GENERATING MORE ACCURATE DIGITAL ELEVATION MODELS INCORPORATING OFF THE SHELF GIS SOFTWARE BY USING DRONE IMAGERY

Thiran De Silva[1], Rasika Kahandagamage[2], Indunil Sanjeewa[3], Chamila Kulasinghe[4], Randika Ariyarathne[5]
Centre for Research and Development (CRD), Ministry of Defence(MOD)
[1]dg@crd.lk , [2]rasika@crd.lk, [3]rcsanjeewa@gmail.com ,[4]chamila@crd.lk , [5]randika@crd.lk

ABSTRACT: The use of drone imagery in disaster response has become increasingly popular in recent years. As high resolution Digital Elevation Model (DEM) is highly useful in disaster risk reduction. However it is observed that the execution of this mechanism found to be very minimal in the industry. Drone imagery fundamentally modeled using the photogrammetric principles can be used as an input for the flood simulation models. Hence it presents as a valuable tools to survey and identify disaster-prone areas for a better understanding of flood risk.

Robust DEMs with accurate greater spatial resolutions are useful for flood risk mapping. Precise and detailed DEMs improve the predictions overland flow in urban areas minimizing the associate uncertainties in the modelling process. This study was based to examine the use of tools indicated to generate DEM from Digital Surface Model (DSM) obtained from the drone images. The operational approach to derive a DEM from the DSM calculated from the aerial images was based on processing raster data by filtering algorithms. The fully autonomous quad copter developed by the Centre for Research and Development (CRD) for aerial photography, navigation and video streaming process was used to acquire the data needed for experiments. This study conducted in Kelaniya area, which found to be most identical area due to the flood risk mapping. All the images have been acquired by Cannon SX260 camera mounted on a 3-axis high performance gimbal. Tailor made software was used for mission planning and few main off the shelf geo-processing software were used for image processing. The identified algorithms and limitations in processing are valid for most other commercial photogrammetric software available on the market. The key element in a very high resolution images from drone obtained with large variation in its geometry is the accurate geo-referencing. The data processing of drone images have been carried out using the algorithms ranging from classical photogrammetry to modern Computer Vision (CV) algorithms. Furthermore manual GIS digitizing had been carried out for generate DEM.

The accuracy assessment of DEM result from every process is done using the highly accurate ground control points as the reference data. Ultimately provided centimeter level accuracy in the output results. It was required extensive field work to extract DEM for certain areas like forest and vegetation. One main advantage of the findings is the fitness of the Drone images to the processing of freely available modeling software's.

Key Words: Digital Elevation Model, Digital Surface Model, Drone

1. INTRODUCTION

In recent years unmanned aerial vehicles (UAVs) have entered the field of aerial imaging. Low operation and hardware costs with low altitude UAVs compared to the aerial imaging with high quality mapping sensors from manned airborne platforms have made UAVs an attracting choice for aerial photogrammetry in many application areas.

Among natural disasters, flooding presents a substantial threat, with an average of over 100 events occurring every year (Guha-Sapir, 2015). According to the CRED/OFDA International Disaster Database, nearly 7,000 human beings are killed and around 100 million affected annually by flood events, with economic costs estimated at 14 billion US dollars (Guho, 2015). Exact damage to infrastructure, water portability, public services, agriculture and the economy are difficult to quantify, not to mention the negative effect flooding has on society due to loss of human live and hardship inflicted on survivors.

Flood prediction is currently based on a variety of complex behavioral prediction models, which are used by hydrologists and emergency management administration to estimate flood scale, timing and risk for specific areas. Specialized, tailored models are needed due to variability in topography and interaction of contributing flood factors. In addition to a calibrated model, quality hydrological, meteorological and geological data is essential. Meteorology stations collect data from ground equipment to satellite, adding it to recorded information and creating weather forecasts: the large amount of climate information provided by satellite and remote sensing as well as ground observations is vital to support long and short-term flood prediction models.

A basic requirement for these prediction models is a Digital Elevation Model (DEM): a 3D topographic map that shows the elevation data, contour lines and slope of an area in digital format. These are traditionally obtained via airborne surveys, satellite imagery and LiDAR sensing. Accurate DEMs facilitate reliable flood inundation modeling, as flood model predictions are affected by both DEM scale and resolution (Sulebak, 2000).

