DESIGN AND IMPLEMENTATION OF A SMART FOREST ENVIRONMENT MONITORING SYSTEM

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Ethics Statements

As for the plagiarism checking status we got 15% plagiarism in our report which is below the maximum plagiarism percentage limit which is 35%.

Abstract/Executive Summary

Understanding the forestry health and environment—air and water quality, and the density of trees—is the primary objective of our project. From the numerous ways of analyzing the forest, our aim was to find the most effective, but accurate method—the use of a UAV (Unmanned Aerial Vehicle)—to monitor the forest. Given the size, accessibility, and unpredictability of a forest, the UAV has made it possible for us to precisely and efficiently gather the necessary data. Additionally, the health of a forest can be determined by a number of factors—but our project focuses primarily on the three: Air Quality, Water Quality, and the forest's canopy. These factors help us determine the rate of deforestation and the gradual environmental deterioration of a specific forest—over a period of time. In terms of the project's goals, a device was made with sensors for data collection, later the data was analyzed with Standard Data for a comparative idea; and a machine learning model was created to predict the future condition of the forest. Along with this, a camera was used in the device to periodically collect images for processing and calculating the area of the forest. We received fairly accurate test results for our project, and these findings let us comprehend the general state of the forest according to our criteria.

Acknowledgment

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Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Introduction

Trees are the predominant life form in forests—a complex ecological system—to maintain stable weather and temperatures for living things, it is crucial to improve current forest conditions, as a result of current global warming. For this reason, we are developing a modern solution to protect the forest. To monitor the forestry environment and protect the forest ecosystem—our primary study goal is to calculate and comprehend the forest's overall status. The forest is without a doubt the world's most significant source of resources for both people and other living things.

1.1.1 Problem Statement

Design and Implementation of a Smart Monitoring System for the Forest Environment.

1.1.2 Background Study

Starting with the forest-water interactions that—contribute to the improvement and restoration of groundwater recharge, the cooling of the earth's surface, and the enhancement of flows from the many water reservoirs—found around the planet. Despite being the main consumers of forest water, trees and forests also play a key role in the cycle of atmospheric moisture. This typically leads to rivers being present in the forested area and to the growth of human civilization alongside the rivers. One of the most noteworthy qualities of forests is their capacity to cool the air through evapotranspiration. As they transpire—trees release water into the atmosphere through their leaves.

As water transforms from a liquid to a vapor, the temperature of the environment decreases. In recent years—as global temperatures have risen—trees have been able to somewhat offset the increase. Regular exposure to other hazardous pollutants, such as nitrogen oxides, ammonia, and ozone, which are absorbed by trees or forests and can lead to respiratory problems—can also be harmful. As natural air filters, trees are particularly good at removing carbon dioxide, one of the most harmful greenhouse gasses. A tree's lifetime effort to accumulate greenhouse gasses is reversed when it is cut down and burned—because the carbon is released back into the environment, as carbon dioxide.

Consequently—the forest has a big impact on the quality of the air around us. To keep track of the health of the forest, we'll employ UAVs in our project to monitor the biotic components of the forest. Our sensors will keep an eye on the water and air quality in the forest—but the UAV will also occasionally compute and record forest regions. To achieve the best and most accurate results from our data; we are deploying UAVs with cameras and sensors, and we will use image processing and machine learning to assure specific and accurate data—from the data collected.

1.1.3 Literature Gap

Global deforestation has created a crisis for the planet right now. Without a doubt—recent human actions are the main cause of this. Natural ecosystems are being converted into rural and agricultural areas, and many forest areas are rapidly disappearing due to the rising human population and demand for food supply. Most ecosystems—including protected areas—may be impacted by the process of fragmentation and losing connection if deforestation continues at the current rate (73000 sq. km/year). We have relatively little information about threatened species around us. Ecological research must identify the intricate connections between species, habitat, and the forest; there is—however, a lack of data that can be used to establish this connection between the impact of forests on life. Though the studies are typically restricted to specific regions and within the capabilities of any given country; they are occasionally hampered by industrial activities in and around the forest. Various models and data research on forests can help us define the core conditions that are most suitable to fulfill the requirements for saving the forest. Controlling deforestation requires thorough research in regions of forests with a high rate of deforestation. There is no such work in Bangladesh. In Bangladesh, there is only an old method of monitoring forestry.Due to the current global deforestation of trees and forests, national forest inventories and monitoring systems are more crucial than ever. In a nation like Bangladesh, which is characterized by a high population density, sensitivity to climate change, and reliance on natural resources, these systems are particularly crucial. The Bangladesh Forest Inventory (BFI), which consists of three components: a biophysical inventory, a socioeconomic survey, and remote sensing-based land cover mapping were created with the goal of aiding the Government's efforts toward sustainable forest management through accurate information [58].So, we can see that our proposed method is not available in Bangladesh which is very much efficient for the forest monitoring process.

1.1.4 Relevance to current and future Industry

It is difficult to overstate how important forests are; we are dependent on the forests for our most fundamental survival necessity—oxygen. In addition to offering homes for animals and a means of subsistence for people—forests also safeguard watersheds and slow global warming. As the second-largest carbon sink, forests help to absorb harmful greenhouse gasses that contribute to climate change. In other words, the forest gives us access to clean water for drinking, bathing, and other domestic needs, lessens chemical pollution and soil erosion, provides food and medicine, serves as a buffer against natural disasters like floods and heavy rains, and serves as a habitat for more than half of the world's land-based species. On top of that, forests give jobs to more than 13 million people across the world; and over 2 billion people rely on forests directly for survival [18].

Forests cover around 30% of the world's land surface, but they are rapidly disappearing[1]. According to the United Nations Food and Agriculture Organization, the world has lost 4.2 million sq. km of forest since 1990[18].

Most businesses involved in forest-related operations—will be able to use our surveillance system. More specifically, our method can be advantageous to businesses that deal with timberland, paper, natural resource gathering, mineral extraction, and forest observation. Since these businesses require forest-related information—we can provide it to them. These businesses must understand how much of their consumption is affecting the environment and to what degree it needs to stop. Additionally, it will stop the unlawful destruction of forestry lands with adequate observation.

In short, the impacts of deforestation-

- Habitat Destruction

As a result of widespread forest devastation, many animal species are in danger of going extinct. Due to a constantly expanding population, people require more and more land—we are using the resources too much.

- Climate Change

Our planet is on the verge of a climatic catastrophe as a result of the endless production of greenhouse gasses like carbon dioxide and methane. The earth will be three to four degrees celsius warmer by the end of the century; whereas, ecosystems are adversely affected by every half-degree increase in temperature.

- Pollution

As the world's population increases—levels of pollution rise sharply, endangering many people's living standards. Deforestation would also likely have a negative impact on the environment and all animal species—including humans.

Now, if we take a close look at our own country, it is obvious that Bangladesh has also been severely harmed by deforestation. About 17% of Bangladesh's total land area, or 26,000 square kilometers, is covered in forests[1]. The Bangladesh Forest Department (BFD) owns and manages about 61.52% of the forest lands, the Deputy Commissioner (Executive Chief of a district) is in charge of 26.80% of the unclassified forest, and the community is in charge of 10.38% of the private woodland and community forests[1]. Bangladesh has one of the lowest per capita forestlands in the world while having rich biodiversity, largely because of the dense urban population. Moreover, the country has also experienced one of the highest rates of deforestation in South Asia—26 sq. km per year [1]. In Bangladesh, the top 1 regions were responsible for 93% of all tree cover loss between 2001 and 2020. This region had the most tree cover loss at 1830 sq. km compared to an average of 281 sq. km[1]. Therefore, preserving the forest with the use of technology is extremely necessary in the recent world.

1.2 Objectives, Requirements, Specification, and constant

1.2.1. Objectives

1. **Design smart monitoring systems to keep track of forested area reduction**
   Our data will be collected digitally so that an app or website can monitor it. Data will be readily available at all times and will be easy to use as a result. Additionally, the

UAV can provide us with a clear view of various forest regions, allowing us to monitor the area covered by trees. After processing this image, we can obtain a more or less precise representation of the forest's tree cover. To further reduce the loss of forests, our initiative will be able to offer information regarding a forest's deforestation.

2. **Collect information and observe various components of a forest scientifically, and save data for future use.**
   Our monitoring system will be able to determine the water and forest's air quality, including the health of the forest. This entire collection of data will be stored in the cloud. This will make it easier to collect data on the various forest elements, and the collected information may be compared over time to get a better sense of the forest over some time.
3. **Analyze data—to understand forest health conditions**
   Air and water sensors will provide us with data. The image of the forest will also be captured by our device, and this information will be analyzed and compared to the typical environmental conditions for forest components. We shall thus discover a general assessment of the health of the forest. We will be able to capture an image of the forest—so we can occasionally determine the canopy area of the forest with the use of image processing.

1.2.2 Functional and Nonfunctional Requirements

Functional:

1. **Capture forest images using UAVs:** To locate the areas of deforestation one of our major tasks is to collect images of those areas. As a part of the UAV, we want to capture those images using a UAV. At the same time, we can get an idea of the zones where we can do reforestation.
2. **Collecting water, and air samples:** We must assess the quality of the forest's components, such as its water and air, in order to evaluate the health of the forest as a whole. If one of them turns poisoned, the trees and animals can also be harmed. At the same time, in order to plant plants that are appropriate for that specific place, we need to understand the quality of each component used in reforestation.
3. **Sending data to the IoT cloud:** After collecting all the data from samples our task is to send them to the IoT cloud for further processing.Through this, we can get the proper information from each of the collected data and analyze them for preparing reports.
4. **Performing Image processing**: The captured images need to be processed through image processing.We need to perform image processing to get an enhanced image and extract the necessary information from the images.
5. **Analyzing collected data:** As we need to collect data for a certain time, we need to analyze the changes in every element with respect to time. That helps us to get the forest condition in different seasons.
6. **Preparing a report on overall forest condition:** Our final goal is to prepare an overall report about the condition of the forest. After analyzing all the data we can get

an idea of a particular forest condition. We want to prepare a report on it that provides the current forest situation in detail.

7. **Sending the report to appropriate stakeholders:** We can check the forest condition and can provide proper solutions but we can not apply those by ourselves as the forest is government property. The changes must be done by the appropriate authority. As a result, we have to send our report to them. Besides, scientists and researchers may need that data for their research purposes.

Non-functional:

1. **Ensure human and public property safety while flying the UAV**: While flying a UAV we keep in mind that any kind of harm should not happen to humans, animals, or properties. Lots of people work in forest areas for different reasons like collecting honey, cutting wood, or even hiking. We should keep their
2. **Taking permission from dedicated authority for flying UAVs**: For using UAVs we need to maintain the rules and regulations given by the government of the people's republic of Bangladesh.
3. **Take necessary battery backup for emergency purposes**: The life of a UAV comes from its battery. UAVs have frequently stopped operating as a result of battery failure. So, we can run into this quite frequently while performing our duties. This is why we always have extra batteries on hand in case of emergencies.
4. **Making sure that the entire process is done in an environmentally friendly way**: sample collection, Image capturing, UAV monitoring everything must be done in an organized way that would not create any adverse impact on nature.

1.2.2 Specifications

- **Water Quality Measurement**

The connection between forests and water may be seen in the direct impact that water availability has on the health of forests and the populations that inhabit them. Trees require a consistent water supply to thrive and sustain good health because they are made up of more than half water. On the other hand, forests in many parts of the world provide high-quality water for domestic, agricultural, industrial, and ecological requirements. In certain places, water supplies are intimately connected to the health of the forests. Wildfires can substantially affect aquatic ecosystems and community drinking water supplies by affecting the quantity and quality of water. Living things would face a different threat from poisonous forest water. This could be the result of several events, including wildfires, illegal human hiking, and so on. Again, forest water can be damaged due to acid rain as well. The forest water supply is linked to the nearest water source, such as a river, and if the water which comes from the forest area becomes affected, the river becomes polluted as well. For example, the Ratargul swamp forest is the only freshwater swamp forest located in the Gawain river, Sylhet. This forest goes underwater during the monsoon. If the forest is in pollution it may easily mix with the water and make the river polluted. Because of the lack of a suitable forest ecosystem, many species from this forest have already vanished.

In order to ensure the safety of the animals, trees, and people, we must protect the safety of the water. We'll use a range of sensors to gauge the water quality—using a turbidity sensor, the number of suspended solids in the water will be counted. Turbidity sensors use optics to measure turbidity using a liquid solution and a scattering rate of transmittance. The biological species that live in the water as well as people who drink it can be harmed by turbidity, which quantifies suspended materials. Water with high turbidity levels can be extremely harmful to ecosystems, agriculture, and human health. To determine the pH of the water, we will also utilize a pH meter. The pH of water indicates whether it is alkaline or acidic. A pH of 7 denotes neutrality; a pH of more than 7 suggests alkalinity; a pH of less than 7 indicates acidity. Acidity is common in forested areas [7].

- **Air Quality Measurement**

Air pollution directly harms trees by destroying living tissue, especially leaves, and interfering with photosynthesis and respiration. Furthermore, it weakens trees, making them vulnerable to additional harm from pests and diseases. The forest is one of the major ecosystems that affect the planet's temperature. In addition, the destruction of trees is a substantial source of greenhouse gases. They carry out important duties that enhance air quality, lessen city pollution by trapping particles and aerosols on the surface of the leaf, and absorb and reduce the air movements that cause them to rise to the surface. By eliminating CO_2, they also lessen the effects of greenhouse gasses. It has been demonstrated in numerous studies that a green zone around a city reduces the lead proportion by about 85%[8].

Carbon dioxide is absorbed by forests, which reduces global warming. In contrast to people, insects, and animals—trees are heavily affected by air pollution—because they cannot discharge dangerous chemicals through their pores or have lungs. If a tree's leaves start to fall off, it is typically thought to be dead. Trees don't actually perish for several months after air pollution starts to impact them. Typically, a tree loses more than half of its leaves at one time. Forest air pollution is one of many factors that might contribute to leaf loss. Even wildfires produce carbon dioxide (CO_2) and other toxins into the air and water, which kills plants and other animals.

As a result, to maintain a healthy forestry ecosystem, we must evaluate the air quality in a forest. We'll be in a better position to judge the state of the air and take the necessary precautions to keep it clean. The monitoring system will employ several sensors. The air quality will be monitored using the MQ-135 gas sensor, which also measures CO_2 and NH_3, and natural resource discovery will be done using the MQ-5 methane gas sensor. We'll utilize a temperature sensor, the DHT22 digital temperature humidity sensor, to gauge the temperature and humidity of the forest. Air temperature affects the growth and reproduction of both plants and animals, with warmer temperatures encouraging biological growth.

- **Forest Components (Biotic) Monitoring**

Although they can stand on their own—trees are usually seen in a group known as a forest. Living things (biotic) like trees, animals, plants, and other species make up forests. We will use the photo data from the UAV to obtain more detailed information on the forest—giving us a bird's eye view of it. Even though trees are an essential component of the forest, humans nevertheless, need to cut them down for a variety of reasons. Our goal is to deliver precise information on the number of trees existing in a forest; as sometimes without anyone's knowledge, a significant amount of a forest is heavily cut down, which decreases its overall area. So if we have the data regarding which part of the forest has the lowest tree density then decisions can be made accordingly. While this is happening, some forests are vanishing so rapidly that it will take some time before they can return to their natural state. So that the appropriate decisions may be made before it is too late to stop deforestation, our data will provide a particular forest density of trees or detect the area covered in trees. By doing this, a better natural environment for animals will develop.

The above-mentioned activities will require image processing that includes both—hardware and software expertise. Here, segmentation-based image processing will be used for detection. There is various hardware that is used for image processing, in our project we will be using Raspberry Pi. The Raspberry Pi has a dedicated camera input port that allows for recording video and high-resolution photos. Afterward, we will use Python and Specific python libraries written for the Pi and image processing to analyze them in real-time or save them for later processing.

Our target is to estimate the tree cover area—in this case, the image segmentation process will be used for image processing. Gaps' spatial features have a significant impact on forest regeneration dynamics and species mix. However, utilizing field measurements, such features might be difficult to quantify over broad spatial areas. As a result, image processing will be used.Image segmentation is the process where images get partitioned by their texture and it works by detecting discontinuities in brightness [9]. Image segmentation can be done in two ways: edge segmentation and region segmentation. All pixels that relate to an object are grouped and labeled to show that they belong to one region in the region-based method. Segmentation is the term for this procedure. We will utilize similarity measures for regions with homogenous gray levels, and we will build the regions recursively by including the adjacent pixels that are comparable and connected to that pixel. The procedure is iterated in the same way that any other data clustering technique is iterated. In a picture, a region is a collection of connected pixels with comparable properties. Because they may correlate to items in a scene, regions are significant for picture interpretation. An image may contain numerous objects, each of which may contain various regions corresponding to various portions of the item. A picture must be partitioned into regions that correspond to objects or parts of objects to be interpreted precisely. Because much of the shape information we need is included in the regions, this might be quite effective in extracting information from the image.

1.2.3 Technical and Non-technical considerations and constraints in the design process

- Weather Issue

Generally, common drones can not fly safely in adverse weather conditions[11]. If precipitation occurs, it gets inside a drone and ruins electrical components, and makes the drone inoperable, which can cause it to crash. Again, in windy conditions, the speed of the drone reduces to one-third of its maximum speed. So, to conduct our project properly, weather can be a big issue and we need to avoid strong wind, rain, and snow to fly the drone safely. Similarly, it is tough for the sensors to sense the data from the samples in bad weather conditions.

- Battery Life

Cold weather conditions can damage the lifetime of a drone strongly. Besides, though it is simple and easy to deploy sensors in a drone, one of the challenges is their limited lifetime issues[13].To get rid of this issue, we need to keep the battery in low power mode after using the sensor or use a larger battery which is also a problem as it is difficult to handle.

- Drone Balance and Flight Time

Operation of a drone is quite complicated as it requires proper orientation and alignment [12]. Lack of control may cause accidents. On the contrary, drone maintenance is also necessary for safe flying. We can lose control of the drone if any kind of malfunction happens in these parts. As for flying the drone in the air, the flight time can be an issue. Before every flight, we have to check if the battery is fully charged or not, keep the software updated, and motors and other parts of the drones must be in good condition.

- Forest fire

Wildfire is a general case for the forests though it is not that common in our country, again it can create problems to conduct our monitoring. Because due to smoke we may lose control of the drone and getting proper images will be difficult. Besides, sensors may fail to provide actual data [13].

- Permission

For flying drones we need to get permission from the air traffic control authority. This is one of our limitations as we can not fly drones at any time without authorization. Even this permission needs to be submitted 45 days before flying from the Civil aviation authority of Bangladesh(CAAB) [14].

- Pollution (Sound)

While flying a drone, the propellers of it are rotating very fast which creates a sound that people may find disturbing[15]. This type of continuous sound also creates an unfavorable impact on the forest as it destroys its calmness of the forest. Even wild animals and birds may get frightened after hearing this noise. As there is not any solution to this problem yet it would be a great challenge for us.

1.2.4 Applicable compliance, standards, and codes

To conduct this project, we need to follow some international protocols and standards. There are a few standards that we should obey to design our project.

P2700/D1.00, Dec 2013 - IEEE Standard for Sensor Performance Parameter Definitions This standard denotes a framework for the performance of sensors, their limitations, conditions, etc. The reliability, and performance of temperature, humidity, and other types of sensors are discussed[33].In this project, one of our tasks is to measure the conditions of forest elements such as soil, water, air, etc. We need to use different types of sensors to measure their quality. So, we should follow this standard.

IEEE 2413-2019 - IEEE Standard for an Architectural Framework for the Internet of Things (IoT) adheres to the international standard ISO/IEC/IEEE 42010:2011, which includes descriptions of various IoT domains, definitions of IoT domain abstractions, and identification of commonalities between diverse IoT domains[34]. This standard discusses an Internet of Things architecture framework definition (IoT). The use of IoT in projects is also defined by this code. IoT is one of the most effective growth accelerators for many technological deployments nowadays. This standard must be followed to build the system because all quality measurement data must be gathered and transferred to the IoT cloud. Then, gathering and analyzing those cloud-based data will be our next responsibility. The IoT will assist the stakeholders in connecting and obtaining the information they need.
ISO/IEC 21990:2002—specifies the GSM 03.40. service in the telecommunication system with the support of Short Message Service (SMS).[35] In our project in the GSM module, we are using a cellular data connection for transmitting data that is connected to the standard of ISO/IEC 21990:2002. As this standard follows fellows we need to maintain this.
IEEE 1936.1-2021—states the Draft Standard for Drone Applications Framework. This standard has established drone applicability in this case. It contains fundamental drone application classes, application situations, and environment execution. It also refers to the management of drone safety and its standards, including those for airworthiness and air traffic, operator qualifications, and others. [36]. Drones are being used to track the number of trees in the forest and identify regions that are being deforested (UAVs). We record images through the operation results and provide the data for additional processing. We must adhere to IEEE 1936.1-2021 guidelines for this.

The Bangladesh agency responsible for drone safety, the **Civil Aviation Authority of Bangladesh(CAAB),** has provided several internet-accessible details on flying for fun or work.

Important rules and regulations from CAAB [14]

1. Any person conducting such operations shall be responsible for conducting a safe operation and shall not pose a risk to aviation safety.

2. Any person conducting such operations shall be of a minimum age of 18 years.

3. Any person conducting such operations shall subscribe to appropriate liability insurance covering risks of injury or damage to public and/or property.

4. The pilot shall not operate an RP AS within eight hours after consuming alcohol, while intoxicated, or while using any drug that compromises judgment to the point that the operation's safety is in any way threatened. Illicit substances, as well as prescription and over-the-counter medications, may cause impairment.

5. Any person conducting operations shall obtain permission from the owner(s) of the property on which an RP AS intends to launch from and/or land/recover.

6. The pilot must have a fire extinguisher on hand at all times

7. Do not fly your drone higher than **60 meters** (200 feet)

8. Do not fly your drone over people or large **crowds**

9. Respect others' privacy when flying your drone

10. Do not fly within **9 km** (5 miles) of built-up areas

11. Stay **300 meters** (1000 feet) away from buildings, people, and vehicles

12. Do not fly your drone within 18.5km (10 miles) of airports or in areas where aircraft are operating

13. Must fly during daylight hours and only fly in good weather conditions

14. Do not fly your drone farther than a visual line of sight – FPV equipment is not allowed unless specifically permitted

15. Do not fly your drone in sensitive areas including government or military facilities. The use of drones or camera drones in these areas is prohibited.

Permission: One has to obtain permission from the air traffic control authority before any maneuvers. **Authorization**s have to be submitted **45** days in advance to the Civil Aviation Authority of Bangladesh (CAAB)[14].

As we want to conduct the monitoring system using drones, we need to maintain these International and national codes and standards since any kind of violation of those codes and conducts may lead to legal action or even cause accidents.

Since we will be collecting our data digitally, an app or website can be used to monitor them. Data will be readily available at all times and will be easy to use as a result. Additionally, the drone can provide us with a clear image of various forest regions, allowing us to monitor the area covered by trees. After processing this image, we can obtain a more or less precise representation of the forest's tree cover. To further reduce the loss of forests, our initiative will be able to provide information regarding forest deforestation.

Our monitoring system will be able to pinpoint the origins of pollution—which typically affects air, water, or soil, as well as the locations of bushfires. By monitoring wildlife's habitat and physical condition without impairing it in its natural state, the observation of the forest can be expanded to include animals. This entire collection of data will be stored in the cloud. This will make it easier to collect data on the various forest elements, and the collected information may be compared over time to get a better sense of the forest across a range of time.

In addition to the image of the forest being captured by our drone camera, we will also receive data about the air, water, and soil via sensors. This data will be analyzed and compared to—the typical environmental conditions for forest components. So, we will discover a general assessment of the health of the forest. We will be able to capture an image of the forest, so we can occasionally determine the canopy area of the forest with the help of image processing.

1.4 Conclusion

We will use a UAV in our project to monitor the biotic components of the forest to maintain track of the health of the forest. The water and air quality in the forest will be monitored by our sensors, but our UAV will also occasionally compute and record forest regions. We are deploying UAVs with cameras and sensors, and we will utilize image processing and machine learning to ensure precise data from the data obtained. This will help us get the best and most accurate findings from our data.

Chapter 2

Project Design Approach

2.1 Introduction

It is impossible to exaggerate how important forests are. We are dependent on the forests for our most fundamental survival necessity—oxygen. In addition to offering homes for animals and a means of sustenance for people, forests also preserve watersheds and slow down global warming. As the second-largest carbon sink, forests help to absorb harmful greenhouse gasses that contribute to climate change. In other words, the forest gives us access to clean water for drinking, bathing, and other domestic needs; lessens chemical pollution and soil erosion, provides food and medicine, serves as a buffer against natural disasters like floods and heavy rains—and serves as a habitat for more than half of the world's land-based species. That's why we need to protect the forest. In modern days we have different monitoring systems, which were used in the past a little, and can be used in the future with further modification.

2.2 Identify multiple design approaches

I. Manual Remote Sensing
II. Robotic Ground Vehicle
III. Unmanned Aerial Vehicle - UAV

2.3 Describe multiple design approaches

1 . Manual Remote Sensing

The use of intelligent technologies in conjunction with human labor is the most crucial component of mobile monitoring or remote sensing. This technique required human effort to complete, but it was assisted by a variety of smart devices. A major obstacle to this method is human labor. A human cannot monitor the entire forest from every angle. On the other hand, monitoring forest—involving human labor—routinely, is a risky task while it will take longer and involve more work, this approach will yield fewer data points.

Figure 1: Forest monitoring human approach [3]

In this monitoring process human approach in every segment like land(soil), water and deforestation will be monitored by counting or assuming data from that area of the forest which will be time-consuming and costly.

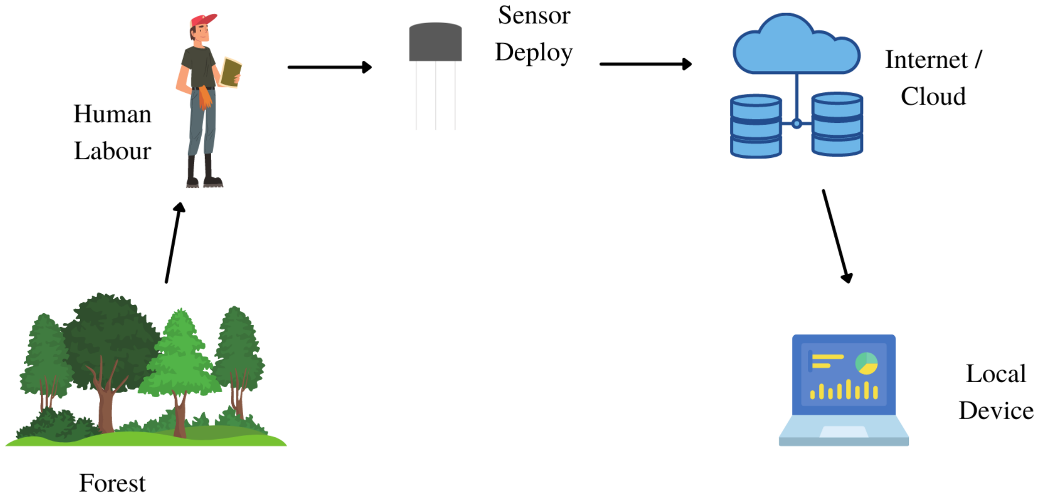


Figure 2: Forest monitoring human approach flow

2. Robotic Ground Vehicle

In this method, the environment is monitored by robotic vehicles equipped with numerous sensors. The robotic vehicle, which can be operated remotely, produces results of the same caliber as conventional surveying while posing no threat to human health and safety and using a fraction of the manpower normally required.

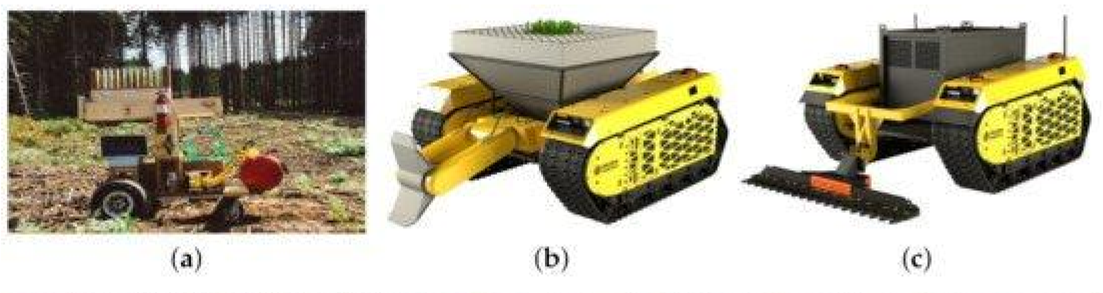


Figure 3: Examples of robotic applications used in forests for planting, pruning, and harvesting tasks: (**a**) TreeRover, (**b**) Multiscope Forester Planter, (**c**) Multiscope Forester Brushcutter [4]

Because the forest is an unstructured environment, it is challenging to detect. Localization and navigation in a forested environment are two of the most difficult tasks in robotics. Mobility is another highly challenging task. On the surface of the forest, controlling the car is particularly challenging. Robotic vehicles are limited in their range compared to drones. Vehicle-based deforestation detection is difficult and time-consuming.

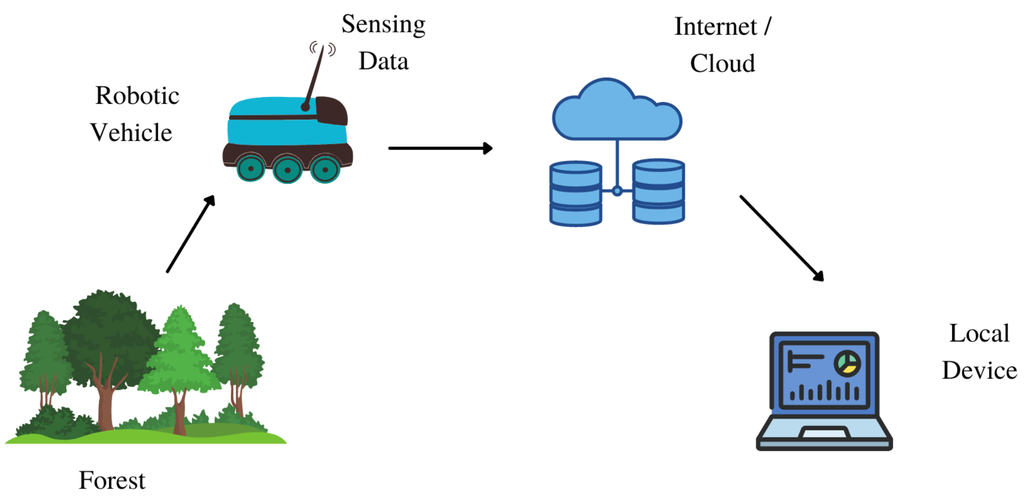


Figure 4: Flow of robotic vehicle approach of forest monitoring

3. Unmanned Aerial Vehicle - UAV

Technology advancements rapidly accelerate in terms of capabilities and cost-effective integration. Recent technical advances in drones make them increasingly relevant and important tools for forest measurements [5]. Unsafe work environments continue to be a problem for the surveying industry, with limited or even prohibited access causing project delays, higher dangers, and difficulties in collecting measurement data on time. Drone rather than other ways is the best answer in this case. Small-scale commercial fixed-wing or multi-copter drones fill a niche in this portfolio of sensor platforms, as they provide information at high spatial resolution for target areas and have been proven flexible and cost-efficient concerning flight scheduling and weather conditions [5]. It has become an integral tool for mapping and monitoring large projects in much of the world. It can be obtained at reasonable costs and can be perceived as a forester's eye in the sky, capable of performing forest inventory and analysis periodically. These lightweight machines can be remotely operated from the ground and can fly below the cloud cover.

