Application of geographical information system for the 3d modelling of close-range photogrammetry for documentation and landscape development of historical monuments

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Abstract. Historical monuments, in the form of immovable objects such as temple buildings are part of our lives, they represent our history. Historic buildings must be preserved for future generations, by documenting buildings in 3D. Three-dimensional (3D) Geographic Information System (GIS) can be used for landscape development planning around the building. 3D-GIS with GIS analysis function to provide information related to geographical location and 3D visualization. 3D GIS models can be interpreted as digital representations of terrain and objects contained in around. In this study, the method used is a close range photogrammetry method for 3D modeling using a non-metric digital camera. For the stages of research implementation, the stages of camera calibration, object shooting, processing of 3D models are divided. For the calibration process, 80% is obtained, fulfilling the calibration requirements. The building modeling phase consists of Automated Projects, the process of calculating and creating 3D models, 3D coordinate transformations, 3D model visualization and statistical analysis. Documentation of Gedong Songo Temple in Semarang Regency. This study 3D model results testing is done by calculating the difference in the distance of the model with measurements in the field (terrestrial) with the Electronic Total Station (ETS) and the distance measuring Tape. The results of the distance comparison analysis obtained a maximum distance shift value of 4.00 centimeters and an RMS value of 4.69 centimeters. The values obtained are relatively small.

1. Introduction
Documentation of historic buildings carried out for development planning including for reconstruction and conservation has the highest level of accuracy and work detail. Reconstruction is the rearrangement of a damaged or collapsed building structure, which is the original building material that has been lost. In this case we can use new materials such as colored paint or other materials whose shapes must be adjusted to the original building. Conservation is an activity to preserve and protect places that are beautiful and valuable, so that they are not destroyed or modified to a reasonable extent. Reconstruction and conservation usually refers to building documentation before change. To illustrate the real condition of an object, and to measure angle from corner in all directions, especially points that cannot be accessed, making accurate 3D models is needed. The development of historical 3D modeling monuments, especially the processing of detail structures and textures has recently been greatly improved. [3,7].
Three-dimensional (3D) geographic information system (GIS) can be used for landscape development planning around the building. 3D-GIS with GIS analysis function to provide information related to geographical location and 3D visualization. The 3D GIS model can be interpreted as a digital representation of the terrain and objects around it. 3D GIS models have varying levels of information detail depending on the type of information and the details of the object delivered. The level of detail of the 3D GIS model consists of LD0, LD1, LD2, LD3, and LD4. Accurate 3D modelling and visualization can use the Close Range Photogrammetry method by extracting 3D coordinate points from images shot at close range. Digital photogrammetry takes all the right measurements of the image itself rather than measuring it directly from the object [4]. Documentation is not only limited to knowing the geometrical dimensions of buildings, but also relates to how much changes in the geometry dimensions of buildings that occur within a certain period of time. A close range photogrammetry method can be used if the distance between objects to the camera is less than 100 meters. Close range photogrammetry applications are expected to be used for the preservation of historic buildings in Semarang. The problems that arise from the background of the study are 3D GIS methods and Close Range Photogrammetry can be an alternative in building documentation which is then used as a reference for reconstruction and conservation.

2. Methods

2.1. Description of Study Area
The study was conducted in Gedong Songo Temple complex Semarang District. This temple is 45 km from the city of Semarang and located on Latitude 7° 12’ 39.72” S and Longitude 110° 20’ 32.88” E. Gedong Songo (Nine Buildings) is the name of a temple in the hills of the Ungaran mountains show in Figure 1.

![Figure 1.](image)
(a) Location of study area in Semarang Distric, (b) Inside the temple I site Gedong Songo Temple complex, (c) Gedung Songo Temple I photo

2.2. Experiment
The method this study was followed in this study, the activities carried out were:
- Camera Calibration;
- Measurement Framework and Point Details;
- 3D Model Generation; and
- Texturing and 3D Visualization

2.2.1 Camera Calibration
The implementation of Camera Calibration is required for the process of determining the camera's internal parameters. Internal parameters are needed to reconstruct the beam of light when shooting and determine the systematic error of the camera. The principle of calculating the camera's internal parameters analytically uses the self calibration bundle adjustment method to the target point in the
calibration field. The calibration field is used with the form of black dots on white paper size A0. The calibration field is the default calibration field of the Photo Modelling Scanner software. In this study, using 12x12 field calibration to anticipate if the number of photos is more than 8 photos and the result show in Figure 2 and Table 1.

