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CONCURRENT VOLCANO ACTIVITY MAPPING SYSTEM WITH GROUND FIXED SINGLE DIGITAL CAMERA

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ABSTRUCT: Mapping of volcanic activity during eruption is very important to monitor their behavior such as lava flow, pyroclastic flow, mudflow, and so on. Eruption events are usually of short duration. It is very important to obtain information of volcanic phenomena or damaged area on real time basis in order to predict and mitigate calamity that is caused by eruptions. In this research, a ground fixed single digital camera is used, and the automatic mapping system is designed for real time monitoring. Once a digital photo is obtained, a final output is provided concurrently with volcanic activity. Through this system, orthophoto image is created as a final output. A digital photo is rectified onto 3D computer graphics to obtain texture image with fixed location and attitude. This 3D computer graphics is created from DEM. Rectification is done by matching of skyline between two images. Then, the rectified digital photo is converted to orthophoto with DEM. Through this system, volcanic activity is automatically mapped as orthophoto on real time. This system helps chronological change analysis of volcanic activity, especially for short time period time series. Volcanic activities which are mapped by this system would be utilized by volcanologist and other concerned parties to help people evacuate from hazards in case of eruption.

1. INTRODUCTION

Volcanic eruptions are natural hazards that destroy human property and lives. Monitoring of volcanic activities is essential to save people from eruptions and related hazards. This creates a concern on hazards mitigation and identification hazardous area with sufficient accuracy to develop mitigation plans for disasters and calamities. Mapping of active volcanoes is important to monitor, to document and to understand their behavior in detail. Mapping of land cover is important to monitor the features of the volcanic activities, and to provide information to identify each phenomenon such as vulnerable areas, lava flow, pyroclastic flow, mud flow, debris flow and so on. Satellite remote sensing technology is often used for volcano monitoring (for example, Gupta and Badarinth 1993). Though satellite remote sensing is safe and widely covers target area, sometimes it is not enough to monitor the activities of volcano. Ability to monitor volcanic activity using satellite remote sensing is constrained by the temporal, spatial, and spectral resolutions of detector. Nowadays, because of development sensor technology, there are so many varieties of satellite remote sensing sensors. These new satellite sensors may solve the problem of spatial and spectral resolution of detector in monitoring volcanic activity.

In terms of temporal resolution, however, it is very difficult to monitor active volcano by satellite remote sensing. Even aerial remote sensing, it is not always applicable because of high cost, weather condition, and so on. Eruption events are usually of short duration. In most cases, the eruptions occur without any pre-warning and it cannot be stopped. It cannot estimate precise eruption time. When a volcano erupts, a satellite is not always over the eruption. This is disadvantage of satellite remote sensing for monitoring volcanic activity.

Ground fixed digital camera is used for mapping, and it provides information of volcanic activity on real time. It is very important to obtain information of volcanic phenomena or damaged area on real time in order to predict and prevent calamity, which is caused by eruption. Also, location of ground fixed camera is safe enough from active volcano. Digital photos may be taken automatically by remote control. In this study, the volcanic activity is monitored through the digital camera on the ground instead of satellite sensor from the sky. This research is the part of disaster mitigation for volcanic activity. The two main purposes of this research are to design of the real time volcano activity mapping system with a ground fixed single digital camera for real time monitoring, and to convert ground base photo to orthophoto images for volcano activity mapping.

