# NaturePill

# Creating an Immersive Virtual Reality Environment Capturing the Relaxing Properties of Nature

Project Proposal


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## 1 Project Description

Spending time in nature is important since it has a positive impact on people's mental health and wellbeing [1] by helping reduce stress [2], improve sleep [3], and bring greater happiness and life satisfaction [4]. However, not everyone has access to nature sites, whether it be due to lack of time, poor proximity [5], or lack of transportation and/or mobility due to physical disabilities [6]. With the benefits of this nature interaction, healthcare providers in some countries have started to prescribe nature, often referred to as "nature pills".

As technology improves, we have found a shift in habits in urban environments, and with the availability of online shopping and virtual meetings with friends, the need to go outdoors decreases, which leads to increased screen time and time spent indoors. Therefore, we need to start looking for alternative ways to access the benefits of nature. Nature pills in the context of our study is a digitalised exposure session to nature. Research shows that even just looking at nature can help recover from mental fatigue [7], and from stress [8], and creating a virtual environment would help provide properties of real nature from the comfort of one's own home [9].

We therefore plan to tackle the following problem: access the therapeutic benefits of nature through building a multi-sensory Virtual Reality (VR) environment that simulates nature and allows for interactive exploration.

## 2 Related Work

### 2.1 Existing Nature Pills

Virtual nature environments have been created in the past to see the effects virtual nature can have on an individual. McAllister [10], Kjerllgren [11], and Brooks [12] et al. showed that 2D screen-based exposures produced similar positive effects on an individual compared to exposure to real nature. Their studies did not place users in an immersive, nor explorative environment, which led to some participants feeling bored [11, 12]. Adding immersion and exploration could be more useful in reproducing the positive effects of nature, as a more immersive environment (by increasing screen size) has been found to generate stronger stress reducing effects [8].

VR headsets could allow users to be completely immersed in a virtual environment. Browning [13], Calogiuri [14], and Yu [15] et al. have done studies making use of 360-degree videos of nature, which can be experienced in VR. Browning et al. [13] found that exposure to virtual nature had similar effects as real outdoor nature exposure. Calogiuri et al. [14] compares real and virtual nature walks using 360-degree videos, but motion sickness negatively impacted their findings. Yu et al. [15] compared the influence of virtual and urban VR environments on restoration, and generated greater psychological benefits when participants were immersed in the forest environment. These three environments were not interactive, and users were only passive spectators of first-person videos.

Computer Generated Virtual Reality (CG-VR) environments create a lot of new opportunities to allow users to explore and interact with the environment, and as development tools become increasingly powerful, this allows for more realistic and immersive environments to be developed. Yeo et al [16] found that CG-VR offers a qualitatively different experience when compared to the television and 360-degree video exposure methods. Their CG-VR environment allowed users to move around in an underwater environment within the confines of the room and allowed interaction with fish and corals using provided handheld controllers. The environment was not created with the intent of relaxation, and users could not venture beyond the bounds of a single room.

Deltcho et al. [17] created a CG-VR forest environment to compare the restorative effects of nature of that forest environment to a slide show presented in VR. They found that the explorative environment promoted restorative effects, and that the artificial nature of the forest did not negate the benefits of the virtual nature walk. Their study is an excellent example of an environment that uses all four senses you would usually experience in a virtual forest. The environment was rendered in real time in high resolution with realistic lighting (sight), had nature sounds (hearing), used forest air freshener in the real room (smell), and had somatosensory[1] feedback (touch) by having users stand on a rumble pad that would shake slightly upon every step taken in the VR environment. Though all these senses were incorporated, their environment did not allow for interaction with objects in the scene, and the addition of this could lead to a more pleasant user experience.

# 3 Problem Statement and Research Question

A user's feeling of immersion in a Virtual Reality environment corresponds to the feeling of being physically present in the non-physical world. Presence refers to how real the user feels the virtual environment is. We hypothesize that by including interaction and exploration in a multi-sensory environment, the user will feel more immersed in the virtual environment. Since it will be closer to a real nature environment, the benefits of real nature could be captured. As a precursor to testing this hypothesis, the virtual environment needs to be created.

