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Collaborative Drones for Low Altitude Photogrammetric Survey

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ABSTRACT: *With the technological advancement in the development of small-scale unmanned aerial vehicles (UAVs) also known as drones and their decreasing costs, there is a growing emphasis on the utilization of these UAVs for various purposes such as disaster management, surveillance, payload delivery etc. In this paper we try to develop a system for aerial imaging using multiple cameras mounted on the drones. Real time data will be transmitted by drones hovering over a large area. We then use aerial triangulation to make calibration in the distortion of the obtained images.*
Keywords: *Collaborative Drones, Autonomous Systems, Photogrammetry, Automatic Aerial Triangulation, Aerial Imaging, Camera Calibration.*

I. INTRODUCTION

With remote sensing technology having surpassed the capabilities of its carriers i.e. satellites and manned aircrafts there is a growing need for development of a technology that could provide facilities like environmental, agricultural monitoring etc.

Various problems were associated with the existing carrier systems. For example, the data obtained from satellites i.e. images etc. were inferior in quality and were not so accurate. It needed various environmental conditions (e.g. cloudless weather) to facilitate its data transfer. Manned aircrafts could beat the erstwhile satellite systems in terms of accuracy as it provided a better resolution but it faced slack over its competitors when it came to operational costs. This paved way for the need of development of a technology that could overcome the shortcomings associated with these technologies.

The ideology behind unmanned air vehicles is not a new one. Their history dates back to the 1800s when the Austrians had used them to attack Venice. These were primarily used for training purposes but over the time we have seen them being used in a wide variety of fields.

With the advent of control engineering and advancements in material sciences, development of drones has taken an excellent stride forward. Although the technology takes its roots from military applications, of late, due to the reducing costs we can see various organizations involved in drone research and development like Hubsan, Pico and Parrot to name a few.

Advantages of collaborative drones

- Collaborative drones provide a greater coverage area as compared to the conventional single drone system that has a limited sensing area and also help overcome the problems associated with it such as occlusion.
- Multiple cameras focusing on an area lead to improvement in image quality, one with greater depths. This helps in three dimensional modelling of the environment contributing to augmented reality research.
- Failure of one of the systems will not have a considerable impact on the overall system owing to the concept of task sharing.

II. PLATFORM

There are three kinds of platforms for mapping UAV system. One of them is the remotely-piloted aircraft while the other is the unmanned helium airship and the last one is a quad copter. The payload can go up to 15kgs, while the flight height is between 100-4000 meters and an operational speed of up to a maximum of 250 km/hr. Remotely piloted aircraft and a quad copter can have both manual remote operations and also a programmed control unit.

Length of Aircraft	**2.8m**	**Take-off Weight**	**50Kg**
Wingspan	**3.6m**	**Size of Task Cabin**	**300mm×500mm×300mm**
Take-off Speed	**70km/h**		
Task Load	**>8kg**	**Speed**	**70～160km/h**
Aviation Time	**3～4h**	**Navigation Precision**	**≤80m**
Radius of Control	**50km**	**Control**	**Program-controlled, remote-controlled, self-control**
Height of aviation	**100m～4000m**		

Fig.1. picture of unmanned aircraft

Figure 1 shows the unmanned aircraft for low altitude photogrammetric mapping.

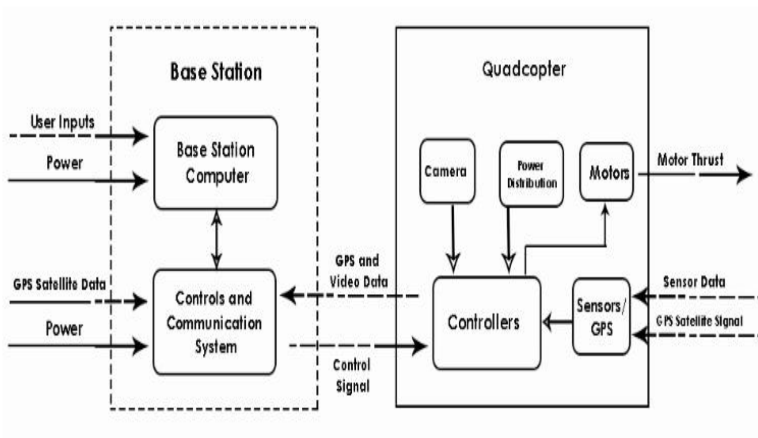

Fig.**2.** Block Diagram of Drone and Base station

Figure 2 shows the flying control system and equipment'sand working of Base station and Drone