The approach of forest image segmentation can be more accurate data on forest cover area. Comparing one point cloud data set to another is currently a popular monitoring survey approach for analyzing deformation, especially in complicated or dangerous contexts. Using the drone to obtain point-cloud data sets allows us a comprehensive picture output, allowing us to measure, analyze, and show any change between surveys over time.

To monitor the air quality Gas sensors are embedded in the drones which will collect data from the environment. On the other hand to collect the water and soil; the equipment is attached to drones with the appropriate functions.

2.4 Analysis of multiple design approach

Manual Remote Sensing

Human labor combined with smart technologies is the most significant part of mobile monitoring or remote sensing. This technique was completed using human labor and a variety of smart devices. With this method, human labor is a huge challenge. For monitoring, it is difficult for a human to visit every corner of the forest.

Monitoring Process

Human labor monitoring was commonly used in the past days of the forest monitoring system. In that approach, human life may fall into hazardous and high-risk situations.

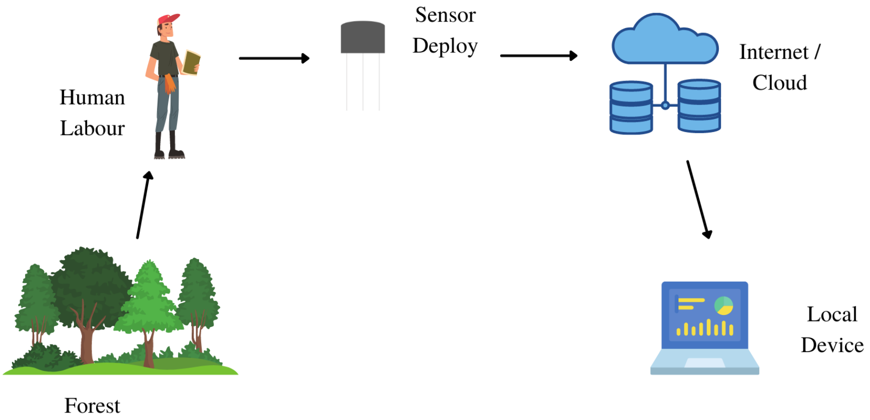


Figure 5: Flow of forest monitoring with manual remote sensing

This way will take more time and effort, but the amount of data obtained will be smaller, and the procedure will be longer. Human methods in every segment such as land, water, and deforestation will be monitored in this monitoring procedure by counting or assuming data from that part of the forest, which will be time-consuming and expensive.

Robotic Ground Vehicle

Robotic ground vehicles equipped with a variety of sensors are utilized to monitor the environment in this technique. The robotic ground vehicle, which is controlled remotely, produces the same high-quality results as traditional surveying, but without putting people's health and safety at risk, and with fewer people involved than would normally be required.

Monitoring Process
The unstructured nature of the forest makes it tough to perceive. Localization and navigation in the forest, which are exceedingly challenging issues, are one of the most important tasks in robotics. Mobility is another exceedingly challenging task.

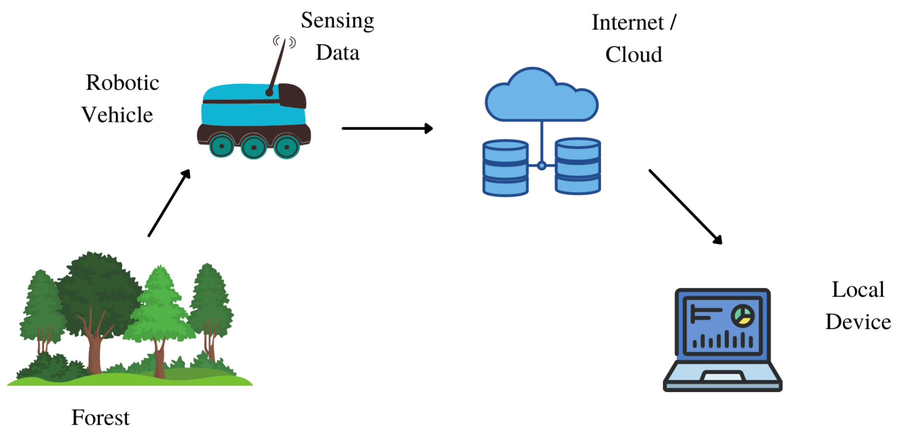


Figure 6: Flow of robotic ground vehicle approach to forest monitoring

On the forest floor, controlling the vehicle is quite tough. Robotic vehicles will complete the task of sample collection and the canopy cover area detection with expensive technology like LiDAR.But robotic ground vehicles cannot travel as far as a UAV.

It's difficult and time-consuming to identify the canopy area with a robotic ground vehicle. Because it can not take the full view of the forest from the forest floor. On the other hand, this technology is expensive to buy in developing countries.

Unmanned Aerial Vehicle - UAV
Technology advancements rapidly accelerate in terms of capabilities and cost-effective integration. Recent technical advances in UAVs make them increasingly relevant and important tools for forest measurements [5]. Unmanned aerial vehicles; can fly with remote control or autonomously. Unsafe work environments continue to be a problem for the surveying industry, with limited or even prohibited access causing project delays, higher dangers, and difficulties in collecting measurement data on time. UAVs are the best answer in this case.

Monitoring Process
Small-scale commercial fixed-wing or multi-copter which are under UAVs fill a niche in this portfolio of sensor platforms, as they provide information at high spatial resolution for target areas and have been proven flexible and cost-efficient with regards to flight scheduling and weather conditions [5]. It has become an integral tool for mapping and monitoring large projects in much of the world. It can be obtained at reasonable costs and can be perceived as a forester’s eye in the sky, capable of performing forest inventory and analysis periodically.

These lightweight machines can be remotely operated from the ground and can fly below the cloud cover.

To monitor the air quality Gas sensors are embedded in the UAV which will collect data from the environment. On the other hand, to collect the water the equipment is attached to the UAV with the appropriate function. The approach of forest image segmentation can be more accurate data on forest cover area.

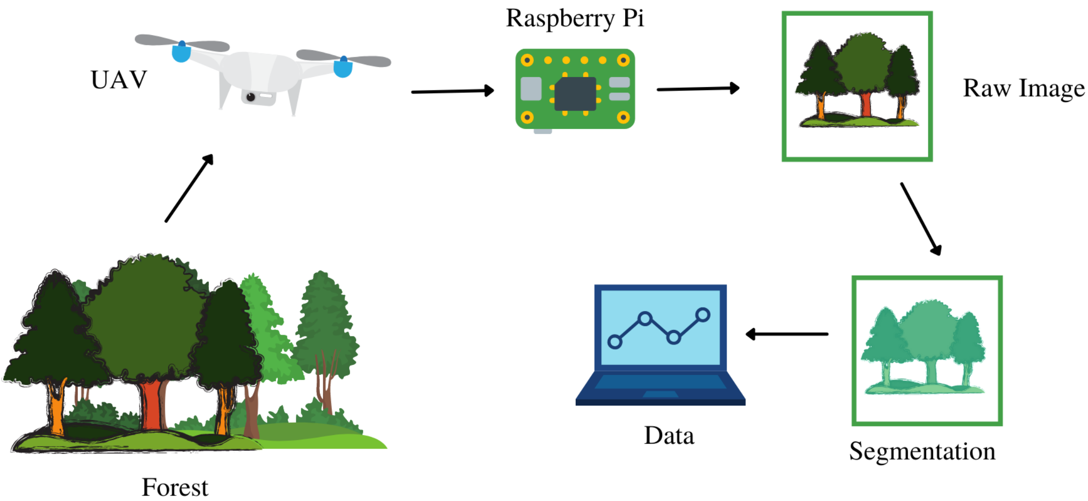


Figure 7: Flow of image segmentation to capture forest cover area

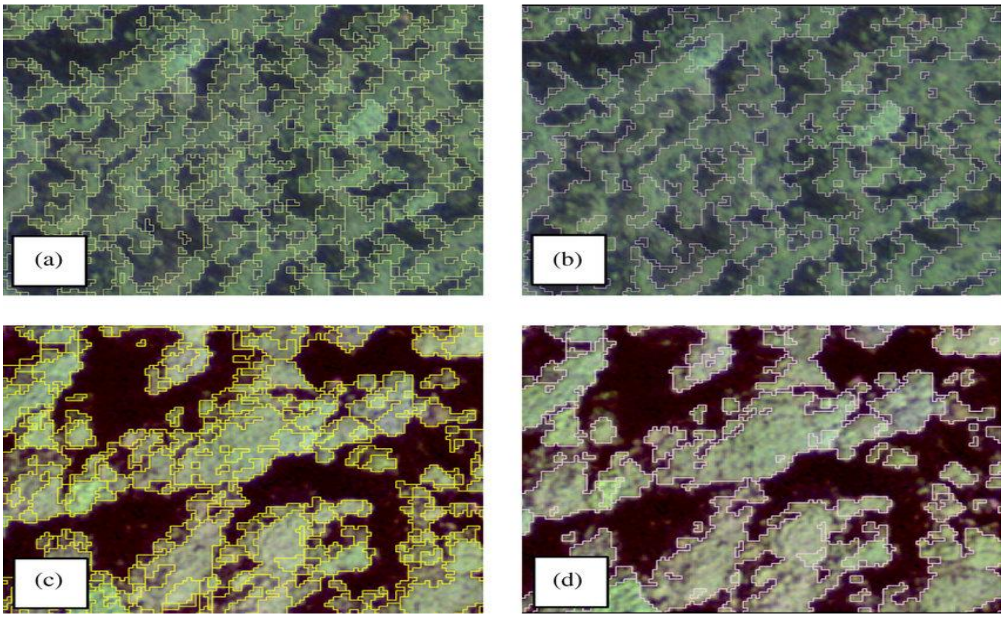


Figure 8: Segmentation result of forest cover area [6]

Comparing one point cloud data set to another is currently a popular monitoring survey approach for analyzing deformation, especially in complicated or dangerous contexts. Using the UAV to obtain point-cloud data sets allows us a comprehensive picture output, allowing us to measure, analyze, and show any change between surveys over time.

2.5 Conclusion

GIS (Geographic Information System) specialists have a lot of potential with drone monitoring. Topographic surveys may be carried out with a drone that is of the same high quality as those gathered using traditional methods but in a fraction of the time. This significantly minimizes the expense of site monitoring as well as the workload of field personnel.

Using a drone to collect topographic data (information about the elevation of the Earth's surface) is up to five times faster than using land-based methods and requires fewer people. Finally, outcomes are delivered faster and at a reduced cost.

A drone capable of aerial mapping can take off and fly to practically any place. As a result, it is no longer limited by inaccessible places or dangerous steep slopes for monitoring; in this scenario, typical measuring equipment is insufficient. It is capable of capturing data while in use.

Chapter 3

Use of Modern Engineering and IT Tool

3.1 Introduction

Technology is a part of modern engineering—but it is also focused on the advancement and comprehension of technological systems, their products, effects, and appropriateness. Additionally, non-technological methods are a concern. We have used various modern engineering tools for this project. This is accomplished by first making an effort to learn how the tool is used, using it to comprehend topics in appropriate courses, and then applying it to—develop, design, implement, and demonstrate an individual work. This has allowed us to get proper knowledge, and results for the analysis of the data collected. We have properly explained each of the tools for this project.

3.2 Select appropriate engineering and IT tools

Hardware

UAV

The major component of our monitoring system is the unmanned aerial vehicle (UAV), which we use to meet our specifications and criteria. The UAV will be flown over the forest area to capture photos and environmental data. Unmanned Aerial Vehicles are employed for tasks that humans cannot complete or that are dangerous.

UAVs were originally designed for the military and aerospace industries, but due to their safety and efficiency, they have found their way into the public. It is now employed in practically every industry. UAVs have shown to be quite useful in the surveying industry. UAVs may travel over a wide range of heights and distances. Close-range UAVs, which are essentially quadcopters controlled remotely and capable of traveling up to three miles, is largely utilized by ordinary people. UAVs can be used for intelligence gathering, scientific studies, and meteorological research in a variety of ways. They're ideal for taking on some of the world's most challenging occupations thanks to their comfortable control system.

Raspberry Pi

A single-board computer, or Raspberry Pi, is a small computer with a single processor. They are intended to educate programming skills, construct hardware projects, perform home automation, and investigate industrial computer applications. Itares based on the Linux operating system and features general-purpose input and output pins that enable users to manipulate electronic components for physical computing and Internet of Things exploration (IoT).

Linux is the operating system used by all Raspberry Pi models. Linux is an open-source operating system that connects the hardware and software on a computer. It has now become the most convenient method of performing any machine learning or robotics task. The

Raspberry Pi Zero or Raspberry Pi Zero W are the most basic models; the Zero W has WiFi and Bluetooth capabilities, whereas the Zero does not. To implement the software design with the hardware, we used a Raspberry Pi 3B+ in our project. It has the features that we require to complete our tasks; for example, we can analyze and develop Image Processing and Machine Learning methods using it.

Camera

There will be a camera attached to the UAV for capturing photos of the forest that are required for analysis. The use of the camera is quite self-explanatory as we need images for our data collection. Here we will use a NOIR camera that has night vision. In low light, we can also capture images from the UAV. The camera will be equipped with a UAV.

Syringe Pump

The water collection method used here is a syringe pump. An RC remote will be used to operate this machine. It will be simple to gather the water sample using this technique. This syringe pump's key component is a servo motor that will be operated remotely. This component is portable and simple to mount on the UAV.

Syringe drivers—also known as syringe pumps—are powered tools that precisely control the flow of fluid from a syringe by manually advancing or retraction the plunger. Stepper motors are used in syringe pumps to precisely move a platform that is coupled to the plunger of a syringe. The syringe's body is secured to the unit's body such that the motor's movement is the only source of movement. Simple models can be employed for the regulated infusion (and occasionally withdrawal) of liquids at a predetermined pace.

Figure 9: Syringe Pump

Multiple Sensors

Although there are various sensors available for measuring air quality, we use the MQ135 sensor. In this instance, sensors for both humidity and temperature will be employed. The UAV will be equipped with all of these sensors. The pH level of the water will be the key factor in determining the water quality when we take the sample. To determine the total suspended solids in the water, the turbidity sensor will be employed once the water sample has been collected. Using a liquid solution and a scattering rate of transmittance, turbidity sensors use optics to measure turbidity.

Software

Ardupilot

ArduPilot is an open-source autopilot technology for rovers, boats, submarines, multi-copter aircraft, and fixed-wing aircraft. For the benefit of all, ArduPilot helps us create and implement dependable, autonomous unmanned vehicle systems. Although ArduPilot does not manufacture any hardware, its software can be used to control a wide range of unmanned vehicles. When paired with ground control software, unmanned vehicles running ArduPilot can have improved capabilities, including real-time communication with operators. Both PCs and portable electronics can use the program. Advanced packages enable autonomous mission planning, execution, and post-mission analysis. As the main monitoring medium in our study, it is used to calibrate the quadcopter's motor.

Fusion 360

An online 3D modeling and CAD program is called Fusion360. It is utilized in the creation of products. Using this software is easy. because UAVs play a significant role in our surveillance system. The quadcopter or UAV frame we used isn't very adaptable. To meet our requirements, the frame must be altered or attached in some way. We'll need 3D software to design that part because of this. As an illustration, water samples will be taken using a syringe pump. This component must meet our design requirements and easily fit into the quadcopter frame.

Google Colab

Another platform for programming is Google Colab which is also handy for programming using a local server. We utilize this platform to analyze forest data. We calculated the forest health using CSV files in Google Colab using various criteria for the various forest components. We can use the forest's current state of health after assessing its constituent parts.

- **Image Processing**

As we have to do image processing to complete the requirements of forest biotic monitoring we used different software to run our code and make the machine learning model.

Jupyter Notebook

Jupyter notebook is a coding environment that is interactive and web-based. Users can configure and arrange workflows in data science and machine learning using its versatile interface. This mostly uses the local device as a disk to save the machine learning model's data set. We execute the code in a Jupyter Notebook, and our machine-learning model has flawless accuracy.

Kaggle
We use Kaggle to refine our machine learning model so that it is more accurate and works better on the Raspberry Pi. Kaggle is a web-based coding environment. Kaggle has a cloud system for storing large amounts of data needed to train machine learning models. Users can search for and publish data sets, as well as explore and develop models. There is a community framework in place where people may collaborate and exchange data science and machine learning work. Kaggle has a better accuracy level of 83% than Jupyter Notebook, which is 72%.

3.3 Circuit Simulation

Proteus 8 Professional
Proteus is a proprietary software suite that is mostly used for electronic circuit design and simulation. The software is used by electronic design specialists and technicians to create schematics and electronic prints for printed circuit board manufacturing. For circuit simulation, we used Proteus Professional 8. Simulation shows us which way we should solder the components to one other to get the best results.

Matlab Simulink
Simulink is a graphical editor with customizable block libraries and solvers for modeling and simulating dynamic systems. Matlab Simulink techniques are used to simulate the results for further analysis. It is used for modeling, simulation, and analysis of dynamic systems in their proper environment. We utilize Matlab Simulink to model the quadcopter's basic structure and the human workflow in a forest environment.

3.4 Use of modern engineering and IT tools

Image Processing
Due to the need for image processing for forest biotic monitoring, we used distinct tools to run our code and build the machine learning model.

Matlab Simulink
Simulink is a graphical editor for modeling and simulating dynamic systems. It comes with adaptable block libraries and solvers. The results are simulated using Matlab Simulink tools for additional examination.

Multiple Sensors
Although there are various sensors available for measuring air quality, we use the MQ135 sensor. In this instance, sensors for both humidity and temperature will be employed. The UAV will be outfitted with all of these sensors.

UAV

An unmanned aircraft or vessel that is piloted remotely or automatically is referred to as a drone. An example of a multi-copter drone is seen above. An unmanned Aerial Vehicle, or UAV for short, is a flying object without a pilot.

The unmanned aerial vehicle (UAV), which we utilize to meet our requirements and criteria, is a key part of our monitoring system. To take pictures and gather environmental data, the UAV will fly over the woodland area. Unmanned aerial vehicles are used for jobs that are risky or impossible for people to complete.

3.5 Conclusion

For this project, we used a wide range of modern engineering technologies. As a result, we were able to analyze the information collected and produce accurate results. Each of the tools used in this project has been fully explained. Utilizing these numerous tools has helped us better comprehend advanced technologies, including hardware development and programming.

Chapter 4

Optimization of Multiple Designs and Finding the Optimal Solution

4.1 Introduction

The environment and economics of the world depend heavily on forests—as all living species directly or indirectly depend on them. Nowadays, due to natural and manmade disasters forests are in danger. To maintain, or improve the health and productivity of a forest and to achieve the forest safety objectives, proper monitoring and maintenance need to be ensured. Forest management is looking for new ways to survey land and maintain it with the help of modern technology. All the possible ways have both positive and negative sides. Among them, we need to find the optimal one which can provide us with maximum output with minimum errors. The major goal of our research is to use continuous data and information to monitor the forestry environment and save the forest ecosystem. For that, we choose different solutions for the monitoring system and choose the suitable ones for monitoring the system and analyzing the design from various angles.

4.2 Optimization of multiple design approach

There are three design approaches for our monitoring system.

1. Manual Remote Sensing
2. Robotic Ground Vehicle
3. Unmanned Aerial Vehicle - UAV

4.2.1 Manual Remote Sensing

The most important aspect of manual remote sensing is human labor mixed with smart technologies. In the early days of the forest monitoring system, human labor monitoring was widely used. Human life may be put in perilous and high-risk situations as a result of this technique. Technologies in this system are IoT-based devices that are used to collect data for specific parts of forest health.

Table 1: Basis of Analysis Manual Remote Sensing

Air Quality Measurement	Water Quality Measurement	Forest Biotic Monitoring
Sensor Initialization	Sensor Initialization	Area Measurement
Humidity and Temperature Measure	pH Measure	Vision
Sensors Result Collection	Sensors Result Collection	Accurate Analysis
Sensor Data Analysis	Sensor Data Analysis	

Workflow of manual remote sensing

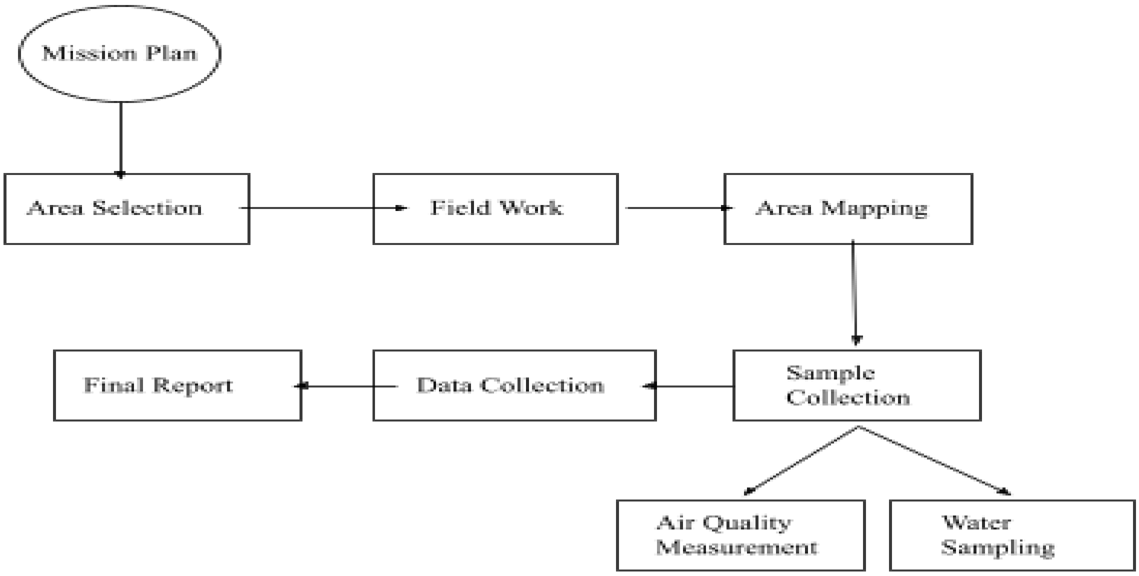


Figure 10: Forest monitoring manual process

Simulation

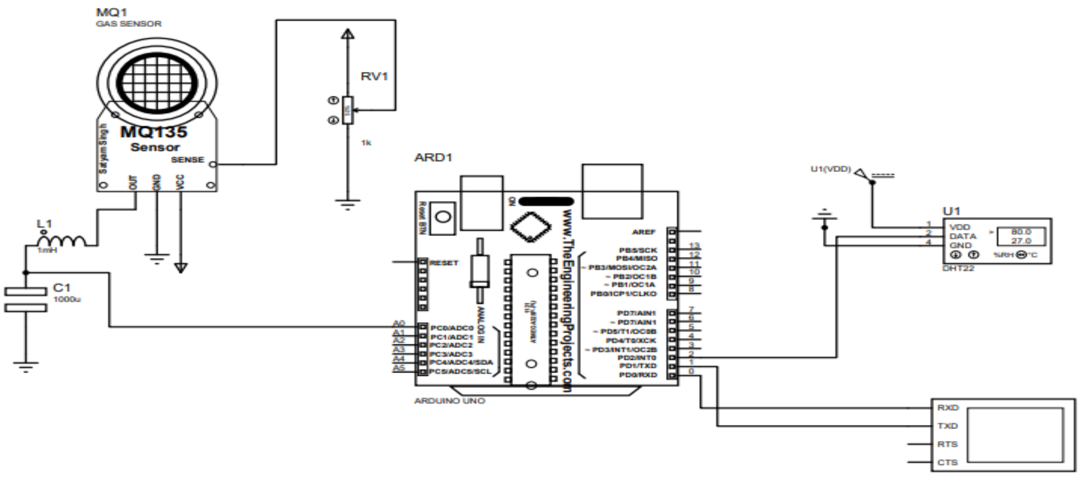


Figure 11: Air quality measure device circuit simulation

There is a Matlab Simulink demonstration of human manual workflow in the forest area with simulation. In that, we simulate the skills humans need to work in a forest environment.

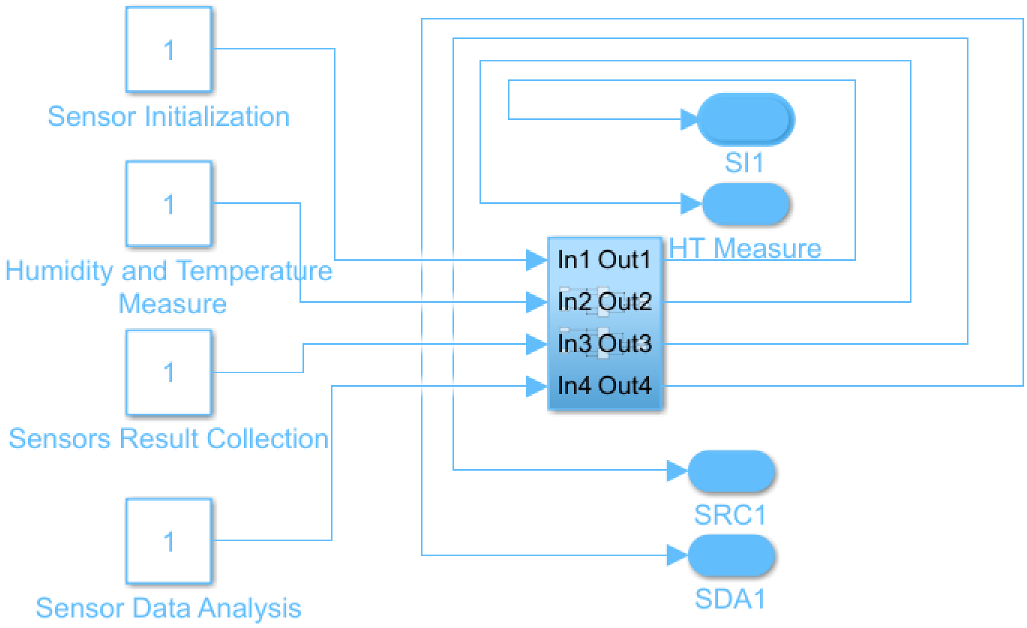


Figure 12: Basis of Air Quality Measurement

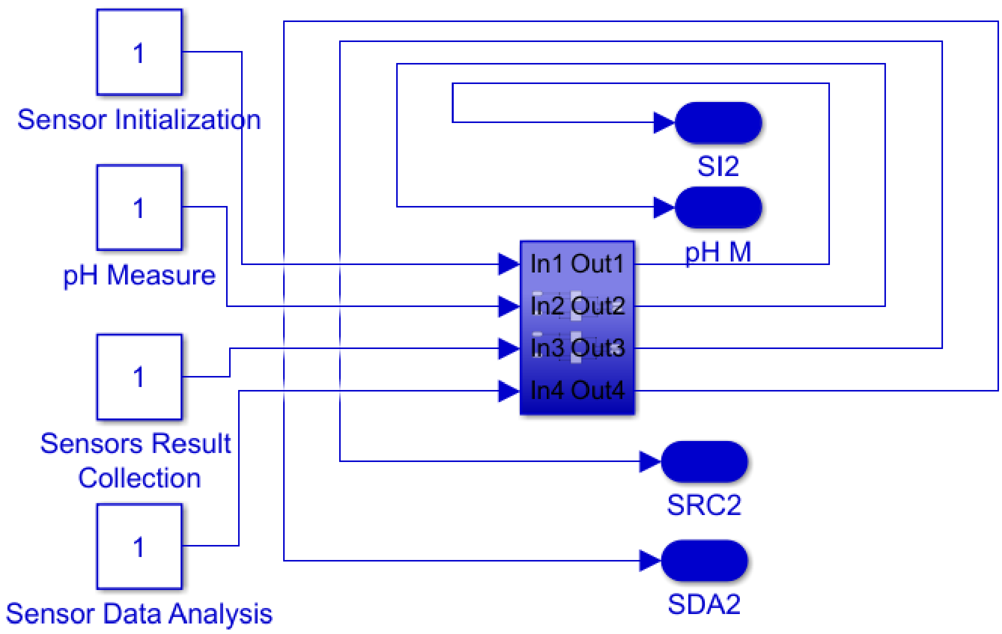


Figure 13: Basis of Water Quality Measurement

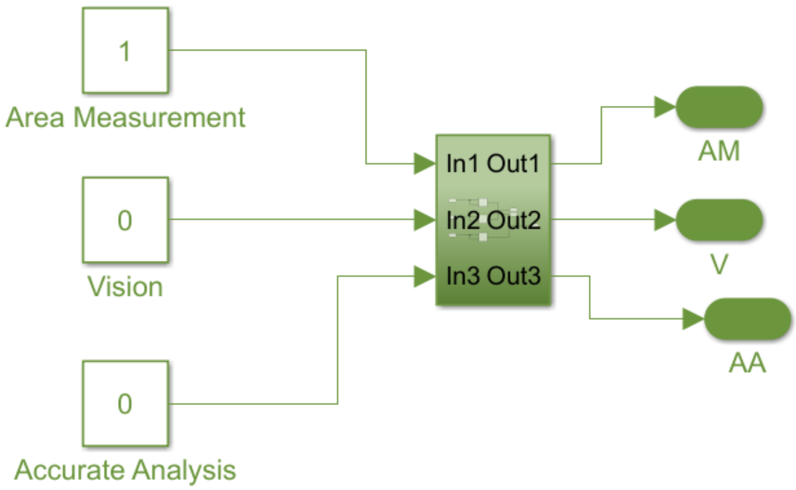


Figure 14: Basis of Forest Biotic Monitoring

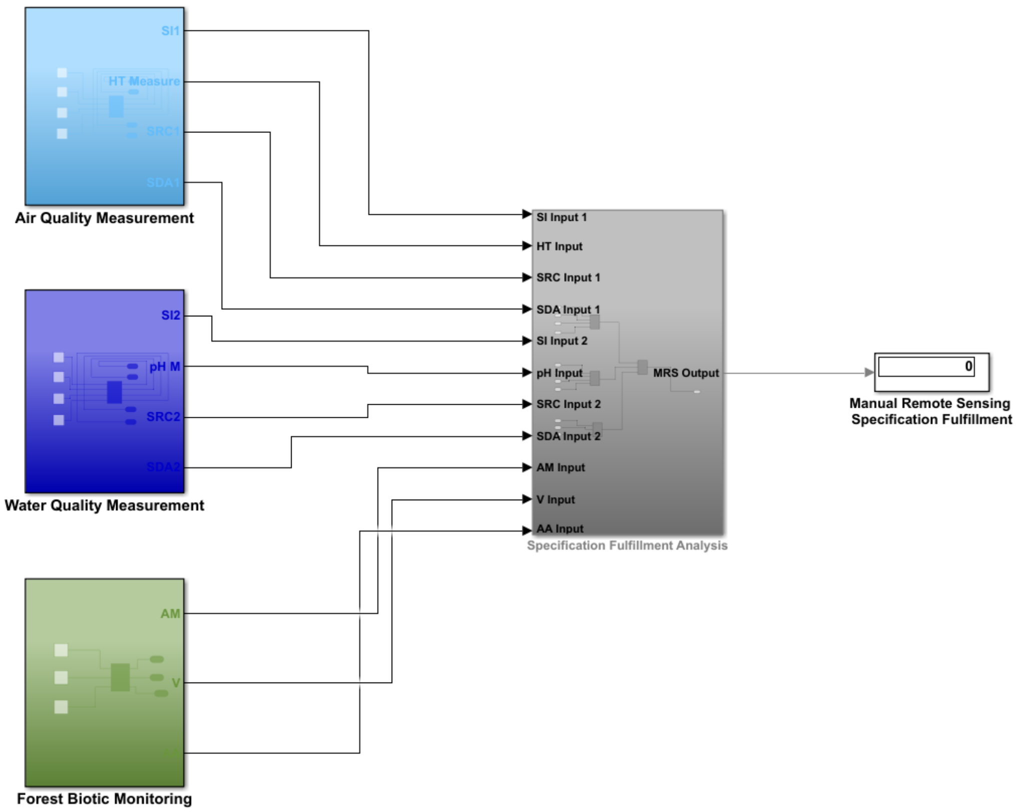


Figure 15: Manual Remote Sensing Specification Simulation

Here, we see that the final output is zero. Though humans can do the quality measurement of air and water, they cannot get the proper view of the canopy area of the forest to map the area with appropriate data. So, all three specifications can not be fulfilled by manual remote sensing. That’s why the final result is zero. We can see that in the simulation result.

