Computing the NDVI of Classified Trees

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Abstract

Rapid expansion in efforts to stop the deforestation of our planet has led to an increase in the information gathered about the forest so that we can better understand their needs. In this research project I aim to create a robot for estimate the number of trees inside a forest and the stress levels that are affecting these trees. These stress levels have been heightened with an influx of human activity to previously untouched forest areas. The Robot will map such stress levels on a visual display on so that a heat signature shows the area of concern in an area to help show a correlation that is not able to be pictures but by a human working to collect data through the forest.

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1 Introduction

The forestry profession has been a steady decline since the 1980s leading to a reduced workforce[1] in the forestry field and with Europe being affected by upwards of 65,000 fires a year[2] this means that there is a need for a more efficient way to prevent the spread of wildfires.The less dried vegetation there is for the fire to use a fuel the less spread will occur

Spot Fire are started by the collation and release of burning particles that have been created by vegetation present in the forest. The plumes of smoke lead to the spreading of burning particles[3]. This causes burning and smoldering particles to land on vegetation on the ground. If this vegetation is Dead it means that there is a high chance that it will catch fire. The particles can spread to the canopy of the trees that may have died or are deceased.governments need to look to other alternative to prevent the spread of wildfire this is where robot can be used to fill the gap left behind by the shrinking forestry work force.[1] Robots are viable alternative to best mitigate the issues.

Active crown fires[3] are created by wildfires crossing from one tree to another both on the ground and through the canopy of a tree. This type of Wildfire is very hard to contain and the spread of the fire is considerable. One of the main factors that effects a crown fire is the moisture levels within a forest.

This paper will look a tree classification and computing the Normalized Difference Vegetation Index (NDVI)[4] readings of vegetation to better understand what type of vegetation is present and how using the data industry professionals can better predict and adapt forestry practises to lower wildfire damage caused by diseased or dying vegetation creating a platform to spread wildfires. NDVI is an index calculated of the difference between near infrared and red light index. Chlorophyll which in vegetation reflects near infrared and absorbs red and blue light[5]. The report is as follows: Chapter 2 discusses the solutions that are already being used and the reasons for choosing specific components for the project and how they could better previous research into mitigating the spread of wildfires. Providing background information that will be beneficial later on in the project.

Chapter 3 discusses the new ideas project Aims. Looking at information gained from chapter one and how it can be used to further develop the solutions that have been discussed. This section will discuss the timing of the project and how the time scales will fit together to be able to finish the project on time.

Chapter 4 discusses the components needed for the project and how they will be used, looking at the software and hardware as how they were used to create an overall solution. Discussing the aims of the project and how they work towards the desired outcome.

Chapter 5 discusses the results found from the implementation looking at what the results mean and if the results have come out as expected. Afterwards, the results are checked against results from other research to check if the data that the project has collected is advantageous for helping to mitigate the spread of wildfires. Discussing the limitations of the research and what could be changed to gain better results.

Chapter 6 discusses the conclusion of the project. what went well on the project and things that could have been improved including technique drawbacks, any issues that were found whilst collecting resources for the project. This section also discuss how the project overcame difficulties and how creating solutions impacted the project.

2 Literature Review

2.1 Mobile robotics

2.1.1 Aerial Robots

The use of Unmanned Aerial Vehicles (UAV) has been widely used in fields such as emergency response, military and research. The landscape after a natural disaster such as a hurricane or a flood can mean that there is limited access to areas where people could be trapped. With the use of UAVs it allows exploration meaning research and rescue team can survey a larger area giving themselves a better chance of being able to save lives [6].

Drones are often deployed to undertake these tasks using SWARM tactics, SWARM [7] tactics increase the amount of information detected because they are able to work together to make decisions. Swarming UAVs are able to search a much larger area together because their line of sight is much further meaning in a natural disaster [6] they are able to identify signs of life a lot sooner.

2.1.2 Aquatic Robots

The use of Aquatic robots is increasing because the the ability to use them in application that until now would of need a large amount of man power. The use of lake learning robots is a useful implementation of robotics because lack of efficient practises. For a private lake to be cleaned they need to be drained which is costly and for public or large lakes the proccess of leaning can cost even more [8]. With a robot it can be left to navigate the water and clean as it goes travels. The efficiency is increased because unlike a manned workforce the robot does not need to stop until it's battery is low. A normal workforce would only work a set number of hours a day creating times of little activity [9].

2.1.3 Terrestrial Robots

Terrestrial robots provide the desirable flexibility for installing multiple sensors (multi-/hyper-spectral, thermal and stereo cameras) and actuators. These should be used to increase the understanding of the environment around the forest. The use on the infrared camera means there is the ability to understand the presence of water inside of the vegetation this will increase the understanding of the robot as to what is facilitating the forest fires..At present, the robot only understands what needs to be removed autonomously by using artificial perception.With the ability to be able to sense water this means you are able to identify many general areas of vegetation because of trying to identify specific types of trees you are able to purely identify the health state of plants [10]. The use of terrestrial robots improves the readings of the position trees when compared with drones readings [11]. Depth cameras installed on land robots can be use to locate trees (using the angle and the depth of the tree). UAVs would not be able to accurately plot the location of trees and canopy cover leading to a more accurate representation of information.

With a terrestrial robot, users are able to gain AI information on the truck of the tree meaning you are able to make correlation from the trunk as to the canopy that is going to be present on the top of the tree. This is important in farming/forestry applications as particular tree species have different canopy structures at different times of the year.[12] For example, when specific species of the tree go into hibernation they lose their leaves. This means that if this not accounted for. It means that false reading as to the health of specific trees can lead to wrong information being collected and when the information is directly helping to prevent life lost it is imperative that the information collected is as accurate as possible.

2.1.4 Agriculture and Forestry robots

With the decrease in the number of people enrolling in the forestry profession [1] there has been ever rising need for other methods of completing labour intensive jobs [13] such as clearing forests. Robots have become an emerging option in recent years as a way of helping forestry experts to continue to maintain forests whilst still sustaining lower employment rates.

Robots often used to undertake tasks that could be hazardous for a normal forestry professional to undertake. This means they can be sent into high risk areas with less risk to life [13].

The use of robot in surveying has lead to a large increase in data that is being collected because robot are able to undertake multiple task that could take a team of professionals considerably more time to undertake than a robot [14].

Figure 1: Tree Monitoring Drone

2.1.5 Robotics and Artificial Intelligence

Artificial intelligence (AI) is a form of intelligence that is closely linked to that of human thought. AI can be implemented into almost everything from au-

tonomous driving to facial recognition and can be used to design smarter robots capable of perform complex tasks [15]. AI can be used for:

1. Planning

   - The ability to be able to understand the outcome and plan a route to be able to create the desired outcome. An example of this could be mapping software that has been trained from previous routes that a person has travelled with the purpose of creating dynamic routes for unmapped pathways [15].

2. Reasoning

   - The ability to be able to understand why a situation is occurring. For example, an AI model could be made to understand how climate conditions change plant growth of specimens in real-world scenarios [15].

3. Problem Solving

   - The ability to be able to look at a problem and understand how to solve it. This type of AI uses representation to understand what is happening. The graph below shows how AI is given a problem and then runs its model to try and create the problem outcome. From this, it can then compute the steps that can then be taken to solve the problem [15].
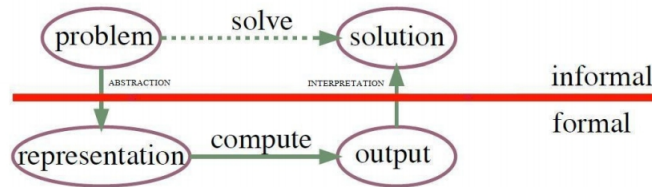
Figure 2: Problem Solving Diagram

4. Representation

   - The ability to be able to look at a particular situation and be able to mimic what is going on. An example of this could be crash test programs used by car companies. Using a program to crash test cars is much more efficient than using a real car and with the correct inputs put into a program the AI would be able to produce an accurate outcome that mimics that of the real-life situation [15].

5. Perception

- The ability to understand what is happening in a specific situation. This is used by car companies to understand the driver of a car. This means using a camera they are able to understand if a driver is falling asleep at the wheel. Meaning it is able to perceive the tiredness of a driver [15].

2.1.6 The Impact of Artificial Intelligence

Artificial intelligence has impacted the way humans live their day to day lives. It has increased the level of productivity for industries that previously were heavily reliant on man power [13]. This has lead to huge government investment in AI infrastructure in multiple different discipline because of the positive impact that AI can have on public sectors such as self driving buses and increases in efficiency in the health care sector. Increases in performance of machine learning has lead to AI in many fields where it wouldn't have previously been possible to use [16].

The increase productivity creates a financial advantage for companies as the cost of implementing AI is decreasing as it become more readily available. Google, Microsoft, Apple, Amazon, IBM, Yahoo, Facebook, and Twitter made 26 acquisitions of new AI related companies [16]. In 2014 Google acquired DeepMind [16] who are a deep learning start up based in London that has been developing AI technology that is able to learn using cumulative rewards meaning the technology is able to apply a basic set of rules to create a knowledge about a specific subject and continuously learn. This is able to do with whilst also exceeding Human level performance leading, this was demonstrated by defeating the world champion at GO game[16].

2.1.7 Pipe Inspection Robots

Pipe inspection robots will be deployed to inspect and repair water pipes. These robots will be able to be left with the ability to be self sufficient. This is achievable with the ability to use the flowing water of the water pipe to create energy so the robot does not need to resurface. It will use algorithms to be able to detect using AI crack and blockages in pipes and repair them without the need for human intervention. This decreasing the need for human labour in pipe maintenance and increases the information professional can collect on the health of water networks [17].

2.1.8 Autonomous Bridge Repair

With the use of AI Autonomous Robots will be able to repair bridges without the need for them to be closed down creating disruption for local road networks. Databases of 3D models [17] will be stored in the cloud and accessible by these robots so they can analyze the bridge to check that it matches up to the 3d model on the database. The application of the robot could be on-the-fly meaning that it continuously checks the bridge for issues and planned checks for routine maintenance that a normal professional would normally undertake.Using this

type of robot increases efficiency levels because of the risk to life that is a occupational hazard of working on bridges and with the use of this robot there is a decrease in risk to life [17].