![Field Calibration size 12x12 and Position the camera against field calibration](image)

**Figure 2.** (a) Field Calibration size 12x12 and (b) Position the camera against field calibration

| Inner Orientation Parameter | Value       | Deviation |
|-----------------------------|-------------|-----------|
| Focal Length                | 27.726851 mm| 0.004 mm  |
| Xp (principal point position)| 11.375051 mm| 0.003 mm  |
| Yp (principal point position)| 7.528632 mm | 0.004 mm  |
| K1 (Radial Distortion)      | 1,290E-01   | 1.1e-006  |
| K2 (Radial Distortion)      | -2,659E-04  | 7.7e-009  |
| K3 (Radial Distortion)      | 0.000e+000  | 0.000e+000|
| P1 (Radial Distortion)      | 2,562E-02   | 1.1e-006  |
| P2 (Radial Distortion)      | -3,871E-02  | 1.6e-006  |
| Average Photo Point Coverage| 85%         |           |

At close range photogrammetric measurement techniques are measured against the objects recorded from several sensors. When the photo is taken, the beam from the object file will spread like a straight line to the center of the camera lens to reach the film field. A condition where the point of an object in the photo plane is located in a line in a space called a collinear ray condition or a collinearity condition show in Figure 3.

![Principle beam collinear condition or the condition of collinearity](image)

**Figure 3.** Principle beam collinear condition or the condition of collinearity

2.2.2 Measurement Framework and Point Details

At this stage, it is doing the basic framework and detailed point measurements using an electronic total station. This measurement is used as coordinates that are bound to the ground. The basic framework is known to coordinate a number of points in a particular system that has a function as a binder and a new point controller [1,8]. The points are spread evenly throughout the mapped area. The basic
framework consists of flat plane coordinates (X, Y) and those that have altitude values (Z). How to measure the basic framework is by using polygons. The shape of the polygon used in this measurement is a closed polygon with local coordinates. The coordinates as the starting point are P1 (5000,000; 5000,000; 0,000). For detailed point measurements, the method used is the targeted tachymetry method from the base frame point. Building side measurements are carried out as validation of building model data. The side of the building is measured using a measuring tape and electronic total station to be compared with the side of the building model. The side of the building that is measured is the dimension of the building which covers the width and length of the building. In this study the outer side of the floor and main building were measured as data validation.

### 2.2.3 3D Model Generation

Although the coordinates of point calculation in 3D models are done automatically, but in reality there is still a need for human interaction in the selection of specific object points in the formation of the model [5,6]. 3D models without surface or texture are the shape of the wireframe model. The wireframe model represents buildings as the number of vertices and edges. This representation is true if someone is interested in the general form of the building. The main software used in this research in the formation of 3D is the Photo Modeler Scanner, this is software created by Eos Systems Inc. who are members of Windows Corporation. The main use of this software is a process called reverse camera, the process can make accurate measurements in undefined origin photos. Photo Modeler Scanner Module is used to create 3D models from a series of images of an object. The resulting model is a set of three-dimensional points that have Cartesian 3D coordinate values. When starting to use the Modeler Scanner software, Getting Started will appear. To start a new project can use the selection of Point-Based Projects. This option is used if the 3D object model is formed by dots on the photo. At this stage, mark the point object and identify the same point in a different photo. To form a 3D model the same points are needed in at least two different photos. The Marking and Referencing process can be done in two ways, first is Marking pictures and references in overlapping photos or can also the Marking and Referring process simultaneously to two or more photos show in Figure 4.

