Application of augmented reality and close range photogrammetry technology for mapping of cultural heritage areas (case study: Ai Renung Site, Sumbawa Regency)

A A H Aljabar, A B Cahyono and H Hidayat

Department of Geomatics Engineering, Institut Teknologi Sepuluh Nopember Kampus ITS, Keputih, Sukolilo, Surabaya, 60111, Indonesia

Abstract. The Ai Renung site is the first megalithic complex site on Sumbawa that has 8 sarcophagus objects and has been used as an ancient park by the NTB Provincial Cultural Heritage Preservation Hall. Unfortunately, until now it does not have a cultural heritage map that describes the location and condition of the site, so the presentation of spatial information that describes the location is not conveyed to tourists. In this study, an augmented reality application was made from a combination of 3D model visualization and orthophoto maps. Augmented reality application is implemented on an Android device. Application users can see the visualization of the 3D sarcophagus model virtually using an Android device when scanning one of the markers found on the Ai Renung Site Cultural Heritage Map. This study also analyzes 3D models and orthophoto. The results of the control point analysis on orthophoto, the RMSE value of 0.293 m was produced. Based on the CE90 test of the RMSE value, orthophoto can be used as a base map in making Cultural Heritage Zone Maps with a scale of 1: 1000 and entering into order class 3. As for forming a 3-dimensional model, most 3D model objects have RMSE values that are less than 0.5 m. So that it meets the Level of Detail 3 order criteria.

1. Introduction

The Ai Renung site is located in Batu Tering Village, Moyo Hulu District, Sumbawa Regency, West Nusa Tenggara and is divided into 5 sites with the main findings in the form of sarcophagi. The location of the Ai Renung site is in hilly areas and protected forests which are managed into plantations and rice fields. This location is quite difficult to reach and far from residential areas. In addition, the Ai Renung Site also does not have a cultural heritage area map that describes information on the location and shape of the situation from the five sarcophagus sites [1].

Currently, 3-dimensional modeling visualization has added value in the strategy of delivering visual and spatial information on cultural heritage objects. The acquisition method that is often used in 3-dimensional modeling is Close Range Photogrammetry [2]. Augmented reality is one of the new technologies in the field of multimedia which is the development of virtual reality. Augmented reality adds existing and real reality with elevated objects where this technology seems to eliminate the 3-dimensional virtual world and merge with the real world [3].

In this study, the application of the Ai Renung Site Cultural Heritage Area Map was based on augmented reality technology. This research is expected to be able to produce an application of...
augmented reality technology that can display 3D virtual objects into real environments. The main component of this study uses a target image in the form of an orthophoto map and a virtual object in the form of a 3D model. The way this system works is that when the target image is detected by the AR camera, the 3D sarcophagus virtual object will appear in a real environment [4]. This study also analyzes the RMSE value of the 3D model and orthophoto. By looking at the map of the cultural heritage area, it can be used as a reference for research, planning, and development of historical objects, especially in the Ai Renung Site Area. In addition, augmented reality technology can also help and attract tourists to explore historic objects from the Ai Renung Site area.

2. Methodology

2.1. Study area and data
The location in this study was at the Ai Renung Cultural Heritage Site, Batu Tering Village, Moyo Hulu District, Sumbawa Regency, West Nusa Tenggara. This location is located between coordinates 8 ° 41'33" - 8 ° 41'59" LS to 117 ° 26'45" - 117 ° 27'10" BT.

![Figure 1. Research location.](image)

The data used in this study include aerial photographs of the Ai Renung Site acquired on November 17, 2018, with the DJI Phantom 4 Pro Drone, photo terrestrial Ai Renung Site acquired on November 17-18, 2018, with Sony Mirrorless Camera and Nikon Coolpix Camera Aw 130 , and control point coordinates of the Ai Renung Site acquired on November 17-18 2018 using a Hi Geodetic GPS Target and 202 Gowin TKS Total Station.

