Assembling fixed wing UAV for the low-cost aerial mapping

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Abstract. The development for the improvement of technology of spatial information may be challenged in the future the spatial information is photogrammetry technique using Unmanned Area Vehicles (UAV). In this paper, the aim is to assembly the low-cost UAV particularly named “fixed-wing.” The photos derived by UAV were processed by photogrammetry technique to obtain the aerial photography map. The experiment was in Kandangan village, Duduk Sampeyan district, East Java Province. The map layout should be accorded with The BIG rules number 15 /2014.

1. Introduction

Unmanned Aerial Vehicle (UAV) is a type of aircraft that is controlled by a remote-control system via radio waves. UAV is an unmanned system, which is an electromechanical based system that can carry out the programmatic mission with the characteristics of a flying machine that functions with remote control by a pilot or can control itself (autopilot). Autopilot systems require fast processing, so to make a reliable UAV, it requires a responsive and fast control system in handling commands. In the UAV several main parts are connected directly to the main processor including sensors (data retrieval), telemetry (output to the ground station), inputs (from controllers at ground stations), and control systems (aircraft movements). Each of these sections requires fast processing so that they can immediately respond to the mission that must be done by the UAV [1]. Today, the application of unmanned aircraft itself is as extensive as the application of unmanned aircraft in the military field which is used to carry out a mission of attack or defence of a country. Besides in the military field, the use of unmanned aircraft is also widely used in aerial photography, documentaries, mapping an area, monitoring a disaster area, and others.

This research-based community service made its UAV prototype so that the price was lower compared to factory products. The study aims to use UAV with fixed-wing runs on an autopilot system and uses an action camera for mapping the potential of a village in Gresik and analyze the geometrical accuracy and adjusted to BIG number 15 of 2014 concerning the accuracy of the base map [2].

2. Tools materials

2.1. Aircraft design
In the design of unmanned aerial vehicles (UAVs) using hardware and software [3,4], which is the implementation of mechanical systems and control systems on aircraft propellers to map potential villages.

1. Tools and Materials
   - Brushless DC Motor. Functioning as a propeller of an aircraft for flying
   - Ardupilot Mega 2.8. Functioning as the brain or main controller in an automatic system.
   - 3DR Pixhawk autopilot for automatic pilot control.
   - Radio control receiver (RX). Functioning as a signal received from a signal transmitter (TX).
   - Servo motor. Serves to move the aircraft's wings, both Aileron, Elevator, and Rudder wings
   - ESC (Electronic Speed Control). Serves as a driver or speed regulator for brushless motors.
   - GPS Functioning as a reader of the position and direction of the aircraft
   - Xiaomi / YiCam action camera. Serves as a camera for photographing the area to be mapped.
   - Telemetry. Functioning as a link between the aircraft and computer/mission planner software, to enter the program into Arupilot and to see the status of the aircraft

Figure 1. Components layout design.
2.2. Autopilot flyway planning
The creation of the flight path using Ardupilot's Mission Planner software. The base map is provided in this software which can be used for work maps. By forming POI (Point of Interest) in the work area and determining parameters such as overlap, side-lap, flight height, the aircraft will automatically fly according to the parameters that have been used.

2.3. Flight test
The best test is done after the aircraft assembly. When the flight test is monitored from the ground known as the Ground Control Station (GCS) aims, during flight testing to monitor aircraft status and health status. This consists of a laptop computer running GCS software that is connected via serial to a data modem. The GCS software is a Java-based program inspired by the Open Source Glass Cockpit Project. Designed to provide observers with vital flight information in real-time to assess aircraft performance during flight tests. GCS software includes a Head-Up Display, a moving map that shows the location of the aircraft, and an indicator to display the state of the aircraft [5,6]
Figure 4. Flight test on the Ardupilot’s mission planner software display.

The flight test was accompanied by aerial photo shoots using the yicam version of the Xiaomi Cam Action. Aerial photo shooting uses a time-lapse system, where photos will be taken every two seconds.

Figure 5. The Yicam-xiaomi action camera.
2.4. Data processing

The following subsection is describing the UAV image data processing (Figure 6)

![Data processing flow diagram.](image)

The explanation of the data processing flow diagram is as follows.

1. **Flyway Planning** The flight path planning stage includes the design of the polygon area plan, the determination of the side-lap & overlap, the calculation of the number of photos, the planned take-off and landing location, as well as the session plan and flight height. At this stage, the software used Mission Planner.

2. **Ground Control Point (GCP) measurement** uses GPS Geodetic type to get the ground coordinate value. Ground coordinate values (X, Y, & Z) use the UTM Zone 49S coordinate system.

3. **Aerial Photography Acquisition** of aerial photo data using the Drone DJI Phantom 4 Pro was carried out to obtain photo data of objects in the Kandangan Village area of Gresik Regency.

4. **Photo Selection** After taking photos from various sides, the next step is to make photo selection with the provisions of overlap 70% and photos that contain images of the region.