![Figure 4](image)

**Figure 4.** (a) Views marking and referencing process from the side and (b) from the front

### 2.2.4 Texturing and 3D Visualization

The object of texture mapping results is the result of merging of 3D geometry and 2D imagery. To obtain a form of a real object model, a number of 2D images are needed representing all sides of 3D geometry. But for objects that have irregular geometry such as balls, cones, tubes, etc., a certain algorithm is needed to minimize the distortion that occurs so that the texture mapping object matches the real conditions [2][9]. The end result of the 3D model of the texture object is displayed in VRML. For the visualization of the three-dimensional model formed in the form of the shadow surface and the skeleton model, the sub menu used for visualizing 3D models is the Open 3D Display found in the
Display menu. In order for the building to resemble the actual physical, the building can be given a texture. Texturing can be done in 3D Viewer Option to select Quality Textures in the Display Style sub menu show in Figure 5.

![3D Viewer Options](image)

**Figure 5.** (a) 3D Option display and (b) Front side view of the 3D model with Quality Texture

3. Result and Discussion

3.1 Evaluation Results Calibration

Calibration results are one of the important results in the formation of 3D models. Calibration results that affect the camera's internal parameters are needed to reconstruct the beam when shooting. Following are the results of camera calibration used in this study. From the results of camera calibration it can be seen that the focal length of the camera used in this study is 27.726851 or 28.00.

The average value of the photo point is 85%, this value is included in the Photo Modeler Scanner camera calibration requirements as the minimum value for the average photo point coverage is 80%.

3.2 Comparative Analysis Distance

Comparative analysis is carried out on the outer side of the ground floor and the main building in Gedong Songo Temple. The measurement uses a measuring tape and electronic total station show in Figure 6.

![Figure 6](image)

**Figure 6.** Sketch of the measurement side of the building Gedong Songo Temple

The result distance measuring tape (2), distance from coordinate measurements to electronics total stations (ETS) (3) with 3D models (1) show in Table 2.

| No. Side | Measuring Model (1) (centimeter) | Measuring Tape (2) (centimeter) | Measuring ETS (3) (centimeter) | Difference (2)-(1) (centimeter) | Difference (3)-(1) (centimeter) |
|----------|---------------------------------|---------------------------------|-------------------------------|-------------------------------|-------------------------------|
| A        | 263                             | 266                             | 265                           | 3                             | 2                             |
B  120  122  123  2  3
C  245  247  248  2  3
D  761  763  764  2  3
E  756  759  760  3  4
F  759  763  765  4  6
G  248  246  246  -2 -2
H  111  117  117  6  6
I  392  397  398  5  6
J  389  394  393  5  4
K  387  394  395  7  8
L  391  395  396  4  5

| Difference total | 41 | 48 |
| Difference average | 3.42 | 4.00 |
| RMS | 4.09 | 4.69 |

3.3 Comparative Analysis coordinates
The maximum value difference between the model and the tape is 7 centimeters and the minimum value is -2 centimeter. The total error value is 41 centimeters and the average error value is 3.42 centimeters. While the maximum value of the difference in distance between models with ETS is 8 centimeters and the minimum value is -2 centimeter. The total error value is 48 centimeters and the average error is 4.00 centimeters. The RMS value of the distance between the model and the tape is 4,09 centimeters, while the value of the RMS distance between the models with ETS is 4,69 centimeters and shows a greater value.

4. Conclusion
From building 3D modeling research with close range photogrammetry method, it is concluded that:
1. The results of the distance comparison analysis obtained a maximum distance shift value of 4.00 centimeters and an RMS value of 4.69 centimeters. The value of the distance comparison between photogrammetric methods and field measurements still has differences, this can occur due to errors in the field when placing the same point between measurements in the field with points on the 3D model. But from the results of the distance comparison the values obtained are relatively small or are said to be relatively precise results.
2. The method of close range photogrammetry using a non-metric digital camera can be used to model the temple building. To get a 3D model with good geometry, it must first do camera calibration accuracy. Close range photogrammetric methods can be used for alternative documentation of temple buildings and references for reconstruction and conservation.

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