2.1.9 SEMFIRE project

SEMFIRE project [2] is a project looking at implementing a network of robots to help reduce the number of combustible materials in forests. Reducing the amount of combustible material in a forest environment means there is less chance of forest fire. Forest fires have a large knock-on effect for local areas including but not limited to a substantial decrease in tourism leading to an increase in local unemployment. The robots used in SEMFIRE [2] are working together to identify and eradicate high-risk areas by surveying the landscape and removing high-risk material. There are two robots used in the process. The Ranger which is a large robotic mulcher [2] and a surveillance drone. The job of the scout is to explore wildfire areas. The drone achieves this by using SWARM tactics which involve using multiple scout robots to great create a map of the surrounding areas for the Ranger to either work autonomously or semi-autonomously with the use of a human operator. The purpose of the Ranger is to remove the combustible material, this is achieved with the use of artificial perception identifying offending materials and extracting them [2].

Issues with the use of a drone in A monitoring role are that they have a short battery life due to the need for light batteries to decrease the weight. This means an increase in the number of scouts is necessary to facilitate the time needed to charge scouts. The use of charging station to facilitate the 4-hour charge capability means the scout robots are limiting the range of the infrastructure because these charging stations[2] will need to have a power supply meaning the availability deep in forest environments will be lacking. The scouts will have to accommodate for the lack of battery capacity with the use of land robots there is less need to accommodate lighter batteries leading to an increase in battery life. Leading to less time needed spent charging increasing the amount of time used to explore areas of forest.

The use of land robots would mean that SEMFIRE [2] would be able to explore underneath the canopy of the forest. This increases information gathered as the scout drone will have the view of its camera obstructed by the canopy. This increases time spent unable to survey what the Ranger robot is doing, this decreases the amount of information available to the ranger operator on the surrounding area. The amount of information that the ranger will know before deployments will be limited.

The SEMFIRE [2] project states that the information that it provides is stored in a local database but there is no information regarding any graphical information. SEMFIRE [2] states that the users of these robots will be local authorities and councils. This means that unlike Robotics companies there will be limited knowledge of the information provided.

The main issue that faces tech companies when working with local councils is the statistical language barrier. The need for local councils to understand

the impact a project such as SEMFIRE [2] could make to mitigate the impact of forest fires there needs to be a way to show the information in a way that is user-friendly so that it is inclusive the everyone.

Using graphical interfaces make information simple using defining factors to determine different values such as trees and the value of water presence make it a lot simpler for people to understand the information being provided.

The ability to communicate increases the further development of ideas inside of the industry and with the lack of graphical interface this means that only specialist users that are trained on the network are able to understand the information.
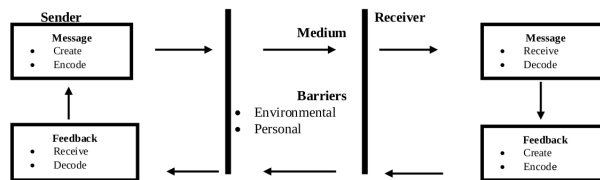
Figure 3: User Interface Diagram

If the user can decode information in a way that communicates the information well then the user can then bring in other professionals such Forestry consultants that can then give a more in-depth understanding of the issues that the forest is facing.

Figure 3 shows that it is necessary to implement a level of encoding when displaying information to a user. It involves encoding the message into a format that to more widely understood. There are multiple ways in which information can be encoding.

Heatmaps are graphical representations of data where the value of the data being represented is stored in a matrix that is represented as colors. Often for visualising areas of interest heatmaps are used and can be used to implement a level of understanding of the extent of an issue. Finding similarities between industries is important when visualising information and heatmaps works on a very cross-discipline using red for areas of high interest and green for areas of low interest. At present in SEMFIRE there is no way for the operator to purposely show the level of water presences of areas of the forest.

2.2   Neural Networks

2.2.1   Perceptron

Perceptrons are algorithms used for supervised learning of binary classifiers. Binary classifiers are function that are able to decide what class a input stream belongs to this is represented by a vector of numbers. These function completely depend on the framework that the preceptrons have been trained for example if the perceptrons are classifying animal there could be a number of classes including size of animal and tail size [16].

2.2.2 Convolutional Neural Network (CNN)

Convolutional Neural networks use Convolution filters to preform complex operations. They use data specific kernels that are represented by locally connected neurons. there is an input layer and an output layer with a hidden layer. The hidden layer can be multiple layers and using a mathematical equation specific to the framework. The idea of Convolutional Neural Networks is that it simulates the actions of the human visual cortex [16].

2.2.3 Recurrent Neural Nets (RNN)

RNN has hidden units in memory that hidden units that can analyze data streams as input and convert those streams into specific output streams, this could be a language translator or speech recognition software that can translate sound into type text [16]. Neural Networks are multiple layer principle whilst the layers themselves and the decisions they make are often too abstract for humans to understand. The way in which the Neural Networks learns to predict an outcome works the same way as a human.

2.2.4 You Only Look Once(YOLO)

YOLO is a object detection system specifically made for real time processing. This means that it is design to work frame by frame detecting objects that are present in the video. Once YOLO has identified a object it gives a probability value for that object this is usually in the form of a decimal such as 0.79. This corresponds to it being a 79 percent chance of it being the classified object.[18] Once this value is attained it then gives you the region of interest of the classified object. this is the area that can be used to do calculations on.

The project will be using the latest version of YOLO, "YOLOV3" to identify the trees in real time, with the trees being identified in real time it means that calculations that are needed can be done can be preformed on the fly with the information that yolo produces [18].

2.2.5 Object recognition

Using Artificial Intelligence to be able to further identify the species of trees means that the operator will be able to collect information on the characteristic of trees, bushes and other relevant visual information. For example, eucalyptus trees have bark that often splits, this bark then drys on the ground. This then becomes flammable and can cause wildfires [2]. With the use of Tree recognition, it means that the operator would be able to log areas of increased levels of this bark leading to an increase in efficiency when trying to clear the flammable vegetation. Failure to notices vegetation such as dried eucalyptus bark leads to an increased chance of wildfires [19]. Using AI to mitigate this factor means that the robot would be able to autonomously recognise these sign without the need for an operator meaning the robot can be left to survey the areas without the need for human intervention. The local council can then act of the scout and

ranger saving the council time and money sending train professionals into the forest to survey the area[20]. The AI would need to be trained on the species of

Figure 4: Tree Recognition

the trees that are present in the forest. This would involve the council having to process images for the AI to learn from and create an AI model that the robot would be able to understand and use it to check if a tree is present.

If a robot is able to identify trees and vegetation this means it can run check the trees for signs of disease If implemented in applications as in SEMFIRE [2] it would mean the robot would be able to understand if a tree is dead or alive[4] meaning it can mitigate the risk of if it is causing a threat to the forest.

2.2.6 Water Detection Using NDVI

Plants using photosynthesis Active radiation as a source of energy in the process of photosynthesis. Healthy vegetation will absorb most of the visual sunlight for the photosynthesis process. Because unhealthy plants have a much lighter colour it means they reflect more visible light [4].

The Near Infrared and red are the satellite bands that are the most reactive to, therefore, they will be the best representation of the amount of live vegetation that is present in a region.

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

where NDVI is the normalized difference vegetation index, the NIR is the Near Infrared image (750 nm) and the RED is the RED channel. Using equation 1 takes into consideration different parts of a region of interest could have multiple values meaning that dividing the diving the sum of the reflectances [4] gives an average number that accounts for these differences. This is necessary because

brighter pixels in the image would have larger values and would have larger differences between bands.[4]

$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$
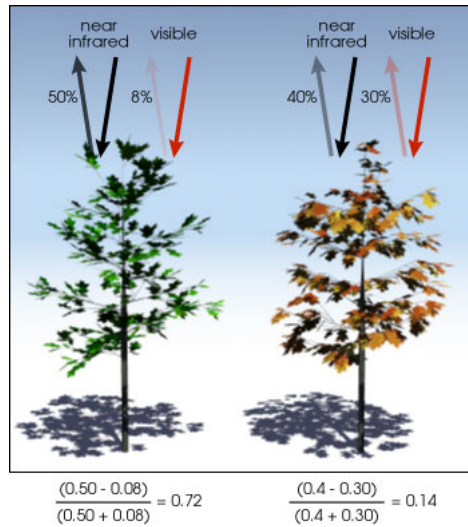
Figure 5: Example of the NDVI results [5]

Including information on the water presence in the forest itself will give the robot operator a much better perception of the times of the year when the deployment of the SEMFIRE[2] network will be most affected as you can look at trends of Water presence against that of forest fire reports to understand when is the best time to send out a Ranger robot for the best results The accurate prediction of forest fires and the way in which they spread is a critical necessity to mitigate the effect of forest fires as effectively as possible. With the information gathered from the presence of water and knowledge of other factors such as wind speed that can also affect the spread of forest fires [2].

Managing Weeds in a Cherry Orchard - In Chile they are using NDVI with drones to identify weeds in a field of cherry trees as an efficient way of getting rid of letting the farmers know where they need to spread weed killer to get the most efficient effects. This works by identifying irregular NDVI reading across the cherry field. Once the weedkiller was given time to take effect they were then able to take a second view of the the same field and found the reading showed the only vegetation in the field was that of the cherry trees themselves [21].

Checking optimum Harvesting times for cherry trees In this case study, they used NDVI to provide them with optimal time to harvest cherries. This worked on testing the correlation between the change in pigment and the level the NDVI was producing. The computation of the NDVI enables to infer the levels of maturity in fruit by checking the levels of chlorophyll in fruits from 0.4 relative units in the fruits to +0.5 in overripe fruits [22].

Similar approach can be applied to projects similar to SEMFIRE.

3 New Ideas

3.1 Big data analysis

Data is the main way that local councils can prevent the creation and spread of wildfires. With extended knowledge, they will be able to facilitate more in-depth analysis of areas of interest within the forest with the intentions of reducing the impact of wildfires.