The topography of many floodplains in the developing world has been surveyed with high resolution sensors, providing high quality DEMs of a majority of populated areas. Access to this data is limited, however, due to the costs associated in obtaining and analyzing it, as well as the reluctance of the authorities to release it for security reasons (Sampson, 2016). For remote areas and spaces in many developing countries, quality terrain data is often simply not available. Publicly accessible or free data sets, notably the global digital elevation models provided by the Shuttle Radar Topography Mission (SRTM) and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER), have a raw data resolution of between 30m and 90m, which has limitations due to the resolution and present errors (Nikolakopoulos, 2006).

In Sri Lanka digital elevation maps provided by survey department with the accuracy of 5m interval. However these maps are not sufficient for flood hazard mapping and flood risk mapping. It is important communities to provide accurate flood hazard and risk data to guide them to mitigation actions. But with the invention of Digital aerial photography using UAVs accuracy has come down to 25cm to 30cm. Moreover CRD has already developed 3D modeling tools to identify flooding areas. Thus it is a need a develop accuracy Digital Elevation Model (DEM) for used in flood hazard mapping and CRD is going to create DEM using drawn images which has 50cm accuracy. The survey was carried out using quad copter developed by CRD which is a cost effective method.

2. GPS SURVEY

GPS survey is aiming on providing the representative GCP network with a good spatial distribution. In principal, GCP measurements will cover two main purposes of the field survey. The first one is to check the quality of the acquired photograph including photo orientation and the latter one is to establish accurate GCPs network for orthorectification purpose. During the UAV campaign, 8 new GCPs have been measured using geodetic GPS double frequency L1/L2 with good distribution covering the AOI. Implementing rapid static differential positioning, every GCP must be measured not less than 30 minutes in order to get sub centimeter accuracy. These measurements also have provided synchronization of positional reference between static and real time modes which are in the range below 1 m accuracy. Hence it will ensure the consistent positioning reference both for UAV data processing and accuracy assessment. These GCPs were signalized by black circular targets on a white background. GPS data is used to remove the scale ambiguity of the initial model. This information allows recovering the 3D position of points matched using feature detectors.

3. HARDWARE USED FOR DATA ACQUISITION

Centre for Research and development developed a fully autonomous mobile robot for navigation purpose. It is embedded with following capabilities, Video streaming, geo tag image capturing, it can travel speed of 20ms-1. With the existing batteries it has more than a 15 minutes flight time. During that period it can fly around 2.5Km. Quad copter is connected with GPS, Electronic compos and air pressure sensor for its navigation use. Camera is fitted with gyro stable gimbal to obtain undisturbed photos. The camera has a 12 Megapixel sensor and a fixed length camera lens with a focal distance of 17 mm. It can operate manually and autonomously. Quad copter frame and other hardware are made out of light weight carbon fiber and it has the capability of carrying around 1Kg pay load.

Figure 1- CRD Quad Copter (Fully autonomous mobile robot)

4. DATA ACQUISITION

Mainly four persons were required for data acquisition for each of the periodical measurements, a GNSS operator, a quad copter pilot and supporting team. GNSS operator selected the positions for 08 ground control points. GCPs were signalized with black circular targets on white background, and determined their positions in Kadawala coordinate system using a GNSS rover RTK system.

Meanwhile, the quad copter pilot prepared the drone for take- off. The pilot manually lifted the drone into the air. Once on the safe altitude, it switched the UAV from manual to autonomous mode, and the drone began its pre-programmed 15 minute path over area.100m continuous height used to take images throughout the mission. Altogether, the drone took 220 images from the altitude of 100 meters. The images had an overlap of 66% both in the vertical and horizontal direction.

5. SOFTWARE AND DATA PROCESSING

CRD Polios is the navigation software which CRD made drones used to fly. CRD Ploigos is developed by customize an open source navigation software's to suit to the CRD requirement. Software is embedded with the almost all the navigation capabilities. Figure 2 indicate the logo of CRD navigation software.