2.2. Data processing
- Making a Site Object 3D Model
  The object's 3D model is made from terrestrial photo data selected first. The first process is aligned photo which functions to combine selected photos. After that, masking photos and georeferencing are carried out using the control points of the total station. The next process is to build dense cloud which functions to close dots that represent 3D models with higher density. The next process is meshing and texturing which functions to refine the shape and make the coloring of 3D objects. Then the geometric precision analysis of the 3D model was carried out to meet the Level of Detail order of 3. The last stage is to export the data into a format (.Fbx) which will be used as a virtual object in making augmented reality applications.
• Making Orthophoto Region of Ai Renung Site
  Ortofoto is made from previously selected aerial photograph data. The orthophoto processing process is the same as processing 3D models, namely aligning photos, masking, georeferencing, building a dense cloud, meshing, and texturing. The georeferencing process is carried out with GCP points of 4 points acquired using geodetic GPS. The next stage is orthomosaic build which functions to form upright photos according to the coordinate system used. The last step is to export the data into a format (.tif) which will be used as a base map in making maps of cultural heritage areas. This map serves as a marker image on augmented reality applications.

• Making Augmented Reality
  Augmented reality is made from 3D model data and orthophoto maps. The first stage is Development Image Target. At this stage, the target image is formed. Image targets needed include the license manager and a marker. The license manager is useful for supporting AR Camera to recognize the target image that has been registered into the AR world and is useful as a build application. After that, the marker is registered into the AR system by checking the marker pattern through vuforia, so that the marker performance will be seen through the rating indicated by each target image created.

• Check State Image Target
  Import markers that have been registered into the target image in Unity software. Then import the virtual object you want to project, which is the 3D object model with the format (.fbx). After that, adjust the scale, rotation, and position of the 3D model object to the target image to fit the size.

• 3D model rendering with Marker
  At this stage, the rendering process of the 3D object model (virtual image) is carried out with markers found on the orthophoto map of cultural heritage areas to become an augmented reality technology. After that, the conformity test process is carried out on the marker. If the marker is by the virtual object, then the process of making the augmented reality is declared successful.

• Making User Interface and Application Testing
  The final stage in this research is the creation of augmented reality applications. Therefore the author needs a user interface so that the application can be accessed easily and user-friendly. Testing this application is done on the Android system and aims to determine the function of the entire application. Testing is done by trying the button contained in the augmented reality application, including the Play AR Camera button, credits, help, and exit. Button Play AR functions to see augmented reality, the credits button serves to display the description of the application's maker name, the help button serves to display the application usage guide, and the exit button functions to exit the application. The testing of virtual objects includes magnification and rotation of objects on the AR camera.

3. Result and discussion

3.1. Dimensional model results and analysis
In this study, there were 8 3-dimensional models of sarcophagus objects on the Ai Renung Site made using the close-range photogrammetry method. The details of the number of photos on Site 1 were 168 photos, Site 1a as many as 186 photos, Site 1b as many as 204 photos, Site 2 as many as 283 photos, Site 3 as many as 244 photos, Site 4 as many as 206 photos, Site 5a as many as 292 photos, and Site 5b as many as 78 photos.

After processing, 3D models are produced with a large number of point clouds and polygons. The details of the number of point clouds on Site 1 produced 2,037,875 points, Site 1a 7,586,776 points, Site 1b 4,334,207 points, Site 2 6,239,697 points, Site 3 12,725,750 points, Site 4 8,420,008 points, Site 5a as many as 4,629,802 points, and Site 5b as many as 4,174,249 points. Whereas the number of polygons
on all sites does not exceed 20,000 polygons. The following are the results of the Ai Renung Site 3D model.

