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OBSERVATION AND ANALYSIS OF REMOTE FOREST AREAS AND EARLY FOREST FIRE DETECTION USING DRONES [8]

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Abstract: *The unmanned aerial vehicles (UAVs), sometimes simply referred to as drones, are becoming increasingly popular. Recent technological and scientific advances in the manufacturing processes have led to significant reduction in the drone prices and have made them simpler to control, use and maintain. Besides being used for capturing of aerial photos and videos, the unmanned aerial vehicles are also being implemented in and for various other activities and processes. One of them is for observation and analysis of remote or hard to reach zones, where the drones are replacing the conventional aircrafts or the satellite technologies. Nature parks, forest agencies and even governmental institutions have taken advantage of this technology and are now using UAVs to perform vegetation analysis, to detect poachers, to fight invasive species of animals and plans, to observe remote forest areas or to develop systems for early forest fire detection. In this paper, we provide analysis on the UAVs applications, in terms of their use specifically for observation and analysis of forest areas. We present briefly the structure and the components of the UAVs and then continue with their potential payload, which can range from a simple camera to a sophisticated sensor system for multispectral analysis. The paper continues with an actual analysis of a forest area, which is part of the Rusenski Lom Nature Park in Bulgaria. We further investigate also the possibility for implementation of drones for early forest fire detection in the Balkan-Mediterranean area and we analyse and present a solution based on several different types of UAVs.*

Keywords: *Unmanned aerial vehicles, drones, forest fires, 3D and digital surface models, location analyses*

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INTRODUCTION

The use of unmanned aerial vehicles for early detection of forest fires is widely used technique [1, 2, 3] but due to the need of manual human operation this approach is considered quite risky. Modern techniques related to the development of unmanned aerial vehicles reduce the aforementioned risks and make possible for these aircrafts to be integrated in different applications for early detection and prevention of forest fires [4, 8]. One such application is the development of a system for detection of forest fires based on two diverse type of aircrafts – fixed wing and rotary wing UAVs. The platform is part of the THEASIS system for early detection and surveillance of forest fires [7]. The system developed by the University of Ruse "Angel Kanchev" consists of three different unmanned aerial platforms. The constant surveillance is going to be carried out by a fixed wing UAV with vertical take-off and landing. The developed system will be built over the territory of nature park "Rusenski Lom". The main objective of the fixed wing UAV is to constantly monitor the thermal characteristics of the surface of the territory of the park. If the system detects a temperature increase in a specific area, a signal will be send to the ground control station, which besides the message for potential fire alarm will also include and the GPS coordinates of the potential fire. In order to confirm if the fire alarm was true or false another two UAVs with much lower altitude will be used. In this particular component of the system, a module for computer vision will be integrated. The module is going to be used to detect smoke from images taken during the flight of the aircraft. It is clear that the detection of smoke, could lead to early forest fire detection and could prevent greater damages. If the rotary wing UAV, hovering at low altitude (10-350 meters), confirms that there is a fire outbreak, a signal will be immediately sent to the fire department services. During this process, the rotary wing UAV will continue to hover over the area of interest and will serve as an aid during the suppression of the fire outbreak.

SPECIFICATIONS OF THE SYSTEM COMPONENTS AND CONCEPTUAL DESIGN OF THE SYSTEM

For the implementation of the long endurance fixed wing UAV an ALTi VTOL (vertical take-off and landing) [5] will be used. A distinct feature of that drone platform is the hybrid structure of the fuselage. This feature allows the aircraft to vertically take-off/land and automatically transitions into forward wing-bound flight. The feature is extremely valuable and useful for the project objectives because it allows the aircraft to take-off virtually from any point of interest, which eliminates the need of providing take-off/land lane, maintenance of expensive equipment such as hydraulic parachutes, catapults and others. The automatic transitions into forward wing-bound flight provides the possibility to use the fixed wing platform at its full capacity and ensure longevity of the flight up to 12 hours on a single charge. The vertical take-off/land of the aircraft is achieved by four brushless electric motors, while the forward wing-bound flight by an internal combustion engine (ICE). The platform is equipped with all the necessary avionics to carry out completely autonomous missions with full control of the flight from the ground control station. The unmanned aerial platform could carry up to 5 kg of payload, which is going to be a specialized spectral camera with an integrated module for the implementation of computer vision and artificial intelligence algorithms. The module provides a completely autonomous processing of the video information on board of the drone by detecting predefined object, events and sends georeferenced information to ground control station. This makes the aircraft complete independent and eliminates the need of further processing of the video information at the ground control station.