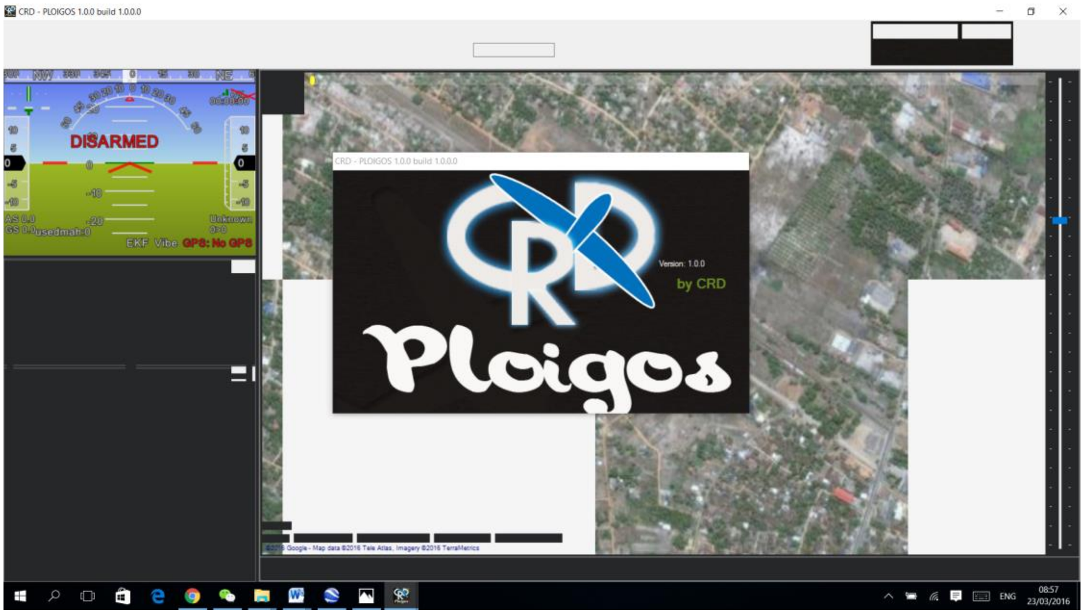

Figure 2- CRD Ploigos CRD navigation software for Quad Copter.

CRD has identified Pix 4D, Acute 3D and Autodesk softwares to develop DSM to suit for mapping exercises.
Pix 4D 3D modeling software was selected for the study through a trial and error process. Selected some photos for the study omitting photos which are not clear and errorless. Focal length and the flight height were considered for the study as mainly required parameters. Calibration of data was done incorporating the GCPs to make it more accurate.

6. METHODOLOGY

This paper will mainly concentrate on generating of Digital Elevation Model (DEM) using aerial photographs. In order to verify and identify the geometric accuracy of DEM, it is necessary to use valid and independent geospatial data source and techniques with certain quality.

Basically there are 3 aspects to be evaluated for this drone data processing namely Sensor, Image Processing Software and GCP schemes (Figure 3). Combination among them will identify the best possible geometric accuracy for large scale topographical mapping purpose.

