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UAV Application in Creating 1:2000 Topographic Maps for Wind Power Projects in Ha Tinh Province, Vietnam

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ABSTRACT

In the survey area (high coverage density and 1km height difference between the foot and the top of the mountain), the UAV with LiDAR sensor is used. From the assigned coordinates and altitude, GNSS RTK technology is used to establish ground control points (GCPs). From these GCPs and terrain conditions, 29 aerial photography subdivisions are designed for the project. The flight route design is carried out on the principle of covering the entire flight area, ensuring the highest accuracy. Based on the subdivision boundaries, ground resolution of the image, vertical coverage and horizontal coverage of the image, flight direction, camera photography parameters, and technical specifications of the UAV device, proceed. Determine flight altitudes and specific flight routes for each flight subzone. GCP Ground Control Point and CP Check Point (Check Point) are used. Check the vertical coverage and horizontal coverage of the photo compared to the design; then proceed to link and correct the image blocks. When the image block correction results meet the requirements, proceed to create a dense point cloud from the image volume results that have been adjusted to a size not smaller than the resolution of the original image. Use point cloud data to create a DEM model. The RMS error in horizontal is 10.4 (cm) and vertical is 1.3 (cm) confirming enough reliability to create a 1:2000 scale topographic map.

Key words: UAV LiDAR, DGPS, flight segmentation, vertical-horizontal coverage, image blocks, point clouds, DEM

INTRODUCTION

The history of Unmanned Aerial Systems (UAS) goes back over centuries and the hot-air balloons first used by Austrian people to send explosive war heads to Venice in 1849 is its starting point. As a tool to detect enemy territories, military people basically invest a lot to develop unmanned aerial vehicles and then the modern sensor system brought it up to the present condition. Thus we are now getting its benefit for humans' life activities (Santise, 2016). Nowadays, UAS has become a popular tool for many fields such as agriculture (Grenzdörffer & Niemeyer 2011), cadastral applications (Cramer et al., 2013; Cunningham et al., 2011; Barnes et al., 2014; Manyoky et al., 2011), geology (Eisenbeiss, 2009), cultural heritage (Remondino et al., 2011; Rinaudo et al., 2012), archaeology (Chiabrando et al., 2011), disaster management (Molina et al., 2012; Choi and Lee 2011), damage assessments (Vertivel et al., 2015), coastal management (Delacourt et al., 2009) and so on.

However, the acquisition of high resolution data or dense data sets over the landscape is a requirement for many Earth science and mapping studies (Hackney and Clayton, 2015). With the advent of sensor systems UAS, i.e. a data acquisition system designed to operate with no on-board human pilot, are being promisingly used for surveying and mapping (Koeva et al., 2018; Nex & Remondino, 2014). Though the term UAS is commonly used, the other terms such as drones, Unmanned Aerial Vehicles (UAV), Remotely Piloted Aircraft Systems (RPAS) have been often used by the different user community. The UAV refers to the platform itself while the UAS refers to the entire system including platform, control unit together with the communication sub-system and the operator (Chio & Chiang, 2020; Nex & Remondino, 2014). Therefore the term UAS is more suitable to describe the technology. In fact, UAS has changed the way that the data has been collected in traditional land surveying methods such as theodolite, tacheometry, and total station traversing, and so on, and as well as in modern land surveying methods such as robotic total stations, RTK GNSS surveying, and so on (Wheeler, 2019). By the UAS photogrammetric surveying, the surveying crew, time and cost required for land surveying methods have been fully changed while preserving the product accuracy similar to the field surveying (Wheeler, 2019; Hackney and Clayton, 2015). The high accuracy, of course, is not practicable even with the digital aerial surveys due to the limitation of flying heights. Technically, UAVs can fly almost everywhere. Because of their high flexibility, location of the platform and their viewing angle can be altered within a short time (Watts et al., 2012). Even with the commercially available low cost UAS, flying at low altitudes is no longer an issue for photogrammetric user community. As such, imageries with high Ground Sample Distances (GSD) close to 1cm are achievable enabling users to accomplish remarkable positional accuracy without any effort. Though the available low cost drones are being used for topographic surveying, it is still debated which platform, hardware, and software should be best used for achieving the survey grade accuracy. Having sufficient number of accurate Ground Control Points (GCPs) and on-board Real Time Kinematic (RTK) positioning facility with accurate Inertial Measurement Unit (IMU), the expected accuracy can be achieved easily (Wheeler, 2019). In fact GCPs, it should be carefully selected and well distributed and should be visible in many images. Furthermore, the GCPs can be easily identifiable from the acquired images. On the other hand, with the UAS, recursive data acquisition that many studies are required can be achieved at any time. This of course cannot be achieved by super high resolution satellite images that have fixed temporal resolution. This is another factor to popularise the UAS. However the major disadvantage of UAS with optical payload is inability to view underneath vegetation canopies. This is the main reason that many surveyors still integrate expensive field surveying methods to the topographic surveying (Pueschel et al., 2008; Remondino et al., 2009). With the advent of light weight LiDAR (Light Detection And Ranging) sensors, UAS with LiDAR payloads are being used for topographic surveying (Nagai et al., 2004; Vierling et al., 2006; Wang et al., 2009; Berni et al., 2009; Kohoutek & Eisenbeiss, 2012; Grenzdoffer et al., 2012). This certainly helps to avoid drawbacks given by the optical payload. However, UAV LiDAR is still not popular among the community due to its high initial cost. As such, a remedy that allows to acquire the topography beneath the canopy with the usual UAS is required which is still not fully investigated. This paper addresses a way that one could follow to achieve the goal.

