Visualising how different weather conditions affect the vision of a UAV drone in search and rescue

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Abstract

In recent years, the utilisation of Unmanned Aerial Vehicles (UAVs) has become increasingly more important when conducting search and rescue missions. Their combined versatility and efficiency make them an effective tool when looking for missing persons in unpredictable conditions. However, as this tool is recently new, there are drawbacks when it comes to making full use of them. In particular, vision can be impaired due to the limited quality that most UAV drones can produce in a short space of time which is only worsened by poor weather conditions. This dissertation displays an attempt to provide a simulation in Unity 3D for search and rescue drone pilots to give them some experience viewing typical weather conditions through the drone's camera. This is in the hope that this experience can make the difference between saving a life as time is of the essence when dealing with search and rescue operations. The quality of these simulations was measured by using a side-by-side comparison with real life drone footage within different weather conditions as well as an FPS counter. This is to measure how realistic the simulation is compared to the actual drone footage. This paper concludes that the different simulations produced in the project are viable tools to experience what impact the weather can have on the vision of a UAV drone

Declaration

I declare that this dissertation represents my own work except where otherwise stated.

Acknowledgements

I would like to thank my supervisor, Dr Ken Pierce, for his support and guidance throughout the course of this project.

Table of Contents

Table of Figures

1 - Introduction

This section will provide the reader with an introduction to the project by outlining the structure of the dissertation, the motivation and rationale for conducting this project and the aims and objectives to complete this project.

1.1 - Motivation and rationale

Context: Over recent years, the use of UAV drones in search and rescue missions has become increasingly necessary due to their efficiency when compared with ground teams. This is backed up by Gene Robinson (2020), "the godfather of search and rescue drone operations", who claims that drones can provide detailed data quickly and efficiently **[1]**. Not only are they more efficient, but UAV drones are also more versatile due to the ability to scan areas that are hard to access by ground teams such as mountains, cliffs, etc. Robinson (2020) also went on to state that because drones can fly over the landscape, they can then alert ground teams of any obstacles such as cliffs so they can be well prepared to traverse the terrain instead of going out blind and unprepared **[1]**. UAV drones are effective during difficult weather conditions as the terrain would only be more difficult to manoeuvre in causing even more delays to the ground team search.

In 2017, the Exercise Northumberland Report described an experiment where different methods of search and rescue were tested near Rothbury in Northumberland. The paper concluded that drone searches were able to provide an equally high success rate as ground teams but at a greater speed **[2]**. Thus, supporting the fact that UAVs can be a cheaper, more sustainable tool for search and rescue compared to helicopters as both were concluded to be faster than ground teams **[2]**.

Problem: Although drone searches are more efficient than ground teams, the Exercise Northumberland Report also states that interpretation of the images can be difficult and time consuming **[2]**. This would be more challenging when weather conditions intervene, such as fog, as vision can be significantly affected. The time to interpret the drone images would therefore increase which could make the difference in saving someone's life as time is of the essence in search and rescue missions.

Rationale: The aim of this project is to create a realistic visualisation of a drone flying in different weather conditions, each affecting the drone's vision in some way. This may be used to provide UAV drone pilots with experience interpreting drone images to speed up search and rescue times which could prove to be vital to finding a missing person.

1.2 - Aim

The aim of this project is:

To create a realistic visualisation of the effects of different weather conditions on the vision of a UAV drone when carrying out search and rescue across Northumberland national park.

1.3 - Objectives

The objectives to measure my success in this project are to:

1. **Read exercise Northumberland paper from 2017 and a previous dissertation in a similar field then summarise key findings.**

   These papers will form the bulk of my background knowledge to give me a better understanding of the subject area.

2. **Gather footage of real-life examples of drones in different weather conditions.**

   Collecting samples of real-life drone footage will help to compare my work against and check how realistic my simulation is.

3. **Implement a copy of a section of terrain from Northumberland with realistic vegetation to make the visualisation more accurate.**

   Vegetation can also decrease vision therefore adding this feature will make my simulation more realistic which is the aim of the project.

4. **Implement four different weather conditions, raining, foggy, snowing and sunny.**

   These are the most common weather conditions in Northumberland, so it makes sense to implement these first and add more if time permits.

5. **Simulate the drone’s vision in each weather condition and record how easy it is to see objects.**

   Run the simulations that were implemented in the last objective to see how difficult it is to see objects placed on the terrain.

6. **Analyse the results of the UAVs vision and compare the different simulations to real life drone footage for each weather condition.**

The comparison will measure how realistic my simulation is and also where my simulations can improve.

1.4 - Measuring Objectives

Objective **1** will be complete when the two papers mentioned have been read as well as other smaller, less relevant pieces of information. Objective **2** will be complete when real life drone footage has been gathered for each weather condition that is to be implemented in this project. This will conclude the research stage of this project and is expected to be completed by the middle of February.

Objectives **3** and **4** will take longer to complete as that is the implementation stage. These will be done when the four weather conditions mentioned have been implemented and there is vegetation on the terrain that is as realistic as possible with the time restraints. Once these two objectives are complete, the implementation stage of this project will be over which is expected to be halfway through April.

Finally, Objectives **5** and **6** will use the completed implementation from objectives **3** and **4** to conduct simulations and then analyse these simulations to gather results. Objective **5** will be completed when multiple simulations for each weather condition have been completed and recorded the necessary results. Objective **6**, once completed, will dictate the completion of the project, and will require an analysis of the previous simulations by comparing them to the real-life footage gathered in objective **2**.

1.5 - Structure

The following outlines the way that this report has been structured and how the information has been split up within the chapters.

2 - Technical Background

Describes the investigation into the knowledge base for this project with details of the background research, the key technologies that can be used to complete this project and a brief plan of how the work will be carried out.

- 2.1 - Research
    - 2.1.1 - Exercise Northumberland Report (2017)

3 - What was Done and How

This section goes into detail about the steps taken to achieve the aim of this project and how these steps were achieved. Starting with the design process for this project which then continues onto the implementation phase with accompanying screenshots. Finally, the testing method for the simulations is described before a summary at the end.

3.4 - Summary

4 - Results and Evaluation

The results of this project, which are the simulations, are compared against real life footage and then evaluated on the similarities and differences between the simulation and the footage.

4.1 - Results

4.1.1 - Foggy Conditions

Results

Evaluation

4.1.2 - Rainy Conditions

Results

Evaluation

4.1.3 - Snowy Conditions

Results

Evaluation

4.1.4 - Sunny Conditions

Results

Evaluation

4.2 - Evaluation of Method

4.2.1 - Key Technologies

4.2.2 - Methodology

5 - Conclusion

Decisively, concluding the project through the aim and objectives to measure the success of the project. A summary of future work that could be done to improve the project is also given. Finally, a conclusion of what I have learned throughout the course of completing this project.

5.1 - Aim and Objectives
- 5.1.1 - Aim
- 5.1.2 - Objectives

5.2 - Future Work
5.3 - What I have Learned

1.6 - Summary

This chapter outlined the background context for this project and the motivation as to why this project is to be completed. An aim is stated that is the intended outcome of this project which is then split into six objectives to be used to measure the success of the project. Finally, the structure of the later chapters has been included with a brief introduction to each chapter.

2 - Technical Background

This section aims to provide the reader with the background research that was carried out, the key technologies that will be used, a plan for the work to be carried out and the methodology being used to carry out this work.

2.1 - Research

2.1.1 - Exercise Northumberland Report (2017) [2]

This paper describes an experiment of different methods of search and rescue techniques such as ground teams, helicopters and more relevant to this project, drones. The main finding from this paper is that drones and helicopters can be an efficient alternative to ground teams. Additionally, the paper outlines the difficulty looking through drone images and time consuming, due to the poor quality of the drone images. The relevancy of this paper to this project is that it proves that the vision on a drone's camera can be low at times, even when there are no weather conditions to affect this. Given this information, it could be useful for search and rescue operators to be able to gain some experience in viewing things from the drone's camera.

2.1.2 - Visualising Simulations of Drone Searches (2020) [3]

This previous academic report provides a rationale and is the main foundation of this project. The paper outlines the effectiveness of drones in search and rescue as well as different ways of visualising and modelling a drone's flight path and stitching an orthomosaic map together. It also details the useful technologies to create a visualisation like this such as the INTO-CPS tool for modelling. The main take-home point of this paper is that a visualisation of a drone flying can be a useful tool for search and rescue operators to decide what the best methods of flying the drone are. This is all relevant to the project as it is the rationale towards different weather conditions being added using Unity. It is a good demonstration of what goes into the project completed by the student and is well documented in case a problem with the system is encountered.

2.1.3 - Exploring the Range of Weather Impacts on UAS Operations (2017) [4]

With investigating the effects of different weather conditions, the flight and visibility of UAV drones may be impacted during search and rescue operations. The paper classifies these weather conditions by determining their impact on a UAV drone and highlights the dangers that come as a consequence of flying a drone in these conditions. In particular, the paper discusses the effects of fog and glare which are two of the conditions that affect vision that have been replicated within this project. It gives details of how these weather conditions arise and what effect it has on the vision through the camera onboard the drone. These details can be linked to my project as the weather is the main focus for the visualisation and it paints a clearer picture of what the requirements are to replicate these conditions.

2.1.4 - Busiest year on record for Northumberland National Park and North of Tyne Mountain Rescue (2021) [5]

This is an article that details the statistics of search and rescue missions in the Northumberland National Park and the North of Tyne Mountain. The article outlines how it has been the busiest year for callouts on record. Stated within this article, the number of callouts has risen in the last year by 50 reaching over 200 callouts in total across both sites. 105 of these callouts involved a response from mountain rescue teams which could have also involved the use of UAV drones. This is why this article relates to the project detailed in this dissertation. The article shows that mountain rescue is becoming more important due to the rising numbers of callouts being made and the need for effective search and rescue is becoming more vital. Because of this, the aim for this project was to create a tool that rescuers can use to provide more experience to help deal with the rising numbers of callouts being made.

2.1.5 - Drones in Search and Rescue Operations (2018) [6]

In this article, the uses of UAV drones in search and rescue operations are highlighted and why they can be an effective tool when conducting such operations. It discusses some of the common applications of drones in search and rescue and some of the benefits that come with using them. Along with the benefits, it also details some of the limitations that come with using drones in search and rescue such as they cannot directly help a missing person and it only informs the drone pilots and rescue teams of the missing person’s location. The article also provides multiple cases of UAV drones being used in this manner to help rescue teams successfully locate and assist the missing person which displays the effectiveness of drones during search and rescue operations. This therefore further backs up the motivation behind this project as it demonstrates the need for drones in search and rescue and reliance on experienced rescue teams to use them effectively.