The aim of this project is to create a nature pill in the form of a natural forest within a virtual reality environment. The environment will allow the user to explore a small section of the virtual forest, where they can interact with certain elements of the environment whilst being completely immersed due to the inclusion of sight, hearing, smell, and touch. To the best of our knowledge, there is no existing nature pill that incorporates all these aspects.

Our research questions focus on the design of such an environment:

- What is the best environmental design to incorporate each of the senses?
- What elements should we model in the virtual environment in order to maximise relaxation?
- What is the most suitable locomotion technique for our natural environment given the challenges of a fixed element in the scene, and that we want to maximise immersion while minimising cyber sickness (motion sickness experienced in VR)?

# 4 Procedures and Methods

## 4.1 Design Features and Challenges

We plan to create an immersive, multi-sensory environment. Since our research questions revolve around the design of this environment, in this section we mention what aspects we plan to incorporate and research, as well as provide the initial layout of our environment, which we expect to change in the duration of this project.

Figure 1 shows the initial birds-eye view of the elements we plan to add to the virtual environment. Each aspect is discussed in more detail below.

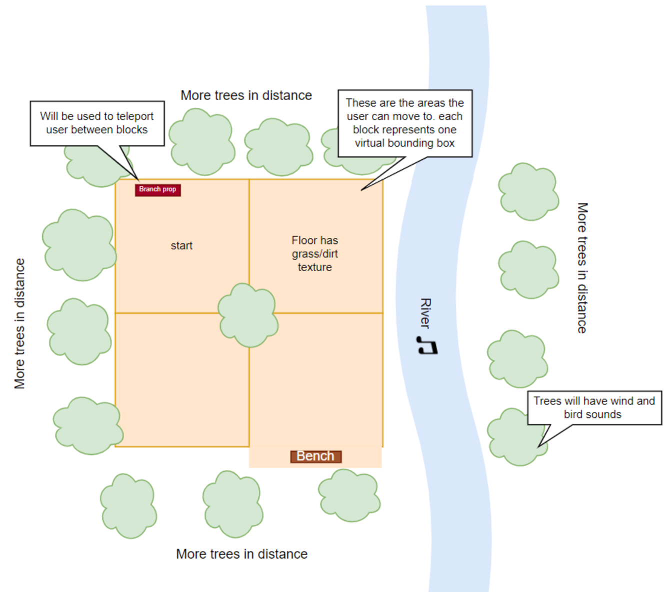


**Figure 1: A birds-eye view of the initial environment layout**

Since we plan to create a forest environment, one of the most important elements that need to be present are trees. These will be rendered using textures mapped onto polygons for close range viewing (within the areas in which the user can move), but as this is expensive, we would reduce the level of detail as the distance from the viewer increases. Billboards, or quadrilaterals with texture mapped onto them, will be used to render further trees, with multiple trees being mapped to a single billboard for the furthest trees.

To model the sky, clouds, and other celestial objects such as the sun we will use a skybox which is a dome which encloses the virtual environment. Skyboxes are similar to billboards where the entire dome has a single texture mapped onto it, and have the property of being unreachable and have images projected onto them. Thus, they are very suitable for objects at infinite distance, where parallax would not be an issue.

A real bench will be bought and placed in the physical room where we will be testing the virtual environment. This real bench will be modelled and placed in the bottom right block of the virtual environment. When in this block, users will be able to sit on the bench both physically and virtually. The user will be able to feel the bench's texture, adding to the immersive experience. Two big challenges come with this addition. The first is to find the best way to keep users immersed while indicating that they can physically sit on the bench. Perhaps a virtual sign within the environment would be useful. The bench could have a phrase such as "relax, sit down"

[1] "The somatosensory system is the part of the sensory system concerned with the conscious perception of touch, pressure, pain, temperature, position, movement, and vibration, which arise from the muscles, joints, skin, and fascia." [18]

engraved on it. Alternatively, we could inform the user that the bench is something you can sit on before entering the virtual environment. The second challenge is to find a way to allow the user to move freely within other blocks and indicate when the bench is in the correct position for sitting. HTC Vive trackers will be attached to the bench so that the program can track where it is in the environment.