STUDY AREA AND MATERIALS

Location: Ky Anh Township and Ky Anh District, Ha Tinh Province, Viet Nam (Figure 1).

Figure 1: Topographic survey area

Project size: Total area: 1080 hectares.

Reference system: Building benchmarks according to the national coordinate system VN2000, the axis meridian in Ha Tinh is 105030‘ with distance distortion coefficient k=0.9999, projection zone 30. National elevation reference system takes the mean sea level at Hon Dau, Hai Phong, VietNam. The coordinates and elevation at the project are as follows.

Table 1: Coordinate landmark information

ID	***Coordinate***		
	x(m)	**y(m)**	**H(m)**
269427	1995323.119	588678.664	13.417

Equipment: 02 Hi Target V30 GNSS receiver with RTK technology and 01 DJI Matrice M300 with LiDAR were used.

Figure 2: Receiver GPS Hi Target

Figure 3: DJI Matrice M300 drone and Zenmuse L1 sensor

Data for checking accuracy and improving accuracy includes 28 points, including 13 CP points and 15 GCP points.

METHODOLOGY

As mentioned in part 1, GCPs are measured using the GNSS-RTK method. Known points are used as base stations for measurements using GNSS-RTK technology. The x,y,H coordinates are according to the information in table 1. Although the GCP locations do not follow the exact grid pattern due to canopy cover, an extended location will be selected. After establishing the GCPs, prior to image acquisition, the spots that do not appear sharp features were painted by cross marks or located by pre-designed cross boards in order to gain an easy recognition with the image data. Further to that, we make sure to maintain sufficiently wide cross marks, larger than the GSD, larger than the GSD (4cm), to accurately assign GCP locations during the processing step of the data collected by the UAV. Data for checking accuracy and improving accuracy includes 28 points, including 13 CP points and 15 GCP points. Further to the checkpoints, surveyed features including building corners, culvert or cannel edges or corners could be used as the checkpoints.