2.2 - Key Technologies

2.2.1 - Unity

Unity is a free game engine that can be used to make well detailed simulations as well as modern games and interactive tools. The use of Unity allows a free alternative to otherwise paid for game engines such as unreal. It also comes with an in-built particle system and terrain tool which was mainly used for this project to simulate the different weather conditions. According to the Unity tutorial on their particle system tool **[7]**, it is a versatile and robust system with lots of configurable settings to help create an unlimited number of effects. With this in mind, it became the clear choice when deciding what tool to use for visualising weather conditions. This was further backed up by the copious amount of documentation and tutorials available that are a guide to solve any problem encountered during development.

2.2.2 - Unreal Engine

The unreal engine is an alternative to the Unity engine that is mainly used to make video games but can be used effectively to create visualisations such as the one detailed in this project. It also includes the tools that would be needed to complete this project such as a particle effect system and other lighting tools. Despite being able to produce higher quality graphics than the Unity engine, little experience using this engine has been obtained and it would be more suitable to use the Unity engine given past experience using the tools needed in Unity.

2.2.3 - Photoshop

Photoshop is an image editing software that is useful for making textures for Unity to use in different aspects of the application. This project specifically made use of photoshop to design different textures that were used in the particle system such as cloud textures. Despite the expenses, it offers the tools needed to make the textures and is easy to access when required. However, due to the lack of experience using Photoshop meant there would be a reliance on easily accessible support. This was the main reason for the decision to use this program as there was plenty of documentation online that would offer guidance when editing images or in this case, creating textures.

2.2.4 - GIMP

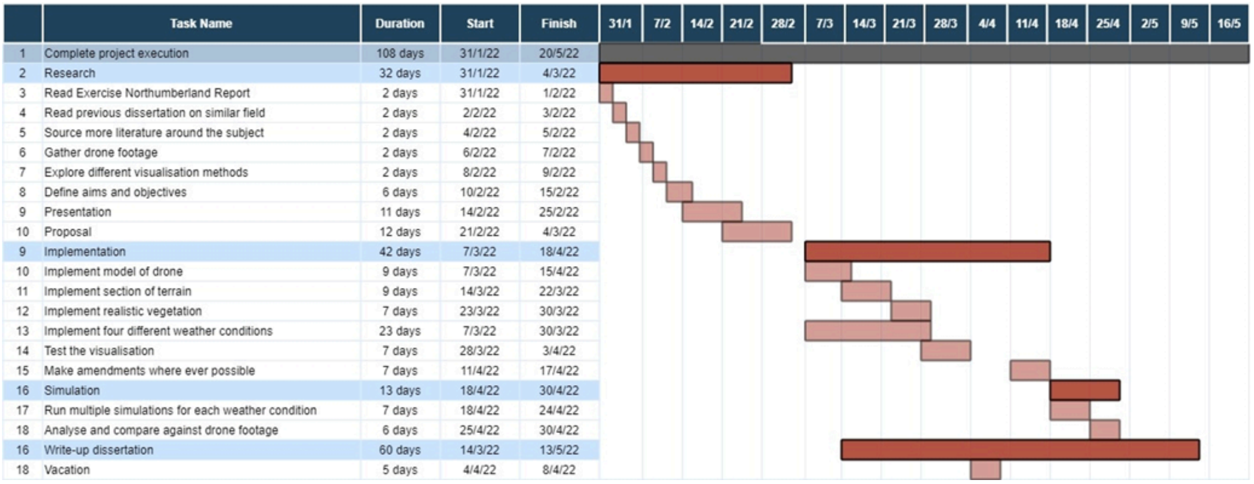
GIMP is another image manipulation program similar to Photoshop that is free to use and offers a wide variety of tools to produce textures. There is also plenty of documentation to go with it on the wiki page that offers support when using the tools provided. This would have been a good alternative to Photoshop to avoid any expenses involved.

2.3 - Work Plan

2.3.1 - Methodology

An iterative approach was used to produce the simulations as this best suited the project’s needs. The need was to split the project up which was easily done as the individual weather conditions and the terrain can all be done independently of each other. This way made it easier to work on one weather condition at a time, making quicker progress on that weather condition, instead of all of them at the same time making little progress. Doing this meant that comparisons between the simulations and the real-life drone footage could be done as soon as possible. Then, using these comparisons, improvements could be made to the simulations to make them more alike to the drone footage. Working on just one simulation at a time meant that there was more focus on the requirements for that simulation instead of juggling the different requirements of the other simulations.

2.3.2 - Project Gantt Chart



	Task Name	Duration	Start	Finish
1	Complete project execution	108 days	31/1/22	20/5/22
2	Research	32 days	31/1/22	4/3/22
3	Read Exercise Northumberland Report	2 days	31/1/22	1/2/22
4	Read previous dissertation on similar field	2 days	2/2/22	3/2/22
5	Source more literature around the subject	2 days	4/2/22	5/2/22
6	Gather drone footage	2 days	6/2/22	7/2/22
7	Explore different visualisation methods	2 days	8/2/22	9/2/22
8	Define aims and objectives	6 days	10/2/22	15/2/22
9	Presentation	11 days	14/2/22	25/2/22
10	Proposal	12 days	21/2/22	4/3/22
9	Implementation	42 days	7/3/22	18/4/22
10	Implement model of drone	9 days	7/3/22	15/4/22
11	Implement section of terrain	9 days	14/3/22	22/3/22
12	Implement realistic vegetation	7 days	23/3/22	30/3/22
13	Implement four different weather conditions	23 days	7/3/22	30/3/22
14	Test the visualisation	7 days	28/3/22	3/4/22
15	Make amendments where ever possible	7 days	11/4/22	17/4/22
16	Simulation	13 days	18/4/22	30/4/22
17	Run multiple simulations for each weather condition	7 days	18/4/22	24/4/22
18	Analyse and compare against drone footage	6 days	25/4/22	30/4/22
16	Write-up dissertation	60 days	14/3/22	13/5/22
18	Vacation	5 days	4/4/22	8/4/22

Figure 1 - Project Gantt Chart

2.3.3 - Outline of Work Plan

Figure 1 is a rough schematic of this project layout. This plan included estimated time for completion and the dates tasks are to be completed by. However, this is subject to change throughout the course of the project. Within this estimated time, an extra day or two was included to provide a bit of slack and to make sure enough time was planned in case an inconvenience was encountered. For example, the impact of personal circumstances needed to be accounted for, in specific, the vacation planned for the start of April. The strategy to try and avoid these risks having an impact on the project was to update this plan as progress was made and amend the time taken for each task.

The plan was divided into three main sections that dictated when objectives had been completed. The Research section contains all the background research that had been done and correlates to the objectives **1** and **2**. The implementation section covers objectives **3** and **4** and the simulation section finally completes objectives **5** and **6**, meaning that the project is completed. The plan was grouped this way to better manage time and resources by allowing the focus to be on two of the objectives at one time therefore splitting the work out as evenly as possible. It also made it easier to track and tick off once the pairs of objectives had been completed. The time it takes to complete the deliverables during this project was also accounted for as they took up a lot of the resources available. This was to avoid spending too much time on one part of the assignment and not as much on the others. To do that, work was done on these deliverables in parallel to make sure all are completed to the best standard as possible. This way of dividing the work up proved to be an effective tool that helped manage the time available and it gave rough deadlines for tasks to be completed by. There are more details regarding the effectiveness of this plan in the conclusion section of this paper.

2.4 - Summary

Within this chapter, any background research that was done was described and evaluated on the relevancy to this project. The key technologies that were used during this project were also described with reasons as to why they were to be used. Comparisons were drawn between similar applications and why Unreal engine and GIMP were not used for this project. A plan for the work that was done was also included along with an outline that explained what the plan was used for and the reasons for this.

3 - What was Done and How

In this section, the work that was done is investigated with reasons for doing what I did and how they were done. This project was built off of a previous system made by a prior student, so the main part of the implementation is the weather conditions that were added.

3.1 - Design

In the design stage, project planning and structure was decided and also an investigation into what the key details for each weather condition were to make the simulations more realistic.

3.1.1 - Project Work and Structure

The way this project was set up was to benefit using an iterative process to complete the work that was to be done. To do this, the work was split into the four different weather conditions with each being a sprint to finish and then iterate through to fine-tune the simulation. Once each weather condition had been completed, the vegetation and adding realism was to be done next and this would mean that some of the project's objectives had been met. Finally, a UI system was to be put in place to make it easier to navigate between the different scenes as a finishing touch.

3.1.2 - Weather Condition Designs

Before development began, research was done into the real life footage of drones flying in these four weather conditions to find the key details that would make the simulation more realistic.

For foggy conditions, the key details were:

- Thick clouds
- Hard to see anything after a small distance from the camera

For rainy conditions, the key details were:

- Some grey clouds
- Drizzle on the camera lens
- Overcast sky

For snowy conditions, the key details were:

- Ground covered in snow
- Snow moves more when falling
- Some grey clouds
- Overcast sky

For sunny conditions, the key details were:

- Lens glare
- Bright blue skies

These key details were good starting points when implementing the different conditions as they painted a clearer picture of what needed to be added to make the simulations more realistic.

3.2 - Implementation

The following points detail the steps taken during the implementation stage describing what was done and how with accompanying screenshots as evidence of what was done. All of the following weather conditions were completed using the Unity particle system.

3.2.1 - Foggy Conditions

Due to the way the project work was split up in the design phase, the starting point was to tackle one of the four conditions listed in the objectives for this project. The first step was to look at the drone footage that had been gathered in the research and make a list of key details that would be important when trying to replicate this condition. The key focus for the foggy conditions was that the clouds were thick, and it was difficult to see anything further away. With this in mind, development began using the iterative process mentioned above in the design phase starting with the designing of the cloud texture to be used.

This was done using Adobe Photoshop, with little experience, producing a suitable texture proved to be difficult. After exploring the different brushes, opacities and colours, eventually what was produced seemed an appropriate design for the cloud texture shown in **Figure 2**, resembling a cloud of smoke. This was done by mixing the opacities for each click and using the eraser tool to make it look like the cloud dissipates on the edges.