4.2.2 Robotic Ground Vehicle

In this technology, robotic ground vehicles equipped with a variety of sensors are used to monitor the environment. The robotic ground vehicle, which is controlled remotely, gives the same high-quality data as traditional surveying, but without endangering people's health and safety, and with fewer people involved than would be required otherwise.

Table 2: Basis of Analysis Robotic Ground Vehicle

Air Quality Measurement	Water Quality Measurement	Forest Biotic Monitoring
Sensor Initialization	Sample Collection	Mapping
Humidity and Temperature Measure	pH Measure	Vision
Sensors Result Collection	Sensors Result Collection	Accurate Analysis
Sensor Data Analysis	Sensor Data Analysis	

Simulation

The way information on forests is acquired and processed has changed dramatically over the last two decades as a result of technological advancements in remote sensing and processing capabilities. Airborne laser scanning (ALS), often known as LiDAR scanning, has been the primary method for creating estate-level forest inventories in Fennoscandia. Ground vehicles will be able to collect data about the forest air and can collect data about the forest canopy area with help of LiDAR.

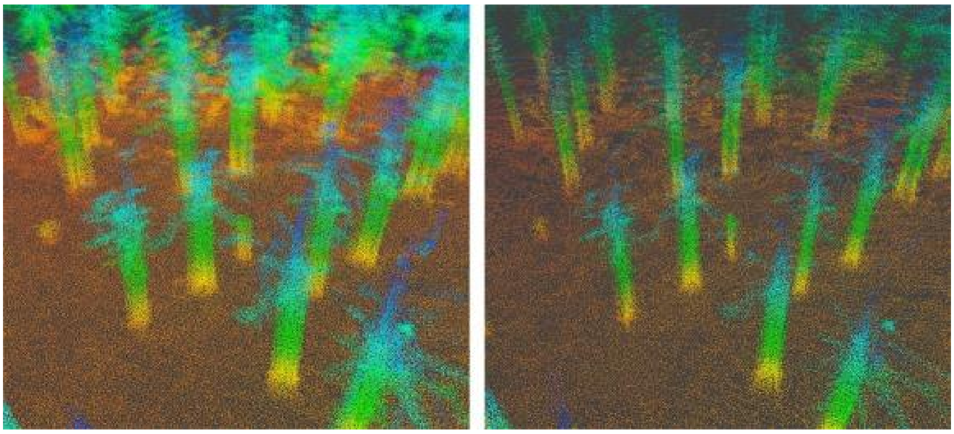


Figure 16: LiDAR 3D mapping of forest area [27].

To conduct the field tests, the survey people should build a dedicated mobile platform on top of a standard 4-wheeled rover ‘Superdroid 4WD IG52 DB’, which was controlled via a Spektrum DX5e remote controller for driving the vehicle in the forest [27].

Figure 17: Four-wheeled rover Superdroid 4WD IG52 DB [27].

An aluminum frame bolted on top of the Superdroid was used to carry the various sensors. At the highest point of the frame was our main sensor for mapping, a Velodyne VLP-16 LiDAR, used for the acquisition of the 3D point clouds [27]. Here the Velodyne VLP-16 LiDAR cost around 4000 US dollars [28] which is around 346,389 BDTk according to the current dollar price. Which is quite expensive if we calculate the total cost of the ground vehicle. This design of robotic vehicle can be used on land but the ground robotic vehicle will not be able to collect the water sample. The vehicle is not waterproof so it will not work in water.

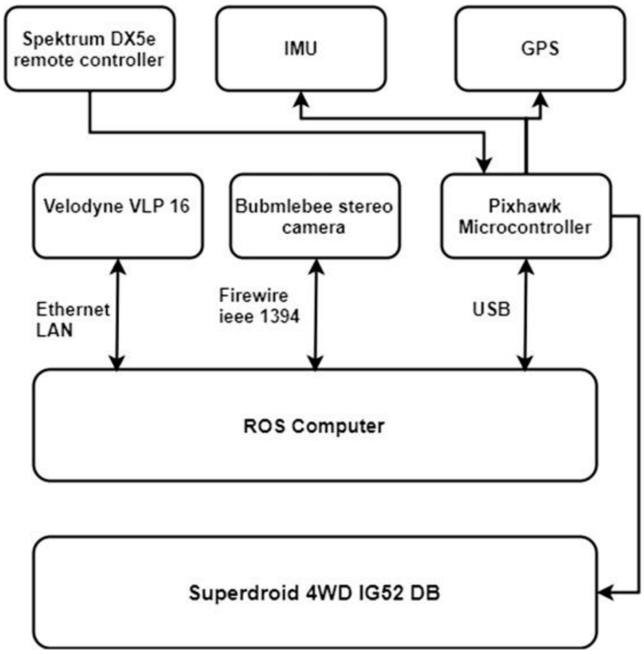


Figure 18: Ground Vehicle Structure [27]

4.2.3 Unmanned Aerial Vehicle - UAV

Simulation

For plantation forests to remain healthy and extremely productive, research into remote sensing technologies for monitoring stress response brought on by biotic and abiotic variables is essential [25]. The assessment of forest health using remotely sensed data from piloted aircraft and satellites has received significant scientific attention[25]. The use of unmanned aerial vehicles (UAVs) to collect data with extremely high temporal and spatial resolutions may result in the development of new tools for enhanced forest health monitoring[25]. Forest plantations offer a wide range of economic, social, and environmental advantages throughout many regions of the world. The third-largest source of export revenue in New Zealand is forestry, which generates almost $5 billion annually and directly employs 18,000 people [25]. By extending the spatial coverage and providing unbiased evaluations of tree and forest health, contemporary remote sensing methods can enhance ground-based surveys. The best sensor and resolution can be chosen based on the targeted sensitivity of the surveillance as well as the biological responses of the stressor on observable features like the spectral characteristics of foliage. The expanded area that can be covered and analyzed via remote sensing is often significant, and full coverage may even be attainable with the right sensor selection and resolution established, greatly enhancing the accuracy and thoroughness of surveillance [25].

There are several research studies about this fact, forest surveillance with UAV. One of them is in New Zealand which has great forest resources. The study site was located in Kinleith Forest in New Zealand’s Central North Island (Fig:15) (latitude 38° 24′18.74S, longitude 176° 0′59.28E), approximately 28 km southeast of the township of Tokoroa [25].

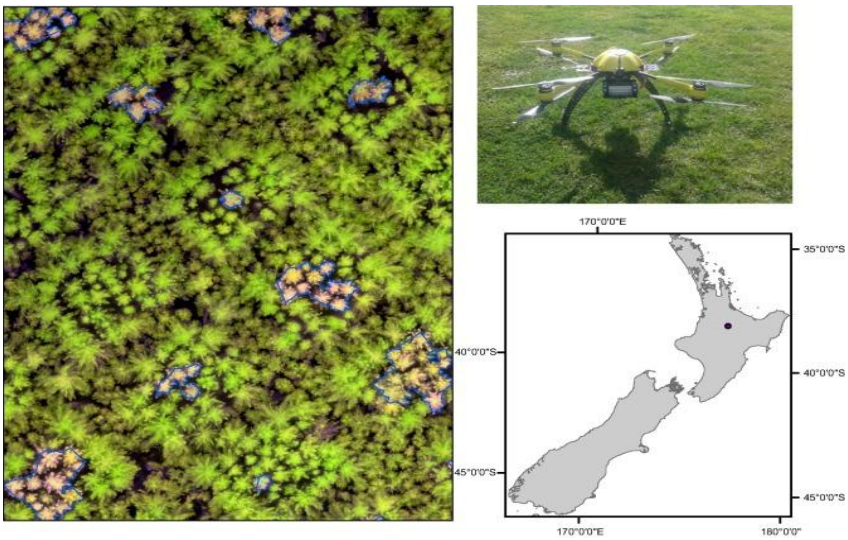


Figure 19: Location of the study site within New Zealand and an image of the coaxial quad-copter UAV used during data collection [25].

The entire forest will not be covered by a single UAV unit. As a result, utilizing the original field plots, experimental treatments were spread across the study region. These were chosen because they were well-marked and well-mapped, making access and navigation simple. With the use of a UAV, this study was able to find trees. Air pollution is a key cause of worry.

Because of its negative impact on the region's living conditions, climate, and economy. Data on microlevel pollution, which includes severe air pollutants and their consequences on forest and human health, is urgently needed, according to recent research.UAVs are more flexible and prominent operationally when compared with ground-based methods or other aerial techniques such as crewed aircraft and satellites [26].

There is a basic structure of the quadcopter Matlab Simulink model; Quadcopter is a variation of a UAV.

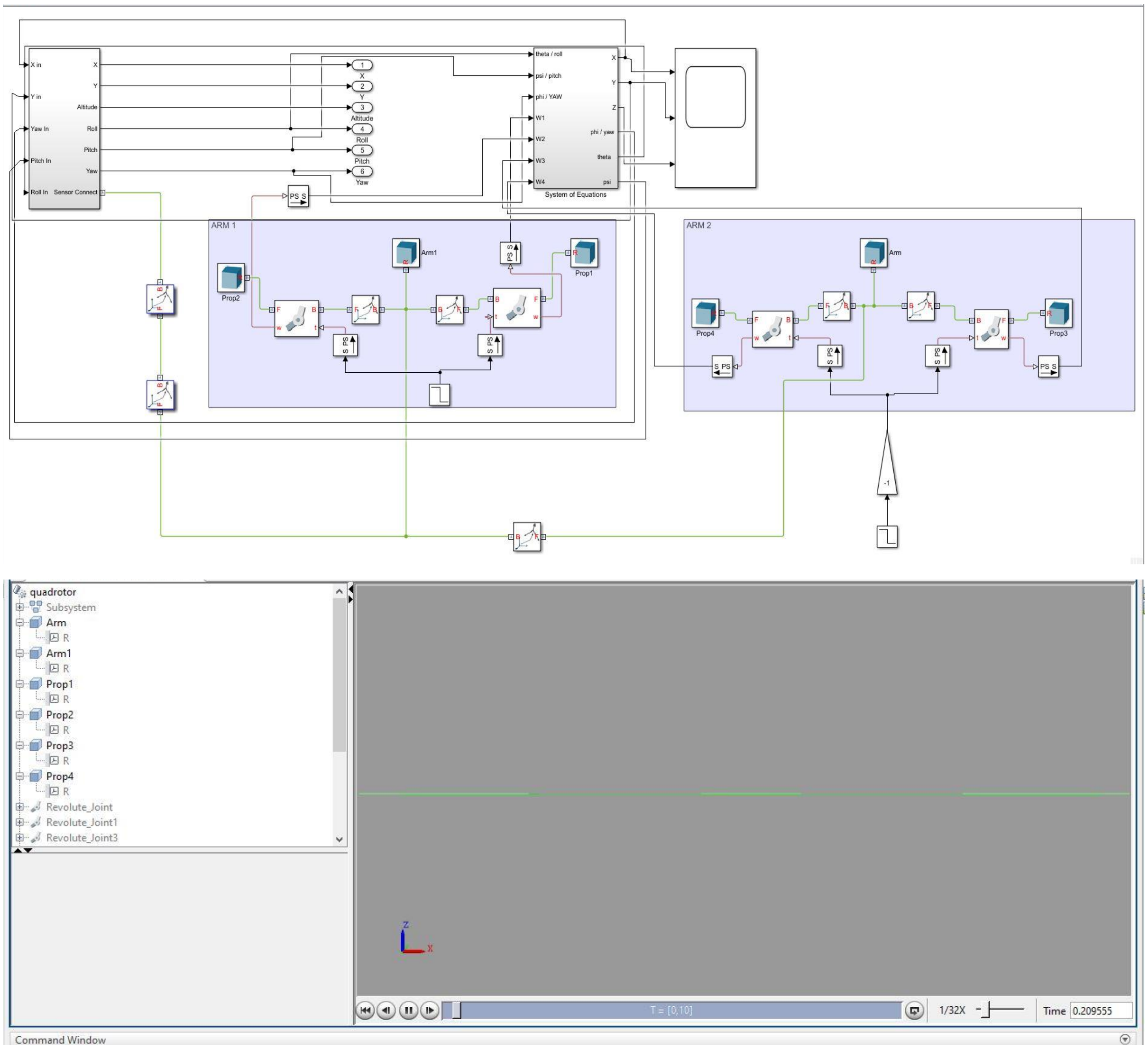


Figure 20: Quadcopter Structure Matlab Simulation

Table 3: Type of sensors and UAV with its endurance used for monitoring air pollution

Target Variable	Sensors Used	UAV Type	Remark
CO_2	MQ-135	Quadcopter	This system's advantages include its capacity to assess CO_2 and CO concentrations in the air, identify when they are

			too high and provide pollution reduction solutions as needed.
NH3	MQ-135	Quadcopter	The quadcopter was flown to observe vertical fluctuation in gasses at a constant altitude.
Temperature, Humidity	DHT22 Digital Temperature Humidity Sensor	Quadcopter	These studies show that a quadcopter outfitted with a DHT22 Digital Temperature Humidity Sensor can accurately estimate temperature and humidity. To collect data, it was flown vertically at a fixed altitude.

Water is one of the most important elements of the environment. Effective water quality monitoring is critical for water resource programs due to increased human population growth and industry pressure that can degrade water quality in coastal and inland waters [29].

4.3 Identify optimal design approach

4.3.1 Manual Remote Sensing

Case Study

Remote sensing has been useful for applications in forest ecology and management, including tracking changes in land cover, habitat fragmentation, and deforestation. Remote sensing is a technique for monitoring forests that allows data and images from sensors on satellites and other platforms to be used to gather information about the forest and its characteristics. However, it has serious flaws that make it uncomfortable to use for modern forest monitoring. Through the employment of a variety of clever devices for manual remote sensing, new technology, and human labor are combined. The use of human labor in this method is one of its drawbacks. We, humans, are unable to keep an eye on the entire forest. On the other hand, this is a procedure in which employees must do their duties in the face of several dangerous and high-risk elements. However, this method involves more effort, even though the amount of data collected will be less, and comparing other types of methods will be a lengthy procedure.

For instance, in Uganda, a group of NGOs made a team with rangers in some parks to explore forest monitoring technology to protect area management by early detection of deforestation. To do so they wanted to train the rangers of the ‘Kibale National Park’ to reduce deforestation and save forests[53].However, they ran into difficulties when it came to launching remote sensing because the technology had not yet reached that part of the forest. Forest management in Kibale is deficient in terms of competence and intelligence, both of which are required for effective forest management. As a result, they began receiving training. However, due to several obstacles, they found it to be less effective. They discovered that most of the locations identified by the warnings were in distant sections of the park. Rangers are unable to gain entry to certain areas. Similarly, internet connection restrictions have made it impossible to load. Another issue was human capability, as well as a lack of knowledge and interest. As a result, the rangers must be motivated to test out new tools and be provided with the necessary training and resources.On the other hand, a similar type of scenario is observed in Kenya. Though remote sensing has high demand in Kenya, its implementation has been hampered because of various issues including financial problems, technological gaps, lack of trained people, and socio-political and socio-economic constraints[54]. Because of those difficulties or limitations, people in underdeveloped countries can not use this technology to monitor forests.Remote sensing is a beneficial technology that has to be improved to make it more accessible, user-friendly, and affordable. For developing countries to benefit from this technology in their forests. In addition, long-term remote sensing database systems and image processing capabilities should be established with international monetary aid.

4.3.2 Robotic Ground Vehicle

Case study

Robots technology is getting famous in different places even in our households nowadays.The reason behind this is, that it can reduce the human workload through the use of machines. Similarly, robotic vehicles are also used to perform forest surveys through constant monitoring. Robotic applications in the forestry area are used to conduct different types of activities such as environmental preservation and monitoring, wildfire control, a forest plantation, etc. But the problem is that forests are naturally unstructured which makes the survey process difficult to perceive.

Forest engineer and researcher Marek Pierzchala got an opportunity to participate in a workshop based on forest robotics which was held in Montreal[17]. But he found that the forest research community is disinclined to use modern technology[17].Because they found that many industries are using unmanned machines such as UAVs which are getting popular as well. So people are not interested in using robotic vehicles. Moreover, perception of the forest is not an easy task to conduct.People who study forest science also realize that many of the forest properties are not quantifiable and mostly general knowledge is applied to forest management and planning activities. For all those reasons, robotic technology requires more research and experiments in the forest to overcome these barriers.

We are aware that the forest environment lacks structure, making surveys challenging. The location and navigation of woods are one of the main responsibilities of mobile robotics. Conducting these jobs is not simple. Localization is the process of locating an object in its surroundings. Due to poor signal reception, the Global Navigation Satellite System (GNSS) is not a dependable or sustainable solution for localization in the forest. because communication networks are frequently down in wilderness areas. This demonstrates that there is still a significant amount of study in that area that needs to be done. Moreover, we can do localization without GPS with the use of sensors such as laser scanners and depth sensors as well as heavily exploited cameras. A combination of multiple measures can aid in the precise localization of the machine as well as the creation of a map that depicts both free and occupied space. This process is conducted with the help of dedicated software utilizing robot algorithms to detect landmarks[55]. In artificial environments like cities, we can use a robot easily to monitor or for data collection. But, when we use a robot in the forest it loses track because the trees in the forest all look similar. Mobility is another challenging task for forestry. For localization one can use wheel odometry though in the forest it is not efficient because of the rough terrain of the forest and the wheel's slip. So, these are the possible problems that make forest monitoring difficult.

4.3.3 UAV

Case study

Due to its efficiency and services, UAV utilization is expanding globally in many different industries. Similar to that, it is now formally utilized in practically every nation's forestry management. And everyone is benefiting from the use of UAVs in the system for managing forests. Similar to India, researchers at the Wildlife Institute of India (WII) developed several UAVs that are tailored to various forest terrain types. According to K. Ramesh, the wildlife scientist in charge of the project at WII, they will be able to advance to second-generation technology for monitoring the forest environment, which will also be more affordable and capable of accessing places where humans and robots find it challenging[18].

Likewise, it is difficult and challenging to measure the height of Brazil's towering rainforests. But an international research team says that they are working together to make unmanned aerial vehicles (UAVs) into efficient, low-cost data collector devices that can monitor the progress of forest restoration[56]. The team has developed a UAV equipped with three-dimensional laser scanning and hyperspectral imaging systems which is capable of producing high-resolution maps and collecting hundreds of images at different wavelengths for a dedicated area.

A senior researcher at the Universidad Nacional Autónoma de México (UNAM) named Michael McCall, said that UAVs can measure forests with a low budget far more frequently than conventional more costly remote-sensing technologies[57]. The set-up costs of UAVs are relatively low and within reach of groups of communities or local organizations. Even McCall said that the price is dropping very rapidly nowadays. Though the camera equipment of UAVs is still costly, some people are working to use just a regular digital camera, with open-source software which one can put together and build up a sufficient image from that.

4.4 Performance evaluation of developed solution

4.4.1 Manual Remote Sensing

Usability

Human labor combined with smart technologies is the most significant part of mobile monitoring or remote sensing. This technique is combined with human labor and a variety of smart devices. Forest monitoring through remote sensing requires several people who are assigned to go to every corner of a forest and collect all necessary data manually. They need to carry various devices, cameras, sensors, etc., and reach every part of a forest for proper investigation. For collecting data they have to collect water and air samples. The source of remote sensing data is the electromagnetic radiation that is emitted or reflected by any particular object, which later on helps in their identification and classification for preparing proper reports of any object or place. Remote sensing systems may use either passive or active sensors to obtain data on an object in an area of interest. The data acquired by remote sensing instruments are characterized by their spatial, spectral, radiometric, and temporal resolution [21]. Here the received electromagnetic radiation is transformed into a signal. This signal will be recorded and displayed in a form of numerical data or an image. Data must be in digital form for computer processing, so air images must be converted to a digital format before being subjected to image analysis and advanced data processing.

Cost

A group of workers must be assigned to sample collection, data gathering, and analysis in the manual remote sensing procedure. We must pay those individuals a monthly income. Remote sensing, on the other hand, necessitates specialized expertise to properly evaluate photos and receive accurate information about a forest's status. Because users of the gadget require additional training, using remote sensing technology is more expensive in the long run. Furthermore, if there is a need to evaluate different elements of photography qualities, it is costly to analyze repeating images.

Table 4: Manual Remote Sensing Cost

Task	**Components**	**Price(BDTk)**
Area mapping, Sample collection	Human	25000 (Per Person)
Data analysis	IoT device/Lab facilities	20000

Efficiency

Though manual remote sensing provides for the easy gathering of data at a range of sizes and resolutions, there is no less efficiency for people in manual remote sensing because humans are the major source of collecting the main element of the survey, which is sample collection. Humans are limited in their ability to collect samples since they cannot go everywhere. Similarly, several types of training are required to conduct the complete procedure as well as to analyze the photos while using remote sensing. It is challenging to manage people who can carry out the treatment with ease in developing countries. Apart from that, humans choose which sensor to use for data collection, specify the data resolution and calibration of the sensor, choose the platform on which the sensor will be carried, and decide when the data will be collected. In this type of study, all of these actions introduce human error. As a result, there's a good chance you'll make a calculating error, and you can get an erroneous concept about a forest, which might lead to more complications. The efficiency of manual/human-based remote sensing suffers as a result of this intricacy.

Manufacturing and Maintainability

The manufacturing of human-based remote sensing of a forest consists of both humans and technology. As we said earlier, it is a complex process to do this analysis as a huge amount of human labor is required to run this monitoring. Besides, for conducting remote sensing we need a group of modern engineering technologies which is difficult to set up in an underdeveloped country where many people do not have the knowledge of manufacturing and maintaining this system. In remote sensing first of all a platform needs to be chosen. The carrier for remote sensing sensors is referred to as a platform. There are various sorts of platforms, such as ground-level platforms, aerial platforms, and so on. A ground-based platform is required for manual remote sensing. Handheld cameras, cranes, ground vehicles, and even towers are examples of ground-based platforms. It typically delivers remote sensing data from up to 50 meters above ground level and is excellent for obtaining low-altitude pictures with frequent coverage for dynamic purposes.
The maintainability of the sample will be the main goal of that approach. There is some maintainability of sensors that will be used in sample tests. In manual remote sensing processes, humans collect samples which increases the possibility of human errors. Similarly, the collected data cannot be enough sometimes to make decisions. Lack of manpower and misplacement of expertise, and lack of remote sensing centers make the process difficult to conduct monitoring. Apart from that sensors that are used for collecting samples of forest elements require continuous monitoring as they can be damaged while roaming around the forest by human labor.

Sustainability

As in the manual monitoring process humans are the only way for sample collection, which raises questions about the sustainability of this process. A group of people is required to conduct the project of data collection which may not be available sometimes. It requires special training and they need to have a proper idea about that forest. Apart from that, it is not possible to reach every corner of the forest. As a result, we will fail to get information about lots of places in a forest. Which makes this monitoring incomplete.

Impact

In the present world, manual remote sensing is a tertiary form of forest management that is less successful. Though it has some advantages, such as the ability to cover large areas with remote sensing, allowing regional surveys on a variety of themes, and the identification of extremely large features; as a group of people is engaged in sample collection, they can share their practical experiences about a particular forest condition; and remotely sensed data can be easily processed and analyzed quickly using a computer, allowing the data to be used for a variety of purposes.

However, its negative aspects of it render this technique inapplicable in today's reality. Because rangers and forest managers must be trained in remote sensing to correctly interpret the photographs, it is vital to provide them with training. It is also costly for long-term use due to the specialized training that users of the equipment must receive. Human work is also required for sensor selection, sensor calibration, data resolution specification, and data collecting time determination. As a result, the likelihood of human error rises. Because it is one of the more expensive ways of examination, it is not utilized to examine a tiny area. As a result of these drawbacks, the manual approach to remote sensing is losing ground to new technologies.

4.4.2 Robotic Ground Vehicle

Usability

Robots can help humans with activities that humans may not be willing to accomplish for a variety of reasons, such as forest monitoring, fire prevention, planting, and harvesting. Localization and navigation, which are complex procedures to accomplish, are the key tasks in mobile robotics. Furthermore, forest monitoring can be carried out with a variety of robotic vehicles, each with its own set of capabilities. One of them is ground robotic vehicle systems. Because the forest is naturally unstructured, it is difficult to perceive.To do so a legged robot can be used to carry out environmental monitoring activities in a forest. This type of monitoring system is used in Amazon to do environmental monitoring activities. [22]

The Amazon rainforest is known for being an unstructured and difficult-to-access area, which is why this robotic vehicle was used. In the same way, being in a wild environment is perilous for humans. The robot is equipped with a Light Detection and Ranging (LiDAR) system that maps the world around it and uses the Simultaneous Localization and Mapping algorithm to perform autonomous navigation that adapts to the terrain slope. Remotely controlled robotic ground vehicles provide high-quality results without the help of humans. Legged robots are designed for accessing and navigating facilities that are built for humans and can carry several different types of sensors for conducting monitoring tasks. Nevertheless, the unstructured nature of the forest makes it tough to perceive, and localization and navigation are one of the major challenges.

Cost

Cost of a robotic ground vehicle in a precise-legged robot is higher than the wheeled mobile robots. To fulfill our requirements, we need to use LiDAR which is quite expensive. The LiDAR price is nearly 200000 BDT and it is not available in developing countries like ours.

Table 5: Robotic Ground Vehicle Cost Analysis

Task	Component	Price(BDTk)
Area Mapping	LiDAR	200000
Sample Collection	Robotic Ground Vehicle	50000

Efficiency

For their outstanding features, robots are more exact than humans. They are capable of completing jobs quickly and accurately without the risk of human error. This method's efficiency is sufficient for future projects. It also saves time by eliminating the need for humans to conduct monitoring. The greatest advantage of robotic vehicles is their versatility and efficiency and the fact that they can also move on different surfaces though in forests it may face difficulty to reach every corner of it which sometimes damages their structure. Apart from that, robotic vehicles provide better mobility, better energy efficiency, better stability, and a smaller impact on the ground compared to human-based monitoring systems.

Manufacturing and Maintainability

Robots can be built in a variety of ways, with a variety of features. However, most robots share some characteristics. As a result, apart from the other particular qualities, the robotic ground vehicle for forest monitoring must have those common features. Sensors allow a robot to gather information from its surroundings in a robotic vehicle. This data is utilized to direct the robot's actions. By taking photographs, cameras allow a robot to create a visual representation of its surroundings. This enables the robot to discern environmental attributes that can only be determined through vision, such as shape or color, item size and distance, and so on. We can obtain a sense of the forest conditions from this. Microphones aid in the detection of noises by robots. Some sensors, such as buttons integrated into bumpers sensors, are used for robot safety. These sensors help the robot to recognize when it has collided with an object or a wall. Thermometers and barometers are used in some robots to sense temperature and pressure. We need to employ these types of sensors to check the quality of water and air in the forest. Other types of sensors have more complicated properties, allowing a robot to perform more fascinating tasks. As they navigate around the world, robots equipped with Light Detection And Ranging (LIDAR) sensors employ lasers to create three-dimensional maps of their surroundings. To ensure great performance and consistency while operating, every robot requires preventative maintenance. Parts and components of robots can break down or malfunction if they are not subjected to regular preventative maintenance checkups. Through efficient maintenance of robotic systems, we can reduce repair time and allow for optimal reconfiguration of the system for diverse tasks.

Sustainability

The majority of people link industrial robotics with an unsustainable economic model. Robotics, on the other hand, offers qualitative benefits due to its precision, strength, sense capabilities, and computer capacity. As a result, innovative applications and deployment models can be developed to increase the robots' long-term viability and quality of life. To accomplish so, new approaches to robot design, robot-using systems, and IT systems that use robotics and AI methodologies are needed. Robotics for sustainable development is currently one of the challenges to which research, education, and industry from both developed and developing countries may contribute and profit equally.

Impact

One of the jobs that robots are good at is sorting recycled material. They can do it quickly and efficiently, and they do not require all of the safety gear and training that humans need. Humans can sort about 800 items in an hour, but robots can sort around 2,000 items in the same amount of time. Therefore, robotic ground vehicles also can collect data faster and more accurately compared to humans.

Design key technology and ability

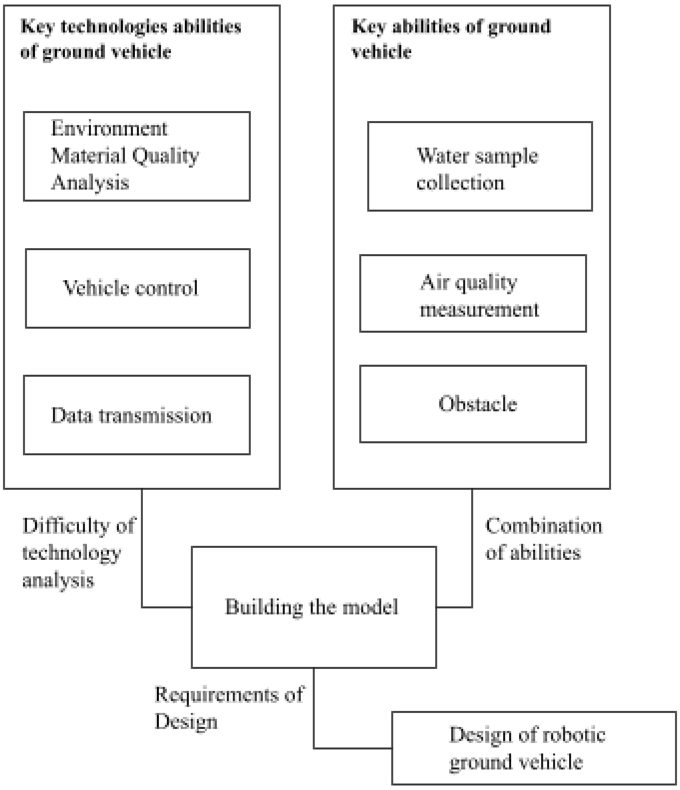


Figure 21: Robotic ground vehicle key technologies and abilities

Table 6: Design key technology and ability

Technologies	**Task**	**Abibilities**
Data Collection	Air quality measurement	Possible
Sample Collection	Water sample collection	Not possible

Vehicle control	Obstacle	Precisely possible
Data transmission	Data sending	Possible

4.4.3 Unmanned Aerial Vehicle - UAV

Usability

UAV technology is getting popular for maintaining the ecosystem of trees and forest cultivation. Although in its neonatal stages, the high flame of UAV innovation is burning ever-so-brightly in the spheres of forestry and forest cultivation. Managing a forest is a never-ending job—and one that requires constant maintenance and surveillance. After all, these critical ecosystems are at risk from a variety of natural and human-caused threats. it becomes difficult for forest managers and workers to take immediate action owing to the large span of areas that constitutes forests. As a means of relief, Unmanned Aerial Vehicles (UAVs) help in terms of aerial surveillance mapping, aerial photography, thermal imagery, and topographic monitoring. [23] The flexibility of UAVs allows them to capture high-resolution images and video in real-time, even during the humid tropical climate. Artificial Intelligence-powered UAVs, along with UAVs that use LiDAR can monitor and inspect large areas with focussed coverage that yields faster and more precise results and data. UAV provides some features that can be beneficial for forestries such as;

Capturing Images

Aerial photography is a fascinating UAV application that is beneficial to a variety of organizations and sectors. This is a term that is commonly used nowadays all across the world. UAVs with thermal, infrared, or HD imaging capability can be used to acquire clear photographs of a person's plants and trees. UAVs with cameras are also proven to be highly useful for studying wildlife behavior and forest biotic views.

