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Study of 3D bathymetry modelling using LAPAN Surveillance Unmanned Aerial Vehicle 02 (LSU-02) photo data with stereo photogrammetry technique, Wawaran Beach, Pacitan, East Java, Indonesia

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Abstract. Coastal is an ecosystem that has unique object and phenomenon. The potential of the aerial photo data with very high spatial resolution covering coastal area is extensive. One of the aerial photo data can be used is LAPAN Surveillance UAV 02 (LSU-02) photo data which is acquired in 2016 with a spatial resolution reaching 10cm. This research aims to create an initial bathymetry model with stereo photogrammetry technique using LSU-02 data. In this research the bathymetry model was made by constructing 3D model with stereo photogrammetry technique that utilizes the dense point cloud created from overlapping of those photos. The result shows that the 3D bathymetry model can be built with stereo photogrammetry technique. It can be seen from the surface and bathymetry transect profile.

1. Introduction

The Aerial remote sensing using airborne becomes one of remote sensing techniques that can be used to obtain remote sensing data with very high spatial resolution. Aerial remote sensing becomes an alternative of satellite remote sensing to overcome the existing problems related to cloud cover, expensive satellite operational costs, until acquisition period. By using the aircraft, remote sensing data acquisition can be more easily, efficiently and flexibly in expected high spatial resolution related to adjustable flying height [1,2]. Several types of airbornes used in the acquisition of aerial photograph data can be either manned or unmanned aircraft. In a paper review by [3] described how UAS (Unmanned Aerial Systems) develops in photogrammetry and remote sensing both from the airborne and sensor.

Other remote sensing for coastal and small island study is important to help better coastal management including monitoring and identification of changes or dynamics of coastal and marine environments [4]. Several remote sensing studies for coastal and small islands application have been conducted, for mapping shallow water habitats by considering basic topography of waters; Analysis of growth rate, productivity rate, productivity of seagrass enhalus acoroides; seagrass mapping to species level based on spectral library in situ measurement using the SAM algorithm (spectral angle mapper) then perform the accuracy assessment [5-7]. Meanwhile another study was conducted to determine the value and variability of remote sensing reflectance (R) from sea levels in different seasons and different types of seawater [8]. Remote sensing with UAV data has been widely used for coastal area monitoring even the quantitative measurement of dune and coastal surface that can be conducted immediately after storm, which was previously difficult [9].

Bathymetry depicting seafloor topography has been studied using remote sensing data by utilizing existing bands as performed in the bathymetric mapping accuracy testing between single band and ratios was also performed in [10], it indicated that the ratio bands were able to normalize the variation of underwater coverage, it was shown with lower SE than single band.

The method that will be used in this research is bathymetry modeling using stereo technique which utilizing photographs to create a 3D model. UAV utilization has been used in surface modeling by using overlap points from overlaid photographs, until the quality assessment of photogrammetric UAV products with DSM accuracy [11]. In small and medium scale, method for obtaining high-resolution data for landform modelling is Structure from Motion (SfM) technique by using overlaid point cloud on images as the basis for building their 3D models [12]. Photogrammetry technique by utilizing photo sequences have been applied in various studies, including for measuring the construction of underground coal mines [13]. Further research to create a three-dimensional model with photogrammetry was made in [14] to build a three-dimensional model of urban areas by utilizing a combination of oblique and nadir photogrammetry that produced texture information for subsequent three-dimensional model. The creation of a three-dimensional surf zone waves model with stereo techniques has also been performed [15]. In another study surface modeling is done with Structure-from-Motion (SfM) Multi-view Stereo (MVS) method of photogrammetry which obtain accuracy up to 2 mm [16]. Micro-bathymetry measurement with underwater stereo camera has been done and obtained precision to the millimeter level [17]. Another study of shallow water bottoms measurement made with UAV data has also been performed [18].