5. **Orthorectification** is the stage of georeferencing by rectifying photos of objects on the model using GCP coordinate data.

6. **Making Orthophoto** Stages of making orthophoto are:
   - Photo Alignment
   - Geometry Modeling
   - Texture Formation
   - Transform coordinates
   - Orthomosaics

7. **Align Photo**, after selecting photos, photos have to align with one another based on the camera's position. When aligning a photo, 2 activities occur:
1. Feature Detecting
   Feature matching the point detection of photographs is influenced by the viewpoint and the lighting. In its detection using SIFT (Scale Invariant Feature Transform) algorithm [7]. Meanwhile, to get IOP (lens length, exposure point, radial distortion, tangential distortion), the algorithm used is a bundle adjustment of self-calibration. So that the align photo produced sparse clouds of photos that overlap.

2. Marking, Photos of the selection are marked/marked in easily recognizable corners. This sign will be given coordinates as a control point when georeferencing the model. One photo is strived to have three-dot markers that overlap with other photos [8].

3. Masking, to make the model formed efficiently, masking is done as a filtering stage so that the process is more focused on the object. Masking is done if there are things that disturb the photo, such as the presence of moving objects, the sky, etc.

4. Build Dense Cloud, after that form a dense cloud which is dots that are more detailed than those produced at the align photo stage. The process of dense cloud formation is formed from a collection of high points with the number of thousands to millions which will produce ortho aerial photographs.

5. Build Mesh. After the dense cloud is formed, the next step is to form a net. Nets/mesh are formed by drawing lines at dense cloud points so that the geometric shape of the region has been formed by a triangle network (TIN) [9].

6. Build Texture, Provision of texture is the final stage in the formation of image images [10]. This process is giving the texture of the object according to the original photo.

3. Result and discussion
   UAV flights the following mission lines according to the planner (Figure 3). By using overlapping around 70%, the flying height of 100 meters and several BMs for GCP, photo maps can be rectified so that photos become upright by maintaining a GSD of 2.73 cm/pix.

Geodetic GPS measurements are performed for acquiring GCP points as an image georeferences of aerial photographs. GCP measurements were carried out for 1 hour 15 minutes. In addition to GCP measurements ICP (Independent Control Point) measurements with GPS for 15 minutes, Independent Control Point (ICP) ICP is used as quality control of orthoimages of aerial photographs. The following is the distribution of GCP and ICP in this study.

| Table 1. GCP accuracy. |
|------------------------|
| GCP | Easting (m) | Northing (m) | Altitude (m) | Error (m) |
| 1   | 662951.24   | 9209569.26   | 40.136       | 0.028356   |
| 2   | 663420.21   | 9209407.738  | 33.473       | 0.012433   |
| 3   | 662986.118  | 9209901.268  | 36.175       | 0.027252   |
| 4   | 663041.711  | 9210311.011  | 38.411       | 0.00994    |
| Total Error | 0.02072 |

| Table 2. ICP accuracy. |
|------------------------|
| GCP | Aerial Photo Coordinates | GPS Coordinates | ΔΞ | ΔΨ | ΔΞ² | ΔΨ² |
|     | X (m) | Y (m) | X (m) | Y (m) |     |     |
| 1   | 663100.37 | 9210298.9 | 663100.53 | 9210298.7 | -0.16 | 0.208 | 0.026 | 0.043 |
From Table 2, and we can compute the Root Mean Square Error (RMSE) is 0.1404. By using CE90 standard to check the quality of measurement, and then the CF90 is 0.214. Based on the quality standard from BIG [5] Table 3, the CF90 from the measurement in scale 1:2500 is accepted (max 0.75 m for Horizontal and Vertical).

| No. | Scale | Work Map accuracy |
|-----|-------|-------------------|
|     |       | 1<sup>st</sup> Class | 2<sup>nd</sup> Class | 3<sup>rd</sup> Class |
|     |       | Horizontal (m) | Vertical (m) | Horizontal (m) | Vertical (m) | Horizontal (m) | Vertical (m) |
| 1   | 1 : 10,000 | 2 | 2 | 3 | 3 | 5 | 5 |
| 2   | 1 : 5,000 | 1 | 1 | 1.5 | 1.5 | 2.5 | 2.5 |
| 3   | 1 : 2,500 | 0.5 | 0.5 | 0.75 | 0.75 | 1.25 | 1.25 |
| 4   | 1 : 1,000 | 0.2 | 0.2 | 0.3 | 0.3 | 0.5 | 0.5 |

4. Conclusion

Unmanned aerial vehicles (UAVs) that have been assembled have stability when flying and can carry out autopilot missions according to plan. This fixed-wing assembly is made from economical and easy to reach materials. Flight test results show the aircraft is capable of high flight and can be used for mapping large survey areas. The results of the photoshoot with the action-cam also show an orthophoto map that has been processed into the second class for 1: 2500 scale mapping in BIG [5] number 15 of 2014 so that it can be used as a basic map in village planning, development, and archives.

5. References

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