Fig.3. Flying Control and on board Equipments used in Drone

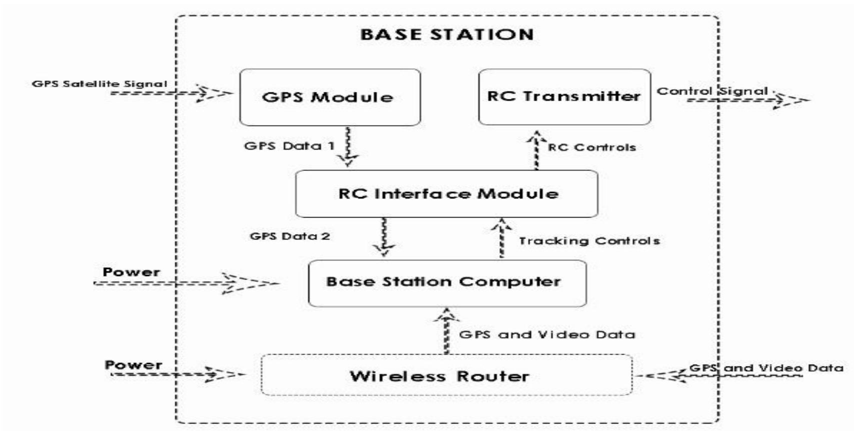

Fig.4. Base station and its components

Fig.5. Base station components

Figure 3, 4 and 5 shows the flying control, data communication and monitoring equipment's forthe Drone.

III. SENSOR SYSTEM

The sensor system of an UAV depends on its payload. With more refined payloads it is easier to envision the usage of spectrometers, miniaturized spectrophotometers, and other technologies like infrared sensors, visual sensors, and high resolution cameras for applications in various fields like defence, environmental monitoring etc. to name a few.

A few variety of sensors that are used in the unmanned aircrafts include:

1. Multispectral Sensors: Used for vegetation assessment and index calculation.
2. Bolometer thermal sensor: Used for heat signature detection, water signature detection to name a few.
3. Visual Sensor: Ideal for aerial mapping, imaging, photogrammetry, surveillance etc.
4. Lidar Sensor: Used for Short range, 270° scanning LASER rangefinder, surface variation detection, vegetation penetration etc.

In our experiment owing to the limited efficient load, we have stuck to the basic digital cameras which have been grouped together to form a multi-angled camera system. The camera system produce a series of overlapping images that are then calibrated. Thus the geometrical distortion present in the images obtained from the digital cameras is resolved. Figure **5** shows theshow the multi-angled camera systemconstructed with the help of four digital cameras.

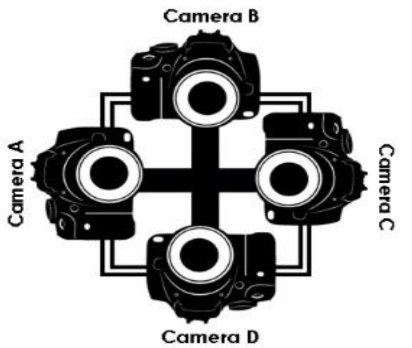

Figure**5.** Theappearance of multi-angled camera system

Figure **6** shows the overlapping representation of the images projected from the multi-angled camera system.