In previous research, the method that has been used in various studies to build a three-dimensional model using photo sequences, has not been attempted on remote sensing aerial data acquired with an unmanned aerial vehicle where the spatial resolution reaches more than 10cm in particular for bathymetry modeling. This study aims to create an initial model bathymetry with stereo photogrammetry technique using LSU-02 data.

2. Materials and methods

2.1. Materials

The aerial photography data used in this initial three-dimensional bathymetry study was acquired using LAPAN Surveillance Unmanned Aerial Vehicle 02 (LSU-02) on April 7, 2016 at 15.11 WIB. The camera used is the Sony Alpha A6000 with a pixel size of 6000 x 4000 pixels with spatial resolution reaches 10cm. The areas included in the study area are Wawaran Beach, south coast of Pacitan Regency, East Java (figure 1).

Figure 1. Orthomosaic image of sudy area.

2.2. Methods

In this research, study of bathymetry modelling uses a stereo photogrammetry technique consist of overlaid point cloud of photographs that will be the mosaic, which then constructed to be a three-dimensional model of the point cloud. Figure 2 shows the flowchart of bathymetry modeling using LSU-02.

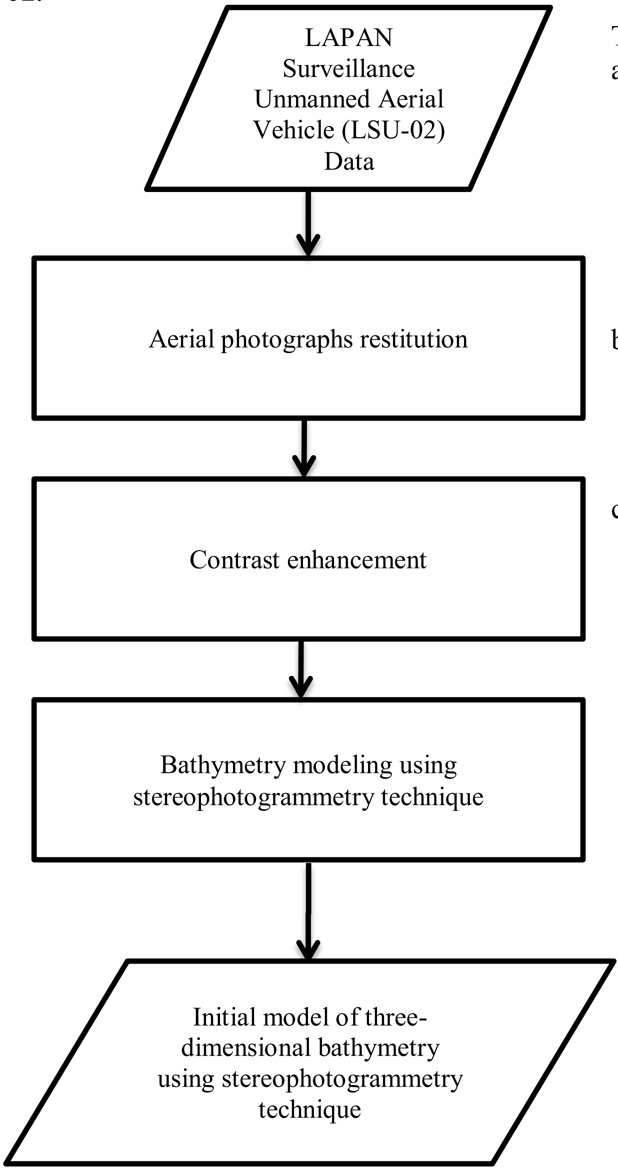

Figure 2. Flowchart of bathymetry modeling using LSU-02.

The stages of data processing is,

a. Restitution of stereo aerial photographs
The initial stage of data processing is restitution or reconstruction of stereo aerial photographs that will be constructed to become three-dimensional model from two-dimensional data or overlaid photographs. These overlaid photographs generate orthomosaic image data of study area.

b. Contrast enhancement
Further process after generating orthomosaic image is contrast enhancement that aims to clarify the color gradation of bathymetry study area.

c. Bathymetry modeling with stereo photogrammetry
Stages conducted in this modeling are as in [19] where the dense point cloud is built in several stages, named search for points on all scales and locations, determining the exact location of the point, and determination of point direction.