Like the bench, a real-life physical branch will be modelled and placed in the virtual environment, with attached trackers to track its movements. The user will be able to pick up and feel the textured branch. Possible usages of this prop will be researched, but the initial plan is to use it as an aid for teleportation, where the teleportation arc (see figure 2) spans from where the branch is pointing to, to where the user will be teleported to.

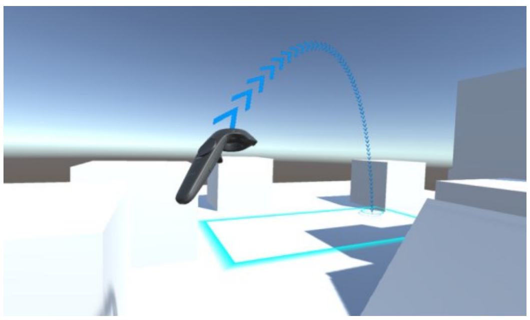

**Figure 2: an example of a teleportation arc [19]**

We plan to (initially) have four blocks/virtual rooms worth of area which the user can move to and explore. When the user approaches the boundary of a box a grid will appear indicating that they are approaching the bounds of the physical room they are in, and should stop before colliding with real-world objects. Due to the physical bench in the real world, the explorable area of all other blocks will need to be slightly smaller to prevent the user from colliding with the bench.

The best method of locomotion between areas will require extensive research. We want the user to move freely between boxes, while incorporating the fixed bench. An initial suggestion is teleportation between the blocks with the teleportation arc locking to a position in the block being pointed at by the user, that makes sense in the context of the real world. For example, if the user is in the top left corner of block 1 (and so also in the top left corner of the real room) and wants to go to block 2, the teleportation arc will lock on the top left corner of block 2, so that the user can know where they will teleport to. Though this is a good solution to the fixed bench issue, and is well known to not induce motion sickness, it restricts motion and so other methods of locomotion and their suitability to our project will be researched. Motion sickness, immersion, and ease of aligning the user with the bench will need to be considered.

Other elements we plan to include in our forest environment are a river and textured ground. We will research whether terrain elevations will be a valuable addition to our nature pill and adapt our plan accordingly.

We suspect that including other senses such as sound and smell would help provide a more immersive experience. Initial suggestions are the addition of wind and bird sounds, and the use of air fresheners in the room. The specifics of what will constitute good sound and smell design in a virtual forest environment will be researched further.

Design aspects may have suitable alternatives, such as locomotion techniques, which could be implemented and compared through heuristic evaluations.

If time permits, we will investigate more ways we could have the user interact with the environment. Possible extensions that could add to the immersive environment are: allowing the user to draw on the sand while sitting on the bench, adding movement in the trees due to the wind, and winds periodically generated by a real fan mapped to virtual wind sounds.

## 4.2 Implementation Strategy

We plan to create the environment using the Unity game engine. For the development of the environment, we plan to follow an agile model with iterative development cycles of the various elements in the scene. Starting with the low-fidelity prototype sketch in figure 1, elements will be researched and slowly added to the scene. Work by the two members will be integrated from an early stage using Unity Collaborate. We plan to have three iterations, each with a prototype release. After the first two releases, heuristic evaluation from preselected testers will provide feedback for our next release. Alternative design ideas will be researched and explored, with feedback given by supervisors.

The first iteration will be the equivalent of a "first playable", an environment that allows users to move around with some aspects still being placeholders. The second iteration will replace placeholders with their intended objects. The third and final iteration will be adding final details to the scene, and incorporate sound and smell design. However, this is all subject to finalisation through research.