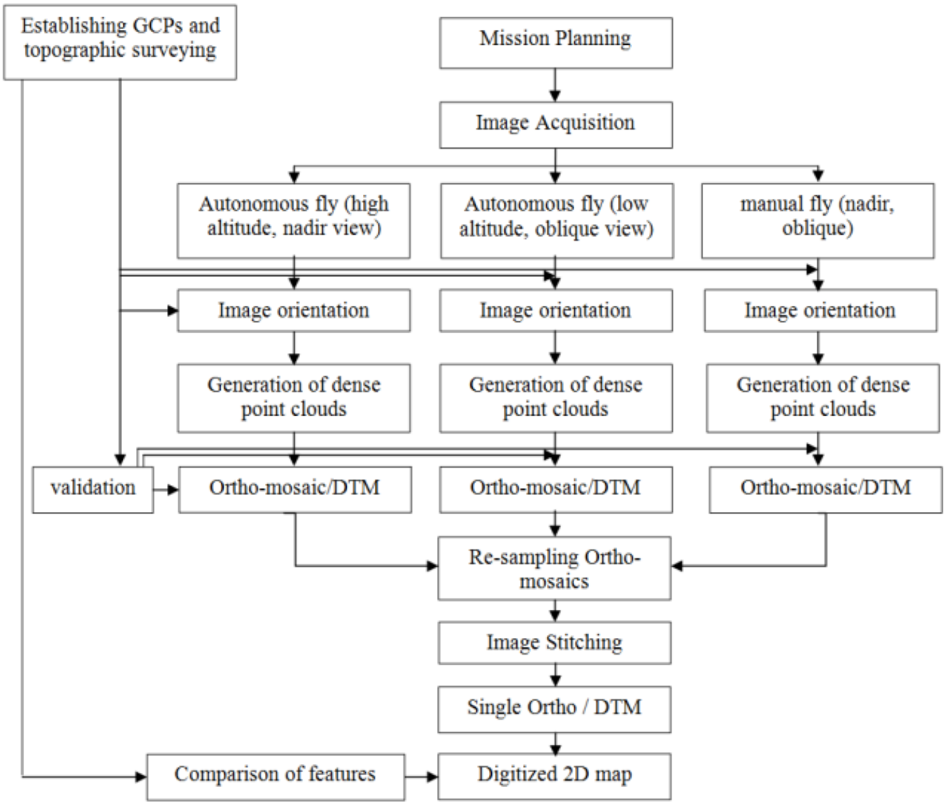

Figure 4: Schematic diagram of workflow

Establishing a System of Benchmarks to Control Flight

Based on the scope, shape, topographical characteristics of the survey area and the UAV LiDAR equipment used, determine the location to establish a control benchmark system to ensure convenient flight organization. From the coordinates and altitudes using DGPS technology to establish a system of benchmarks to control flight capture. The control benchmark system is evenly distributed near the flight area to capture and control each flight area to ensure continuous and stable signal reception. All established benchmarks have good ventilation range to ensure the reception of satellite signals. The benchmarks are placed in a place with stable soil and rock for long-term use, and are located far away from the source of radio waves to avoid signal interference.

Establishing light using DGPS technology:

To measure DGPS, use two dedicated GNSS receivers (GNSS Hi Target), one at a fixed location - called a Base station. The base station coincides with the coordinates that have been handed over by the general contractor at the project, and a mobile device to the points to be measured, called Rover Station.

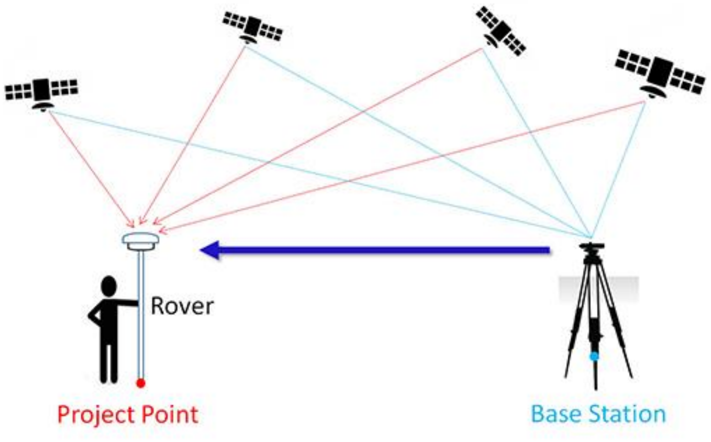

Figure 5: DGPS measurement technique

Design of Flight Zone

From the established control point system and topographical conditions, the scope of the project designed 29 flight subdivisions for the project.

Figure 6: Pictures of the arrangement of control points and flight zones

Flight Design

The design of the flight route is carried out according to the principle of covering the flight area, demonstrating the highest accuracy.

On the basis of subdivision boundaries, ground resolution of the image, vertical and horizontal coverage of the image, flight direction, camera's photographic parameters, and specifications of the UAV, conduct identification determine flight altitude and specific flight routes for each flight subdivision.

The flight range of each subdivision is designed to overlap outside the boundary of the flight zone at least equal to the width of a route.

