Geometry accuracy analysis of the three-dimensional model using the close-range photogrammetry method for conservation object of culture (case study: Cow Statue, Faculty Of Livestock, Diponegoro University)

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Abstract. Conservation of cultural objects in the form of maintenance and protection to keep objects from damage and authenticity important. Documentation using a three-dimensional model (3D model) is a cheap, effective and relatively fast solution. The documentation results in the form of a three-dimensional model, which itself must have a good fit of visuals and geometry. The purpose of this study was to analyze the geometry accuracy level and the suitability of the three-dimensional model of physical objects using the close-range photogrammetric method (CRP). This study, using a non-metric camera, namely a DSLR camera to take photos of objects simultaneously and thoroughly according to the CRP concept. The results of the photos are processed based on near-range photogrammetric methods using the VisualSfM technique in point cloud creation followed by Meshlab in making three-dimensional models. The results showed that the shape and color of the model were quite good but still had some rough areas due to a lack of point cloud data. The level of color suitability of the digital model is quite good with several colors in coarse-textured areas that look less suitable for physical objects. The suitability of the geometry of the model through the difference in distance between the test points has an average of 3.524 mm and a standard deviation of 2.989 mm.

1. Introduction
The development and growth of tourist areas and cultural reserves is very rapid in recent years and requires special attention in its management. Some tourism objects rely on their attraction in the form of buildings that have certain historical and unique values. Thus giving a special impression and charm to the visitors of these objects. Apart from the uniqueness and attractiveness of the building, there are several things that need further attention, namely the importance of preserving and conserving the building. This is necessary because the country of Indonesia is one of the countries located in a vulnerable area to natural disasters. So that special measures are needed for the preservation and conservation of buildings, especially cultural heritage buildings. The compilation and making of digital documentation of the structure of the building is extremely important because it is a digital basis in the reconstruction and conservation of buildings of cultural heritage or tourism if it is physically damaged. Law Number 11 Year 2010 Article 53 Paragraph 4 on Cultural Preservation states that the preservation of cultural preservation must be supported by documentation activities before activities that can change the authenticity. In addition, Article 76 Paragraph 2 states that in the maintenance of cultural heritage, documentation must first be carried out, and Article 78 Paragraph 4 states that any cultural heritage development activities must be accompanied by documentation. Based on this law, it can be concluded that the importance of the role of documentation in the preservation of cultural heritage.

Documentation of cultural objects is identical to the activity of taking photos or videos. The weakness of this documentation is the inability to describe the depth of detail and the whole object in three dimensions. Three-dimensional model is the answer to these deficiencies where the three-dimensional
model has the same detailed depth information as the original object. Three-dimensional models also have color information from the original object. Research related to the formation of 3-dimensional models can be seen in research [1] that have examined the use of the Close Range Photogrammetry (CRP) method for 3D modeling of human faces. So that this research will use a three-dimensional object modeling method based on the CRP method in tourism buildings or cultural reserves using non-metric cameras. The object taken as a research sample is a statue of a cow in the area of Diponegoro University. Utilizing the software used is open source, namely VisualSfM in making point cloud and Meshlab in making surface models. Including the three-dimensional printing process using Raise3D N2 Plus printing technology. The final result of this research is a three-dimensional physical model based on a digital three-dimensional model with the object of research being a cow statue that is close to the accuracy of similarity to the original structure.

2. Research Methodology
This research was arranged in several stages which could be described, as follows:

2.1. Definition of Close Range Photogrammetry
Photogrammetry is the art, science, and technology for obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of radiation recorded on electromagnetic energy [2]. Using the basic principle of photogrammetry, the formation of 3D models was developed using the concept of Close Range Photogrammetry. Close range photogrammetry is used to explain the photogrammetric technique where the distance between the object and the camera is below 100 meters [3]. Another characteristic that distinguishes close range photogrammetry from udata photographs is the shooting position. Close range photogrammetry takes pictures around (sometimes from inside) objects. The starting point of a close range photogrammetry is the Central Perspective Projection in Figure II-3 the center of the camera is indicated by the symbol O. The center of the camera is orthogonal to the projection plane which intersects at the principal point P as in Figure 1.

![Figure 1. Central Perspective Projection [3]](image)

2.2. Building of 3D Model
The formation of a 3D model is based on processing point cloud data in VisualSfM software that can do 3D reconstruction and is open source based on the application of the Structure from Motion (SfM) method. VisualSfM runs by utilizing multicore for feature detection, feature matching, and bundle
adjustment. The basic processing steps in VisualSfM according to [4] are divided into 4 main stages: adding image files into VisualSfM, feature detection and image matching, sparse point cloud reconstruction and tight point cloud reconstruction. This feature detection and image adjustment step requires a Graphic Card with a minimum GPU memory of 1GB, while bundling adjustments require NVIDIA CUDA and CPUs with multiple cores. VisualSfM saves the file in an N-View Match (NVM) file containing the location of images and 3D models, the NVM arrangement itself can be seen in Figure II-20. In addition to the NVM file, VisualSfM also releases a file called cameras_v2.txt which contains the internal parameters of each image on the camera that is used as many as 8 parameters.

