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UTILIZATION OF UNMANNED AERIAL VEHICLE (UAV) IN DAM DISASTER MANAGEMENT: EVACUATION PLANNING

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Abstract: *With the increase of world population and eventually the increase in populated areas at disaster prone areas, a disaster that previously would have been low in risk, is getting more catastrophic each year. Various counter measures are being undertaken to ensure that the impact of a disaster is being well mitigated to ensure the safety and sustainability of the population at risk. This paper will be looking at more depth on the use of Unmanned Aerial Vehicle (UAV) in emergency preparedness, particularly towards the identification effective evacuation routes, in order for the targeted population to safely reach the identified safe haven.*

Keywords: Community resilience, UAV, disaster management, emergency preparedness.

1. Introduction

With the increase of world population and eventually the increase in populated areas at disaster prone areas, disaster have imposed greater risk to the population within its coverage area. Various counter measures are being undertaken to ensure the impact of a disaster is being well managed, in order to ensure the safety and sustainability of the population at risk. Among the technological approach undertaken by the authorities is the utilization of Unmanned Aerial Vehicle (UAV) throughout the disaster from the early stages to the end of the cycle. In this paper, we will be looking at more depth on the use of UAV in emergency preparedness, particularly towards the identification of effective safe haven and evacuation routes, in order for the targeted population to safely reach the newly identified safe haven.

2. Literature Review

Dam is known for its human benefit, such as water storage, hydroelectricity and flood control. However, as a cascading impact of natural disasters such as earthquake landslides and extreme environments such as intense and sustained floods, dams are also a significant threat to human life and high economic losses (Ghazali et al., 2018). As defined in the 2015-2030 Sendai Framework for Disaster Risk Reduction to Enhance Disaster Risk Governance, efforts by various stakeholders related to the safety of dams must be collected. The use of recent technical developments, such as the use of an unmanned aerial vehicle, are among the options for handling such incidences (UAV)

UAVs were first developed and used in military applications where flight identification in enemy areas, unmanned inspection, surveillance, reconnaissance and mapping of enemy areas without any danger to human pilots were the primary military objectives (Remondino, Barazzetti, Nex, Scaioni, & Sarazzi, 2012). Nowadays, UAVs are increasingly being used in civil and scientific research activities in various fields of use. For example, for agriculture, planning, surveying and cadastral applications, archaeology and architecture, geology, coastal management, mapping and cultural heritage (Eisenbeiß, Zurich, Eisenbeiß, & Zürich, 2009). The goal of this paper is to investigate the use of UAVs for disaster management and planning, to use UAVs for map development and updating. Other examples of applications for forest fire monitoring have been demonstrated. There are also studies on the use of UAVs for tree classification, the Normalized Difference Vegetation Index (NDVI) measurement (Harwin & Lucieer, 2012) and the monitoring of stream temperatures (Bao, Sha, Li, Hanchiso, & Shifaw, 2018)

UAVs are proving to be a successful data acquisition technique designed to operate without a human pilot on board. UAV is widely used, but other terms such as drones, Unmanned Aerial Systems (UAS), Remotely Piloted Aircraft (RPA) or Remotely Piloted Aerial Systems (RPAS) have also been frequently used in the geomatics community (Koeva, Muneza, Gevaert, Gerke, & Nex, 2018). UAV refers to the aircraft itself intended to be controlled without a pilot on board, while UAS refers to aircraft and other components that may be needed, such as navigation software and communication equipment (Dyer, Wasson, & Moorhead, 2016). According to ICAO Standards1, RPAS is a subset of UAS that is directly piloted by a licensed 'remote pilot' located at a 'remote pilot station located outside the aircraft." RPAS refers to the whole scheme, while RPA refers to the aircraft itself. The pilot license should cover legal, organizational and safety aspects. In the geomatics group, the terms UAS and RPAS are sometimes used interchangeably and can be considered synonyms.