Since Unity is a game engine with existing prefabs (existing Unity game objects) and libraries, some parts will be done automatically, such as the rendering of trees, but the implementation of locomotion specific to our project (such as incorporating the branch, and the alignment with the bench), will require coding in C#. The environment will be designed and developed from scratch using Unity's Terrain editing tools.

## 4.3 System Evaluation

The system evaluation would be done with respect to whether the environment is sufficiently responsive, realistic, and does not induce motion sickness with moderate usage. We are not doing a full user evaluation in this project, and instead we will use heuristic evaluation while keeping track of important metrics such as latency, frame rates, and visual fidelity.

Low latency would be important as an increase in latency has been found to increase the chance of cybersickness occurring. Brunnström et al. [20] have shown that a display latency greater than 20ms starts to cause cybersickness in some users and should be avoided and kept below 30-35ms. They also show that for hand controllers longer delays can be tolerated but should be kept below 500ms before it becomes noticeable enough to affect the experience negatively. Their focus was not on whether it affects the emotional state but rather simulator sickness while performing some task using a joystick, so it could be worthwhile to investigate whether such latencies would significantly influence the emotional state of the user.

Frame rates are to be close to 90fps, which is the benchmark advised by a VR software company called IRIS VR [21]. Since our environment will not have rapid rotations, it may be tolerable to have lower fps, but it would likely need to remain higher than 60fps so the stutter that results would not induce cybersickness which is associated with lower frame rates. Unity provides an option to view frame rates during testing.

Graphics quality affects the perceived fidelity of visual and overall experience as shown by Debattista et al. [22]. Higher graphics quality would be desirable for a better experience, and it may even correlate with stress relief (but remains an open question requiring research). However, Tiiro [23] notes there is some evidence that visually highly realistic virtual environments are more likely to induce cybersickness. Realism on their part meant levels of detail, animated models, lighting and fog. This study did not refer to the frame rates of highly realistic renderings compared with the frame rates of less realistic renderings, so there could be a false correlation due to lower frame rates resulting from highly realistic renderings which may have been a major factor in inducing simulator sickness. Additional shortcomings of the work are: not establishing a baseline metric for simulator sickness, using two different systems to run the experiment, and testing some users more than once, which would have affected the validity of their experiment. It would be worth investigating how realism affects stress relief, but user evaluation is out of scope.

Visual fidelity for this project will need to be high while maintaining high frame rates. Measuring visual fidelity will involve qualitative assessment of lighting, level of detail, and texture, subject to change with further research. A high visual fidelity environment would have realistic lighting, a high level of detail while using realistic models of trees, and realistic texture to render, for example, grass and branches on the ground.

The different design alternatives will be evaluated through heuristic evaluation, to see which is most sensible given our environment.

### 4.4 Expected Challenges

We expect there may be challenges in obtaining suitable models. Due to time constraints, we will be looking for existing models on the Unity Assets store or from artists. For the branch and bench, it will be difficult to find a model closely resembling the real object, which means we will likely have to model these by hand (which would take time). Safety would also be of concern where these physical objects are involved. As discussed in design features, the user moves within the physical environment while wearing the HMD (Head-Mounted Device), and must be directed away from the bench as necessary while not breaking the immersion too much.

Cybersickness is to be avoided whenever possible as it would go against our purpose of providing a restorative experience. Adhering to the recommended performance requirements, i.e., high frame rates and low latency, will be challenging.

Choosing the best locomotion technique will be a challenge, as various techniques would need to be compared in order to choose the best technique in our context. A brief look at Colburn [24] reveals that manual movement could result in more discomfort and cybersickness, compared to teleportation and flying which generally results in disorientation.

## 5 Ethical Professional and Legal Issues

We constrain our project to the development of the environment tested through heuristic evaluation by the project developers and the supervisors, and possible a few selected individuals. A formal user experience study is beyond the scope of our project, and this project does not require ethical clearance from the university board.

The supervisor based heuristic evaluation is only to explore ideas and see what is sensible for the environment. Additional research and formal user testing would be required before publication, which is at the discretion of our supervisor, James Gain.