![Figure 2. Results of the 3D Model Objects of Ai Site Devotional](image)

A control point is needed to analyze the position and size error values in an object's 3D model. The results of the control point coordinates on each object of the Ai Renung Site are as follows.
Table 1. Coordinate result of object control points.

| Numb | Point | Easting (m) | Northing (m) | Altitude (m) | Site |
|------|-------|-------------|--------------|--------------|------|
| 1    | TK1   | 549392,514  | 9038586,761  | 460,005      | 1    |
| 2    | TK2   | 549393,188  | 9038586,301  | 459,911      | 1    |
| 3    | TK3   | 549394,347  | 9038587,774  | 460,133      | 1    |
| 4    | TK4   | 549393,765  | 9038588,239  | 460,062      | 1    |
| 5    | TK9   | 549382,540  | 9038601,241  | 458,802      | 1a   |
| 6    | TK10  | 549385,860  | 9038599,131  | 459,396      | 1a   |
| 7    | TK11  | 549383,329  | 9038598,572  | 459,570      | 1a   |
| 8    | TK12  | 549386,099  | 9038600,801  | 459,544      | 1a   |
| 9    | TK2   | 549399,931  | 9038590,477  | 460,202      | 1b   |
| 10   | TK3   | 549398,478  | 9038591,667  | 460,052      | 1b   |
| 11   | TK4   | 549398,422  | 9038589,976  | 459,908      | 1b   |
| 12   | TK1   | 549433,791  | 9038673,346  | 463,863      | 2    |
| 13   | TK2   | 549430,414  | 9038668,874  | 463,872      | 2    |
| 14   | TK3   | 549428,278  | 9038673,326  | 464,335      | 2    |
| 15   | TK4   | 549431,983  | 9038675,779  | 464,238      | 2    |
| 16   | TK5   | 549433,409  | 9038674,874  | 464,015      | 2    |
| 17   | TK1   | 549431,438  | 9038877,094  | 451,835      | 3    |
| 18   | TK2   | 549430,327  | 9038884,894  | 451,094      | 3    |
| 19   | TK3   | 549434,538  | 9038879,784  | 451,764      | 3    |
| 20   | TK4   | 549439,278  | 9038884,822  | 451,063      | 3    |
| 21   | TK1   | 549297,798  | 9038743,534  | 459,114      | 4    |
| 22   | TK2   | 549296,417  | 9038751,134  | 461,805      | 4    |
| 23   | TK4   | 549300,222  | 9038747,651  | 461,963      | 4    |
| 24   | TK5   | 549300,693  | 9038747,903  | 462,242      | 4    |
| 25   | TK7   | 548946,431  | 9038655,266  | 496,971      | 5a   |
| 26   | TK8   | 548946,447  | 9038655,648  | 497,031      | 5a   |
| 27   | TK9   | 548947,612  | 9038655,854  | 496,132      | 5a   |
| 28   | TK10  | 548947,662  | 9038655,337  | 496,127      | 5a   |
| 29   | TK5   | 548920,815  | 9038629,792  | 507,197      | 5b   |
| 30   | TK6   | 548919,485  | 9038629,101  | 507,831      | 5b   |
| 31   | TK7   | 548919,846  | 9038628,638  | 507,871      | 5b   |
| 32   | TK8   | 548920,474  | 9038630,218  | 507,296      | 5b   |

Based on the results of the above coordinates, then the calculation of position accuracy and height is calculated in the Root Mean Square (RMSE) value. The results of the RMSE on the Ai Renung Site are as follows.

Table 2. 3D Model RMSE Value

| Numb | Site  | RMSE X (m) | RMSE Y (m) | RMSE Z (m) | Total (m) | Notice |
|------|-------|------------|------------|------------|-----------|--------|
| 1    | Situs 1| 0.009      | 0.013      | 0.031      | 0.035     | Accepted |
| 2    | Situs 1a| 0.109      | 0.107      | 0.249      | 0.293     | Accepted |
| 3    | Situs 1b| 0.015      | 0.015      | 0.009      | 0.023     | Accepted |
| 4    | Situs 2 | 0.056      | 0.116      | 0.016      | 0.129     | Accepted |
| 5    | Situs 3 | 0.035      | 0.023      | 0.009      | 0.043     | Accepted |
| 6    | Situs 4 | 0.074      | 0.043      | 0.031      | 0.091     | Accepted |
| 7    | Situs 5a| 0.015      | 0.014      | 0.009      | 0.023     | Accepted |
In this study, an accuracy analysis was described in the 3D Root Mean Square (RMSE) model and used the 3rd order LoD tolerance limit with a minimum RMSE value of 0.5 m. Based on the RMSE value table above, most 3D models meet the 3rd order LoD criterion. The smallest RMSE values are found on Site objects 1b and 5a with RMSE values of 0.023 m and the largest values found on Site 1a objects with RMSE values of 0.293 m (not accepted). Based on the analysis, the Site 1a RMSE value is large because the determination of control points is not easily marked. This is because the sarcophagus on Site 1a has an asymmetrical shape and there are many carvings. In addition to accuracy, the 3D model of the object produced is in the form of exterior and structure formed according to the actual object on the Ai Renung Site. The diagram of the 3D model RMSE value is as follows.