For photogrammetric applications, the payload of the whole device consists of a sensor, a Global Navigation Satellite System (GNSS) and an Inertial Measurement Unit (IMU) (Molina, Blázquez, Cucci, & Colomina, 2017). The camera takes overlapping pictures as it flies over the study field. These images can be processed into a photogrammetric workflow to obtain a point cloud (or a Digital Surface Model), an orthophoto, or a complete 3D model of the scene. The on-board GPS system allows these data items to be geo-referenced. However, in the sense of low-cost UAVs, the accuracy of such GSP is often limited. Additional Ground Control Points (GCPs) are therefore typically acquired in the study area in order to preserve the accuracy of the orientation of the block image and derived mapping items, such as orthophotos, and to facilitate their integration with other spatial data. These GCPs need to be carefully chosen and well-distributed and should be visible in many images, as well as easily recognizable in post-acquisition images, and quantifiable with accurate technologies such as GPS surveying. The goal of this study is in particular, to examine the orthophoto production process using Unmanned Aerial Vehicles for the development and updating of maps as a low-cost solution that can be affordable for many users.

Mapping updates are important to ensure the accessibility of spatial data as well as to provide a sound foundation for informed decision-making and planning. The map update consists of three key steps: I comparing the new data source to the original database map; (ii) finding changes and updating the database; and (iii) checking the logical compatibility of the current version with the old version (Rusnák, Sládek, Kidová, & Lehotský, 2018). Aerial or satellite imagery collected by remote sensing or Earth observation is used as a data source for a variety of base map update activities. Significant aspects of the urban area, such as roads and buildings, can then be digitized either by experts or by the general public in participatory mapping exercises (Padawangi et al., 2016)

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Here comes the importance of the UAV to disaster management. UAV works independently in the development of high-resolution maps of the disaster-affected area (Erdelj & Natalizio, 2016). Disasters can dramatically alter the affected area, which may fully reverse previous maps. Drones will fly over the region with 3D cameras and automatically build up-to-date 3D maps of the area with the help of GPS (Global Positioning Systems) and publicly accessible relief maps of the region. These maps can be used to understand the effects of the disaster on the region and for example, to determine which roads need to be closed, which are the best ways to access the most affected areas, or even to help prepare the distribution of relief supplies. Among the active roles they may perform in the search and rescue operation, we may highlight the infrared scanning of the region, the use of ground penetration radars or the systematic quest for cell phones by detecting their specific radiation (Tanzi et al., 2016).

Regulation and Legal Aspects

Although the research work presented in this article focuses primarily on technical and scientific aspects, the regulatory framework which regulates the use of UAVs needs to be taken into account. This legal structure varies from country to country. Globally speaking, it is increasingly changing and aims to find a balance between a highly restrictive approach that forbids most non-certified pilot UAV operations and a freer one.

In the United States for example, the law developed at the end of 2015 to make UAV registration compulsory along with a declaration of ownership (Federal Aviation Administration, 2016). In order to prevent sensitive protected area fly-by, manufacturers must now provide no-fly regions in embedded software and pilots are requested to keep their drone in line-of-sight.

All these regulations may be significant obstacles to the autonomous aerial vehicle idea that is being presented here. The fact that the conditions that apply under normal situations are not the same when a catastrophe strikes must, however, be taken into account. In these unique situations, special permits can be obtained within a specific system supervised by experts from all sides: rescue teams, states, communications providers, municipal authorities, etc (Erdelj & Natalizio, 2016). A clear example of such a particular method designed to handle a crisis, such as Hurricane Katrina, was previously described (Moynihan, 2009). Many unique exceptions were made at that time in multiple domains, particularly frequency allocations, communication routing and flight control. There is no question that it is possible to upgrade this system to allow autonomous UAVs to be used, but this has to be implemented at the early stages of the project.

