Mapping Landslide Potential Area using Fault Fracture Density Analysis on Unmanned Aerial Vehicle (UAV) Image

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Abstract. Photogrammetry with fault fracture density analysis adds high-resolution image of surface structure so that landslide potential of research area can be mapped comprehensively. The main notion in this paper is to distinguish regions and excerpt individual components from an unmanned aerial vehicle (UAV) image comparing to satellite image. Using Chan-Vese segmentation approaches to, we detect regions around the edge around the images. This paper presents an effective initialization method for segmentation using the Chan-Vese model by varying on the iteration. The method is tested on several models and provides considerable rise in performance. Finally, we developed program in Matlab for unravelling resulting equation numerically in fault zone case.

1. Introduction
Geomorphology and Geographical Information System (GIS) are important contributory for landslide risk assessment in which understanding site characterization. The power of GIS is that enables us to simplify questions of a database perform spatial operation. Aerial photograph can be used for interpretation (API) for qualitative analysis and photogrammetry for extracting quantitative information. GIS facilitates the application of API in term of archiving the photos and producing geomorphological maps [1]. Nowadays unmanned aerial vehicle (UAV) are widely used in many API applications for different purposes to enhance traditional methods for creating digital elevation method in which are very costly and time consuming because of field surveying. Today there many UAV photogrammetry systems in use for hazardous environments like landslides to gain information in very dangerous area of interest. Direct measurements in such area often are impossible [2], [3].

Unfortunately, UAV-based photogrammetric evaluation is still very complex analysis for generating the best result on interest area. Vegetation and lighting of camera become a big problem for determining sighting area of landslide, like faulting, jointing, valley, and hill topography. Image processing is definitely needed to solve and determine where the exact evidence area is related to landslide appearance. Rectified photographs can simply be merged to a large mosaic for generating digital terrain model (DTM) in photogrammetric processing [4]. However, this method still has a problem in optical distortion analysis. In landslide systems, dense vegetation, valley, or hill may become appearance for faulting or fracturing zone. Fault and Fracture Density (FFD) is a simple method which is applied in geothermal exploration to locate highly fractured areas [5]. Zones with high FFD values usually correlate well to thermal indicators and associated subsurface reservoirs. On the other hand, these
fractures may be tectonic in nature, and this type of fracture develops due to rock deformation during tectonic activity, such as folding and faulting.

In this research, we announce image segmentation technique to enhance and extract image terrain problem analysis. The formulation of segmentation as region-based variation problems has proved to be useful in many applications, especially where reliable edge-maps are difficult to construct. Region-based segmentation models are often inspired by the classical work of Mumford-Shah [6] where it is argued that segmentation functional should contain a data term, regularization on the model, and regularization on the partitioning. An easy case of this is the popular piece-wise continual image model of the Chan-Vese model [7]. In this paper we will study initialization techniques for the Chan-Vese model. The contribution of this paper is introducing a program in Matlab for unravelling equation numerically in fault zone case for the Chan-Vese model which dramatically increases the performance of UAV images compared to satellite-based images.

2. Methods
The study area (latitude -6.8216° and longitude 107.5949°) is a partly dense vegetation area with approximately 5000 m2 near Universitas Pendidikan Indonesia campus, Bandung. This section shows the proposed initialization procedure for making the script program on Matlab. First, the matching to data type was studied on a satellite image due to the format variation of images. Then, we made same treatment with UAV-based images. Original images, that it was taken from Google Earth™ [8] and DJI Mavic Pro™ [9] with 4K resolution are shown in Figure 1 where it can be seen that the method implemented to the satellite-based and UAV-based image. The final segmentations are equally good and in some cases better than with variation of iteration on the script command. The appearance of contour segmentation is shown in Figure 2 and Figure 3 for 100 and 1000 times of iteration, respectively. For simplicity, all scripts initialization was performed using matrix 200x600 in maximum.

![a) Original images in segmentation method](image1_a)
![b) Original images in segmentation method](image1_b)

**Figure 1.** Original images in segmentation method a) satellite-based, b) UAV-based
3. Results and discussion

In geomorphology, low to moderate terrain, the application of FFD to landslide systems is optimal. This is because the manifestations that are mainly caused by the interaction of two blocks, hill and valley with the surrounding dense vegetation through faults and fractures. The morphology produced by this surface manifestation may be undulating topography along the fracture or lineaments of faults. These lineaments, in turn, control the results of high or low FFD anomalies. On the other hand, the FFD method only detects the surface structure, where in this case, the anomaly is associated with fractures caused by tectonic deformation. Detection lineaments with FFD can be achieved by Chan-Vese model, where in this case, the dense vegetation and undulating topography is becoming a key to fulfill digital elevation model problem. Numerical calculation by finite difference method may help the problem to enhance a good result with high intensity inhomogeneity landslide area.

Figure 2 and Figure 3 show that the red colour density of the surface model of the entire interest area of landslide is illustrated. Some sparse areas can be detected (illustrated by blue, green and orange) as an outcome of delivering too few pictures of this areas to the processes. These substantial deviations reflect the existence of plants which was impassive in only one of the explored models. In general, it can be concluded that both photo-based methods provide consistent surface models. Unlike the UAV data, which is more consistent with the apparent appearance of the observed region, satellite images do not have a good response to the Chan-Vese model, so the FFD analysis cannot be interpreted properly as a fault region. In fact, satellite imagery shows that the area has the same manifestation as UAV one. In terms of iteration, 100 times the repetition is considered to have been able to show results that resemble iterations that are 10 times more significant than the original data. This can be used as a preliminary simulation to get a quick analysis of the area under study. But, again, this only happens to UAV-based image with high resolution camera used. Actually, on uav with high resolution camera there
are still limitations, especially in lighting techniques and aircraft control at the time of measurement so that it is reflected in the results of image processing. For example, in FIG. 2 and 3 parts c and d, in the upper right corner there is a very dense vegetation, but because the lighting is too bright, the segmentation response is not accurate. Thus, improvements on these limitations should be addressed in future research, especially for large coverage of landslide area. Finally, in order to verify the real result and condition of the surface appearance constructed from this FFD with segmentation-based, it is necessary to incorporate it with the subsurface method, such as geophysical method for knowing the subsurface potential landslide area [10].

![Figure 3](image)

**Figure 3.** Contour segmentation for 1000 times iteration a) process on satellite-based image, b) Chan-Vese segmentation model of satellite-based image, c) process on UAV-based image, d) Chan-Vese segmentation model of UAV-based image

### 4. Conclusion

This study shows the ability of UAVs, which are an unconventional data collection technology. The application indicates that the UAV combined high digital camera resolution systems can allow to assemble operational data for geomatics applications such as mapping landslide potential area. The research shows that UAV-based data can be used for FFD by photogrammetric techniques with a qualified numerical computation and image processing method. It can be state that the UAV photogrammetry and image analysis can be used to map making, measuring, and some other engineering applications. Moreover, the created landslide area model is satisfactory to enhance risk and hazard assessment. On the other hand, except FFD some restrictions such as weather, control of vehicle, and software directly affects the process and model accuracy.

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