UAV BASED MONITORING SYSTEM AND OBJECT DETECTION TECHNIQUE DEVELOPMENT FOR A DISASTER AREA

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ABSTRACT:

In the case of natural hazards the spatial extent of the disaster area is usually large. It is often difficult to conduct search and rescue operations from the ground. Such operations are often hindered due to the inaccessibility to the locality due to the damaged infrastructures. But it is often crucial that the victims are identified and rescued as soon as possible so that timely help can reach to them. Usually manned aircraft equipped for covering wide area with special sensors are used in such purposes. Since it is difficult to operate the manned aircraft from low altitude, a binocular telescope is usually employed to detect small targets from high altitude. In that case, the range of vision for searching becomes narrow and the possibility of oversight must increase. Since UAV can fly at a very low altitude, high-resolution images can be acquired which then can be used to detect the victims.

In this research, a UAV based monitoring system and object detection technique is proposed in order to enhance the search and rescue operation in a disaster area. The main focus here is to develop a data processing system, which would provide a faster, logical and accurate means of handling and processing a large amount of data acquired by the UAV system. The data processing system, henceforth termed as Data Viewer, consists of several components in order to carry out different responsibilities e.g., flight design, extraction of useful data, data quality checking, data integration, image viewing, object detection etc.

1. INTRODUCTION

Numerous applications require aerial monitoring. Civilian applications include resource exploration, monitoring forest fires, oil fields, and pipelines and tracking wildlife, search and rescue operation in disaster area. Applications to homeland security include border patrol and monitoring the perimeter of nuclear power plants. Military applications are numerous. The current approach to these applications is to use manned vehicle for surveillance. However, manned vehicles are typically large and expensive. In addition, hazardous environments and operator fatigue can potentially threaten the life of the pilot. Therefore, there is a critical need for automating aerial monitoring using unmanned air vehicles (UAVs). UAV provides a platform for intelligent monitoring in application domains ranging from security and military operations to scientific information gathering, disaster area monitoring etc.

It is often crucial that the victims in a disaster area be identified and rescued as soon as possible. If the spatial extent of the disaster area is large, search and rescue operation becomes more difficult with traditional methods. The usual approach for this purpose is to use manned aircraft equipped for covering wide area with special sensors and to assign the actual recognition task (surveillance) to the crew. However, in the usage of manned aircraft, it is difficult to operate from low altitude. A binocular telescope is usually employed in the manned aircraft for the magnification to detect small targets from high altitude. In that case, the range of vision for searching becomes narrow and the possibility of oversight must increase (SUMITOMO, T., 1997). Compared to the manned aircraft, mini helicopters are highly manoeuvrable, due to their capability to hover and to change flight direction around the centre of rotation. Any low cost still and video camera can be fixed onboard of a model helicopter (EISENBEISS, H., 2004). Furthermore, because of the small size of the system it is possible to fly close to the area of interest and to capture high-resolution images using low cost digital cameras. The decision to pursue UAVs to meet the growing demand for search and rescue is based on increased effectiveness, and reduced cost. Although the UAV has no inherent rescue capability as a helicopter does, a properly equipped UAV can cover a very large area with varied types of sensors. It can easily locate people in trees or on rooftops in floods, infrared sources in wooded areas (lost or disaster stranded campers, hikers, etc.). It can be deployed to disaster areas quickly, or flown there from a distant location if satellite equipped. UAVs have the advantage that they are more easily retasked, reconfigured, and upgraded to take advantage of different payloads or new sensor technology.

In a disaster response, incident commanders must function to effectively coordinate personnel and resources, often with delayed and inaccurate information on the hazards. Therefore, timely and accurate information collection is critical to the central commander since a delay in the received information could have catastrophic outcomes. Data processing, the step followed by information collection, is crucial in terms of time efficiency and accuracy in victim detection. A logical workflow within the *Data Viewer* would enhance the efficient handling of large data. The conceptual framework and the development of the *Data Viewer* would be discussed in the section 3. The following section (# 2) provides an overview of the UAV type and the sensor used for imaging purpose. The data collected through the experiment is partially processed by the *Data Viewer* in order to assess its functionality.