3. Method

The overall methodology for aerial mapping process, are carried out as follows (Remondino et al., 2012):

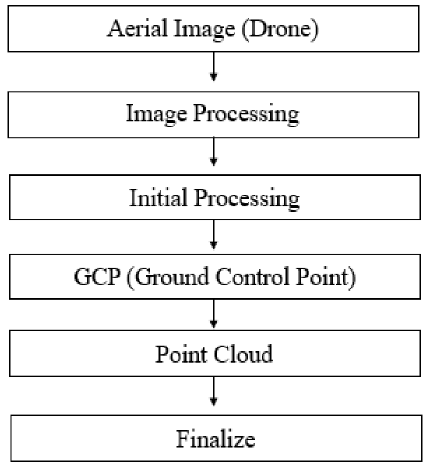

Figure 1: Aerial Image and Mapping Technique

Flight planning, image acquisition and GCP collection

The first mandatory part is to start with flight planning for any aerial survey project using UAVs or classical acquisition techniques. This section includes activities for mapping purposes, such as obtaining flight authorization, selecting software, comprehensive area analysis and the appropriate pixel size on the field (ground sample width, GSD), among others. Some important aspects should also be considered, such as flying height, the use of GNSS and Inertial Navigation System (INS) on board, and the calculation of GCPs on the ground with the necessary technical equipment (Nex & Remondino, 2014). The quality of the final product to be used for mapping, which is usually orthophotography, depends heavily on the quality of the images acquired. In general, high overlaps (such as 80 percent and above) between images are used to improve the quality of the final products particularly the results of dense image matching. In order to prevent gaps due to platform instability caused by potential turbulence, high overlap is also suggested (Koeva et al., 2018).

Image Processing and Output

Photogrammetry's main objective is to derive 3D details from 2D images. For this reason, the internal orientation, the IO (defining the location of the projection centre of the camera in relation to the image, the main distance or focal length and distortions of the lens) and the external orientation, the EO (defining the position of the projection centre of the camera and the rotation of the assembly of its optical axis in relation to the mapping frame) must be composed of the images (Koeva et al., 2018). When these data are not available or of bad quality, then indirect sensor orientation is achieved by integrating GCPs. The distribution of GCPs is of great importance not only for the orientation of images, but also for the prevention of the effects of block deformation that may arise from the remaining structural errors in the calibration of the camera.

Aerial images captured by Drone will then be processed using drone mapping software such as Pix4D. Such software is able to process captured images automatically by finding thousands of common points between images and stich them together, each characteristic point found in an image is called keypoint. It allowed aerial images to be aligned and geotagged with an actual coordinate. In initial process, the key points on the image has been aligned among other keypoints. Generally, when 2 keypoints on 2 different images are found to be the same, they are matched keypoints. At the end, those matched keypoints help all the patches images tie with other images to create a larger image area (Ruzgiene, Berteška, Gečyte, Jakubauskiene, & Aksamitauskas, 2015).

The GCP process emphasis on how to correct the coordinate between the images with the correct reference datum, especially the one utilized by Google Earth, so that the coordinates of image will be matched up as in the Google Earth. Meanwhile, point cloud is a process to match keypoints to generate 3D for 3D image, compassed digital terrain model (DTM) which work on terrain and elevation, whereas digital surface model (DSM) on slope. During the final process, the images that have been aligned was converted to tiff images with high resolution of aerial image with current site condition.

Analysis of Secondary Data

Once the updated base map has been completed and updated on the google earth, this should setup the important base map for other purposes for disaster management. In this case, the next step will be to assess the extend of the disaster itself. It is very important to understand the nature and the extend of the disaster in order to successfully plan and control the situation (Campos, Bandeira, & Bandeira, 2012a). In this case, the disaster being considered is the dam failure, which flooded the population downstream of the dam, on the path of the disaster itself.

The two most important thing to consider are the population and the extend of the disaster. The information we need from the population would include the topography of the populated area, the type of buildings in the area, the access road, the demography of the population and the common method they would use for transportation (Mamat, Mohd Hussain, Tukiman, Muda, & Rabe, 2019). This is crucial for evacuation purposes. In the past, the gathering of such information have been very costly, but with the availability of UAV and the mapping processing facility, this data can be obtained at much lower cost and in much shorter duration.