Location and Navigation

During mapping, surveillance, geospatial research, and other applications, UAVs outfitted with GPS trackers and radar are utilized for navigation and location sensing. Unmanned aerial vehicles may be tracked with this important UAV application, reducing the risk of their being lost due to unanticipated events. UAVs with GPS systems, whether remotely operated or autonomous, play a vital role in gathering and sharing precise data.

Providing information about trees

Aside from measuring the number of trees in the forest, UAVs powered by Artificial Intelligence and Machine Learning have proven useful in the identification and prevention of tree diseases. UAVs equipped with LiDAR sensors collect and process data related to the health of trees, plants, and bushlands. Thermal imaging, topographic surveying, and aerial mapping enable horticulturists and forest officials to detect unhealthy flora and guide them toward bettering their circumstances.

Getting information about forest elements through sensors

In our everyday lives, we use a variety of sensors. Companies have begun to integrate sensors into UAV technology in order to broaden the scope of UAV applications. A UAV can collect data from a variety of sensors, including changes in speed, distance, temperature, wind, chemical signals, light, sound, and the presence of magnetic objects. Temperature sensors, humidity sensors, and moisture sensors can all be used in forestry to measure the temperature of the forest weather.

Cost

UAVs are less expensive than the other two types of environmental monitoring. Small UAVs are excellent for applications where aerial coverage is limited, piloting experience and skill are limited, and the operational budget is often low. Many smaller UAVs are now capable of collecting photographic data, video footage, multispectral, thermal, and hyperspectral imaging, as well as LiDAR, because of advancements in battery technology, navigational controls, and payload capacity. Larger and more powerful UAVs are necessary to cover a wide area of land in a forest. It is dependent on the number of regions we need to cover at any one moment. However, a human-driven car will always be less expensive than a robotic one.

Efficiency

In terms of efficiency UAVs can provide the best service among the other forms of monitoring. UAVs improve aerial surveillance, allowing forestry teams to capture more footage from different angles and perspectives. UAVs are also much easier and more cost-effective to deploy, making them more suitable for daily use. Forestry departments need to be careful when planting trees to ensure the new saplings benefit the forest and ultimately achieve maximum growth. UAVs can collect a variety of data points and help with predictive planning and analysis to increase the chances of this happening. Moreover, it saves time and the collected data provides more accuracy than the other types of surveillance technology.

Maintainability and Manufacturability

UAVs are true engineering gadgets that may be employed for most technological applications. Quadcopters, hexacopters, and a wide range of professional gear, from foam to high-grade materials, are now being produced by UAV firms. Quadcopters are being used to monitor the forest here. A quadcopter is a multirotor unmanned aerial vehicle (UAV) with four arms or booms, each with a rotor, that provides lift to allow the aircraft to fly. The operating idea is that one pair of rotors rotates clockwise while the other rotates anti-clockwise, and by adjusting the speeds, thrust and turning motions can be generated.

Quadcopters are often easier to build and fly than unmanned helicopter UAVs, making them an excellent alternative for some applications like surveying and aerial photography. Frame, motors, propellers, ESC (electronic speed controller), Flight controllers, batteries, and RC receivers are some of the essential parts of quadcopters. The main construction of a quadcopter is its frame. A quadcopter's brain is the Flight Controller (FC), which has sensors onboard to understand how the drone is moving.The FC employs algorithms to compute how fast each motor should be spinning based on the data provided by these sensors for the craft to behave as the pilot instructs via stick inputs on the TX (Radio Transmitter). It also needs to be connected to the RX (receiver) so that the craft can be taught what the pilot wants it to perform. For the motors to carry out the FC commands, each of the ESC signals and ground wires must be connected. The quadcopters' power sources are LiPo batteries. Because of its high energy density and discharge rate, LiPo is used. An ESC is a device that analyzes data from the flight controller and converts them into phased electrical pulses to determine the brushless motor's speed. Because the quad's motors are the primary drain on battery power, finding an efficient propeller and motor combination is critical. Without the prop attached, the motor speed is measured in kV; a lower kV motor will create greater torque, while a higher kV will spin faster.

UAVs require regular maintenance checks to ensure everything is in working order. it is most efficient to perform maintenance on a per-flight basis, rather than a set timeframe. It is not a complex task to take care of a UAV. For routine maintenance, we need to check a few things like doing key performance tests, UAVs, and batteries before flying, Cleaning of any dirt, Upgrading to software, Visual inspection of all moving parts, etc. This maintenance is affordable and ensures safe flying which reflects in the result of monitoring.

Impact

In recent days, UAVs have become popular in various study fields. Forestry is a popular field among them. It has become popular due to its various technological benefits, precisely due to the high-resolution data which can be collected easily in a short time and at a comparatively low price. UAV technology has become one of the successes of the progress and advancement of forest ecosystems. The features of UAVs such as forest mapping, forest management planning, canopy height mapping, etc will be very beneficial for future forest applications. It will also help to take the necessary initiative in emergency cases. That ensures the sustainable management of forests. However, it also saves time, reduces risks, and provides almost accurate information about a certain forest which helps to provide precise conditions of a forest. Moreover, with the help of UAVs, forestry can undergo a series of improvements and successes. Many countries have already experienced this improvement which motivates others to use UAVs for saving forestry and human life also.

Table 7: Performance Analysis[24]

Basis	Manual Remote Sensing	Robotic Ground Vehicle	UAV
Average Time (s)	1200	150	540
Average Distance (m)	100	64	100

Table 8: Design Comparison

Basis	Manual Remote Sensing	Robotic Ground Vehicle	Unmanned Aerial Vehicle - UAV
Sample Collection	Possible	Not all Possible	Possible
Canopy Area Coverage	Not possible	Possible	Possible
Accuracy	Less accuracy	Precise accuracy	Most precise accuracy
Area Coverage	Less	Less	Most area cover
Time Needed	Longer period	Longer period	Shorter period
Industrial Value	Less	Precise	Most
Cost	Expensive	Most expensive	Less expensive
Cost-Effective	Lowest	Lower	Highest

Table 9: Design Approach advantage and disadvantages

Design Approach	Priority	Advantage	Disadvantage	Quantity	Time (Minutes)	Cost (BDTK)
Manual Remote Sensing	Subordinate	1.Sample Collection	1.Time-consuming 2.Risk to human life 3.Less area	3 Group of people per 100 meter	180 Minutes	25000 (Per Person) 20000 (Device Cost)
Robotic Ground Vehicle	Subordinate	1.Only air quality measurement 2.Canopy area cover (LiDAR)	1.Less movement 2.Time-consuming 3. Expensive 4.No water sample collection	One unit per 100 meters	40 Minutes	250000(Per Unit)
Unmanned Aerial Vehicle (UAV)	Primary	1.Canopy area cover 2.Sample collection 3.Time-saving 4.Map inaccessible areas	1.Flight time 2. Controlling	One unit per 100 meters	30 Minutes	Around 50000 (Per Unit)

4.5 Conclusion

To reduce human risk and workload, forestry has advanced from manual methods to machine-oriented solutions. Humans, on the other hand, are unable to visit every location in a forest and collect data. As a result, robotic ground vehicles for forestry have been developed. In the forestry industry, robots have increased productivity by being able to enter areas where humans cannot because the environment is dangerous, difficult, or lacks vision. Because they can elevate their feet for mobility, legged robots for forestry have a significantly smaller footprint, making them ideal for forest soils and protecting the forest from injury. It has sensors that can collect data. However, it fails to capture photos from higher elevations, which are necessary for detecting deforestation. Because one of our key goals is to prevent deforestation, ground robotic vehicles, despite their many advantages, cannot be the best choice for our monitoring needs. Another consideration is the price. Both the manufacturing and maintenance of robotic vehicles require large sums of money, which may be insufficient to assure their long-term viability in any developing country.

Unmanned aerial vehicles (UAVs), sometimes known as drones, are our final strategy. Drones are currently having a significant impact on the forestry business due to their incredible features and benefits. They can visualize the ground and simulate the canopy structure at the same time, which has substantial benefits for the forestry industry. For terrain classification, foresters and forest managers had to rely on topographic maps in the past. They also had to rely on time-consuming field-based surveys to determine tree volumes and heights. We use capabilities in our system that allow us to monitor the forest from multiple points. A forest is a complex ecosystem that is primarily made up of trees.

As a result, one of our responsibilities is to identify areas of deforestation by counting the number of trees or their density. For this, we're putting together a camera for our UAV that can capture pictures of the forest, which we'll then process through image processing to identify the density of trees in the forest. It can assess the three-dimensional properties of plant canopy structures. With the available data, it is possible to estimate the volume and growth rate of trees to evaluate the forest's value.

Chapter 5
Completion of Final Design and Validation

5.1 Introduction

The environment and economics of the planet depend heavily on forests. Because it is necessary for all living things, either directly or indirectly. Forests are in danger now because of natural and man-made calamities. A forest must be properly monitored and maintained to preserve or increase its health and productivity as well as to meet safety goals. With the aid of contemporary technologies, forest management is exploring innovative ways to survey and preserve property. Every feasible path has both advantages and disadvantages. We need to choose the one that will provide us with the most output with the fewest faults among them. Here we have shown three possible solutions to the forest monitoring system in detail and came up with one optimal solution with a UAV. One of the most exciting technologies that public and private companies are now using to conduct various operations are unmanned aerial vehicles (UAVs) which are more commonly known as drones. Due to its increasing demand and advantages, people are willing to use drones to conduct any type of monitoring process.

5.2 Completion of final design

5.2.1 Design Methodology and Design Process

A type of unmanned aerial vehicle is the quadcopter (UAV). Unmanned aerial vehicles (UAVs) are generally known as flying machines that do not have an onboard pilot. These are also known as remotely piloted vehicles (RPVs), which are driven remotely by a ground control operator. Applications for quadcopters include aerial recognition, search-and-rescue operations, and industrial monitoring tasks, among others. Monitoring farmland is a more tranquil use for UAVs, as demonstrated by the business AGX Tecnologias, which created multiple configurations of aerial vehicles to map various crop types. Quadcopters can range in size from that of an insect to that of a professional aerial aircraft. Dimensions vary depending on the kind of application these UAVs will be used in and the equipment they will be carrying. For instance, a small quadcopter needs to be equipped with sensors in applications where it is necessary to identify harmful compounds in the air. Imaging-based automatic inspection and analysis can be provided for applications like automatic inspection and process control using a camera and the appropriate software. A quadcopter is a multirotor UAV that has four rotors for lifting and propulsion. A quadcopter features four propellers that are set up either in a cross or plus configuration for flight. A major benefit of the quadcopter robot's ability to take off and land vertically is that it reduces the need for an adequate landing platform. Additionally, it enables the quadcopter to hover steadily in one area. The quadcopter's hover stability keeps it from crashing in the event of high wind or because of its weight. Below we can see the six-degree freedom of the quadcopter. Here, x and y represent the translational motion along the x- and y-axes respectively.

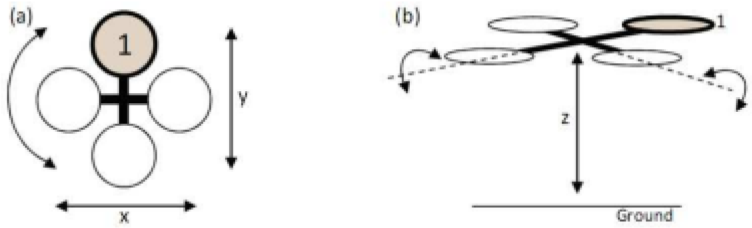


Figure 22: The six degrees of freedom of the quadcopter [29]

Two identical sets of fixed-pitch propellers, two rotating in the opposite direction, are used by quadcopters. These regulate lift and torque by varying RPM. By modifying the torque load and thrust/lift characteristics of one or more rotor discs, one or more rotor discs can be used to control the motion of a vehicle. The left and right propellers turn clockwise, while the front and rear ones rotate counterclockwise. The requirement for a tail rotor is eliminated by this arrangement of opposing pair directions. Below we can see the motor rotation of the quadcopter.

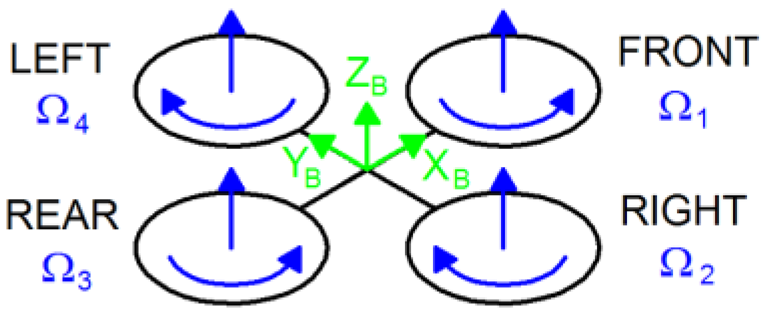


Figure 23: Quadcopter motor rotation [29]

We use ardupilot; which is the brain of the quadcopter with a nine-channel receiver. We choose a nine-channel receiver as we have to operate the syringe pump also to collect the water sample.

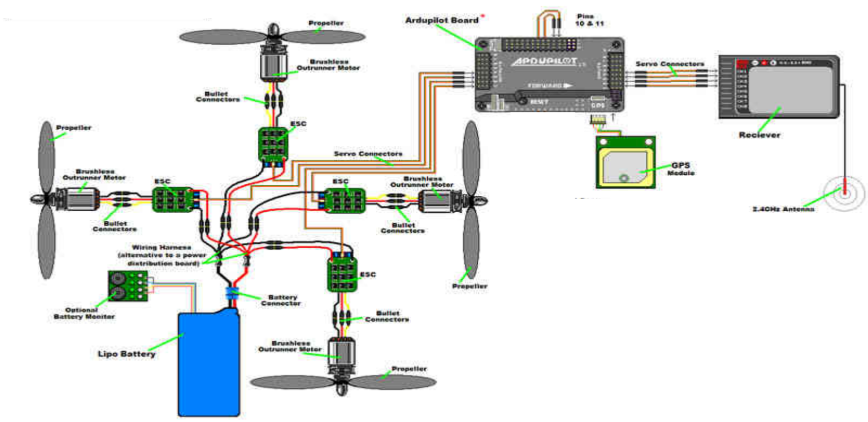


Figure 24: Quadcopter design diagram view using ardupilot

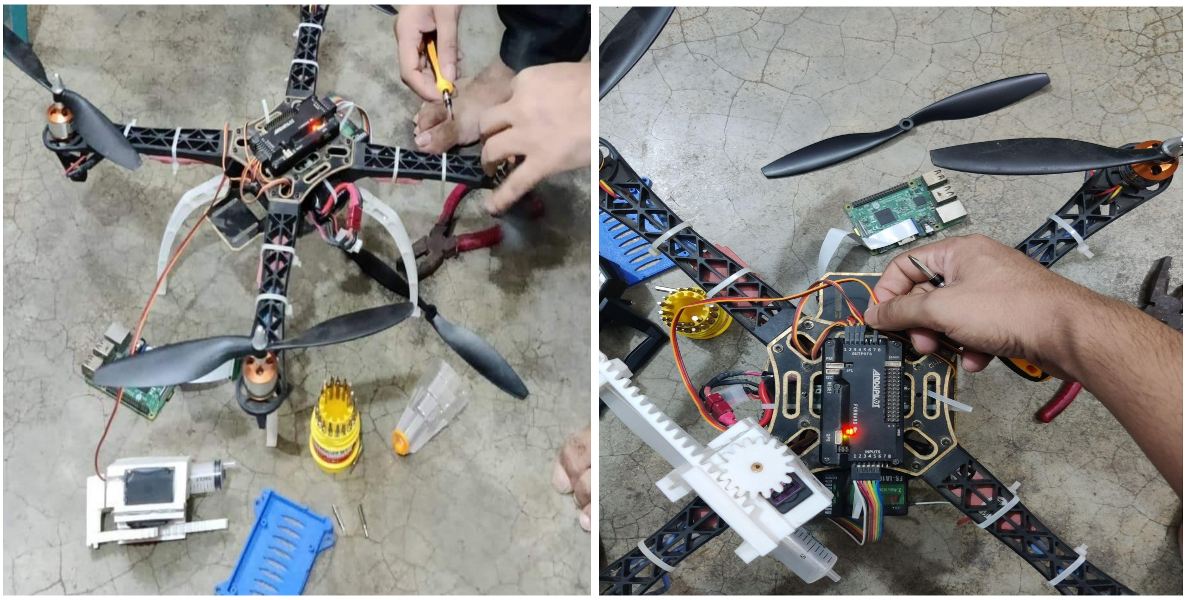


Figure 25: Device-making process

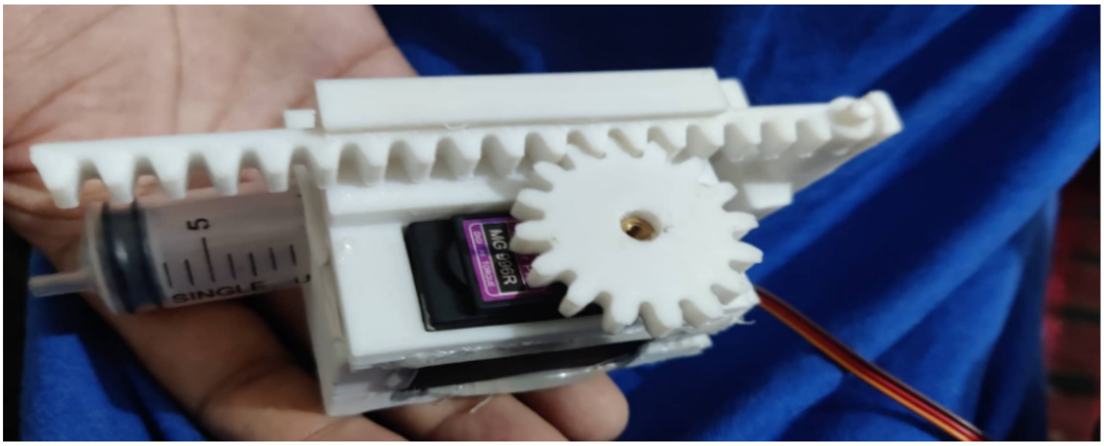


Figure 26: Designed syringe pump

Motorized syringe pumps precisely control the flow of a liquid from a syringe by mechanically advancing or retraction the plunger. Syringe pumps have motors that can precisely move a platform connected to the syringe's plunger. The syringe's body is secured to the unit's body such that the motor's movement is the only source of movement. Here, we use a servo motor to create a syringe pump. This is perfectly suited to meet our needs.

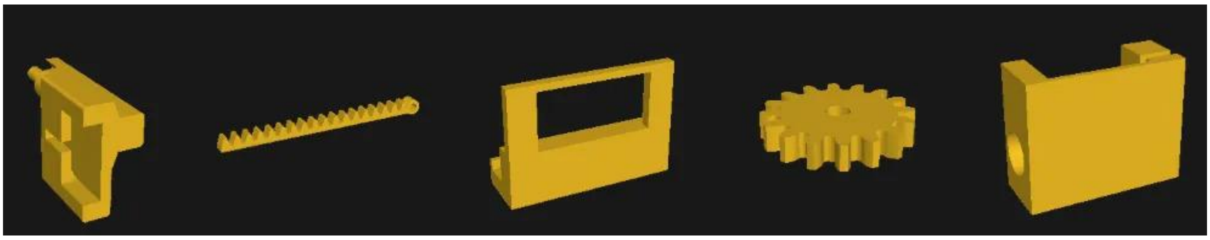


Figure 27: CAD Design of syringe pump

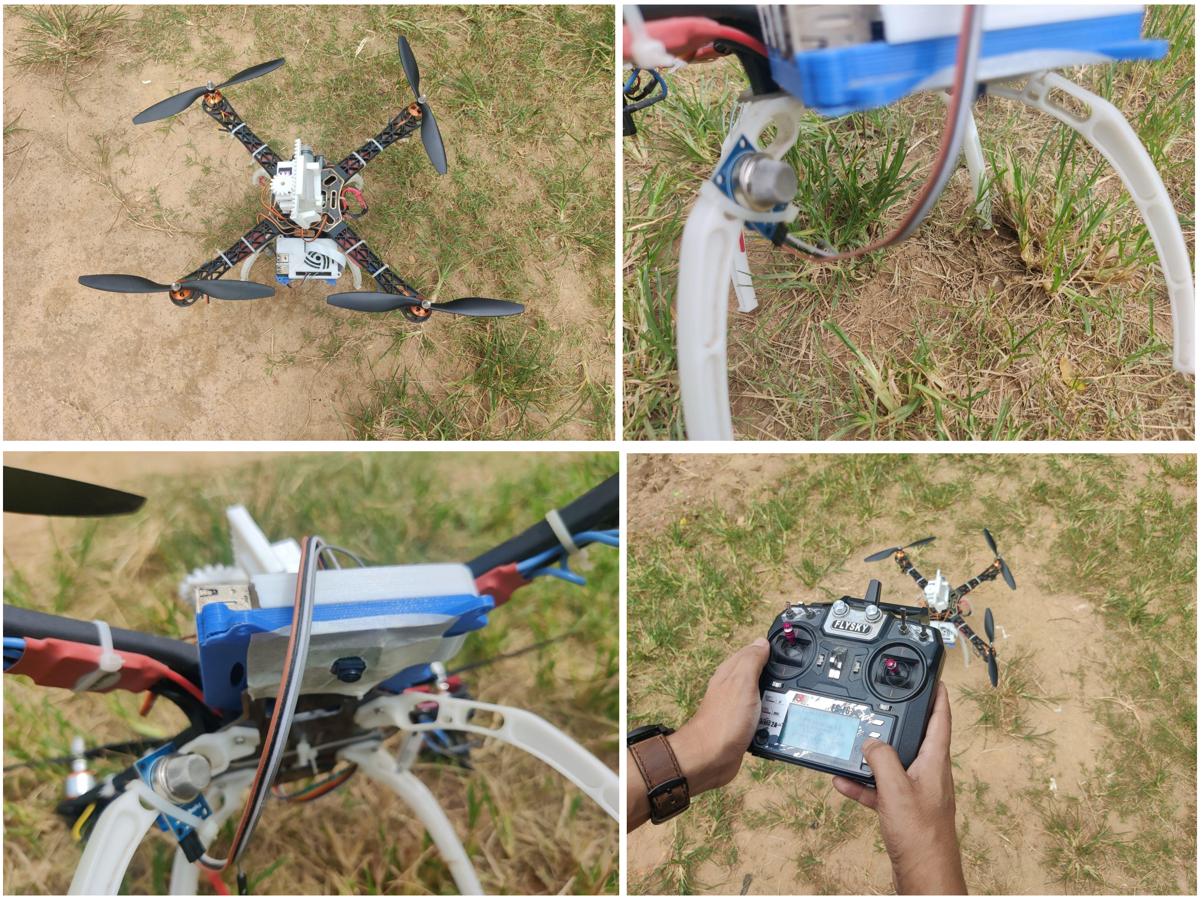


Figure 28: Complete UAV

5.2.2 Data collection

We produce large amounts of data at an unprecedented rate every day in the modern world. With the use of machine learning, these data can be utilized to anticipate the future as well as to understand the current state of our surroundings. This information can be categorized numerically, such as temperature, human growth, customer retention rate, and highest degree attained, among other examples. The practice of obtaining and analyzing information from a wide variety of sources is known as data collection. The data we gather must be acquired and kept in a way that makes sense for the specific business problem at hand if we are to use it to create useful artificial intelligence (AI) and machine learning solutions. To employ data analysis to discover repeating patterns, the collection of data enables you to keep a record of earlier events. Utilizing machine learning techniques, you may create prediction models from these patterns that track trends and foretell future changes. Effective data collection techniques are essential to creating high-performing predictive models since predictive models are only as good as the data on which they are based. The information in the data must be accurate and pertinent to the work at hand.

To collect the data use a raspberry pi as the main unit, sensor, and the pi-cam all the necessary equipment was mounted with the UAV we use. We control the raspberry pi with help of open-source software RealVNC—VNC stands for virtual network computing in this context. It is a cross-platform screen-sharing tool designed for the remote control of an additional computer. This means that a remote user can operate a computer's screen, keyboard, and mouse from a different device as if they were seated right in front of it. VNC utilizes a client/server architecture. A VNC viewer, or client, is installed on the device you want to control from, and a server component is installed on the distant computer. This might be a tablet, another computer, or a phone. A copy of the distant computer's screen is sent to the connected server and viewer via the server.

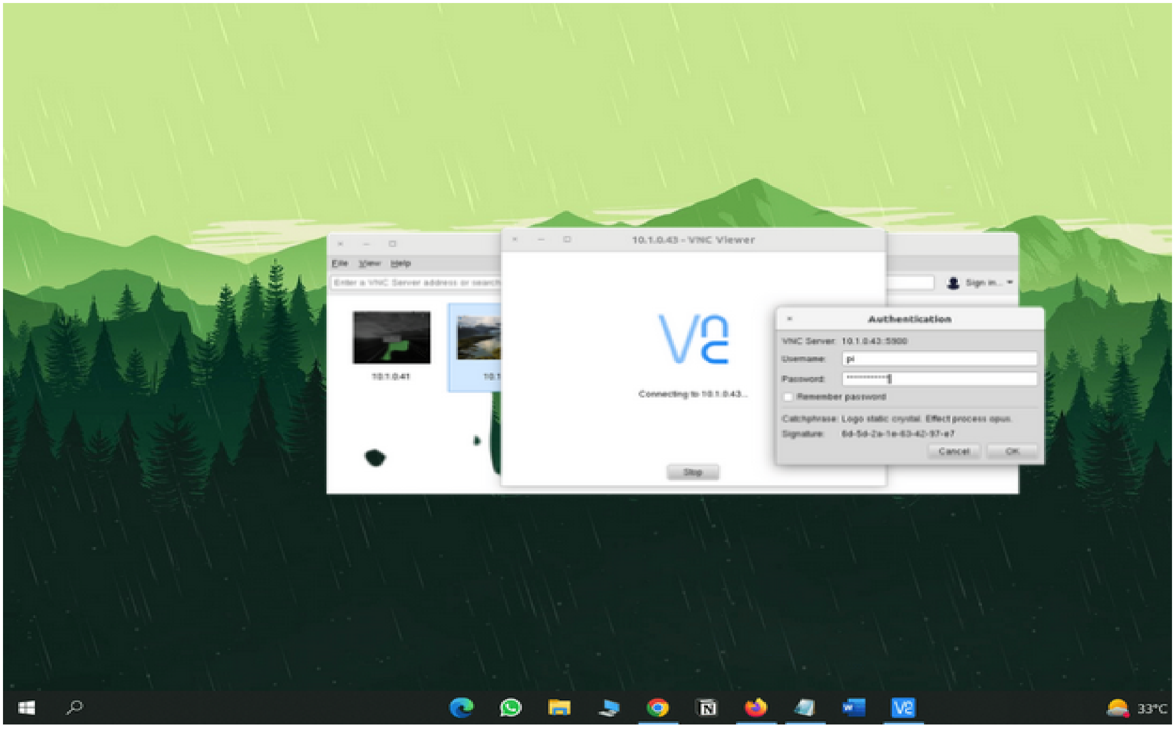


Figure 29: Configuring VNC in Laptop with Raspberry pi

For the first time, we use wifi connection and ethernet cable connected with the raspberry pi and laptop to configure the raspberry pi. After the connection, we use Linux code to update the raspberry pi and make the device applicable to our project. Then we enable the raspberry pi's VNC connection. This is the only way to control the raspberry remotely.

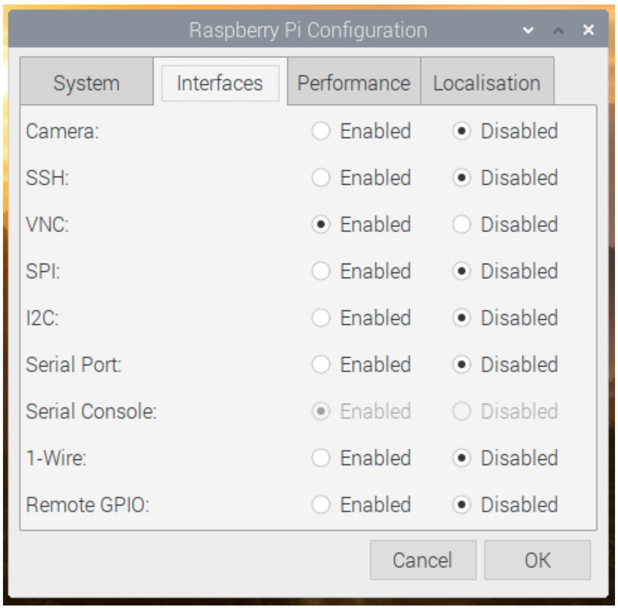


Figure 30: Enabling VNC option in raspberry pi

To connect the raspberry pi and the computer both have to be under the same network. For this connecting system, we use a mobile hotspot for both devices under the same wireless connection system.

To collect the data we use a python script for the sensors which are connected to the raspberry pi. Both the raspberry pi and sensors were mounted on the raspberry pi. Here is the sample of collected sensor data. To collect the air quality data, we take values for temperature, humidity, and carbon dioxide. All the sensor data were collected as .txt files then we convert the .txt data into an excel sheet and save it as .csv to make it easier to run the file with our python script.