![RMSE 3D Model Value Chart](image1)

**Figure 3.** RMSE 3D model value chart.

Also, this study also analyzed the error in the size of the 3D model of the object. Analysis of size errors is carried out with the help of a 0.5 m scale bar placed on each object on the Ai Renung Site. The minimum number of scale bars on each site is 1. Then georeferencing of the scale bar is carried out according to the length of the size. The results of the size error on each object on the Ai Renung Site are as follows.

![3D Model Average Value Error Chart](image2)

**Figure 4.** 3D Model Average Value Error Chart

Based on the results of the diagram above, the error value of the average size of each object is less than
The smallest error value is found on-site 1b with a value of 0.005 m and the biggest error is found on-site 5b with a value of 0.095 m.

3.2. Results and analysis of orthophoto
In this study, orthophoto was made using aerial photo data of 608 photos. After going through the processing stage, the orthophoto produces 9,348,921 point clouds and 1,869,709 polygons. Ortofoto is used as a base map in making maps of the Ai Renung Site Area. The orthophoto results are as follows.

![Orthophoto results of Ai Renung Site.](image)

In the georeferencing process, of course, produces a difference in horizontal coordinates between the model coordinates and map coordinates. The difference in the coordinate value results in a horizontal error value, so it needs to be analyzed [5]. The results of the analysis of horizontal error values are as follows.

| Point | X (m)       | Y (m)       | Altitude (m) |
|-------|-------------|-------------|--------------|
| GCP1  | 549563,299  | 9038917,952 | 421,835      |
| GCP2  | 549381,275  | 9038608,329 | 458,141      |
| GCP3  | 549428,103  | 9038674,921 | 464,389      |
| GCP4  | 549431,438  | 9038877,093 | 451,950      |
| GCP5  | 549297,798  | 9038743,534 | 459,114      |
Table 4. X Coordinate Error Test Results

| Point | X Model (m) | X Map (m) | Error (m) |
|-------|-------------|-----------|-----------|
| GCP 1 | 549563,299  | 549563,254| -0,045    |
| GCP2  | 549381,275  | 549381,305| -0,030    |
| GCP3  | 549428,103  | 549428,011| 0,092     |
| GCP4  | 549431,438  | 549431,427| 0,011     |
| GCP5  | 549297,798  | 549297,280| 0,518     |

Table 5. Y coordinate error test results

| Point | Y Model (m) | Y Map (m) | Error (m) |
|-------|-------------|-----------|-----------|
| GCP 1 | 9038917,952 | 9038917,956| 0,004     |
| GCP2  | 9038608,329 | 9038608,062| 0,267     |
| GCP3  | 9038674,921 | 9038674,657| 0,264     |
| GCP4  | 9038877,093 | 9038877,046| 0,047     |
| GCP5  | 9038743,534 | 9038743,451| 0,083     |

Based on the results of the analysis, the RMSE value that exceeds 0.1 m is caused by a lack of premarked GCP photos. So that in georeferencing, the process of giving markers is less evenly distributed. After knowing the horizontal error value, then calculate the RMSE (Root Mean Square Error) to determine the accuracy of reading predictions. The RMSE value is calculated using the following formula:

\[
RMSE_x = \sqrt{\frac{\sum (X_{model}-X_{lapangan})^2}{n}}
\]

\[
RMSE_y = \sqrt{\frac{\sum (Y_{model}-Y_{lapangan})^2}{n}}
\]

\[
RMSE_r = \sqrt{RMSE_x^2 + RMSE_y^2}
\]