3.1.1 Tree Classification

Tree classification is necessary for the project to get information on the Tree in the forest and the canopy that needs to be scanned. This can be done using an YOLO that can be trained on the different types of species of tree that are found in the forest.This could improve classification of plant life that could cause wildfire and decrease the risk of false reading that could damage a forests own eco-system.

3.1.2 Artificial Intelligence

The use of YOLO for processing the captured visual data enables users to process live capture feeds or pre-recorded visual data from the forest. This means robot operators are able to record the footage they are streaming and analysis it after or can keep it as a record for future review.

3.1.3 Tree Positioning

Using the newly created AI model that is able to classify the truck of the tree the robot can use depth data of the tree and the angle in relation to the robot to geolocalise the tree. The same visual information can be used for planning forest interventions (e.g. keep a safe distance between trees and remove the others).

3.1.4 Water Detection

Retrieving the water retention levels for the canopy is useful for infer the health status of the plan and the fire risk. This information can also be used when trees need to be removed as consequence of high density of trees in not planned forests.

3.1.5 Regions of Interest

When taking the reading of water detection. To get the most accurate reading there needs to be a region of interest using the output of the YOLO classification (i.e. the NDVI is computed from the area classified as canopy).

3.2 Graphical User

In the literature review, it stated that decoding information in a visual format was a solution to showing information to team members that may not have the necessary expertise to understand the raw data collected from the robot. With the use of a graphical interface this will make it possible to highlight areas of interest in a understandable format.

3.2.1 Markers

The use of Markers could be used to identify the location of the tree. An example of this is using a tree icon for the marker so that the user is able to locate trees and get a layout of the area. Therefore if there is a number of trees all in one area with diseased NDVI readings then knowing where they are positioned means the robot operator can remove them efficiently. This makes it a lot more understandable to less technical team members the problem areas of the forest that need the attention of the robot. This make it more understandable to team members where

3.2.2 Heat Maps

The use of heat maps for the graphical interface mean that trends of disease can be better manages because the more recording of diseased vegetation in one area. This helps local councils to better locate areas that need urgent care. Using heat maps mixed with markers mean that the robot operator should be able to pin point exactly what trees need to be fell to lower the risk of wildfires

3.2.3 Implementing ROS For Increased Data Collection

The use of ROS with the graphical user interface could be useful to survey a larger and more detailed area. This means that with the use of multiple land robots or UAV in SWARM formation collecting data on the surrounding area. They could send multiple publish requests that the GUI could listen to to create a more detailed map. This would give users a more in depth analysis of the data and increase the data availability.

Figure 6: Heat Map of San Francisco
1

3.2.4 Poly Lines

Using poly lines creates uses way points to create a line which the follows the robot this means for a Ranger operator they are able to make sure they have not returned to the same spot they have already surveyed creating a more efficient and cost effective way for councils to be able to operate this type of infrastructure.

3.3 Project Aim

The main Objective is the on-the-fly NDVI computation using a mobile robotic platform and/or smart-phones to accurately assess the stress levels of the trees, this can be done with a thermal camera attached to the robot, this is to be done when the robot validates that an object is a tree wit will then scan the canopy with the thermal camera and then turn that thermal rating into an NDVI.

3.3.1 Project Milestones

1. Milestone 1: Calculate the NDVI of the Classified Objects on-the-fly

   - This aim is to create a solution to be able to classify trees on the fly and then be able to calculate the NDVI. This needs to work with multiple trees as the Neural Network will be able to identify more than one tree for each frame meaning multiple calculations is necessary.

2. Milestone 2: Calculate the position and the robots and the Trees

   - This aim is to create a way of calculating the position of the tree and the robot using GPS a depth camera. This will need to work for every tree the Neural Network classifies and create a latitudinal and longitudinal coordinate for the tree so it can be placed on the Graphic user interface.

3. Milestone 3: produce information onto a graphical user interface

   -

3.4 Project Plan

For Project Plan Please see Gantt Chart.

4 Design and Implementation

4.1 System Analysis and Design

4.1.1 Requirements

Table 1: Requirements list

Reference	Description	Priority level	Implications
A	Scan tree canopies to check the NDVI of that tree to check for stress levels	Must Have	Implement NDVI calculation of the ROI
B	Find Adequate field pace for testing	Must Have	Survey Area For testing
C	Gather adequate dataset information for training	Must Have	Procure and collect dataset for training
D	Recognise trees Using Artificial Intelligence	Must Have	Protyping AI model
E	Plot the coordinates of the trees that it identifies	Should Have	Computing Coordinates of Trees
F	Graphical User interface showing plotted trees	Should Have	plotting Tree coordinates with Markers on GUI
G	Graphical user Interface Showing plotted path of the robot	Could Have	Plotting Robots Path value with Poly Lines on GUI
H	Graphical User Interface showing Heat maps of disease areas	Could Have	Plotting NDVI Values with Heat Maps on GUI
I	Detect Vegetation growth	Won't Have	None
J	Detect the floor area	Won't Have	None

4.1.2 Graphical User Interface Sequential Diagram
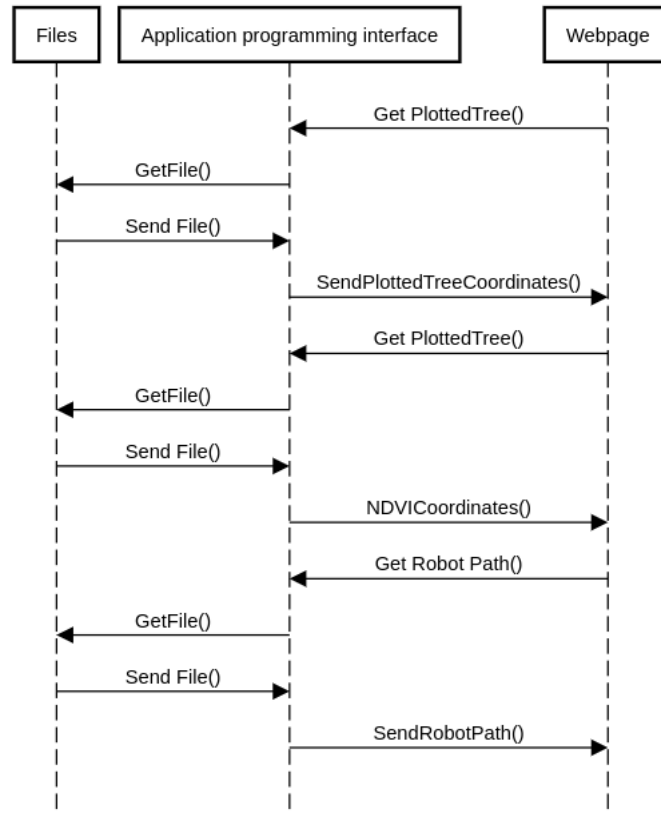
Figure 7: Graphical User Interface Sequence Diagram

4.2 Control Flow

The initial Call is for the plotted trees this will the send back the plotted tree coordinates to the webpage from the api which old the different .txt files the robot created which can then be turn into markers with Tree icons to indicate the plotted trees.

The next step is to call for the NDVI coordinates from the api, the coordinates are then turn into a heat map vector that can then show areas that are at risk.

The final step is to call for the robot path coordinates so that the web page can turn it into a polyline showing where the robot has been

4.3 Object Detection Sequential Diagram
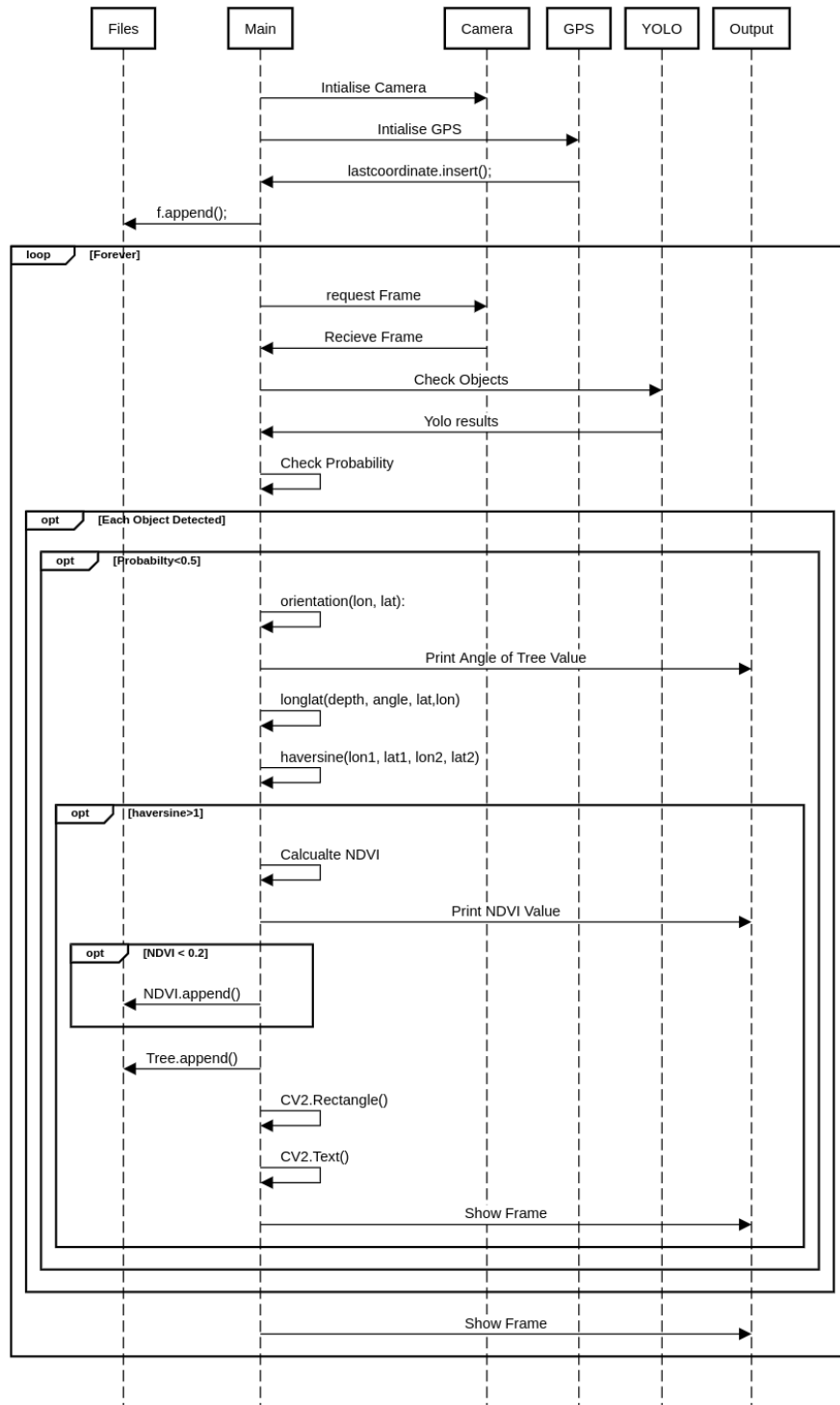
Figure 8: Robot Sequence Diagram

4.3.1 Control Flow

The first step in the sequence diagram is the intilisation of the GPS and the camera. The GPS then sends the coordinate back to Main Function. f.append() is then called to save the coordinates to path.txt

The next step is a forever loop that loops thought the video stream and send the request to yolo to check again the NN model for objects. If there is no objects then it will just show the frame.

