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Using terrestrial laser scanner for Malay heritage documentation: preliminary approach to Istana Balai Besar, Kelantan

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Abstract

The digital heritage documentation and 3D modeling in cultural heritage field with using Terrestrial laser scanner was applied extensively in recent years. This study attempts to highlight a preliminary process of digital documentation for the Malay heritage, namely a royal palace known as Istana Balai Besar, Kelantan, with an emphasis on the potential of laser scanning in replacing an old methods of building heritage documentation. Leica Scan Station P16 has been used to scan an exterior and interior spaces of the palace's main building, which includes façade and Hall of ceremony *(Balai Istiadat).* A total of 26 scan targets for exterior façade and 14 scan targets for interior space with spending less than 5 minutes on each target have captured the millions point clouds that represent the information of architectural elements and physical building structures. These information is very useful to most of architects, conservators or any decision makers who are involved in the documentation, preservation and conservation works of heritage buildings. The finding shows that, point cloud is able in capturing physical structure of architectural elements with detail measurement included. This method is proven useful to minimize the time spending and manpower including obtaining accuracy and precision of measurement.

Keywords: Terrestrial Laser Scanner; Documentation; Spatial Metadata; Malay heritage Building; Istana Balai Besar

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1. Introduction

Recording and documenting heritage buildings are important for us to preserve information for future generations in appreciating past historical and socio-cultural values. It is also important due to recently the risk of the cultural property that was threatened by destruction, wreathing, hasty and inadequate repair and restoration brought by a timeline. The cultural property can be an important asset to a country and become a one precious element in conserving a culture and custom (Basir et al., 2014). In the last twenty years, architects and conservators deployed traditional surveying techniques to make inventories and measurement of heritage buildings and the techniques were selected to accomplish the overall task. Measured drawing was the popular method to document all information regarding the buildings. Harun (2011) stated that measured drawing also known as *found drawing* means a set of line drawings that are accurately drawn, with additional information collected from interviews, pictorial data, craftsmen opinion and physical evidence on site about particular buildings. This drawing delineates the building subject according to its existing condition. It also illustrates the interior and exterior of a building including the structural detail. The method was able to describe the defect areas such as cracks in plaster and the missing elements through the detail observation and recording process.

Documentation of the rich heritage and traditional architecture is important not only to recognize building language of the Malay world, but also to understand the lifestyle and cultural values of its users or occupants. There are three categories of Malay traditional architecture, namely palace, house and *masjid* (Tajuddin et al., 2005). The principal structures of these buildings are confined to the local vernacular traditions and they are distinctly recognized in their regional stylistic features. In Malaysia, traditional palaces, houses and *masjid* are important heritage buildings. The available description from the Malay Annals describe Malaccan palace of 15th century have a long and honored record (Tajuddin et al., 2005). Hence, this establishes the fact that the palace was the first recorded Malay traditional architecture of the past. The centuries old building bears distinct architectural features and many surviving old palaces in today's world are honored as Malaysia's heritage building. Heritage building represents any building of one or more premises or any part thereof and structure or artefact which requires conservation and preservation for the purpose of historical, architectural, artisanry or aesthetic, and cultural value (Falser, 2015). Istana Balai Besar (The Grand Palace) in Kelantan is among the oldest and the finest traditional Malay palaces which remains intact until today. However, this timber structure is subjected to the threats of natural decay, major flood and destroyed by fire, thus preserving its architectural and historical significance has become paramount importance for posterity.

1.1. Laser scanning instrumentation

Terrestrial laser scanner (TLS) was proved a powerful tool towards the recording of objects and sites for heritage preservation purposes, scientific research and built environment applications (Fontana et al., 2002; Kheder, 2009; Ruther et al., 2009; Wei et al., 2012; Basir et al. 2014; Baik, 2017). TLS is well known to produce 3D point clouds during measures process (Haddad, 2011). Recent technology in the rapid TLS technique also is capable in documenting objects without requiring a direct contact to it. In parallel to this

study, the restoration and conservation of historical building of Istana Balai Besar need detail information such as structures; types of materials and reliable components for 3D model of historical objects. This equipment can capture all the necessary data in an extremely short time while the well-developed visualization tools and first aid tools can assist greatly as a first step in analysing and visualising tools at a later stage.

