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Vegetation Scanning Using LiDAR-Based Drone

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ABSTRACT

Vegetation scanning has become fundamental since it gives pivotal data about the applications, including environmental monitoring, biodiversity conservation, agriculture, forestry, urban green infrastructure, and other related fields. Many remote sensing methods can be used to scan vegetation like SAR imaging, Landsat imaging etc. We use a LiDAR-based drone with an UTM setup since it allows fully automated surveying of large areas. Compared with the present LiDAR surveying technology, to survey a critical area, we don't need to place the way-points in each area manually and manually fly the drone and collect required LiDAR data when we use a LiDAR-based drone with a UTM setup. Our project puts forward the idea of making the LiDAR-based drone with a UTM setup, which can help obtain more accurate 3D images of the area under study, useful for vegetation scanning.
Keywords : Vegetation scanning, UTM setup, surveying, LiDAR

I. INTRODUCTION

Drones are flying robots which include unmanned air vehicles (UAVs) that fly thousands of kilometers and small drones that fly in confined spaces [7]. Airborne vehicles that do not carry a human operator, fly remotely or autonomously, and carry lethal or nonlethal payloads are considered drones. LiDAR means light detection and ranging. It uses a pulsed laser to calculate distances from the earth surface. The light pulses are put together with the information collected by the airborne system to generate precise 3D data about the earth surface and the target entity. Nowadays, in the present LiDAR surveying, technology, to survey a critical area, we need to manually place the way-points in each corner of the area and manually fly the drone and collect required LiDAR data. Compared to traditional LiDAR surveying methods, we use UTM integrated LiDAR drone since we can get more accuracy, less manpower, and reduced time consumption. Most LiDAR-based drones that are used nowadays fall under the small category (2 – 25kg), which has more regulations to fly but in our project, we use a drone that falls under the micro category (less than 2 kg), which has fewer regulations to fly.

A. LiDAR

LiDAR means light detection and ranging. It uses a pulsed laser to calculate object variable distances from the earth surface. Based on the functionality, the LiDAR systems are divided into airborne LiDAR and terrestrial LiDAR [3, 9]. In a LiDAR system, light is emanated from a hastily firing laser. The light travels to the ground and reflects off things like buildings, trees and branches. The reflected energy then returns to the LiDAR sensor where it is logged. Light pulses are put together with the data composed by the airborne system to create accurate 3D data about the earth surface and the target object [10].

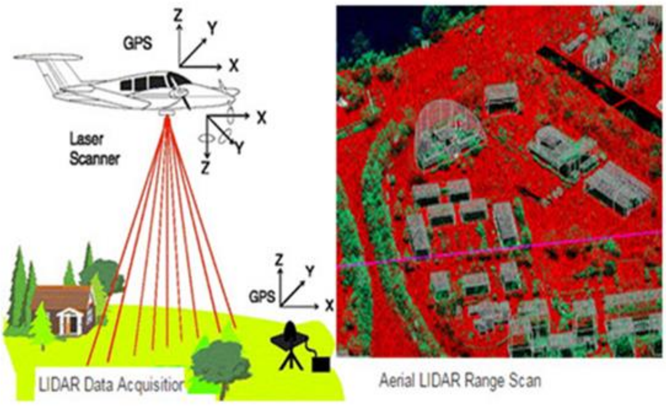

Figure 1: working of LiDAR system

B. Vegetation scanning

The vegetation scanning provides relevant data on terrestrial vegetation growth, vigor and dynamics can be particularly beneficial for applications in environmental monitoring, biodiversity conservation, agriculture, forestry, urban green infrastructures, and other related sectors. In particular, these sorts of data used to agriculture provide not only an objective basis for agricultural production macro- and micromanagement, but also, in many cases, the necessary information for crop yield estimation. The vegetation scanning can be done using satellite based remote sensing methods. The advantages of satellite-based remote sensing in terms of platforms include high spatial resolution, which enables the extraction of long time data series of consistent and comparable data at a low cost. Some satellite systems, such as Landsat 7-8, also provide free access to visible and multispectral data. However, there are two major issues with these platforms for precision agriculture applications: per-pixel resolution and orbit period.

The second issue with satellite-based remote sensing is the 16-day average re-visitation period, which complicates agricultural applications, particularly those involving water and fertilizer management. Furthermore, because passive sensors are unable to penetrate clouds, no data can be collected on overcast days.