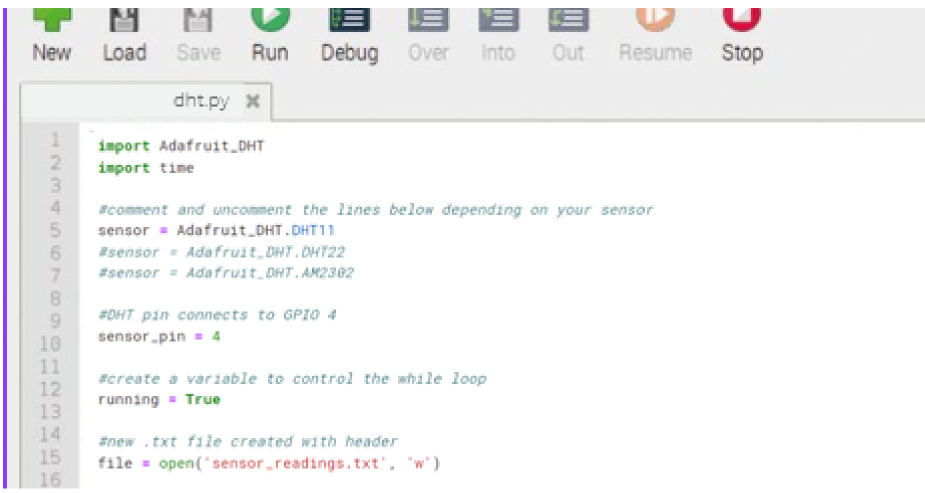
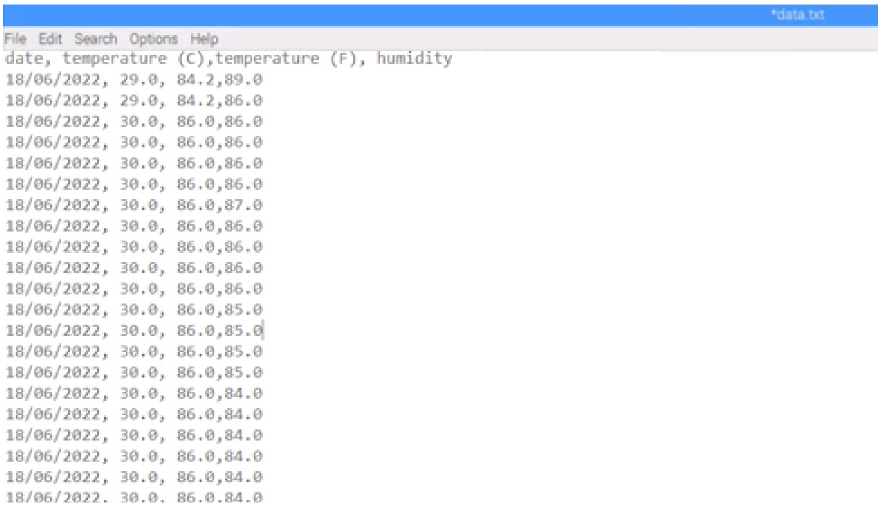


Figure 31: Running python script in raspberry pi



```
*data.txt
File Edit Search Options Help
date, temperature (C),temperature (F), humidity
18/06/2022, 29.0, 84.2,89.0
18/06/2022, 29.0, 84.2,86.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,87.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,86.0
18/06/2022, 30.0, 86.0,85.0
18/06/2022, 30.0, 86.0,85.0
18/06/2022, 30.0, 86.0,85.0
18/06/2022, 30.0, 86.0,85.0
18/06/2022, 30.0, 86.0,84.0
18/06/2022, 30.0, 86.0,84.0
18/06/2022, 30.0, 86.0,84.0
18/06/2022, 30.0, 86.0,84.0
18/06/2022, 30.0, 86.0,84.0
18/06/2022, 30.0, 86.0,84.0
```

Figure 32: Sensor data collecting

As we have to capture the image to measure the forest canopy area prediction. We use raspberry pi cam which is easy to use and it was lightweight for the UAV to carry on. It has a great resolution system that was able to test the image with our machine-learning model.

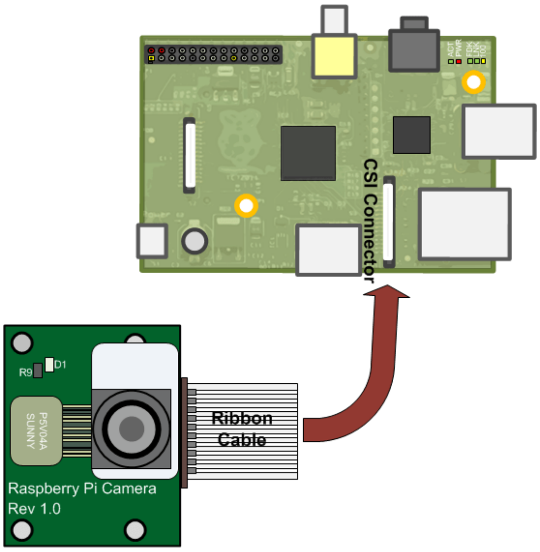


Figure 33: Raspberry pi camera connection system [31]

To capture the image we use a python script to run the camera to get the desired image. Below we can see the image we capture for our test image collection which will be used to predict the canopy section in the forest

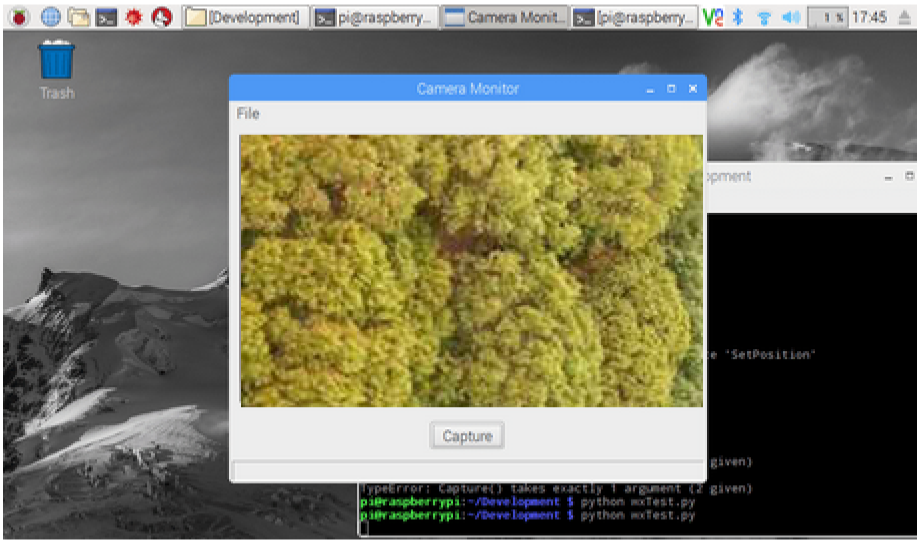


Figure 34: Image capturing with Pi-cam

We collected water with the help of a syringe pump. The syringe pump was mounted with the drone. We used a servo motor for the mechanical function of the syringe pump. The motor was connected to the RC receiver which was remotely controlled by the pilot of the UAV. A servo motor is a kind of motor that has extremely precise rotational capabilities. This type of motor typically has a control circuit that gives feedback on the motor shaft's present location. This feedback enables the servo motors to rotate very precisely. We utilize a servo motor because we want to move the syringe plunger a certain distance. It consists of a straightforward motor that drives a servo mechanism. Syringe pumps are used to accurately do small amounts of a particular fluid. As a result, the syringe pump system operates on a discontinuous premise. By moving the syringe plunger in the pump cylinder, a predetermined volume of fluid is pulled in and delivered in the same channel to a dosing needle. On the needle part, we use a rubber pipe to get closer to the water easily. As the syringe pump was mounted with the UAV. It was risky to fly the UAV over the water. That's why we use the rubber pipe so that we can easily pump the water into the syringe cylinder. Then we collect the water into a jar.

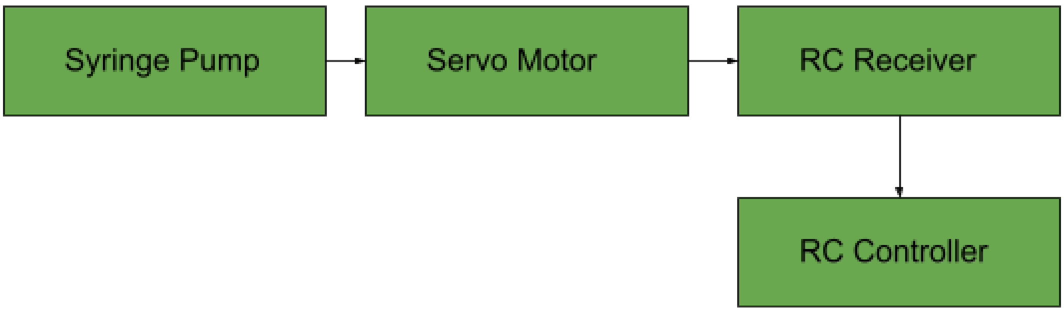


Figure 35: Syringe pump controlling system

Figure 36: Collected water sample

After collecting the water sample we collect the water turbidity and ph value with the help of Arduino and turbidity sensor and ph meter. Below we can see the connection of the turbidity sensor with the Arduino for the turbidity test of the water.

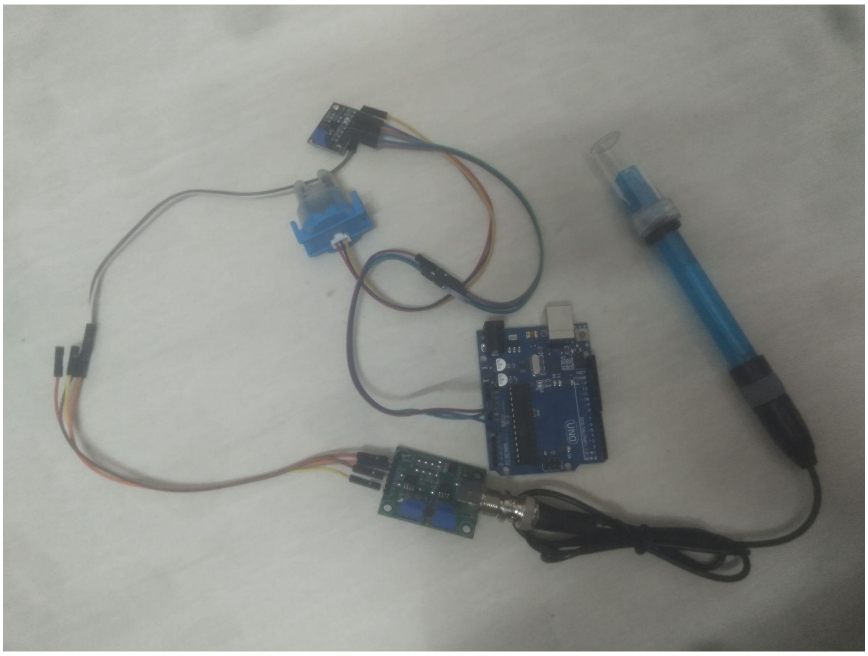


Figure 37: Turbidity sensor Connection with Ardunio

5.2.3 Data Analysis

Using more than a century's worth of historical meteorological data, we will attempt to solve the problem of estimating the average worldwide land and ocean temperature. We're going to pretend that we don't have access to any forecasts for the weather. We do have access to historical data on temperature and humidity, such as the maximum and minimum temperatures in a forest. With all of this, we may conclude that the problem is one requiring supervised, regression machine learning. For data prediction, the machine learning method will be quite helpful. After collecting all the data we have to analyze the data to get the desired output which is to know the forest's health condition.

Weather Component Analysis

For a forest to be healthy, clean air is essential. Life quality is lowered by poor air quality. Pollutants in the air can irritate people. On tree leaves, some air contaminants might lead to respiratory conditions. That will have an impact on the growth of the forest's trees. Temperature, humidity, and atmospheric gasses like carbon dioxide are only a few of the variables that affect air quality. To measure the air quality we used sensors to collect data on air components. After that, we use a machine learning algorithm to predict the air quality for the next few days. To make the machine learning algorithm we must use the python script as a prediction we have to use python libraries. For our prediction system, we use an XGBoost library to predict air quality. A new set of predictors can be used to forecast a response using regression.

For a forest ecosystem to be healthy, water quality is essential. If the ph value of the water source is less than 4, it will immediately harm the roots of trees. If the water quality was located inside the forest, such as ponds or channels, and there was considerable rainfall, floods could occur. That will impact how healthy the forest is. By regulating flows, evaporation, and precipitation, healthy forests contribute to the regulation of the water cycle. Rainfall is regulated by the layers of the forest canopy, branches, and roots, which can collect and release water vapor. By obstructing and reducing the flow of runoff, forests can also assist in lessening the effects of floods from storms. After collecting the sensor data we use our python script to get the design output. There is the visualization of our predicted data as we see in the below graph showing the real data with a blue mark and a golden mark representing the predicted data of water pH and turbidity.

Forest Health Analysis Based On Weather Component

After analysis, we will analyze the total forest health condition. For that, we have to get the standard value of sensor values such that the suitable temperature value for the forest air condition is below 35 degrees celsius or the suitable carbon dioxide level for forest growth is 260 - 350 ppm [33].

After comparing our sensor's value with the standard value we measure the forest health condition under 100% measurement. After measuring the forest health condition our model will give suggestions based on the forest health.

```
CO2 is within range
Humidity is 38.801328502415465 % more than the standard range
Temperature is 0.7487922705314057 % less than the standard range
Turbidity is within range
PH is within range
```

Figure 38: Each component's health percentage for the standard range after running the code

```
Index Value: 94%
Category: Good
Color: Green
Description: Forest quality is satisfactory, and forest population poses little or no risk
```

Figure 39: Forest health conditions after weighted estimation of all the components

Now for the image processing—we have to know the canopy area from the image. As predicted images are in RGB we have to calculate the RGB value of the image then we will be able to calculate the percentage of the area consisting of trees. As from the previous mask from our training data set yellow was set for the tree consist area then we will calculate the value for the yellow consist area in percentage then our model will show the color name or the closet color of yellow if we put the RGB value manually to the input.

```
src_image = cv2.cvtColor(src_image, cv2.COLOR_BGR2RGB)
reshape_img = src_image.reshape((src_image.shape[0] * src_image.shape[1], 3))

# Display dominant colors Present in the image
KM_cluster = KMeans(n_clusters=5).fit(reshape_img)
visualize_color = visualize_Dominant_colors(KM_cluster, KM_cluster.cluster_centers_)
visualize_color = cv2.cvtColor(visualize_color, cv2.COLOR_RGB2BGR)
#cv2.imshow('visualize_Color', visualize_color)
#cv2.waitKey()
```

```
[252.17650062 230.87980454  36.00069287] 95.49 %
[68.03078533   1.48197584 84.43077265] 4.51%
```

```
        closest_name = actual_name = webcolors.rgb_to_name(requested_colour)
    except ValueError:
        closest_name = closest_colour(requested_colour)
        actual_name = None
    return actual_name, closest_name

requested_colour = (252, 230, 36)
actual_name, closest_name = get_colour_name(requested_colour)

print ("Actual colour name:", actual_name, ", closest colour name:", closest_name)
```

```
Actual colour name: None , closest colour name: gold
```

Figure 40: Calculate the RGB value and color pattern name

Canopy Area Detection

AI and machine learning are gradually taking over the planet. Image processing is now a technique for applying various operations to an image to improve it or to extract some relevant information from it. It is a kind of signal processing where the input is an image and the output might be another image or features or characteristics related to that image. Image processing is one of the technologies that is currently expanding quickly. For our project purpose—we use image segmentation—which is a kind of image processing that usually breaks down the image into some subgroups. So, we can say Image segmentation is a technique that helps to simplify future processing by dissecting a digital image into several smaller groups called image segments. In segmentation, images are broken down into subgroups with a pixel value.

For our image segmentation-making processing we use the U-Net image segmentation model which is very much perfect to get our desired output.

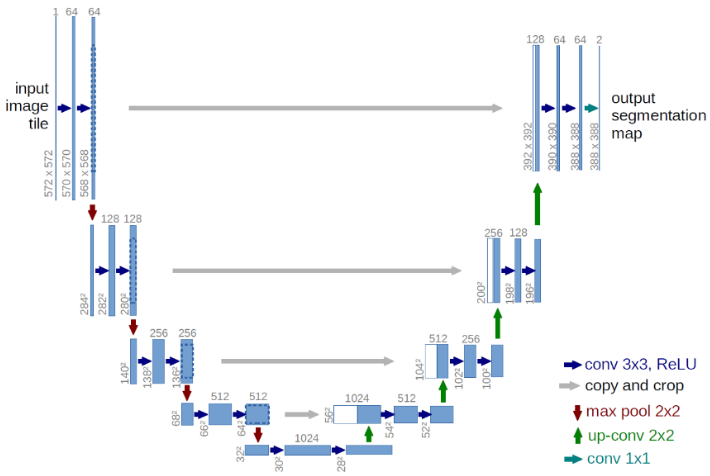


Figure 41: U-Net Architecture

Costructing the UNET Architecture

```
In [13]:
def conv_block(input, num_filters):
    x = Conv2D(num_filters, 3, padding="same")(input)
    x = BatchNormalization()(x)
    x = Activation("relu")(x)

    x = Conv2D(num_filters, 3, padding="same")(x)
    x = BatchNormalization()(x)
    x = Activation("relu")(x)

    return x

def encoder_block(input, num_filters):
    x = conv_block(input, num_filters)
```

Figure 42: U-Net architecture construction with python script

Building the Model

```
In [15]:
input_shape = (img_dim, img_dim, 3)
model = build_unet(input_shape)
model.summary()
```

```
Model: "U-Net"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 256, 256, 3) 0
__________________________________________________________________________________________________
conv2d (Conv2D)                 (None, 256, 256, 32) 896         input_1[0][0]
__________________________________________________________________________________________________
batch_normalization (BatchNorma (None, 256, 256, 32) 128         conv2d[0][0]
__________________________________________________________________________________________________
activation (Activation)         (None, 256, 256, 32) 0           batch_normalization[0][0]
__________________________________________________________________________________________________
conv2d_1 (Conv2D)               (None, 256, 256, 32) 9248        activation[0][0]
__________________________________________________________________________________________________
```

Figure 43: U-Net model building processing

To make our image processing model we collected the proper dataset from the open source website on the internet. These data contained four thousand aerial images with appropriate mask data which are very appropriate to train the machine learning model.

Figure 44: Image data set

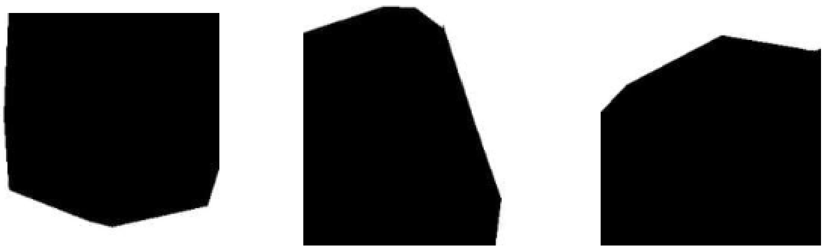


Figure 45: Mask data set

To train the model properly we use fifty epochs. Epoch is the term that indicates the number of passes of the entire training dataset the machine learning algorithm has completed.

```
In [18]:
hist = model.fit_generator(datagen.flow(X_train,Y_train,batch_size=32),
                                        validation_data=testgen.flow(X_test,Y_test,batch_size=24),
                                        epochs=50, callbacks=[earlystop, checkpoint])
```

```
/opt/conda/lib/python3.7/site-packages/tensorflow/python/keras/engine/training.py:1844: UserWarning: `Model.fi
t_generator` is deprecated and will be removed in a future version. Please use `Model.fit`, which supports gen
erators.
  warnings.warn('`Model.fit_generator` is deprecated and '

Epoch 1/50
128/128 [==============================] - 64s 388ms/step - loss: 0.5588 - iou_coef: 0.5258 - accuracy: 0.7350
- val_loss: 13.0446 - val_iou_coef: 0.0046 - val_accuracy: 0.3962

Epoch 00001: val_loss improved from inf to 13.04463, saving model to tree.h5
Epoch 2/50
128/128 [==============================] - 45s 355ms/step - loss: 0.4763 - iou_coef: 0.5407 - accuracy: 0.7764
- val_loss: 3.0013 - val_iou_coef: 0.0258 - val_accuracy: 0.3979
```

Figure 46: Machine learning model training process

After training the data properly we will be able to get our proper output to predict the canopy cover area.

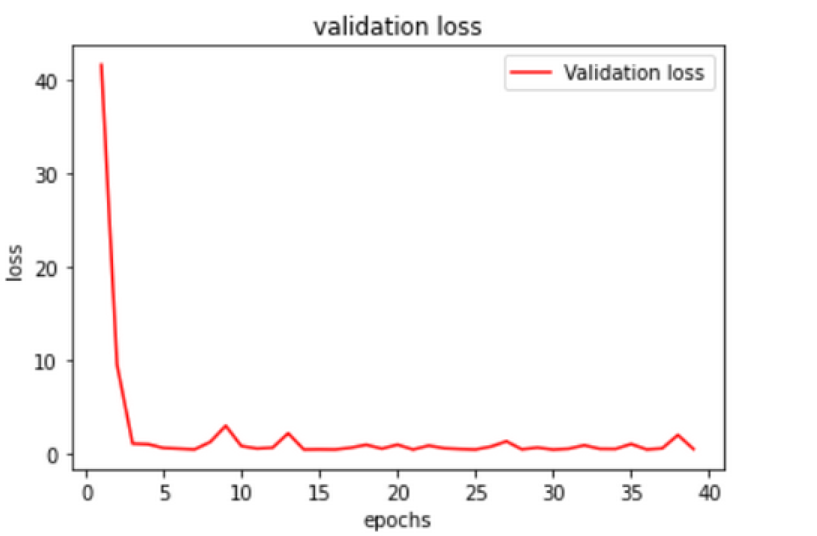


Figure 47: Validation loss

Here we can see the validation loss— the validation loss indicates how well the model fits new data—of our model is very much low. So that we can say, our trained model will fit very well with the testing data set.

```
Epoch 00034: val_loss did not improve from 0.40916
Epoch 35/50
128/128 [==============================] - 45s 354ms/step - loss: 0.3289 - iou_coef: 0.6203 - accuracy: 0.8465 - val_loss: 1.001
1 - val_iou_coef: 0.3501 - val_accuracy: 0.6257

Epoch 00035: val_loss did not improve from 0.40916
Epoch 36/50
128/128 [==============================] - 45s 354ms/step - loss: 0.3199 - iou_coef: 0.6303 - accuracy: 0.8515 - val_loss: 0.419
7 - val_iou_coef: 0.6263 - val_accuracy: 0.8166

Epoch 00036: val_loss did not improve from 0.40916
Epoch 37/50
128/128 [==============================] - 45s 354ms/step - loss: 0.2971 - iou_coef: 0.6381 - accuracy: 0.8626 - val_loss: 0.537
8 - val_iou_coef: 0.4515 - val_accuracy: 0.6968

Epoch 00037: val_loss did not improve from 0.40916
Epoch 38/50
128/128 [==============================] - 45s 355ms/step - loss: 0.2987 - iou_coef: 0.6422 - accuracy: 0.8612 - val_loss: 1.959
9 - val_iou_coef: 0.1403 - val_accuracy: 0.4360

Epoch 00038: val_loss did not improve from 0.40916
Epoch 39/50
128/128 [==============================] - 45s 354ms/step - loss: 0.2883 - iou_coef: 0.6431 - accuracy: 0.8682 - val_loss: 0.463
3 - val_iou_coef: 0.6594 - val_accuracy: 0.8194
Restoring model weights from the end of the best epoch.

Epoch 00039: val_loss did not improve from 0.40916
Epoch 00039: early stopping
```

Figure 48: Model Accuracy of Image processing

Based on the input data or training data, the machine learning model accuracy is the measurement that is used to assess which model is best at recognizing correlations and patterns between variables in a dataset. Machine learning models are used by organizations to make defensible strategic decisions, and improved model results lead to better judgments. The cost of errors can be extremely high, however, this cost is reduced by improving model accuracy. There is, of course, a threshold of diminishing returns at which the value of creating a more accurate model will not lead to a comparable profit rise, but frequently it is advantageous everywhere. Enhancing model accuracy has advantages that save time, money, and unnecessary worry.

After running the model, now we will be able to predict the image from our testing data set. As our data set accuracy is 86 percent which is very much well.

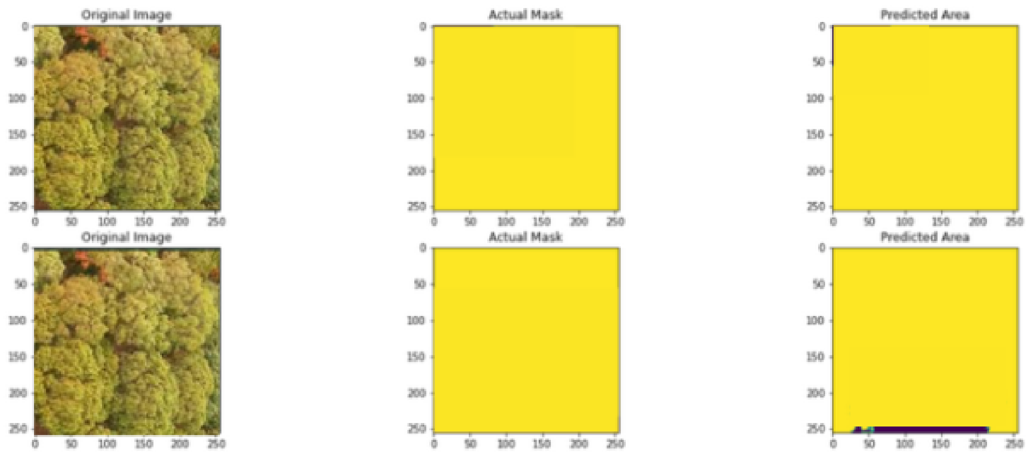


Figure 49: Predicting Canopy Area with Test Image

```python
# Load image
src_image = cv2.imread('./output.png')
src_image = cv2.cvtColor(src_image, cv2.COLOR_BGR2RGB)
reshape_img = src_image.reshape((src_image.shape[0] * src_image.shape[1], 3))

# Display dominant colors Present in the image
KM_cluster = KMeans(n_clusters=5).fit(reshape_img)
visualize_color = visualize_Dominant_colors(KM_cluster, KM_cluster.cluster_centers_)
visualize_color = cv2.cvtColor(visualize_color, cv2.COLOR_RGB2BGR)
#cv2.imshow('visualize_Color', visualize_color)
#cv2.waitKey()
```

```
[ 61.11299435 154.05084746 122.63276836] 0.03%
[15.69558522 13.09856263  3.55749487] 0.28%
[68.01176524  1.15276642 84.13823022] 3.15%
[252.87595813 230.9822382   36.00214093] 5.41%
[255. 255. 255.] 91.14%
```

Figure 50: Prediction area percentage

We can predict the canopy area successfully. After that, we calculated the percentage of the predicted area. As our prediction, we can see from the above picture that 91% of the area is covered with trees. Calculating the area from an image requires computing the distance from our camera to an object; in both cases, we need to define a ratio that measures the number of pixels per a given metric, this is the “pixels per metric” ratio.

GSD (Ground Sample Distance) Calculation

Sw; the sensor width of the camera (millimeters) = 25

FR; the focal length of the camera (millimeters) = 9

H; the flight height (meters) = 30

imW ;the image width (pixels) = 3280

imH ;the image height (pixels) = 2464

GSD ;Ground Sampling Distance (centimeters/pixel) = 2.54
Dw ;width of single image footprint on the ground (meters) = 83

DH ;height of single image footprint on the ground (meters) = 63

Dw = The footprint width / distance covered on the ground by one image in width direction

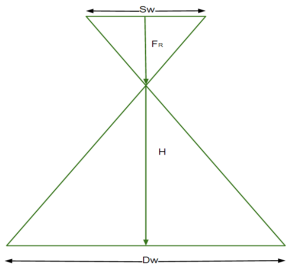


Figure 51: GSD

5.3 Evaluate the solution to meet desired need

In today's world forestry is seeing much more than before with the timeless technology it’s getting better every day. Challenges make more inventions in the forestry sector. As we discussed before, there are so many challenges in the forest monitoring sector. The acceptance and application of recent advancements in UAV and sensor technologies resulted in significant benefits for society, including improved worker safety and other operational efficiencies. Besides, the earth’s climate is drastically changing nowadays. One of the main reasons behind this is that the amount of forest is decreasing day by day. This destruction is caused due to man-made and natural disasters. As the biggest plants on the planet, they give us oxygen, store carbon, stabilize the soil and give life to the world's wildlife. Hence, for saving the life of people, forest monitoring is mandatory. We analyze three different designs for forest monitoring. from where we have chosen the best solution for our monitoring process which can fulfill the desired need more effectively than others. After successfully completing the model implementation for our sensor data and image processing we are now able to know the forest’s health condition. We divided the forest area into hundred meters for our experimenting area. As our UAV’s flight time was not long enough we had to divide the forest area as per our requirement. Our target is to promote the forest monitoring system in order to save forestry for the sake of human lives. Hence, we are using a small UAV that can capture a little amount of forest coverage. When this monitoring system will be used officially depending on the budget one can use a better UAV that can cover more forest area with a better battery backup.

As we are seeing in the data collection part we can collect the air quality data and analyze it with the machine learning algorithm.

Forest monitoring is a vast research area. There are lots of properties present in the forest environment and directly or indirectly they create an impact on forest health. But considering the economic condition of our region, we have chosen some important properties of forest which can cause a direct impact on forestry. The following table shows which research covers which areas.

Table 10: Project Object

Basis	**UAV - Unmanned Aerial Vehicle**
Air quality measurement	Possible
Water sample collection	Possible
Canopy area measurement	Possible

Our ultimate goal is to monitor forest health and provide an idea of the condition of the forest a to dedicated authority. Therefore, now we are going to evaluate how our research matches our desired needs.

Table 11: Evaluate the Model results with the desired needs

Objectives	Procedure	Result	Fulfill desired need (YES/NO)
Air quality measurement	Collect air samples through air sensors. Analysis of the data using a Machine learning Algorithm.	Get an idea of the current air condition and can predict the air quality for the next few days using ML.	YES,
Water sample collection	Collect the samples through a syringe pump. Find the water pH, and turbidity level Use the python script to get the real data output	From the water sample analysis, the quality of water is measured, and from this, we can know its level of toxicity.	YES,
Canopy area measurement	Through image processing we find the canopy area measurement that shows the trees cover an area within 100 m range.	Get the information on forest total tree coverage which can help to monitor the deforestation rate.	YES,
Overall forest health condition	Compare the value of sensors with the standard value then measure the forest health condition under 100% measurement	This percentage rate can define whether the forest is safe or under threat.	YES

As from the evaluation of all objectives from our project we were able to complete all of them. In the surveillance system using UAVs is increasing day by day this will be the future for monitoring in any system. UAV surveillance makes it possible to covertly obtain data on a target that has been captured from a distance or an altitude.

5.4 The Forest Report on Ramna Park with Real Data

Introduction

We visited Ramna Park in Dhaka to collect information about a forest area in preparation for writing a sample forest report. Although this park is small, it is exactly suitable for collecting data and testing the efficiency of our project. This is a report on the forest, and how our project will examine the composition of the forest—with detailed analysis and comparison.

Parameters of Data collection:

Natural components: Air and Water

Air:	Water:
Temperature, T	pH Level
Humidity, Hm	Turbidity
Carbon-di-oxide, CO_2	

Digital Component: Image

Height of data collection (from the ground): 24m

Collected for—Canopy Area Calculations.