a. Technical specifications of ALTI VTOL fixed wing UAV

The ALTI Transition airframe is completely modular and can be rapidly deployed for under 10 minutes with only two operators required. This along with zero need for a runway or heavy and expensive catapult systems, provides a quicker and safer operation, anywhere, any time. The Transition is designed as a hybrid system allowing for a combination of multirotor flight and traditional fixed wing flight, the practicality of multirotor flight for take-off and landing, with the efficiency, range and endurance of a fixed wing aircraft. The incorporation of VTOL technology into the fixed wing system allows the Transition to take-off and land in confined spaces in a very short time, offering massive advantages over traditional systems as well as a lower impact and stress on the aircraft with long term use, usually associated with catapult launchers and hard and unpredictable parachute landings.

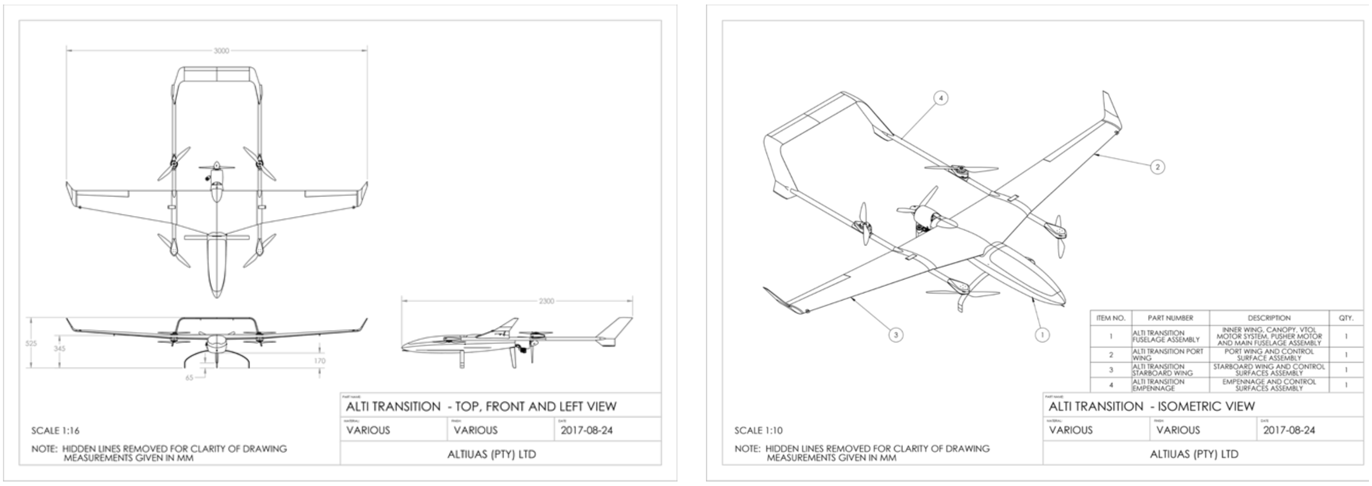


Fig.1 ALTI Transition dimensions

The dimensions of the aircraft are 3000 mm wingspan, 2300 mm length and 525 mm height and its maximum take-off weight is 16 kg, which allows it to carry several different types of payload simultaneously (fig.1). The payload bay can be tailored to fit and mount a wide range of cameras, sensors and other equipment, the system offers great flexibility without limiting the operator or mission scope.

The ALTI autopilot was developed from the ground up as an advanced VTOL flight controller specifically tailored for the Transition aircraft system. A wide range of safety features have been built into the flight controller that auto-detect sensor failure detection and failover. Flight envelope failures such as stalls, excessive roll/pitch, motor failure, etc. will be detected with an auto-failover to multirotor mode for fast recoveries. The Transition comes completely ready to fly with a ground control station, including a control link, an advanced digital datalink for aircraft data as well as video along with a Laptop PC station and a travel case.