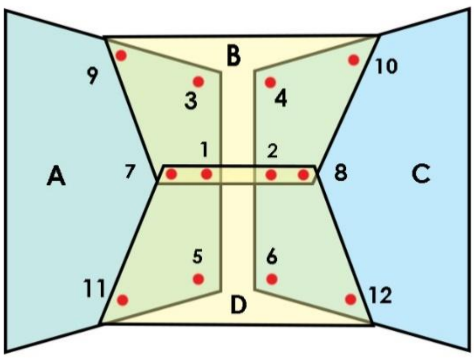

Fig.6. Representation of overlapping of the images projected from the multi-angled camera system

In the above figure points 1, 2… 12 are selected for calibration. The mathematics involved is as follows:

$$v_{1BA}(x) = \Delta Bx - \Delta Ax + (f + \frac{x_B^2}{f})\Delta\varphi_B - (f + \frac{x_A^2}{f})\Delta\varphi_A + \frac{x_B y_B}{f}\Delta\omega_B$$
$$- \frac{x_A y_A}{f}\Delta\omega_A + y_B\Delta\kappa_B - y_A\Delta\kappa_A - \Delta x_{BA}$$

$$v_{1BA}(y) = \Delta By - \Delta Ay + \frac{x_B y_B}{f}\Delta\varphi_B - \frac{x_A y_A}{f}\Delta\varphi_A + (f + \frac{y_B^2}{f})\Delta\omega_B - (f + \frac{y_A^2}{f})\Delta\omega_A + x_B\Delta\kappa_B - x_A\Delta\kappa_A - \Delta y_{BA} \quad (1)$$

Where $\Delta X_{BA}$and ΔY_{BA} are the parallax values obtained by matching the images from camera B and camera A.

X_B, Y_B, X_A and Y_A are the coordinates of point 1 as projected from A and B. ΔA_x, ΔA_y, $\Delta B_x$and $\Delta B_y$are the deviation values of the optical centre A and optical centre B. $\Delta\varphi_A$, $\Delta\boldsymbol{\omega}_{\mathbf{A}}$, Δk_A, $\Delta\varphi_B$, $\Delta\boldsymbol{\omega}_{\mathbf{B}}$, $\Delta k_B$are the errors we have to collect.

The relative errors in all the other overlapping frames can be obtained similarly.

The following conditional equations are used.

$$\begin{aligned} \varphi_B + \varphi_D &= 0 \\ \omega_A + \omega_C &= 0 \\ \kappa_A + \kappa_B + \kappa_C + \kappa_D &= 0 \end{aligned} \quad (2)$$

From the above set of equations 1 and 2 we can derive the values of errors mentioned above.

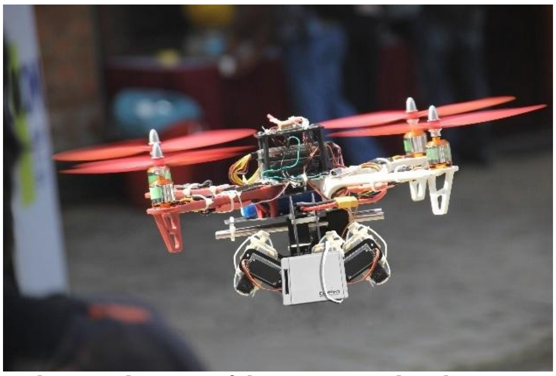

Fig.7. The actual image of the Drone used in the experiment.

Figure **7** shows the real image of the Drone mounted with a multi-angled camera system. Figure **8** a, b, c, d and figure 9 show the images taking from camera A, B, C, D and the resultant image produced.

a b c d

Figure**8.** a, b, c, d are the images obtained from camera A, B, C, D

Figure**9.** The resultant image obtained from four cameras.

IV. PHOTRGRAMMETRIC PROCESSING

a. Aerial Triangulation

Aerial triangulation refers to the mathematics involved in developing relationships between coordinates of acquired image and a defined piece of data and the ground (often referred to as projection). The principle objective behind aerial triangulation is to produce sufficient number of points in the photogrammetric model (from ground reference) such that models involved can have an accurate orientation as required for stereo compilation in line mapping.