To solve these two main problems, the airborne LiDAR-based drones can be used. In our project we use a LiDAR based drone with UTM setup which provides automated surveying of the area under study. The data collected from the drone LiDAR is saved in the system as a “las” file or a “.lidar” file. This file is then loaded into the Green Valley LiDAR 360 software to process the data and to analyze the required parameters of the vegetation.

II. METHODOLOGY

For Designing and assembling a Lidar based drone with less interference of signals and more efficient flight time [6]. First, a CGS system is implemented into the flight controller and is connected with the mission planner. Then grid points are assigned in the required survey area. By marking the area in UTM, the grid is taken as the first point. The other points are marked according to an area that we need to cover. Then the drone and hence the Lidar is activated. Then the next step is surveying the required area enabling the “Ready to flight” switch in the GCS controller. The drone automatically takes off and covers the required data. Then the Lidar image obtained is processed [11]. The drone captures a bulky number of high-resolution photos above an area. As these images overlap, the same point on the ground will appear in multiple photos and at different vantage points. In a similar method that the human brain uses information from both eyes to give a more profound impression, photogrammetry uses these multiple vantage points in images to create a 3D map.

High-resolution 3D reconstruction includes high/ altitude information and texture, shape, and colour for each point on the map, making the resulting 3D point cloud easier to interpret. Drone systems that use photogrammetry are inexpensive and offer excellent flexibility in capturing 2D and 3D data where, when and how, etc. [12].

This high-resolution 3D is saved in the system as "las" or ". lidar" files after surveying with the LiDAR based drone. Good LiDAR data processing software is essential to analyze the required vegetation parameters. We chose the Green Valley LiDAR 360 software for our project since it produces simple and detailed results more quickly. The data is then fed into the Green Valley LiDAR 360 software, which is used to examine the vegetation's required parameters.

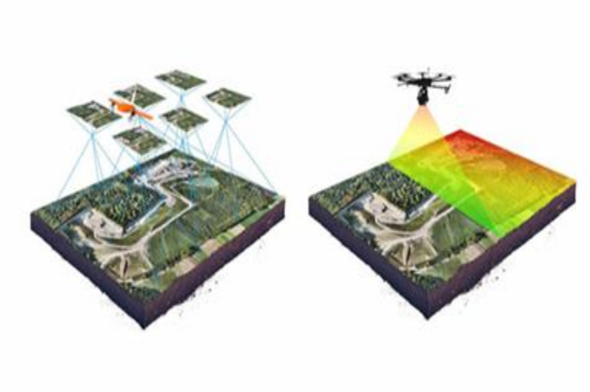

Figure 2: - Drone analysis

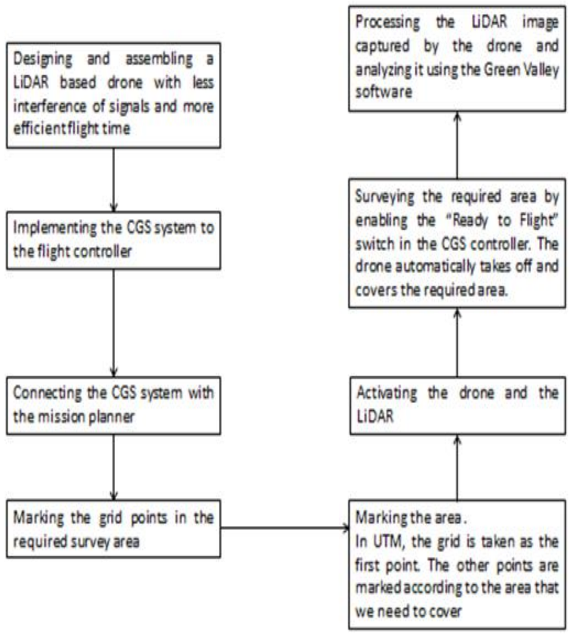

Figure 3: - Methodology block diagram

III. HARDWARE SECTION

The hardware section of the drone consists of the following components: motors, electronic speed controller, flight controller, Lidar, transmitter, GPS and Battery.