Fig.2 ALTI Transition ground control station

The ALTI Ground Control (fig.2) is a complete control and command station for the ALTI Transition unmanned aircraft system. The ALTI GCS includes a compact pelican case, high quality laptop computer, pre-loaded with mission planning and control software, Microhard modem and payload/video software, a main C2 control link for full time manual control and override, data telemetry as well as video Link for long range applications. Also included is a radio controller for aircraft control, power packs, and antennas.

The flight control data is transmitted from the ground station towards the UAV. It usually consists of packets, containing various commands for controlling the speed of the aircraft. This is mainly accomplished by controlling the UAVs engines and motors, their rotations per minute and other parameters. Other flight control commands might include commands for changing the positions of the elevators, the position of the flaps, commands for extending or retracting the landing gears and other. All commands are sent from the ground control station to the UAV trough a low speed radio uplink, which usually provides speeds of up to 30 Kbps. The flight control data is extremely time sensitive, but its volume is very low and thus presents no challenge for the modern communication interfaces and standards. A very interesting fact is that this type of data is not mission critical. Even though it is always good to have means for remote control of the UAV, in the cases when the uplink fails, the aircraft can still continue with its mission. This is possible when the UAV is capable of detecting the failed link and uses its autopilot feature. This feature requires more computational power and can drain the batteries of the UAV more quickly but can also save the drone when the control uplink fails.

The flight status data (also known as telemetry data) is used for evaluating the parameters of the UAV. There are several categories of flight status data based on the observed parameters – UAV location data, battery condition data and spatial positioning data. The UAV location data is used for presenting the global or the relative coordinates of the aircraft, as well as the distance to the home base. The battery condition data is used for determining the state of the batteries and for estimation of the possible flight time. The spatial position telemetry of the aircraft consist of information about the speed and the direction of the drone, its altitude and the vertical and horizontal offsets.

Payload data is the only mission critical data and thus the loss of the communication channel, which is used for its sending can cause the failure of the mission tasks. The payload data can be defined as the data streams from the various on-board sensor devices, including the on-board cameras, the temperature and pressure sensors and all other sensing devices. Due to the huge amount of data that has to be sent to the ground control station the payload data is usually sent using a separate radio link, which is a broadband high-speed link with speeds of over 2 Mbps. This link is both uplink and downlink. This is due to the nature of the data, the requirements to acknowledge some of the sent information, the necessity to send additional data for maintenance of the sessions between the drone and the base station, etc. Sending and receiving the payload data still presents a lot of challenges, including how to format the data in a more appropriate way, how to maintain real-time transmission, how to provide high quality video data without overconsumption of the channel bandwidth and many other.

The communication between the UAV and its GCS influences the UAV system operational performances directly (fig.3). The basic robustness of a UAV communication links is secured by additional on–board UAV power supply. Higher level of redundancy is ensured by the introduction of an additional radio link. With the multiplication of data–links to and from the UAV and its GCS i.e. with the multiplication of the transceivers, receivers, transmitters and by the multiplication of the communication frequencies a continuous data–link availability and sufficient communication exchange between the UAV and its GCS is guaranteed. The energy consumption for the communication purposes is one of the major problems for the UAVs. Using a redundant power supply is sometimes a solution, but it also requires space an increase the weight of the UAV – two of the mission critical parameters. Sometimes it is impossible to use a redundant power source. In those cases, the communication approaches and the range of the UAV antenna array are the major element for the success of the mission.

