論文の内容の要旨

論文題目　Development of Unmanned Aerial Vehicle Borne Search and Detection System for Disaster Area

（和文：災害地における無人航空機搭載探査検出システムの開発）

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Bangladesh is frequently hit by many natural disasters, particularly cyclones, floods, mud slides, and drought. The country's approximately 710 kilometers of coastline leave huge tracts of land open to the destructive effects of cyclones and storm surges. The cyclones generate surges up to a height of several meters which sweep over the flat coastal region. It damages lives, properties including crops and infrastructure etc. Since late 1960s, remote sensing is being used for monitoring cyclones in Bangladesh. Early Warning System has been established in the country, which effectively reduces the damage to life and property. The researchers in Bangladesh believe that effective search and rescue operation can further reduce the death toll. During severe cyclone, one of the biggest challenges is that it takes several days for the aid workers to gain access to some of the hardest-hit areas. The roads might be blocked due to the fallen or broken trees, which take time to clear out. Some roads are also obstructed by flood waters, which have to recede. Under these circumstances the search and rescue (S&R) operation is greatly hindered and timely aid does not reach to the victims. As a consequence, death toll might increase. Ministry of Food and Disaster Management (MoFDM), in association with the Bangladesh Red Crescent Society (BDRCS), is implementing Cyclone Preparedness Programmes (CPP) in the 12 coastal districts of the country to minimize loss of lives and properties in cyclone disaster. Bangladesh Air Force (BAF) also plays a vital role in the disaster management in all stages. During emergency response stage, only BAF conducts aerial surveillance for S&R operations. 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. On the other hand, S&R operation from ground is conducted by NGOs, Bangladesh Military, and other government organizations with the aid of community involvement. Different organization with their own accessories, works as different group in order to carry out their own disaster response activities. But these operations are often hindered and delayed significantly due to inaccessibility to the area caused by damaged infrastructure or due to the lack of resources. Also it is very difficult for the ground workers to predict the location of the victims unless they have detailed spatial information of the disaster scene. As a consequence, the S&R operations may be conducted where it is unnecessary or maybe omitted where it is must. Hence the possibility of not being able to identify victims might increases. During severe cyclone it is impossible to conduct aerial surveillance for the entire coastal area of Bangladesh with the limited resources of BAF. The other approach might be to provide the ground teams with detail spatial information about the disaster scene so that the search area can be narrowed down and if possible pinpointed. In that case, the rescue commander would be able to allocate resources with more efficiency. And the success rate of search and rescue operations might increase.

Aerial images can play a vital role in this case. The usual methods for acquiring aerial images are conventional aircraft or the satellite systems. But both of these systems have their own limitations. Acquiring aerial imagery using conventional aircraft during a disaster can be difficult when there is a lack of suitable runways. Such situation might occur if the runway is damaged by the disaster or the disaster area is far away from a suitable runway. Satellite systems can also provide imagery and have proven valuable in widespread disasters such as hurricane, flood, forest fire etc. Unfortunately, the temporal and spatial resolutions of satellite systems make them relatively ineffective for emergency response. Unmanned Aerial Vehicle (UAV), as shown in the figure below, can be effectively used for capturing aerial imagery. A properly equipped UAV can cover a large area with varied types of sensors in order to capture detail spatial information of the disaster scene. Because of the small size of the system it is possible to fly close to the area of interest and capture high resolution images using low cost digital cameras. Since UAV is not heavy, it can be carried to the disaster scene and can be operated as on need basis.

Figure: RPH2 UAV, a Product of Fuji Heavy Industry

The objective of this research is to develop a UAV based tool to enhance the existing S&R operation in Bangladesh. This tool, which is intended to be used by the ground S&R teams, would be able to captures high resolution images of the disaster area as on need basis and to cover a large area within a short period of time. The tool should also be able to handle and process the acquired data in order to pinpoint the search area as well as to detect victims from image sequences processing. The tool would provide support for visual inspection of the raw and processed data, which would help the disaster commander for effective disaster response and efficient resource allocation. Successful S&R operation based on this tool lies in the fact that, it must maintain a specific time frame for data capturing, processing, and interpreting. The proposed Search and Detection (S&D) tool can be incorporated within the existing S&R operation framework in order to make the existing disaster emergency response by the ground workers more effective. The tool must possess the following specific characteristics:

- Convenient → easy to use and operable in the disaster area
- Fast → in acquiring spatial information
- Reliable → in pinpointing search area and locating victims from the acquired spatial information.
- Cheap → so that it is affordable for individual union (group of villages) in the remote marine islands.