A. Motors

The new KDE Direct 5215XF-435 multi-rotor brushless motor is a highly efficient and powerful motor for many multi-rotors and UAS heavy-lift applications, designed to deliver high quality and vibration-free motors to the market. The motors are designed with performance and resilience in mind, with features not found in the current market like high grade, 240°C continuous (340°C maximum) high-temperature solid-core copper windings for failure-free operation in extreme-climates, Japanese-built, 0.2 mm silicon-steel stator laminations and Kevlar tie-wraps for high-efficiency performance, and triple-bearing supported, ABEC-7 bearings for hundreds of hours of unmaintained and carefree flight [6]. These are just some of the built-in advantages of these motors, and all the details of the motors have been scrutinized to produce the best available: for a wide range of flight applications. The motor includes 200°C, 15 AWG, pre-soldered to the motor leads and ESC matching Bullet Connectors). 760mm silicone-wire leads and ϕ4.0mm 24K Bullet Connectors (KDEXF-BC40).

Figure 4: - KDE Direct 5215XF-435 motor

B. Electronic speed controller

An ESC is a device that regulates the speed of the motor according to the command of the flight controller. It is compatible with UAS series 2S LiPo-8S LiHV power systems. It allows sUAS and multi-rotor applications to reach next levels of performance and efficiency. The new series pre-loads the latest production firmware, which includes regenerative braking, active braking during the motor desolation phase, quick responsiveness to flight controller signals, compliance commands and compliance with acceleration profiles [5]. During flight, it has less "float".

Temperature controlled synchronous correction: New monopoly method for keeping motors in good working order. Dynamic Timing and Start-up Power: – fine-tuned for smooth, précised operation-controlled start-up over the whole UAS Brushless Motors (no hesitation, stuttering, or response lag).

Increased Drive and Throttle Frequency Resolution: – high-accuracy, linear throttle response over the whole control range.

Motor Synchronization is a frequency-matched start-up protocol that ensures that motors run smoothly and efficiently. Anti-Spark Circuitry-at first plug-in and system power-up, this circuitry ensures the integrity and lifespan of crucial connectors.

Automatic detection of PWM control-signals – Most applications are compatible with factory calibrated automatic throttle calibration.

The new KDE direct US multi-rotor Electronic speed controller (ESC) is designed for multi-rotor applications and features a patented algorithm that allows for higher rate control up to 600 Hz and faster response to flight system commands. For best flight performance, dynamic PWM and motor advance timing algorithm are used; this series has been specially built and optimized for the KDE direct USA multi-rotor brushless motor series. The system is tailored for optimal flight controller stability and performance, with near instantaneous responsiveness for flying commands.

ESCs include 200°C, 14 AWG silicone-wire power leads, and 15 AWG silicone-wire motor leads with dual ϕ4.0mm (KDEXF-BC40) and ϕ3.5mm (KDEXF-BC35) 24K matching B. As a result, the KDE-UAS55HVC ESC is the best option for the drone [8]. It calibrates the speed of the drone and changes it in response to the drone movement. When this form of ESC is used for longer periods of time, it produces less heat. High efficiency, thermal stability is among the drone's additional benefits.

Figure 5: - KDE-UAS55HVC ESC

C. Flight Controller

It is known as the brain of a drone. It controls all the components in the drone. The information given by the transmitter goes to the flight controller of the drone. In our drone, we use an orange cube flight controller. This is one of the top and most reliable flight controllers available in the market [9]. The primary function is that we can implement UTM in this flight controller.

The controller is designed with a domain-specific carrier board to reduce the wiring and improve dependability and ease of assembly. For example, a carrier board for a marketable scrutiny vehicle may include connections to a companion computer. In contrast, a carrier board for a racer could include ESCs for the frame of the vehicle. The cube includes vibration isolation on two of the IMU's, with a third fixed IMU as a reference/backup [6].

The key features of the flight controller include: - Abundant connectivity options for additional peripherals (UART, I2C, and CAN), integrated backup system for in-flight recovery and manual override with dedicated processor and stand-alone power supply (fixed-wing use), redundant power supply inputs and automatic failover, External safety switch, high-power, multi-tone piezo audio indicator etc.

Figure 6: - Orange Cube FC

D. Propeller

A propeller is used to provide thrust. KDE carbon fibre propellers are the most suitable for the drone. Carbon fibre propellers are used here to provide more thrust. The propeller moves in the direction of the motor. The 12.5x4.3 (length x width) size is perfect for the design. These propellers are lightweight, provide high thrust and are very durable.

Propeller blades are dynamically balanced matched sets for smooth and vibration-free flight operation. Blades cannot be intermixed between sets-make sure to keep organized as matched blades to prevent balance-related concerns. If a single blade is damaged during operation, make sure to replace the propeller blade sets (CW-CCW).