TLS captures highly dense cloud points either in black and white or colour mode with some laser scanners have integrated cameras, and it also can be optionally mounted on top with 12 million pixels. Surveying done by this equipment essentially results in a density of cloud point where each point has the coordinates x, y and z (Khaled, 2012). The information of cloud point obtained from TLS is able to proceed for the comprehensive three-dimensional (3D) image that records culturally important objects such as heritage buildings, monuments, and sites, which can serve a variety of invaluable purposes. The data can assist in the conservation, management, and repair of a structure, as well as provide a visually engaging educational resource for both, public and scholars (Baik, 2017; Barrazetti, 2016; Chien et al, 2016; Dore et al, 2015; Fai et al., 2012). The acquired data acts as a form of digital preservation that is a timeless virtual representation of the as-built structure. The capability of these systems particularly is suited for the documentation of a richly articulated and detailed building such as the King's Palace, Istana Balai Besar. This is especially in obtaining a precise documentation of its cultural heritage for its protection and scientific studies. This method can improve the documentation works as the common practice is time consuming and needs more man power. Thus, the digital method is able to replace the common or conventional methods of data collection.

Therefore, this study is to highlight the preliminary attempt of using TLS in relation to architecture and built environment works, focusing on documentation of a building heritage information. The Palace of state of Kelantan known as Istana Balai Besar has been selected as a sample to scan and document its interior spaces and exterior façade information consisting of identified Malay architecture elements such as wall, windows, door and roof. This study will lead to the further integration task with Building Information Modelling (BIM) in strengthening the architectural documentation process.

2. Study area

The town of Kota Bahru in Kelantan grew around a new palace, Istana Balai Besar, which was built by Sultan Muhammad II in 1845 on the east bank of the Kelantan River, a few kilometres from its mouth (Neil et al., 2017). The palace is situated at the centre of the town, close to Open Square. Istana Balai Besar is the sultan's *(king)* palace which symbolizes his sovereignty who had reigned from 1839 to 1886. It is a single-story palace made of Chengal wood and surrounded by strong palisades. Istana Balai Besar is recognized as a historical palace, with an area of 175,000 feet square with main palace in the centre surrounded by its small king family houses in the past time. It was considered a new palace in replacing Istana Kota Lama that was known as the centre of government for Kelantan during 19th century. This palace was used as the official office for the Sultan of Kelantan and the government's official welcome ceremony. This palace is famous for having a large hall, a throne and a collection of tools royal dignity. Today, this historic palace is used only for

royal functions and official ceremonies, for examples, sultan's coronation day and sultan's birthday. The palace houses the various traditional artifacts and royal regalia for exhibition.

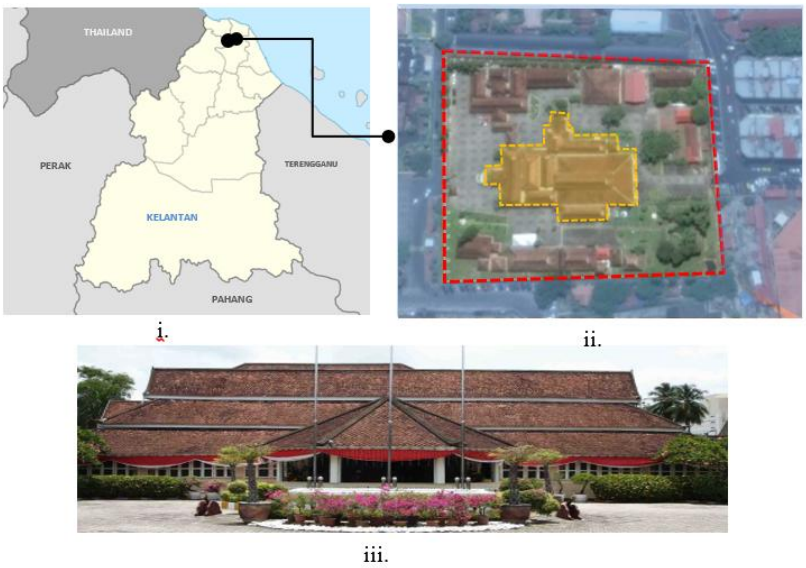


Figure 1. i) Key map of study area; ii) boundary for Istana Balai Besar and iii) Istana Balai Besar

Figure 2. i) Carved timber panel and, ii) timber panelled wall at rear facades of Istana Balai Besar