2.3. Concept of Geometric Validation on 3D Model
Structure from Motion is a topographic survey technique that develops from computer vision and photogrammetry. This method can produce high quality point clouds, meetings as well as cheap prices. As a topographic survey technique, SfM is more widely applied to earth science [5]. The results of the 3D model were performed geometric validation using the method of comparing the distance of research objects with digital models based on 4 distances that are easily identified from the research object, digital models and print models. Where the physical object geometric coordinates are bound using the terrestrial measurement method that is bound to the contral point of the ground using the concept of perfectly closed polygons. The distance of the object of research is obtained from the field measurements and the distance of the digital model is obtained from measurements on the meshlab software. The results of the measurement of the difference in the position of the coordinates of the binding results in the field and in the 3D model are indicators of the accuracy and accuracy of the research results.

3. Results and Discussion

3.1. Data Preparation
The preparation phase consists of the study of literature, object survey and preparation of tools described as follows:
1. Literature study
   Literature study is an activity to determine the theoretical basis along with previous research in accordance with the research theme as a reference and facilitate researchers in conducting research. Literature study is mandatory for every researcher.
2. Survey of objects
   The next stage is a survey of research objects. The object survey is conducted to determine the location of the object, the condition of the field around the object and the constraints in taking data so that a photo capture strategy is obtained. The object survey results are also used as material for designing terrestrial measurement polygons.
3. Preparation of the tool
   Tool preparation is done on two devices, namely the camera and the total station. Camera preparation is done by checking the completeness of each device. The equipment for the camera is in the form of a camera body, lens, SD card, battery and tripod, while the equipment for the total station is the total station itself, batteries, stative, reflector and other markers.

3.2. Data Acquisition
The data collection phase consists of camera shooting and polygon and point detail measurements.
1. Camera shooting
   Taking photos is done using a tripod to get stable results without shock in each photo. The shooting itself is carried out at three heights that can be seen in Figure 2 done to take areas that are difficult to reach, namely the lower and upper cows, to minimize areas that are not covered by photos and areas with little point cloud.
Object shooting also uses manual camera settings. The settings are made by taking a few sample images and adjusting parameters to the image. The settings made in the form of lens focus, shutter speed, ISO and aperture can be seen in Table 1.

![Figure 2. Camera Height Simulation](image)

**Table 1. Camera Setting**

| Parameter   | Setting |
|-------------|---------|
| Fokus       | 18 mm   |
| Shutter Speed | 1/25   |
| ISO         | ISO-100 |
| Aperture    | F22     |

ISO 100 on the camera is used to minimize the amount of noise in photos because photos that have high ISO tend to have a lot of noise. The aperture that is used is f / 22 is used to minimize blur in the image, so the image has a large focus area. ISO 100 and f /22 aperture have the characteristics of a dark image when taken in inadequate lighting, but when taking light photos at an adequate location, the results of the photo looks bright and minimal noise. In addition, a shutter speed of 1/25 is used to finalize photo brightness settings. The photos can be seen in Figure 3.

![Figure 3. Image Result](image)

2. Measurement of polygons and point detail

Polygon measurement using electronic total station. This measurement is used for detailed points on ground coordinates. The type of polygon used is closed polygon with 2 points whose coordinates are known. Detailed point measurements are made from points near the Cow Statue. Polygon sketch can be seen in Figure 4.
3.3. Data Processing

1. **Polygon Data and Detail Points**
   X and Y polygon coordinate calculations are done by the Bowditch Method. Detailed point calculation uses the polar coordinate method which uses the distance of horizontal and vertical reading angles of the instrument.

2. **Sparse Reconstruction**
   Sparse reconstruction processing in VisualSfM is useful for creating sparse point cloud from the process of matching images in three-dimensional space. The next step is 3D reconstruction which is carried out to process the results of match image into sparse point cloud. The match image process will display the photo orientation in the field as well as the sparse point cloud as shown in Figure 5.

3. **Dense Reconstruction**
   Dense reconstruction using CMVS. This process will close the point cloud so that the result will have more point clouds than the sparse point cloud that can be seen in Figure 6.
4. Filtering
Filtering is the stage of cleaning vertexes that are not needed. The result of dense reconstruction is to do filter points that are not needed manually. The results of this process can be seen in Figure 7.