The new-fangled KDE Direct Carbon-Fibre Propeller Blades are made of accurate carbon-fibre 3K materials. All propellers are dynamically balanced and provided in matched sets, so install the blades and fly - no need for unimportant balancing or other headaches that plague competitive offerings [4]. The propeller Blade series is designed for KDE direct UAS multi-rotor propeller blade adapters and the USS Multi-rotor Brushless motor series for unprecedented ease of use and efficient flight performance.

Figure 7: - KDE carbon fiber propeller

E. LiDAR

The RPLIDAR A3M1 is a generation of 360-degree 2D LiDAR's. Due to the high rotational speed each RPLIDAR A3 can take up to 16000 samples of laser range per seconds. The onboard system can perform 2D 360° scans within 25 meters in enhanced mode and 20 meters in outdoor mode. Additionally, 2D points generated can be used for cloud data mapping, localization and object / environment modelling.

The RPLIDAR A3M1 consists of a long-range scanner core and mechanical powering parts, making the core rotate at high speed. When it is running normally, the scanner rotates clockwise and scans, allowing you to obtain range scan data through RPLIDAR's communication interface and control the start, stop and rotation of the rotation motor via PWM. The distinctive scanning frequency of the RPLIDAR A3 360-degree laser scanner is 10 Hz (600 rpm), with a scanning frequency that can be adjusted freely in the range of 5-20 KHz [7].

Figure 8: - RP LIDAR A3M1 360°Laser Range Scanner

F. Transmitter

Here we use Radio Master TX16S Multi-protocol RF Module Open TX 2.4GHz RC Transmitter. Radio Master set out to create the very best radio in its class. The TX16S has the best of everything that could fit in today's radios and expandability and upgradeability for the future, such as the Touch panel ready mother board that will support future touch compatibility versions of Open TX firmware and UART expansion slots. The main features of the transmitter used are: - Built-in USB-C Charging, USB-C Data/simulator port, External SD card slot (SD card included), two external UART ports for updates and DIY, Improved menu navigation with Page back and forward, better housing design with improved grip ergonomics, better switch quality and placement design etc. The specifications of the transistor used are: -

- Size: 180x190x58mm
- Weight: 820g including 2×18650 batteries
- Input Voltage: 7V – 8.4V DC
- STM32 F429 MCU
- 4.3″ 480×272 Color Screen
- Rolling wheel menu button
- Full-Size Hall Gimbal

Figure 9: - Transmitter

G. GPS

Processor - 32-bit ARM Cortex M4 with FPU: - The Cortex-M4 processor is developed to address digital signal control markets that demand an efficient, easy-to-use blend of control and signal processing capabilities. GPS stands for the global positioning system. It is a tool for locating the drone and its parameters like altitude, speed etc. Combining high-efficiency signal processing functionality with the low-power, low cost and ease-of-use benefits of the Cortex-M family of processors satisfies many markets [3]. These industries include motor control, automotive, power management, embedded audio and industrial automation markets.

MPU6000 as primary accelerometer and gyrometer: - 3-axis gyroscope, 3-axis accelerometer in a 4x4 package. The MPU-6000 is the first 6-axis I²C Motion Tracking device designed for the low cost, low power, and high-performance requirements of smartphones, tablets and wearable sensors. The MPU-6000 is contained of two parts. To save space, the package dimension of the devices has been determined down to a footprint of 4x4x0.9mm (QFN). The features of this type of GPS module are: -

- Digital-output X-, Y-, and Z-Axis angular rate gyroscopes with a user-programmable full-scale series of 250, 500, 1000, and 2000/sec
- Exterior sync signal connected to the FSYNC pin supports image, video and GPS synchronization
- Integrated 16-bit ADCs enable simultaneous sampling of gyros

- Enhanced bias and sensitivity temperature stability decreases the need for user calibration
- Improved low-frequency noise performance
- Digitally-programmable low-pass filter
- Gyroscope operating current: 3.6mA
- Standby current: 5A
- Factory calibrated sensitivity scale factor

Figure 10: - GPS system

H. Battery

Lithium-ion battery or commonly known as Li-ion battery is a type of battery that can be recharged. Lithium-ion batteries are commonly used for portable electronics and electric vehicles, and are popular for military and aerospace applications [4]. Lithium ions interchange from the negative electrode through an electrolyte to the positive electrode during discharge and backwards during charging. Li-ion batteries use the intercooled lithium compounds as the positive electrode and usually graphite on the negative electrode. The batteries have a great energy density, no memory effect (other than LFP cells) and low self-discharge. However, they can be a safety hazard since they contain flammable electrolytes, and if damaged or incorrectly charged, they can lead to explosions and fires. Or more flight time and a better experience [12]. The specifications of this type of battery are: -

- It is a 4S battery (4 cells are used)
- 3000mAh battery

Figure 11: Li-ion battery

IV. SOFTWARE SECTION

In our project, we have used 2 types of software: Mission Planner and Green Valley LiDAR 360.