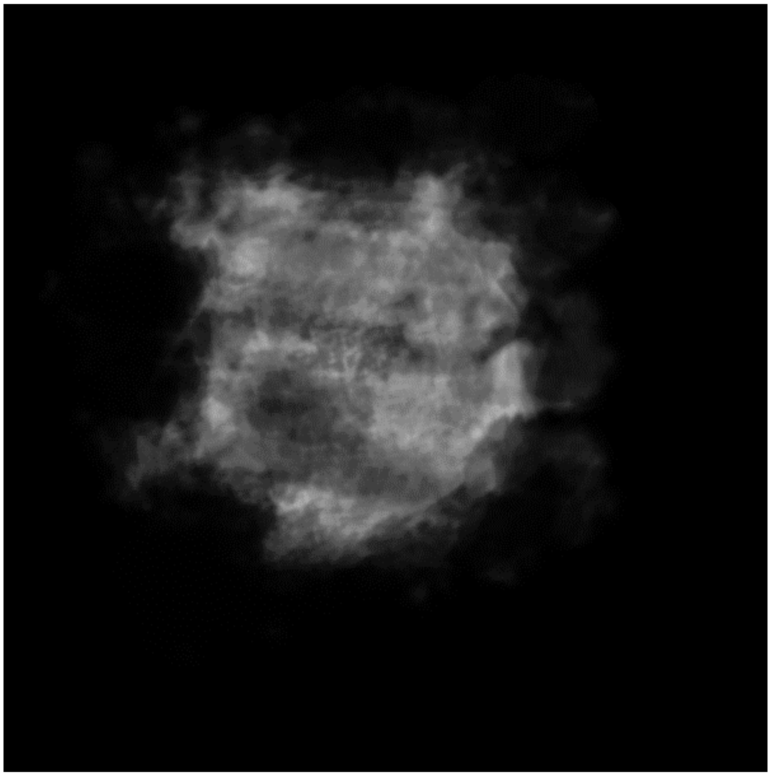


Figure 2 - Cloud texture designed in photoshop

Once the cloud texture had been designed, the next step was to import it to the Unity project that had been left by the previous student. With this imported, work began on creating the fog particle system within Unity.

Figure 3 - Final setup for fog particle system

Figure 3 is the set up for the final fog particle system that was a product of lots of tweaking of these variables trying to find the right balance. As well as these variables, there was also a velocity over time to make it look like the clouds are moving slowly as well as a rotation over time to reach the desired effect. However, the main variables that changed how thick the clouds felt, which was the key focus for producing the fog, were the Start Size, Max Particles and the Rate over Time which dictated how many clouds would appear in the scene and how large they would be.

3.2.2 - Rainy Conditions

As with the foggy conditions, the first step when starting the rainy simulation was to watch some of the drone footage and gather key features. The main details to try to replicate were the fact that there are clouds which is the main obstruction to vision in this weather condition as well as drizzle on the camera. To start this condition, the same cloud texture was used to generate the overcast atmosphere in a similar way to the foggy condition.

Figure 4 - Final setup for cloud particle system in rainy simulation

Figure 4 shows the cloud system for this simulation which is similar to the foggy condition as this worked well. However, the number of clouds on the screen and the rate of emission was dramatically reduced as in the footage, the clouds were not as thick when raining compared to fog.

Figure 5 - Final setup for rain particle system

After lots more tampering with the different variables in the particle system such as the start size and speed at which the rain fell, **Figure 5** was the final product of trying to find the right balance between these variables. One big difference from the cloud is that the render mode is set to stretched billboard instead of the billboard render mode which gave the rain a slight trail as it fell, making it appear more like the drone footage. For the texture in this particle system, the standard Unity particle was used as it was easy enough to edit to make it look like a raindrop whilst saving on performance.

Finally, a raindrop effect was attached to the Unity camera to give the simulation more atmosphere and make it more realistic. To do this, a couple of textures created by someone named Dobbey that they published online **[8]** were used to produce four smaller particle systems that follow the camera around and give the effect of rain landing on the lens and falling down it. **Figure 6** is an example of this effect when running the simulation.

Figure 6 - Example of drizzle effect on the camera lens

3.2.3 - Snowy Conditions

Starting with watching drone footage and making a list of key features, it showed that, when snowing, there are still clouds similar to those that appear when raining and that the ground is snow covered. What was also a key point from the drone footage is that the wind affects the snow a lot more than rain and causes it to look like it is moving from side to side instead of falling straight down. To achieve this, a similar approach was taken to the one to complete the rainy simulation using an alike cloud particle system shown in **Figure 7**.

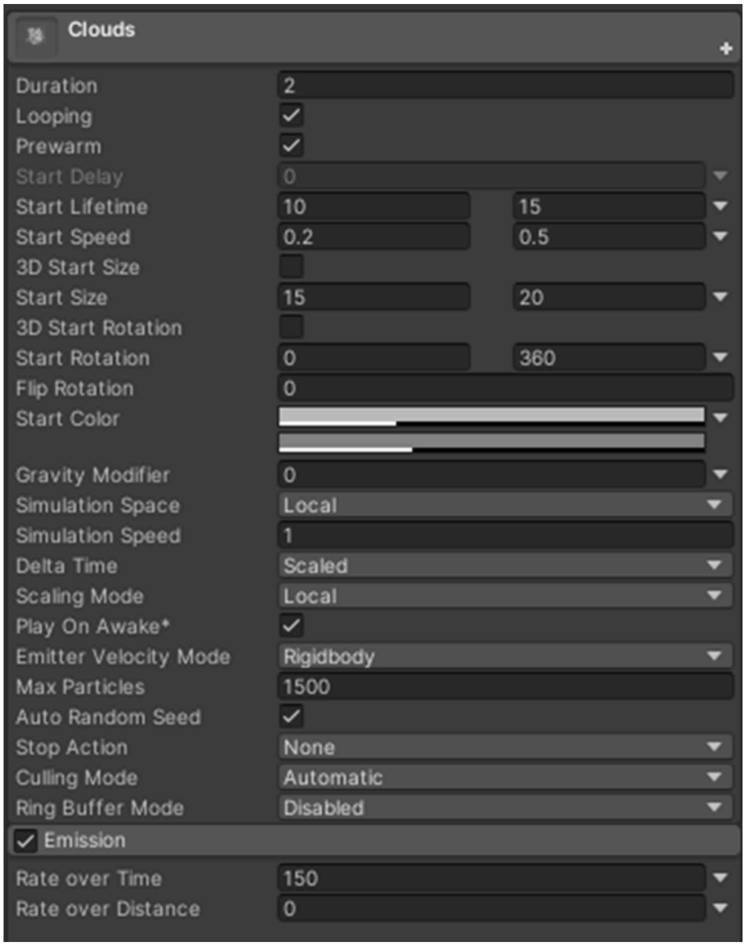


Figure 7 - Final setup for cloud particle system in snowy simulation

To create the snow effect, another particle system was added using the Unity standard particle once again. As with the rain particle system, a stretched billboard render mode was used to make the particles fall down from the sky.

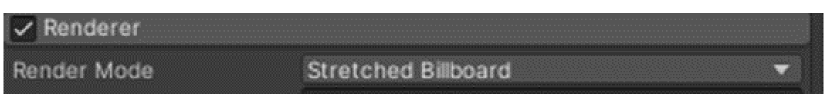


Figure 8 - Render mode for the snow particle system

The main difference from making the rain system was that the snow needed to move side to side a bit more as this was one of the key points from the real-life footage. To do this, the velocity over lifetime module was used to add a velocity in the x and z axis so that the movement looks more random to give the effect of wind blowing the snow.

Figure 9 - Velocity over Lifetime module setup for the snow particle system

To make it look like the ground is covered in snow, a new material was applied to the terrain in the terrain settings as shown in **Figure 10**. The material was created, and a custom shader was applied that applied a white colour to the object the material is applied to.

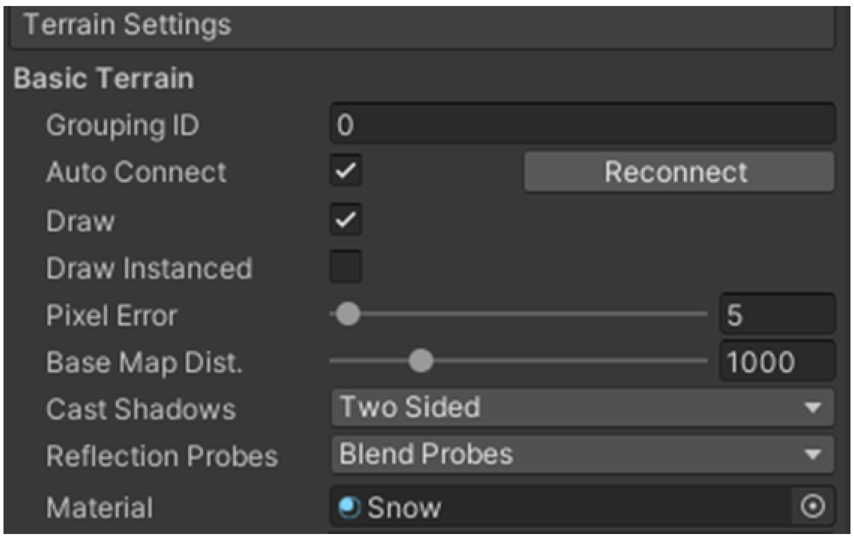


Figure 10 - Terrain settings in the snowy simulation

3.2.4 - Sunny Conditions

Upon viewing the drone footage, the main impact to vision in these conditions was the lens glare that is seen when the sun is facing the camera. This can take up a lot of the camera’s field of vision and distort the image sometimes. To achieve the lens flare effect, Unity has its own Lens flare game object component which can be added to a directional light source. **Figure 11** shows the lens flare component that is attached to the light in this scene. As you can see in the Flare box, a 50mmZoom flare is used from the Unity standard assets pack which can be downloaded for free from the official asset store. The brightness has been increased by 0.5 from the default value of 1 to make the flare more intense.

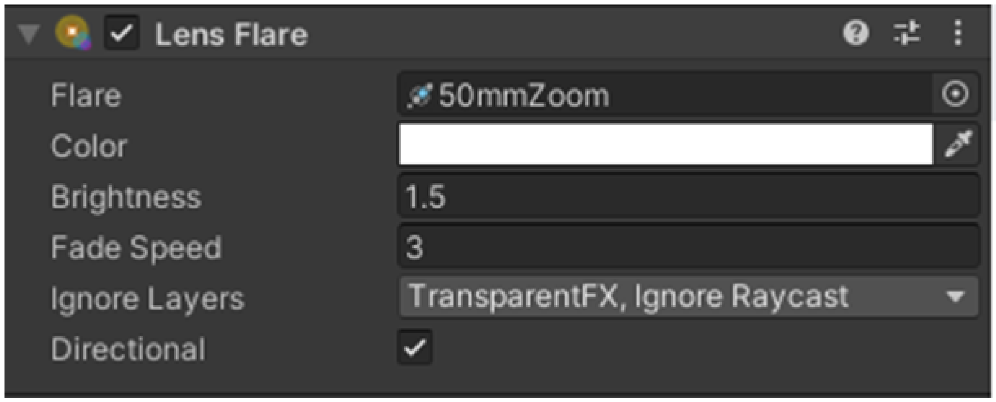


Figure 11 - Lens Flare module attached to the directional light object

At first, only adding this component did nothing when playing the scene. After investigating the problem in the Unity documentation, the solution was to add a Flare Layer component to the camera in Unity so the camera can then render the flare which then fixed the issue.