Istana Balai Besar was originally designed in a regular square grid and arranged in a formal layout consisting of main buildings and few areas enclosed within walls. As a royal palace, the building has been embellished with the ornamentations that reflect its former status as a grand residence, especially a royal residence with a high-ranking of dignitary. The whole building showcases the Malay woodworking skills of local craftsmen from Kelantan and the building form and layout are traditionally derivation. It is now much valued for its excellent architectural feature including the exquisite wood carvings of a century ago. Many traditional carving elements are found within the interior and exterior spaces of the palace. In this building,

the collection varies from a simple elegant structure of a carving panel to timber wall facades of the main hall and additional rooms, for examples as shown in Figure 2. The architectural and historical status marks the building as a heritage palace apart from having its cultural significances. This study focuses on the documenting of the heritage building through digital documentation in 3D modeling with the aid of Terrestrial laser scanner. This documentation also needs to include information on the detail elements of architecture, thus full coverage with precise documentation of Istana Balai Besar as the cultural heritage is potential for its protection and conservation.

3. Material and methods

3.1. Equipment used for measurements

We realized that Terrestrial laser scanning technology allows measurement of a large number of points placed on the object monitored without the need for them to be accessible but only visible, with the simple principle the scanner emits a laser beam that is reflected from the object in that building. When measuring a characteristic point on the surface of the object, three observations are made; slope distance and two angles-horizontal angle α and vertical angle β and the result is represented by a set of points that define the monitored object; commonly they are called "point cloud" (Negrilla and Onose, 2013). The palace building has been scanned with Leica Scanstation P16. The capability of this instrument distributes the laser beam of field of view at vertical range of 290° and horizontal range of 360° and the measurement scan rate is up to 1,000,000 point per second. It was selected from a range of scanners as the School‟s work is focused on building architecture and city modeling therefore the extended range was seen as favorable over the alternative phase-based scanner technology. Table 1 presents the scanning characteristic of the instrument.

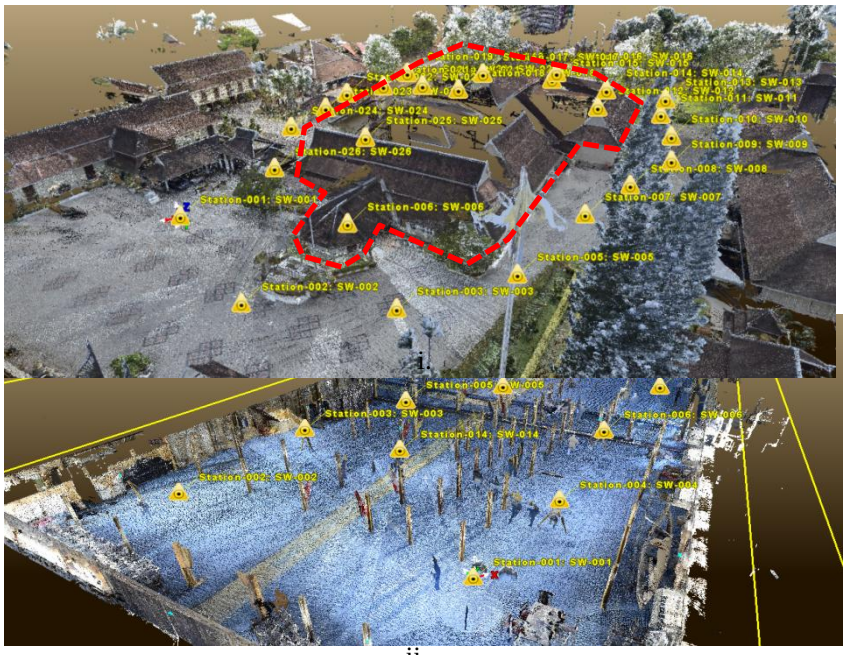
Table 1. Scanning Characteristics of Leica ScanStation P16

SCANNER/CHARACTERISTIC	LEICA SCAN STATION P16
Laser Class	3R
Scanning method	Time of Flight
Vertical field of view (º)	270º
Horizontal field of view (º)	360º
Range (m) and reflectivity	Up to 40m; 18 % reflectivity (minimum range 0.4m)
Scan Speed (pts/sec)	1`000`000 points per/second
3D scanning accuracy	3 mm at 40m
Camera (single image pixel resolution)	4 megapixels per/each 17o x 17o color image; 700 megapixels for panoramic image
Processing software	Cyclone 9.1.6
Tilting Sensor	Dual axis compensator