Stages of Aerial Triangulation:

The process of aerial triangulation involves three main stages:

1. Preparation:
   This involves the identification on ground control. Image numbering is done here i.e. the points and the strips involved in measurement. Also in this stage we provide the flight details i.e. coordinates of the photo to be taken and camera calibration.

2. Image Measurement:
   In this stage we try to identify the tie points using the pyramid level of the images. We then measure the ground control points. After this the manual tie points are measured if their usage is considered necessary.

3. Block Measurement:
   We enter the observations in this stage i.e. the coordinates and various parameter values. Preliminary data processing is done in this phase and values for bundle adjustment parameters are generated. After all the above processes the results are given out.

b. DEM (Digital Elevation Model) Production

For visualization purposes, the still frames are put together just like a panorama. DEM is finally produced with image matching and TIN interpolation. Final images are adjusted manually to separate certain specific points.

c. DOM (Digital Ortho Images) Production

The imagery is produced automatically based on the DEM results obtained and also on the orientation elements. The overlapping elements that arise due to flight direction are rectified into the ortho-photo imagery.

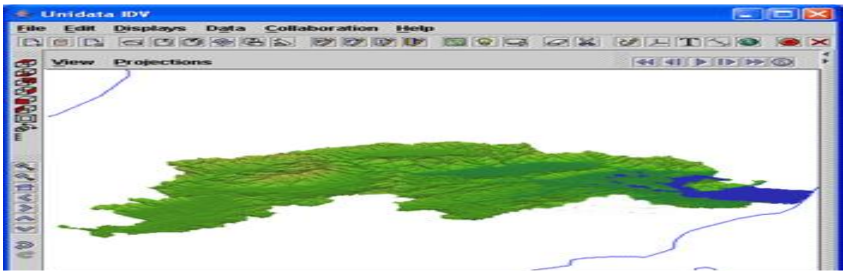

Fig.12. Thegeneration of DEM

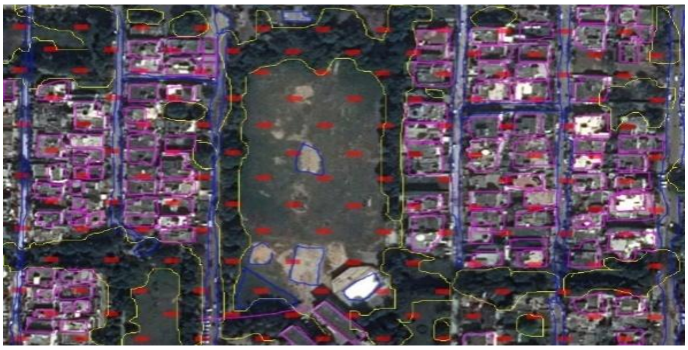

Fig.13. Surveying and mapping results and the DOM

Fig.14. Ortho-photo imagery

V. CONCLUSION

Practice shows that use of drones for large-scale topographic mapping is feasible. We can design the light and small combined 'multi-angled camera system'which has the self-calibration function to construct the practical low attitude UAV system.Using collaborative drones along with the multi-angled camera system makes it fast and flexible to get the High Resolution images which can also solve the problem of large scale mapping.

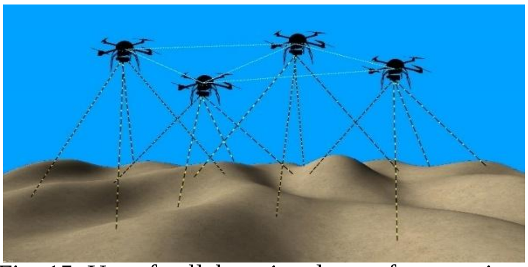

Fig. 15. Use of collaborative drones for mapping

So it greatly reduce the production costs and labour intensity and improve the efficiency

It can be used in river mapping, urban planning, disaster response, construction sites and so on with a support of large scale mapping.

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