



International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 8, Issue 3, March 2020

Elevation Mapping Using Drone Imagery

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ABSTRACT: The objective of this paper is the development and analysis of a system for generating three dimensional maps or models from multiple aerial photographs of the area captured using an aerial vehicle and photogrammetric techniques. The system involves two stages, the initial stage being capture of several images of the area from an aerial perspective and the second is the 3D reconstruction of the scene from the available multiple aerial images using photogrammetric techniques. The system minimizes the immense human effort and labor needed to generate maps and elevations of objects in an area.

KEYWORDS: Photogrammetry; 3D Reconstruction; Structure from Motion; Elevation Mapping.

I. INTRODUCTION

In the modern times there is an increased for 3D models and maps in the industries such as and gaming, movie and also in the fields of scientific research and analysis. Generating the 3D models of an area or infrastructure can be a labor intensive task. Developing these models from a sequence of images is much cheaper and less labor intensive. These techniques have also taken advantage in the development of digital cameras and the increasing resolution and quality of images they produce along with the large collections of images over the internet. This development in digital imaging coupled with the more accessibility of drone technologies provide a platform for developing greater applications as specified above. The requirement for 3D models and maps in various industries such as gaming and movie industry are very high and they are million dollar industries with the modern development in technology and computational photographic techniques. The generation of these models can be largely automated reducing the huge human involvement, these models also possess scientific applications such as 3D simulation of flood zones and better city management. This paper focuses developing a complete system for generating 3D maps or models of an area or a large infrastructure using photogrammetry. The 3D reconstruction is achieved using Structure from Motion (SFM) algorithms and the methods to generate dense 3D reconstructions using the Multi View Stereo (MVS) algorithms.

II. RELATED WORK

- i. Extraction of digital elevation models for airborne laser terrain mapping data.

This was proposed by Amy Neuenschwander, Melba Crawford, Christopher Weed, and Roberto Gutierrez in 2000. Using the airborne laser terrain (ALTM) data coupled with the potential for acquiring multiple return for each outgoing pulse, provided new potential for obtaining more accurate digital elevation models (DEM's) which are critical for many applications such as hydrology and shoreline mapping. An Optech 1210 airborne laser terrain mapping instrument was flown over the Kennedy Space Centre (KSC) in summer 1999 for the purpose of generating a high-resolution DEM of the space complex and the extended wetland environs. Features such as relict dune ridges and swales, impoundment dikes, and man-made features are all clearly visible in the DEM. However, the data exhibited inter-flight line biases and cross track artefacts [1].

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- ii. Generation of Digital Elevation Map for Steep Terrain Region Using Landsat-7 ETM+ Imagery.

This was proposed by Sowmya D R, AvinashRao S, P DeepaShenoy, Venugopal K R in 2018. In the proposed method, we have generated DEM for steep terrain region using Landsat 7 ETM+ imagery. The Rational Polynomial Coefficients (RPCs) are used to generate epipolar line, epipolar resampling generates template image. Normalized Correlation Coefficient (NCC) is used as template matching technique to match template image with target image. The RMSE at elevation points are calculated against Ground Control Points (GCPs). The proposed approach is a replacement of physical sensor model which are used to generate DEM [2].

- iii. From a physical scanned map to a digital elevation model using the legend and kriging.

This was proposed by Carol Rus, JaakkoAstola, and CorneliuRusu in 2005. They developed a method for producing digital elevation models from physical scanned maps having as little as possible human interaction. The elevation layers are identified based on the map's legend using the CIE L*u*v* color space, the mean shift filtering and the randomized local search color clustering. The non-elevation layer within the map image generates unclassified pixels. Their values are estimated using geostatistics(i.e. kriging). In the end, the elevation contours are extracted and interpolated [3].

III. PROPOSED WORK

The process starts with imagery acquisition and analysis. A Drone Flight Planning is necessary for minimizing the manual effort and increasing the accuracy.