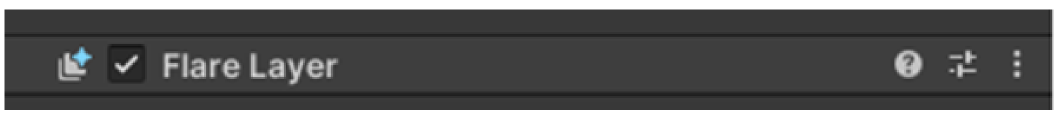


Figure 12 - Flare Layer module that is attached to the camera

Finally, to add a bright blue-sky effect was done by changing the skybox in this scene to a clear blue sky making the scene feel more complete than when using the default Unity skybox. **Figure 13** shows a side-by-side comparison between the clear blue skybox used in this scene on the left and the default Unity skybox on the right.

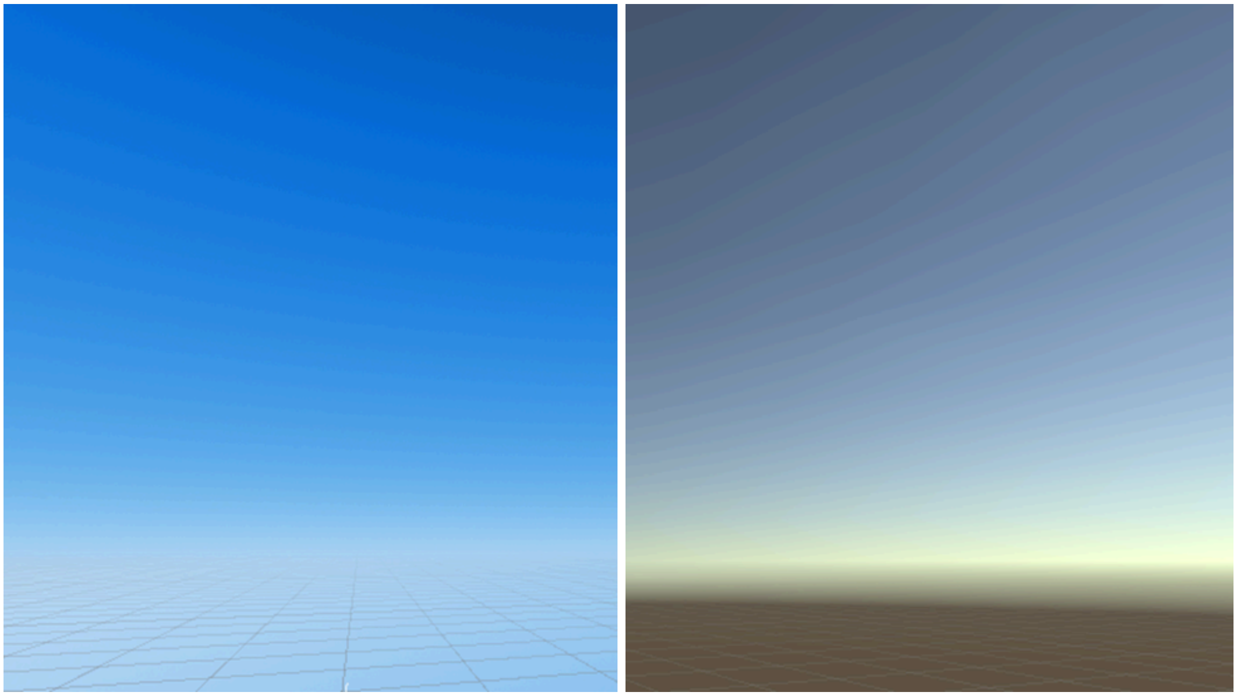


Figure 13 - Comparison between the default skybox (right) and the clear blue skybox (left)

3.2.5 - Adding Vegetation

Once all the weather conditions had been completed and iterated through to add any improvements, the next step was to add vegetation such as the trees and bushes that would be spotted across Northumberland. To do this, two of the trees from the Unity standard asset pack were used to add a bit of randomness to the scene. Unity has its own terrain tool which can be used to add trees such as the two below to the terrain using a brush.

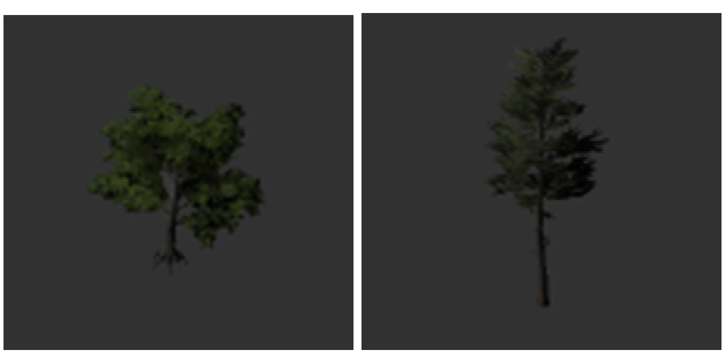


Figure 14 - The two trees that were used for vegetation

The brush settings can be tweaked to give a higher or lower density of trees as well as the differing heights that the trees are painted on the terrain. To achieve a realistic look, the tree heights were randomised between certain levels to give a variety of trees.

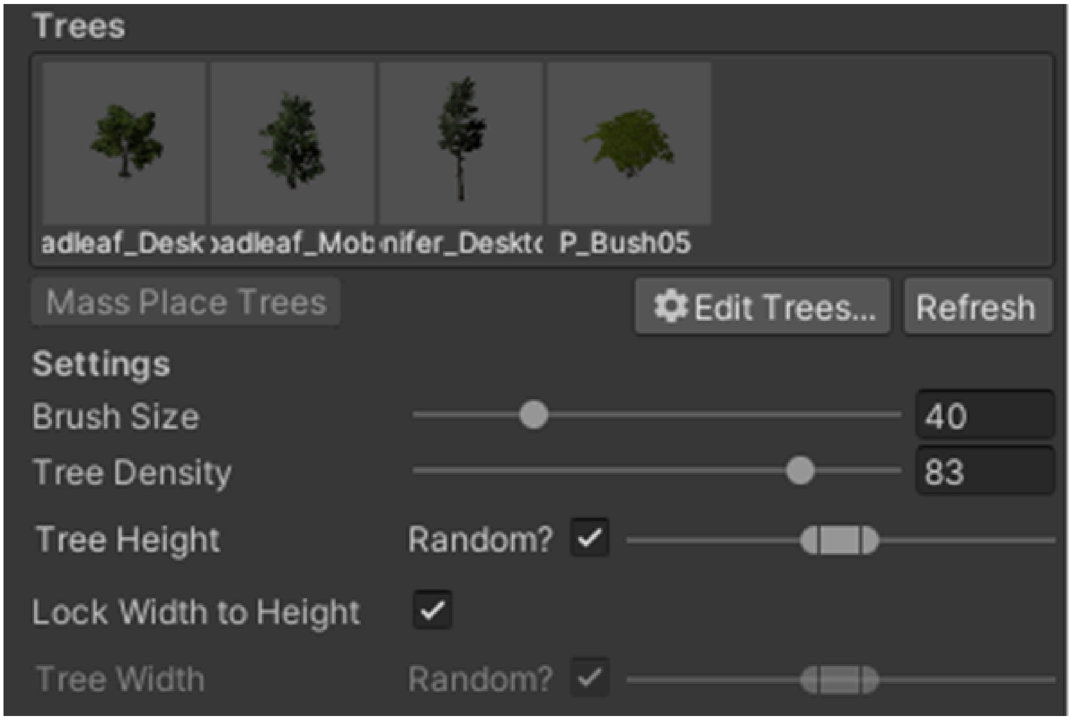


Figure 15 - The brush settings used to paint the trees onto the terrain

As well as trees, bushes were also added to give the ground a more realistic look with some smaller vegetation that would be on the ground like grass or bushes. To do this, an asset pack named Yughues Free Bushes 2018 was used which provided different types of bushes that could be painted onto the terrain like the trees. The one that was used in this project is shown in **Figure 16**.

Figure 16 - The bush used on the terrain

Finally, in the terrain settings, the rendering distances for the trees and the bushes was upped to the maximum possible number so that the trees that are far away are still rendered in as this makes the simulations more realistic instead of the trees suddenly spawning in as the drone moves closer to it. **Figure 17** shows the settings for the terrain and what values were used for the rendering distances.

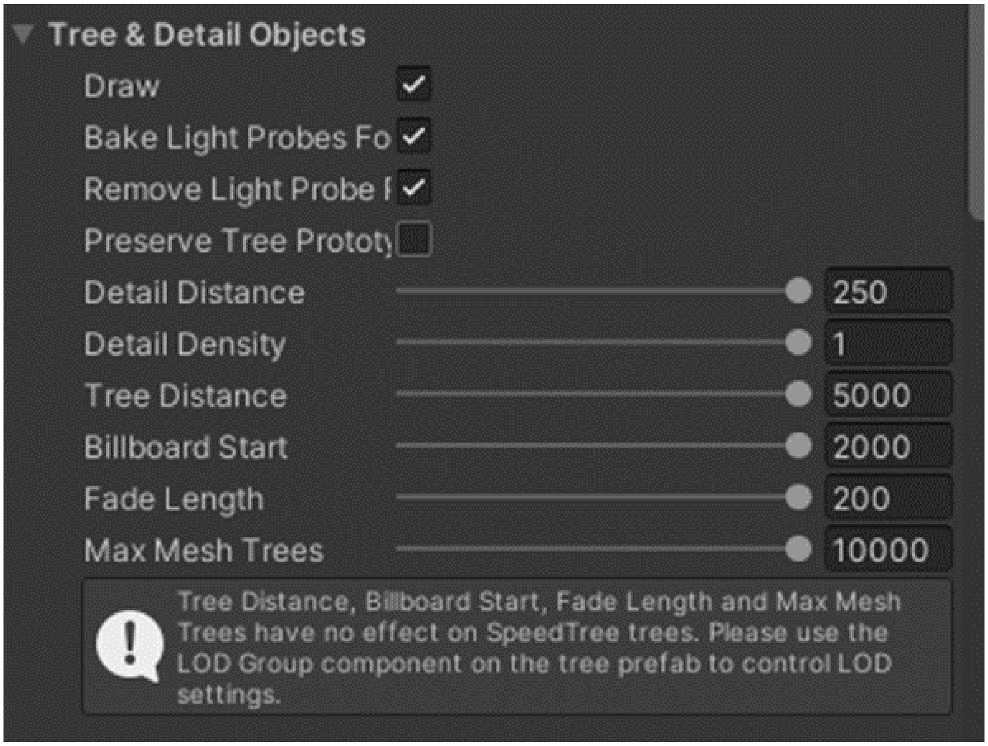


Figure 17 - The terrain settings for the rendering distance of the vegetation

3.2.6 - Adding Realism

At this point, objectives **3** and **4** were completed but there was still time to add things to enhance the simulation. One thing that was added to make the simulations more realistic was a wind effect that would affect the trees and bushes to make them move with the wind. Unity comes with a wind zone game object which can be added to a scene to provide the effect of wind blowing across the scene. As shown in **Figure 18**, the default value for the main force of the wind is 1, however this felt too violent for the scene and needed dialling down to 0.75 which felt more natural.