2. METHODOROGY

Over Viewof System

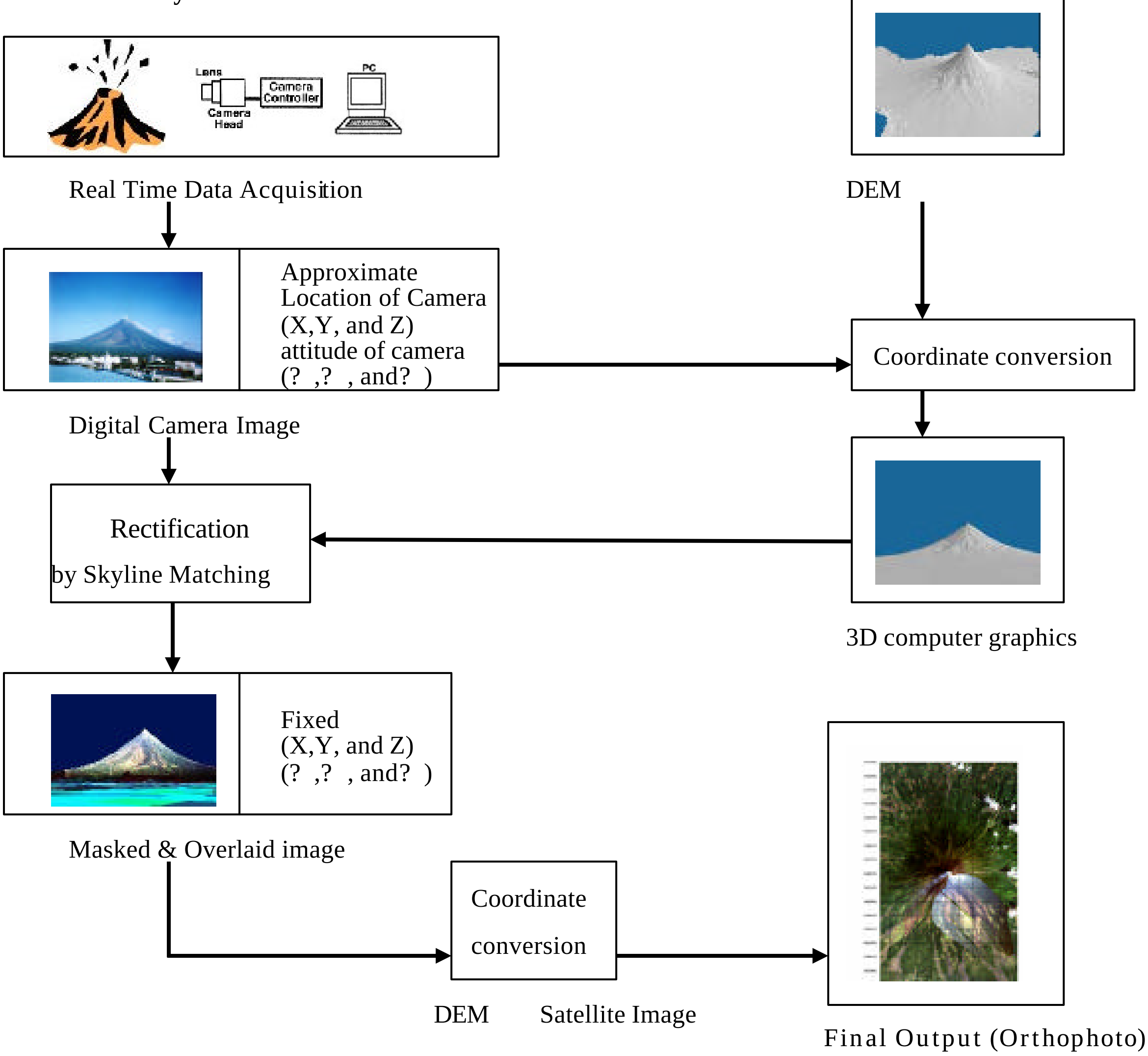


Figure 1. Over view of the system

Digital Image

In this research, digital images has to be acquired from commercial digital camera are used. Usage of commercial digital camera is one of the key points of this research to design inexpensive and applicable system for variety of fields. From digital camera images, view coordinate (Figure 2) and attitude of camera (Figure 3) is approximately estimated. View coordinates (Xs0,Ys0,Zs0) are measured by GPS. Attitude of the camera (? ,? ,?) are approximately estimated using the view coordinate and coordinate of summit (Figure 4). Top of the mountain suppose to be the center of the image. This digital camera image suppose to be horizontal, that is, ? is 0 ° .