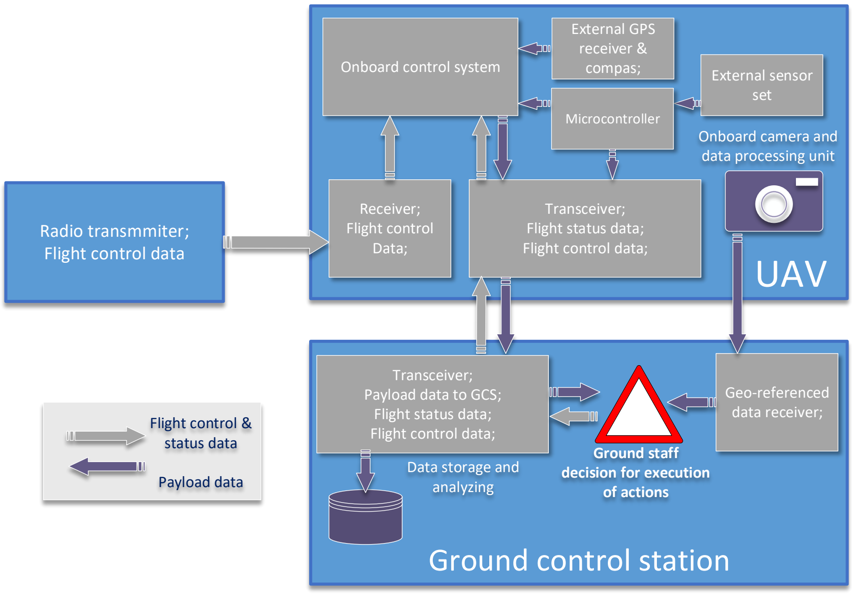


Fig. 3 ALTI Transition design of UAV communication system

b. Technical specification of the rotary wing UAV

The implementation of the rotary wing UAV will be achieved by using a DJI Matric 210 RTK (fig.4) [6]. The advantages of these series is that it has a gyro stabilized stand for two separate cameras – one thermal camera and a standard optical camera from the X4S series. The M200 series folding body is easy to carry and easy to set up, with a weather- and water-resistant body, ideal for field operations. The aircraft is equipped with more than 20 internal sensors for maximum redundancy and reliability, including compass, GPS system, dual inertial measurement units (IMUs) and three barometers. Gimbal controllers have been integrated in the aircraft body for protection and to prevent drift. The aircraft features two stereo-vision systems below and in front of the aircraft and has an upward facing infrared sensor for obstacle avoidance. A redundant battery system improves safety and also allows the craft to stay powered while batteries are swapped in sequence.

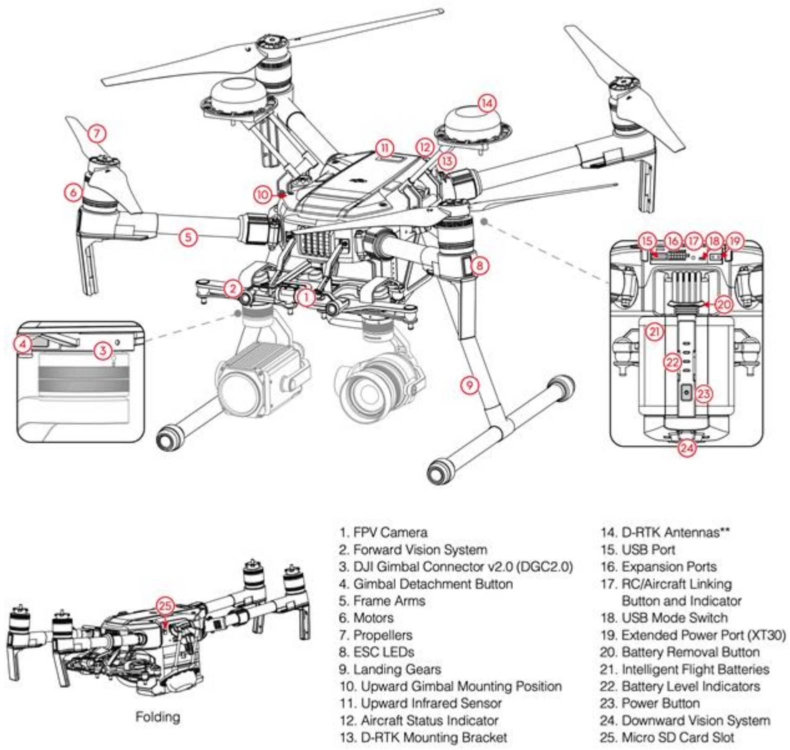


Fig.4 Matrice 200 Series D-RTK

The M200 series features DJI AirSense, a built-in ADS-B receiver, enhancing airspace safety by automatically providing the operator with real-time information about the position, altitude, and velocity of nearby manned aircraft equipped with ADS-B transmitters. AirSense enables safer and more efficient use of airspace, particularly in locations where other manned aircraft may be operating. The M200 series is also equipped with an integrated flight controller, featuring two IMUs and a GNSS unit, with additional analytical redundancy systems. Working together with advanced diagnostic algorithms, it can seamlessly switch from one IMU to the other to maintain reliability and precision.

