Geospatial Survey Analysis for 3D Field and Building Mapping using DJI Drone and Intelligent Flight Battery

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Abstract. Geospatial industry undergoes revolution for every few years. The industry used total stations, GPS, and robotics for the past mapping method. Now, professionals around the world are using drones for mapping which boast quick data collection times, excellent accuracy, and safe operator experience. However, the method for making a 3D map of field and buildings are different. For making a 3D model of buildings, drone must collect the data of buildings by orbiting each of the building. Surveyor will need more time and effort to make a 3D map of buildings than field in the same quality. Therefore, professionals have to make an effective plan to survey different kinds of region. For this research, we used DJI Phantom 4 Pro which has the intelligent Lithium Ion Polymer Battery with the capacity of 5350 mAh. Using the drone, we used different kinds of grid plans to collect map data of regions with buildings and a sport field in Institut Teknologi Bandung, Indonesia. A 3D modelling software is being used to construct an orthophoto and 3D model of the surveyed region which results error data of 3-5 m. According to this research, we can survey about 111.180 m² area with 0.045m/px resolution using only one battery by the overlap image of 80% We believe these flight plans can inspire researcher and professionals of geospatial to develop other plans for bigger survey application.

1. Introduction

Land Surveying is basically an art and science of mapping and measuring land [1]. It is one of the oldest professions on earth [2]. Geospatial or land survey is very important as without this service, maps cannot be made, there would not be any railroads, railway, reservoir etc [3]. It also helps us to prepare cadastral maps showing the boundaries of properties, servitudes, and many other usages [4]. Several methods have been developed to get excellent accuracy, and quick data collection time [5]. One of the most advance method is Photogrammetric Survey, in which measurements made on photographs are used to determine the positions of photographed objects [6]. The method can be implemented by aerial photogrammetry using UAV (Unmanned Aerial Vehicle) [7].

Von Blyenburg defines UAVs as uninhabited and reusable motorized aerial vehicles [8]. UAVs also known as drones have many kinds of design, dimension, and shape for each of its application [9]. Some of them were big and heavy, where other small, light, and agile [9]. Drones have tremendous attention from people around the globe by its function of monitoring and delivering demands [10]. Companies and governments start to use drones for various application [11]. Moreover, it is trusted because drones believed to be able to fly at any time throughout the year and can be flown in harsh environment.
Drones have the ability to fly freely across regions and having camera to capture what it sees. It makes drone platforms become a valuable source of data for inspection, surveillance, mapping, and 3D modelling [11]. Moreover, the process is cheaper and faster than the classical method (Human Survey or Total Station) [12]. Although there is still problems and limitations, drones are a really capable source of imaging data for various applications. In agriculture, producers can take reliable decisions for their farm from the quick and accurate record of damages or other problems [13]. In archeology and architecture, 3D Surveying and mapping sites can be performed by low-altitude image-based approaches [14]. There are many other applications in different fields, such as forestry, environment, emergency management, and traffic monitoring [7].

In order to do mapping, we need photo of every part from the region that we want to map. To do that, drones will have to fly following certain pattern. During the process, drone will take photo for every few seconds, and the photo will have to overlay one and another [15]. Therefore, for mapping field type region, it has to fly using grid pattern, [16]. By using grid pattern, drone can take photo form every part of the region that we want to map. Walter Volkmann of micro aerial projects suggest overlaps of 80% (forward) and 70% (lateral/side) [16], which will produce enough overlapping photographs for post-processing software to work with. For buildings, drones have to fly circular by the building at its center which needs more time and battery usage [17]. Therefore, surveyor/pilot have to make an effective plan flight for drone mapping to resolve the problem.

This paper discusses mainly on the survey plan or flight plans of drone to survey a certain region. The goal of each survey is to get an excellent data accuracy needed for making an orthophoto and 3D model as efficient as it can. One of the biggest concerns is the battery usages needed for finishing flight plans of photogrammetry survey on a certain size of region. This research will be useful for photogrammetry surveyor around the globe in terms of making an effective plan flight for buildings and field region.

2. The equipment and data processing software

2.1. UAV

In the past, development of UAV systems and platforms are focused on military needs, surveillance, and reconnaissance [18]. Whereas geomatics applications first executed by Przybilla and Wester-Ebbinghaus [19]. In the last few years, UAV had been used for various new application. One of its most useful application in research and civilization is on geospatial survey that can become a low-cost alternative to the classical manned aerial photogrammetry [20].

![Figure 1. (a) DJI Phantom 4 Pro Box, (b) UAV, (c) DJI Remote control (d) Intelligent Flight Battery [21]](image)

The drone in possession for this research is a quadcopter DJI Phantom 4 Pro. It has gimbal and camera that can capture 12 megapixel with greater clarity. Moreover, the drone has intelligent flight battery with the capacity of 5870 mAh with the ability of source management system to provide flight
at up to 28 minutes [21]. The drone is controlled by specific phantom 4 pro remote control and having smartphone attached with DJI GO 4 apps installed. The maximum recommended distance between the remote control and the drone is 500 m in a city [22].