A. **Mission Planner: - The Flight Control Software**

Mission planner is open-source software. It can be installed on for free in a PC or Laptop. The GCS system can be controlled using this software, and also, we can easily calibrate the drone. The flight plan is done in this software. The site area can be seen in mission planner software. First, we need to specify a starting point then give other points and the ending point. If an emergency like adverse weather occurs, the drone will traverse the same route to move forward and return to the starting point [1].

Figure 12: - mission planner software

B. Green Valley LiDAR 360: - The Data Processing Software

Green Valley LiDAR 360 is fully automated software. This software is used to process and analyse the data collected after LiDAR scanning. The data loaded into this software can be ". las" format or ". lidar" file format. There are mainly three models on which this software works, and they are: - Framework Model, Terrain Model and Aerial & Terrestrial Forestry Metrics [5].

1) Framework Model

The LIDAR 360 frame work forms the basis of the entire software suite. The frame work contains the tool needed to effectively manage and manage LiDAR point cloud data. Functions include data management, automatic strip alignment, and point cloud classification. The various functions offered by the framework are-Classification Tools, Automatic Strip Alignment, Displays by elevation, intensity, category, RGB, combination, etc. Display modes: Mixed display, tree ID, EDL, Glass, Display and measure flight path files, and Clip flight path.

2) Terrain Model

The terrain model provides a series of involuntary and manual-editing tools for sorting ground points clouds. It makes available a set of GIS tools for interpolating surface models (e.g., Digital elevation model/ DEM, digital surface model/ DSM) and envisaging and editing them in 3D. It comprises tools for repairing surface models from spikes and holes. It allows users to analyse the terrain model to generate derivatives from the surface models, e.g., slope, aspect, and roughness. The latest version of the change detection and deviation analysis functions to better support users' needs in different fields, e.g., disaster monitoring and land-use change analysis. The services offered by the Terrain model are: Generate DEM, DSM & canopy height models, Generate and edit TIN models based on the point cloud, generate contour lines from rasters, Generate TDOM models, Calculate terrain slope, aspect, roughness, hill shade and more from terrain surface models]1].

3) Aerial & Terrestrial Forestry Metrics

The forestry unit comprises tools to method point cloud data attained from aerial laser scanning (ALS) systems, terrestrial laser scanning (TLS) systems, and mobile laser scanning systems. This module provides effective individual tree segmentation and editing tools for all types of point cloud data. Users can recover the topographic information with the de normalization tool after the segmentation and editing. The services offered by this model are: Height Variables, Intensity Variables, Leaf Area Index (LAI), Artificial Neural Network Regression, and CHM Segmentation, Point Cloud Segmentation, Ground Point Filtering, Extract by tree ID [4].

V. DESIGN STRUCTURE OF LIDAR DRONE

The software used for designing our drone is Catia V5 pro. Here we use this software because it delivers the unique ability not only to model any product but also to do so in the context of its real-life behaviour: design in the age of experience. Systems architects, engineers, designers, construction professionals and all contributors can define, imagine and shape the connected world [6]. It allows the user to convert all forms of 3D mechanical design geometry and assembly and attribute information, maintaining colour or layer information during translation. In addition, the input data may be filtered to optimize the overall translation process between these CATIA V5 and Creo Parametric. The 3D images of every hardware component are loaded into the software and assembled together to obtain a complete drone image [10].