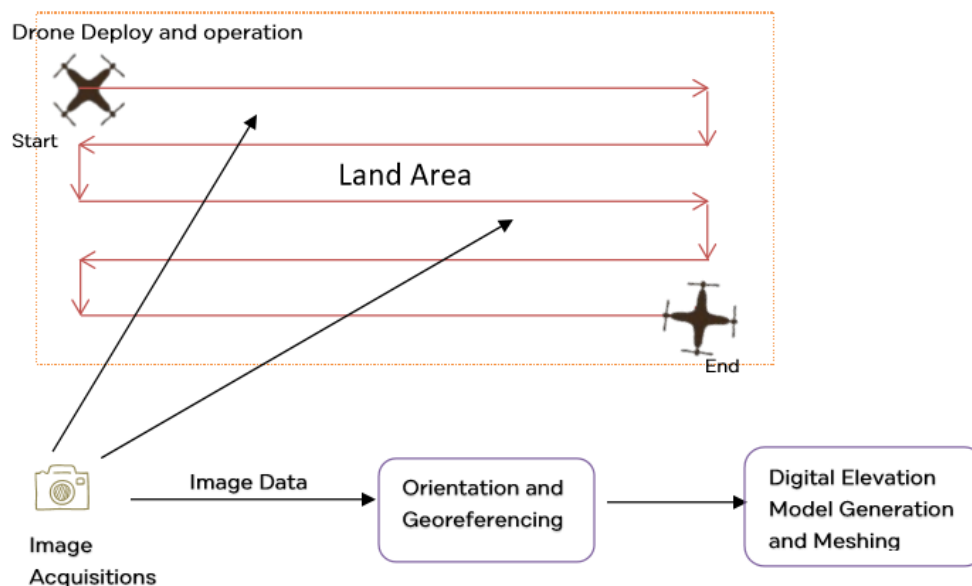


Fig.1. Methodology.

The drone parameters are weight, volume, speed and torque are considered in flight planning; position, angular acceleration, orientation, shutter speed of the camera and testing the manual control of the system are needed to be configured firstly. The flight planning software uses the above parameters and compute the full flight plan consisting of way-points that are the location points where the drone takes photographs along its flight path automatically. The way-points of drone will be programmed or will be manually driven. Aerial images are taken in these fixed way-points, lane by lane. After the image acquisition, the orientation and Geo-referencing is carried out in image processing system. At



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last, the orthophoto and elevation model of the area is generated. The methodology diagram is given above Fig 1. The development of this project has certain phases they are:

- Phase 1 – Develop a drone/quad-copter capable of aerial photography.
- Phase 2 – Deploy the drone to the specified area for the mapping.
- Phase 3 – Resulting images captured from the UAV are processed using SFM algorithms to generate a 3D model of the area.

A. Drone construction and camera integration:

A drone is an unmanned aerial vehicle; every drone consists of four main components. That is its structure/frame, DC motors providing the thrust, a flight controller and electronic speed control. It usually is made of light composite materials to reduce weight and increase manoeuvrability. Here is a basic list of the components that is required for this project.

- Frame - The frame is the structural part or the chassis of the drone. It has to be light weight and strong material for maximum efficiency and endurance. The frame should be levelled the arms of the frame should be separated in equal angles
- Flight Controller - The flight controller is a control unit that takes care of the flight of the system. Additional control units are also required for capturing and transferring images for photogrammetric calculations to the base station.
- Motors - For the proposed quad-copter development only four brushless motors are required. Motor selection criteria are such that the system should generate a thrust in total greater than the payload weight including the chassis.
- Propellers - The blades or the propellers are the ones that act as the air foil that generates the lifts in order to pull the weight into the air.
- Camera - In this project, camera is an integral part of the system. A medium to good quality camera is required for optimal results.
- Battery - The amount of flight time depends on the battery capacity. So select a suitable battery with compatible output.