3.2. Methods

3.2.1. Measurement process

The main building of Palace of Balai Besar was carried out in 26 stations for external façade scanning with 45 targets have been used during a data collection. Figure 3 shows the distribution of 26 TLS stations location surrounded Palace Main building. The duration of scanning the data in each point can be averaged about 3 minutes and 5 minutes including photographing process. The data acquisition at the Istana Balai Besar was carried out with the phase –shift based scanner, Leica ScanScanner P16. The data capturing procedure was executed in two steps, laser scanning and photographing. The geometry and the intensity of façade data were captured by TLS while the RGB values of the geometric object were captured by a high resolution digital camera. At a later stage, appropriate scanning positions need to be established to capture the full coverage of the façade data.



ii.

Figure 3. i) Location of 26 TLS stations selected surrounding the Palace main building *(red line)* and*;* Location of 14 TLS stations for the Palace's Hall of Ceremony *(Balai Istiadat).*

Once measuring process of the façades of palace's main building are obtained, all recorded digital data are directly stored in the controlling laptop by using the Cyclone 9.1.6 software. Then, laser scanner only continued with image acquisition process. The well-known integrated digital camera would take 10 photos at each scan station to provide panorama view of the surrounding. At the stage of point cloud processing, the process involves the basic checking data and data cleaning process to ensure a good point cloud to represent the objects. Millions of measurements have been taken for the palace building and it contain several of noise

and errors. Therefore, data filtering process need to be done to correct or remove the selected scan point from the raw data. The registration involved point clouds from a total of 26 scan stations covered the whole exterior of the main building of Istana Balai Besar and 14 scan stations covered for interior of Hall of ceremony *(Balai Istiadat)* with clockwise direction.

These point clouds have registered to Geocentric Datum (GDM2000) coordinate system in order to achieve a complete visualization model for Istana Balai Besar.

3.2.2. Main processing

The registration of 3D point cloud was done using Cyclone 9.1.6. Data filtering process was proceeded to correct and remove selected scan point from the raw data to ensure that the geometric object has an active target to fit that is represented by the range of colors. The color information from high resolution digital images would be fused with the 3D registered point clouds after geometric object had correctly meshed. In order to simplify 3D visualization model, a data reduction was applied and to speed up the loading process when visualizing the whole 3D merged surface at Istana Balai Besar. Also, texture editing was done to remove noise and smooth the model and completing the 3D registered colorized model from TLS. The next process will involve rendering and completing documentation with integration of Building Information modeling (BIM) and this process will be in Revit processor and will not be discussed in this paper.

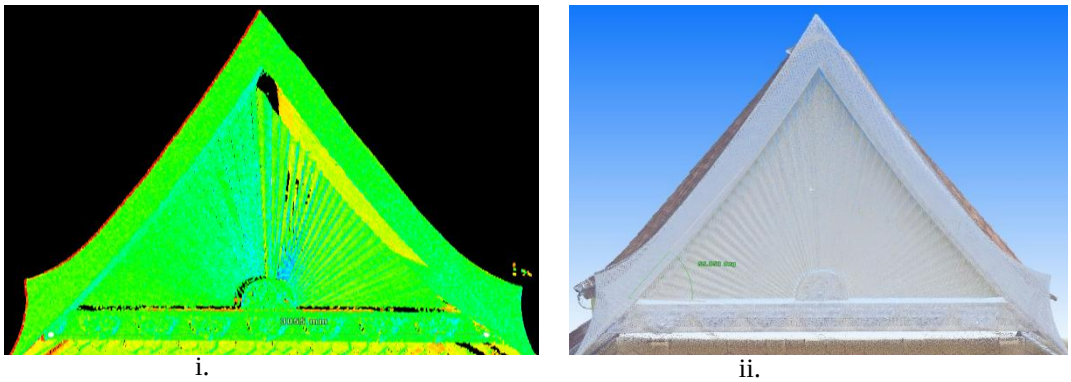
4. Result and discussion

4.1. Exterior scanning result

At this stage, we managed to have a processing and getting a preliminary result for 3D visualization model of architecture elements and the structure of the main building as a whole. Figure 3 shows the result of 3D visualization of the architectural element known as gable end which is found at Istana Balai Besar. The outer frame of the gable end board is known as *Pemeleh* (fascia board). As shown in the Figure 3, the complete visualization can be seen with a detail measurement of each item that also can be carried out through conventional documentation with the use of measured drawing.

