Unmanned Aerial Vehicle (UAV) Data Acquisition for Archaeological Site Identification and Mapping

W Handayani1, E A Ayuningtyas1, F S Candra R2, B Arif S3 and B Argadyanto3

1Diploma Program of Remote Sensing and Geographic Information System, Vocational College, Universitas Gadjah Mada, Yogyakarta, Indonesia
2CV. Mitra Geotama, Yogyakarta, Indonesia
3CV. Systemaptic, Yogyakarta, Indonesia

warsini.handayani@ugm.ac.id

Abstract. Archaeological sites as part of human history and located around community are important to be preserved for connecting historical information from generation to generation. Mapping of archaeological sites can be done as one of preservation efforts. Yogyakarta has several archaeological sites such as Pleret Palace, the former royal palace of Mataram Islam in the 16th Century. Data limitations and the difficulty of reconstructing the site sketches into a map become obstacles in archaeological sites mapping. Unmanned Aerial Vehicle (UAV) can be an alternative of high-resolution spatial data acquisition for detail mapping, including archaeological sites mapping. This study aims to see how far the UAV acquisition results can be used for Archaeological Site mapping in Pleret Palace. Data acquisition using UAV generated to mosaic orthophoto, Digital Surface Model (DSM), and Digital Terrain Model (DTM). Archaeological sites identified using DTM and matched with site sketch made by Cultural Agency. From these data, it can be recognized some relics form, such as palace fortress, moats and canals, and also dikes of Segarayasa. This research is expected to be a reference in archaeological site mapping using detailed spatial data, especially UAV. Furthermore, it can be obtained archaeological site map close to real condition; as well as archaeological sites preservation in Indonesia.

Keywords: UAV, Identification and mapping, Archaeological Site, Pleret Palace

1. Introduction

1.1. Background and Research Problem

Archaeological sites have an important role in part of human history and society. The previous culture of the community as the perpetrators of history as well as heritage buildings have an effect on the behaviour patterns of people living in the present. Therefore, archaeological sites are important to be preserved for connecting historical information from generation to generation [8]. Mapping of archaeological sites can be done as one of preservation efforts.

Yogyakarta has several archaeological sites such as Pleret Palace, the former royal palace of Mataram Islam in the 16th Century. This site is located in Pleret SubDistrict, Bantul District, special province of Yogyakarta. Based on existing historical records, this palace include area about 2,000 m² surrounded by...
water buildings [4]. One of the privileges part of this palace is the existence of an artificial sea located behind the palace.

Archaeological site mapping as one of spatial data management effort in archaeological potential has been done and made the national archaeology mapping system (SPAN) [12]. Each agency of heritage site management is expected to make detailed mapping for each research or field activity. However, archaeological sites mapping has not been optimal recently due to lack of data, resources, and existing site conditions which have changed from the original conditions. The condition of the Pleret Palace site is now quite worrying. Preservation is supposed to be contrary to current conditions. Land indicated as a relic of the palace has morphological changes by settlements development. This condition makes difficulty in identifying the palace sites by using remote sensing imagery, especially limitation in topographic information in order to archaeological sites identification. On the other hand, terrestrial mapping will be less effective due to a long time survey. Furthermore, spatial data preparation and site mapping become constrained.

Up to present, site reconstruction based on the Pleret Palace sketch (Figure 1) into the map (with more suitable geometry) was not yet possible. Special characteristic of Pleret Palace is the existence of some detail water building like dam and irrigation channel. This object identification requires more detailed and comprehensive data mainly related to existing topography of Pleret Palace site.

![Figure 1](image-url)  
**Figure 1.** (a) Sketches of the ancient Pleret Palace [4], (b) environmental conditions at Kraton Pleret Site and surrounding which have been changed into settlements

Remote sensing technology is now widely developed by researchers for mapping and monitoring activities. One of technology has been developed is Unmanned Aerial Vehicle (UAV) as a platform for aerial photography which can produce orthophoto and digital elevation model (DEM) with high resolution [9][10][11]. It makes UAV become an effective, efficient, and economical method for detailed mapping and geographic phenomena monitoring [3][6]. By looking at these opportunities, the results of UAV can be an alternative of high-resolution spatial data acquisition for detail mapping, including archaeological sites mapping by recognizing and identifying objects in the image images and detailed topographic data as past relic based on the characteristics described in historical documents. Furthermore, archaeological site management can be helped with the archaeological site map which is closer to real condition, both in position and geometry aspect. Therefore, this research will help the archaeologist to do the archaeological sites mapping using UAV particularly Pleret Palace as the historical relic of Islamic Mataram Palace.

1.2. Research Purposes

2. This is a preliminary research in mapping of archaeological sites using UAV in Pleret Palace Site. The purposes of this research are: (1) perform data acquisition (aerial photography) using UAV to
generate detail spatial data at archaeological site of Pleret Palace, (2) identify and map Pleret Palace Site based on spatial data resulted from acquisition data using UAV.

