UNMANNED AERIAL VEHICLE APPLICATIONS OF 3D MODELLING, VISUALIZATION AND PARAMETER CALCULATIONS

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ABSTRACT:

Photogrammetric surveying with the use of Unmanned Aerial Vehicles (UAV) have gained vast popularity in short span. UAV have the potential to provide imagery at an extraordinary spatial and temporal resolution when coupled with remote sensing. Currently, UAV platforms are fastest and easiest source of data for mapping and 3D modelling. It is to be considered as a low-cost substitute to the traditional airborne photogrammetry. In the present study, UAV applications are explored in terms of 3D modelling, visualization and parameter calculations. National Institute of Technology Raipur, Raipur is chosen as study area and high resolution images are acquired from the UAV with 85% overlap. 3D model is processed through the point cloud generated for the UAV images. The results are compared with traditional methods for validation. The average accuracy obtained for elevation points and area is 97.99% and 97.75%. The study proves that UAV based surveying is an economical alternative in terms of money, time and resources, when compared to the classical aerial photogrammetry methods.

1. INTRODUCTION

An unmanned aerial vehicle (UAV) is a category of aircraft that drives without a human pilot on-board. UAVs can also be abbreviated as Uninhabited Air Vehicles (Sanna and Pralio, 2005). Previously, UAV systems and platforms were mainly used for military applications. At present UAV have become a common platform for data acquisition in the field of geomatics. UAV photogrammetry is definitely a low-cost substitute to the traditional airborne photogrammetry for detailed 3D modelling of ground information (Colomina et al., 2008 and Eisenbeiss 2009). Photogrammetric products primarily DSM and orthoimages from UAV-based aerial images are offered by the private sectors. When compared to the traditional aircrafts, these flying platforms comes in variable dimensions having less weight and high ground resolution.

1.1 UAV Platforms

Mainly, UAVs are classified as multi rotor, fixed wing or helicopter types. Fig. 1 shows the different types of UAV platforms. A basic flight of any UAV totally depends on the flight control system. These system mainly includes an inertial measurement unit (IMU) which is linked to a processor through which power distribution is managed in the motors thereby stabilizing the flight. In addition to it, magnetometer, barometer as well as a Global Positioning System (GPS) is also attached to the control system.
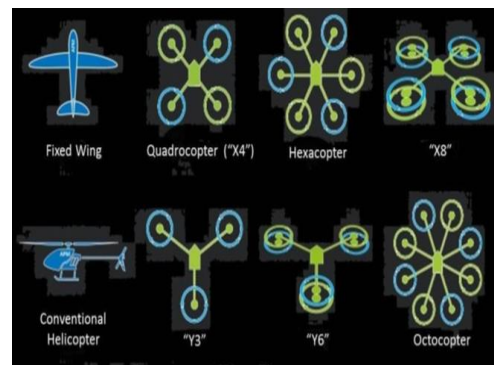

Figure.1. General flow chart for 3D mapping using UAV
(Source: http://planner.adrupilot.com)

1.2 Basic Flight Planning for UAV

Flight planning of any unmanned aerial vehicle primarily depends on the factors such as the focal length, camera resolution, flying height and ground resolution required. For obtaining high resolution images, the Ground Sampling Distance (GSD) should be least. GSD is the measurement of a square on the ground covered by single pixel (p) in the image and is a function of the camera resolution, the focal length (f) and the flying height (H) which is the distance between camera and ground. GSD can be calculated as shown in eqn. (1)

$$\frac{GSD}{p} = \frac{H}{f} \tag{1}$$

In aerial mapping done for obtaining 3D models, it is necessary to capture the images with sufficient stereo overlap (60-80%). Depending on the mission specifications, environmental conditions and type of UAV platform, flight can be manual, assisted or autonomous.

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1.3 Data Acquisition and Processing

The basic requirement for a UAV based aerial survey is flight planning and Ground Control Points (GCP) measurement for geo-referencing purposes. The acquired images are mosaicked for further processing (Neitzel and Klonowski, 2011). Digital Surface Model (DSM) is generated by initially accomplishment of camera calibration and image triangulation. The subsequent outcomes are finally used for the production of ortho-images, 3D modelling applications. Fig. 2 shows the general flow chart for 3D mapping using UAV.