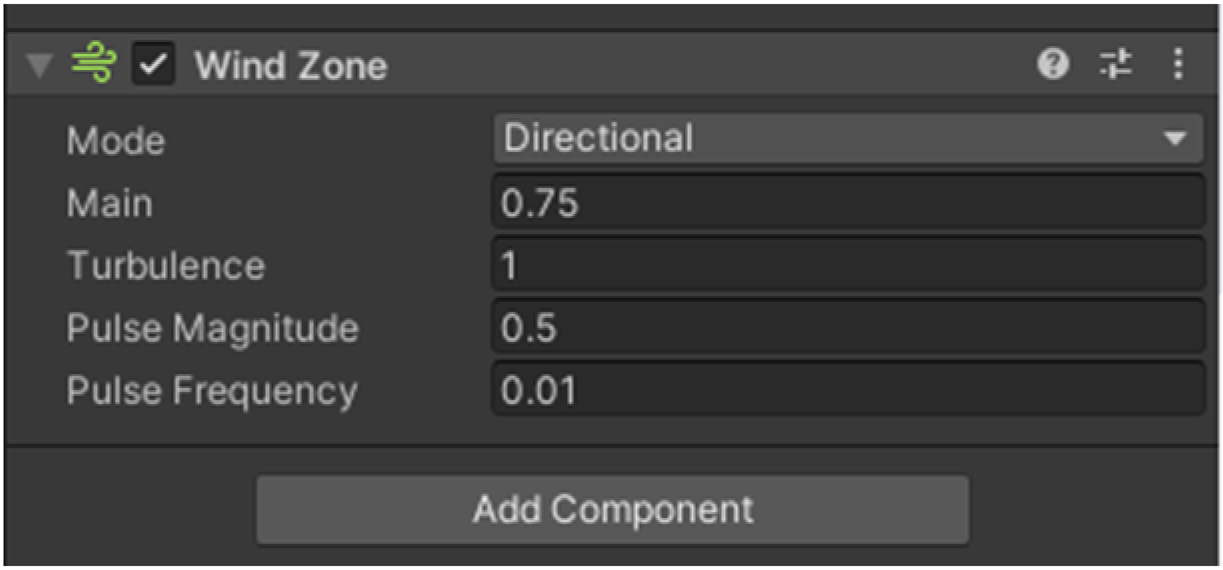


Figure 18 - The wind zone component that was added to each scene

Another way that realism was added was that the model of the drone was changed from the previous project to a more realistic model of a drone. **Figure 19** shows the drone model that was used by the previous student that this project is based off of. Compared to **Figure 19**, **Figure 20** shows a much more realistic version of a drone model making the simulations feel more like real life.

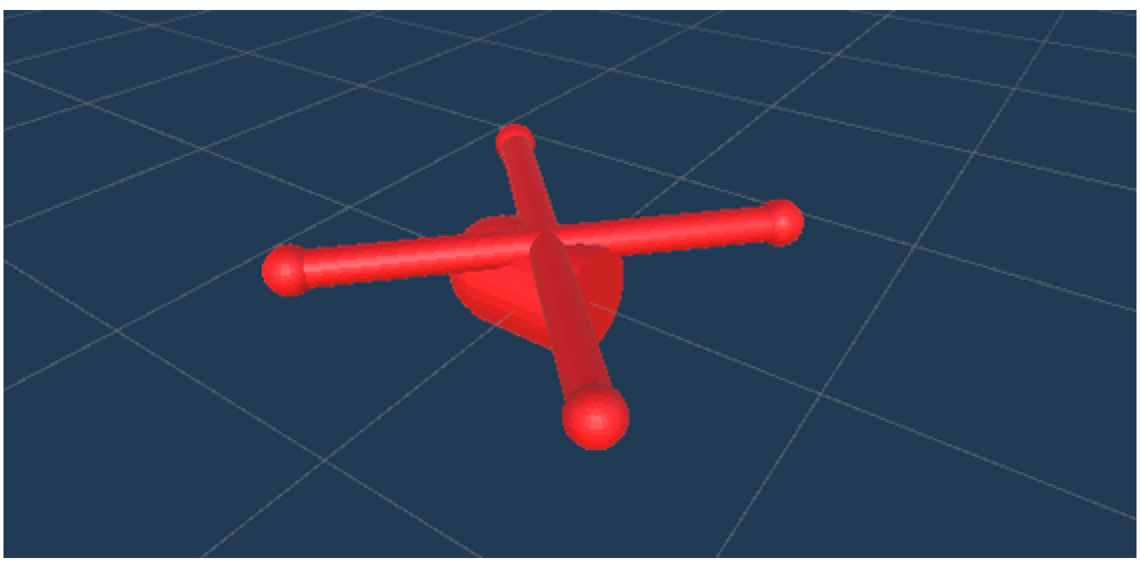


Figure 19 - Drone model from the previous project

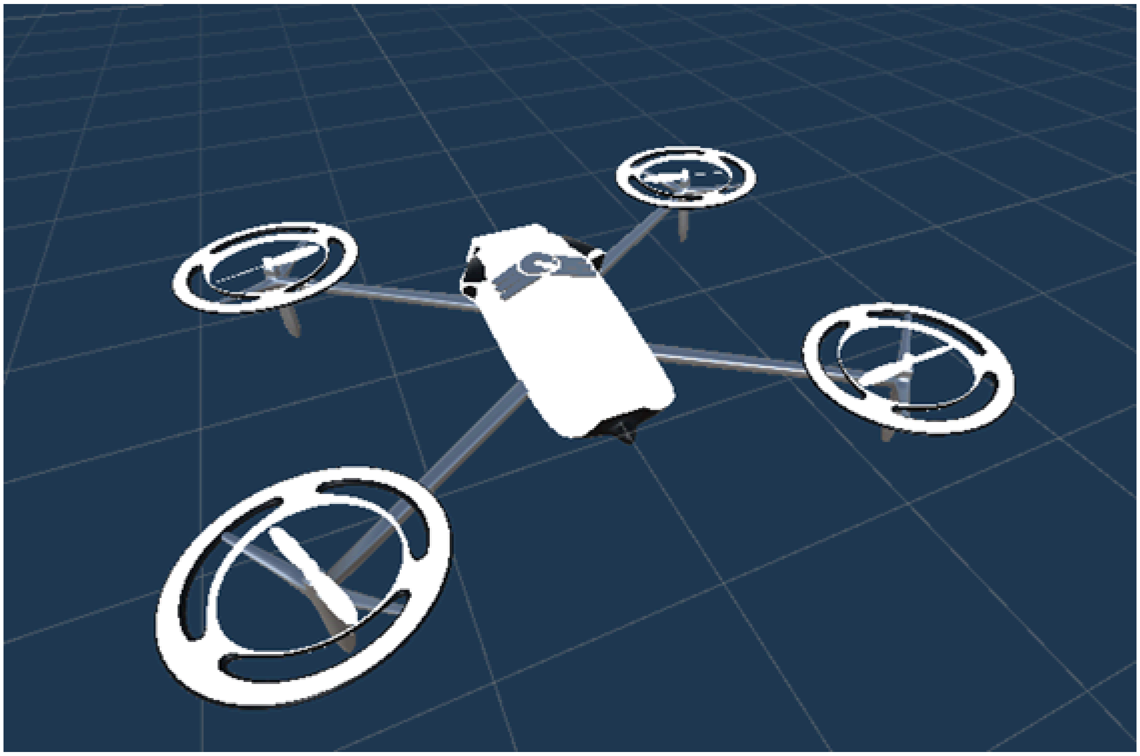


Figure 20 - Updated drone model used in this project

After changing the model of the drone to a more realistic version, a camera was also attached to the bottom of the drone as a child of the game object so that it would follow the drone around when the scene is played. This was added as most UAV drones have a camera attached to the belly of the drone that looks down at the ground. However, adding this second camera caused the problem of what camera would be used when playing the scene. Therefore, a C# script was added to the drone to be able to swap between the two cameras during the running of the scene offering two different camera angles. This script then allows the user to press the spacebar and the active camera would swap around to the other.

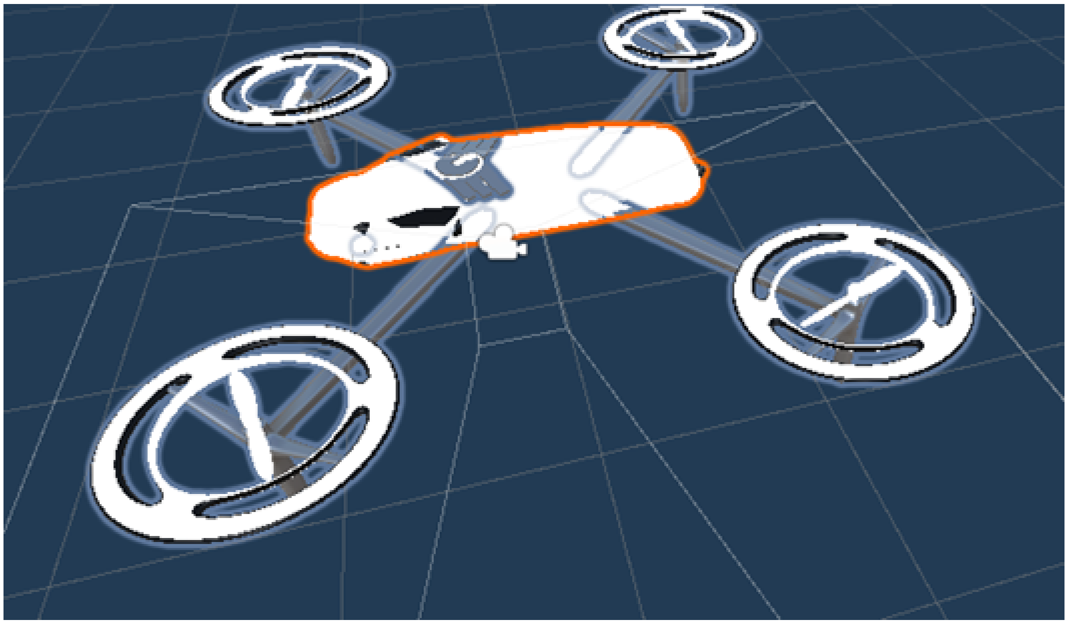


Figure 21 - Shows the addition of the secondary camera attached to the drone

A final addition to add more realism into the simulations was to change the other skyboxes for the different scenes to a more overcast and grey sky to give the simulation more of a darker atmosphere as that was one of the key details for the snowy and rainy conditions picked up on in the design stage. **Figure 22** is an example of what the skybox was changed to.