If an object is detected it will the check if the probability is more than a predetermined level, in this case it is 0.5. If it is, main will then get the degree of the tree. From this it can use the depth to find the coordinates of the tree identified.

After this check if there is a tree nearby incase the tree has been identified before using haversine() if the tree is within a metre of another tree already found then it will discard the tree else it will then calculate the NDVI value of the tree. The value is then printed to the output. If NDVI is below 0.2 which means it could be at risk it will then be saved to NDVI.txt.

After the coordinates have been saved the object will then have a rectangle drawn around it to indicate the object on the frame, the text of the class and probability will then be attached to the rectangle and the frame will be sent to the output.

## 4.4 Implementation

4.4.1 Lean UX Methodology

Lean UX methodology can be followed working with artificial intelligence because you are able to create prototypes continuously so that you are able to test continuously. This illustrates that AI model is able to go though multiple iterations before the final one is actually produced this give more time to be able to create a better working.[23]

Using this Methodology the project can further develop the AI model as the main aspect of the methodology is to prototype. this enables creating prototype AI models, continuously changing the data set variable accordingly to create the most efficient AI model possible.

The Lean UX steps:

1. Identify

   - Identify what the end goals is and the steps needing to be taken to get there. Including the different resources that are needed to make sure that the project runs smoothly. In this example this stage would be procurement of data for elements such as and information necessary.

2. Execute

   - Execute the task creating the project making sure that the steps laid out in the identify stage have been followed through properly.

Because this will be a multistage process this allows initial executions can involve paper copies or simple elements of the project that can be built onto create the final product.

3. Review

- Review the executed items reviewing them to check for anything that can be improved on to better improve the project. This could be improving iterations of the AI model to improve the overall finding of the product. This could also include testing other positioning techniques to lower the error count.

4.4.2 Components

For forestry robots to be able to recognize species of trees one must use artificial intelligence. This is achieved by training a CNN to allow the robot to make decisions. CNN models are specific to the dataset that they are trained on meaning that the dataset being used needs to be made specifically for the purpose of the application. The application the project needs for the CNN Model is to recognise forest image features meaning that the data collected need to be multiple images of trees and any other vegetation that needs to be identified that could be high risk to wildfires.

The Components used in the project:

4.4.3 Intel Realsense D345

The Intel RealSense D345[2] comes with dual depth sensors, an RGB sensor and an infrared projector and will be the base for Tree classification. Using this camera mean everything that is necessary for imagery is available in one camera without the need for multiple sensors.

Figure 9: Intel Realsense D345 Camera

4.4.4 OpenCV 4.0.1 [3]

OpenCV is a computation vision library and is used in the project to manage the video input and manipulation of the image frames from multiple feeds. The project uses this library because OpenCV provides the useful Computer Vision tools.

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[2]retrieved from `https://www.intelrealsense.com/depth-camera-d435`, last accessed on the 24/3/19

[3]retrieved from `https://opencv.org/opencv-4-0`, last accessed on the 24/3/19

Using the example of AI, this is necessary because each frame needs to be check for any objects that are present and if there is an object detected the coordinates need to be drawn over the top.

4.4.5 Darknet

Darknet [4] is an open source neural network that YOLOV3 uses to create a neural network model. Darknet can be compiled with GPU support for accelerating the training and testing phases of CNNs.

YOLO version 3 To be able to scan trees in realtime the project will be using YOLO version3 (YOLOV3). YOLOV3 stands for "You Only Look Once Version 3". YOLOV3 is a real-time object detection system. This shows that it looks at each frame of a video or stream and scan the frame and provides a probability rating as to if there is an object present. This is simply done by using the OpenCV function "cv2.dnn.readNetFromDarknet". this then provides a probability for a object and then provides the coordinate as to where it has been discovered on the image.

This shows that YOLOV3 is able to give the user continuous data as to what is present meaning the operator does not need to save imagery data for analysis later which can be costly regarding time and can collect data on the fly. This shows that surveillance drones such as the SEMFIRE Scout would be able to continuously feed the operator with data of the surrounding area.

4.4.6 AI Dataset

When collecting data for the dataset it was necessary to highlight issues that may occur when collecting data for the application of tree recognition. Normally when performing object recognition the objects are under controlled conditions. This shows that often the surroundings are the same meaning there is a good level of control when choosing the background and the colours of the objects being classified.

When collecting dataset data for tree recognition is necessary to have a multitude of different environmental situations so that it gives the AI model the best chance of being able to classify the trees. This is where the lean UX methodology was used as much of the AI training was trial and error this meant creating prototype models and testing them out to see if they increased the probability or increased the level of false negatives.

Lighting is a major issue, in computer vision, when collecting forest images. This is because the light hitting the camera when streaming imagery as a result of the image is different from that of a cloudy day outside. This shows that as a result when collecting data there needs to be different climate variables to make sure that information the AI has is varied and the AI able to understand what the different species look like in different climates. Variation in the health of trees can be an issue when collecting data as it impacts the colour of the tree.

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[4]retrieved from `https://pjreddie.com/darknet/`, last accessed on the 24/3/19

This can happen when moss forms on the tree creating a different colour variable. Without taking this into account it can lead to a tree not being classified.

4.4.7 Depth of Tree

Obtain the depth in meters is possible by taking the Region OF interest (ROI) and taking the mean depth of that area. this is important for when plotting trees with GPS. This is done using the inbuilt depth sensor that comes with the Intel real sense camera.

4.4.8 Global Satellite Positioning (GPS) Using GPS[5]

(VK-172 Ublox7) allows the robot able to keep track of its location. This enables operator to be able to track the location of the robot whilst being remotely operating it. The GPS uses the GPRMC format which gives the date, positional coordinates and positional data.For this implementation, the project only needs to use the positional coordinates.

Figure 10: VK-172 Ublox7

4.4.9 Robot Operating System (ROS) [6]

ROS is the primary way of running software on the robot. ROS provides services that the developer can use to control the robot and gather data. For use in this project, all fundamental information on how to use ROS can be found on the ROS Wiki page[7] ROS Nodes are used to control the robot. using nodes you can control physical components such as wheels and camera or send the robot messages to initiate scripts. A ROS Topic can be used to communicate with the robot. There are different types of topics that a developer can either publish to or subscribe to. This allows outputs from the scripts to be published and access

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[5]retrieved from "https://www.u-blox.com/sites/default/files/products/documents/, last accessed on the 24/3/19

[6]retrieved from https://www.ros.org, last accessed on the 24/3/19

[7]retrieved from http://wiki.ros.org/ROS/Tutorials, last accessed on the 24/3/19

remotely. ROS Messages can be simple data types such as strings or integers. they can also be used to send camera footage in the form of arrays. A developer can also create their own custom classes so they can send custom data types.

4.4.10 Annotation tool

The annotation tool[8] is an application that is used to create BBoxs which YOLOV3 uses to learn how to classify objects. it works by the user annotation the object over the number of images which is determined by the complexity of the AI models. once all of the annotations have been made it then save them into a text file that you can load into Darknet.
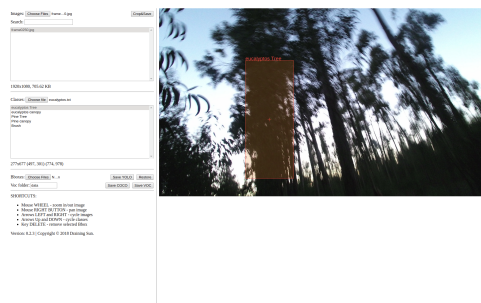
Figure 11: annotation Tool

4.4.11 Google Maps

Google maps [9] is a JavaScript library that gives the project the possibility to visually plot the location of trees and any problems with vegetation that could occur. This API allows multiple types of data at once in layers meaning you can show different data at the same time. for example, the robot will be able to show its path whilst also showing the trees it's plotted and any abnormalities in the vegetation.