Figure.2. General flow chart for 3D mapping using UAV
(Khaula and Abdelgadir, 2017)

1.4 Camera Calibration and Image Orientation

Camera calibration and image orientation are prerequisites for construction of a 3D image. It requires the generation of tie points followed by a bundle adjustment which is a non-linear optimization technique to minimize a suitable cost work (Brown, 1976; Triggs et al., 2000; Gruen and Beyer, 2001). The all above parameters can be obtained using the commercial softwares available. These software needs the availability of GPS data for extraction of tie points and for direct goerereferencing of the acquired images. In applications where rapid data acquisition is required and low quality images are acceptable e.g. for disaster prone area, the accuracy of GPS observation is sufficient (Pfeifer et al., 2009 and Zhou, 2009). The basic objective is to obtain a good quality of images in order to calculate the coordinates of the objects and 3D shape of image.

1.5 Surface reconstruction and Orthoimage generation

After the orientation of the images, the 3D modelling is done in step by step process which includes surface measurement, feature extraction and orthophoto generation. As the camera orientation parameters are known, any part of the image can be recreated with the help of automated dense image matching technique. The output is a thin or a dense point cloud, which describes the feature of the shape which has been surveyed. Dense point clouds are preferred for surface reconstruction while sparse clouds are preferred when modelling buildings (manmade structures). In order to attain accurate ortho-rectification and complete exclusion of distortions, dense point cloud is necessary to generate orthoimages (Neitzel and Klonowski, 2011).

2. STUDY AREA AND METHODOLOGY

National Institute of Technology Raipur, Raipur is chosen as study area for this study (Fig.3). The campus spreads in an area of approximately 100 acres. The study has been carried out on the main building of the campus along the stretch of 298.16 m.
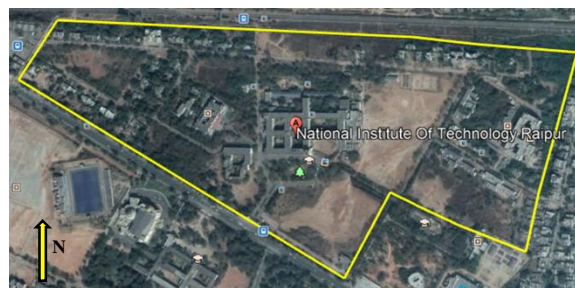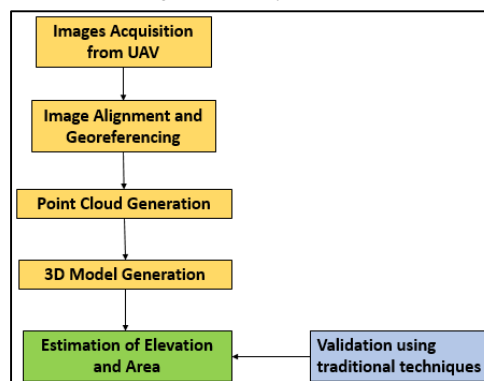

Figure.3. Study area

Figure. 4. Methodology

The main objective of this study is to explore UAV applications in terms of 3D modelling, visualization and parameter calculations. Main emphasis is given on the measurement of the height and area calculations. Methodology adopted for the study is shown as Fig.4. UAV model, DJI Inspire has been used for acquiring images of the study area. 12 MP Zenmuse X3 gimbal camera is used for the purpose. Table 1 shows the UAV parameters. The pathway for flying the UAV mainly depends on the flying height, percentage of overlap (side and forward) of images acquired, tilt angle of camera. Fig. 5 shows the flight pathway of the study area.

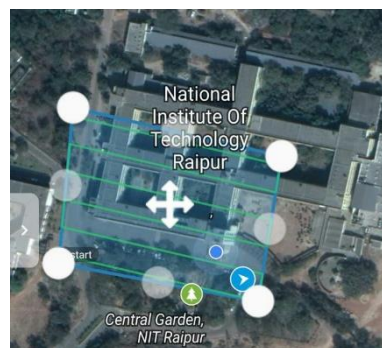| Name	DJI INSPIRE 1
Weight	3.06 kg
GPS Accuracy	0.5 m (vertical), 2.5 m (Horizontal)
Maximum tilt angle	35º
Maximum flight time	18 minutes
Camera resolution	12 MP
Focal length	2.8
Field of View (FOV)	94º
Shutter speed	1/8000 seconds