Figure 22 - Updated skybox for the rainy and snowy conditions

3.2.7 - UI

With limited time remaining to complete the project, the last thing that was done was the main menu screen shown in **Figure 23** which allows the user to select which weather condition they would like to simulate. Once one of these buttons are pressed, a C# script was added to using the Unity scene management system to switch between scenes. There is also an option for the user to simulate none of the weather conditions by pressing the Clear Skies button at the bottom.

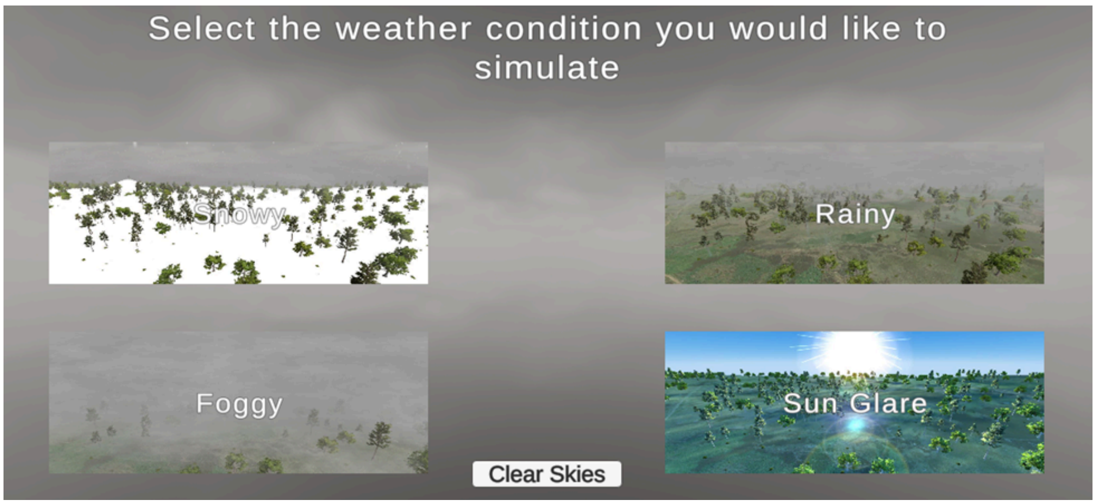


Figure 23 - The main menu screen

3.3 - Testing

Whilst developing the different weather conditions, on the spot tests were done when finding the right balance for the particle systems. These were done by running the simulation and finding where it could be improved by comparing the system to the real-life drone footage.

The main part of the testing was done once the different weather conditions had been completed. This involved using an fps counter whilst running the simulations to see if the frame rate can support the particle systems in place. Ideally, a well-built system will run at a frame rate of at least 60 frames per second (FPS), therefore this was the benchmark for the simulations described in the implementation stage. The results from the fps test are detailed in the following table, **Figure 24**.

	Foggy	Rainy	Snowy	Sunny
Minimum FPS	46	53	89	124
Maximum FPS	159	221	166	233
Average FPS	116	185	150	208

Figure 24 - Table containing the minimum, maximum and average FPS for each simulation

This FPS was calculated by using (1f / Time.unscaledDeltaTime) in a C# script.

Each of the four weather conditions were able to maintain a consistent frame rate that was able to surpass the benchmark of 60 FPS. This meant that the simulations were able to run smoothly without any frame lag or buffering. This is important as it gives the user a better system to work with that is more like the one that they would use in the field. However, the foggy simulation did have trouble occasionally with frame rate. From **Figure 24**, the minimum FPS measured in the foggy simulation was 46 which also led to some screen lag. This could be due to the amount of particles that are apparent in the scene. Decreasing this number would lead to the fog not being as thick which was one of the requirements for this simulation.

3.4 - Summary

Throughout this development cycle, work was completed in short sprints that was then reviewed and improved once a working prototype for each weather condition was completed. Each weather condition was first broken down into key details based off of real-life drone footage to get a good idea of what the requirements were for each.

Once this was done, the workload was split up into the individual conditions which were then worked on iteratively to produce a simulation. After each condition had been completed then there were added features that improved the realism of each simulation such as the vegetation and the different skyboxes. Finally, the last touch was to add a main menu to make it easier to navigate through the simulations.

To make sure the implementation was up to a good standard, an FPS test was carried out on each scene to make sure they were all able to run above a 60 FPS frame rate which they all succeeded.

4 - Results and Evaluation

The results and outputs for this project are explained in this section with evidence of the simulations running and an evaluation of each simulation's effectiveness. The measure for each simulation's effectiveness is a side-by-side comparison against the real-life drone footage that was gathered in the research stage of this project. Towards the end of this section, an evaluation of the development method and the key technologies used is described.

4.1 - Results

The results of this project are the four different simulations that were produced to replicate specified weather conditions of foggy, rainy, snowy and sunny conditions as stated in objective **4**. The output is the visual effects that occur when the simulations are run. As stated in the aim for this project, the goal was to create realistic visualisations of different weather conditions and see how this affects the vision from the drone. To decide whether the simulations have met the aim, side by side comparisons of the simulations and real-life drone footage have been made to find the difference between them.

4.1.1 - Foggy Conditions

Results

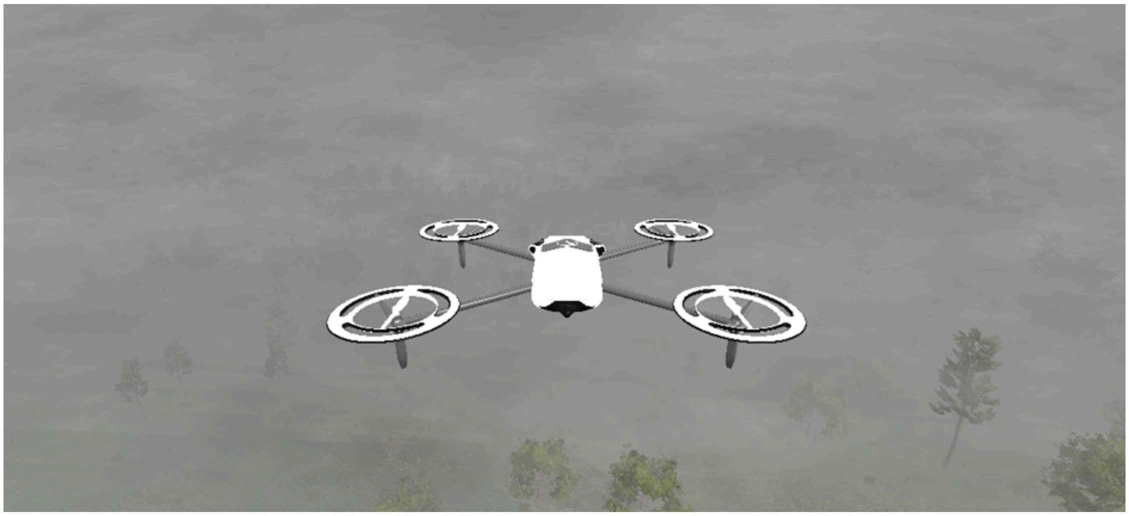


Figure 25 - Screenshot from foggy simulation

Figure 26 - Screenshot from real life footage in foggy conditions

[9]

Above is a comparison between the simulation output when it is run (**Figure 25**) and the real-life footage obtained in the research phase of this project (**Figure 26**). This comparison shows the similarity between the two images, for example the vegetation closer to the camera is much more visible than those further in the distance. It is still possible to see the ground in the simulation however it is much less visible than that of the real-life footage. This could be because of the different drone heights that the screenshots were taken or that the simulation has used too many clouds near the ground. With regards to visibility, it is difficult to see anything in these conditions shown by **Figure 26**. This is demonstrated well within the simulation as the only visible things appear to be the trees and the ground in a near vicinity to the drone itself.

Evaluation

The foggy simulation works well to visualise the conditions that would be experienced in real-life, shown by the comparison to the drone footage. Despite this, there is room for improvement, especially for the cloud texture as it appears to be more pixelated compared to the real-life footage. What works well though is that the clouds look to be thick making it difficult to see things in the background which was one of the key details picked up on that guided this specific implementation. This effect can be seen in real life meaning the simulation can be regarded as accurate in that sense. Overall, this simulation is a reasonable visualisation of a foggy scene that demonstrates the weather condition in an efficient way that is capable of running above 60 FPS. Although it is capable of running above 60 FPS, there are drops in framerate which causes some screen lag to appear due to the high number of particles that appear in the scene. This could be solved by slightly reducing the number of particles until the simulation can steadily run at 60 FPS.

4.1.2 - Rainy Conditions

Results

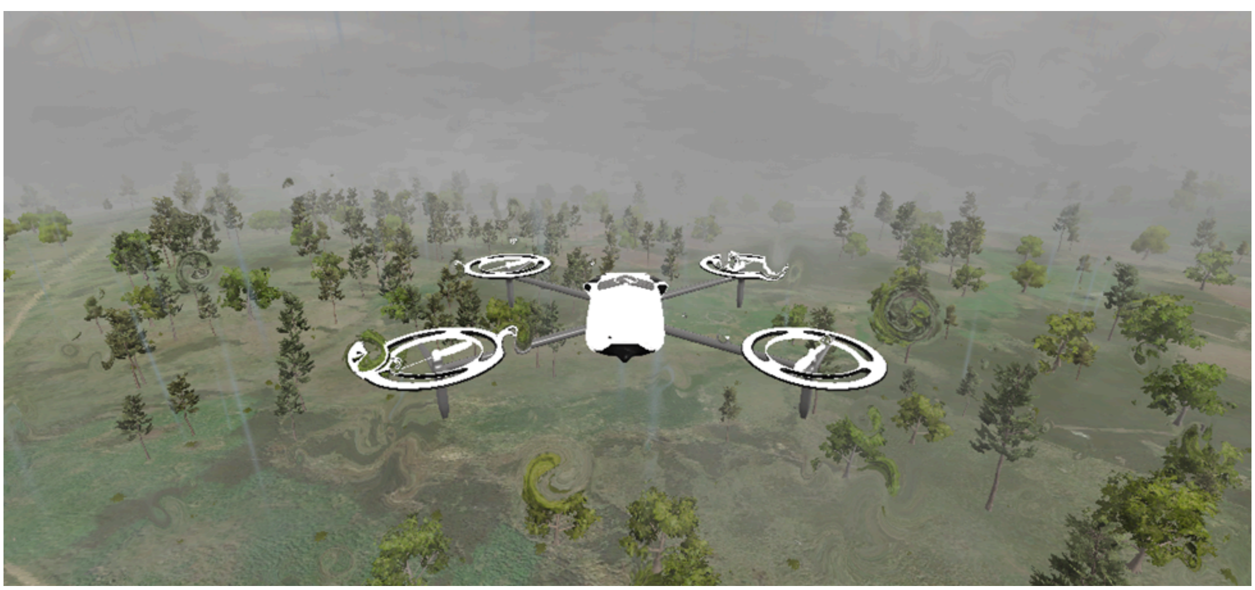


Figure 27 - Screenshot from rainy simulation

Figure 28 - Screenshot from real life footage in rainy conditions

[10]

In **Figure 28** It is difficult to see the rain from the screenshot as this is not the main aspect that affects the visibility of the scene. The main thing that reduces the visibility when raining is the grey clouds that appear. **Figure 27** shows there are grey clouds in the background that make it difficult to spot details from afar. There are also clear rain drops falling from the sky in the simulation which are easier to see than those from the real-life footage. This could be due to the colour of the simulation rain being a lighter blue or the fact they are bigger than those in the footage. Another key difference between the two images is that the simulation does have a drizzle effect on the camera lens whereas the real-life footage does not. This is because the drone camera in the footage is on the belly of the drone meaning no rain can touch it. This was added into the simulation due to this specific camera not being attached to the drone's belly. When using the camera attached to the drone in the simulation, the drizzle effect cannot be seen for this reason. This is evidenced below in **Figure 29**.