Based on the range, shape, topographical and meteorological conditions of each flight subdivision to select the flight direction so that the flight time is the shortest.

Figure 7: Route design

Establishment of Control Point (GCP) and Checkpoint (CP)

GCP (Ground Control Point) ground control points are the points used to correct the aerial image to the correct coordinates of the project area. Check Point CP (Check Point) is used independently to evaluate the results of the captured flight in terms of coordinates and altitude. The points GCP and CP were established according to the VN-2000 coordinate system, the projection zone of 3 degrees longitude axis of Ha Tinh province is 105°30' with deformation coefficient k = 0.9999. Image control points and checkpoints are selected at clear features, objects with high contrast compared to the surrounding surface such as intersection points of linear objects or independent feature points, painted lines on the road surface. Image control points, checkpoints must be marked with paint in the field, ensuring survival during the flight time. Coordinates and heights of image control points, checkpoints are determined by or using DGPS (GPS RTK) technology as mentioned above.

Figure 8: Measuring control points and checkpoints using DGPS (GPS RTK)

Flight Capture and Image Data Acquisition

Photographic data was collected through UAV. The flight capture process includes:

- Selecting an area where the UAV takes off and lands is safe, avoiding areas with obstacles and high height that affect take-off and landing
- From the established flight control benchmark system and designed flight routes, using RTK (Read-time Kinematic) technology for real-time dynamic measurement. to conduct project shooting.
- Setting the Base station at the established base point for each subdivision, the Base station is responsible for receiving signals from many satellites at the same time, in many different frequency bands to ensure accuracy, and then transmitting signals and signals. Adjust to the aircraft (Rover).
- Simultaneously, the UAV aircraft during flight capture also receives continuous satellite signals like the Base station on the ground, and it also receives additional correction signals from the Base station, then compares and calculates to thereby giving the most accurate results about coordinates and elevation at each pixel.
- Base station is turned on and set parameters 5 minutes before flight and turned off after UAV landing 5 minutes at the end of flight shift.
- After connecting the UAV and the ground base station, check the satellite parameters, the solution is fixed, then proceed to the UAV take off.
- The height of the GNSS receiver antenna at the base station is measured independently 3 times with a steel ruler, reading to mm at the start of flight, mid-shift and before the end of the shift.

Figure 9: Base station image

- During the shooting flight, the operation of the UAV and equipment must be monitored. In case the weather conditions are not secure or one of the equipment related to data acquisition during flight captures unstable operation, it must stop flying and control the UAV to the starting position.