Table 1. UAV Parameters

Figure.5. Flight pathway

UAV was flown at an altitude of 222 feet from ground level. To attain the stereo pairs, side and forward overlap has been kept at 85%. A total of 181 images were obtained for the 4 acres of study area. The images were processes in Photoscan software which works on Structure from Motion (SFM) algorithm which is a low-cost photogrammetric technique for high-resolution topographic reconstructions. It works on the principle of the stereoscopic photogrammetry. This method is most suitable to sets of images having degree of overlap that takes into account the 3D structure of the scene (Szeliski, 2010 and Westoby et.al. 2012). The elevation and area from the model are validated with the values obtained from standard surveying instrument like theodolite and Electronic Distance Measurement (EDM).

3. RESULTS AND DISCUSSION

As the number of images is higher, it was desirable to divide the whole project into chunk (sub-parts). It allows the improvement in image processing. Image alignment was done automatically by the software. The Ground Sample Distance (GSD) was found to be 3.75 cm per pixel. High quality point cloud of 32480724 points has been processed from all 181 images. Fig.6 shows the point cloud of the UAV acquired images.
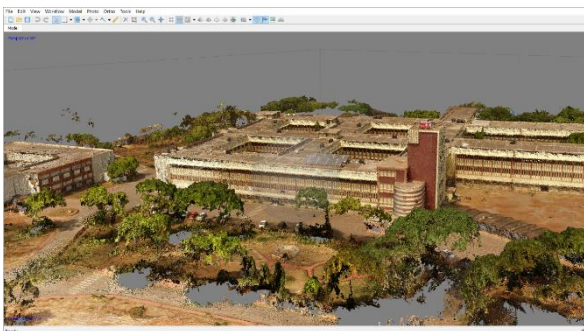

Fig.6. Point cloud of NIT Raipur

The elevations of six different points of NIT Raipur main building were calculated. The average accuracy obtained for elevation points and area is 97.99% and 97.75%. Fig.7 and Fig.8 shows the 3D model of the building with the points of elevation and area are calculated respectively.

Figure.7. 3D model with sample points for elevation

Table 2 depicts the comparison of elevation values obtained from standard techniques. Table 3 represents the area calculated using the model and standard measurement.
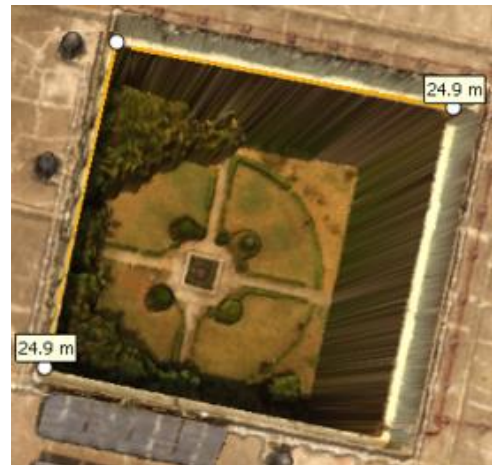

Figure.8. Dimension measurement for area

S. No	Point	Elevation Obtained from model (m)	Elevation obtained from Theodolite (m)	Elevation obtained from EDM (m)	Model Vs EDM Accuracy	Model Vs Theodolite Accuracy
1	Point 1	14.68	14.24	14.30	97.41 %	97 %
2	Point 2	27.43	27.36	26.90	99.74 %	97.58 %
3	Point 3	11.98	11.77	11.75	98.08 %	98.24 %
4	Point 4	17.85	17.60	17.48	97.92 %	98.59 %
5	Point 5	14.68	14.24	14.30	97.41 %	97 %
6	Point 6	14.68	14.24	14.30	97.41 %	97 %

Table 2. Comparison of elevation values obtained from different techniques

Area Measurement	Length (m)	Width (m)	Area (m^2)
From measuring tape	25.23	25.14	634.28
From model	24.9	24.9	620.01
Accuracy	98.69 %	99.04 %	97.75 %

Table 3. Comparison of area obtained from different techniques

4. CONCLUSION

In this study, UAV is deployed for accruing high resolution images for generation of 3D models. The results are compared with traditional methods for validation. The average accuracy obtained for elevation for elevation points and area is 97.99% and 97.75%. The study proves that UAV based surveying is an   economical alternative in terms of money, time and resources, when compared to the classical aerial photogrammetry methods.

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