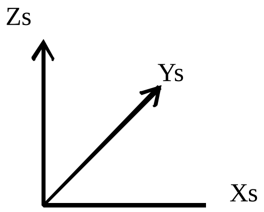


Figure2. View Coordinate(Xs0,Ys0,Zs0)

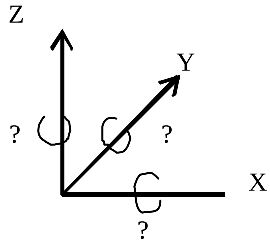
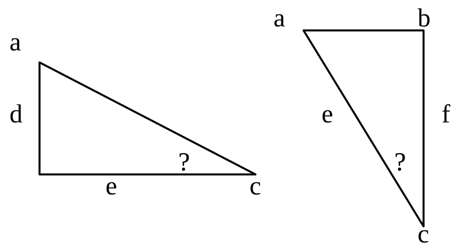


Figure 3. Attitude of Camera (? ,? ,?)



? = $\tan^{-1}$ (d / e) ? = $\cos^{-1}$ (e / f)

a. Summit
b. North
c. Location of taking photography
d. Height of mountain form position of Digital camera
e. Distance of summit form position of Digital camera
f. Distance of Ys of summit and Ys of position of Digital camera

Figure 4. Estimation of Attitude of Camera

3D Computer Graphics Image

3D computer graphics is a kind of virtual reality system. Even though it is impossible to view all of the area from bird's eye view, the image from that view is shown by 3D computer graphics technology. The magnitude for elevation is set to be 1.0. The shading effect is considered while base images are mapped on 3D DEM surface. For coordinate conversion, view coordinate and attitude of camera, which are acquired from the digital camera image is used, and 3D image coordinate is converted to the same coordinate of the digital camera image (Figure 5. and 6).

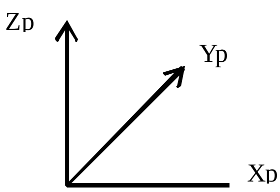


Figure 5. 3D Image Coordinate (Xp0,Yp0,Zp0)

(Xp, Yp, Zp, 1)

$$= \quad (X, \quad Y, \quad Z, \quad 1) \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -Xp0 & -Yp0 & -Zp0 & 1 \end{pmatrix} \begin{pmatrix} \cos\kappa & 0 & \sin\kappa & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\kappa & 0 & \cos\kappa & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\varphi & -\sin\varphi & 0 \\ 0 & \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\omega & -\sin\omega & 0 & 0 \\ \sin\omega & \cos\omega & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$= \quad (X, \quad Y, \quad Z, \quad 1) \; Mp$$

$$= \quad (Xs, \quad Ys, \quad Zs, \quad 1) \; Ms^{-1} \; Mp$$

Mp: Matrix of ground coordinate to aerial photo coordinate.
Ms: Matrix of ground coordinate to view coordinate.

Figure 6. Coordinate Conversion Method

Rectification

The 3D computer graphics is used as the master image for this rectification process. The pixel's position coordinate can be obtained from the 3D computer graphics image, which has already been rectified. Rectification is done by matching of skyline edge between the digital camera image and 3D computer graphics image. The navigated image, skyline edge image of the digital camera image, is overlaid on the reference image, skyline edge image of the 3D computer graphics, for determining parameter of the rectification, shift and rotation, and a final correction is carried out by registration of the navigated image to the fixed reference image. In past research, pattern matching of edges has been used for recognition of objects (Wagner 2000, and Olson and Huttenlocher 1997). Pattern matching of edge has to be very fast and suitable for real time application. Edge pattern recognition method is applied skyline to rectifying the navigated image. In this method, only skyline is needed for rectification, sometimes surface feature may change because of eruption. Whole skyline is not necessary, in case of summit is covered by cloud. In the future research, this matching process must be used for thermograph image.

Skyline Matching Algorithm

Skyline is detected by gradient-based sobel operation method Mountain body and sky, as a background, is clearly different form each other, that is, gradient-based sobel operation method is the most effective. After this processing, appropriate thresholds value is applied to both of the reference image and the navigated image to obtain binary image. The edge in the reference image is only from skyline, while the edge in the navigated image includes edges of skyline and others such as texture of mountain and houses. SSDA (Sequential Similarly Detection Algorithm), which is suitable for binary image and saving calculation time, and image correlation method, which is more accurate than SSDA, are applied to match between the reference image and the navigated image. For saving calculation time, mask image is used to avoid calculating whole image. The mask image is prepared by mathematical morphology of dilation using the reference image. A 3 by 3 of structural elements is used for dilation to make the mask image. Pyramid method is also applied for saving calculation time. The 1/10, 1/2, and 1/1 images are prepared for both the reference and navigated. At first, 1/10 image is roughly matched by SSDA. Then, next process is 1/2 image with SSDA. Finally, 1/1 image is matched exactly by correlation method. Finally, rectification is carried out by registration of the digital camera image applying the parameter, shift and rotation value, which is obtained by skyline matching algorithm.