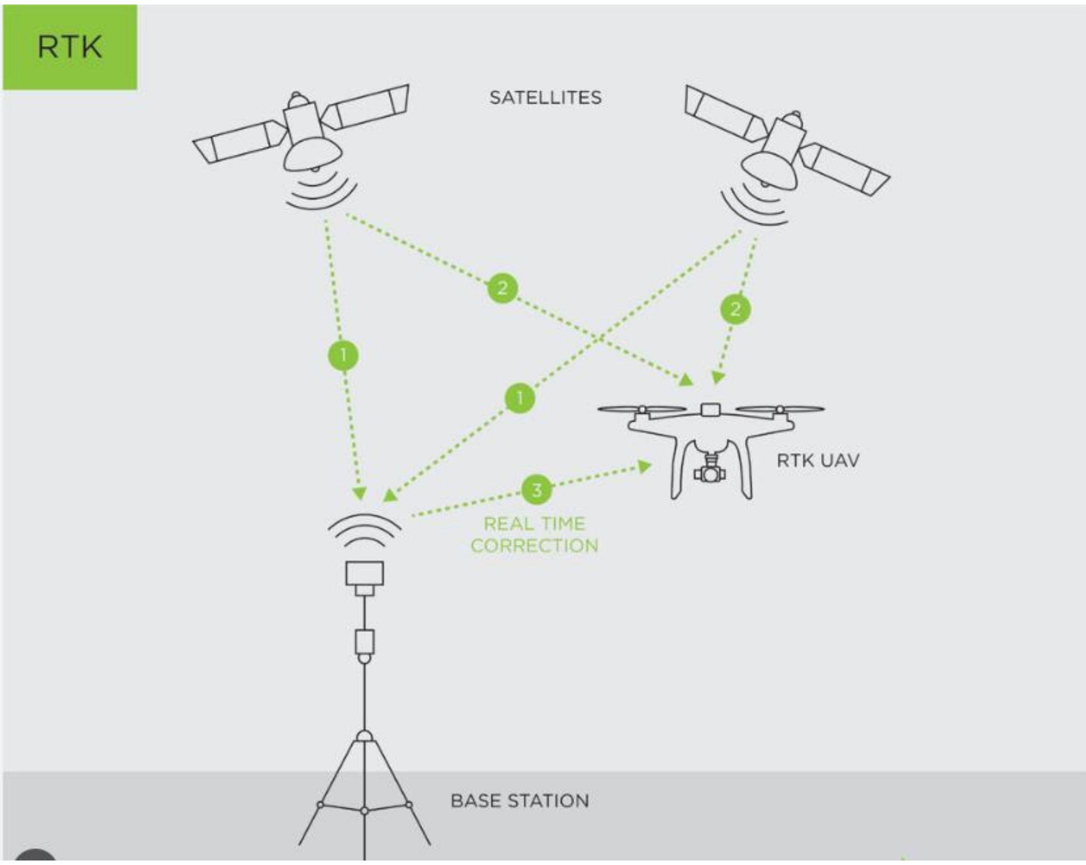

Figure 10: RTK shooting flight method

Post-flight Data Processing

Backup original image data from camera

Check the quality of data after flight capture:

- General check of shooting conditions such as aircraft speed, wind level, shooting time compared to design;
- Check the image skew to the boundary of the flight segments compared to the design, the open and missed flight areas;
- Check the vertical coverage, horizontal coverage of the photo compared to the design; vertical coverage, horizontal coverage of the photograph is not less than 5% of the design;
- Check the quality of photos taken, evaluate image quality through image clarity, contrast, lighting conditions, shade of sunlight, shadow of clouds; assess the image quality in the area where the control points and the checkpoints are located.
- In case the flight range and image quality are not satisfactory, make up flights.

RESULTS AND ANALYSIS

Images Block Adjustment

All image data from 29 partitions are processed as follows:

Using the program DJI Terra attach all image control points, which appear on the images. Linking and correcting the tile. The process of linking and correcting the tile uses the maximum number of images.

Evaluate the Quality of Images Block Adjustment

After Images Block Adjustment, must check for in-camera orientation prime error, error at image mode blind spots, checkpoint and access the following requirements:

- The error of the internal orientation factors of the camera must be stable: the coordinate error of the main point of the image should not exceed 1/2 of the pixel value, the error of the focal length should not exceed 5%;
- The square error of the plane position and the height of the external image control points after the tile correction must ensure that the plane does not exceed 0.2 mm according to the map scale, and the height does not exceed more than 1/3 of the average height of the baseline; the limit error does not exceed 2 times the mean square error;
- The difference between the coordinates and the elevation at the test points after the adjustment compared to the coordinates, the elevation measured outside is not allowed to exceed 0.3 mm according to the map scale in terms of the plane and 1/4 of the height is the baseline of the altitude.

Creating a Point Cloud

When the Images Block Adjustment result is satisfactory, proceed to create a dense point cloud from the adjusted tile result with a size not less than the resolution of the original image. Review and remove points with sudden elevation values compared to the surrounding area.

In the case of multiple Images Blocks, a point cloud edge must be performed between adjacent subdivisions. Marginal error should not exceed 0.3 mm according to the map scale in plane and 1/4 of the equidistant elevation of the basic contour of the elevation of the map to be established.

Establishment of Surface Numerical Models and Image Normals

Use point clouds to create surface numerical models for airfields. Set the DSM grid cell size at the scale of 1.0 x 1.0m.

Create image map:

- Use surface and original digital models to create tile-based image plots. The image map must ensure uniform tone, average contrast.
- The boundary between adjacent images block according to the feature of the same name on the image map must ensure that the error in the plane does not exceed 0.5 mm according to the scale of the map to be established.