For situations that require a balance between weight and image quality, the Zenmuse X4S has a 1-inch, 20-megapixel sensor with 11.6 stops of dynamic range and a 24 mm equivalent focal length. The Zenmuse X4S offers aperture control (f2.8-11) and a mechanical shutter capable of 1/2000 shutter speeds, eliminating rolling shutter distortion when taking images of fast-moving subjects or when flying at high speed. The Zenmuse X5S has a larger Micro Four Thirds sensor with 20.8 megapixels and 12.8 stops of dynamic range and supports eight lenses from wide angles to zooms. DJI’s Zenmuse XT, powered by FLIR, provides high-sensitivity thermal imaging ideal for analytics and telemetry. DJI’s Zenmuse Z30 is the first integrated aerial camera with an optical zoom up to 30x and digital up to 6x, making image data collection significantly faster while greatly reducing the risk of harm to both personnel and equipment.

LOCATION ANALYSIS OF NATURAL PARK “RUSENSKI LOM”

In this section of the paper authors provide results achieved during the location analysis of the nature park. During the work the team have implemented different tasks and as a result a 3D model of the park was created. In addition orthomosaic and corresponding Digital Surface Model of the location ware also provided.

There are many different software that could be used for processing of images captured form the unmanned aerial vehicles, but the choice which software to use very depends on several factors: the quality of the photographs, the type of the object that is to be digitalized and many others. After making a thorough analysis it can be concluded that the most appropriate software product for implementing digitalization of earth surface is Pix4D Mapper. The steps necessary to create high quality 3D model of earth surface from a given number of photos taken by the use of unmanned aerial vehicles are given as follow: create a project, import images, image correction (if necessary), choosing appropriate template, finalizing and ovserving the results.

Fig.5 Projecting a grid with GSD spacing onto the surface of interest

The use of modern geographic information systems allow the reconstruction of three dimensional object as well as taking accurate measurements on those objects. Those measurements include but are not limited to – measuring distance, area, volume, etc.

- Distance – the distance measurement is a process that defines the distance between two specific points located onto the object/surface. The accuracy of this measurement is based on the resolution of the orthographic image and more precisely the ground sampling distance (GSD). The bigger the value of the GSD, the lower the spatial resolution of the image and the less visible details. The GSD is closely related to the flight height. The higher the altitude of the flight is, the bigger the value of the GSD. Based on the initial report the spatial resolution of our orthographic image is 6.95 cm/pixel.
- Area – the area measurement is very similar to the distance measurement. It is also based on the resolution of the orthographic image with the difference that at least three points should be defined.
- Volume – the volume measurement is divided into two major groups – measuring excavation and embankment. The measurement is carrying out by projecting a grid with GSD spacing onto the surface of interest, as shown on fig. 5

The volume of the surface is based on the calculated volume of each cell of the grid (fig. 6), which is given by the formula below.

$$V_i = L_i * W_i * H_i, \tag{1}$$

where

$L_i = W_i$ is the distance between two pixels

H_i = Height ot each cell

The height of each cell is represented as a difference between the altitude of the 3D terrain corresponding to the center of the cell "i" and the altitude of the base surface of the volume corresponding to the center of the cell "i".