- Search for points on all scales and locations,
  In this stage the searching process of points on all scales and locations of the study area is applied with the principle of Difference of Gaussian (DoG). This formula has been developed in the theory of edge detection [20].

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{x^2+y^2 / 2\sigma^2} \quad (1)$$

Where
x,y = position
σ = scale

- Determining the exact location of the point,
  Determination of exact point location is conducted by measuring stability and interpolation with Taylor expansion as in [19]. Taylor expansion is written in the formula.

$$D(X) = D + \frac{\partial D^T}{\partial X} X + \frac{1^2}{2} X^T + \frac{1}{2} X^T \frac{\partial D^T}{\partial X} X \tag{2}$$

  Where
  x= (x,y)= offset of the point

- Determination of point direction
  At this stage, each key point is determined in a direction based on the direction of the slope. This is the assignment stage of orientation as has been done in [19] to place the direction.

$$m(x, y) = \sqrt{((L(x+1, y) - L(x,1, y))^2} \tag{3}$$

$$\theta(x, y) = \arctan \frac{L(x,1, y) - L(x,1, y)}{L(x, y-1) - L(x, y-1)} \tag{4}$$

  Where
  L (x, y) = sample image
  m = gradient magnitude
  θ= direction

  When the points used to create a three-dimensional model (point cloud) has been obtained then the next stage is the finalization of 3D model bathymetry and analysis.

3. Result and discussion

3.1. Contrast enhancement of orthomosaic images

A total of eight photos were used in this study to become an orthomosaic image (figure 2) and experienced several processes to be a 3D model. The result shows that the coverage area including land and water in the coastal area. The existing land covers in land area are settlement, forest and moor. Deep blue color is a natural character of pure water color where the particles, one of them is sand, can affect the absorption which, of course affect the natural color of seawater [21]. Thus shallow seawater that has suspended particles and closer to the seafloor with certain materials will result the lighter color of the seawater than the deep seawater. Before the contrast enhancement process, the orthomosaic image is still the image with natural color, seen how the color of water has a gradation of light blue in the shallow area and darker blue in the deeper seawater. In sea water area, the contrast enhancement process is conducted to reinforce the color gradation in seawater.

Contrast enhancement was performed in the orthomosaic image of the study area as shown in figure 3 where the color used is false color, the water color is brown gradation and vegetation color is green. Through the enhancement result, the color of vegetation becomes darker. From the result it is known that the water color gradation from light to dark in the area of sea water means that the depth is vary. In figure 3, the color of the darker water is as the distance from the land area further. It indicates that the depth of the seawater increases.

3.2. Digital elevation model

The digital elevation model (DEM) of the study area is made by converting the mosaic result into two dimensional view, with color gradation that represents the elevation of the area. The DEM here was produced through the stereo photogrammetry technique (figure 4).

For DEM accuracy in land area, DEM accuracy assessment for DEM generated from UAV data at a small area and capable of achieving very high accuracy has conducted in [22]. This shows that the acquisition of DEM from the UAV is able to show the morphological condition in the field. The color gradation that appears is yellow to red and green to blue which means that the yellow color is the highest point while the dark blue is the deepest point. This is confirmed by the transect crossing from the yellow point to the dark blue point is from highest to lowest point.