The dimension of this drone is 420mm. The dimension of the drone is measured as the distance between two opposite arms of the drone. In our drone, we use the '+' configuration. The plus configuration means that the adjacent arms of the done make a 90-degree angle with each other. The key features of this software include: It converts all types of geometry, wireframe, surfaces, trimmed surfaces (faces) and solid models, transforms assembly structure between the systems, converts attribute data excluding colour and layer data, the conversion process can be run interactively, or in Batch mode, data can be sifted by layer and entity type, geometry can be filtered and selectively processed. The advantages of this type of drone are: -

- Lightweight
- Aerodynamic model
- Strong landing gear

Figure 13: Design structure of the drone

VI. UTM SETUP

The word UTM stands for Unmanned Traffic Management. It is the best way to fly the drone autonomously. To fly any drone in a given area, it is required to take permission from the concerned authority. The goal of UTM is to create a system that can integrate drones safely and efficiently into air traffic that is already flying in low-altitude airspace. When delivery drones and passenger drones begin operations shortly, UTMs will ensure that they do not interfere with manned aircraft operations. To make commercial drone operations feasible in the Indian airspace, the DGCA has introduced regulations for establishing UTM services. This process of flying the drone autonomously using UTM setup can be explained using the following three steps: -

Step 1: - create a flight plan using a mission planner and save it as a KML file. Here, KML stands for Keyhole Markup Language. It is a file format that is used to display geographic data.

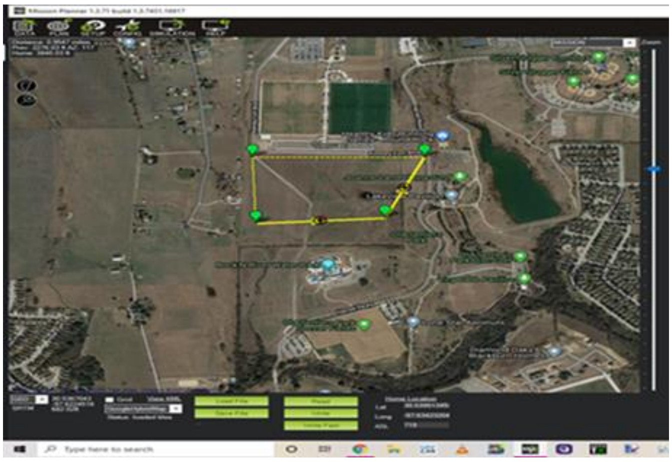

Figure 14: creating a flight plan

Step 2: - upload the flight plan to DGCA and take permission. The second step is to take permission from the DGCA to execute the flight. Here DGCA stands for Director-General of Civil Aviation. It is a regulatory body in the field of Civil Aviation; it primarily deals with security issues. It is responsible for regulating air services to/ from India/ in / out and enforcing civil air regulations, air safety and air fitness standards. The flight plan created using the mission planner software is uploaded into the DGCA website to seek permission.

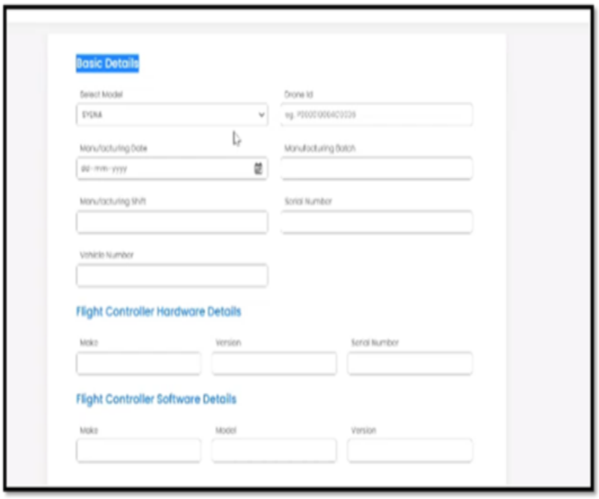

Figure 15: - the UTM site

Step 3: - Execution of the Flight. After taking permission from the GCDA, the flight plan is opened through the mission planner software, and the execution of the flight is done.

Figure 16: - execution of the flight

7. RESULTS

The data collected from the drone LiDAR is saved in the system as a las file or a lidar file. This file is then loaded into the Green Valley LiDAR 360 software to process the data and to analyse the required parameters. A few results after the simulation are shown below: -