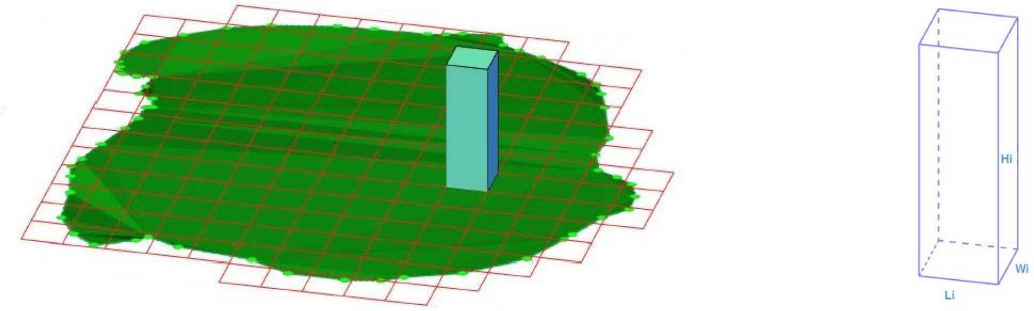


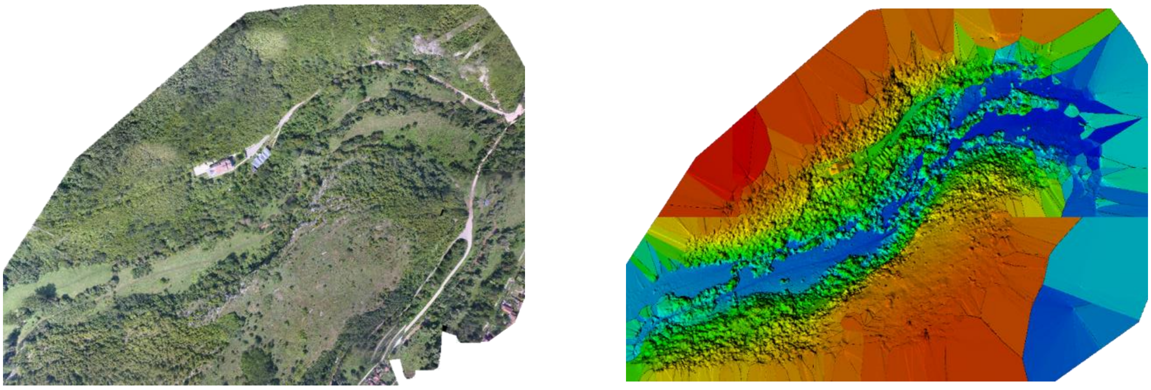
Fig.6 Calculating the volume of individual cell from the object surface

Fig.7 Calculating volume characteristics of bulk objects

Fig. 7 presents the volume characteristics of the national part "Rusenski Lom".

After the end of the reconstruction process the software generates different output formats, which are useful for diverse purposes. For example, the outputs could be Orthomosaic, DSM, Point

Cloud, 3D textured Mesh, Index Map. Which output is generated depends on the type of chosen template. Orthomosaic photo is an image that is created by stitching multiple photos. As a result newly created image has extremely high resolution, which allows for accurate measurements of distances of earth surface. Fig. 8a represents the generated orthophoto of "Rusenski Lom" project. The orthophoto generated for "Rusenski Lom" has a resolution of approximately 13000x9000 pixels and it is generated from 174 aerial photographs.

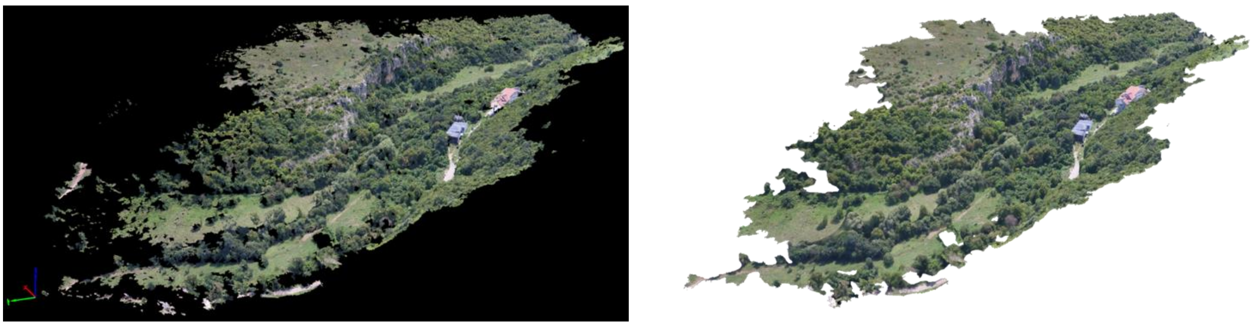


a) b)

Fig. 8 Orthophoto image of National Park "Rusenski Lom" (a) and Digital Surface Model (b)

Digital Surface Model (DSM) is a representation of terrain's surface, created from a terrain's elevation data. It is an image that illustrates the height of the objects to the lowest point of the model. Fig. 8b represents the DSM model for National Park "Rusenski Lom", generated from the software. The blue color in the image indicates the lowest part of the terrain, where the river bed resides, while the highest part are mark with red color.