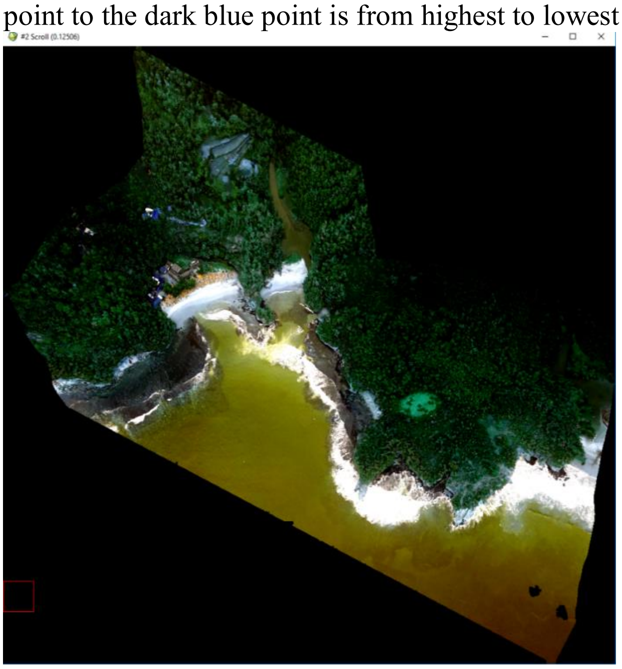

Figure 3. Result of contrast enhancement of orthomosaic image.

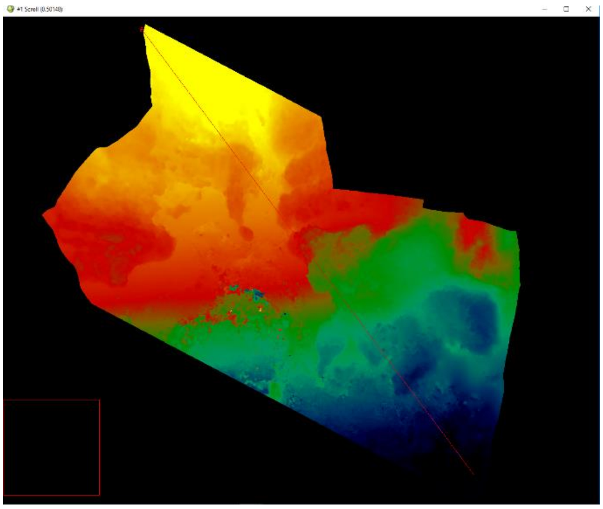

Figure 4. Digital elevation model of the study area.

3.3. Profile of surface and bathymetry

Figure 5 shows how the profile of the surface and bathymetry in the study area. The transect line is red as shown in figure 4. In figure 5 the blue line shows how the relief on the surface and under the sea. Horizontally, it represents the distance along the transect while vertically shown profile from the surface to the bottom of the sea water. The transect starts from the surface with hill morphology that is the highest point with bright yellow color in figure 4, and the transect terminates at the deepest point with dark blue color of sea water in figure 4. Based on y-axis it is known that the range of vertical value is the highest value reaching more than 200 while the lowest value reaching -100. This value is the measurement in the digital number resulting from the overlapping of LSU-02 photo data.