2. Study Area
Study area of this research is site of Pleret Palace located in Pleret, Bantul, Yogyakarta. This area covers approximately 676.3 hectares (Figure 2). Pleret Archaeological site is one of the historical relics of the Islamic Mataram Palace that was built during the period of Susuhunan Amangkurat I (1646 - 1677). The palace is built with various elements, i.e. king’s residence, fortress that surrounds the king’s residence, great mosque (Masjid Agung), palace square, garden, water canal, artificial sea (Segarayasa), settlements, cemetery, hunting area (Krapyak), dikes and dam [2]. Based on historical records written by Van Goens [5] the form of the Pleret Palace was diamond with 2,256 m² area wide; different from others Javanese palace in general (square). This palace building was surrounded by water canal and artificial sea for security defense function.

![Figure 2. Map of Study Area.](image)

3. Data, Instrument, and Method
3.1. Data and Instrument
This research collaborate spatial data and non-spatial data (ancient documents) for Pleret Site identification. Spatial data used in this research are base map (Rupabumi Indonesia Map) scale 1:25.000 including administrative boundary, roads, and hydrography layer as reference for relative orientation; and Pleret Palace sketch form Yogyakarta Tourism Agency. UAV fixed wing X8 is used aerial data acquisition platform, Sony A5000 camera as aerial photography sensor, and Geodetic GPS for control point measurement. Post processing aerial photos and control points is done using Agisoft PhotoScan software.

3.2. Method
This research is conducted by following stages i.e. initial preparation and field observation, data acquisition using UAV, data processing, identification and interpretation of archaeological sites. Each stage describes as follow.
3.2.1. Initial Preparation and Field Observation

Initial stages of this research include the research method to the data processing technical, field observations, and aerial mission planning. In this stage also conducted data collection or Archaeological Site Pleret documents that have been inventoried by the Cultural Agency of Yogyakarta. This document is used as reference for site object recognition and identification in Pleret Archaeological Site at during field observation. Furthermore, flight plan and control points distribution data were design as data acquisition preparation, as well as equipment preparation for aerial photography mission and field survey.

3.2.2. Data Acquisition using UAV

Data acquisition using UAV is implemented using UAV fix wing and camera sensors. The aerial photography is carried out in accordance with flight plan. Simultaneously with aerial photography, premark of ground control point (GCP) and independent control point (ICP) was measured using Geodetic GPS. This control point which have x, y, and z value function as spatial reference. The results of this data acquisition are aerial photographs (singles) in the overall study area and control points measurement data. UAV flight at altitude ± 500 meters (agl) to produce a 10cm spatial photo resolution. Accuracy of aerial photographs depends on the number and distribution of GCP, so that the GCP evenly distributed throughout the area. ICP is used as a reference points for of aerial photography accuracy assessment. Control point is measured with Geodetic GPS with an accuracy limitation value at least 2 times smaller than aerial photography data resolution to be generated. Furthermore, these two data will be integrated to obtain spatial data that is aerial photography (mosaic orthophoto) and digital surface model (DSM).

![Figure 3](image)

Figure 3. (a) Flight plan, preparation and aerial data acquisition, and UAV monitoring during flight mission, (b) GCP and ICP distribution and measurement

3.2.3. Data Processing

Data processing integrates aerial photographs of acquisition using UAV and control points measurement. Processing of UAV data into mosaic orthophoto and DSM is done by digital photogrammetric technique with block bundle adjustment principle. In this process all the measurement
points and control point coordinates (GCP) are processed simultaneously with one adjustment process that ensures high accuracy on the results [1]. This process is using high difference between objects in aerial photography and generates tie points (Figure 4). The relatively high difference is combined with the elevation on each control point so that a height model is generated on the whole block of aerial photographs. In this process also determined the coordinate system of aerial photographs in accordance with the location of aerial photography and retrieval of control points.

![Figure 4. Determination of camera orientation and tie points on aerial photography](image)

### 3.2.4. Archaeological Site Identification and Mapping

Identification is done by combining DSM, orthophoto, and sketches of the Pleret Palace including components, distribution, and dimensions of each site component. Visual interpretation of orthophoto and DSM is used in site component identification that was described in the historical document. Interpretation in this study is more focused on the relics that have micro morphology due to changes by human activities. These components include: palace wall walls, trenches and canals, embankment and dam of Segarayasa, as well as intact form of Segarayasa.

![Figure 5. Flow Chart of Research Methods](image)
4. Result and Discussion

4.1. Field Survey

Field observation activities bring more detailed information about the Pleret Palace site components, i.e. great mosque of Pleret Palace, water canals, indication of palace square, indication of Segarayasa border, indication of Balekambang, indication of palace wall/fortress. The information is then used in Pleret Palace site component component identification from the aerial photography and DSM. Location observations and site descriptions is presented in Figure 6.