The intellectual property for this project belongs to the researchers, Soo Kyung Ahn and Lynn Weyn, as well as the University of Cape Town, following the standard UCT Intellectual Property Policy.

## 6 Anticipated Outcomes

### 6.1 System

Upon the successful completion of the project, we expect a relaxing natural environment to be fully functional and ready for exploration.

#### 6.1.1 Software

The software deliverable we expect to produce will be executable on the HTC Vive Pro VR headset within the room setup (trackers, props and physical bench) discussed in section 4.1.

#### 6.1.2 Key Features

- A natural scene created with
  - Trees
  - Clouds
  - A river
  - Textured terrain
- A bench present virtually and in the real world
- A branch prop present virtually and in the real world
- Scent of the forest
- Nature sounds
- Realism

#### 6.1.3 Design Challenges

- Realism of the forest
- True-to-life modelling of the branch and bench
- Free motion with a fixed object (the bench)
- Integration of natural scene components
- User immersion
- Minimising motion sickness
- Efficiency

### 6.2 Expected Impact

We aim to have anyone who immerses themselves into our final virtual environment to become relaxed, getting some of the benefits of being in real nature from indoors. Successful outcomes for this project could provide new opportunities for those who do not have access to nature.

### 6.3 Key Success Factors

The success of this project will be dependent on whether we can create a realistic environment that is responsive, providing a restorative experience. Key success factors would include meeting the project deadlines, getting the physical and virtual resources, and communication between team members for the integration of different components.

## 7 Project Plan

### 7.1 Risk and Risk Management Strategies

Various risks associated with this project have been identified. Their associated probability and impact were estimated, and mitigation, monitoring, and management strategies have been created. See Appendix A for this information represented as a risk matrix.

### 7.2 Timeline and milestones

Work on this project started on the 16th of May and will run until 18th of October. The timeline and milestones can be seen in Appendix B - the Gantt chart.

### 7.3 Resources Required

#### 7.3.1 Hardware

- VR Head mounted display and controllers (HTC Vive Pro) - provided by the CS department.
- High-end computers capable of running VR - both researchers have laptops with suitable graphics cards (NVIDIA GeForce GTX 1660 Ti and NVIDIA GeForce RTX 2060) for development, and laboratory computers will be used for heuristic testing.
- Sensors to attach to the bench and branch - provided by the CS department.

#### 7.3.2 Software

- Tree models, provided by our supervisor, James Gain.
- Unity - Personal version.
- Unity Collaborate - the free version should suffice.
- Unity Assets.

#### 7.3.3 Human resources

- Support and knowledge from our supervisor.
- Advice on accessing the psychological benefits of nature from a representative of the psychology department, Gosia Lipinska.

#### 7.3.4 Other

- A bench, sourced by the researchers, and paid for by our supervisor.
- A branch, to be found in a forest.

### 7.4 Deliverables

| **Deliverable** | **Completion Date** |
|---|---|
| Literature Review | 04/06/2021 |
| Project Proposal | 23/06/2021 |
| Project Proposal Presentation | 09/07/2021 |
| Revised Project Proposal | 30/07/2021 |
| First Prototype (Initial Software Feasibility) | 10/08/2021 |
| Final weighting for project marking | 30/08/2021 |
| Draft of Project Paper | 06/09/2021 |

| | |
|---|---|
| Final Project Paper | 17/09/2021 |
| Final Project Code | 20/09/2021 |
| Final Project Demonstration | 04/10/2021 |
| Poster | 11/10/2021 |
| Web Page | 18/10/2021 |

## 7.5 Work Allocation

The following table shows the allocation of tasks to each member. The tasks have been split it in a manner so that the success of one does not depend on the other, but both members will give input on the project, collaborating throughout its lifetime to create a relaxing environment. Though Lynn will be using the models created by Soo Kyung, she can use placeholders (such as a cuboid with the correct height for the bench, and a cylinder for the branch) in order to start development.