Precise information on the flood inundation area, flood time of arrival and flood depth has to be obtained. This data is normally available through modelling process using appropriate software (F.C.Ros, L.M.Sidek, N.N.N.Ibrahim, & Razaf, 2008). It is also important to know the available response time for the community to evacuate, from the early warning system installed at the site, or early information from trusted sources such as from local media and local authorities and community leader

Case Study in Bertam Valley, Cameron Highlands

In this paper, for demonstration purposes, the case study of Bertam Valley in Cameron Highlands, Pahang, Malaysia is being selected as an example. Learning from the event of dam related disaster in 2013 (Ghazali et al., 2018), modelling has been done to get the expected inundation area. This area is being used as a basis for analysis in this paper.

Aerial mapping works were initially carried out where orthophotos data were taken, with the assistance of sufficient number of GCPs for precise reference. These data were then processed with pix4D software to produce the 2D map and 3D model of the area. The processed orthomosaic were then updated in the google earth and compared to the existing map in google earth. The flood map obtained as secondary data were then used to assist in the process of planning for emergency evacuation route and safe haven.

The planning for location of evacuation centre considers a few main factors (Mamat et al., 2019). Some of them are rather complicated to be finalized and custom to each area due to the difference in the social and physical aspect of that area. Regardless of that, some of the factors being considered are the community, the local authority and local regulations in handling disaster, the extend of the hazard and the mode of the evacuation itself. The community factor itself is another broad topic to be covered since each community differs from one another in terms of demography, belief, values and etc (Lovreglio, Ronchi, & Nilsson, 2016)

4. Results and Discussion

From the processing works carried out, the aerial map of Bertam Valley is produced. It revealed that Bertam Valley is being in the immediate downstream of Ringlet reservoir, approximately 500m meter from the Sultan Abu Bakar dam. Farms are extending at most of the area in the map, but those are at higher elevation and would receive no threat from the dam break disaster. Populated area on the other hand, stays immediately downstream of the dam and having the greatest potential from the failure in such unlikely event. Figure 1.2 details the map from UAV aerial mapping works at Bertam Valley, Cameron Highlands.

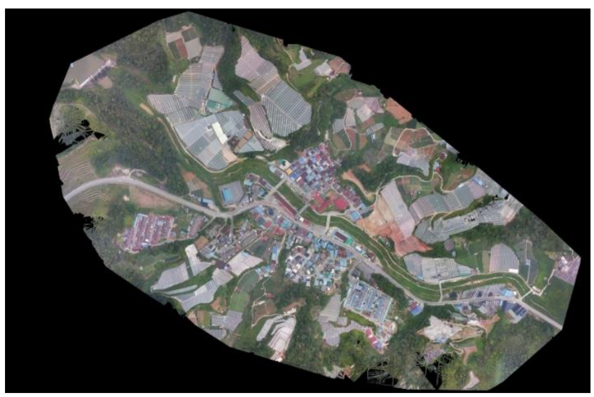

Figure 1.2: Aerial mapping of Bertam Valley

Figure 1.3: Bertam Valley Aerial Image overlaying on Google Earth

Overlaying the image on the google earth reveals a few additional structures over the existing structures captures on the google earth itself. This shows the importance of having an updated map for the accuracy of disaster management planning itself

Figure 1.3 shows UAV orthomosaic overlaid with Google Earth at downstream of Sultan Abu Bakar Dam. These Google Earth satellite images are then exported into ArcMap by georeferencing them based on the longitude and latitude coordinates that have been created in Google Earth.