One of the distinctive features found at the *tebar layer* (gable end) of Istana Balai Besar is in the form of gable fascia boards locally known as *pemeleh*, a frame along the gable ends of the roof edge curve gable edges (Hasyim and Nasir, 2011). These gable fascia boards were fitted at both gable ends of the building. As such the presence of the *pemeleh* makes the grand palace looks distinctively different and unique in character. Since the old Malay palace design is almost similar with the house design, it suggests that the fascia board is discernible and suitably fits within the gable ends of the palace. The *pemeleh* shares similar character with those found at the twelve-pillared house of Kelantan reflecting its regional characteristics. Figure 4 shows the simple model for exterior part of Istana Balai Besar on its main gate and main entrance door. Also, the exterior compound of the palace was captured in detail visualization including the exterior structures of the building. Istana Balai Besar has a wealth of traditional architectural features, especially on the front facade.

Various components from the exterior walls and spaces are important tangible heritage that requires all-embracing documentation.



i. ii.

Figure 4. Preliminary result in i) RGB Mode point cloud for Malay gable end of Istana Balai Besar ii) 3D visualization model using Terrestrial Laser Scanning (TLS) shows the example of measurement for Malay gable end with the fascia board *(Pemeleh)* of Istana Balai Besar

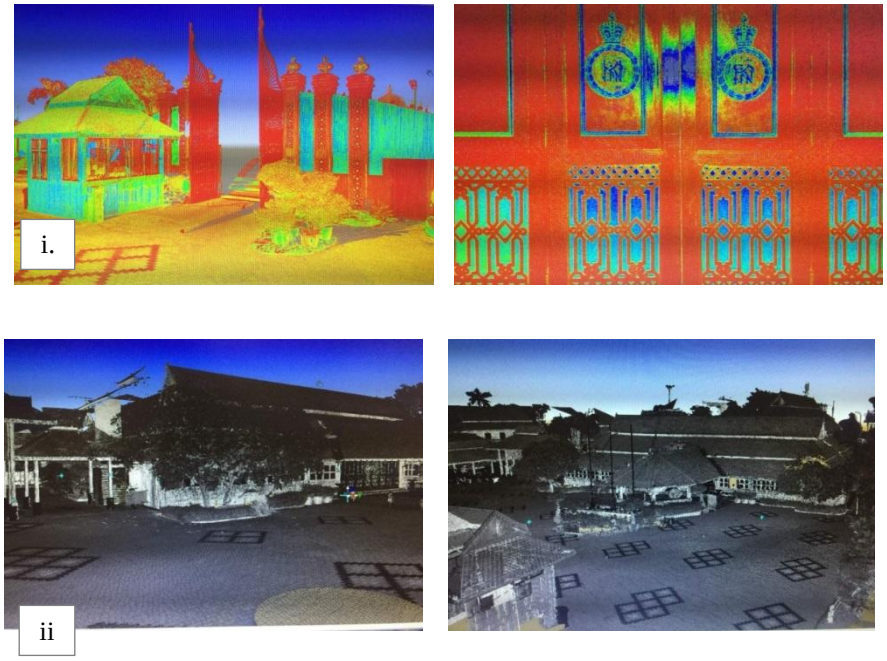


Figure 5. 3D visualized model captured on exterior part of Istana Balai Besar i) in RGB mode of main gate and palace door and ii) greyscale mode of Istana Balai Besar compound.

4.2. Interior scanning result

The three-dimensional model resulted from the point cloud modeling for this study was considered as a simple model, made using data taken from the field. Figure 5 shows the 3D visualization captured for interior part of Istana Balai Besar in RGB and Greyscale mode. This visualization shows clearly the architectural elements of the space consisting of arrangement of columns and the seating division, throne and structure of wall. Each of the elements have detail feature and physical measurements.