2. UAV SYSTEM OVERVIEW

The UAV used in this experiment is RPH2, which is a product of Fuji Heavy Industries Ltd, is shown in figure 1. It is 4.1m long, 1.3m wide and 0.8m high. Table1 shows the main specification of RPH2. Two operators were engaged in controlling the UAV in order to fly it along the predefined path for imaging the desired area.

Figure1: RPH2 UAV

The data collection system consists of a digital still camera, a digital video camera and two GPS. These are tightly attached to the UAV through a tailored steel platform as shown in figure 2.

Weight	330 kg
Pay load	100 kg
Motor	83.5 Hp
Main Rotor	2 rotors, diam: 4.8m
Tail Rotor	2 rotors, diam: 0.8m
Range	3km or over
Endurance	1 hour
Ceiling	2000m

Table1: Specification of RPH2 *UAV*

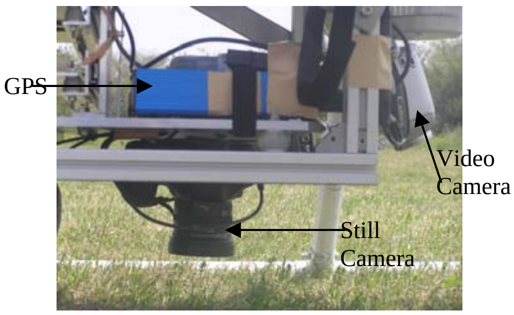

Figure2: Sensor Arrangement

The main specifications of these sensors are provided in Table 2. The still camera and the GPS are connected to a laptop computer. The data collected by the GPS is downloaded to and saved in the laptop computer. Another GPS is connected to the laptop, which synchronizes the still camera and the GPS. The synchronized Camera-GPS imaging system is developed by Dr. Nagai (Nagai, M., 2004). External batteries were used for supplying power to the computer and GPSs, while the cameras used power from their own batteries.

Sensors	Model	Specification
Digital Still Camera	Canon EOS 5D	Image Size: 4368×2912 pixels *f*: 24.0mm , Weight: 700g, Shutter Speed: 9sec.
Digital Video Camera	Canon IVIS HV20	Frame Size: 1920×1080 pixels *f*: 6.1mm , Weight: 600g, Frame Rate: 24fps.
GPS	Ashtech G12	Accuracy Differential: 40cm Velocity Accuracy: 0.1(95%) Weight: 400g

Table2: Specification of Cameras and GPS

The experiment was conducted on a riverside in order to mapping the riverside environment. Images of the surrounding area were captured from different elevation with the same configuration of the system.

3. FRAMEWORK OF DATA VIEWER

Time efficiency of the search and rescue operation in a disaster area given the UAV type and sensors used is one of the most critical deciding factors for the success of the system. The entire process can be divided into various time components among which, the followings are of particular interest for the present discussion:

- Time required to pre-process the raw GPS data
- Time required to extract useful flight time from GPS data and to integrate it with other sensor data
- Time required to do the data quality checking
- Time required to process the images for viewing
- Times required to image processing and to identify the target objects and their locations.

The step-by-step workflow from data acquisition to object detection, as stated above, reveals that there is a need for developing an efficient data handling, processing and viewing system. This provides the basis for developing the Data Viewer, which would encompass the entire data processing task under one platform. Another important aspect of the system design is to define the flight of the UAV. Efficient flight design is important for the efficient use of the flight duration of the UAV. Based on fulfilling the above requirements, the components of the Data Viewer is selected as follows:

- Flight Design
- Useful Flight Time Extraction
- Data Integration
- Data Quality Checking
- Image Processing for Object (Victim) Detection
- Image Browsing for Visual Inspection by the Rescue Team

3.1 Flight Design

Accurate design of flight path is important for the UAV based surveillance over a disaster area. Thorough understanding of the topography and the infrastructure of the target area are important for this purpose. The success of the search and rescue operation would largely depend on the successful flight design. A number of factors have been identified which influence this design, as evident from the following discussion:

For cheap UAV type, flight duration and payload can be serious limitation, which should be considered while designing the system. Often multi-camera system is preferred over the single camera system since the previous system covers larger area than that of the latter system. But again the number of cameras may be limited due to the payload constraint. So the choice of camera type and it's physical dimensions are important factors for designing the imaging system. For multi camera system, it's advantageous to use oblique camera in order to increase the field of view, thereby increasing the area coverage. The angle of inclination of such oblique cameras with respect to the vertical camera can be easily computed provided that the required overlap (usually 10~15%) between vertical and oblique images is supplied to the Flight Design computation system. Figure 3 shows a possible imaging system with camera arrangement.

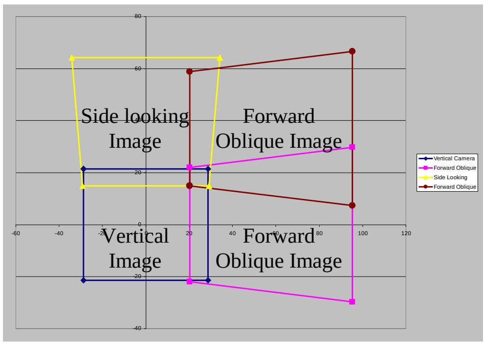

Figure 3: An Example of Camera Arrangement in a test-bed onboard UAV

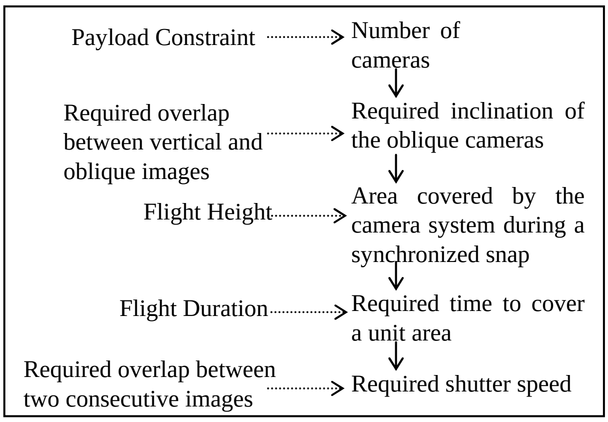

Figure 4: Step by step Computation for the Flight Design

After the camera arrangement has been selected, the area covered by one synchronized snap with this arrangement is computed with the given UAV flight height. Usually the flight height is determined according to the size of the UAV, since it can't be flown so high that the operator can't see the orientation of the UAV. Flight height is also calculated based on the image resolution, focal length of camera. The area imaged in a single snap along with the UAV flying speed is then used in computing the time required to cover a unit area (e.g. 1 square kilometre) of the disaster scene. Such time computation is important since flight duration of UAV is limited. It will help us to decide where to and when to land the UAV for refuelling purpose. The required shutter speed for the synchronized system can be determined from the above area coverage computation, which is based on the required overlap (usually 60~80%) between two consecutive images. One important output that is obtained from the above calculations is the size of the ground covered by 1pixel. Such information is necessary in order to compute the size of the target (disaster victims in this case) to be identified from the images. The workflow for the flight design computation is illustrated in figure 4.