B. Drone Deploy:

Once the drone and mapping solution has been selected the next step is flight planning. Select the area where you want to do drone mapping along with it ensure safety majors. After finalizing the area, select altitude at which you want to fly the drone. After selecting the area plan the flight. The mission (flight and data acquisition) is planned manually or program controlled/automated, starting from a point, or an area of interest, the required ground sample distance, and knowing the intrinsic parameters of the mounted digital camera. The basic requirement for a Drone based aerial mapping is flight planning and Ground Control Points (GCP) measurement for geo-referencing purposes.

C. 3D Geometry Generation:

Step 1: Camera Calibration:

- Prepare camera and patterns to be used.

In order for better results use between 10 and 20 images of the calibration pattern captured by the camera used in the drone. The camera calibrator app only uses check-board patterns. Other calibration methods with different patterns can also be followed. The calibrator requires at least three images. Use uncompressed images or lossless compression formats such as PNG [4].



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- Add images

Add images to the calibrator app. Saved images from folders can be selected. The calibrator analyses the images to ensure they meet the calibrator requirements. The calibrator then detects the points on the checkerboard [4].

- Calibrate

Once you are satisfied with the accepted images, click the Calibrate button on the Calibration tab. The default calibration settings assume the minimum set of camera parameters. Start by running the calibration with the default settings. After evaluating the results, you can try to improve calibration accuracy by adjusting the settings and adding or removing images and then calibrating again. If you switch between standard and fish-eye camera model, you must re-calibrate [4].

- Export camera parameters

When you are satisfied with calibration accuracy, click Export Camera Parameters. You can either save and export the camera parameters to an object by selecting Export Camera Parameters or generate the camera parameters as a MATLAB script [4].

Step 2: Structure from Motion:

Structure from motion is a stereo-photogrammetric imaging method for estimating 3D-structures from 2D images that sequences i.e., partially overlaps with another image that creates correspondence points between the images. In simpler terms, it's a 3D construction of object from stereo vision.

- Scale-Invariant Feature Transform

It is an algorithm to detect and describe local features in images. The key points of objects are first extracted from a set of reference images and stored in a database. An object is recognized in a new image by individually comparing each feature from the new image to this database and finding candidate matching features based on Euclidean distance of their feature vectors. From the full set of matches, subsets of key points that agree on the object and its location, scale, and orientation in the new image are identified to filter out good matches [5].

- Bundle Adjustment

Given a set of images depicting a number of 3D points from different viewpoints, bundle adjustment can be defined as the problem of simultaneously refining the 3D coordinates describing the scene geometry, the parameters of the relative motion, and the optical characteristics of the camera(s) employed to acquire the images, according to an optimal criterion involving the corresponding image projections of all points. Bundle adjustment is almost always used as the last step of every feature-based 3D reconstruction algorithm. It amounts to an optimization problem on the 3D structure and viewing parameters [6].

- Dense Point Cloud - Geometry Generation

A Dense point cloud is a set of data points in space. Point clouds are generally produced by 3D scanners, which measure many points on the external surfaces of objects around them. As the output of 3D scanning processes, point clouds are used for many purposes, including to create 3D CAD models for manufactured parts, for metrology and quality inspection, and for a multitude of visualization, animation, rendering and mass customization applications [7].



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IV. CONCLUSION AND FUTURE WORK

The classical methods used for mapping are labor intensive and error prone due to large human intervention. Mapping and generation of large areas and their digital elevation maps proved to be difficult by using traditional methods of mapping. In this project, we use a different approach; a quadcopter is deployed for acquiring raster images for generation of 3D models. The images from the drone are used to develop a digital elevation map using photogrammetric techniques. The development of photogrammetry techniques helps the system to generate better digital elevation maps. The results of the new system will be compared with traditional methods for validation. The project is intended to prove that drone based mapping is a viable alternative in terms of economy, time and resources, when compared to the classical aerial photogrammetry methods.

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