Figure 29 - Screenshot of secondary camera the simulations

Evaluation

Overall, this simulation feels like a good visualisation of rainy conditions but could be improved in certain areas like the raindrops being enhanced to look more realistic. The clouds resemble those that appear in the real-life footage which make this simulation effective as this is the main detail that affects the visibility in this situation. The drizzle effect was not as useful as first pictured since most drone cameras are located on the underside of the frame meaning that they are more likely not to see this effect take place. In terms of results, this particular simulation could be used to gain experience in these conditions as it is able to run smoothly at a frame rate higher than 60 FPS. However, changes could be made to make this feel more realistic to make the experience gained when using this more meaningful and applicable to real life.

4.1.3 - Snowy Conditions

Results

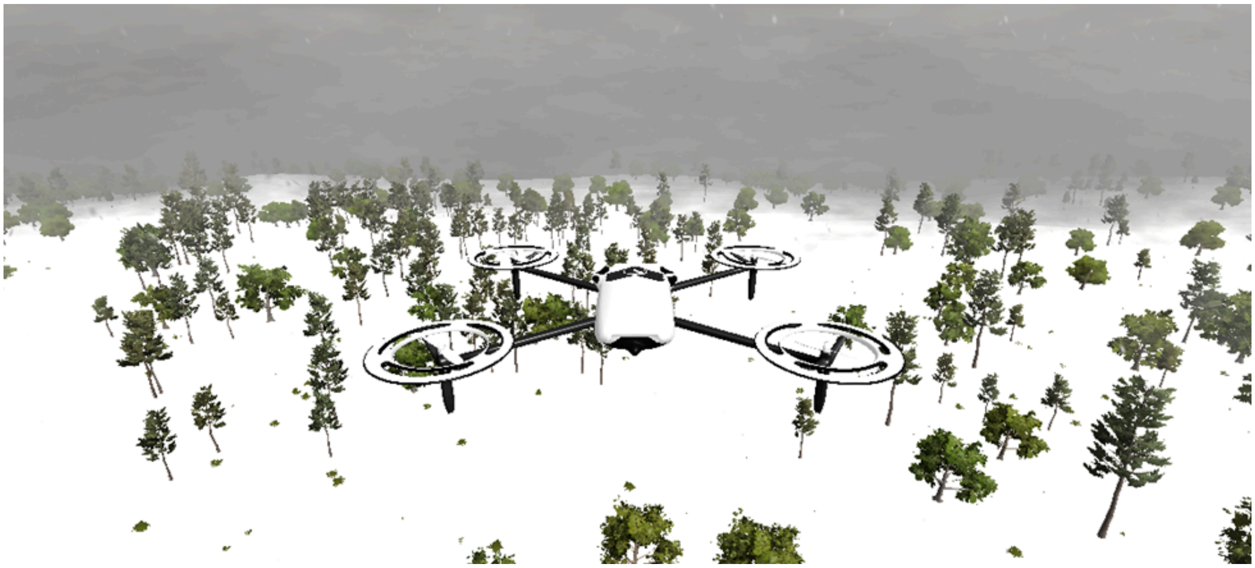


Figure 30 - Screenshot from snowy simulation

Figure 31 - Screenshot from real life footage in snowy conditions

[11]

Similar to the rain simulation, the snow falling from the sky is difficult to see in the real-life footage, however, this may be due to the overwhelming white colour from the snow on the ground. This is translated well into the simulation as the only snow that can be seen falling is when it is at the top of the screen in the grey clouds. As well as the snow, the clouds in the simulation are a suitable visualisation of what the clouds look like in real life. The main detail that would affect vision in this condition is the snowy detail on the ground. As shown in **Figure 30**, the ground is covered in a white material to replicate the snow-covered ground that you see in **Figure 31**. The main difference in the two images is the fact that the trees and other objects are covered in the snow in the footage but are still unchanged in the simulation. This is because when attempting to add collisions to the snow particles, the simulation would suffer dramatically with respect to FPS and would make the screen noticeably lag.

Evaluation

This could be considered an accurate representation of what flying a drone in snowy conditions is like. One thing that does hold the simulation back is the lack of snow detail on the trees and other vegetation. This detail was difficult to implement due to being unable to find an effective way that would not cause the frame rate to suffer therefore this feature was not added to the simulation. Despite this setback, the overall result of this simulation is a reasonably realistic visualisation of a snowy scene that could be used as intended, to provide experience of searching for people in conditions like this. As well as this, this simulation in particular is able to run at the benchmark frame rate of 60 FPS proving that it is an efficient attempt at replicating snowy conditions.

4.1.4 - Sunny Conditions

Results

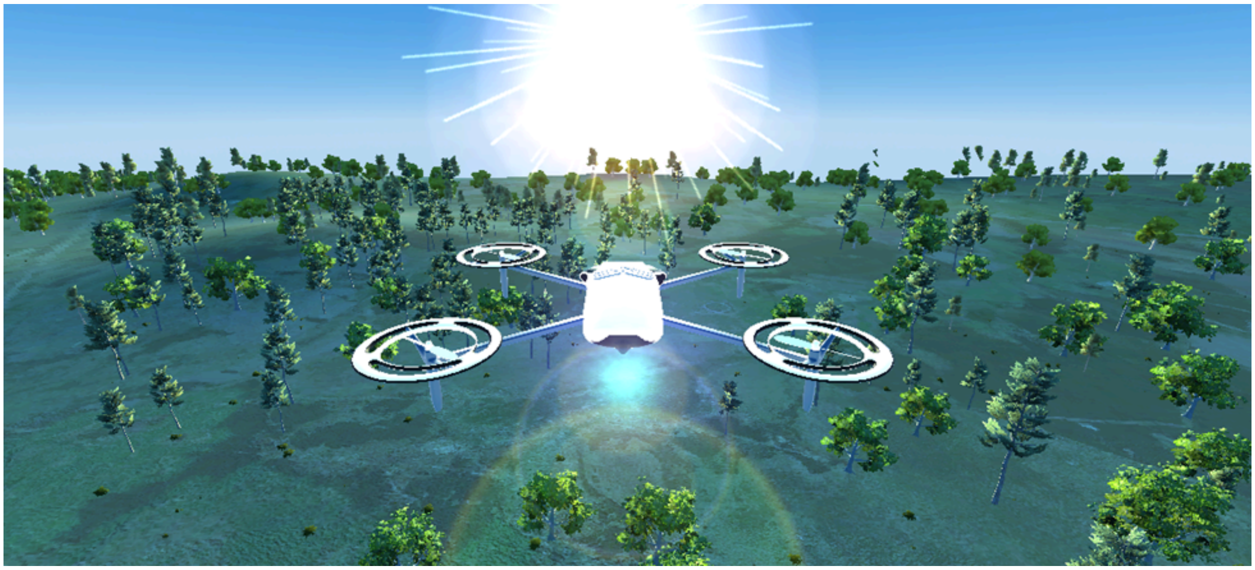


Figure 32 - Screenshot from sunny simulation

Figure 33 - Screenshot from real life footage in sunny conditions

[12]

The main feature of this weather condition is the fact that there is a lens glare when the camera is facing the sun. This was the one of the key details picked up on in the design phase and was the biggest factor in visibility for this condition. Therefore, when implementing, the lens glare had to be the main focus of the simulation. As you can see from **Figure 32**, the directional light has a lens flare that is picked up by the camera which is similar to the lens flare in the real-life footage in **Figure 33** as they both have the lines coming off the light. One thing that was added was the extra faint circles that can be seen in the simulation to amplify the effect to make it more difficult to see things. As well as the lens flare, the light intensity has been increased from the other simulations to make the scene brighter as the sun is shining on the ground. To further add to this effect, the skybox was changed to one that looked more like the sky in the drone footage to make the scene feel more realistic.

Evaluation

This was the easiest simulation to develop as there is not as much detail in the scene compared with the other three simulations. That being said, the sunny representation is a considerable attempt to match that of the real-life footage shown by the lens flare being similar. The lighting in the scene is a good demonstration of how light works in the real-life footage but could be improved to match the real-life aspects like how the trees have shadows and that some parts of the ground are brighter than others. Overall, the simulation is able to perform well without any dips in frame rate, keeping it above the benchmark of 60 FPS, and display suitable detail in comparison to the real-life details when flying a drone in sunny conditions.

4.2 - Evaluation of Method

The following is an evaluation of the key technologies used as a part of this project, going into detail as to whether they were good choices or not. Also in this section is an evaluation of the methodology described in the technical background chapter, explaining where it worked well and where it could be improved.

4.2.1 - Key Technologies

As described in the technical background section of this report, the Unity engine was utilised to develop the main part of this project alongside the use of Photoshop. This proved to be the right choice for this project as the necessary experience using Unity was already obtained before starting this project so using the software was comfortable. This meant that the development stage was a smoother process compared to if the Unreal engine was used to create the simulations due to familiarity.

However, when it came to using Photoshop, there was a struggle to become accustomed to the interface at first. Upon using the program more and becoming more familiar with the layout, designing the cloud texture became easier due to this growing familiarity. Being able to adapt quickly to this setback meant that the project was able to get back on track after spending more time than planned to produce the textures. Overall, the technologies used in this project were effective tools to produce the different simulations that run efficiently. With the experience gained whilst using these programs, future work in a similar field to this will be easier due to the skills developed while completing this project.

4.2.2 - Methodology

Before starting the development phase, it was decided that work would be done using an iterative approach with each iteration being a sprint as the work was easy to split into chunks. Sticking to this process during the course of the development phase proved to be a good way to get the necessary work done. This was because it allowed work on the individual weather conditions to be done separately meaning that the focus was on just one aspect of the final product at a time. Doing this made it easier to concentrate on the requirements for each simulation as there was no back and forth between the different weather conditions that could have caused confusion. One struggle of using this methodology was that there were points in the development cycle where too much time was being used on the same aspect. Because of this, the same details were repeatedly gone over, changing values by small amounts each time trying to find the right balance. This meant that more time was spent on some aspects than others that needed it. This could have been avoided with better planning and organising of time and resources.