From the application point of view, the S&D tool is divided into the following three components:

a) Data Acquisition System: This system consists of the
   - UAV platform
   - Sensor system:
     i. For capturing spatial information.
     ii. Includes GPS and Camera (still and/or video) etc depending on the application type and the payload constraint of the UAV.
   - Synchronized data acquisition system and data storage

b) Data Processing System: The data processing system, named as "DataViewer" provides a faster, logical and accurate means of handling and processing a large amount of spatial data acquired by the UAV system. This component deals with the processing of the data in order identify the objects (victims) from image sequences and compute its real-world location.

c) Image Browser: This component provides a graphical user interface for browsing the raw as well as the processed images. It helps the rescue commander for visual inspection of the processed spatial information in order to narrow down the search area for the ground workers.

In order to implement the proposed UAV based tool within the existing disaster management

framework, we have focused on the 'Disaster Preparedness' and 'Emergency Response' phases of the disaster management cycle as shown in the following figure:

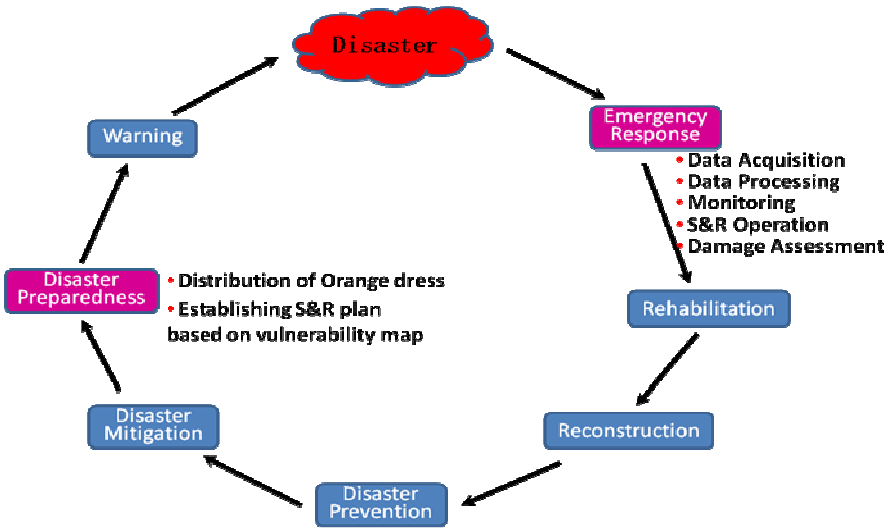

Figure: Conceptual Framework for Disaster Management

During preparedness phase, as part of public awareness program, the people of the target area would be requested to wear a specific color (bright orange for example) dress during early warning period of cyclone. This specific color can be easily identified in the images by visual inspection as well as by automatic image processing. In this phase, UAV flight plan for data acquisition is also established based on the respective area maps which can be explained with the following diagram:

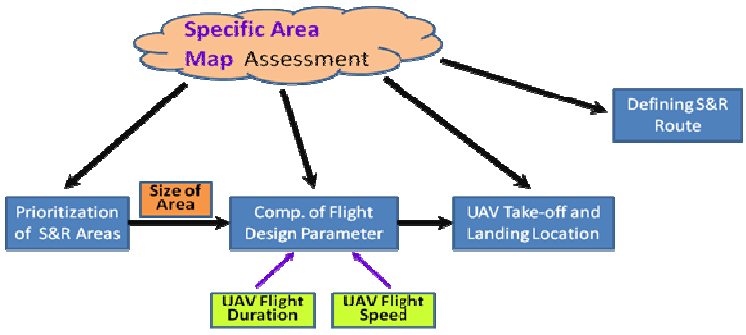

Figure: Establishing Flight Planning and Campaigning for Specific Color Dress

The flight design parameters include flight height of the UAV: in order to achieve a certain ground resolution in the acquired images, camera exposure interval: in order to maintain a specific overlap among the consecutive images in a strip, and location for take-off and landing of UAV considering intermediate refueling in order to cover a specific size of area. After the cyclone hit, UAV is deployed for data acquisition of the disaster area. The acquired data is then processed with