4.2. Aerial Photography

The aerial photography resulted in 649 aerial photographs. Processing includes standardization of brightness, sharpness, and colour, and mosaic orthophoto processing. The orthophoto mosaic is generated from the input of a series of aerial photographs and 4 GCP. GCP serves as the coordinate point in the field on the georeferencing process. Mosaic orthophoto processing is done with Agisoft PhotoScan software to obtain aerial photograph of the study area (Figure 7).

Based on the accuracy assessment with 9 ICP, mosaic orthophoto result 0.23meter horizontal accuracy and 3.2 meters vertical accuracy. This accuracy conforms mapping specification at scale
1:2.500 for horizontal accuracy and scale 1:10.000 for vertical accuracy based on the regulation of Geospatial Information Agency’s head (PERKA BIG) No. 15 year 2014 about Technical Guidance of Basic Map Accuracy. Mosaic orthophoto resulted have 7 cm spatial resolution; sufficient for detail mapping in Pleret Palace site. Detail of aerial photo is shown in Figure 8.

![aerial images](image)

**Figure 8.** (a) Mosaic orthophoto resulted from aerial photography using UAV and detail object recorded, (b) digital surface model.

### 4.3. Archaeological Site Identification and Mapping

The initial identification of Pleret Palace is done by referring to four main references: Pleret Palace map from de Graaf version, Pleret Palace map from Yogyakarta Cultural Agency, Historical Map of Trunojoyo Attack Scenario, and field observation results. In general, all maps show Pleret Palace location is on the northwest side of the Opak River, with geometry skewed to the northeast. There was road on the north side of the palace runs from north to south entering the palace. On the northwest side, there was a building of the Great Mosque and on the west there was a building of keputren (princess building complex). The maps also show the existence of water canals and dam that surround the palace building (Figure 9).

Based on the of the Pleret Palace components identification and existence interpretation, of similar phenomena on DSM, aerial photographs, field survey, and references map, there are several indications of the site of palace fortress, water canal, palace square, Balekambang, and embankment of Segarayasa. Interpretation of aerial photography to identify the Pleret Palace is done by using several interpretation keys such as shape, pattern, and association.
Figure 9. Identification of Pleret Palace site based refers to Pleret Palace map from de Graaf version, Pleret Palace map from Yogyakarta Cultural Agency, Historical Map of Trunojoyo Attack Scenario, and field observation results

On the west side there are indications of waterways that look concave along the field and there are bamboo and sugarcane plants that indicate the presence of natural water quantities. In the aerial image imagery, it can be recognize from the elongated area and lower altitude than the surrounding. This area has been utilized as a rice field whose pattern is different from the surrounding (Figure 10). The points that indicate the presence of drains in the field are combined with orthophoto and DSM object identification and connected to form a whole water canal.

Figure 10. Water canal and palace fortress identification and interpretation from DSM and orthophoto
The next identification is the situation of the Pleret palace consisting of plains and hills area boundary, Segarayasa embankment, fortress/wall, Great Mosque, palace square, and keputren. Objects depicted on the reference map can be identified using aerial photographs by looking at the patterns. For example, fortress identified by looking at the straightness pattern that has higher elevation than surrounding, grand mosque identified by delineating the excavation area of the grand mosque, keputren identified by delineating the area of ‘settlement (kampung) with toponimi keputren (from reference map), and Segarayasa embankment identified by straightness pattern on east and south side of fortress. It can be seen clearly pattern and distinct elevation from DSM that indicate fortress and embankment. Identification and interpretation of Pleret Palace situation is shown in Figure 1.

![Figure 11](image)

**Figure 11.** Identification and interpretation of Pleret Palace situation including plains and hills area boundary, Segarayasa embankment, palace fortress/wall, Great Mosque, palace square, and keputren

The results of archaeological site identification in this research show that the existing phenomena from detail aerial photo and digital surface model can be the interpretation key of palace building/construction that exist in kingdom period. The existence of the palace, great mosque, Balekambang pond, Segarayasa embankment, Segarayasa artificial sea, road, and water canal built in the Pleret Palace can be identified and mapped by using orthophoto and DSM from data acquisition using UAV.

5. Conclusions

Data acquisition with UAV in Pleret Palace site can produce detail mosaic orthophoto and DSM that suitable in detail scale. These results can be used as input data for the identification of archaeological sites and recognize difference height as well as topographic patterns. Interpretation of aerial photography to identify the Pleret Palace is done by using several interpretation keys such as shape, pattern, and association. Based on the result, it can be identified some site element i.e. palace fortress, water canal,
road, great mosque, palace square, Balekambang pond, and Segarayasa embankment, and Segarayasa artificial sea.

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