5. Surface Reconstruction
Surface reconstruction is the stage of building the surface of point clouds/vertexes that have been cleaned by filtering. The method used is screened Poisson surface reconstruction. Screened poison surface reconstruction produces a waterproof surface so there are no holes on the surface. The surface reconstruction treatment is then continued by scaling 1:1 using detailed terrestrial measurement data.

5.1. Data Validation
Based on the above results, it can be concluded that the polygon measurement meets tolerance in Class IV [6] in Table 2. The results of the polygon calculation and details can be seen in Table 3.

Table 2. Polygon Coordinates

| No | Titik | X (m)        | Y (m)        | Z (m)        |
|----|-------|--------------|--------------|--------------|
| 1  | GD 28 | 438102.859   | 9220279.867  | 210.096      |
| 2  | GD 5  | 438005.076   | 9220310.133  | 207.596      |
| 3  | P1    | 438133.763   | 9220270.910  | 210.585      |
| 4  | P2    | 438130.790   | 9220262.764  | 210.647      |
Table 3. Detail Coordinates

| No | Point | X (m)   | Y (m)   | Z (m)   | Description          |
|----|-------|---------|---------|---------|----------------------|
| 1  | MT1   | 438130.363 | 9220265.937 | 211.972 | Inner Left Eye       |
| 2  | MT2   | 438130.315 | 9220265.933 | 211.980 | Outer Left Eye       |
| 3  | MT3   | 438130.417 | 9220265.878 | 211.968 | Inner Right Eye      |
| 4  | MT4   | 438130.429 | 9220265.825 | 211.969 | Outer Right Eye      |
| 5  | KP1   | 438130.111 | 9220265.981 | 212.036 | Left Ear             |
| 6  | KP2   | 438130.558 | 9220265.671 | 212.002 | Right Ear            |
| 7  | HD1   | 438130.436 | 9220265.971 | 211.787 | Front Nose           |
| 8  | HD2   | 438130.380 | 9220265.960 | 211.791 | Left Nostril Nose    |
| 9  | HD3   | 438130.451 | 9220265.928 | 211.791 | Right Nostril Nose   |
| 10 | KA1   | 438130.101 | 9220265.576 | 210.932 | Front Left Nose      |
| 11 | KA2   | 438130.307 | 9220265.632 | 210.941 | Front Right Foot     |
| 12 | KA3   | 438130.245 | 9220264.878 | 210.930 | Back Left Foot       |
| 13 | KA4   | 438130.518 | 9220264.712 | 210.932 | Back Right Foot      |

Figure 8. 3D Digital Model

The digital model results that can be seen in Figure 8 obtained as a whole already resemble the shape of the research object. The details obtained are also quite good, this can be seen from the folds of fat that can be processed in a cow's body. This level of detail is influenced by the level of camera resolution. The camera resolution used is 12.20 MP with dimensions 4272x2848. This high resolution produces a lot of pixels that can be matched to produce a denser point cloud like the digital model results obtained. This dense point cloud also produces a good level of accuracy by minimizing software-intervened points in sparse areas. In addition to good detail the object also does not have a hollow area because the surface reconstruction process uses the screened poisson surface reconstruction method to produce a watertight surface so that it does not have a hollow area. Although overall the digital model has no holes, there are several places on objects that have a rough-looking texture due to the rarity of point clouds in that area which can be seen in Figure 9.
Comparison of the distance of research objects with digital models using 4 distances that are easily identified from the research object, digital models and print models that can be seen in Table 4. The distance of the object of research is obtained from the field measurements and the distance of the digital model is obtained from measurements on the Meshlab.

### Table 4. Comparison of object distance with digital model

| Name       | Distance (m) | Diff (m) |
|------------|--------------|----------|
| HD2 – HD3  | 0.078039     | 0.000182 |
| KA1 – KA2  | 0.212917     | 0.002358 |
| KP1 – KP2  | 0.545186     | 0.008332 |
| MT2 – MT4  | 0.157025     | 0.003224 |
| Total      | 0.014097     |          |
| Mean       | 0.003524     |          |

The results of distance measurements show the highest value of difference, namely KP1-KP2 of 0.008332 m (8.332 mm) and the lowest value of HD2 - HD3 of 0.000182 m (0.182 mm). The average value obtained was 0.003524 m (3.524 mm) and the standard deviation value was 0.002989 m (2.989 mm). The distance calculation results show a pretty good difference in objects where all the results are in units of millimeters.

### 6. Conclusions

Based on the results of the study it was concluded that the results of the digital model of the cow statue in terms of visual color are quite good but there are some parts that have a color that is less appropriate due to the rarity of point clouds in the area. The visual aspect of the captured detail is also quite good as seen from the detail of the fat folds on the side of the cow. The geometry of the accuracy distance has an average of 3.524 mm and a standard deviation of 2.989 mm shows good results which are in units of mm.

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