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[8] retrieved from https://github.com/drainingsun/boobs, last accessed on the 24/3/19

[9] retrieved from https://developers.google.com/maps/documentation/, last accessed on the 24/3/19
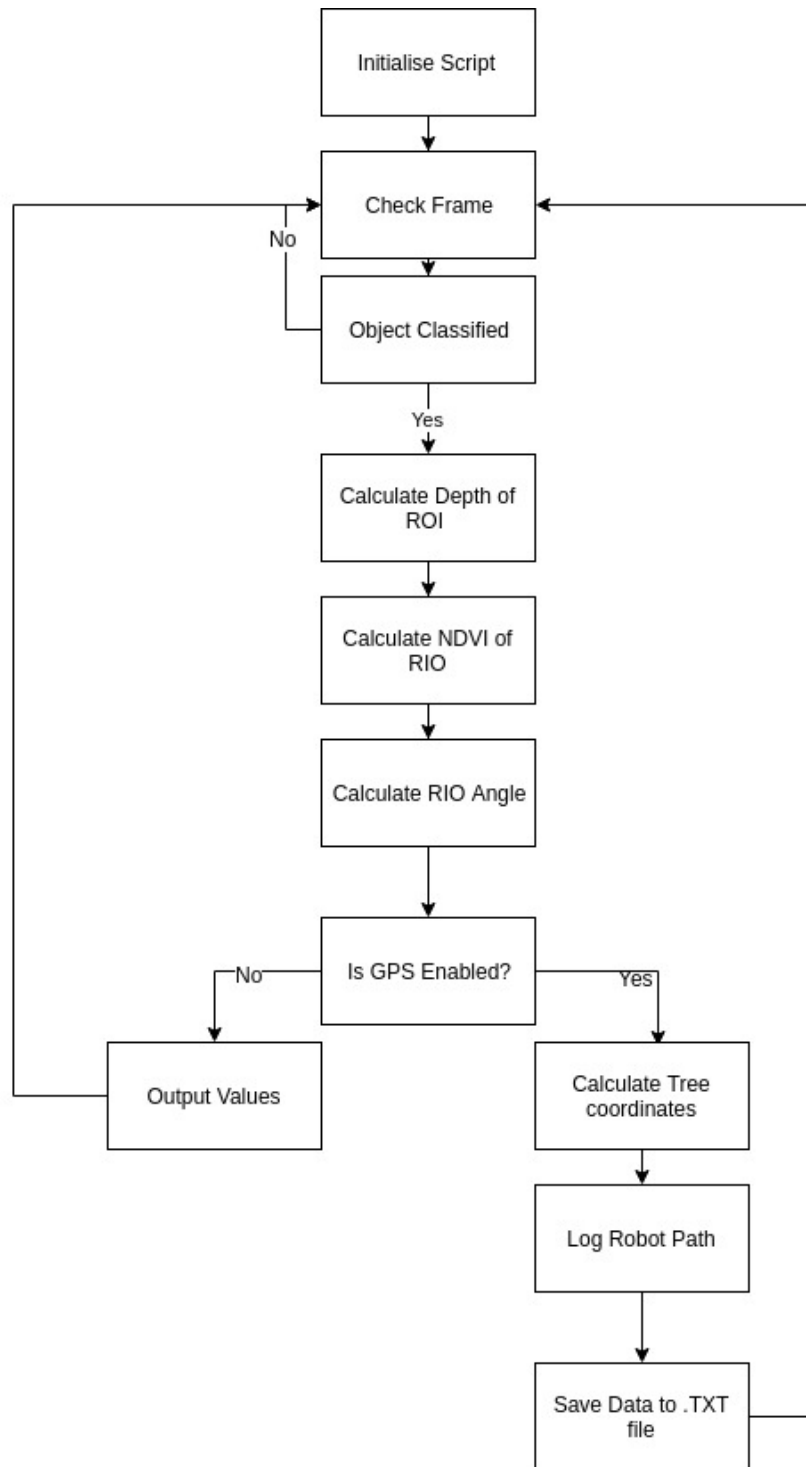
Figure 12: Software Flow Diagram

4.5 Project Development

Creating Dataset and Training The dataset for the project was collected on multiple days to make sure that the maximum amount of environmental variables was accounted for increased accuracy in the tree classification. The data that was collected was then annotated with making sure that the BBoxs selected are as precise to help mitigate as many false positive as possible

This was then trained using Darknet with YOLOV3 to create an AI model that could then be used in the software to check again frames from the camera for Trees. This has satisfied requirement C Object Classification Once an image has been received it is then turned into a blob and can then be sent to the Darknet module that it in OpenCV which checks against the weights of that have been previously trained on the collected dataset.Once this has been done the Darknet module returns the X and Y values and height and width of the ROI and with these values, a box can then be drawn over the area to indicate the classification of the tree or vegetation.

If nothing is found in the image the software will then loop round and process the next frame and look for objects. This for fills the requirement to recognize trees using artificial intelligence. Calculate the depth of the ROI Calculating the depth of the ROI is necessary for plotting the location of trees related to the robot. This was achieved by cropping the frame to the dimensions of ROI and then splitting the image into individual pixels. The depth was then taken form each individual pixel using the Realsense "Get Distance" Module. creating a mean value from the array gives an average depth of the ROI which can then be used for further calculations. Calculating the NDVI of the ROI Calculating the NDVI is calculated to understand the health of the vegetation. This was achieved using the same initial method as the depth of the RIO by cropping the image by the dimensions of the RIO and splitting the image into individual pixels. The red band is then taken from the RGB image to be used later in the calculation.

After the pixels have been split each pixel is then calculated against the NDVI equation this the results from this equation.

$$NDVI = (NIR - RED)/(NIR + RED) \qquad (2)$$

After each pixel's NDVI value has been calculated the mean value is then taken to give an overall average for the ROI. This has satisfied Requirement A

4.5.1 Calculate the ROI Angle

The first step to calculate the angle of is to work out the degrees per pixel (DPP) using equation 3.

$$DPP = \frac{FOV}{WOI} \qquad (3)$$

where FOV is the field of view and the WOI the width of image The first step to calculate the angle of is to work out the degrees per pixel which can be done

by dividing the field of view by the width of the image. Once the Degree per pixel(DPP) the X value of the Object detected can be used to determine in relation to the center of the image where the object is located.

$$DO = DPP(X - 320) \tag{4}$$

where DO is the Degree of Object and X is position of the tree horizontally.

4.5.2 Calculate the Tree Coordinate

The tree coordinates were calculated using the coordinates of the robot and the angle and depth of the tree that has already been calculated the equation to do this is.

$$distance = \frac{Depth}{1000} \tag{5}$$

$$Lat_2 = asin(sin(lat_1) * cos(\frac{d}{R}) + cos(lat_1) \times sin(\frac{d}{R}) * cos(brng)) \tag{6}$$

$$Lon_2 = Lon_1 + arctan\frac{(sin(brng) \times sin(\frac{d}{R}) \times cos(Lat_1)}{cos(\frac{d}{R}) - sin(lat_1) \times sin(lat_2)} \tag{7}$$

Lat_2 and Lon_2 represent the coordinates for the tree in radians and to get them into coordinate format, Radius of the Earth (R) = 6378.1 Km. this is then saved into
text file named trees which can then be read by the graphical user interface.This has satisfied requirement E.

4.5.3 Save the robot path

The path of the robot is taken from the GPS module and is then saved into a text file that can be loaded into the graphical user interface.

4.5.4 ROS Intergration

ROS was integrated into the project to make it easier for the robot to be able to integrate. I have done this by making all of the values the robot collects send to through the standard message topic which can then be picked up by external software and documented.

4.5.5 Graphical user interface

For the graphical user interface, I used Google maps JavaScript API which called an external API that had access to the ".txt" files the robot has created. Then iterates through the coordinates marking them down on the map with a tree icon to let the user know that a tree was plotted at that location. If there is an indication of disease or abnormality in the vegetation it will then create a heat map showing the affected area.

It also shows a line where the robot has been so that the operator knows exactly where the robot has been so they do not scan forest that has already been scanned.

5 Results and Evaluation

5.1 Tree Classification

"tree's detection"[10] is the results from the first test conducted using the Intel Realsense camera to gather video data that was used to check how well the nn model was recognising species of trees. It contains the initial NN models used to classify trees. The model was able to recognise the oak trees. But continuous recognition was not correct. This meant that a large majority of trees were not classified at the same time and often the model would lose track of the tree and then detect it again. This can become an issue when plotting the coordinates of the tree as if a tree is continuously being recognised it will lead to being plotted multiple times.

After looking through the results it was decided that the AI needed more variables to train from as the model did not recognise the majority of trees. This lead to the inclusion of more images into the dataset increasing the amount of data the model can learn from.

"Classification of trees and computation of the NDVI"[11] the model working on a sunny day, this meant that the camera was having to record in much more varied conditions because of the way the sun was hitting the trees and the camera. The model performed well and the majority of trees were eventually classified. The variable that had not been accounted for at this point was a sunny day which meant that the model had not learned how to adapt to changing light exposure. This means the dataset need more information on trees in the sunlight. In "Trees detection and NDVI computing" [12], you can see that the model has to recognise the majority of the tree very quickly and is also picking up other objects such as tree stumps and flowers as well. This shows how YOLOV3 can be used to create a model to classify vegetation.

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[10]retrieved from `https://www.youtube.com/watch?v=Nj4C7Urb-e8`, last accessed on the 24/3/19

[11]retrieved from `https://www.youtube.com/watch?v=qvVkQNzYJ5M&t=16s`, last accessed on the 24/3/19

[12]retrieved from `https://www.youtube.com/watch?v=WqE9EyK46-E`, last accessed on the 24/3/19

Figure 13: Tree Classification Diagram

The main drawback of the way YOLOV3 learned was that in the case of the flowers it would often draw a box around the whole flower bed meaning that there was a much larger area that NDVI needed to be calculated in. This was a problem as NDVI needs the body and leaves fo the plant to calculate an NDVI score but because the flower box was much larger than intended it meant that there was a large section of the box that contained the building behind.

5.2   Plotting Trees

5.2.1   Using GPS

The use of the GPS worked well under test conditions and was able to pick up its global position whilst under test conditions. One issue that was apparent was that in much thicker forest conditions this type of positioning system may not work well due to the signal not being able to penetrate the forest canopy. The GUI showed the path of the robot accurately meaning that the plotting of trees would be accurate as this was a concern as much of the other processes relied on the use of the GPS coordinated.