Building a Digital Model of Elevation (DEM)

Use point cloud data to proceed with the establishment of a digital elevation model. Identify the surface of the ground, proceed to filter out the objects located above the ground from the point cloud data. Perform interpolation of ground elevation in areas that have been filtered from surrounding elevation points; create a preliminary DEM for the entire airfield. Using image map, DSM, water surface digitized data, standardization and preliminary DEM correction; generate DEM for the entire airfield. The digital elevation model, after being normalized, created, edited, cut in a rectangular shape covering 1cm outside the project boundary. DEM products after being created must be checked and evaluated, compatibility between the DEM and the image map and the classification and point filtering data, and the 100% inspection level of the flight area;

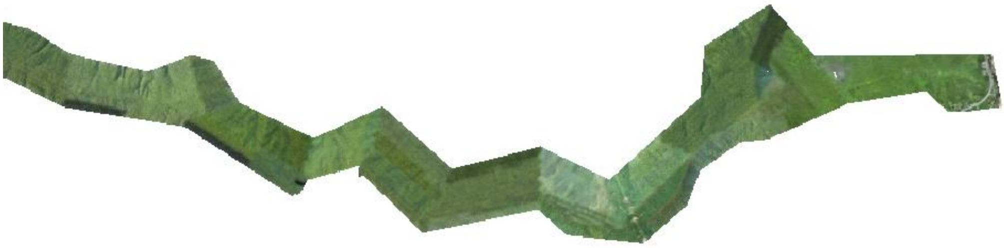

Figure 4: Flight image data

Figure 5: RGB photo

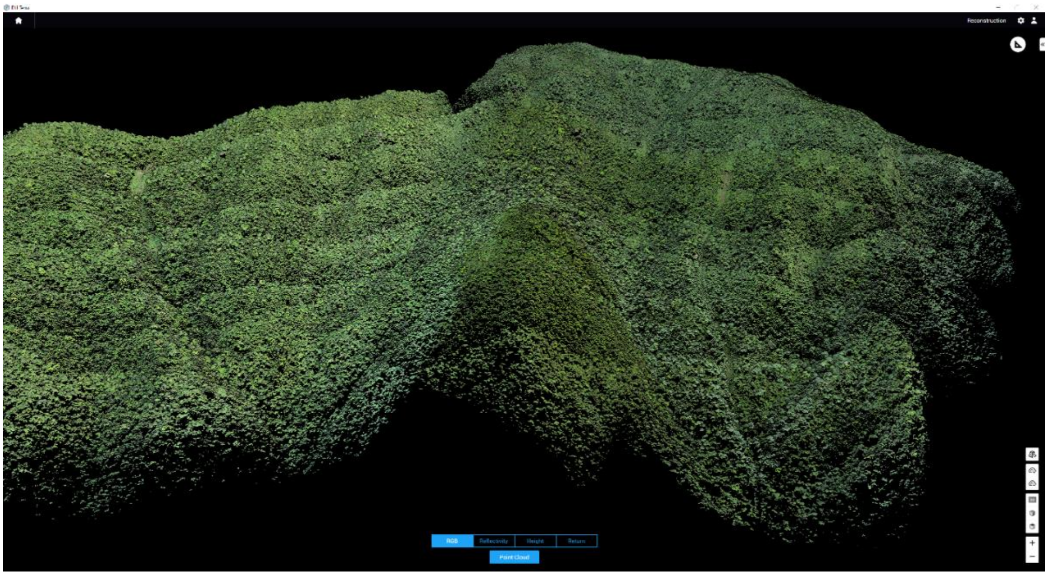

Figure 6: Point Cloud data after processing with DJI Terra software

Evaluation of Location Accuracy

From 3D PoinCloud data, data of checkpoints is extracted using Global Mapber software and compared with coordinates measured by DGPS technology in the field.

Figure 7: Coordinates of the checkpoints on the image map

The square error on the plane of the geographical features represented on the topographic map is calculated according to the formula 0.5mm x M (M is the denominator of the scale of the map to be established). Regulations in TCXDVN309: 2004 "Geodetic Work in Construction - General Requirements".

Plane mean square error: 0.5mm x 2000 = 1000mm (100cm).