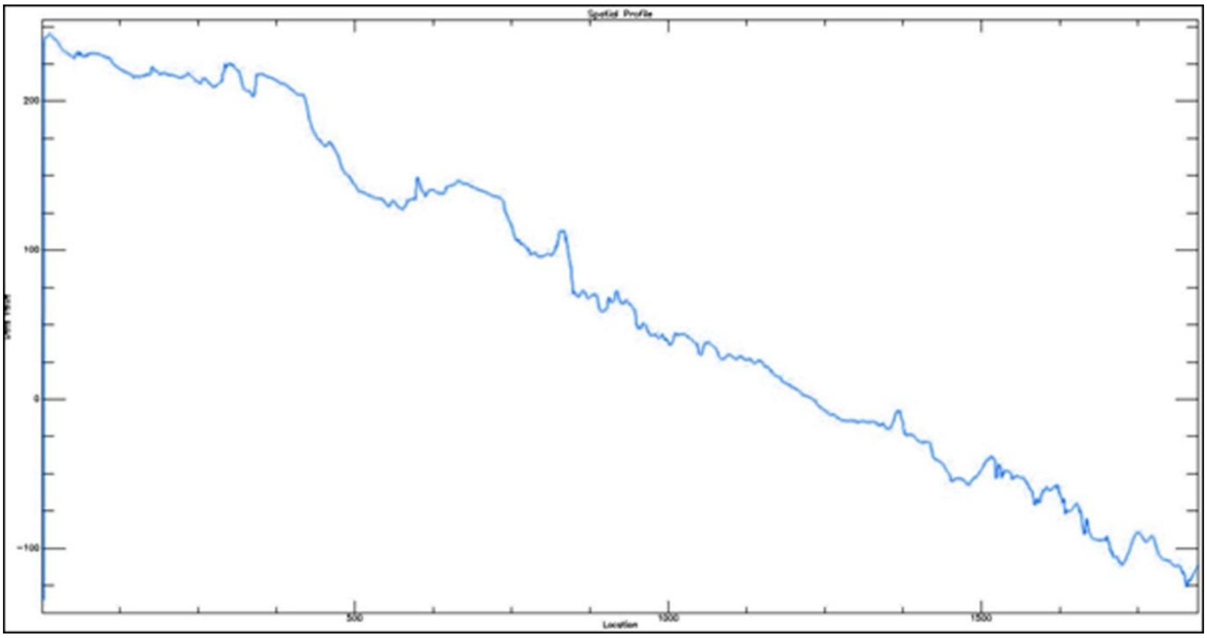

Figure 5. Profile of surface and bathymetry.

3.4. Perspective of 3D surface and bathymetry

Figure 6 shows perspective of 3D surface and bathymetry of the study area, both land and sea water area. From the figure, it can be seen how the appearance of land and sea on the coast in the study area. The land part of the study area appears to have higher areas on the ridge or hill and undulating area. Land covers in this section are vegetation consists of forest and moor and settlement on the coastal plain. Steep slopes on certain part of the coast are also seen in the picture.

The color of seawater visible in the study area is graded from light to dark which indicates depth difference. The gradation, that is, in the area close to the land has lighter water color which indicates shallow water. Meanwhile in the region that is farther from the land is deeper which is shown by the darker color of seawater.

This condition is clearly represented by a 3D model built from overlapping points that form the dense point cloud. The 3D model shows that in areas close to the land, the condition is shallower than area further away from the land.

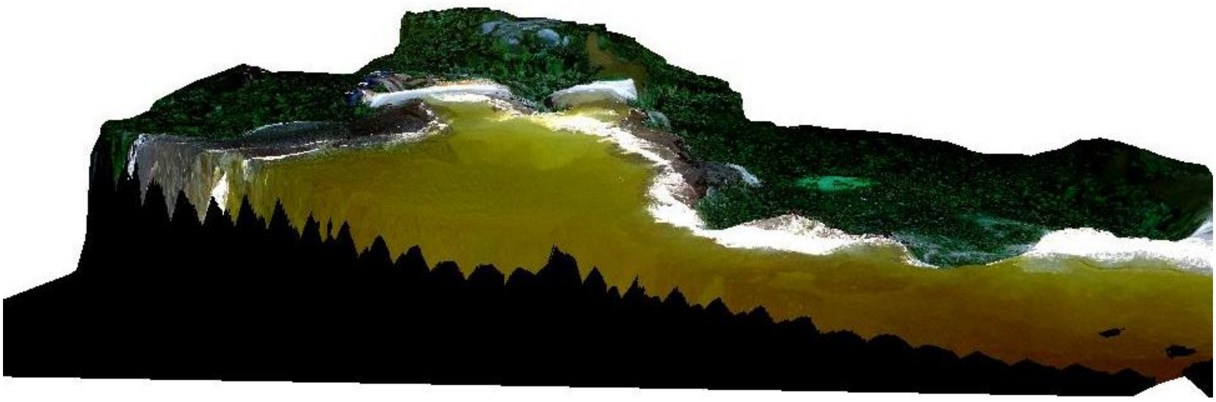

Figure 6. Perspective of 3D surface and bathymetry.

4. Conclusion

The proposed method of this research to build bathymetry model with stereo photogrammetry technique is capable of displaying the three-dimensional model of sea water depth in Wawaran Beach, Pacitan.

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