Table 2: Tree Plotting GPS Results

GPS Location	Tree Species
52.909652,-1.187902	Oak Tree
52.909645,-1.187988	Oak Tree
52.909691,-1.188068	Oak Tree
52.909768,-1.188235	Oak Tree
52.909875,-1.188198	Oak Tree
52.909869,-1.188412	Oak Tree
52.909943,-1.188514	Oak Tree
52.909969,-1.188471	Oak Tree
52.910021,-1.188600	Oak Tree
52.910082,-1.188680	Oak Tree
52.910027,-1.188305	Oak Tree
52.910001,-1.188246	Oak Tree

5.2.2 Results

5.2.3 Calculating the Tree Coordinates

Plotting the trees shown in Table 2 that were detected by the NN model was harder than expected the objects were detected frame by frame the script would keep trying the plot the tree in the same location. This means that the map would quickly fill with trees that were not actually present. This meant that the robot needed a way that it could detect duplicate readings. This can be seen in this graphical representation.
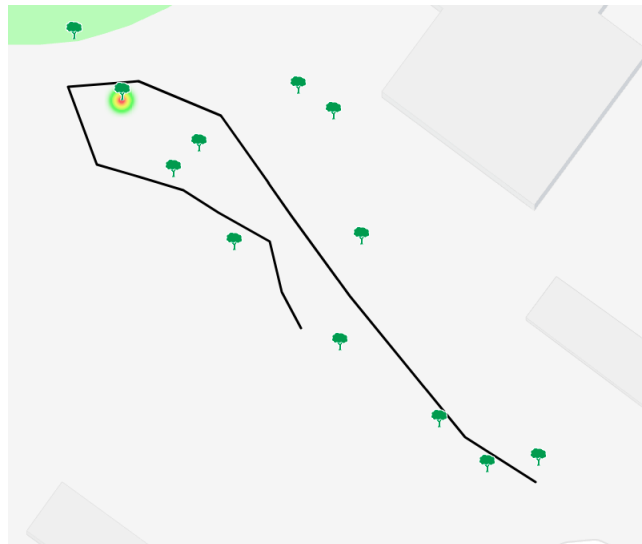
Figure 14: Graphical User Interface

Using the haversine formula the robot was able to detect if a tree was within

a specified distance of another tree. After undertaking test the best solution was to make sure that there wasn't another tree within a metre. This could be changed in thicker forests if much smaller values if needed. This was a success with much smaller false readings than before leading to a much better collection of data.

5.2.4 Results

Table 3: Plotting Oak Tree Results

No of Trees	Trees Classified	False Classifications	Trees Plotted
11	11 oak Trees classified	8	11
15	15 oak Trees classified	7	15
13	13 oak Trees classified	3	13
10	10 oak Trees classified	8	10

The Table 3 shows the number of trees that were recognised in 4 separate tests. All Tree data collected was collected with a time constraint of 1 minute.The table shows how the NN model was able to recognise all of the trees the camera images captured. but some of the trees were detected more than once. using the haversine the robot was able to understand if an object detection was a duplicate and not duplicate the information.

The previous videos failed to identify the majority of the trees that where is the video meaning that in a real world implementation this could lead to false reading leading to a underestimation of the risk of wildfires for a forest. One of the major aims of the project was to plot trees on the fly which means without the ability to do so that aim would not have been met.
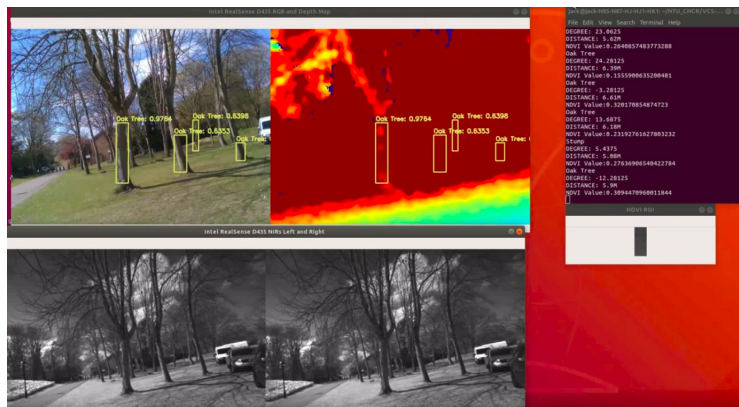

Figure 15: NDVI Analysed Video

5.2.5 Pine Trees and Eucalyptus Trees

For the project a second dataset was trained that held Pine Tree and Eucalyptus Trees. This is because the Oak Trees did not contain any canopies because of

the time of year. This is why the Second dataset was needed to test the idea of being able to identify tree canopies and brush.
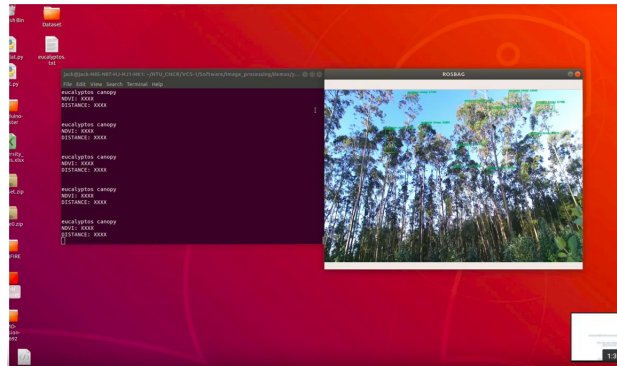
Figure 16: Canopy Analysed Video

"pine eucalyptus detection" [13] Shows a set of test images that were used to test the ability to scan pine canopies and Brush. This video was created using still images to give a control to test the ability to scan canopies.

Image 16 shows the NN model being able to detect the canopy of the tree. It is able to show multiple canopies at once meaning that it would be possible to scan the tress to give an accurate NDVI check, because the dataset used did not contain an NIR feed the NDVI test was not possible.

"eucalyptus detection" [14] show a logging process of eucalyptus trees, this is a real world scenario where this AI could be implemented. The results form this video where positive with the NN model being able to identify the majority of the trees and canopies.

"pine tree detection"[15] showed the NN model running on a video that shows a pine forest. This is a good test for the NN model because of different variation of pine trees and the variation of canopy and brush that are present. The initial results where positive with the majority of trees and canopy being noticed. It did however not notice far away canopy which could be a indication that it could struggle with taller trees in the future.

The 3 videos showed a positive result with the majority of the Trees being identified. This indicate that this dataset could be versatile enough to work in a number of different environments. This has accomplished Requirement A and D because the majority of the trees were recognized and the canopies of the trees were able to be scanned and with the results from the Oak Tree dataset it is possible to scan the NDVI levels of the vegetation.

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[13]available online `https://www.youtube.com/watch?v=RxboGda9UGE`, last accessed on the 24/3/19

[14]available online `https://www.youtube.com/watch?v=2EP6Mzxcs6Q`, last accessed on the 24/3/19

[15]available online `https://www.youtube.com/watch?v=ygjXCRg5_vE`, last accessed on the 24/3/19

When computing NDVI the number that indicates shrub and grasslands are 0.2 to 0.3 so the result of the project should show the average values being between these numbers. An issue that occurred when gathering these results was the fact that YOLO gave a very general ROI that often lead to there being a large area of unwanted areas being present when trying to compute the NDVI value pixel by pixel means that this could lead to false reading because of the unwanted areas or objects being present. The video in the link shows the NDVI reading of multiple trees that have been classified using the NN model.

Table 4: NDVI Calculation Results

Tree Classification	NDVI Value	NDVI Reading
Oak Tree	0.26	Shrub/Grassland
Oak Tree	0.15	Stone, Rock or Sand
Oak Tree	0.32	Tropical
Oak Tree	0.23	Shrub/Grassland
Stump	0.26	Shrub/Grassland
Oak Tree	0.30	Shrub/Grassland

Table 3 show that the majority of them have come back as expected. The result shows that the NDVI shows 4 out of 6 as being vegetation with one of them being rainforest and one being sand, rock or stone. The reason for the false NDVI reading could be as previously discussed the ROI have too large of an area to scan as you can see in Figure 8 there is a slight area of the ROI which is not the tree. This means that the NDVI reading will not be as accurate is if the ROI only contained the vegetation.

The graphical user interface worked well showing where the trees were being plotted. It gives the user the intended representation of the data that the robot has collected. The web page created to show the results of the robots finding accurately depicted the trees that the robot had plotted and the level of NDVI meaning it could plot the heatmap showing affected areas that would need to be removed by the robot.

The tree plotting worked well. using a simple API to pull the information from the .txt files created by the robot in a format that can be used by Google maps to plot the location of the trees. This worked well and there were minimal issues with this approach. One issue that did arise was the fact the use of a web page meant the internet access to the network was necessary to see that data in a readable format. In more remote areas this can become a problem because of the lack of mobile service and the fact that in the forest satellite signal can be an issue. This has satisfied Requirement D.

Recording the path of the robot worked well and the result showed it was accurate. This was necessary for the project as if there are any anomalies with data that is collected it was easier to troubleshoot. For example, one of the NN prototypes would detect a drain cover as a tree stump this could mean there has been a false positive detected. This is why it is necessary to produce a path of where the robot has been so you can retrace the steps of the robot to check

if there was actually an object detected or not. This has satisfied Requirement G.

The heat map was used to show the values of NDVI graphically this meant that if a tree was detected and the NDVI was below a predetermined level it meant that a heatmap would show giving the user an understanding of areas of interest to either reevaluate in person or to direct the robot to remove the vegetation that is present. This has satisfied Requirement H.

6 Conclusions and Future Work

6.1 Conclusions

The results of this project have shown how it is possible to classify trees using the YOLOV3 object detection system and use the ROI of the detected project to compute the NDVI levels. The project showed how different variables can affect the outcome of object detection. Detecting objects under changing environments bring issues that are not apparent when working in a controlled environment. Environmental changes such as the amount of sunlight change the way the camera is able to see the trees and increasing the probability that the NN model will not be able to detect the tree. This increased amount of pictures were was negligible without the use of pictures with different environments such as the environments in different weather conditions.

The need to create accurate image detection when working with tree classification is not just for detection the species of tree but also making the ROI of the image as exact as possible.

This project has given a better knowledge of computer vision and how it can be applied to a profession to help increase efficiency and knowledge not possible purely by human means.

The use of NDVI created a way of better understanding the threat level of vegetation that would not be possible purely from just detecting the where a Tree is, Trees can be diseased or dying which will lead to them trying out and creating a risk of fire which would help experts better understand what vegetation needs to be cleared other than just identifying risk material such as brush.