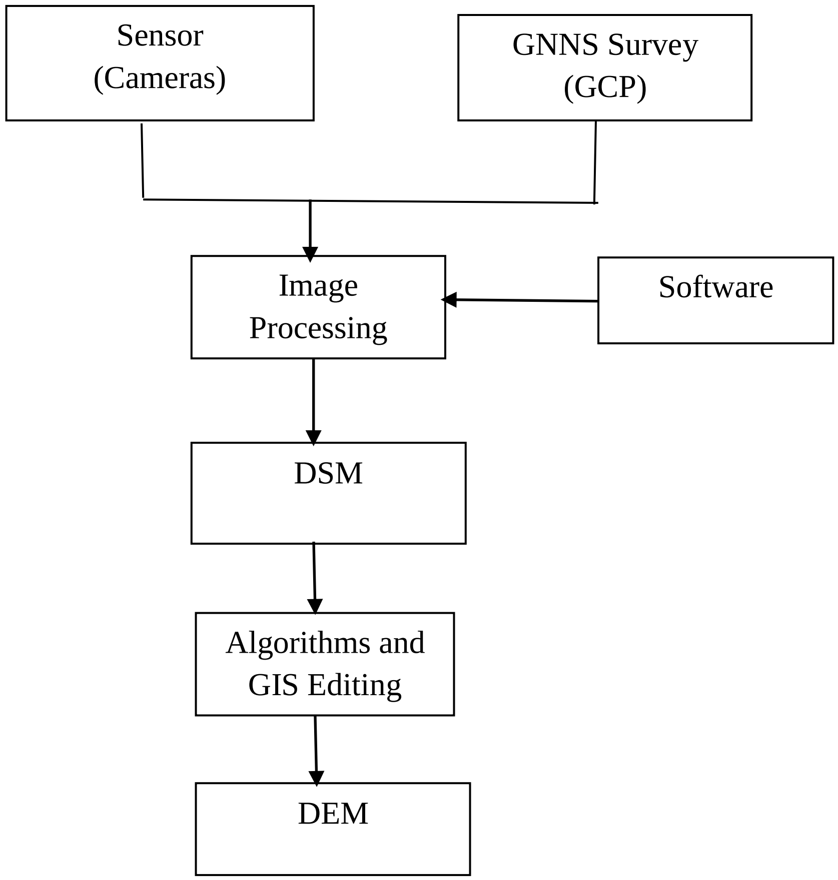

Figure 3 – Methodology Diagram

7. DEM GENERATION

A DSM extracted from stereo images represents the earth's surface and includes all objects on it, for examples, buildings, vegetation, and other objects (Figure). Many applications require a DEM which represents the bare ground surface without any objects. To convert a DSM to a DEM through manual editing is a very time consuming process. There are some automatic DSM to DTM conversion programs can be found. These algorithms are capable of generating high quality high resolution DSM and DTMs from stereo pairs. CRD research team have done an extensive research work and develop a systematic approach to generate the DEM from DSM.

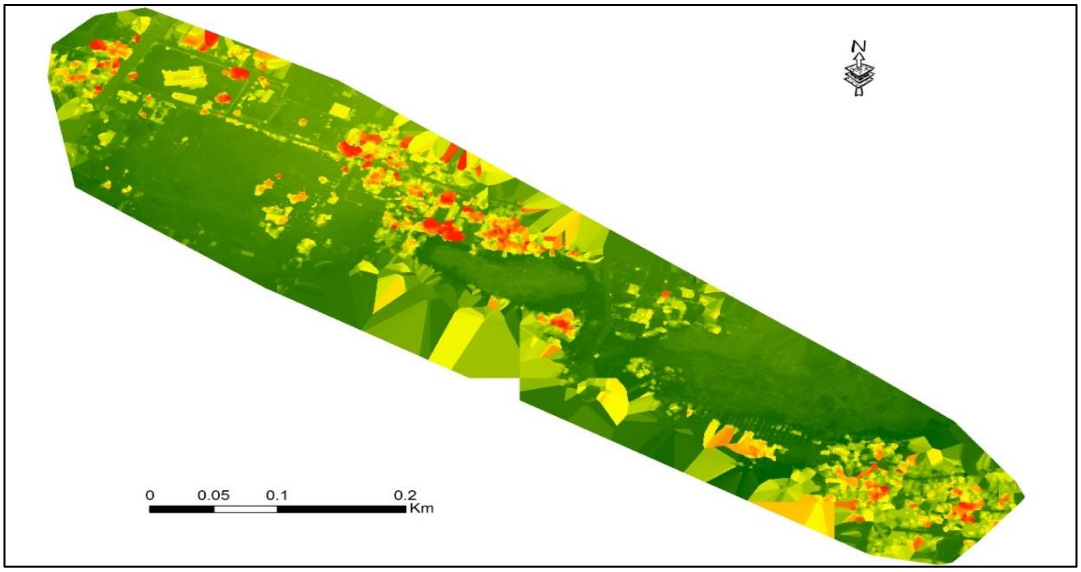

Figure 4-DSM created using Aerial imageries

Initially the DSM is segmented into regions of limited slope. A gradient filter is applied to the DSM raster to highlight height transitions. A connected component algorithm labels the different regions separated by those transitions.

Furthermore, regions whose perimeter is on the average higher than their surrounding are discarded. Generally, a dimension is used that is large enough to remove most buildings and surface features. However, some manual editing is usually required to refine the final product. The constraints on size, slope and neighboring height differences are easy to derive from the sole DSM and geometrical rules are intuitive and implemented with understandable parameters.