Processing and Analyzing:

A. Sensor Data and image:

With our data collected, we made a detailed analysis of the forest, in terms of each natural component and their weighted significance to nature—this will allow us to be aware of any recent forest degradation in terms of health and natural components. Compilation of this data will provide us with the analysis of forest health. The image of the forest is processed with the help of machine learning to get the canopy area of the forest.

B. Weather Report based on the data collected:

- Data from the sensors
- Compared and analyzed—with Standard Forest Condition
- Estimation of the forest health with the information
- Estimation of the tree-covered-area area of the forest

This data will provide the current condition of the forest, and understand the health of the forest, with detailed comparison, and analysis.

Table 12: Analysis of the Data collected (1 Week)

Standard Forest Health Condition [1,2,3,4,5]			
Components	**Parameters**	**Units**	**Range**
Air	Temperature, T	℃	$30<T<35$
	Humidity, Hm	g/kg	$40<Hm<60$
	CO_2	ppm	$270<CO_2<350$
Water	pH	(No units)	$6.5<pH<8.5$
	Turbidity, Tur	NTU (Nephelometric Turbidity Units)	$1<tur<5$

With over 500 data samples of each of the parameters for 7 days, we determined the mean value of temperature, humidity, CO_2, pH, and turbidity—to compare them with the standard range of a forest (*sources cited*). The data is compared to the standard range for a forest, then the standard deviation is calculated to observe the condition of each parameter. We input the data into our system to get the following result:

Table 13:Founded Data Comparison

Founded Data Comparison					
Components	Parameters	Mean Value (7 days)	Standard Deviation	Decision	%-of Precision (*within the range)*
Air	Temperature, T	29.77536℃	0.748%	Less than standard range	99.252%
	Humidity, Hm	83.28079g/kg	38.8013%	More than standard range	61.1987%
	CO_2	342.513ppm	0%	Within range	100%
Water	pH	7.091	0%	Within range	100%
	Turbidity, Tur	4.004NTU	0%	Within range	100%

To get the overall condition of the forest—each parameter is given a weight—according to its impact on the health of the forest.

For this:

- ➔ CO_2 has ⅔ impact on temperature rise [6]
- ➔ Temperature increases pH levels [7]
- ➔ Temperature has an impact on humidity [8]

Considering these conditions every component is dependent on temperature, and CO_2 has a major impact on temperature, therefore, we can arrange these components on some weight—depending on the impact they have on the environment.

CO_2 > Temperature > Humidity > pH > Turbidity

Components	Impact on environment %
CO_2	40%
Temperature	31%
Humidity	14%
pH	10%
Turbidity	5%

From the above figure, we analyzed the forest health index and found a comparative health condition of the forest—which is *94%*—as per our standard data input and the weight of impact of each component on the environment. The impact of the parameters on nature is calculated with the individual parameters' percentage in the forest weather. That means the park falls under the Good zone. This is the health analysis—based on the average one-week report of *03–06-22 to 09-06-22.*

Table 14: Forest Condition Scale [3]

Category and Color	Index Value %	Description
Good Green	75 to 100	Forest quality is satisfactory, and the forest population poses little or no risk.
Moderate Yellow	51 to 74	Forest quality is acceptable. However, there may be risks if we monitor thoroughly we can overcome
Unhealthy Orange	26 to 50	Sensitive for the animal or the current forest canopy area.
Very Unhealthy Purple	0 to 25	Health alert, the risk of deforestation is very high.

C. Canopy Area:

Figure 52: A 100m area range image of Ramna Park

With the help of the drone camera, we got a 100m area coverage of the park. Our image processing model gives us 82% accuracy—in area fragmentation of tree concentration. Since the data is from one week, and 100m we got more or less the same canopy area.

Test Day One

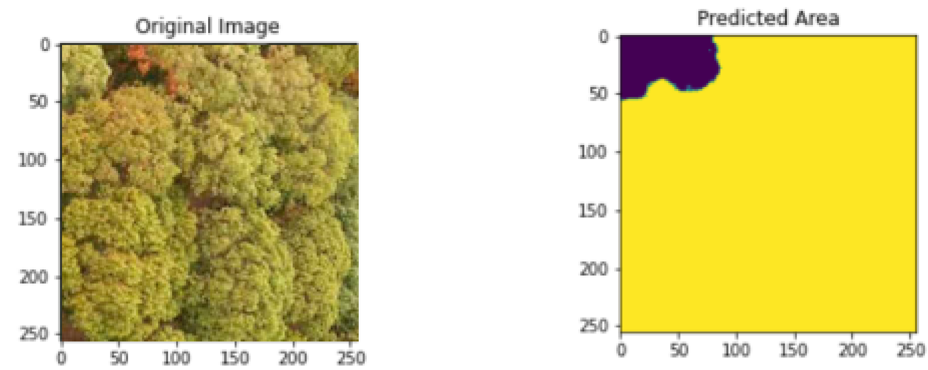


Figure 53: Predicting Canopy Area with Test Image

Canopy Area Calculations = *91.54%* (approximately) of the 100m area. (avg.)

Test Day Two

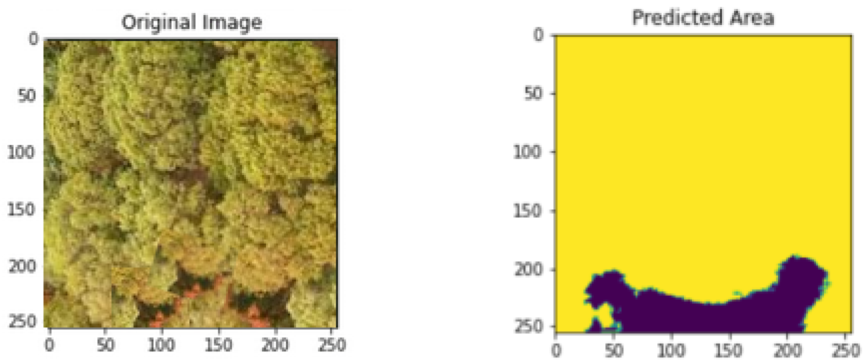


Figure 54: Predicting Canopy Area with Test Image

Canopy Area Calculations = *84.26 %* (approximately) of the 100sq. m area. (avg.)
The data are from two 100 sq. m. portions of Ramna Park—so 87.9% of the area is characterized by the average of these two data.

Result

Our data show that the Ramna Park forest is *94%* healthy, with canopy and trees covering *87.9%* of the 100 sq. meter area.

Suggestions

To monitor the health of the forest, we must frequently verify the most recent data. Any figure below 50% is seen as hazardous to the forest. The health needs are periodically monitored to enrich the data and proper management of the forest. Additionally, we can try to to survey other forest regions to determine the typical forest canopy area over a wider time, which will help us gather more data for our study.

Table 15: Suggestions based on the research result

Air quality	Water quality	Forest tree concentration (Canopy area)
• Plant more trees as trees reduce air pollution and maintain the tree concentration • Following the AQI (Air Quality Index)	• Plant trees on hills and near streams to reduce land run-off • Dissolved CO2 decreases the pH of water as well, it should be maintained. • Turbidity in water is mostly caused by human activities that should be monitored.	• Control deforestation in the future • Maintain a healthy atmosphere in the forest to ensure proper growth of trees • Animal habitat can also be monitored

Conclusion of the report:

The report we have prepared will provide a thorough understanding of how our project will operate. The information, images, and statistics gathered collectively provide a general idea of the forest's state of health.

We will be able to make recommendations and get ready for the steps needed for analyzing forest health and forest preservation with the use of this information.

The above standard values have been found from online resources which are referred to [21],[22],[24],[25].[26].[30],[34],[35],[22]

5.5 Conclusion

Forest ecosystems are our planet's life force. The preservation of the woods is crucial since they are the sole essential source of air for other ecosystems. Ironically, there is a severe impairment in our knowledge of the value and sustainability of forests. UAV technology and its marvelous wonders are being used to produce a warrantable and credible environment, reviving the vitality of the need for forests today. Humans occasionally tend to chase after novelty and change. Through this voyage from time to time, we have discovered the inventiveness and innovative culture of UAVs. UAV technology is enhancing this ecology of trees and forest cultivation by going beyond conventional rules of technology and automation. Because technological developments occur daily. The UAV sector is growing, and as a result, UAVs are entering new industries every day. A relatively new idea, UAV technology in forestry is growing in popularity. That's why we are also going with the flow with the UAV technology. We chose our design compared with the other three designs and came up with a suitable solution which was monitoring a forest with a UAV. To complete the UAV or more precisely the quadcopter configuration, that we selected has better stability than the other configurations and can hover close to its objective in contrast to its rivals. In developed nations, this kind of UAV design is crucial for the observation of terrestrial areas. The main goal of this effort was to develop an appropriate configuration that could operate in the forested region, as well as to improve the balance and stability of our design system from an engineering perspective and be more useful in the current situation.

Chapter 6

Impact Analysis and Project Sustainability

6.1 Introduction

UAV technology is getting popular for maintaining the ecosystem of trees and forest cultivation. Although in its neonatal stages, the high flame of UAV innovation is burning ever-so-brightly in the spheres of forestry and forest cultivation. Managing a forest is a never-ending job—and one that requires constant maintenance and surveillance. After all, these critical ecosystems are at risk from a variety of natural and human-caused threats. it becomes difficult for forest managers and workers to take immediate action owing to the large span of areas that constitutes forests. As a means of relief, Unmanned Aerial Vehicles (UAVs) help in terms of aerial surveillance mapping, aerial photography, thermal imagery, and topographic monitoring. [23] The flexibility of UAVs allows them to capture high-resolution images and video in real-time, even during the humid tropical climate. Artificial Intelligence-powered UAVs, along with UAVs that use LiDAR can monitor and inspect large areas with focussed coverage that yields faster and more precise results and data. UAV provides some features that can be beneficial for forestries such as;

Capturing Images

Aerial photography is a fascinating UAV application that is beneficial to a variety of organizations and sectors. This is a term that is commonly used nowadays all across the world. UAVs with thermal, infrared, or HD imaging capability can be used to acquire clear photographs of a person's plants and trees. UAVs with cameras are also proven to be highly useful for studying wildlife behavior and forest biotic views.

Location and Navigation

During mapping, surveillance, geospatial research, and other applications, UAVs outfitted with GPS trackers and radar are utilized for navigation and location sensing. Unmanned aerial vehicles may be tracked with this important UAV application, reducing the risk of their being lost due to unanticipated events. UAVs with GPS systems, whether remotely operated or autonomous, play a vital role in gathering and sharing precise data.

Providing information about trees

Aside from measuring the number of trees in the forest, UAVs powered by Artificial Intelligence and Machine Learning have proven useful in the identification and prevention of tree diseases. UAVs equipped with LiDAR sensors collect and process data related to the health of trees, plants, and bushlands. Thermal imaging, topographic surveying, and aerial mapping enable horticulturists and forest officials to detect unhealthy flora and guide them toward bettering their circumstances.

Getting information about forest elements through sensors

In our everyday lives, we use a variety of sensors. Companies have begun to integrate sensors into UAV technology to broaden the scope of UAV applications. A UAV can collect data from a variety of sensors, including changes in speed, distance, temperature, wind, chemical signals, light, sound, and the presence of magnetic objects. Temperature sensors, humidity sensors, and moisture sensors can all be used in forestry to measure the temperature of the forest weather.

6.2 Assess the impact of the solution

As from the project's main aspect, the system will be created to monitor the forest environment. This model of the system includes all the main materials of the forest environment like water, air, and forest cover area detection; the detection system will provide data for the detection of deforestation. This system will be more handy and low-cost than other monitoring model systems. People who are connected with the forestry monitoring or survey will be benefited from our designed model.

The data of the environment will be collected with smart sensors and IoT-based devices. The data will be stored to access in the future. For detecting the forest cover area; here image processing-based segmentation will be used. The image processing model will be created before then the model will be deployed in the raspberry pi. This system will be able to detect the forest cover area. The system will provide efficient data for making future decisions to protect the forest environment properly.

- **Social Impact**

Forest plays a major role in the lifestyle of those people who live near any forest. Forest covers almost 2.33 hectares of land in our country which is nearly 17.5% of the total land of Bangladesh [32]. Many civilizations had built up near those forests. Hence many people are still dependent on forests in many ways as it directly or indirectly creates an impact on social and economic lifestyle. [28] The forest is a source of many products [28] for example, honey, wood, timber, herbs for medicine or beauty products, raw materials for many industries, etc.[28]. Besides, they collect food for themselves as well as for trading them on the market. So, Forest plays an important role to make the rural people employed. [32]which on a larger scale takes part in the rural development of the country. [32] Even many businesses are running where most of the raw materials are coming from forests. So, people engaged in that business or production sector all are indirectly or directly dependent on forests. Their economic development makes them socially stable. As a result, a pollution-free safe forest is mandatory for those people as their life fully depends on the forest. On the other hand, lots of people are appointed by the government to take care of the forests. They are also dependent on forests for economic purposes which gives them social stabilization. So the government and appropriate authorities need to pay attention to forest safety and how people can benefit from forests [28]. Therefore, through our research we let the authority know about the condition of the forest which would help to protect the forest and continue forest-based activities.

- **Impact on Health**

Forests take part to improve both our physical and mental health together. Directly or indirectly our health is dependent on trees and plants. From our food to medicine we are relying on forests. Forests or trees balance the ecosystem which ensures a healthy lifestyle for people [27]. Forest is a vast zone for collecting food or ingredients for preparing food. It can be a zone for honey hives. Besides, it is a rich source of herbs that are used for pharmaceutical purposes for making medicines [27]. So, our health largely depends on the forest environment. It helps to protect people from natural calamities. It filters polluted air, provides a huge amount of oxygen, and also purifies water and other toxic particles [27]. In this way, it saves people from dangerous health issues. Even forests mitigate the rainfall as well which creates an impact on the health of people [27]. Along with physical health, forests promote mental health also. [27]. It helps to prevent mental illness and reduce depression, fatigue, or stress from anything. The fresh air and scenic beauty of the forest give a person mental and physical peace. It cures many mental disorders. So, pollution or deforestation in forests directly affects human health which may cause death as well. Therefore, we need to protect forests for the sake of human beings. As long as we can protect the forest, we can get benefits from it. Through our research, we can point out if the forest is suitable for serving those facilities to humans or if it is polluted.Because, if it gets polluted that will create an adverse impact on human civilization.Polluted air, water, poisonous food, herbs, etc. will be a threat to humans. even it will cause an impact on climate change as well[27]

- **Safety Impact**

Forests take part to stabilize the climate on earth. Due to the extreme amount of deforestation, the world is facing serious climate changes* in recent years. Bangladesh is not free from it. To build houses, and earn livelihood people randomly are cutting trees from forests which leads to deforestation and creates natural disasters. For example, due to a huge number of deforestation malaria breaks out in Africa, Latin America, and Asia [27] so the forest works as a safety boundary for humans, and due to deforestation and a toxic forest environment, this safety layer is damaging. Our research report will help to let the authority know if the forest is good enough to provide safety to people and properties. In the previous decade, the Sundarbans prevented people in the coastal area from 3 major cyclones [31]. So forest safety means the safety of people. Our solution will help to ensure that safety.

- **Cultural context**

Culture of a people varies from place to place. As the cities have their own culture and tradition, people near forest areas have their own culture [29]. For living near forests for a long time a different type of culture has been created in those regions. In the name of Urbanization, lots of forests have already been cut down which forces the inhabitants to leave their places. In this way, the culture of those places is getting lost. The culture and tradition of a country must keep alive. People who live near forests have their norms, freedom, education system, food variety, cloth designs, etc. [29]. Due to the damage to forests, there is a chance to lose this type of culture in a country. So, to protect these forest-based cultures we have to maintain proper forestry. Our paper will help to ensure that maintenance. As long as the forest is protected, the culture of forest areas remains alive because along with the other benefits, forests give us cultural services as well [27].

- **Legal Impact**

Our survey report offers a solution to save forestry in Bangladesh. To implement that solution in practical life, there may be some legal issues. For example, many people have already started in places that are under forest areas. Through deforestation, they made those places suitable for their living. In that case, to reforest that area they have to leave that place which may increase local poverty. Besides, the reforestation budget is also a matter so the government needs to sanction the budget for that. So, the implementation of this solution depends on all the sectors related to the forest management of Bangladesh [32].

6.3 Evaluate the sustainability

Unmanned aerial vehicles (UAVs) are aircraft that don't need a cockpit, a pilot to fly them, or any of the specialized equipment, instruments, or safety-critical systems that are often found on human aircraft. UAVs are unmanned, therefore their size can be appropriate for the task without the requirement for human passengers. Most drones currently operate just nicely on batteries, unlike modern airplanes and helicopters. From their design perspective, they are inherently energy-efficient. In terms of efficiency, UAVs can provide the best service among the other forms of monitoring. UAVs improve aerial surveillance, allowing forestry teams to capture more footage from different angles and perspectives. UAVs are also much easier and more cost-effective to deploy, making them more suitable for daily use. Forestry departments need to be careful when planting trees to ensure the new saplings benefit the forest and ultimately achieve maximum growth. UAVs can collect a variety of data points and help with predictive planning and analysis to increase the chances of this happening. Moreover, it saves time and the collected data provides more accuracy than the other types of surveillance technology.

6.3.1 Maintainability and Manufacturability

UAVs are true engineering gadgets that may be employed for most technological applications. Quadcopters, hexacopters, and a wide range of professional gear, from foam to high-grade materials, are now being produced by UAV firms. Quadcopters are being used to monitor the forest here. A quadcopter is a multirotor unmanned aerial vehicle (UAV) with four arms or booms, each with a rotor, that provides lift to allow the aircraft to fly. The operating idea is that one pair of rotors rotates clockwise while the other rotates anti-clockwise, and by adjusting the speeds, thrust and turning motions can be generated.

Quadcopters are often easier to build and fly than unmanned helicopter UAVs, making them an excellent alternative for some applications like surveying and aerial photography. Frame, motors, propellers, ESC (electronic speed controller), Flight controllers, batteries, and RC receivers are some of the essential parts of quadcopters. The main construction of a quadcopter is its frame. A quadcopter's brain is the Flight Controller (FC), which has sensors onboard to understand how the drone is moving. The FC employs algorithms to compute how fast each motor should be spinning based on the data provided by these sensors for the craft to behave as the pilot instructs via stick inputs on the TX (Radio Transmitter). It also needs to be connected to the RX (receiver) so that the craft can be taught what the pilot wants it to perform. For the motors to carry out the FC commands, each of the ESC signals and ground wires must be connected. The quadcopters' power sources are LiPo batteries. Because of its high energy density and discharge rate, LiPo is used. An ESC is a device that analyzes data from the flight controller and converts them into phased electrical pulses to determine the brushless motor's speed. Because the quad's motors are the primary drain on battery power, finding an efficient propeller and motor combination is critical. Without the prop attached, the motor speed is measured in kV; a lower kV motor will create greater torque, while a higher kV will spin faster.

UAVs require regular maintenance checks to ensure everything is in working order. it is most efficient to perform maintenance on a per-flight basis, rather than a set timeframe. It is not a complex task to take care of a UAV. For routine maintenance, we need to check a few things like doing key performance tests, UAVs, and batteries before flying, Cleaning of any dirt, Upgrading to software, Visual inspection of all moving parts, etc. This maintenance is affordable and ensures safe flying which reflects in the result of monitoring.

6.3.2 Sustainability

Forest ecosystems, which are the life and soul of our planet, account for 31% of its biodiversity [1]. The sustainability of forests is crucial since they are the sole essential supply of air for other ecosystems. Ironically, though, there is severe impairment in our knowledge of the importance and sustainability of forests. Drone technology and its marvelous wonders are being used to produce a warrantable and credible environment, reviving the vitality of the need for forests today.

Size of UAV and Weight

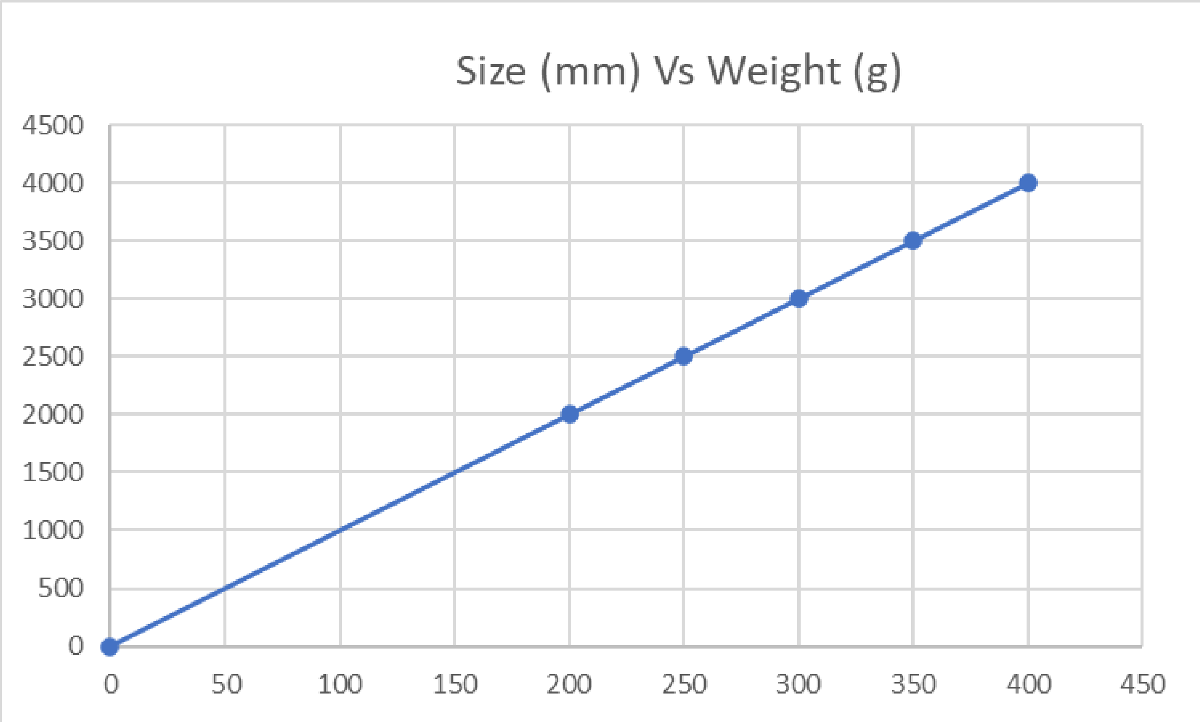


Figure 55: UAV size Vs weight comparison

This graph demonstrates a definite positive relationship between the UAV weight and the diagonal length of the UAV frame size (Diagonally) without taking into account the propellers. From our design, we took the S500 quadcopter frame which is very much strong and capable of lifting a weight of around 3500 grams.

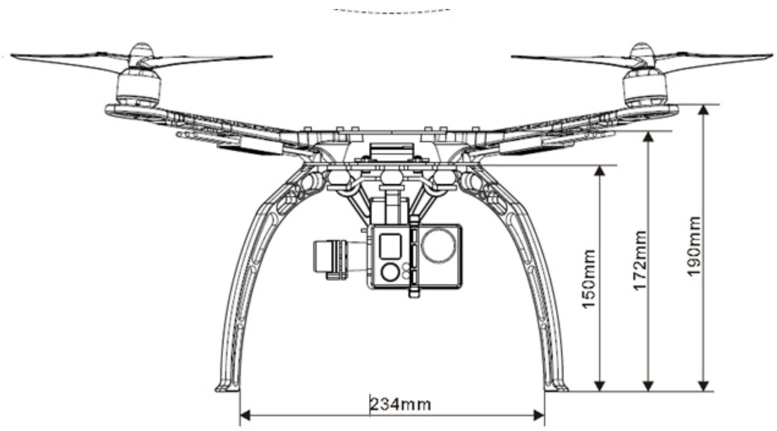
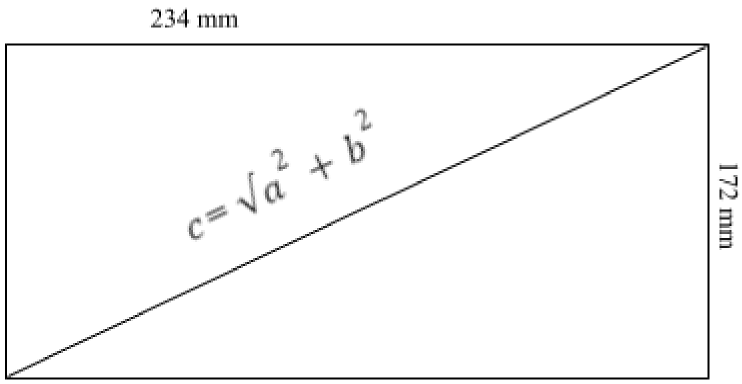


Figure 56: S500 Frame for Quadcopter[3]

Diagonal Area Calculation



Equation

$c = \sqrt{a}^2 + b^2$

C = 290.41

From the diagonal area calculation of the frame we got it is around 290.41 mm and the weight of our UAV including payload is around 3500 gm. From this, we can say the frame we choose is sustainable to carry the survey system accordingly.

6.4 Conclusion

In the end, we can say those who adopt drone technology in the forestry sector stand to gain significantly from doing so. High-resolution photographs can be captured using this innovative and quickly developing technology as part of a much broader data collection that will help organizations and researchers alike better understand and monitor the health of forests and their inhabitants.

Chapter 7

Engineering Project Management

7.1 Introduction

Project management that is entirely concerned with engineering projects is known as engineering project management. The basic approaches and procedures used in project management are the same for all project management types. Anyone with an engineering background who wants to work in project management is likely to be interested in this specialism.

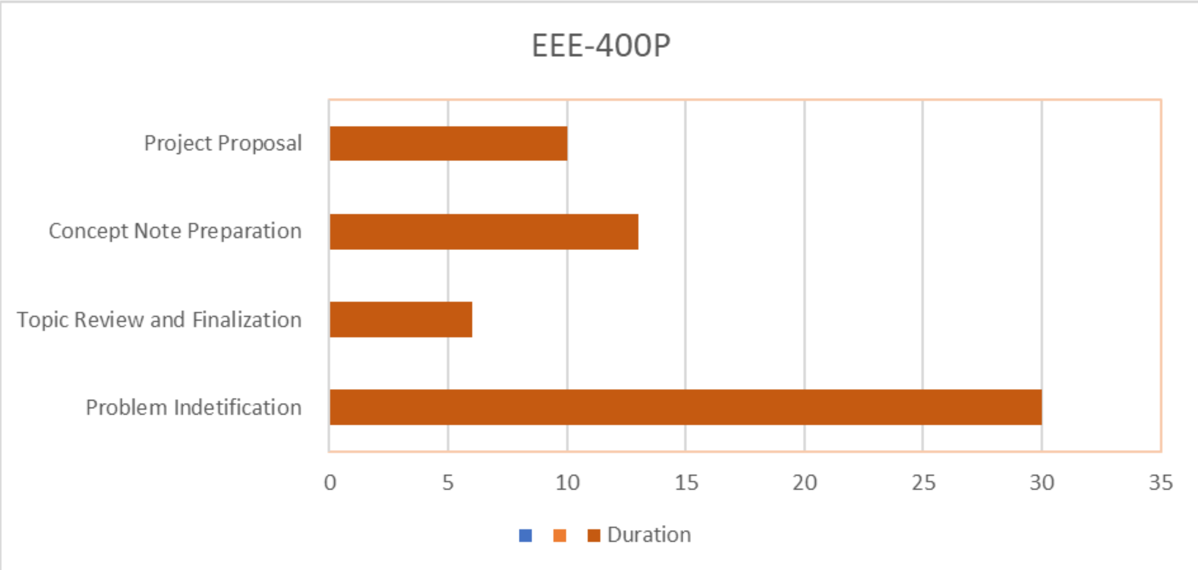
Project management for engineers entails meticulous preparation and dissemination of that strategy to an engineering team. It entails identifying the project's objectives and checkpoints as well as creating various scenarios and backup plans. Any engineering team that skips this step risks having the labor of dozens or even hundreds of employees derailed by the unexpected.

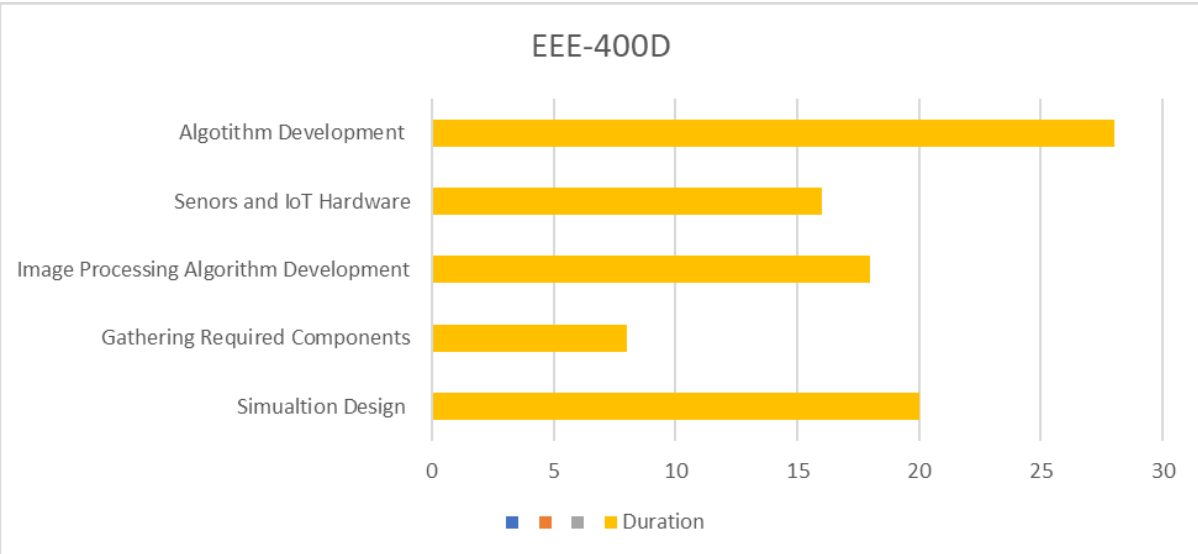
Engineering is a complicated and constantly changing field, thus project managers in this field must be flexible and knowledgeable about all of the most recent best practices. This comprises general managerial abilities as well as engineering procedures pertinent to the project at hand.