| Soo Kyung Ahn | Lynn Weyn |
|---|---|
| Terrain Elevations | Reachable areas and locomotion |
| Trees and Grass | Water and Rocks |
| Lighting effects | Sky and clouds |
| Terrain Texture for grassy and mountain area | Terrain texture for river area |
| Modelling the branch and porting it to Unity | Coding and integration of branch (use with locomotion) |
| Modelling the bench and porting it to Unity | Coding and integration of bench (alignment with user) |
| Smell Design | Sound Design |
| Optimising, tweaking settings | |

A lot of time will be spent researching the design of the environment, including smells and sounds, which neither researcher has experience in.

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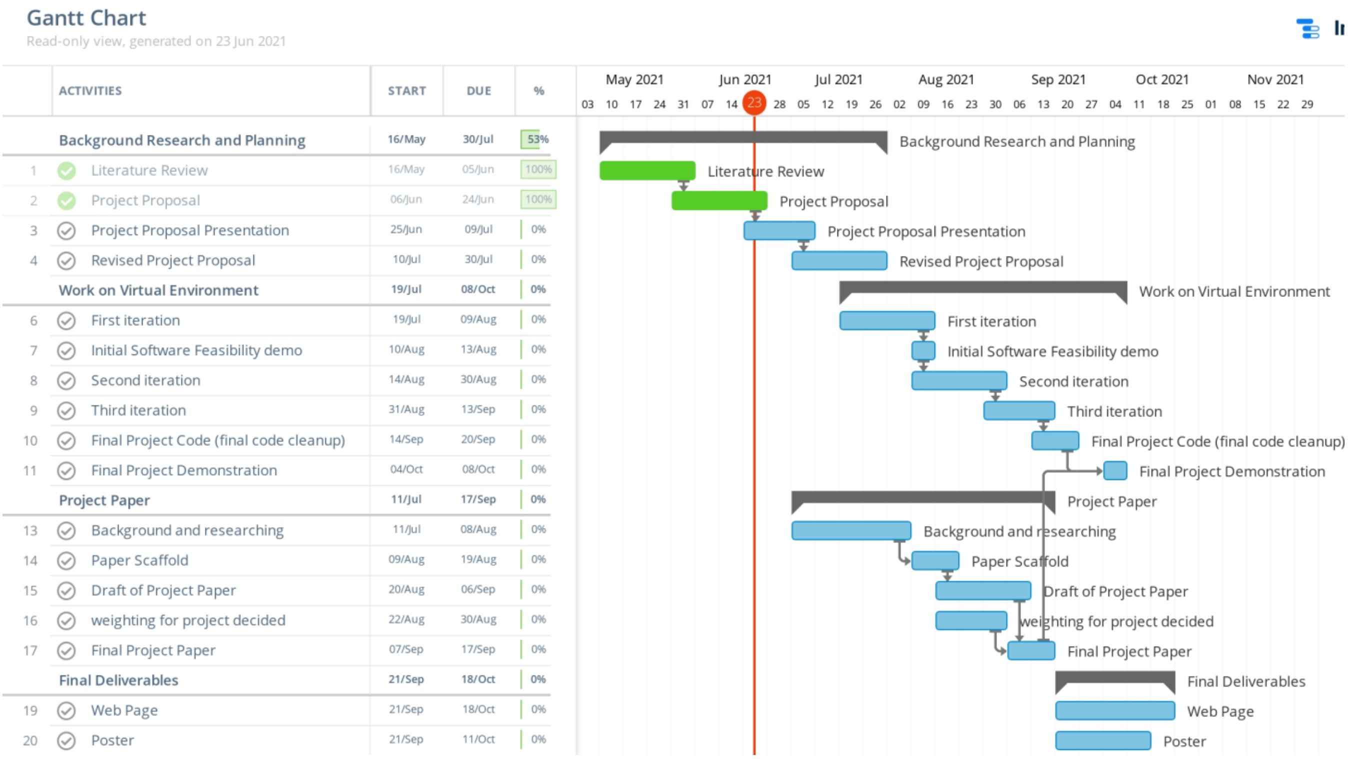
**Appendix A: Risk Matrix**