Point Cloud is the aggregation of all points presented in three dimensional (usually "xyz") coordinating system. The point cloud represents the outer surface of the terrain. Fig. 9a illustrates the point cloud generated for "Rusenski Lom" projects. The number of points in the cloud counts about 11 millions. This is extremely high number such as the cloud looks like a model or surface if it is not scaled. Fig. 9a and fig. 9b looks pretty much the same, the fig. 9a is a point cloud, while fig. 9b is a textured 3D model.



a) b)

Fig.9 Point Cloud (a) and 3D textured model (b)

Textured 3D model – represents textured surface like a skin, which aggregates connected points into polygons from point cloud. Fig. 9b represents 3D textured model of the terrain of National Park "Rusenski Lom".

Another useful feature that can be derived from the software is the Normalized Difference Vegetation Index – NDVI which represents graphical indicator that can be used for analysis of remote measurements with the goal to determine if the observed area contains live vegetation and what is its condition. This is widely spread and used method for quantity and quality assessment of the vegetation. It is calculated by the following formula:

$$NDVI = \frac{NIR-RED}{NIR+RED} \tag{2}$$

where:
NIR – reflection from near infrared area of the spectrum;
RED – reflection from the red area of the spectrum.

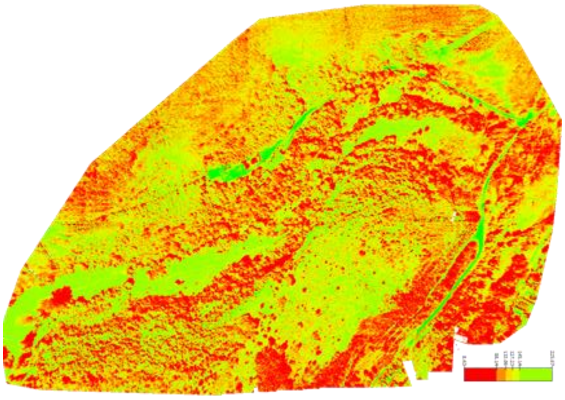


Fig. 10 NDVI index map of National park “Rusenski Lom”

The calculation of NDVI index is based on two of the most stable (not dependent on other factors) sections of the spectral reflection curve of the higher plants. In the red area of the spectrum (600nm-700nm) is the maximum absorption of solar radiation from chlorophyll in plants, while infrared area (700nm – 1000nm) is the area of maximum reflection from cell structure of the leaves. High photosynthetic activity is indicator for less reflection in red area of the spectrum and higher reflection in the infrared area of the spectrum.

NDVI map could be generated from photos taken by unmanned aerial vehicles but in their regular setup the drones come with standard photo camera which can capture near infrared spectrum of the light. The photo taken with regular camera does not contain the desired information for accurate calculation of NDVI index. For correct NDVI index calculation a multispectral camera is required. Despite this requirements the software that is used for generating all of the aforementioned outputs, could generate NDVI map from regular photographs. But this NDVI map would not be as accurate as it would be if a multispectral camera was used. Fig. 16 illustrates NDVI map generated by the software during the computation of “Rusenski Lom” project.

Fig. 10 Field testing of the platform for early forest fire detection

CONCLUSION

The platform for early forest fire detection is improved by introducing an artificial intelligence. A complex algorithms are implemented in neural network models such that the models are trained to learn how to recognize smoke in the imaged captured from the drone. The model works pretty well as expected but its accuracy is not checked. Several onsite experiments have been conducted and fig 11 shows part from that testing. As it is noticed the model can capture and predict smoke from camera feed from the drone.

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