A. Measuring distance between 2 points

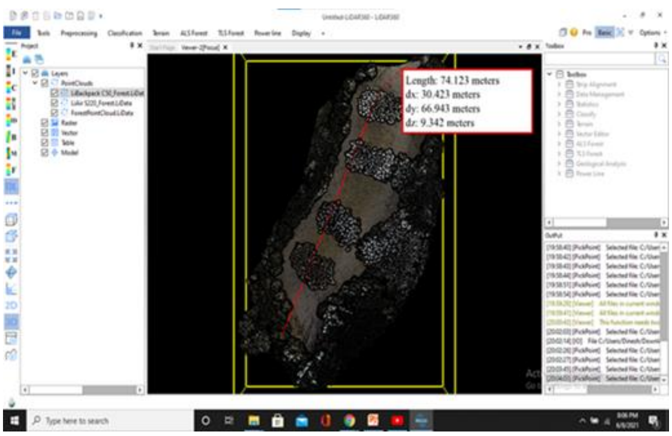

Figure 17: - measuring distance between 2 points

To measure the distance between 2 points, first the length measurement tool is selected. Then a starting point is chosen from where we can measure the distance it makes with any point of the area under study. The distance between 2 points is specified in meters. The coordinates of the end point can also be viewed using this tool.

B. Finding area of the required portion

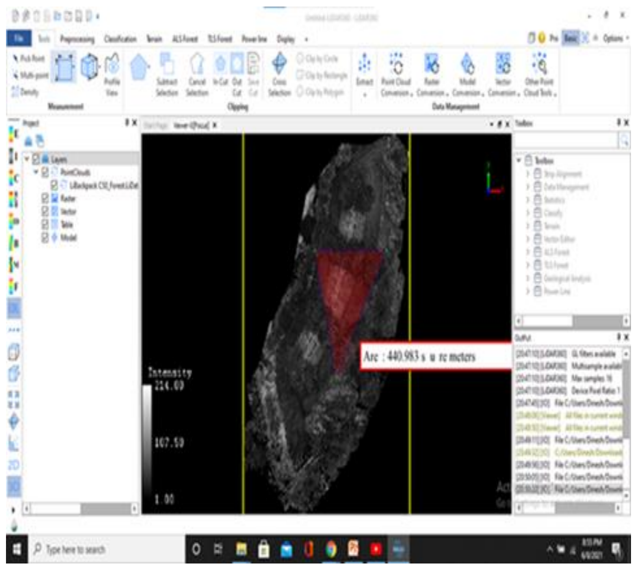

Figure 18: - finding area of required portion

To find the area of the required portion we use the length measurement tool under which area measurement option is selected. The area of the selected portion is shown in square meters.

C. Vegetation classification based on plant heights

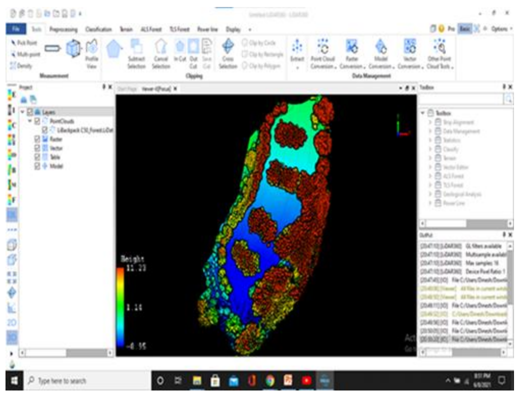

Figure 19: - classification of vegetation based on plant heights

The plant heights of the data obtained can be displayed using the "Display by Heights" option. The height of the vegetation under study is measured in feet. In the above figure, the tallest plants are shown in red colour, the medium height plants are shown in green colour and the shortest plants are shown in blue colour.

VII. CONCLUSIONS

The key goal of our project was to design a LiDAR based drone and implement it in the field of vegetation scanning. Compared to the ordinary drones that require manual controlling, the LiDAR based drones with the UTM setup provide a fully automated surveying of the required area. In the regular LiDAR-based drones, we must manually place the receivers at the coordinates of the required area to obtain the data. Still, in LiDAR-based drones with a UTM setup, the data can be automatically obtained from the required area. This type of drone can help in reducing time consumption, reducing manpower and improving accuracy. As the drone with a UTM setup flies at a constant altitude, we can obtain more minor errors and unique information. In our project, we have shown how LiDAR-based drones can be helpful in Vegetation scanning. Vegetation scanning provides information on the growth, dynamics of terrestrial vegetation can provide valuable insights. The applications of vegetation scanning include environmental monitoring, biodiversity conservation, agriculture, forestry, urban green infrastructure and other related areas. There are many methods like Remote sensing methods: SAR images, Landsat images etc., for vegetation scanning Compared to satellites, the drone operates at a lower altitude. Hence, it's more preferred since we can obtain 3D data of the vegetation understudy with more clarity and accuracy.

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