Based on the RMSE formula above, the value of RMSE X is 0.237 m, RMSE Y is 0.173 m, and RMSE R is 0.293 m. The RMSE value is good because the value is below 1 m, so the accuracy of the photo meets the requirements to be used as a base map in the cultural heritage area map. The accuracy value of the base map position is the CE90 value for horizontal accuracy which means that the horizontal position error (X, Y) on the map does not exceed the accuracy value with a confidence level of 90%. The CE90 value can be obtained by a formula that refers to the 2014 PERKA BIG BIG rule.

\[
CE90 = 1,5175 \times RMSE_r
\]

Based on the CE90 calculation formula above, a value of 0.445 m is obtained. The results of these values belong to class 3 for a 1: 1000 base map. The CE90 table results are as follows.
3.3. Results of augmented reality applications

In this study, augmented reality was created with 3D models as virtual objects and orthophoto maps of the Ai Renung Site Area as a marker image. In making augmented reality, the first process is to develop a marker image. This process aims to build a marker that is used as a marker in augmented reality. The way it works is when AR Camera is directed to the marker, then the 3D virtual object will appear. To build a marker, a pattern is needed from the image marker. The pattern is the target image string captured by the AR camera. After finding the pattern from the marker image, a rating will appear from the image marker on the Ai Renung site as shown in the following image.

| Numb | Target Marker Name | Rating | Status |
|------|--------------------|--------|--------|
| 1    | Situs 1            | 4      | Aktif  |
| 2    | Situs 1a           | 3      | Aktif  |
| 3    | Situs 1b           | 4      | Aktif  |
| 4    | Situs 2            | 4      | Aktif  |
| 5    | Situs 3            | 5      | Aktif  |
| 6    | Situs 4            | 3      | Aktif  |
| 7    | Situs 5a           | 4      | Aktif  |
| 8    | Situs 5b           | 5      | Aktif  |

Making augmented reality is done by combining marker images and 3D objects on Ai Renung's Site. The use of this marker image serves as an identification to bring up the 3D model virtually. There are 8 image markers that will be attached to the cultural heritage area map. In combining the marker image and 3D object model in augmented reality, it is necessary to adjust the size and rotation scale. The results of the orthophoto map are as follows.

![Figure 6. Site Map of Ai Renung](image-url)
Then the results of augmented reality are exported to an Android device. At the stage of making the application, interface design is needed so that users can use it easily. On the first page there is a menu display that contains 4 buttons, namely Play AR, Credit, Help, and Exit. Button Play AR functions to display the augmented reality 3D model of the Site Ai Renung object, the button credit functions to display the information of the application maker, the help button serves to display the application usage guide, and the exit button functions to exit the application. The display of the main menu of the augmented reality application is as follows.

![Initial Menu Application](image1.png)

**Figure 7.** Display of the initial menu application.

![Button Play AR](image2.png)

**Figure 8.** Display of button play AR.

### 3.4. Application Testing

This test is carried out on the Android system to determine the performance of the function of the button. Button tested includes augmented reality performance, magnification and rotation functions on virtual objects, and others. The steps for testing this application include:

- Build an augmented reality application to the Android (.apk) platform
- Download the application then install it to the Android system
- Run the application installed on Android.
- Test several buttons in the application
- On the AR play button, do the AR camera test according to the marker
- Perform observations of virtual objects that appear by magnifying and rotating objects.
4. Conclusion

- Produced 8 3D models of objects from the Ai Renung Site using the close-range photogrammetry method. Based on the horizontal RMSE value, the entire object meets the LoD 3 criteria. As for error, the size of all objects is classified as good because the error value is below 0.1 m.
- An orthophoto map of the Ai Renung Site Area has been produced with a 1: 1000 scale and equipped with 8 marker images. The horizontal RMSE value is 0.293 m. Based on the accuracy value of the base map position (CE90) the value is 0.445 m, so the orthophoto map is included in class 3.
- Augmented reality application Site Ai Renung has been created and implemented on an Android device. Based on the results of the trial, the application was declared successful because it was able to display 8 3D virtual objects in augmented reality.

5. Reference

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