DataViewer for detecting objects based on specific color information as well as for computing their real-world location. Visual inspection of the processed data helps the rescue commander in narrowing down the search area as well as in allocating the resources. The conceptual framework of the S&R operation implementing the S&D tool is shown in the following figure:

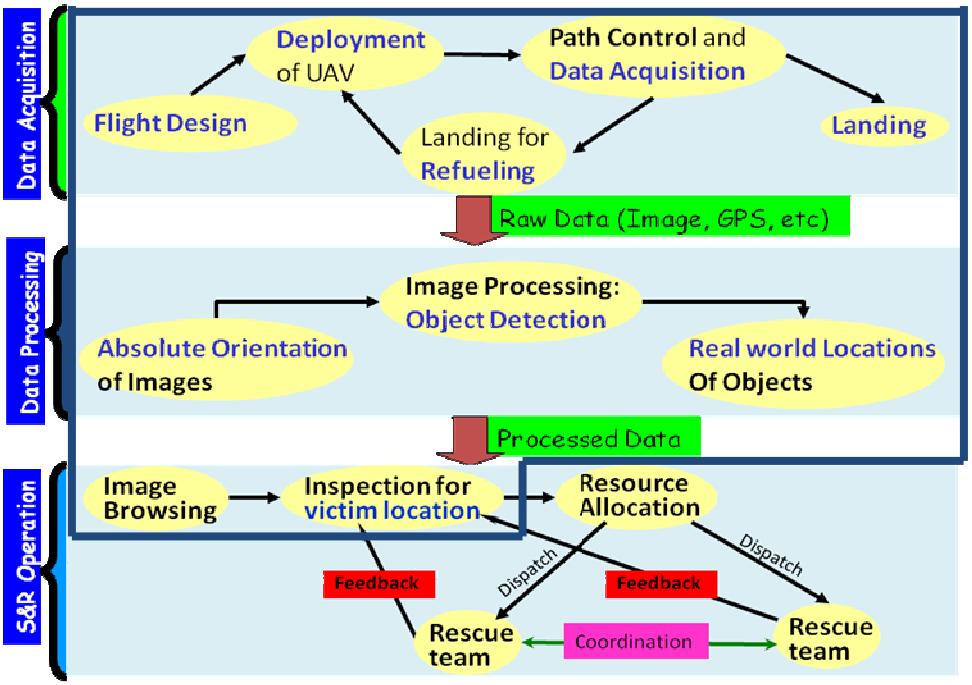

Figure: Implementation of S&D Tool within the Proposed S&R Framework

The blue bounding box in the above figure represents the extent of our research focus i.e. the S&D tool within the proposed UAV based S&R operation.

Several experiments have been conducted with different UAV platform and different sensor system. The acquired data are efficiently handled and processed with DataViewer for data quality checking, data preparation for computing absolute orientation parameter of images, object detection by image sequence processing, computing the real-world location of the detected objects, and finally for visual inspection of the acquired. The experimental results clearly demonstrate the high applicability of UAV borne sensor system for capturing very high resolution images. Data processing results with DataViewer shows that the acquired data can be effectively used to generate very detail and accurate spatial information, which in turn can be used for effective disaster monitoring i.e. effective emergency response. It is also evident that we can easily overcome the limitations of Satellite Images in case we would want to use those for emergency response purpose.

Due to the UAV flight safety regulations in Japan, the test flights for our experiments are restricted to unpopulated areas such as the riverside or mountainous area. Usually such places are very small in

size as compared to the real disaster area. As a result the actual flight design parameters except the ‘UAV Flight Height’ could not be implemented. Flight height is a crucial parameter in order to represent a specific object in images with a certain number of pixel counts. Such requirements are sometimes very important in order to detect objects by automatic image processing. For our future work, we need to conduct a real scale experiment in order to develop a scenario for acquiring and handling real volume of data as well as to validate the full capacity of the DataViewer. Such experiment would also allow us to implement actual flight design parameters such as UAV flight speed, image acquisition interval, and area coverage.