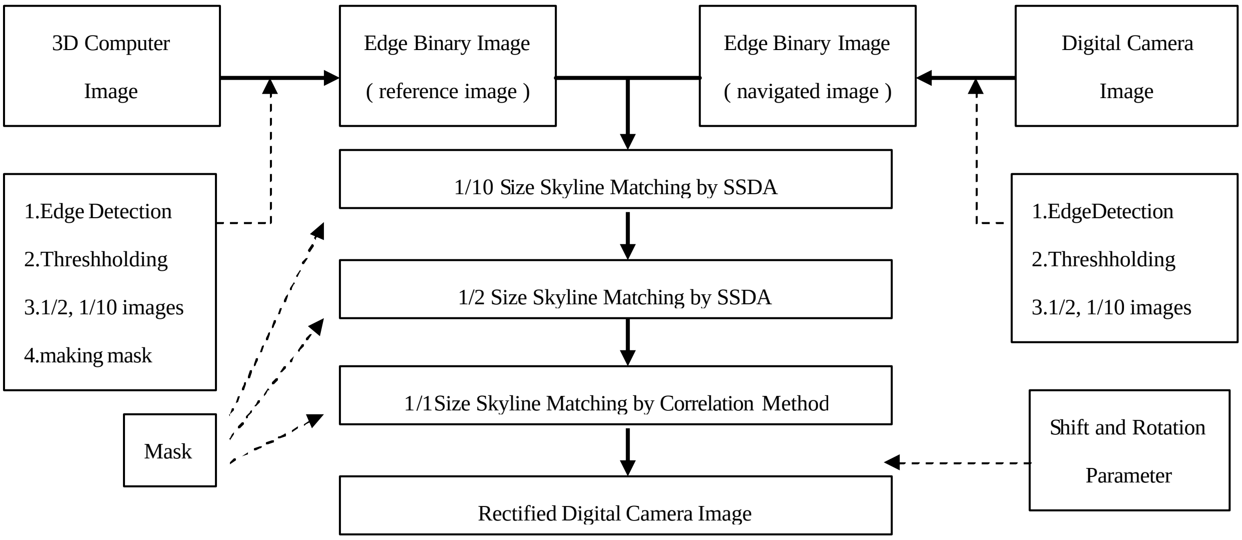


Figure 7. Over view of matching algorithm

Orthophoto

Orthophoto is geometrically corrected for displacements caused by terrain and relief. Because the digital images are geometrically corrected, they can be used as map layers in geographic information system or other computer based manipulation, overlaying, management, analysis, or display operation. Orthophoto is really helpful to know exact location of volcanic activities such as vulnerable areas, lava flow, pyroclastic flow, mud flow, debris flow and so on. Orthophoto is an ideal tool for assessing the completeness and correctness of vector data. Overlaying vectors on imagery immediately draws one's attention to areas of change. In this volcanic activity mapping system, orthophoto is created as a final out put (Figure 8). The rectified digital camera image is converted to orthophoto with DEM. Equation of coordinate conversion is the same as making 3D computer graphics (Figure 5). Also, satellite image is set as a background image for better visualization.