The issues that came with calculating the NDVI of the trees was the size of the ROI because if there was background present inside of the ROI it could lead to false reading leading to the robot damaging perfectly healthy trees instead of clearing trees that are at risk of catching fire. This has an adverse effect on the heat map representation which was used to show high-risk areas because it means the graphic will show false readings the result will mean the council works will not see an accurate picture of the risks that are present in the forest. This issue affects both sides of the arguments with high-risk vegetation having the chance of not being noticed by the robot leading to increased risk of wildfires spreading. The increased dataset size with a higher level of environmental variables made this problem occur less often as the size of the ROI became much smaller increasing the accuracy of the NDVI readings.

6.2 Future work

In the future, the project could be progressed by looking having larger access to forestry datasets for improving the application. At present, there is little information on trees that is useful for creating tree detection software showing that with increases in dataset imagery the ROI of trees will decrease increasing the accuracy of calculations that professionals may want the robot to undertake

on the robot.

This project could also be applied to other industries such as agriculture where the use of moisture indicators could be used to better benefit the rate of crop growth. Decreasing the amount of water that is needed to grow crops

Future project would greatly benefit from being able to detect the floor of the forest highlighting that it can the floor for dried vegetation that can cause risk. At present this is not possible showing that unless the vegetation on the floor is detectable by the NN model it will be unable to notice it and will not collect data on it. Furthermore, a conference paper based on this report will be submitted to the ROBOT'2019: Fourth Iberian Robotics Conference[16].

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A Gantt chart

B Project Planning Document

Compute the Distances of Objects using a Depth Sensor

JACK BONNELL 2015 (N0635248)

Abstract

Rapid expansion in efforts to stop the deforestation of our planet has led to an increase in the information gathered about the forest so that we can better understand their needs. In this research project I aim to create a robot for estimate the number of trees inside a forest and the stress levels that are affecting these trees. These stress levels have been heightened with an influx of human activity to previously untouched forest areas. The Robot will map such stress levels on a visual display on so that a heat signature shows the area of concern in an area to help show a correlation that is not able to be pictures but by a human working to collect data through the forest.

Abstract

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List of Abbreviations

1. NDVI: Normalized Difference Vegetation Index
2. GPS: Global Positioning System

Introduction

I will be looking at is agricultural farming, this is a growing industry and with agriculture being one of the last true manual jobs, Robots are becoming more and more sort after as a way to cut costs and workloads. The Guardian[1] recently wrote a story on a robot called Rachel, this robot is being used by farmers to check on their crops, she works by scanning the ground and crops around her using a camera to and relays that information back to a computer where the farmer can check on his crops.

The Farmer stated, "This is the revolution" as he works in the wheat industry and is often uncertain about how his crop will do through the year. In the forestry industry there are many drones used to survey a landscape, they can be used to give a better picture of rural landscapes, but a reoccurring issue with drone surveys is that they rely heavily on global positioning system (GPS), and often this is not accurate when trying to stitch the surveyed image together; In this project I am looking to increase the accuracy of marking where trees are in a forest. While collecting NDVI data from the canopies of the trees to give a more precise reading of the stress levels of a forest.

This can be done using a hyperspectral camera [2] as the amount of NIR Waves being reflected from the canopy gives us the NDVI levels of the tree. Using this as the robot moves around the field I will be able to build a graphical representation that can then be seen by farmers and be saved in an encrypted format, so they can then keep a secure record of their findings.

Project plan

This section of the project will go into more details on the aims and objectives of the project, looking a key uses for each element and what is expected of the project itself. This will create a structure which can be followed to gain the expected result.

Table 1: MoSCow Analysis

Reference	Requirement	Priority
A	Automate the robot so that that it can work in lights out mode and can navigate the forest.	Must have
B	Scan tree canopies to check the NDVI of that tree to check for stress levels.	Must have
C	Find a Field that is Adequate for testing the.	Must have
D	Secure the data in an encrypted format so that the data collected is not saved in a raw format.	Should have
E	Create a graphical interface so that users can see the data in an easy to understand format.	Could have

Aims and Objectives

The main Objective is the on-the-fly NDVI computation using a semi-autonomous mobile robotic platform. The robot must be able to move semi-autonomously through the forest so that it is able to scan the trees without hitting them. This will be done using the distance matrix and GPS module onboard to accurately pinpoint where the robot is without solely relying on the GPS signal as this could lead to inaccurate readings.

Another objective will to accurately asses the stress levels of the trees, this can be done with a thermal camera attached to the robot, this is to be done when the robot validates that an object is a tree wit will then scan the canopy with the thermal camera and then turn that thermal rating into an NDVI.

The project aims are:

1. Aim 1: The mobile robot will travel from A to B accordingly with the pre-selected trajectory.
2. Aim 2: On-the-fly NDVI calculation to calculate week detection
3. Aim 3: Validation of the NDVI calculation in each of the use-case scenarios

Managing Weeds in a Cherry Orchard - In Chile they are using NDVI with drones to identify weeds in a field of cherry trees as an efficient way of getting rid of letting the farmers know where they need to spread weed killer to get the most efficient effects. This works by identifying irregular NDVI reading across the cherry field. Once the weed killer was given time to take effect they were then able to take a second view of the same field and found the reading showed the only vegetation in the field was that of the cherry trees themselves.[3]

Checking optimum Harvesting times for cherry trees – In this case study, they used NDVI to provide them with optimal time to harvest cherries. This worked on testing the correlation between the change in pigment and the level the NDVI was producing. Using NDVI they were able to produce accurate levels of maturity in fruit on a cherry tree. This was done by checking the levels of chlorophyll in the fruit going "from −0.4 relative units in the fruits to +0.5 in overripe fruits"[4].

This project is aimed at showing an accurate way of measuring the distance between trees. This is will be achievable because instead of using just GPS which is not always accurate. I will be using an Intel Real sense camera which I will be able to use to calculate the distance to the nearest tree whilst keeping a record of the robot's movements means I will be able to calculate where each tree is situated in relation to each other.

Milestones and Deliverables

1. Capture an image from the Intel Real sense and plot the distance's matrix to be able to map a group of trees in a field, calculating the distances between the trees using an Intel real sense camera to help calculate the distance matrix. With this information, I can then use this information to plot the tree and its coordinates.

2. Compute the NDVI from the canopy of a tree[5] Once I have the distance matrix of the tree, I then want to use a thermal camera to scan the canopy of the tree to check for any stress that may be occurring. This will give users of the robot god indication of hotspots of stress across the scannable area.

3. Move the Robot from a from point A to point B outside the lab. This will be a set distance with no physical waypoints this will prove that I am able to move the robot and can then use the methods further on in the project to move the robot around the field.

4. Move the robot from point A identified with a landmark (e.g. tree) to point B using a different landmark (e.g. a specific rock) Once I have these two parts in place, I can then move onto the physical robot which for this project will be the Robotnik Summit XL. My first task on this objective will be to get it to move, this means I will be trying to get it to move from one object to another with the distance travelled being calculated by the real sense camera we discussed earlier. At this stage, I will have a robot that can move relatively semi-autonomously between two points.

Tasks

1. The first task for the project is to register it by Wednesday 10th October. This means I will have a tutor who is happy with the project I am undertaking and can help me finalise the project spec. Without doing this I would have been allocated a tutor who may not necessarily have the same interests as me and I may not be able to do the task that I want to do.

2. The Review Point 2 is where I hand in my planning document and I can get feedback on my ideas and if I am going off topic, they can help me to stay on track.

3. The Next task will be the milestone one, this involves using the intel real sense camera to calculate the distance between two points.

4. The next task will be milestone two, this involves calculating the NDVI from the canopy of a tree using a thermal camera, this will help me to calculate the stress of the tree.

5. The next task will be milestone three, this involves getting the robot to move from point A to Point B without autonomy.

6. The next task will be milestone four, this involves moving the robot from two plotted points such as a rock and a tree.

7. My next task will be to program the robot to search for trees in a field and plot the tree, once it has done this, I then need to use the information gathered from milestone two to scan the stress of a tree I need to make sure this data is synced with the plotted tree to make sure the data is as accurate as possible.

8. My next task will be a mobility test to make sure that the robot is able to move by itself as the robot could be used in light out mode in a field meaning it is set to scan and then left without human input. This means I need to be confident the robot can work by itself.

9. My next step will be a stress test, this involves making sure the NDVI is calculated accurately so that the data collecting is as accurate as possible.

10. My next task after this is to try and find and scan a tree with the robot to make sure it can find the robot and scan it itself without human input.

11. My next task is to test the autonomy of the robot to make sure it can undertake the tasks without human input.

12. My next task is to review the test data to see if there are any issues that need to be addressed.

13. Finish and hand in my dissertation

14. Demonstrate the project

Source of information and Resources Required

Robotnik Summit XL: this is a four-wheel drive robot that comes equipped with accelerometers that can be used to measure speed, also a gyroscope that can be used is used for measuring the orientation of the robot. This model is also equipped with a GPS for location tracking.

- Xilinx ZCU102 board: This board is beneficial because it comes with onboard graphics and a quad-core ARM® Cortex-A53 that will beneficial when used with the intel Realsense Camera to render the images so that they can then be processed accordingly. This means there no need for external components such as a graphical processing unit included in the one board making the robot more portable

- Intel RealSense D435 will be used to create high-resolution 3D depth maps this means the robot will be able to accurately calculate the distance between the robot and the tree using the distance matrix without the need for external sensors such as ultrasonic sensors. The camera also has an infra-red projector which means that I can be used to create an NDVI of the trees being scanned.

- Ubuntu Linux 18.04 64bit LTS: this will be used to build the software for the robot on as it shares a lot of libraries with the ROS operating system meaning I can transfer the scripts created on Ubuntu and load them onto ROS which can then be run on the Xlinux board as efficiently as possible.

- ROS Melodic is an operating system that comes with inbuilt tool and framework to help simplify the creation of a robot. This means the robot can be as efficient as possible whilst processing the images.