3.2 Useful Flight Time Extraction

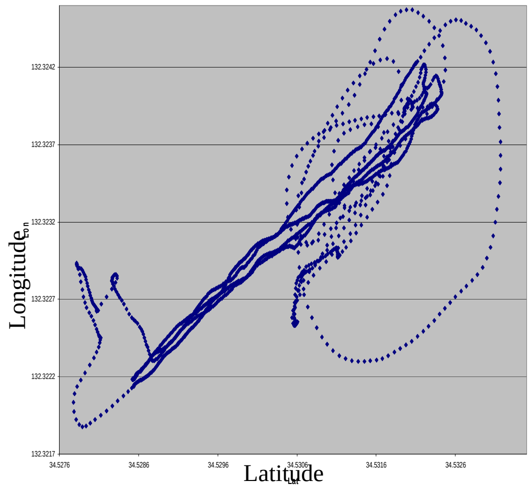

Figure 5: Graph of Lat Vs Lon

After the UAV is being deployed for data acquisition, it takes a while for the UAV to reach to the desired flight height and to the desired flight direction. Meanwhile the UAV takes a few turns as well in order to reach to the desired orientation. Since the sensors start data acquisition as soon the UAV starts flying, it is obvious that not all data are useful for our desired application. In other words, we can say that it is better to extract only the useful data before start any heavy processing such as object detection from the image sequences and calculation of the position of the detected objects. This approach is obviously time effective since it reduces the volume of data before we start automation process. The useful flight time is extracted from the GPS data (consisting of GPS Time, Latitude, Longitude, and Height) alone, which was acquired during the flight of the UAV. The graphs in figure 5, 6, and 7 are generated from GPS data are used in the development of the algorithm for useful flight time extraction.

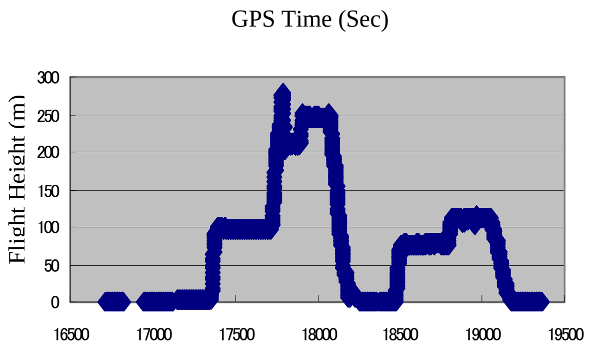

Figure 6: Graph of GPS Time Vs Flight Height

Figure 5 shows the location of the UAV based on the GPS data (Latitude and Longitude) collected during the flight. From this graph, it is obvious that the UAV took a few turns before reaching to every actual flight position. This unnecessary manoeuvring needs to be eliminated in order to extract the useful data only. Figure 6 shows the graph of GPS Time Vs Flight Height. This figure provides the clue that for each flight height there are a number of points, henceforth termed as Point Flock, which lie within a certain range of the average flight height value. Figure 7 depicts a 3-D graph of Lat Vs Lon Vs Height. This figure is very useful to understand how the actual movement of the UAV took place. The UAV started from an arbitrary point and then rises to a predefined height before it

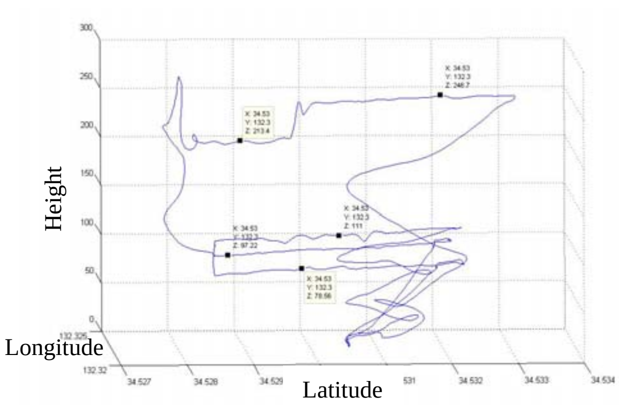

Figure 7: Graph of Lat Vs Lon Vs Height

started the actual flight. After completing one flight, the UAV changed its height for next flight. This process repeated until all the predefined height is covered and then the UAV returns to the ground, completing the flight. Each flight line is more or less straight with little fluctuation from the average flight height. The objective of extracting useful flight time or duration is to extract these straight lines with stable flight height. Figure 8 shows a sample result obtained from this module.