The UAV has next-generation flight controller that provide safer, more reliable flight experience. It can also record critical data from each flight and the Vision Positioning System enhances hovering precision when flying in environment where GPS is unavailable. Moreover, the UAV equipped with dual IMUs and compasses design that provide redundancy to the aircraft [22].

2.2. Image processing software
There are different kinds of photogrammetry processing software on the market, such as Pix4D, Agisoft Photoscan, and 3DSurvey. The result of each software may vary but overall by the same data, we will get the same result of 3D model or orthophoto. The price of each software also different. In this research, we choose 3DSurvey to process our photogrammetry data since they can work with any drone and any camera, and developed based on real projects, make it fast and efficient at land surveying project.

These various photogrammetry softwares use the same basic principle. In 3DSurvey, it starts by “bundle adjustment” the picture that have been uploaded to the software. The software will recognize the camera position, orientation and camera properties like focal length, from each of the images that processed. They will recognize it from the data given by each of the picture. Our UAV, DJI Phantom 4 Pro can collect GPS (Global Positioning System) data of each picture therefore it doesn’t needed GCP (Ground Control Point) data to orientate the pictures. Thereafter, “reconstruction” is used to construct point cloud of our model. To get more detailed 3D model, textured model can also be exported. Moreover, the software can produce an orthophoto or a 2D map of our coverage model area. If the result is unsatisfying, we could improve it by changing the parameter settings [23].

3. Flight planning
In this research, we used dual mobile application from “DroneDeploy” and “PrecisionFlight”. The applications allow the user to create flight plans to capture some images of field that they want to survey. DroneDeploy -a user friendly application- can run either on androids or tablets. The drone is navigated following flight plan by the method of waypoint navigation system. A waypoint is a set of coordinates that identify a specific point in the physical space [24]. By making flight plan, the drone can automatically capture image data for optimal 2D and 3D maps and models following the flight plan from the application.

The application could make regular flight plans with easily adjustment of photos overlay for better image data, while the other application could be programmed for circular flight plan. By combining both image data from flight of each app, we can get the optimal result of 2D and 3D maps and model in field and building region.

3.1. Sport field region
The “Grid Type” flight plan (Fig. 2(a)) is one of the most widely used techniques of aerial survey for generating orthophotos or 2D and 3D maps [25]. By using grid pattern, each image overlaps with other image. The overlap is required to get better result of orthophoto and 3D map. Therefore, each image should overlap at least 60% with the previous image [26]. In this research, the field region that being surveyed was part of a sport field in Institut Teknologi Bandung (ITB) called “Sasana Olahraga Ganesha”. The experiment was being done at about 5 pm in the afternoon.

The field region is actually a running track with flat surface, making it easy to be map as a field region. Because of the remote control’s limitation, we cannot fully survey the area, and only manage to get the data of 102 m × 171 m area of the field with the drone’s flying altitude of 90.4 m above the surface. The survey itself took time for about 4 minutes for one session of grid flight plan.
3.2. Region with building

University courtyard also known as Lapangan Teknik Sipil of ITB (Fig. 3 (a)) together with a building called Aula Timur - a big hall located in west side of the university- of ITB (Fig. 3(b)) was chosen as the target area to perform the combine grid-circle flight plan (Fig. 3 (a and b)). This area was being shoot at about 10 am in the morning.

The region contains courtyard with overall flat surface and can be said as a field, and there’s a unique building on the region. Specific for the building, we will need the photo data of the building from every angle surrounds it. That is why, we use circular flight plan specific for the building. The circular pattern has a radius of 34 m and surveyed for 1 minute. The size of the area is 216 m × 183 m with the flying altitude of 74.6 m above the ground. The full area survey with grid pattern is being finished for 7.11 minutes.
4. Photogrammetry image processing

Once the image data is successfully acquired, we can make 3D model and its orthophoto map by using photogrammetry processing software such as 3DSurvey software which we used in this research. The steps of 3D reconstruction and model using 3DSurvey are: import the images, do bundle adjustment, reconstruction, classification, and finally create the orthophoto by calculate DOF (Depth of Field). In this research, the image taken by the drone has automatically its own GPS data, therefore it didn’t have to be orientated by the GCP for faster and easier processing step.

Bundle adjustment step was then taken where the image data was being adjusted for each image (Fig 2(b) and 3(c)). In this step, the software only registered specific images that correspond correctly to the other image. The more registered image data from the imported images, the more accurate the map and model will be.
In the reconstruction step, a dense point cloud (Fig. 5 (a) and 6(a)) that describe the surface of the surveyed scene (DSM – Digital Surface Modes) was produced. Moreover, the point cloud could be texturized for more detailed 3D model and further analysis.