| Risk | Probability | Impact | Mitigation | Monitoring | Management |
|---|---|---|---|---|---|
| Power outages | High | Medium | Ensure battery-powered devices are charged. Save frequently. | Keep track of load shedding schedules. | Plan to ensure meetings do not coincide with load shedding, and use battery powered devices during the power outage. |
| Lack of expertise | High | Low | Research the topics, refer to online resources. | Track whether a task is taking longer than expected. Ask for assistance earlier than later. | Look for resources online, request assistance from supervisors if online resources are not sufficient. |
| Conflict between team members (during integration of projects) | Low | Medium | Have regular meetings so both members are on the same page. | Track participation in meeting and assess tension between members. | Plan a meeting where members can discuss conflict. If unable to resolve, reach out to an unbiased mediator. |
| Poor integration between environmental objects | Medium | Medium | Integrate early, have regular meetings. | Each time a new element is added to the scene, test interaction with other elements. | Attempt to resolve the issue over a meeting. Consult the supervisor if no solution is found. |
| Failure to find and/or receive key resources (e.g., VR equipment, bench, or branch) | Low | High | Request equipment and follow up early. Search for props early. | Communication with resource providers. | Work on other aspects that do not require the resources. |
| Failure to meet deadlines | Low | High | Start working on deliverables early. | Keep track of progress on Gantt chart. Set own intermediary deadlines. | Update overall schedule, possibly reduce scope. |
| Participants get injured from real objects (bench/ branch) during heuristic testing | Low | High | Ensure the user is aware of the bench or otherwise kept away from the bench through visual cues. Have a first aid kit nearby. | Communication with heuristic testers. | Make use of first aid kit. Replace objects with ones that have no sharp edges. Sand down the branch. Move bench further towards the walls of the real room and in the corner to prevent tripping and maximise space. |
| Modelling of bench and branch not realistic (breaking immersion) | Medium | High | Start modelling early on, find online resources on how to model objects realistically. | Do heuristic testing when each model is created. | Attempt to remodel, seek advice from supervisor. |

## Appendix B: Gantt Chart




| | ACTIVITIES | START | DUE | % |
|---|---|---|---|---|
| | Background Research and Planning | 16/May | 30/Jul | 53% |
| 1 | Literature Review | 16/May | 05/Jun | 100% |
| 2 | Project Proposal | 06/Jun | 24/Jun | 100% |
| 3 | Project Proposal Presentation | 25/Jun | 09/Jul | 0% |
| 4 | Revised Project Proposal | 10/Jul | 30/Jul | 0% |
| | Work on Virtual Environment | 19/Jul | 08/Oct | 0% |
| 6 | First iteration | 19/Jul | 09/Aug | 0% |
| 7 | Initial Software Feasibility demo | 10/Aug | 13/Aug | 0% |
| 8 | Second iteration | 14/Aug | 30/Aug | 0% |
| 9 | Third iteration | 31/Aug | 13/Sep | 0% |
| 10 | Final Project Code (final code cleanup) | 14/Sep | 20/Sep | 0% |
| 11 | Final Project Demonstration | 04/Oct | 08/Oct | 0% |
| | Project Paper | 11/Jul | 17/Sep | 0% |
| 13 | Background and researching | 11/Jul | 08/Aug | 0% |
| 14 | Paper Scaffold | 09/Aug | 19/Aug | 0% |
| 15 | Draft of Project Paper | 20/Aug | 06/Sep | 0% |
| 16 | weighting for project decided | 22/Aug | 30/Aug | 0% |
| 17 | Final Project Paper | 07/Sep | 17/Sep | 0% |
| | Final Deliverables | 21/Sep | 18/Oct | 0% |
| 19 | Web Page | 21/Sep | 18/Oct | 0% |
| 20 | Poster | 21/Sep | 11/Oct | 0% |