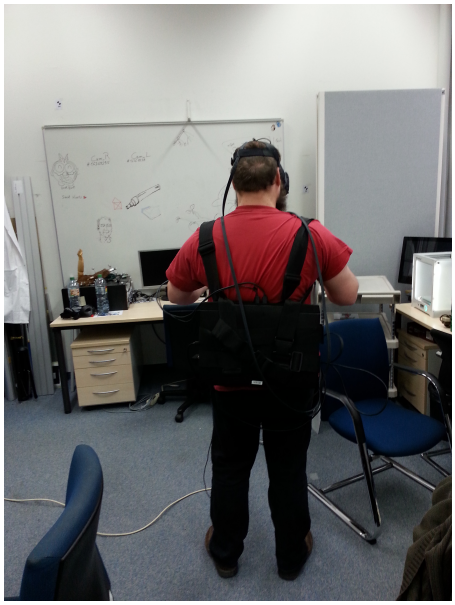

Figure 4.9.: Wearing the setup (back side).

# 5. Conclusion

Here presented are the conclusions, first what was learned in this thesis and second, if it is feasible for a standard player.

## 5.1. Thesis

Topic of this bachelor thesis was to develop a mixed reality game. It was decided what is needed to create such a game and the corresponding hardware and software chosen. The first prototype was created to get to know the specifics of the unreal engine, HTC Vive and ZED Mini. This first iteration showed, that it is possible to create a mixed reality dungeon crawler with that setup.
Before it was possible to construct the second prototype, graphic assets had to be found and integrated in the unreal project. For the unreal marketplace was used.
The second prototype was used to solve different problems which were found while developing. To solve these problems, game concepts and features of the ZED Mini were implemented. More conflicts and some drawbacks of the chosen setup were identified and these were not so easy solved .
The last prototype used the gathered experience of the previous two and build the game anew. Furthermore, the first control mechanism were added and to circumvent the tracking problems of the Vive, the Myo controls were integrated. Because of the time limit these could not be finished, but in the end, there was a workable prototype. After that a transport system was built, that allowed free movement either in the real world or in the virtual world.
Creating this project was time-consuming. There were a lot of technical issues, which show that you need a high-end PC to develop virtual games. Working with graphics always takes time to get them right. But altogether most of the occurring problems were solved or there was an approach to solve them.
Is it a mixed reality game?
It is at least on the way to be one. You have a virtual world in which real world threats are detected. And if you move in reality you do so in virtuality, too.
If the project proceeds besides as a bachelor thesis, it will be a mixed realities game.

## 5.2. Market

A combination of the HTC Vive headset, the ZED Mini and different control mechanism has a lot of potential to create a real mixed reality game that is highly immersive. But there are problems:

1.The hardware is expensive. The HTC Vive pro costs 1098 $, the ZED Mini 449 $ and the Leap motion 79.99 $. The Myo is no longer available to purchase at all. And a graphic card that is able to use virtual reality costs a minimum of 300 $. * all prices are from the 14.11.2018
2. There needs to be enough space. If there are too many real objects, spawning the virtual world is not stable and it jumps around. Without enough space a player cannot move around freely.
3. System requirements are high. Not only does a developer need a good PC to create a game, the player needs a high end gaming laptop to even consider playing it. The minimizes the market to sell the game.
4. There needs to be a way to walk around more comfortable. As it is, a player can walk around with the improvised transport system. But to make it more attractive it should be more compact and easier to use.
If these problems are solved, there should be a market for this kind of game.

# 6. Future Projects

## 6.1. Story

To make a dungeon crawler more like a game and just as engrossing, there needs to be an engaging good story with an interesting setting to absorb the player into the game and make immersion breaks more acceptable. .

## 6.2. UI/HUD

A user interface or a heads-up display would be necessary to show a health status, a mana status, a mini map, and much more possible information.

## 6.3. Inventory/Items

With a place to store items, the interaction with the virtual world can be increased. It allows a far deeper game play and more rewarding combat mechanics.

## 6.4. Better combat mechanics

If a wider range of weapons would be introduced, the game should get more interesting and challenging. It allows different movements and strategies to deploy. There should also be different kind of enemies with different attacks and defenses, so the game does not stagnate. Introducing a way to fight with magic allows a broad spectrum of different actions to be taken.

## 6.5. More control mechanism

As more and more systems are created to interact in a virtual world, it makes sense to integrate and test them. Another idea is to add a smart phone control, as it would be a cheap alternative to all the other control mechanism. This includes gesture controls. These would be especially good for any type of spell casting.

## 6.6. Multiplayer

Playing a dungeon crawler solo can be fun but playing it with your friends would be a lot better. This would be a whole new set of challenges for a mixed realities game.

## 6.7. Non player characters

By adding interactable non player characters the world feels more alive. These would include shops, taverns and many more. By that the player gets an opportunity to have other actions which are not combat related.

## 6.8. Housing/Towns

Giving the player a place to rest and store items, would be beneficial to the immersion. In a town they could get new equipment and quests. All that should get them to want to play more.

## 6.9. User created dungeons

The next step of using dungeons could be building them themselves. It would be possible to create some building blocks for players, so they can create their own dungeons, share them and rate other players dungeons.

## 6.10. Classes

To make the game more like a role play game there could be classes, like warrior or mage. These classes could have special interactions only usable for them.

## 6.11. Avatar

Players using in game items like clothing or armor would be more immersed, if these are displayed on them somehow. For that the player needs to be scanned and a virtual overlay created.

## 6.12. Events

Adding events to the game could increase the fun and immersion. If these events are triggered by actions from the player, the game world should feel more real.

## 6.13. Procedural generating with spatial mapping

It could be interesting to create instant dungeons by scanning the environment and using the result to create a level. The complicated part would be to recognize real objects and give them equivalent virtual object. This could be done in cooperation with robotics.

## 6.14. Wider threat detection

The ZED Mini is able to scan up to 20 meters. At the moment only, threats are detected which overlap with the virtual world. But it should also detect threats, especially movable threat like cars, bikes or thrown objects outside and mark these, if there is a probability that they can hurt the player.

## 6.15. AI

Creating an intelligent behavior for monsters and non-player characters would be a big improvement to the general quality of the game.

## 6.16. Better transportation

Transporting the complete hardware set is not comfortable at the moment. A dedicated bag and clips to adjust the hardware should help here.

## 6.17. Voice command

Voice commands would help disabled players to enjoy the game.

## 6.18. User evaluations

There is a potential for lot of questions for user surveys, such as: Is the game immersive? Do controls feel fluid? Do you get motion sickness? And many more.

## 6.19. Haunted house

This is actually an idea for a new game. In that you play a ghost who can walk through walls, but only the virtual ones. It could be made like a detective game, where you have to find clues about your death. Or a horror game and you can spook other players.

## 6.20. Endless tower

Another game idea. If a player has a free space of 4x4 meters or more, it is possible to create an endless amount of rooms you can traverse with an elevator. It could be better to use an outdoor space for that or even create a game hall dedicated for this kind of game.

# A. General Addenda

As I had to drop the start room, and creating it was not irrelevant, I want to show how it looks.


Figure A.1.: Start room: Perspective from the doorway


Figure A.2.: Start room: Perspective from the first play start

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