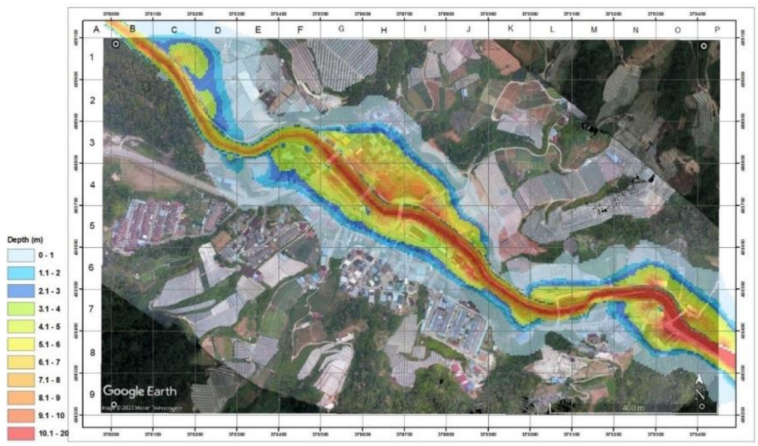

Figure 1.4: 100m x 100m grid cell on Flood Depth Map at Bertam Valley

Dam break hydrodynamic modelling conducted by (Mohd Sidek, Che Ros, & A Aziz, 2011) estimated that a potential dam failure would cause flooding to an estimated 70 percent of the population area in the Bertam Valley. Using MIKE11, the simulation of flood depth due to PMF is set up. For mapping purposes, results in the ASCII format are transferred to ArcGIS. Figure 1.4 displays a flood depth map superimposed by UAV and Google Earth photographs.

A grid is a network of horizontal and vertical lines, uniformly spaced, used to mark positions on a map. In determining the grid relation, there are different techniques. In this research, where single letters are applied for Eastings and numbers for Northings, a basic grid reference system is used. A unique square rather than a single point would be located by this grid reference device (Kennedy & Kopp, 2004).

The precise location of the buildings and the revised map of updated structures were discovered from the UAV mapping carried out. This data was then used to propose the evacuation route and the Bertam Valley dam disaster evacuation shelter. Previous studies carried out has ruled out factors affecting the selection for evacuation route and safe haven for dam disaster (Mamat et al., 2019). Based on the information extracted from the aerial photo, resulted in the proposed evacuation route and safe haven in Figure 1.5 below.

It should also be noted that this proposed evacuation planning was intended primarily for study purposes, as final evacuation planning still needs to undergo various stages of site investigation and verification (Campos, Bandeira, & Bandeira, 2012b)and approval from the authorities, in particular those who are involved in emergency disaster management.

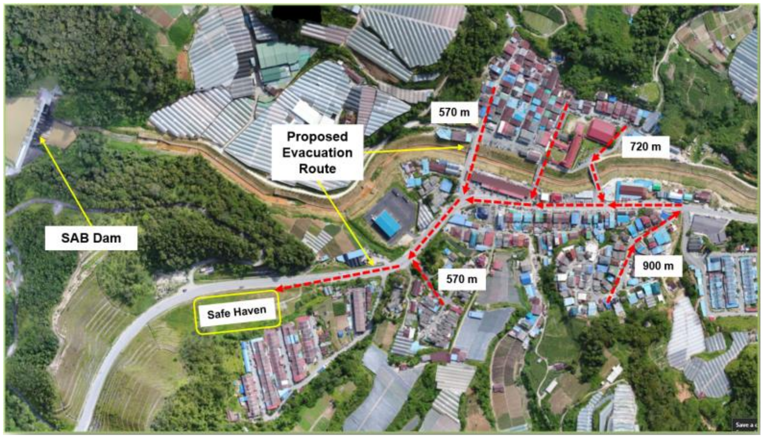

Figure 1.5: Proposed evacuation route for Bertam Valley, Cameron Highlands

5. Conclusion

In conclusion, the use of UAV in disaster management related to dam disaster, especially in planning for evacuation route and safe haven could lead the way to a more cost effective, quick solution and quick guide for disaster evacuation planning. It also demonstrates that UAVs provide promising opportunities to create a high- resolution and highly accurate orthophoto, thus facilitating map creation and updating. Through an example in Bertam Valley, Cameron Highlands, Malaysia, the photogrammetry image is obtained through the processing of orthophoto from the UAV. This important part of the study which shows that due to the high resolution of the UAV orthophoto, new features can be easily extracted, and various outputs can be produced. For the base map updating task of the case study area, clear digitization rules for feature extraction were defined in order to ensure the accuracy of the data.

However, it is important to note that for a more accurate and finalized routes, on-ground assessment still has to be carried out, which includes the activities such as town watching, community townhall gathering for public opinion assessment, and approval from local authorities based on their standard operating procedure and requirement of law and regulations.

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