7.2 Define, plan and manage engineering project

Project Plan			
EEE-400P			
Task	*Start Date*	*End Date*	*Duration*
Problem Identification	17th Oct ‘21	17th Nov ‘21	30 Days
Topic Review and Finalization	17th Nov ‘21	23rd Nov ‘21	6 Days
Concept Note Preparation	26th Nov ‘21	8th Dec ‘21	13 Days
Project Proposal	16th Dec ‘21	21st Dec ‘21	6 Days
EEE-400D			
Task	*Start Date*	*End Date*	*Duration*
Simulation Design	20th Jan ‘22	10th Feb ‘22	20 Days
Gathering Required Components	11th Feb ‘22	17th Feb ‘22	8 Days
Image Processing Algorithm Development	18th Feb ‘22	6th Mar ‘22	18 Days
Sensors and IOT hardware	7th Mar ‘22	22th Mar’22	16 Days
Algorithm Development	23th Mar ‘22	18th April ‘22	28 Days

EEE-400C			
Task	*Start Date*	*End Date*	*Duration*
Building Cloud Database	25th April ‘22	14th May ‘22	20 Days
Prototype Testing	15th May ‘22	4th Jun ‘22	20 Days
Prototype Demonstration Preparation	5th Jun ‘22	19th Jun ‘22	15 Days
Project Final Report	22th Jun ‘22	18th July ‘22	28 Days





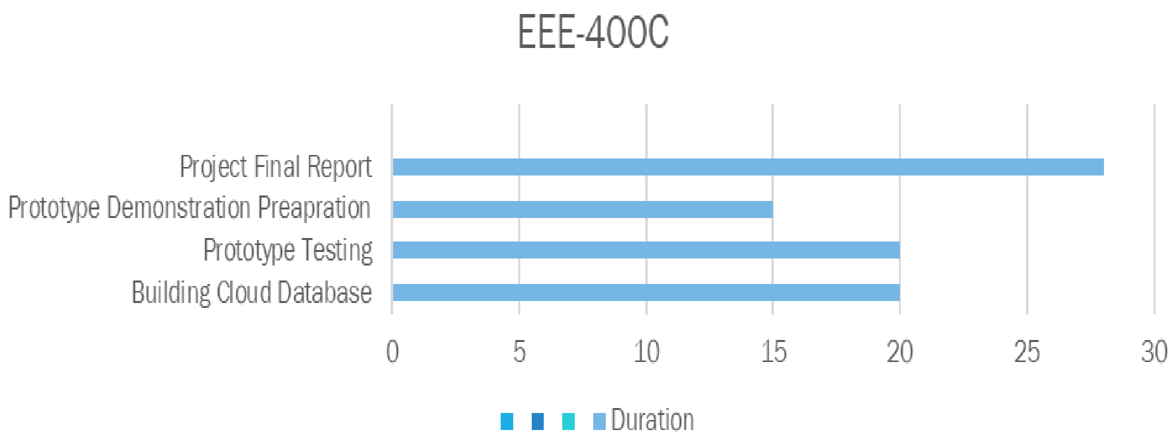


Figure 57: Gantt Chart

7.3 Evaluate project progress

As per our requirement we started working on our project in October 2021. We have done everything step by step. After group formation following the instructions of our respected ATC, we have chosen this project topic among multiple research topics. We wanted to work on something that would be beneficial to humans and nature as well at the same time which is not popular in the context of our country. That is how we have decided to make a forest monitoring system. Then we started reading different papers, articles, and journals related to our project to get precise information and to get an idea about the procedure. We have prepared a work plan for each semester. We maintained the logbook regularly and divided our tasks among the team members equally. Following the project plan, we started working on our project. Due to the pandemic situation, we had to do our research and tasks at home and online. We maintained our weekly online meetings. In the first semester of our FYDP, our task was to prepare the plans to conduct our project. Hence, we discussed the project design, methodology, requirements, and budget. We also pointed out the risk factors, sustainability, and legal issues. In the next semester (400D) we started the simulation part of our project. Here we also briefly described the other multiple solutions of our project with their simulation and also showed why we have chosen our solution among them. Due to the pandemic situation, and academic pressure we failed to maintain our previous work plan. Hence, we prepared a new plan. We need to change the budget also as prices of most of the components have been increased. We showed the impact of why and how our project would be beneficial for humans and nature. Finally, in the last semester of our project, we implemented the device and successfully did our monitoring. We started working on both the hardware and software parts before the start of the semester. After that, we assembled various parts, sensors, and cameras for the UAV and finished with the hardware setup within the first 2 weeks of the semester. Then we started collecting data from the forest. Here, we have chosen Ramna Park to conduct our monitoring because it was difficult for us to collect data continuously from outside of the city during an ongoing semester. We have collected samples of air, water, and images. Then Through machine learning algorithms and image processing, we collected those data from the server. Based on those data we evaluated the forest condition. We compared the result of the sample data with the optimum condition data. In this way, we can get the result about the overall forest condition. Depending on that we prepare a forest report which will be uploaded to a system from which anyone can get it when needed.

Chapter	TASK TITLE	TASK OWNER	START DATE	END DATE	DURATION	PCT OF TASK COMPLETE
Chapter No	**Project Report Writing**					
1	Introduction	Taiubul Islam	7/15/22	8/15/22	30	100%
2	Project Design Approach	Taiubul Islam	7/15/22	8/15/22	30	100%
3	Use of Modern Engineering and IT Tool	Taiubul Islam	7/15/22	8/15/22	30	100%
4	Optimization of Multiple Design and Finding the Optimal Solution	Asif Mahmud	7/15/22	8/15/22	30	100%
5	Completion of Final Design and Validation	Asif, Taiub	7/15/22	8/15/22	30	100%
6	Impact Analysis and Project Sustainability	Asif, Nabila	7/15/22	8/15/22	30	100%
7	Engineering Project Management	Tanvir	7/15/22	8/15/22	30	100%
8	Economical Analysis	Tanvir	7/15/22	8/15/22	30	100%
9	Ethics and Professional Responsibilities	Nabila	7/15/22	8/15/22	30	100%
10	Conclusion and Future Work	Nabila	7/15/22	8/15/22	30	100%
11	Identification of Complex Engineering Problems and Activities	Nabila	7/15/22	8/15/22	30	100%

Figure 58: Task for group members

7.4 Conclusion

To complete a successful engineering project the above protocols and work plans should be maintained. Failure to maintain them can lead to an unsuccessful project. Good teamwork, proper planning, communication, and research work as a support system for an engineering project. Here, in our project, we tried to follow them properly. Without proper project management, we can not make a work plan, we fail to manage time, and also face problems in terms of budget. Hence, proper planning and management are needed in an engineering project.

Chapter 8

Economical Analysis

8.1 Introduction

Economic analysis refers to the evaluation of the costs and benefits of any project or plan. For a project to sustain for a long time, it is important to conduct an economic analysis. We cannot employ low-cost equipment or components that may fail to operate in a short time or have low efficiency. As we have to ensure economic sustainability. Economic analysis of a project aims to ensure that the project provides proper efficiency, and if anyone invests in this project that will bring benefits to a country and it will also raise the welfare of the people of that country. Cost is one of the main concerns in economic analysis. Cost includes initial investment, annual maintenance, and repairs. The initial estimated cost may decrease or increase depending on various factors when the project will be implemented. On the other hand, economic analysis talks about the estimated benefits coming from the project as well. [10]There can be two types of benefits. They are market benefits or non-market benefits. It is hard to convince people of the non-market benefits. As people cannot get immediate benefits from it. A well-conducted economic analysis can convince people effectively, raises the chance to implement the plan successfully, and create a healthy relationship between the planner and citizens. It shows a glimpse of the overall project.

8.2 Economic analysis

In forestry projects Economic analysis is an important element in terms of evaluating the forest condition. It includes the creation of protected forest areas, natural forest management, logging, and processing. Forests are an integral part of national economies. People are directly or indirectly dependent on forests. So it is necessary to protect it from any harm. Hence, our research project is to make a forest survey to get an idea of the forest condition. Thus, forest authorities can use it as a scale and monitor the changes from time to time. From the perspective of economic validation, our project has non-market benefits. Because of air pollution, forest degradation, and turbidity of water these things have no market value. This is why it is difficult to convince people to invest in this kind of project. Hence, we are showing the economic analysis which can help general people to know the concept of our project and how it is beneficial to mankind and nature also. Our economic analysis should be in such a way that the general people who do not have much idea about the importance of forest safety, can understand the value of the survey. As we know, the economic analysis consists of costs and benefits. So our challenge is to build the project and conduct the survey thus people can get maximum benefit at minimum cost. But, we cannot employ low-cost equipment or components which are low in cost but may fail to operate for a long time or have low efficiency. In that case, we may fail to ensure economic sustainability. We must confirm that each product is of great quality before implementing or purchasing it by testing it[11]. We also need to perform routine maintenance on every component, such as the drone, engine, battery, and sensors. We can tell if a component is working well or not, and we can alter or repair it before it causes damage. It will also increase the long-term viability of our project.

8.3 Cost-benefit analysis

In India in the year 2021-22, the Ministry of Environment, Forests and Climate Change has been allocated Rs 2,870 crore, which is an annual increase of 6% over the actual expenditure in 2019-20. In 2022-23, the Ministry has been allocated Rs 3,030 crore, which is a 20% increase over the revised estimates in 2021-22[12]. In Pakistan, A sum of Rs 4. 5 billion has been earmarked for 27 schemes in the forestry sector in the budget 2022-23[14]. Whereas, Bangladesh's budget for 2020 shows that, the allocation for the Ministry of Environment, Forest and Climate Change was Tk 1,246 crore. The following year, the government reduced the amount by Tk 25 crore, and this year's allocation is set at Tk 1,221 crore, Jun 6, 2021. This year the Environment, Forest and Climate Change Ministry in the proposed budget for fiscal 2022-23, which was Taka 280 crore more than that of fiscal 2021-22.[13] but the economic condition of Bangladesh is not running well. In this condition that increased budget may not work properly. From here we can notice that the investment in forestry is increasing every year in our neighboring countries. But the government used to show less interest in this sector. Nowadays the whole world is undergoing serious climate change. Bangladesh is not free from it. As a result, the government has increased the budget for forestry. Though we still are not serious about the health of forests and ignore their contribution to our life. The respected authorities are not serious about the safety of forestry hence though the budget has increased the deployment is not showing in this sector. So, in this situation, we cannot propose a forest monitoring process because the budget is limited. We need to suggest a monitoring procedure with a medium-range budget. At the same time, it is our task to motivate people about the importance of forestry surveys which can make them save the forest from danger. There are various processes for forest monitoring which we have mentioned earlier. Our other two solutions were manual remote sensing and robotic ground vehicle. But in terms of both efficiency and cost, those models cannot be economic for our country.

Table 16: Cost analysis of multiple designs

Design Approach	**Functionality**	**Time (Minutes)**	**Cost (BDTK)**
Manual Remote Sensing	1. Sample Collection 2. quantity: 3 Group of people per 100 meter	180 Minutes	25000 (Per Person) 20000 (Device Cost)
Robotic Ground Vehicle	1.Only air quality measurement 2.Canopy area cover (LiDAR) 3.quantitiy: One unit per 100 meters	40 Minutes	250000(Per Unit)
Unmanned Aerial Vehicle (UAV)	1.Canopy area covers 2.Sample collection	30 Minutes	Around 50000 (Per Unit)

	3. Quantity: One unit per 100 meters 4. Map inaccessible areas		

Here we can see that UAV provides the best possible solution. UAVs are less expensive than the other two types of environmental monitoring. Small UAVs are excellent for applications though the aerial coverage, piloting experience, and skill are limited, so the operational budget is often low. Nowadays because of advancements in battery technology, navigational controls, and payload capacity, the smaller UAVs are now capable of collecting photographic data, video footage, multispectral, thermal, imaging, as well as LiDAR. Larger and more powerful UAVs are capable of covering a wide area of land in a forest. It is dependent on the number of regions we need to cover at any one moment. However, a human-driven car will always be less expensive than a robotic one.

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) requires an outlay of $10 billion for 10 years []. Lack of financing is a major factor for the government in implementing the following plan. Furthermore, the lack of fund management capacity is an additional limitation. Hence, we tried to make our project in a budget-friendly manner. The total cost of making the monitoring system was approximately 46,950 BDT. It is very low compared to the device-making budget in other countries. Hence, our system functionality is not world-class. But it can do the monitoring process. Besides, our project motive is to let the forest authority know about the condition of a particular forest. So that by following this report they can get an idea of the forest's condition and can make necessary changes. Besides, we are also showing the possible results when the forest conditions get worse or better. It will help them to know if the forest is under threat or not. Because of budget limitations, we are working with some of the forest components which can have a direct impact on forests like air, temperature, humidity, pH, and forest canopy area coverage. But there are more properties in the forest. If the authority can exceed its budget following the government protocol, then it will be able to get more information related to forest health.

8.4 Evaluate economic and financial aspects

Forests represent more than just a livelihood to many people in developing countries. In Bangladesh, for example, overwhelming poverty and socio-economic pressures have resulted in an unstable situation where intensive pressure on forest resources is having increasingly negative consequences for the population. Unlike other countries, the government along with the people of our country is hardly seen to show concern about forest health and safety. Hence budget allocation was decreased from 2022 to 2021. But this year the amount has been increased by the government which is a positive sign. But on the other hand, Bangladesh is currently going through a serious economic crisis (2022). In this condition, we are not sure whether all the forestry development projects will see the light. Hence, we cannot propose a plan which is not possible to conduct. We need to suggest a plan in an economic way that can match the financial support for forestry.

Considering the current global climate condition, we can not survive long if we cannot save the forest. People in our country are also facing various disasters due to climate change. So, forest protection is necessary. Our research report will not only help the forest management authority but also can be used to inform the general people about the importance of forests. Here, we can make a system where people can check the forest condition when needed. They can use the result of the report as a scale of forest health and can compare the changes from it. In this current situation, it is not enough for the authorities to take action to save forests. General people also need to be conscious.

8.5 Conclusion

From the above discussion we can say that foreign countries invest huge amounts of their budget in forestry. Modern technologies are being invented day by day to make forest monitoring easier, which makes the monitoring system easier but it increases the budget also. At the same time, lots of awareness programs are also being held annually which make the people over there conscious of forest safety. But in the context of Bangladesh, the scenario is a bit different. Compared to the economy of our country it is hard to invest much in the forestry sector. Hence, we tried to make a solution from which we can get maximum benefits at a lower cost. Comparing the other two solutions our solution provides a more efficient and effective output which can also assure the sustainability of the project. It saves time, labor, and also money which makes our project economic.

Chapter 9

Ethics and Professional Responsibilities

9.1 Introduction

The purpose of ethics is to offer codes of ethics and behavior that can assist people in determining what is right and wrong, as well as how to act and behave. Frequently, ethical standards are higher than the legal minimum. According to the PMI (Project Management Institute), "Ethics is about making the best possible decisions concerning people, resources, and the environment. Various ethical lines might be crossed in project management.[9]The greater the project, the more likely staff will be willing to compromise their ethics to do it on time and budget. Ethical consideration is a major sector in project management as it is a part of scientific integrity, human rights and dignity, and collaboration between science and society. These ethics ensure that the research is safe to execute. If the idea of a project is valuable for society but it violates the rights of humans, then following the ethics the idea will not be supported. There are various types of ethical issues depending on various cases. According to The Code of Ethics and Professional Conduct, ethical values include trust, honesty, responsibility, respect, and fairness. Besides, maintaining confidentiality, ensuring the risk of harm, avoiding plagiarism, accuracy in analysis and reporting, etc. are also part of research ethics.[9] Moreover, there are some codes and conduct given by different international organizations for various sectors. We must follow those protocols and standards while conducting the research. Failure to maintain ethical issues may lead to the rejection of project proposals as well. Even maintaining those protocols ensures project sustainability also. As for our project, we need to follow the code and standards given by the IEEE, and government protocols for flying UAVs, ensure public safety and maintain professional integrity.

9.2 Identify ethical issues and professional responsibility

Our task is to build a device (UAV) by assembling different sensors that are capable of collecting samples from forest properties and preparing a survey report based on our findings related to the forest environment. In that case, we have to follow and maintain ethics and professional responsibility both while making the device and while conducting our survey. We have identified those areas where we need to face ethical issues and maintain professional integrity.

9.2.1 Ethical Issues

- **Electronics**

We use various types of electrical devices to monitor and UAVs as media in our proposed model. This is an era of new inventions, and we can easily locate any electronic component in our hands; however, quality is an issue. As we are using IoT(Internet of Things) in our system; these technologies solve many real-life problems but they create serious ethical concerns and legal challenges; Protection of privacy, data security, Data usability, Data user experience, Trust, and Safety [19]. The extensive use of UAVs raises many new questions regarding ethics and morality [20].

- **People Privacy**

As the UAV will operate manually. Its task is to collect information about the unknown environment, monitor agricultural or forest areas, and control remote borderlines [20]. The ethical issue of UAVs can be collecting data and controlling the UAV. The ethical issues involved relate to the decision as to whether and under what circumstances it is possible to use the data obtained to ensure the safety of persons and things [20].

- **Health and Risk**

The controlling system will be focused on mainly the controller of the UAV. There may be a situation that can be affected mentally by the controller. There can be another ethical issue of availability requirements to build up the designed model. If the component is not available in some regions like underdeveloped countries, that would be unethical.

9.2.2 Professional Responsibility

- **Budget**

In the case of professionalism, many things to concern here as per the ethical issue of unavailability of components will be motivated to use the alternative or cheap components which will work but will not give the expected output. In making the designed model the component will choose with appropriate quality and reasonable price. So, people in underdeveloped countries can buy this model for their work.

- **Conflicts of Interest**

Because fieldwork is required for the project and involves a significant number of individuals, including local residents in the surveying region, there is numerous potential for local residents to become involved in the conflict, such as refusing to survey in that area. As professionals, we must ensure that all project participants are aware of the project's standards and the implications of the project's completion.

- **Area Cultural**

We may conduct our survey in many locations, and there will be a diverse range of people, each with their own cultural characteristics. This is especially crucial when working on projects with a diverse group of individuals because what is accepted in one culture may be considered harassing or even threatening in another. People associated with the project should be well-versed in the culture surrounding the workplace, which entails a grasp of the people's working environment culture. We should be able to cope with the local people's behavior as professionals.

- **Permission from local security authority:**

Civil Aviation Authority of Bangladesh **(CAAB),** has provided a number of internet-accessible details on flying UAVs. We have to maintain those while flying UAVs in public places. For this, we need to ask permission 45 days prior to flying to obey the security protocol.

- **Applicable code and standards**

To conduct this project, we need to follow some international protocols and standards. There are a few standards that we should obey to design our project.

1. **P2700/D1.00, Dec 2013** - IEEE Standard for Sensor Performance Parameter Definitions which denotes a framework of the performance of sensors, its limitations, conditions, etc. In this project, one of our tasks is to measure the conditions of forest water, air, etc. We need to use different types of sensors in order to measure their quality. Hence, we should follow this standard.
2. **IEEE 2413-2019 - IEEE Standard** for an Architectural Framework for the Internet of Things (IoT) followed the international standard ISO/IEC/IEEE 42010:2011, which denotes descriptions of various IoT domains, definitions of IoT domain abstractions, and identification of commonalities between different IoT domains[34].

3. **IEEE 1936.1-2021** - states the Draft Standard for Drone Applications Framework. Here drone application is established in this standard. It includes basic drone application classes, application scenarios, and the execution in environments. It also denotes drone safety management and its requirements such as airworthiness and air traffic requirements, qualification of operators, and others[36].

9.3 Apply ethical issues and professional responsibility

Application of ethical issues and professional responsibility is one of the challenges for research/project management. As we may face lots of practical issues while conducting the research. Firstly, we have identified the areas related to our project/survey where we can face ethical issues. Then our task is to maintain those responsibilities and ensure ethical standards while conducting the research. So, we have pointed out those areas.

- **Electronics**

We maintained ethical standards while buying and assembling our electronic components. We bought those items from a trusted shop. We avoid buying cheap and low-quality products in order to get better performance from the device and ensure ethical standards. Likewise, we followed the international code and standards given by IEEE while buying and assembling those components. All the sensors are capable enough to measure the forest properties perfectly followed by **P2700/D1.00, Dec 2013** - IEEE Standard for Sensor Performance Parameter Definitions. Besides, we have maintained proper ethical concerns in order to send and receive Data from the IoT cloud.

- **People Privacy**

After assembling the components our task is to fly the UAV to collect forest images and data from other properties through various sensors. We have selected Ramna Park admits in Dhaka city to conduct our survey. This is one of the most populated parks in the city. We had to keep that in mind while flying UAVs. As we should not hamper people's privacy. For this, we collected data at a time when people's presence in the park is limited. Though to monitor any changes we need to collect data in the presence of people as well. But we ensured to protect their privacy and make sure that public properties and persons are free from any kind of harm.

- **Risk factors:**

Some risk factors may create unethical circumstances. We worked in such a way as to avoid them. For instance, in the early days, while flying our device, the wings of the UAV had been broken a few times. That could have been an unethical scenario. But it did not harm anyone or any of the properties of the forest. So, we maintained precautions for the next time. Besides, this type of research may damage forest properties. Also, flying UAV creates fear in the birds and animals of a forest. So, we kept that in mind and tried our best not to damage the favorable environment of the forest. As it is against ethics to do any harm to animals and plants.

- **Permission:**

There are certain rules for flying drones/UAVs in Bangladesh. But anyone can fly drones for recreational or personal purposes without any permission but the device must not be more than 5 kg. As our device is below 5 kg so we did not need to ask for official permission for flying.

- **Budget**

It was one of our concerns to do this survey in a budget-friendly way as countries like ours cannot invest huge amounts of money for forest monitoring. So, we tried our best to conduct our research on a medium amount of budget. Similarly, due to the pandemic, there was the unavailability of some hardware parts. To avoid low and cheap quality products we waited for shipping. Because it would be unethical to use low-quality products by minimizing the budget. Therefore, we ensured quality products with a limited budget.

- **International codes and standards:**

We followed all the IEEE codes and standards while making the device, assembling the sensors, and conducting our survey. Even maintained those codes and conducts in terms of data collection and data receiving data from the server with high integrity.

- **Maintain Cultural ethics:**

Different areas or localities have different cultures. For this forest survey, we had to keep that in mind. The culture of the people near the forest can be different from ours. For our survey, we had to talk with them for various purposes so we tried to cope with the local people's behavior as professionals.

9.4 Conclusion

Ethical considerations or ethics are a group of rules or principles that guides a research or project. Following those ethics are mandatory to run a project successfully and to gain public support. following those guidelines are also a part of professional responsibility. Here, in our project, we tried to sort out those ethical issues and tried our best to fulfill them while conducting our research. Firstly we sort the possible considerations that are related to our project and later we apply them. Though some of them are ruled out from the list as in practical experiments some issues did not match our research and some of them we did not apply as they do not match with our project.

Chapter 10
Conclusion and Future Work
10.1 Project summary/Conclusion

Forests are an important part of the earth's environment and economy. As all living species directly or indirectly depend on it. Nowadays, due to natural and manmade disasters forests are in danger. To maintain or improve the health and productivity of a forest and to achieve forest-safety objectives, proper monitoring and maintenance need to be ensured. Forest management is looking for new ways to survey land and maintain it with the help of modern technology. All the possible ways have both positive and negative sides. Among them, we need to find the optimal one which can provide us with maximum output with minimum errors.

Here we have shown three possible solutions to the forest monitoring system in detail. They are manual (human-based) remote sensing, ground robotic vehicles, and UAVs (drones). One of the most exciting technologies that public and private companies are now using to conduct various operations are unmanned aerial vehicles (UAVs) which are more commonly known as drones. Due to its increasing demand and advantages, people are willing to use drones to conduct any type of monitoring process. Monitoring forests through humans is a tertiary process where people's life is always in danger. Even it can not provide appropriate data from the site due to human error. which can mislead us to know the actual scenario of a forest. Moreover, though remote sensing is a popular technology due to its complex process and high cost it is not that much popular in terms of forest monitoring. Because underdeveloped countries are unable to provide the budget for remote sensing in monitoring forests. For the same reason, they do not have proficient people who can control the system properly. Because of those difficulties manual remote sensing systems are not suitable for countries like ours for forest monitoring.

To reduce human risk and workload, forestry has advanced from manual methods to machine-oriented solutions. Humans, on the other hand, are unable to visit every location in a forest and collect data. As a result, robotic ground vehicles for forestry have been developed. In the forestry industry, robots have increased productivity by being able to enter areas where humans cannot because the environment is dangerous, difficult, or lacks vision. Because they can elevate their feet for mobility, legged robots for forestry have a significantly smaller footprint, making them ideal for forest soils and protecting the forest from injury. It has sensors that can collect data. However, it fails to capture photos from higher elevations, which are necessary for detecting deforestation. Because one of our key goals is to prevent deforestation, ground robotic vehicles, despite their many advantages, cannot be the best choice for our monitoring needs. Another consideration is the price. Both the manufacturing and maintenance of robotic vehicles require large sums of money, which may be insufficient to assure their long-term viability in any developing country. Unmanned aerial vehicles (UAVs), sometimes known as drones, are our final strategy. Drones are currently having a significant impact on the forestry business due to their incredible features and benefits. They can visualize the ground and simulate the canopy structure at the same time, which has

substantial benefits for the forestry industry. For terrain classification, foresters and forest managers had to rely on topographic maps in the past. They also had to rely on time-consuming field-based surveys to determine tree volumes and heights. We use capabilities in our system that allow us to monitor the forest from multiple points. A forest is a complex ecosystem that is primarily made up of trees.
As a result, one of our responsibilities is to identify areas of deforestation by counting the number of trees or their density. For this, we're putting together a camera for our UAV that can capture pictures of the forest, which we'll then process through image processing to identify the density of trees in the forest. It can assess the three-dimensional properties of plant canopy structures. They can then calculate the plantation's vertical structure. With the available data, it is possible to estimate the volume and growth rate of trees to evaluate the forest's value.

After that, we want to ensure forest safety as well. If the forest is not suitable for proper plantation, then it may lead to deforestation as well. For this, we are assembling sensors and a syringe pump (for water collection)which will be used to collect samples of soil, air, and water. By which we can determine the temperature, humidity, presence of gas, pH, etc. of those samples. This will help us to know about the condition of forest properties. Finally using machine learning we will analyze the data and prepare a report on the overall forest condition and provide it to the appropriate authority.

10.2 Future work

The future industry of UAV technology has great potential in every sector, especially in the surveillance sector. From our project, we can develop the UAV more with soil collection equipment or make it a more compact design to manufacture. Assembling more sensors can help a UAV to collect vital environmental data. Due to a shortage of budget and thinking about the economic condition of Bangladesh we have used a few sensors to get data on the forest environment. But in the future, considering the budget one can assemble more sensors like soil sensors, thermometers, pressure and humidity sensors, etc. which will help to get the idea of forest conditions more accurately. Moreover, a forest fire is one of the burning concerns in the outside world. keeping the base of our system one can modify it and use it for forest fire detection as well. That may save not only forests but also the lives of people. Our surveillance system can be effective for forest harvesting as well. There are lots of places in the forest where we can plant trees but it is difficult to reach there. In those cases, we can use UAV-based systems to spread seeds of various plants. This same procedure is also applicable to tree plantations in those areas where already deforestation has occurred. Apart from that, wildlife can also be monitored through this type of system. With the help of drones and UAVs, the balance of the ecosystem can be maintained, to better degrees. Aerial imagery, mapping, and data processing as performed by the AI-powered drones express endangerment alerts, scan for potential threats to wildlife, and so on. Time-critical results help to validate data and provide relief and medication in worsened conditions. Artificial Intelligence and Machine Learning fueling the drones have proved beneficial in the space of tree disease detection and prevention. so, drone technology entails merits towards the progress and advancement of forest ecosystems. Drones push the boundaries of forest cultivation and maintenance, redeeming wildlife and vegetation, while also monitoring risks to prevent the felling of trees. Every day new technology is being added to the forest surveillance system. With the adoption of drones, forestry can witness a high cascade of improvement and growth. In the future development can be done in the different sectors of the project to improve and make it more industry-level.

Machine Learning is a powerful tool to predict, analyze and understand data. It can learn from data and improve its performance over time. It can be used for a variety of tasks, for example, image processing, image recognition, data prediction, and natural language understanding.

1. Data Analysis

    The data that we have collected about the Air, Water conditions of the forest has been run through ML to further predict these data in the future. A classification challenge involves predicting a class label for a specific example of input data.

    For sensor data prediction, we employ XGBoost. XGBoost is a scalable and extremely accurate gradient-boosting implementation that pushes the performance and computational speed limitations of boosted tree algorithms. Recently, the applied machine learning and Kaggle contests for structured or tabular data have been dominated by the XGBoost method. A gradient-boosted decision tree implementation created for speed and performance is called XGBoost. It is the top machine learning library for regression (*a method for examining the connection between independent features or variables and a dependent feature or outcome*), classification, and ranking issues and offers parallel tree boosting. We need the decision tree for analyzing the data as—a decision tree is used in tree-based models to illustrate how various input variables can be utilized to forecast a target value. The term "extreme gradient boosting" is "XGBoost"—a machine learning method called gradient boosting is used, among other things, for classification and regression tasks. It determines the optimum tree model by using more precise approximations. Boosting: N new training data sets are created from the original dataset using random sampling and replacement; some observations may appear in more than one training data set.

    XGB has a variety of tuneable hyper-parameters, which gives it a significant edge over gradient-boosting machines. XGBoost offers the ability to manage missing values right out of the box. Intuitive features like parallelization, distributed computing, cache optimization, and more are offered by it.

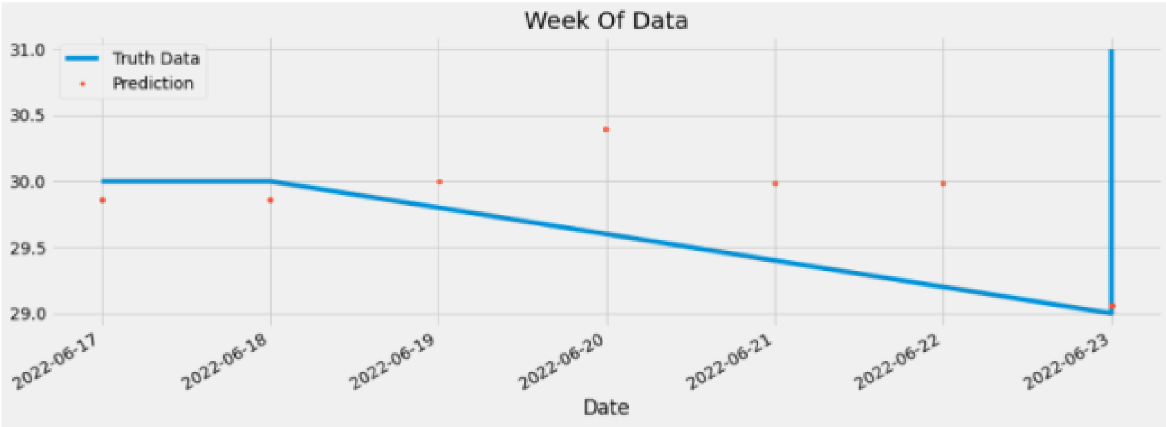


Figure 59: Temperature prediction for one week

2. Image Processing:

To make our image processing model we collected the proper dataset from the open source website on the internet. These data contained four thousand aerial images with appropriate mask data which are very appropriate to train the machine learning model.

At first, we use an image to find segmentation of the necessary part i.e the canopy area. After that, that part of the image is further used to analyze the new image to the prior image. Here, For the sake of our project, we employ image segmentation, a type of image processing that typically divides the image into a few subgroups. In other words, image segmentation is a technique that divides a digital image into some smaller groupings, known as image segments, to facilitate further processing. With pixel values, pictures are divided into smaller groups during segmentation.

Image results for image segmentation where machine learning is required
Approach based on similarity: this strategy uses a threshold to identify segments of comparable image pixels. This method of segmenting a picture provides the foundation for ML techniques like clustering.

In the end, we can say that further optimization and development of that project can be useful for forestry services. Which will help to protect the current world forestry which is currently under threat from global warming.