In order to make the best orthophoto image, we have to proceed to the next step which is classification. In this step, we have to classify our point cloud model and select the big terrain patches to get rid the buildings and other obstructions. Afterwards, we can produce the surface of our model. Finally, we can calculate DOF to produce our orthophoto (Fig. 5(b) and 6(b)).

![Figure 6. (a) Point cloud of building region, (b) Orthophoto of building region](image)

5. RESULT AND DISCUSSION

The results of the experiments are shown in Table 1 and 2 for the courtyard with building region, while Table 3 and 4 for sport field region.

| Table 1. Processing parameters of the courtyard with building region |
|---------------------------------------------------------------|
| **Bundle adjustment statistics**                              |
| Images | 134 | |
| Registered images | 134 | |
| Number of ground control points | 0 | |
| 3D tie points | 98461 | |
| RMS reprojection error | 1.10317 | |
| Max reprojection error | 5.89638 | |
| **Optimization parameters** | f, ppx, ppy, k1, k2, k3 | |
| **Dense point cloud** | | |
| Number of points | 2857877 | |
| **DSM** | | |
| Grid cell size | 1m | |
| Number of triangles | 81770 | |
| **Orthomosaic** | | |
| Size | 13608 × 11529 | |
| Pixel resolution | 0.016m | |
One of the most important parameters of aerial surveying is spatial resolution which described as Ground Sampling Distance (GSD). GSD is the distance between two consecutive pixel centers measured on the ground, also known as the size of pixel in the field, while resolution is the relative accuracy of the model. The expected 3D model accuracy can be calculated by the formula stated in Eq. (1) and (2) [27]:

\[ R = \frac{L_s \times D}{c \times L}, \]  

\[ P = 3 \times R, \]  

Where,

- \( c \) = focal length of the camera (mm)
- \( L_s \) = the greater size of the sensor (mm)
- \( D \) = the distance between the camera and the subject (m)
- \( L \) = the greater size of the photograph (in Pixel)
- \( R \) = the spatial ground resolution of the photos in (m/Pixel)
- \( P \) = the precision of spatial positioning of the vertices of the 3D mesh.

| X error [m] | Y error [m] | XY error [m] | Z error [m] | Total error [m] |
|------------|------------|-------------|-------------|---------------|
| 1.474      | 0.543      | 1.571       | 0.995       | 1.860         |

**Table 2.** Error and survey data of the courtyard with building region

Using the Eq (1) for the experiment data in the table 1 to table 4, and DJI Phantom 4 Pro’s camera, the resolution was 0.016 m/pixel for the courtyard with building region (Table 2) and 0.015 m/pixel for the sport field region (Table 4). Furthermore, the accuracies of the models can be gained using the Eq (2) which is 0.048 m/pixel for the courtyard with building region and 0.045 m/pixel for the sport field region.

| Images | 73 |
| Registered images | 34 |
| Number of ground control points | 0 |
| 3D tie points | 4322 |
| RMS reprojection error | 1.92514 |
| Max reprojection error | 5.32157 |

**Table 3.** Processing parameters of the sport field region
In addition, the time required to survey regular grid flight plan for the sport field region was estimated 5.07 minutes with overlap image of 75%. While the courtyard with building region was estimated 7.11 minutes for the grid flight plan, and 1 minute for the circular flight plan by setting the overlap image of 80%. It should be noted that the area coverage of the surveyed model above was different. Therefore, we can calculate estimated time for surveying a certain area coverage.

| Table 4. Error and survey data of the sport field region |
|---------------------------------------------------------|
| **X error [m]** | **Y error [m]** | **XY error [m]** | **Z error [m]** | **Total error [m]** |
| 3.719 | 0.560 | 3.761 | 0.758 | 3.837 |
| Number of images: | 73 | Number of registered images: | 34 |
| Flying altitude: | 90.4m | Number of key points per images / average: | 247 |
| Ground resolution: | 0.0149m | Georeferencing: | Yes |

For the model of DJI Phantom 4 Pro, the estimated time to fly is about 20 minutes [28]. Using the data above, we can calculate the size of area coverage that can be surveyed for 1 minute. For grid flight plan, using the settings of the courtyard with building area, we can survey 5.559 m² per minute. Meanwhile, for grid flight plan using the settings of the sport field area, we can survey 3.440 m² per minute. Furthermore, it can be arranged a circle flight plan with the radius of 34 m per minute for building(s) survey.

6. Conclusion

By applying photogrammetry survey measurement method, and photo image processing using the photogrammetry processing software, a 3D model and orthophoto of a sport field region (SARAGA ITB) and a courtyard with building region (Civil Engineering yard of ITB) was performed. The model got a confident result with the accuracy of 0.048 m/pixel and 0.045 m/pixel. The intelligent flight battery managed battery usage for the drone to fly with average time of 20 minutes. By that amount of time, theoretically we can survey about 111.180 m² area with one battery by using the setting of the courtyard field with building area with the overlap image of 80%.

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