Average score position error:

$$m_{\Delta x} = \sqrt{\frac{\Delta x_1{}^2 + \Delta x_2{}^2 + \ldots + \Delta x_n{}^2}{n}} = \sqrt{\frac{0.384}{10}} = 0.038(m)$$

$$m_{\Delta y} = \sqrt{\frac{\Delta y_1{}^2 + \Delta y_2{}^2 + \ldots + \Delta y_n{}^2}{n}} = \sqrt{\frac{0.654}{10}} = 0.065(m)$$

$$m = \sqrt{m_{\Delta x}^2 + m_{\Delta y}^2} = 0.104(m)$$

Thus: m = 0.104 (m) = 10.4 (cm) < 100 (cm) the accuracy of the image map is eligible to create a 1:2000 scale topographic map.

Evaluation of Altitude Accuracy

The mean square error of the heights of the features represented on the map does not exceed 1/2 of the basic elevation. According to Industry Standard 96TCN43: 1990.

Therefore, the mean height error is limited to 0.5 (m) with a uniform height of the baseline 1(m).

$$m = \sqrt{\frac{\Delta h_1^2 + \Delta h_2^2 + \ldots + \Delta h_n^2}{n}} = \sqrt{\frac{0.127}{10}} = 0.013(m)$$

Thus: m = 0.013 (m) < 0.5 (m) the accuracy of altitude is guaranteed to establish a topographic map of 1:2000 scale.

Editing Topographic Map of 1/2000 Scale

From point cloud data, surface digital model, image map, edit topographic maps using Autocad Civill 2019 software.

From the image map, digitize the features in the survey area:

- Number of streams in the area: 45 streams;
- Number of houses in the area: 24 houses;
- Number of electric poles in the area: 5 poles.