Chapter 11

Identification of Complex Engineering Problems and Activities

11.1: Identify the attribute of complex engineering problems (EP)

There are some attributes for complex engineering problems. Now, we are going to explain them.

- **Depth of knowledge required:** To build a proper engineering project, we must have proper knowledge about the relevant field. without proper knowledge, we can not get an in-depth idea about a project. Hence, to do research or a project it is mandatory to have proper knowledge about the particular problem.

- **Range of conflicting requirements:** it means when we start doing research or building a project lots of conflicting issues may come up. Our motive should be to overcome those issues and provide a solution in such a way that the project will be effective and harmless. While doing projects lots of conflicting issues may come such as technical issues, legal issues, environmental issues, etc. our target will be to solve them and provide a harmless solution.

- **Depth of analysis required:** it is another necessary aspect of complex engineering problems. To make a successful project proper in-depth analysis is mandatory. Without it, many problems will occur in the future that we may fail to solve hence the project will not be beneficial at all.

- **Familiarity with issues:** it means when a new project is going to be implemented or proposed the general people will not be familiar with it. Moreover, this issue may also come in terms of familiar issues and we want to add or create something new from the old ones.

- **Extent of applicable codes:** to make a complex engineering project there may come lots of issues related to engineering protocols. Here, we need to follow the international codes and standards to run the project. Otherwise, the project will lose its acceptance.

- **Extent of stakeholder involvement and needs:** Extent of stakeholder involvement and needs talks about the demand of stakeholders. It means we need to ensure that the targeted group of our project is getting benefits from our project solution.

- **Interdependence:** Interdependence means that an issue is related to another issue, hence, the problem should be solved to get the final solution.

Of the above attributes, some of them are used in our project. They are shown in the table below,

Attributes of Complex Engineering Problems (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	☑
P2	Range of conflicting requirements	☑
P3	Depth of analysis required	☑
P4	Familiarity of issues	
P5	Extent of applicable codes	☑
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	

11.2: Provide reasoning on how the project addresses the selected attribute (EP)

From the above attributes our project has fulfilled some of them. Now, we are explaining those attributes.

To conduct our project, we had to go through lots of pre-research. So, we can select the optimum solution that can provide maximum benefits at a minimum cost. We have done the entire process step by step. Before starting this project we had gone through some previous papers related to our research topic, which helped us to get an idea about our work. From this, we also gather knowledge about relevant fields which helped us to make decisions about how we can run the project. Then in the hardware part before assembling the sensors, camera, and other parts of the UAV we went through multiple types of research about the selection of the device and the process of assembling. We have tested each of the sensors to know whether they are workable or not. We selected our device and its parts considering modern technology. We did not use any of the components which are out of the market and provide lee efficiency. We ran through a detailed analysis for each of the steps of our project. While selecting the multiple designs we have shown the pros and cons of each of the solutions briefly. which helped us to choose the best one from them. In the software section, we have analyzed the sensor data briefly in such a way that can give clear output about the condition of the forest properties. We showed all the detailed results of our data analysis that can show the proper result of our research. So, the Depth of analysis required for our project has been successfully established. The attribute of conflicting requirements has shown in our project while doing the multiple design analysis. We had chosen three possible solutions for our monitoring system. then analyze each of them and find out which is fulfilling our desired requirement more efficiently and effectively. All of them have some positive sides and some negative sides. We sorted them down and found the optimum one which can fulfill our requirements to get the desired output. On the other hand, the attribute of the Extent of applicable codes has been maintained properly. Because we have maintained all the national and international codes and standards. First of all, we identified those rules and regulations then we applied them while conducting our project. We also made sure that public properties and lives are safe from any kind of harm caused by our monitoring system.

11.3 Identify the attribute of complex engineering activities (EA)

The attributes of complex engineering activities(EA) are described below.

- **Range of resources:** The range of resources includes components that are necessary for successful project implementation. People, equipment, money, time, knowledge, and anything that is required from the project planning to the project delivery phases are under the resources.

- **Level of interaction:** it includes all kinds of communication and interaction with the people related to project topics such as technicians, engineers, stakeholders, and even communication within the team, etc.

- **Innovation:** Innovation is another aspect of an engineering project as we can invent something new from our research project that may be helpful for others. Hence, the solution needs to be beneficial for the targeted group and it should provide a proper level of efficiency.

- **Consequences for society and the environment:** A complex engineering project must have some consequences related to the environment and society. This attribute talks about it. We need to find them out and solve them if possible.

- **Familiarity:** While doing research on a topic or doing a project lots of things may come up which are also new to us and that may make the project difficult to understand. In this case, we need to solve them with proper research and teamwork.

Among these attributes three of them are applied in our project, they are shown in the box below,

Attributes of Complex Engineering Activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	☑
A2	Level of interaction	☑
A3	Innovation	
A4	Consequences for society and the environment	☑
A5	Familiarity	

11.4 Provide reasoning how the project address selected attribute (EA)

Our project required plenty of resources in every step—from planning to execution we had to use various types of resources depending on the project requirement. Project resources are components that are necessary for successful project implementation. They include people, equipment, money, time, knowledge, and anything that is required from the project planning to the project delivery phases. From the first semester of our final year design project, we have gone through lots of articles, papers, and journals that are relevant to our project. Those are also part of the resources. Then we used multiple software like python. Finally, for hardware implementation, we assembled the sensors, and cameras and prepared the entire device by ourselves. We had to prepare the budget and work accordingly. that was also part of the resources. We discussed with our ATC for his suggestion and discussed among ourselves and shared our thoughts which helped us to make further decisions and to make a successful project. So, it can be said that a wide range of resources has been used to complete the entire project successfully. Process interactions can be in several different forms in which the basic project management processes, such as initiating, planning, executing, monitoring, and controlling, as well as closing, can interact with each other during conducting project activities. All of our group members interacted with each other and shared our thoughts and ideas. We maintained our weekly meetings and fulfilled our weekly tasks carefully. We respected each other's opinions and discussed them among ourselves and also get advice from our honorable ATC. A good level of interaction is required for a project to be successful. from the selection of project topics to the implementation of our project all of us shared our ideas. and after discussion, we selected the final decisions. In this way, we have completed our project.

The effects or impacts of any project on the environment are one of the vital sides of project management. Since our project is to monitor forest health, we had to keep an eye on the Consequences for society and the environment of our project. because, while conducting our project or collecting data our device could harm people, trees, or animals. That could have created negative consequences. We maintained the highest safety standards to avoid such kinds of consequences. On the other hand, we have done our monitoring of Dhaka city(Ramna Park). There are residential areas near the park. so that the people over there may face some disturbance when we have done our survey.

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Appendix

Codes

For the Forest Report

```
from google.colab import files
uploaded = files.upload()

import csv


co2_avg=0with open('CO2.csv') as co2_file:     co2_data=csv.reader(co2_file)     count=0     sum=0     for idx,row in enumerate(co2_data):     if idx==0:       pass
else:  if row[1]!='':           count+=1           sum+=float(row[1])    co2_avg=(sum/count)print(co2_avg)

 342.51386156648425

temp_avg=0
with open('Temp.csv') as temp_file:     temp_data=csv.reader(temp_file)     count=0     sum=0     for idx,row in enumerate(temp_data):          if idx==0:          pass          else:          if row[1]!='':          count+=1
sum+=float(row[1])    temp_avg=(sum/count)print(temp_avg)

29.77536231884058

humidity_avg=0
with open('Humidity.csv') as humidity_file:
    humidity_data=csv.reader(humidity_file)
    count=0
    sum=0
    for idx,row in enumerate(humidity_data):
        if idx==0:
            pass
        else:
            if row[1]!='':
                count+=1
                sum+=float(row[1])
    humidity_avg=(sum/count)
print(humidity_avg)
 83.28079710144928

turbidity_avg=0
with open('Turbidity.csv') as turbidity_file:
    turbidity_data=csv.reader(turbidity_file)
    count=0
    sum=0
    for idx,row in enumerate(turbidity_data):
        if idx==0:
            pass
        else:
            if row[1]!='':
                count+=1
                sum+=float(row[1])
    turbidity_avg=(sum/count)
print(turbidity_avg)
 4.004042252780803

ph_avg=0
with open('ph.csv') as ph_file:
    ph_data=csv.reader(ph_file)
    count=0
    sum=0
    for idx,row in enumerate(ph_data):
        if idx==0:
```

```
        pass
      else:
        if row[1]!='':
          count+=1
          sum+=float(row[1])
  ph_avg=(sum/count)
print(ph_avg)
 7.091794547421661

#Accuracy Calculation

#CO2 Calculation
if 270<=co2_avg<=350:
  print("CO2 is within range")
  co2_accuracy=100
elif co2_avg<270:
  derivation=((270-co2_avg)/270)*100
  print("CO2 is",derivation,'% less than the standard range')
  co2_accuracy=100-derivation
else:
  derivation=((co2_avg-350)/350)*100
  print("CO2 is",derivation,'% more than the standard range')
  co2_accuracy=100-derivation

#Humidity Calculation
if 40<=humidity_avg<=60:
  print("Humidity is within range")
  humidity_accuracy=100
elif humidity_avg<40:
  derivation=((40-humidity_avg)/40)*100
  print("Humidity is",derivation,'% less than the standard range')
  humidity_accuracy=100-derivation
else:
  derivation=((humidity_avg-60)/60)*100
  print("Humidity is",derivation,'% more than the standard range')
  humidity_accuracy=100-derivation

#Temperature Calculation
if 30<=temp_avg<=35:
  print("Temperature is within range")
  temp_accuracy=100
elif temp_avg<30:
  derivation=((30-temp_avg)/30)*100
  print("Temperature is",derivation,'% less than the standard range')
  temp_accuracy=100-derivation
else:
  derivation=((temp_avg-35)/35)*100
  print("Temperature is",derivation,'% more than the standard range')
  temp_accuracy=100-derivation

#Turbidity Calculation
if 1<=turbidity_avg<=5:
  print("Turbidity is within range")
  turbidity_accuracy=100
elif turbidity_avg<1:
  derivation=((1-turbidity_avg)/1)*100
  print("Turbidity is",derivation,'% less than the standard range')
  turbidity_accuracy=100-derivation
else:
  derivation=((turbidity_avg-5)/5)*100
  print("Turbidity is",derivation,'% more than the standard range')
  turbidity_accuracy=100-derivation

#PH Calculation
if 6.5<=ph_avg<=8.5:
  print("PH is within range")
```

```
    ph_accuracy=100
elif ph_avg<6.5:
    derivation=((6.5-ph_avg)/6.5)*100
    print("PH is",derivation,'% less than the standard range')
    ph_accuracy=100-derivation
else:
    derivation=((ph_avg-8.5)/8.5)*100
    print("PH is",derivation,'% more than the standard range')
    ph_accuracy=100-derivation
```

CO2 is within range
Humidity is 38.801328502415465 % more than the standard range
Temperature is 0.7487922705314057 % less than the standard range
Turbidity is within range
PH is within range
#Index

```
Calculationindex=(co2_accuracy*(40/100))+(humidity_accuracy*(14/100))+(temp_accuracy*(31/100))+(turbidity_accuracy
*(5/100))+(ph_accuracy*(10/100))index=round(index)print("Index Value: "+str(index)+"%")

if 75<=index<=100:
        print("Category: Good")
        print("Color: Green")
        print("Description: Forest quality is satisfactory, and forest population poses little or no risk")

elif 51<=index<=74:
        print("Category: Moderate")
        print("Color: Yellow")
        print("Description: Forest quality is acceptable. However, there may be risks. If we monitor thoroughly, we can
        overcome it")

elif 26<=index<=50:
        print("Category: Unhealthy")
        print("Color: Orange")
        print("Description: Sensitive for the animal or the current forrest canopy area")

elif 0<=index<=25:
        print("Category: Very Unhealthy")    print("Color: Purple")
        print("Description: Health alert, the risk of deforestation is very high")
```

Index Value: 94%
Category: Good
Color: Green
Description: Forest quality is satisfactory, and forest population poses little or no risk

For the Canopy Area

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import os
import random
import cv2
import tensorflow as tf
from tensorflow.python.keras.models import Sequential
from tensorflow.keras.preprocessing.image import load_img, img_to_array
from tensorflow.python.keras.preprocessing.image import ImageDataGenerator
from tensorflow.python.keras.callbacks import ModelCheckpoint, EarlyStopping
from tensorflow.keras.layers import Conv2D, BatchNormalization, Activation, MaxPool2D, Conv2DTranspose,
Concatenate, Input, Dropout
from tensorflow.keras.models import Model
from sklearn.metrics import f1_score
base_directory = '/base data path'
images_folder = os.path.join(base_directory, 'images')
masks_folder = os.path.join(base_directory, 'masks')
data = pd.read_csv(os.path.join(base_directory, 'meta_data.csv'))
```

```
data.head()
img_dim = 256
def input_target_split(data,images_folder,masks_folder,dim):
    dataset = []
    for index, row in data.iterrows():
        image = load_img(os.path.join(images_folder, row['image']), target_size=(dim,dim))
        mask = load_img(os.path.join(masks_folder, row['mask']), target_size=(dim,dim), color_mode='grayscale')
        image = img_to_array(image)
        image = image/255.0
        mask = img_to_array(mask)
        mask = mask/255.0
        dataset.append((image,mask))
        print(f"\rProgress: {index}",end='')
    random.shuffle(dataset)
    X, Y = zip(*dataset)

    return np.array(X),np.array(Y)
X, Y = input_target_split(data,images_folder,masks_folder,img_dim)
print("Image Dimensions: ",X.shape)
print("Mask Dimensions: ",Y.shape)
plt.figure(figsize = (15 , 9))
n = 0
for i in range(15):
    n+=1
    plt.subplot(5 , 5, n)
    plt.subplots_adjust(hspace = 0.5 , wspace = 0.3)
    plt.imshow(X[i])
    plt.title('Image')
plt.figure(figsize = (15 , 9))
n = 0
for i in range(15):
    n+=1
    plt.subplot(5 , 5, n)
    plt.subplots_adjust(hspace = 0.5 , wspace = 0.3)
    plt.imshow(Y[i])
    plt.title('Masks')
split = round(X.shape[0]*0.80)
X_train = X[:split]
Y_train = Y[:split]
X_test = X[split:]
Y_test = Y[split:]
datagen = ImageDataGenerator()
testgen = ImageDataGenerator()
datagen.fit(X_train)
testgen.fit(X_test)
def conv_block(input, num_filters):
    x = Conv2D(num_filters, 3, padding="same")(input)
    x = BatchNormalization()(x)
    x = Activation("relu")(x)

    x = Conv2D(num_filters, 3, padding="same")(x)
    x = BatchNormalization()(x)
    x = Activation("relu")(x)

    return x
def encoder_block(input, num_filters):
    x = conv_block(input, num_filters)
    p = MaxPool2D((2, 2))(x)
    return x, p

def decoder_block(input, skip_features, num_filters):
    x = Conv2DTranspose(num_filters, (2, 2), strides=2, padding="same")(input)
    x = Concatenate()([x, skip_features])
    x = conv_block(x, num_filters)
    return x
def build_unet(input_shape):
```

```
    inputs = Input(input_shape)

    s1, p1 = encoder_block(inputs, 32)
    s2, p2 = encoder_block(p1, 64)
    s3, p3 = encoder_block(p2, 128)
    s4, p4 = encoder_block(p3, 256)

    b1 = conv_block(p4, 512)

    d1 = decoder_block(b1, s4, 256)
    d2 = decoder_block(d1, s3, 128)
    d3 = decoder_block(d2, s2, 64)
    d4 = decoder_block(d3, s1, 32)

    outputs = Conv2D(1, 1, padding="same", activation="sigmoid")(d4)

    model = Model(inputs, outputs, name="U-Net")
    return model
from keras import backend as K
def iou_coef(y_true, y_pred, smooth=1):
    intersection = K.sum(K.abs(y_true * y_pred), axis=[1,2,3])
    union = K.sum(y_true,[1,2,3])+K.sum(y_pred,[1,2,3])-intersection
    iou = K.mean((intersection + smooth) / (union + smooth), axis=0)
    return iou

def iou_coef_loss(y_true, y_pred):
    return -iou_coef(y_true, y_pred)

def iou_metric(y_true_in, y_pred_in, print_table=False):
    labels = label(y_true_in > 0.5)
    y_pred = label(y_pred_in > 0.5)

    true_objects = len(np.unique(labels))
    pred_objects = len(np.unique(y_pred))

    intersection = np.histogram2d(labels.flatten(), y_pred.flatten(), bins=(true_objects, pred_objects))[0]
# Compute areas (needed for finding the union between all objects)
    area_true = np.histogram(labels, bins = true_objects)[0]
    area_pred = np.histogram(y_pred, bins = pred_objects)[0]
    area_true = np.expand_dims(area_true, -1)
    area_pred = np.expand_dims(area_pred, 0)

    # Compute union
    union = area_true + area_pred - intersection

    # Exclude background from the analysis
    intersection = intersection[1:,1:]
    union = union[1:,1:]
    union[union == 0] = 1e-9

    # Compute the intersection over union
    iou = intersection / union
# Precision helper function
    def precision_at(threshold, iou):
        matches = iou > threshold
        true_positives = np.sum(matches, axis=1) == 1   # Correct objects
        false_positives = np.sum(matches, axis=0) == 0  # Missed objects
        false_negatives = np.sum(matches, axis=1) == 0  # Extra objects
        tp, fp, fn = np.sum(true_positives), np.sum(false_positives), np.sum(false_negatives)
        return tp, fp, fn

    # Loop over IoU thresholds
    prec = []
    if print_table:
        print("Thresh\tTP\tFP\tFN\tPrec.")
for t in np.arange(0.5, 1.0, 0.05):
```

```
        tp, fp, fn = precision_at(t, iou)
        if (tp + fp + fn) > 0:
            p = tp / (tp + fp + fn)
        else:
            p = 0
        if print_table:
            print("{:1.3f}\t{}\t{}\t{}\t{:1.3f}".format(t, tp, fp, fn, p))
        prec.append(p)

    if print_table:
        print("AP\t-\t-\t-\t{:1.3f}".format(np.mean(prec)))
    return np.mean(prec)
def iou_metric_batch(y_true_in, y_pred_in):
    batch_size = y_true_in.shape[0]
    metric = []
    for batch in range(batch_size):
        value = iou_metric(y_true_in[batch], y_pred_in[batch])
        metric.append(value)
    return np.array(np.mean(metric), dtype=np.float32)

def my_iou_metric(label, pred):
    metric_value = tf.compat.v1.py_func(iou_metric_batch, [label, pred], tf.float32)
    return metric_value

#Building the Model
input_shape = (img_dim, img_dim, 3)
model = build_unet(input_shape)
model.summary()
model.compile(optimizer = tf.keras.optimizers.Adam(lr = 0.001), loss = ['binary_crossentropy'], metrics=[iou_coef,'accuracy'])
model_path = "tree.h5"
checkpoint = ModelCheckpoint(model_path,
                             monitor="val_loss",
                             mode="min",
                             save_best_only = True,
                             verbose=1)

earlystop = EarlyStopping(monitor = 'val_loss',
                          min_delta = 0,
                          patience = 9,
                          verbose = 1,
                          restore_best_weights = True)
hist = model.fit_generator(datagen.flow(X_train,Y_train,batch_size=32),
                           validation_data=testgen.flow(X_test,Y_test,batch_size=24),
                           epochs=50, callbacks=[earlystop, checkpoint])
history = hist
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs = range(1, len(loss) + 1)
plt.plot(epochs, val_loss, 'r', label='Validation loss')
plt.title('validation loss')
plt.xlabel('epochs')
plt.ylabel('loss')
plt.legend()
plt.show()
plt.figure(figsize = (15 , 9))
n = 0
for i in range(0,15):
    n+=1
    plt.subplot(5 , 5, n)
    plt.subplots_adjust(hspace = 0.5 , wspace = 0.3)
    plt.imshow(Y_test[i])
    plt.title('Masks')
plt.figure(figsize = (15 ,9))
result = model.predict(X_test)
output = result[0]
```

```
output[output >= 0.5] = 1
output[output < 0.5] = 0
plt.subplot(1, 3, 3)
plt.imshow(output)

plt.savefig('output.png')

import cv2, numpy as np
from sklearn.cluster import KMeans

def visualize_Dominant_colors(cluster, C_centroids):
    C_labels = np.arange(0, len(np.unique(cluster.labels_)) + 1)
    (C_hist, _) = np.histogram(cluster.labels_, bins = C_labels)
    C_hist = C_hist.astype("float")
    C_hist /= C_hist.sum()

    rect_color = np.zeros((50, 300, 3), dtype=np.uint8)
    img_colors = sorted([(percent, color) for (percent, color) in zip(C_hist, C_centroids)])
    start = 0
    for (percent, color) in img_colors:
        print(color, "{:0.2f}%".format(percent * 100))
        end = start + (percent * 300)
        cv2.rectangle(rect_color, (int(start), 0), (int(end), 50), \
                      color.astype("uint8").tolist(), -1)

 start = end
    return rect_color

# Load image
src_image = cv2.imread('./output.png')
src_image = cv2.cvtColor(src_image, cv2.COLOR_BGR2RGB)
reshape_img = src_image.reshape((src_image.shape[0] * src_image.shape[1], 3))
# Display dominant colors Present in the image
KM_cluster = KMeans(n_clusters=5).fit(reshape_img)
visualize_color = visualize_Dominant_colors(KM_cluster, KM_cluster.cluster_centers_)
visualize_color = cv2.cvtColor(visualize_color, cv2.COLOR_RGB2BGR)
import webcolors

def closest_colour(requested_colour):
    min_colours = {}
    for key, name in webcolors.CSS3_HEX_TO_NAMES.items():
        r_c, g_c, b_c = webcolors.hex_to_rgb(key)
        rd = (r_c - requested_colour[0]) ** 2
        gd = (g_c - requested_colour[1]) ** 2
        bd = (b_c - requested_colour[2]) ** 2
        min_colours[(rd + gd + bd)] = name
    return min_colours[min(min_colours.keys())]
def get_colour_name(requested_colour):
    try:
        closest_name = actual_name = webcolors.rgb_to_name(requested_colour)
    except ValueError:
        closest_name = closest_colour(requested_colour)
        actual_name = None
    return actual_name, closest_name

requested_colour = (252, 230, 36)
actual_name, closest_name = get_colour_name(requested_colour)

print ("Actual colour name:", actual_name, ", closest colour name:", closest_name)
```

For the Sensor Data

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

```
import os
import random
import cv2
import tensorflow as tf
from tensorflow.python.keras.models import Sequential
from tensorflow.keras.preprocessing.image import load_img, img_to_array
from tensorflow.python.keras.preprocessing.image import ImageDataGenerator
from tensorflow.python.keras.callbacks import ModelCheckpoint, EarlyStopping
from tensorflow.keras.layers import Conv2D, BatchNormalization, Activation, MaxPool2D, Conv2DTranspose,
Concatenate, Input, Dropout
from tensorflow.keras.models import Model
from sklearn.metrics import f1_score
base_directory = '/base data path'
images_folder = os.path.join(base_directory, 'images')
masks_folder = os.path.join(base_directory, 'masks')
data = pd.read_csv(os.path.join(base_directory, 'meta_data.csv'))
data.head()
img_dim = 256
def input_target_split(data,images_folder,masks_folder,dim):
    dataset = []
    for index, row in data.iterrows():
        image = load_img(os.path.join(images_folder, row['image']), target_size=(dim,dim))
        mask = load_img(os.path.join(masks_folder, row['mask']), target_size=(dim,dim), color_mode='grayscale')
        image = img_to_array(image)
        image = image/255.0
        mask = img_to_array(mask)
        mask = mask/255.0
        dataset.append((image,mask))
        print(f"\rProgress: {index}",end='')
    random.shuffle(dataset)
    X, Y = zip(*dataset)

    return np.array(X),np.array(Y)
X, Y = input_target_split(data,images_folder,masks_folder,img_dim)
print("Image Dimensions: ",X.shape)
print("Mask Dimensions: ",Y.shape)
plt.figure(figsize = (15 , 9))
n = 0
for i in range(15):
    n+=1
    plt.subplot(5 , 5, n)
    plt.subplots_adjust(hspace = 0.5 , wspace = 0.3)
    plt.imshow(X[i])
    plt.title('Image')
plt.figure(figsize = (15 , 9))
n = 0
for i in range(15):
    n+=1
    plt.subplot(5 , 5, n)
    plt.subplots_adjust(hspace = 0.5 , wspace = 0.3)
    plt.imshow(Y[i])
    plt.title('Masks')
split = round(X.shape[0]*0.80)
X_train = X[:split]
Y_train = Y[:split]
X_test = X[split:]
Y_test = Y[split:]
datagen = ImageDataGenerator()
```

```
testgen = ImageDataGenerator()
datagen.fit(X_train)
testgen.fit(X_test)
def conv_block(input, num_filters):
    x = Conv2D(num_filters, 3, padding="same")(input)
    x = BatchNormalization()(x)
    x = Activation("relu")(x)

    x = Conv2D(num_filters, 3, padding="same")(x)
    x = BatchNormalization()(x)
    x = Activation("relu")(x)

    return x
def encoder_block(input, num_filters):
    x = conv_block(input, num_filters)
    p = MaxPool2D((2, 2))(x)
    return x, p

def decoder_block(input, skip_features, num_filters):
    x = Conv2DTranspose(num_filters, (2, 2), strides=2, padding="same")(input)
    x = Concatenate()([x, skip_features])
    x = conv_block(x, num_filters)
    return x
def build_unet(input_shape):
    inputs = Input(input_shape)

    s1, p1 = encoder_block(inputs, 32)
    s2, p2 = encoder_block(p1, 64)
    s3, p3 = encoder_block(p2, 128)
    s4, p4 = encoder_block(p3, 256)

    b1 = conv_block(p4, 512)

    d1 = decoder_block(b1, s4, 256)
    d2 = decoder_block(d1, s3, 128)
    d3 = decoder_block(d2, s2, 64)
    d4 = decoder_block(d3, s1, 32)

    outputs = Conv2D(1, 1, padding="same", activation="sigmoid")(d4)

    model = Model(inputs, outputs, name="U-Net")
    return model
from keras import backend as K
def iou_coef(y_true, y_pred, smooth=1):
    intersection = K.sum(K.abs(y_true * y_pred), axis=[1,2,3])
    union = K.sum(y_true,[1,2,3])+K.sum(y_pred,[1,2,3])-intersection
    iou = K.mean((intersection + smooth) / (union + smooth), axis=0)
    return iou

def iou_coef_loss(y_true, y_pred):
    return -iou_coef(y_true, y_pred)

def iou_metric(y_true_in, y_pred_in, print_table=False):
    labels = label(y_true_in > 0.5)
    y_pred = label(y_pred_in > 0.5)

    true_objects = len(np.unique(labels))
    pred_objects = len(np.unique(y_pred))
```

```
    intersection = np.histogram2d(labels.flatten(), y_pred.flatten(), bins=(true_objects, pred_objects))[0]
# Compute areas (needed for finding the union between all objects)
    area_true = np.histogram(labels, bins = true_objects)[0]
    area_pred = np.histogram(y_pred, bins = pred_objects)[0]
    area_true = np.expand_dims(area_true, -1)
    area_pred = np.expand_dims(area_pred, 0)

    # Compute union
    union = area_true + area_pred - intersection

    # Exclude background from the analysis
    intersection = intersection[1:,1:]
    union = union[1:,1:]
    union[union == 0] = 1e-9

    # Compute the intersection over union
    iou = intersection / union
# Precision helper function
    def precision_at(threshold, iou):
        matches = iou > threshold
        true_positives = np.sum(matches, axis=1) == 1   # Correct objects
        false_positives = np.sum(matches, axis=0) == 0  # Missed objects
        false_negatives = np.sum(matches, axis=1) == 0  # Extra objects
        tp, fp, fn = np.sum(true_positives), np.sum(false_positives), np.sum(false_negatives)
        return tp, fp, fn

    # Loop over IoU thresholds
    prec = []
    if print_table:
        print("Thresh\tTP\tFP\tFN\tPrec.")
for t in np.arange(0.5, 1.0, 0.05):
        tp, fp, fn = precision_at(t, iou)
        if (tp + fp + fn) > 0:
            p = tp / (tp + fp + fn)
        else:
            p = 0
        if print_table:
            print("{:1.3f}\t{}\t{}\t{}\t{:1.3f}".format(t, tp, fp, fn, p))
        prec.append(p)

    if print_table:
        print("AP\t-\t-\t-\t{:1.3f}".format(np.mean(prec)))
    return np.mean(prec)
def iou_metric_batch(y_true_in, y_pred_in):
    batch_size = y_true_in.shape[0]
    metric = []
    for batch in range(batch_size):
        value = iou_metric(y_true_in[batch], y_pred_in[batch])
        metric.append(value)
    return np.array(np.mean(metric), dtype=np.float32)

def my_iou_metric(label, pred):
    metric_value = tf.compat.v1.py_func(iou_metric_batch, [label, pred], tf.float32)
    return metric_value

#Building the Model
input_shape = (img_dim, img_dim, 3)
```

```
model = build_unet(input_shape)
model.summary()
model.compile(optimizer = tf.keras.optimizers.Adam(lr = 0.001), loss = ['binary_crossentropy'],
metrics=[iou_coef,'accuracy'])
model_path = "tree.h5"
checkpoint = ModelCheckpoint(model_path,
                    monitor="val_loss",
                    mode="min",
                    save_best_only = True,
                    verbose=1)

earlystop = EarlyStopping(monitor = 'val_loss',
                  min_delta = 0,
                  patience = 9,
                  verbose = 1,
                  restore_best_weights = True)
hist = model.fit_generator(datagen.flow(X_train,Y_train,batch_size=32),
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                    epochs=50, callbacks=[earlystop, checkpoint])
history = hist
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epochs = range(1, len(loss) + 1)
plt.plot(epochs, val_loss, 'r', label='Validation loss')
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result = model.predict(X_test)
output = result[0]
output[output >= 0.5] = 1
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plt.subplot(1, 3, 3)
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  C_hist = C_hist.astype("float")
  C_hist /= C_hist.sum()

  rect_color = np.zeros((50, 300, 3), dtype=np.uint8)
  img_colors = sorted([(percent, color) for (percent, color) in zip(C_hist, C_centroids)])
```

```
    start = 0
    for (percent, color) in img_colors:
        print(color, "{:0.2f}%".format(percent * 100))
        end = start + (percent * 300)
        cv2.rectangle(rect_color, (int(start), 0), (int(end), 50), \
                      color.astype("uint8").tolist(), -1)

   start = end
    return rect_color

# Load image
src_image = cv2.imread('./output.png')
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    for key, name in webcolors.CSS3_HEX_TO_NAMES.items():
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        rd = (r_c - requested_colour[0]) ** 2
        gd = (g_c - requested_colour[1]) ** 2
        bd = (b_c - requested_colour[2]) ** 2
        min_colours[(rd + gd + bd)] = name
    return min_colours[min(min_colours.keys())]
def get_colour_name(requested_colour):
    try:
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    except ValueError:
        closest_name = closest_colour(requested_colour)
        actual_name = None
    return actual_name, closest_name

requested_colour = (252, 230, 36)
actual_name, closest_name = get_colour_name(requested_colour)

print ("Actual colour name:", actual_name, ", closest colour name:", closest_name)
```