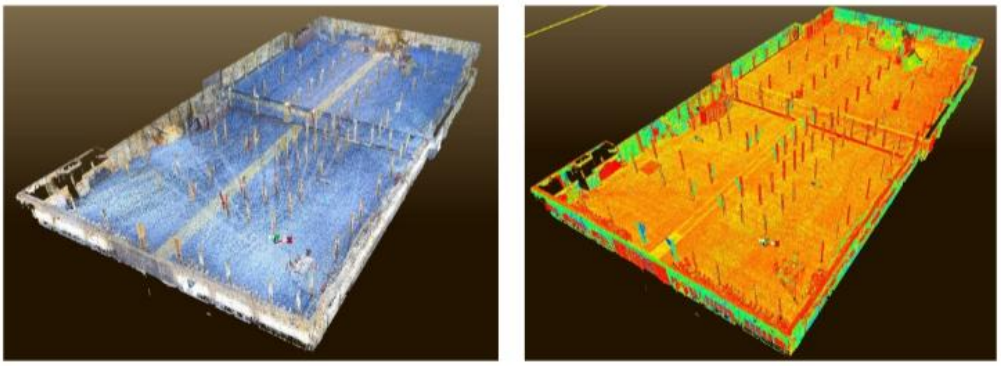


Figure 6. 3D visualized model captured on the interior part of Istana Balai Besar i) RGB mode of Hall of ceremony (*Balai Istiadat)* and ii) greyscale mode of Hall of ceremony (*Balai Istiadat)*.

These results also highlight that the model has the role to graphically restore, as closely as possible the scanned object, thus obtaining all the necessary information regarding the Hall of ceremony. This hall is one of the most important spaces in Istana Balai Besar that is specially designated for royal functions and official ceremonies. The present study is dedicated to the preliminary documentation of the interior and exterior spaces of the palace that reflect its culturally important heritage. Documentation of the Malay architectural heritage was successfully obtainable through a step-by-step process of using digital technology resulting to the full and detail coverage of the spaces. Apart from the spatial physical structure, detail features of building components including walls, columns and seating elements are captured in precise dimensions, shapes and sizes. Accuracy in getting this information is paramount importance for the preservation and conservation of the tangible heritage.

The analysis of the result shows that TLS is a highly potential to replace an old method of building heritage documentation, making it as a leading digital technology, especially in the field of conservation. The ability of 3D scanning to capture an identical physical replica form without any contact, takes conservation to a whole new level and it consider a powerful tool for recording of objects and sites for heritage preservation and conservation purposes and scientific research (Fontana et al., 2002; Kheder, 2009). The information obtained from this method is very useful to related professionals including architects, conservators or any

policy makers and researchers from institutions who are involved in the scientific research, documentation, preservation, and conservation works of cultural heritage.

5. Conclusion

The work introduced in this paper presents the initial phases of establishing a documentation system for the Malay heritage documentation that is represented by a palace known as Istana Balai Besar, which is located in Kelantan. This study has obtained 3D models of cultural heritage monuments that represents a conventional documenting process that can be replaced using TLS. The method depends highly on the quality of cultural heritage asset that is being scanned and processed. The capability of Laser scanning can be used to acquire the shape and texture of an existing old Malay building, while 3D modeling can be used to virtually reconstruct the damaged or incomplete cultural heritage assets. Digital documentation and 3D modeling of cultural heritage through Terrestrial laser scanner helps achieving a complete visualization model for Istana Balai Besar. This important architecture is a manifestation of the Malay culture that profoundly celebrates the traditional values. Therefore, the application of TLS is timely necessary for documentation that contains vital evidence to the expression of the valuable national heritage. Application of this technology is more resourceful and more precise as compared to the conventional approach of architectural documentation and data collection done through measured drawing. As such, the strength of TLS to obtain the data and documentation is unquestionable. This technology is vital in documenting information of the historic buildings for the sake of its heritage preservation, especially those in the midst of disappearance. Likewise, full coverage of documentation of Istana Balai Besar is vital before this old building decays or vanishes in future. The only evidence of its presence in this world as a grand royal palace of the Malay rulers is in the digital archives which serve as easy references for many generations to come. This study was at its preliminary stage of process of digital documentation and analysis, hence further research is necessary to obtain overall information on the historic palace leading to the full coverage in digital documentation. This includes 3D visualization model of the architectural elements and the structure of the building in a whole. This study will lead to the integration of information with Building Information Modelling (BIM) in strengthening the architectural documentation.

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