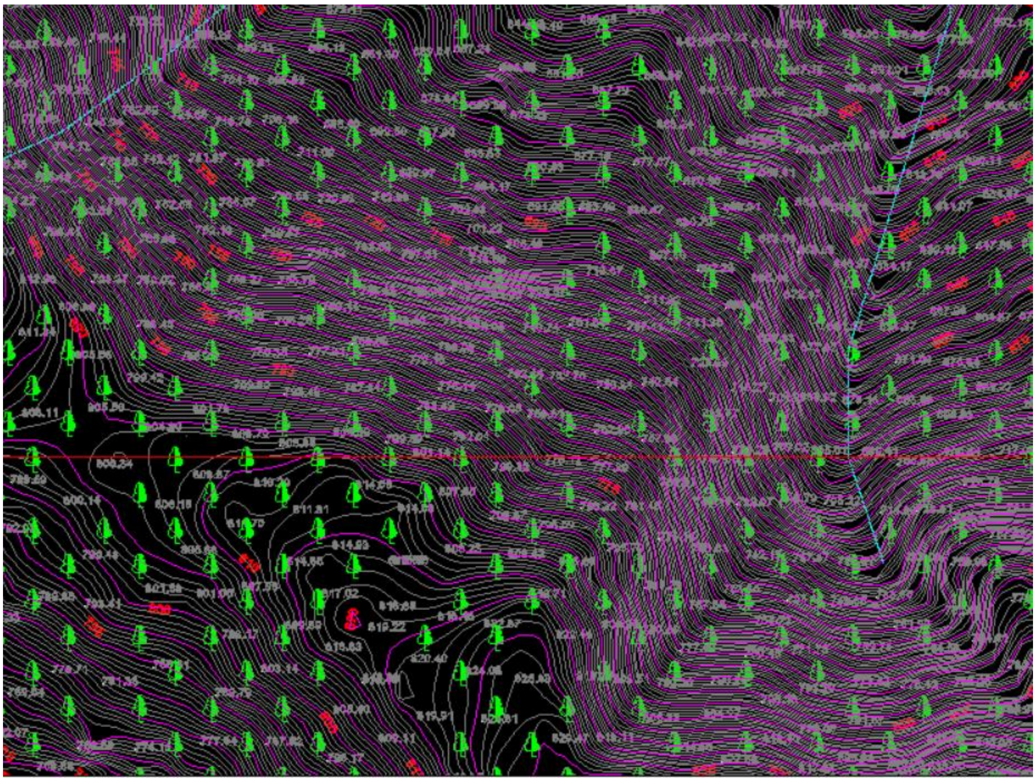

Figure 8: Topographic map 1/2000 after editing

Figure 9: Topographic map on orthogonal image background

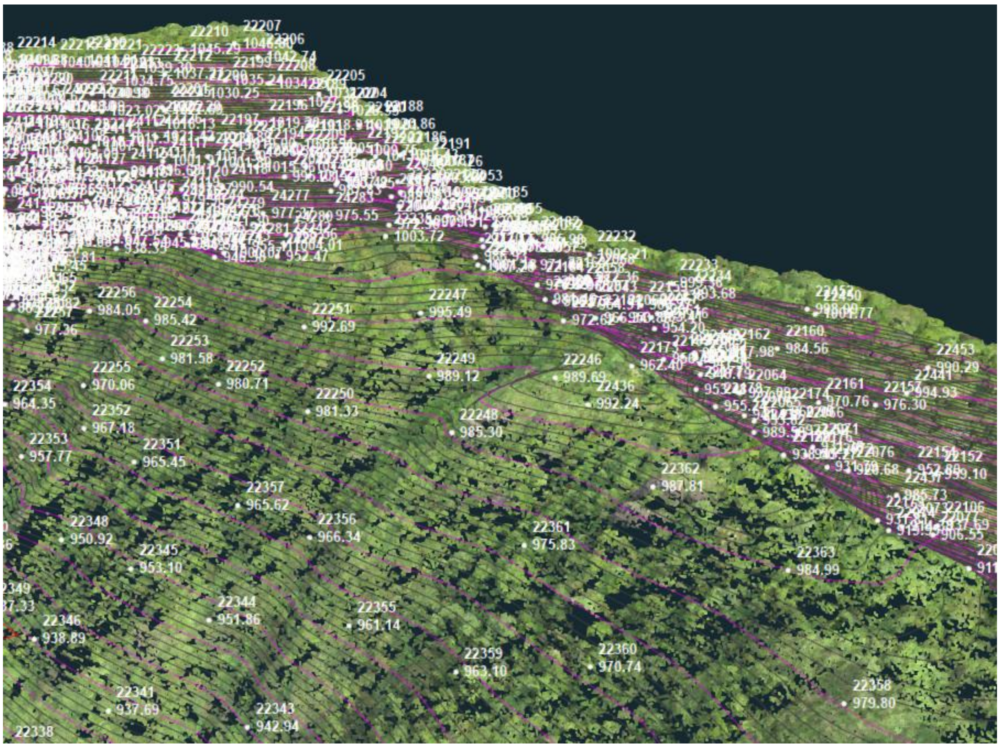

Figure 10: Topographic map and point cloud

CONCLUSIONS

Thus, the article has presented the application of unmanned aircraft (UAV or Drone) in terrain surveying compared to other traditional measurement methods. UAVs have the advantage of achieving centimeter-level spatial accuracy, but the disadvantage is that they cannot see under vegetation or terrain with large elevation differences, which hinders the ability to apply UAVs for terrain surveying. By applying LiDAR sensor this problem has been solved.

In the survey area (high coverage density and 1km height difference between the foot and the top of the mountain), the UAV with LiDAR sensor is used, proceed to determine the location and establish a landmark system to control flight capture to ensure convenience for flight organization. From the assigned coordinates and altitude, use GNSS RTK technology to establish ground control points (GCPs). From these GCPs and terrain conditions, 29 aerial photography subdivisions are designed for the project. The flight route design is carried out on the principle of covering the entire flight area, ensuring the highest accuracy. Based on the subdivision boundaries, ground resolution of the image, vertical coverage and horizontal coverage of the image, flight direction, camera photography parameters, and technical specifications of the UAV device, proceed. Determine flight altitudes and specific flight routes for each flight subzone. GCP Ground Control Point and CP Check Point (Check Point) are used. Check the vertical coverage and horizontal coverage of the photo compared to the design; then proceed to link and correct the image blocks. When the image block correction results meet the requirements, proceed to create a dense point cloud from the image volume results that have been adjusted to a size not smaller than the resolution of the original image. Use point cloud data to create a DEM model. The RMS error in horiazontal is 10.4 (cm) and vertical is 1.3 (cm) confirming enough reliability to create a 1:2000 scale topographic map.

Considering all, it can be concluded that, in near future, field surveying techniques would be replaced by the drone surveying and vegetation canopy would not be an obstacle any more.

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