This DTM from DSM approach is particularly well suited to CRD requirement. However small objects like little streets, terraces and small gardens have little chance to be retained as ground surfaces. However, even at these scales, small objects like cars or garden huts may be erroneously kept in the DEM so that post filtering could improve results.

A very important step in the DSM extraction workflow is ensuring that collect very accurate GCPs for the exercise. So that the geometric model of the two images are updated so that when the image models are applied to the imagery, they will accurately align with one another. If the two images do not line up during the DSM Extraction process, the output elevation layer may have high levels of error.

The resulted DEM shown on Figure 5 and it represent the elevation variation using pseudo colors.

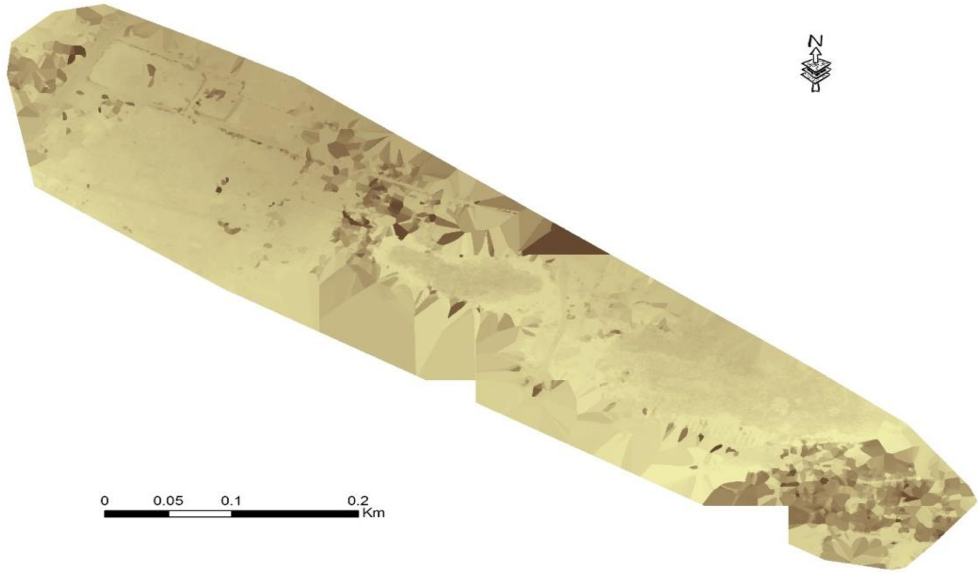

Figure 5-Filtered DEM using algorithms and manual editing

8. RECOMMENDATIONS

Quad Copter can be used to map small areas very effectively provided with good quality cameras. It is strongly recommends using GCPs together to developed geo-referred images to maintain high accuracy of the final output. More over GCPs should install with the gap of 300m or less.

The images should be collected with high forward overlaps, Careful orientation processing is necessary to obtain reliable results. High stereo overlaps should be used; increasing the overlap from 80% to 90% clearly improved the accuracy. The self-calibrating bundle block adjustment approach is recommended because the system calibration can be unstable.

When a camera is used as a measurement tool, it is important to keep in mind that quad copter type UAVs are highly unstable as camera platforms due to vibration caused by motors and propellers and drastic changes in movement speed. A stable and firm lens should be used and it should keep its calibration well. Therefore CRD recommends to use pocket size cameras that have lenses that retract in a moment of shutdown should be avoided in campaigns that require high accuracy measurements.

9. CONCLUSION

Digital Elevation Models of below 1 m accuracy can be achieved with full control GCP from the UAV campaign using non-metric digital pocket cameras, providing relatively inexpensive measures in order to generate DEM sufficient enough for Large Scale topographical mapping requirements in Sri Lanka. This research has shown the significant geometrical improvement of drone photo data processing precisely. However for the DEM, it is necessary to implement full control GCPs as required.

The results reveal that which can be competed against that obtained by much more expensive laser scanning. National Risk Profile Project is expected to obtain over 4000sqkm of elevation data for hazard modeling works. Therefore, this field study will be piloting capability and usability of UAVs for National Risk Profiling Project as well.

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