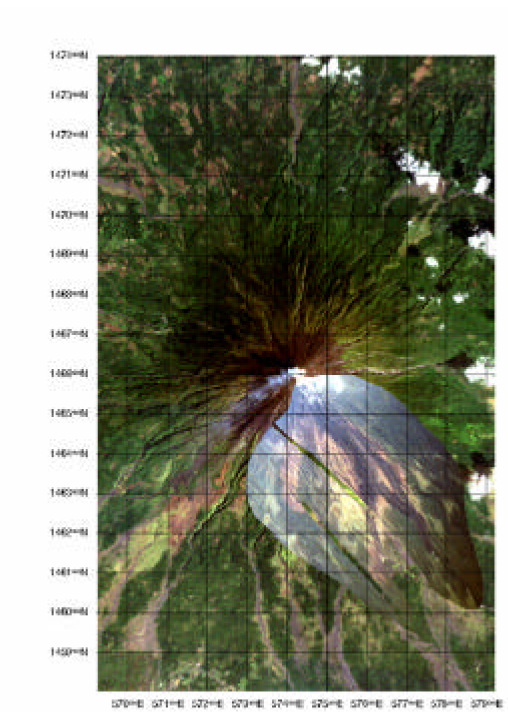


Figure 8. Final Output Orthiophoto

3. RESULT

After acquiring real time data by digital camera, orhthophoto automatically comes out through this system. For the first image, total calculation time is about 3 minutes. After the first image, it takes 1 minute for mapping, because rectification value is already calculated by the first image, that is, it is not necessary to create 3D computer graphics and to calculate rectifying value. If view coordinates or attitude of the camera is changed, only first image takes 3 minutes for processing. Therefore, through this mapping system, image is updating every 1 minute.

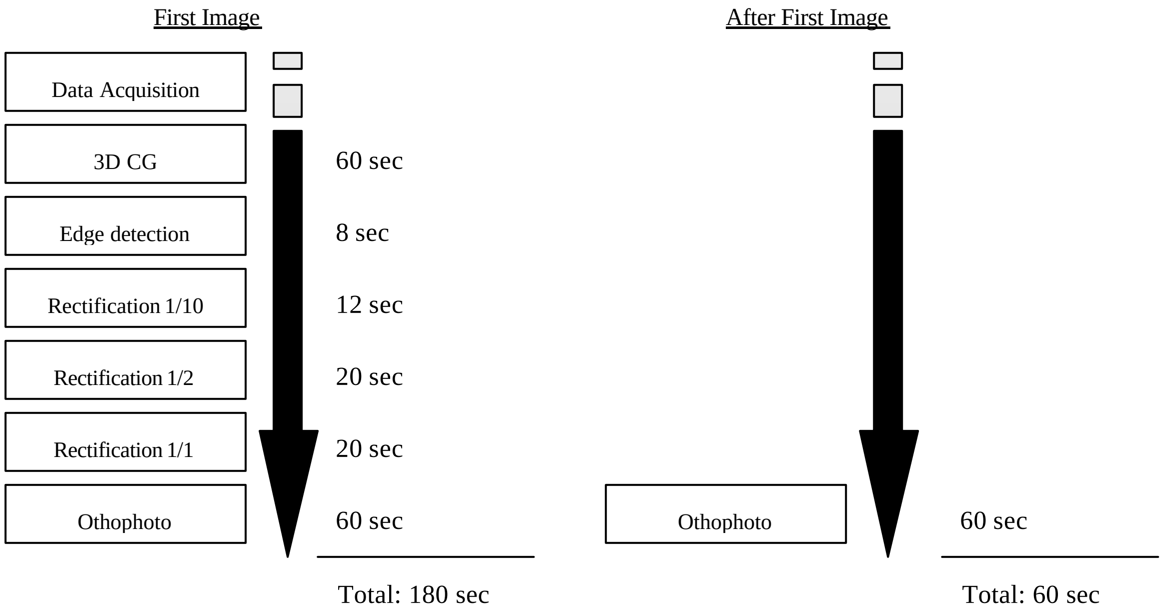


Figure 9. Processing Speed

4. CONCLUTION

Volcanic activity is mapped on real time with this concurrent mapping system using ground fixed commercial digital camera. Every part of the techniques of mapping with ground fixed digital camera is automatic. Once digital photograph is obtained, final output, orthophoto images, is provided concurrently with volcanic activity. Through this system, orthophoto image is created from single digital camera image and 3D computer graphics (DEM). This volcano activity mapping by orthohoto shown here should help people evacuate from hazards in case of eruption on realtime.

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