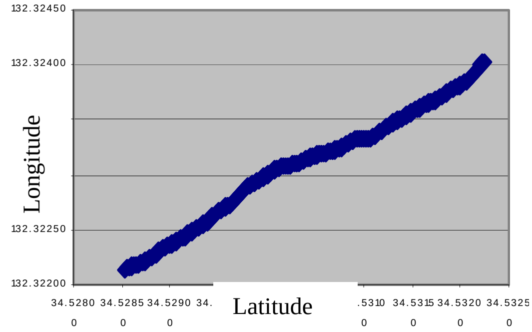

Figure 8: Useful Flight Time Extracted

3.3 Data Integration

Since the camera and the GPS acquire data in a synchronized manner, the images available within the Useful Flight Time are only considered for further processing e.g. for viewing and image processing for object detection. Data integration is carried out in such a manner that the GPS time is matched with the camera time. After the matching is over, a new file is generated, which contains GPS data and the Image number. Such integration is important from the Photogrammetry point of view. Since we want to compute the location of the object on the ground, we must know the time and the real-world position of the camera when the images were taken.

3.4 Data Quality Checking

Data quality checking is another important step before running heavy processing of data such as object detection from image sequence or automated relative orientation of the images for viewing purpose. Here data checking implies to checking for the following missing data:

- GPS Time → Check whether any image was taken during this missing period.
- Image Interval → Check for the consecutive image interval

Due to the mechanical fault or other reasons, sometimes GPS fails to record the data into the computer. Also the shutter control system of the camera may not work properly for the same reason. If images are captured when GPS data are missing, we can't use those images for computing the position of the detected objects. In this sense, these images become useless and we can exclude these before we apply image-processing module onto these images. Usually the shutter speed is controlled in order to maintain a required overlap between the consecutive images. If due to some reason, the camera fails to acquire images within the predefined imaging interval, it may not be possible to run the relative orientation process.

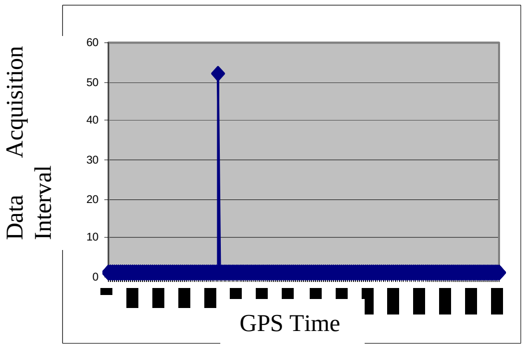

Figure 9: Check for GPS Data

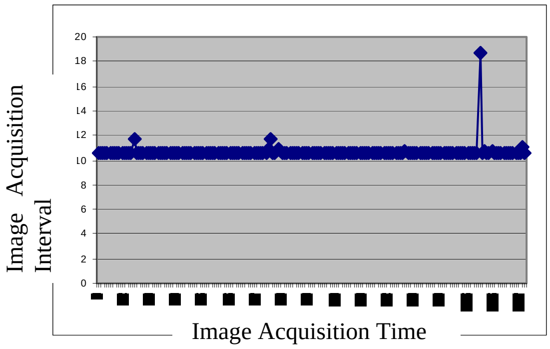

Figure 10: Check for the Inconsistency in Imaging Interval

Figure 9 shows a temporal location GPS data error. GPS captures data in every 1sec. But this figure shows that the GPS could not acquire data for more than 50 seconds. Any images taken during this missing GPS data period are excluded for further processing. Figure 10 shows that the camera failed to acquire images within the designated interval.

3.5 Image Processing for Object Detection and Browsing Images for Human Interpretation

After the errors in GPS data and images are eliminated, these data are used for:

- Detecting Object (victim) from the image sequence
- Computing the location of these objects
- Viewing by the human interpreter (Rescue Team Commander) so that he can properly and timely allocate the resources for rescuing.

This portion of the Data Viewer is yet to be developed. Only the probable and useful functionalities of these modules have been defined so far. Since time effectiveness is one of the major issues for developing a successful search and rescue system, image processing and object detection within the Data Viewer should be faster and robust. Also the processed images with the identified objects should be presented in the viewer in such a manner that these are easy to browse and interpret.

4. CONCLUSION

The Data Viewer is under development stage at the moment of writing this paper. The following four parts: Flight Design, Useful Flight Time Extraction, Data Integration, and Data Quality Checking have been developed and implemented for the flight design and partial processing with the experimental data. The applications of the image processing module and the image-viewing module are to be presented during the final presentation.

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