- Python version 3.7.1

- OpenCV version 3.4.3.18

- Caffe Version (OpenCL)

Project risks

Table 2: Project risks

#	Probability (5-Very likely, 1-Very Unlikely)	Impact (5-Very likely, 1-Very Unlikely)	Description	Plan
A.	3	3	Risk of collision	Implement Fail-safes
B.	2	4	Getting Land Owners Permission	Increased Information and Documentation
C.	3	3	Variation in tree size	Implement procedures to scan are multiple heights
D.	3	4	Disturbing Wildlife	Take into consideration ecosystems inside of the forest
E.	3	2	Illness	Increase allowances for illness

A.   Risk of collision is something that I must take into consideration as this is a big problem when working on site with a robot. For example, you are working in a forest full of listed trees and the robot collides with them this could lead to the tree being damaged. This could lead to infection and disease, killing the tree.

I must make sure that there are fail-safes in place for this scenario such as if the robot cannot verify an object that it will stop until the user allows it to continue, this means that the robot will the minimal chance of hitting a tree. This could also be fixed by adding bumper sensors like they use in hoover robots such as an "IRobot Roomba" where the robot automatically turns 90 degrees to the impact saving further damage to the impact spot.

B. Getting permission from landowners could be a risk to the project as landowners may be wary of having data collected on their land as they could feel it breaches their privacy and they may not be completely trusting of what the data is used for. This means there needs to be concise documentation on exactly what is going to be collected and proof that the robot is only collecting the data stated in the documentation.

C. Variations in tree sizes may be an issue, as the robot will have to angle the thermal camera, so it can see the canopy without this there could be variations in data recording because the robot is either scanning the wrong tree or even the trunk of the tree.

The most likely ways around this will either be to have the thermal camera on a motored angle meaning that it can pivot to the correct angle of the tree, another way this could be fixed is to make sure the robot stay at a set distances, so it can get the chance of scanning the top of the tree.

D. A Risk to the project could be the disturbances the robot could have on animals that live in the forest, the robot will have no way of telling if it is disturbing animals which is something humans will have a sense of while walking through a forest, this could lead to distress for the animals.

Making sure that I take this into consideration is important as part of the forest ecosystem is the animals that live there and there is a chance that this could lead to the animal leaving because of distress.

A. Risk for the project could be illness if I am ill for an extended length of time this could mean that I am unable to complete parts of the project. This would need to be monitored by making sure I gave extra time in key parts for my project so that I can account for times where I am ill or occupied.

Issues

In this section, I will be discussing the areas of PSEL relevant to my project. I will be taking into consideration Professional, social, Ethical and Legal issues that may arise whilst undertaking this project. Failure to take these into consideration could have a negative impact on the project and any data collected.

As part of the project it should consider the safety and care of others, this includes making sure that people are always at a safe distance from the robot, making sure that wires connected to the robot are clearly visible so not to cause a tripping hazard.

Make sure that all data collected is secure and safe. Making sure any third-party survey data is secure and clearly accessible the third party. This includes making sure they find the data acceptable to be used in my project's findings. This includes removing any irrelevant data that may include unnecessary personal data.

Professional Competence and integrity

I must make sure that at any point I am not competent in what I am doing I let it know. making sure I respect the viewpoint of my project supervisor and my peers when receiving advise.

I should try my hardest to make sure there is no damage that happens to any components lent to me by the university, this includes the robot, the Xlinux Board and any other components I may need access further on in my project.

I should make sure I have a good grasp of the knowledge of legislation needed for this project and I follow these legislations whilst I undertake this project.

Duty to the Profession

I will take it upon myself to uphold the values of the IT profession and not take any action that may bring my profession into disrepute. This includes presenting myself properly and respecting participants in the project with respect and professionalism/

I will support and encourage fellow members of my profession to help the development of their project and where applicable offer advise that can be used to further their development.

Ethical

One ethical issue for my project is that of taking jobs away from employees. This is an issue that affects all aspects of industry and can often lead to an increase in consolidated wealth. This can make it easier for people that may already have wealth to improve their wealth because they can afford to implement robotics as a way lowering cost that can often from an ethical standpoint mean that there are fewer opportunities for people working unskilled jobs. [6]

Legal

As the robot will be working in industry, I have to make sure that it follows the Health and Safety at Work Act 1974. [7]. This means the robot will have to be used at a safe distance so that it cannot hurt or injure someone on the job. This means that the robot should be able to be shut off if needed.

As I will be working with confidential data on the forests in have to make sure I follow the data protection act to make sure data is secure for example "An example of a case which may fall within subsection (3)(a) is where measures that render personal data unintelligible to any person not authorised to access the data have been applied, such as encryption." [8] Meaning that if data is mishandled or taken without consent that It is illegible. This means all information collected need to be stored encrypted so it is secure and unreadable without authorisation.

In table 3 the project Gantt chart is shown

Table 3: Gantt chart

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Project Registration	1 day	Wed 10/10/18	Wed 10/10/18	
2		Review Point 1	1 day	Thu 11/10/18	Thu 11/10/18	1
3		Project Planning Document	1 day	Fri 02/11/18	Fri 02/11/18	2
4		Milestone 1	5 days	Mon 05/11/18	Fri 09/11/18	3
5		Milestone 2	5 days	Mon 12/11/18	Fri 16/11/18	4
6		Milestone 3	5 days	Mon 19/11/18	Fri 23/11/18	5
7		Milestone 4	5 days	Mon 26/11/18	Fri 30/11/18	6
8		Review Point 2	1 day	Mon 03/12/18	Mon 03/12/18	7
9		Programming	18 days	Tue 04/12/18	Thu 27/12/18	8
10		Mobility Testing	2 days	Fri 28/12/18	Mon 31/12/18	9
11		Tree Test Testing	1 day	Wed 16/01/19	Wed 16/01/19	10
12		Autonomous Testing	3 days	Thu 17/01/19	Mon 21/01/19	11
13		Test Review	2 days	Tue 22/01/19	Wed 23/01/19	12
14		Dissertation	1 day	Thu 24/01/19	Thu 24/01/19	13
15		Demonstration	1 day	Fri 25/01/19	Fri 25/01/19	14

13

Conclusion and Future Work

In this section will be the discussion of the planning document and future work that could be done to increase the efficiency or functionality of this project.

Conclusion

The project itself is attainable with a good level of complexity, the aims are achievable and supersede each other meaning the project flow well. The use of the real sense camera is good because it consolidates both a depth camera and an infrared camera in one meaning that there are fewer sensors necessary.

Using Caffe means the robot will be able to be as efficient as possible when processing images. This means the robot will be able to asses if an object is a tree or not as efficiently as possible.

The Robotnik Summit XL is a good platform to work from as it has a good level of inbuilt functionality such as GPS that I can use to increase the positioning capability of the project.

Future work

Future work that can be undertaken could be the full autonomy of the robot, so it can be left in much larger spaces such as large forests. To make this necessary the use of wireless comes would also be something to research further, the use of satellites to have more remote access to the robot could be used for places.

The use of external power sources is something that needs to be looked at as it would be the main bottleneck with extensive wireless surveying, one prospect for this could be solar power. Charging the robot by sunlight. There are both pros and cons to this and its something that has to be looked into to see if it is a viable option.

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[8]   "Data Protection Act 2018."

Task Name	Duration	Start	Finish	Predecessors	Reso Nam
Survey Area For testing	20 days	Wed 10/10/1	Tue 06/11/18		
Procure and collect dataset for training	20 days	Wed 07/11/18	Tue 04/12/18	1	
Protyping AI model	30 days	Wed 05/12/1	Tue 15/01/19	2	
Computing Coordinates of Trees	15 days	Wed 16/01/1	Tue 05/02/19	3	
Implement NDVI calculation of the ROI	15 days	Wed 06/02/19	Tue 26/02/19	4	
plotting Tree coordinates with Markers on GUI	10 days	Wed 27/02/19	Tue 12/03/19	5	
plotting Tree coordinates with Markers on GUI	10 days	Wed 13/03/19	Tue 26/03/19	6	
Plotting NDVI values with Heat Maps on GUI	10 days	Wed 27/03/19	Tue 09/04/19	7	
Testing	10 days	Wed 10/04/1	Tue 23/04/19	8	

C   User Guide

1.Open "yolo3$_python$"
2.right click and select "open terminal"
3.python FYPObjects.py

D   Risk Table

#	Probability (5-Very likely, 1- Very Unlikely)	Impact (5-Very likely, 1- Very Unlikely)	Description	Plan
A.	3	3	Risk of collision	Implement Fail-safes
B.	2	4	Getting Land Owners Permission	Increased Information and Documentation
C.	3	3	Variation in tree size	Implement procedures to scan are multiple heights
D.	3	4	Disturbing Wildlife	Take into consideration ecosystems inside of the forest
E.	3	2	Illness	Increase allowances for illness

E   Synoptic

During this project I have learned I am able to adapt and overcome issue that I would of previously no overcome and simply accepted. I feel i have develop a lot because of the experience I have learned the hard way that AI is a matter of trial and error and cannot be rushed.If i was to look back on my project and think about aspect that I could have done different I probably would have managed my time better as this is a necessity for training AI models if you do not have the adequate time to train the AI models there is nothing you can do

and it will not work properly. Giving adequate time for the AI to train gives you a lot more time to make small chances to better your NN model. I think I made some good choice and some bad ones, I feel the creation of the datasets should have been done at an earlier stage so that I had more time to manage the dataset and create a better model. I do think I made good decisions in sticking with the object classification side of my PPD to do the object classification and the autonomous robot at the same time would have been too much.This project will help me have a level grounding before I move into the workplace as I will have already made the simple mistake.

F   PSEL issues

F.0.1   Professional Competence and integrity

Through the project it was integral to make sure there was a level of respect for other people in and around the robotics lab and university, treating the equipment within the robotics lab with care and make sure all the laws of the university are up held whilst understand aspects of the project.

F.0.2   Duty to the Profession

Making sure that professional standard are upheld undertaking the project to was necessary to this includes making sure nothing has been undertaken that will disrespect peers or represent the project.

F.1   Ethical

Making sure the project was able to enhance the jobs that already existed in the forest industry and didn't consolidate the wealth of the few was imperative to the project becoming a success and was followed to make sure the project was a ethical as possible.

F.1.1   Legal

During the project health and safety was taken extremely seriously making sure that to keep the risk of industry as low as possible. The project also followed the freedom of information act meaning that any information that was give in confidence to the project stayed confidential.