Overall, this methodology was an efficient way of completing the work that this project entailed but could have benefitted from better planning to avoid spending too much time on changing small details. Better planning could involve setting time limits on each simulation and working in a round robin style to give each part of the system an equal allotment of time. With the experience gained from using this work methodology, adapting the plan next time will be easier in order to work more efficiently.

4.3 - Summary

The results from this project, the four simulations produced from the steps taken in chapter 3, are highlighted in this chapter, each with evaluations for each simulation based on the side-by-side comparisons that were made between the simulations and the real-life footage. These evaluations concluded that the results produced from this project were realistic attempts to recreate each weather condition. However, there are flaws in the simulations which are also described within the evaluation sections.

As well as the results from the project, this chapter also includes an evaluation of the methodology that was used to complete the work and the key technologies used throughout the project. It states that the key technologies were used to great effect and despite the lack of experience using Photoshop, the simulations were produced to a high quality given the time constraints.

The methodology used in this project was an iterative approach which proved to be effective when completing work for the project. Despite being an effective tool, it could be improved to prevent the available time being spent on small details. When completing a similar project to this one in the future, the experience gained whilst using this methodology will make adapting it easier. This is because the strengths and weaknesses of the method have become apparent while completing this project.

5 - Conclusion

To conclude this report, an evaluation of the project as a whole is given by going back to the aim and objectives and deciding whether they have been met. Additionally, an explanation of what has been learned and developed during the course of this project and what is able to be taken away as a result. Finally, some possible routes for future work have been included that describe where this project can be improved or modified to make it more effective as a search and rescue tool.

5.1 - Aim and Objectives

5.1.1 - Aim

The aim for this project was to:

To create a realistic visualisation of the effects of different weather conditions on the vision of a UAV drone when carrying out search and rescue across Northumberland national park.

Throughout the course of the project, this aim was kept in mind as this was what was strived for. This was a success as a visualisation of four different weather conditions has been produced and the effects they each have on vision have been demonstrated. Each of these weather simulations are unique and use the research done beforehand to guide the design of the scene. In terms of the impact that the weather conditions have on the vision of the drone, the system is a good demonstration of how this visibility is affected by poor weather conditions.

This project was done using a section of terrain from a place in Northumberland which satisfies the aim in that sense. This was included in the aim as the bulk of the research for this project was the Exercise Northumberland Report **[2]**, which took place across the section of terrain near a town called Edlingham and was implemented within the previous project **[3]** that was then built off of to form this project. From the beginning of this project, the motivation was to provide experience to trainee drone pilots across the Northumberland Search and Rescue team which is why the terrain of Edlingham was used.

Whether the simulations are realistic is hard to fully determine, however the simulations produced by this project are good attempts at achieving realism. This is because there is a strong resemblance between each weather condition and the corresponding drone footage. The different weather simulations were not the only efforts in achieving realism as other features were included to come closer to this goal. Such features included adding vegetation to the scene like trees to make the simulations feel more like the real world. Not only was vegetation added, but the model of the drone was also changed to one that is more likely seen in the real world compared to the previous model that was left by the previous student. All these additions helped take strides towards making the visualisation more realistic to make the user experience more genuine.

Regarding the visualisation system as a whole, the aim has been met since the simulations are able to run above 60 FPS without any screen lag. This was important as the system needs to be able to run smoothly and without crashes to get full use of the experience. According to the official HP website, games are played best when running at 60 FPS **[13]**, meaning that this should be aimed for when developing games or visualisations in this case. Hence why 60 FPS was the benchmark used when testing the simulations individually.

5.1.2 - Objectives

At the beginning of this project, the aim was broken down into six objectives that would help guide the project to completion. It acted like a checklist to determine whether the work had been done and help track the progress of the project. There was little deviation from the original objectives throughout this project as they satisfied the aim well enough to make sure that the aim was met. Below are the objectives along with an evaluation for each detailing whether the objective was met and how well it went.

1. **Read exercise Northumberland paper from 2017 and a previous dissertation in a similar field then summarise key findings.**

   This objective was included to make sure that the appropriate research was done before the project. Doing this assisted the production of the simulations. For this reason, meeting objective 1 was important as it was the main knowledge base for this project. This was done effectively because while reading both papers, notes were taken to then use as a reference when doing any project work, especially the previous dissertation. This paper was the most important in this regard as it described the previous visualisation that was then built on for this project.

2. **Gather footage of real-life examples of drones in different weather conditions.**

   Meeting this objective was an equally important stage of the project as a whole due to the fact that the weather simulations that were produced were compared to these examples of real-life footage. This was to determine whether these simulations were realistic which was needed to satisfy the aim of the project. As seen in the results chapter, the real-life images used in the comparisons were from the footage gathered to meet this specific objective. Finding the footage was done by searching on YouTube to find suitable videos of drones flying in the four different weather conditions. This method of finding the videos proved to be an efficient way but creating original drone footage could have been more reliable than searching the Internet as there is no chance of the video being edited.

3. **Implement a copy of a section of terrain from Northumberland with realistic vegetation to make the visualisation more accurate.**

Objective 3 involved the part of the aim to provide a system for Northumberland Search and Rescue to use for experience in these weather conditions. In that sense, this objective was met as a section of Northumberland terrain was implemented which was left over from the last project in this field. However, this project added vegetation to the previous terrain using the Unity terrain tool and the standard asset pack from Unity. Trees and bushes were painted onto the terrain to make the simulations more realistic therefore meeting this objective. Meeting this objective was done effectively as suitable vegetation was included that improved the accuracy of the visualisation. However, there is room for improvement regarding the trees and bushes used in the simulations could be upgraded to look more realistic.

4. **Implement four different weather conditions, raining, foggy, snowing and sunny.**

   Satisfying this objective was the most important part of meeting the aim due to the fact this was what the project was mainly about. The process of meeting objective 4 is described in chapter 3 which shows the steps taken in order to fulfil this part of the aim. The work done to reach this checkpoint relied on an effective plan to complete all four of the weather conditions stated in the objective, however, the plan used to execute this implementation was not as effective as predicted. Despite the flaws in the plan, it was still a useful tool that was used to complete the necessary work to meet this objective. With a more efficient plan, another weather condition could have been added to give the user a wider experience of different conditions.

5. **Simulate the drone's vision in each weather condition and record how easy it is to see objects.**

   Upon reaching this stage in the project, the original objective 5, shown above, was realised to be too vague in the way it does not describe what should be recorded or measured. This led to the more appropriate change shown below in bold of the original objective to one that was less ambiguous.

   Simulate the drone's vision in each weather condition and record the frame rate of each simulation.

Recording the frame rate of each simulation was needed to determine whether the system would run smoothly which is needed for a good visualisation. This was also a much easier measurement to take than how easy it is to see objects because it would not be affected by who was recording the result whereas visibility is relative. This new objective was then met after running the simulations with an FPS counter that produced the outputs used to compare against the real-life footage.

6. **Analyse the results of the UAVs vision and compare the different simulations to real life drone footage for each weather condition.**

   As described in chapter 4, Results and Evaluation, this final objective was met using real life footage to draw comparisons to the simulations that were created during this project. This signalled the end of the project and that the aim had been fully satisfied.

Overall, the project was a success because, as stated before, the aim had been achieved and all the objectives were met. This does not mean that the project was perfectly done though, despite the fact that the aim had been met, there is room for improvement to make the simulations more realistic. On the other hand, what was done well during this project is that a reasonably accurate attempt at recreating these four weather conditions was produced that is able to run smoothly and without any screen lag. Further details on how this project can be improved are given below in the Future Work section.

5.2 - What I have Learned

Over the course of this research project, I have gained valuable experience in lots of different areas. One of these areas is research and how to research well, which I believe I was able to do effectively to find important sources. I feel that without this, the rest of the project would have been near impossible to complete, making it such a valuable skill to have gained from this.

Another area in which I have been able to improve are my skills using Unity, specifically the particle system. This was the main tool used to complete this project and during the course of this project I was able to build on my previous experience to now feel confident when using the tool. I also feel more confident using Unity as a whole after using the tool so often whilst completing this project, I became more familiar with the layout and tools that are available.

As well as building on experience that I already had, this project also introduced me to a new skill, Photoshop. Before starting this project, I had never touched an image editing program so when I needed to create the cloud texture, I struggled at first to get to grips with using Photoshop. Now that the project has been completed, I feel a bit more confident using an image editing program to create textures, but I could still do with more experience using this to be more competent.

5.3 - Future Work

Described below is some future work that could be done to add to what has been done in this project to make it a more effective tool at providing experience in different weather conditions.

Textures

To achieve more realistic versions of these simulations, additional textures could be created to take the place of the standard Unity particle to make the snowy and rainy simulations appear more like the real-life footage. The cloud texture used in this project could also be updated by someone who has more experience in Photoshop than me so that the cloud particle systems are enhanced. As well as all of this, the snowy simulation can be improved to look like the snow slowly settles on the ground and the vegetation.

Vegetation

Better versions of trees and bushes could be used effectively to replace the ones in this project to make it achieve realism. This could mean designing new vegetation assets or finding more enhanced versions to use rather than the ones provided with the Unity standard assets pack. They could also be placed in a more systematic manner than the ones in this project as they were painted onto the terrain in a randomised fashion.

Drone Movement

The system produced does not allow the user to have input into the movement of the drone which is also a big part of the training process for new drone pilots. This feature could be added to make the system more useful during the training phase as this is an important skill when utilising UAV drones. This could involve using a remote to move the drone around and include physics of the wind for example as this would affect the drone’s movement in real-life.

VR

A Virtual Reality version of this project could be released to provide more immersion into the simulation. This could lead to the experience gained using this system to be more useful if the system feels like real life. This could be done as Unity does support VR and allows developers to create VR scenes within the program.

5.4 - Summary

To sum up and conclude this project, the aim is looked back on to consider whether the project has been a success or not. The overall statement is that the project was a success as the aim was met which is explained within this section. The original objectives are also reflected on to measure the success of the project and decide whether the aim was met or not. A modified objective **5** is also stated with the rationale behind making the change. Because all of the objectives were met, it was then concrete that the original aim had been met as the objectives were an indicator as to whether it had or not.

A section on what was learned throughout the course of this project is included with the key developments being research skills, improving Unity development skills and learning Photoshop.

Finally, a description of any future work that can be done with this project to make it a more effective tool for search and rescue drone pilots. This possible future work includes enhancing the cloud texture or adding new textures for the rain and snow. Making the vegetation appear more realistic is another avenue that could be explored to add to this project. Adding drone movement into this system could also be a next step to make the simulation more immersive. Another way of achieving immersion could be to create a virtual reality version of the simulations.

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