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# Development of Application Based on Augmented Reality as A Learning of History and Culture in Architecture Case Study: Pathok Negoro Mosques Yogyakarta

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## ABSTRACT

Pathok Negoro Mosques are an architectural masterpiece. These mosques are part of history in forming Yogyakarta. The existence of the Sultan's Ngayogyakarta Palace is inseparable from the Pathok Negoro Mosques. These mosques also function as a defensive system of the Islamic kingdom in Yogyakarta. Arguably, the current generation is getting deprived of the intellectual heritage of culture and history. The history and culture of the Pathok Negoro Mosques will be the content of this research. This paper reports research to develop an interactive application for learning the history and culture of architecture based on Augmented Reality (AR) using the Unity program. The study was conducted in two stages, i.e., collected the mosques' historical and cultural context and developed an AR application for Android mobile devices. The reference data was made into the AR application with several methods, such as plane detection and image tracking. The research resulted in a mobile augmented reality application in Unity3D 2018.3.14f1 for android devices that consists of the narrative recorded voice of the brief history and culture of the Pathok Negoro Mosques. The app also shows a well-ordered animation of building structures such as roof, roof insulation, roof structure, and column of Pathok Negoro Mosques. In addition, the report offers a precise step and issue of making an augmented reality app as learning of history and culture of Pathok Negoro Mosques.

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## 1. INTRODUCTION

Yogyakarta is a unique artifact with many attractions for tourists, academics, and researchers. Yogyakarta's uniqueness includes the physical and social-cultural phenomena of its people. The Yogyakarta Palace's existence dominates and influences the spirit of life of Yogyakarta and its surroundings. The palace forms a royal city pattern based on specific concepts. Among them are the Mancapat concept, which means the *Qibla Papat Limo Pancer*. In this concept, the Pathok Negoro mosques were used as the boundary and form of defense of the Islamic royal city in the Nagara Gung region [1], [2]. The Pathok Negoro Mosques consist of six mosques: the Wonokromo mosque, the Mlangi mosque, the Ploso Kuning mosque, the Ad-Darojah Dongkelan mosque, the Babadan mosque, and the Kauman Gedhe (Great) mosque. Kauman Gedhe Mosque is the center of other mosques.

The current globalization requires us to be introspective towards an identity crisis. The result of an identity crisis is the lack of ownership and pride in the work of the nation's culture and history. The richness of tradition and artifacts with high historical and philosophical are precious. Furthermore, the efforts to

preserve the heritage need to be encouraged and carried out for sustainability. Arguably, the current generation is getting deprived of the intellectual heritage of the culture and history of the Pathok Negro Mosques. Architecture students, for example, are expected to understand the meaning of the mosques in Yogyakarta. These mosques are part of history in forming Yogyakarta. The existence of the Sultan's Ngayogyakarta Palace is inseparable from the Pathok Negro Mosques.

Augmented Reality (AR) is one of the communicative technologies of digital images and animations. AR, for example, is used to visualize traditional architecture [3] and as a historic building teaching application [4]. In addition, AR technology helps add information about the history and culture of Pathok Negro Mosques. AR is an interactive tool to merge non-visual contents with physical objects.

This research focuses on the domestic context of the Pathok Negro mosques, such as the historical and philosophical artifact of Yogyakarta. The study aims to develop an interactive application based on AR using a game engine for mobile devices. This paper discusses the process and obstacle of making an augmented reality app described in several steps. The application's content focuses on information about the history and culture of the Pathok Negro Mosques.

### 1.1. Pathok Negro Mosques

Pathok Negro is a heritage building with many historical aspects for Yogyakarta City, especially Yogyakarta Sultanate. The record states that the mosques were also becoming a defensive border in the past. The history and culture of the mosques are attached to the six mosques: Dongkelan, Plosokuning, Wonokromo, Babadan, Mlangi, and Kauman. Each of the mosques has its relation to the history and culture of Yogyakarta City. Pathok Negro comes from the word *pathok*, an object that can be embedded either in wood or something else to mark a boundary. *Negoro* means the kingdom or government. Pathok Negro means kingdom boundaries, kingdom rules, or kingdom legal basis. The Pathok Negro Mosques not only functions as a place of worship but also have a social function that includes political and religious functions. The locations of the Pathok Negro Mosques, according to their role, are in the four corners of the city boundary. The Kauman Gedhe Mosque is the *pancer* (the center) of other mosques. Because of its strategic position in the political history of the Mataram Islamic royal city administration in Yogyakarta, the existence of the Pathok Negro mosques needs to be maintained. The Pathok Negro Mosques symbolize the presence of the Islamic Mataram Kingdom in Yogyakarta. In the concept of Islamic royal city space, the mosque is the leading equipment after the palace building. The Pathok Negro Mosques were built in 1755. Until now, the condition of these mosques is still good.



Figure 1. Spatial concept of Pathok Negro mosques in Yogyakarta [5].

Pathok Negro Mosques (in figure 1) consist of six mosques that cannot separate from one another. The interrelationships between them become one of the unique parts of the design concept. The concept of Mancapat is an essential part of the existence of the Pathok Negro mosques. The Pathok Negro Mosques, the only one in Indonesia, are a crucial architectural treasure that needs to reveal. Plosokuning timeline

recorded the modification of the Ploso Kuning mosque building three times, i.e., 1724, 1984, and 2001. There is also a material changing for the floor and on the porch area for Dongkelan mosque.

In comparison, Mlangi mosque has Kyai Nur Imam's tomb, the founder of the Mlangi mosque complex. The word Mlangi comes from the Javanese language, means to return. Mlangi Village intended to return its citizens to an Islamic way of life. Historically, the Dongkelan mosque was used as a military headquarter of the General Diponegoro army. In the case of the Babadan mosque, during the Japanese occupation, the Babadan Mosque was used as an aircraft base and armories warehouse, then moved to the new Babadan Village, Sleman, that was rebuilt in 1960. Wonokromo mosque is where the first sultan Hamengku Buwana disguised himself as a Santri or Islamic scholar. He learned about political science for the national defense of the state Sultanate of Yogyakarta from Kyai Fakhri. The first Sultan Hamengku Buwana advised establishing Pathok in the city's four corners [5].

### 1.2. Augmented Reality in Cultural Heritage

Augmented Reality technology is applied for cultural heritages, such as Mobile Augmented Reality for indoor and outdoor [6]. Recent developments in Virtual Reality (VR) and Augmented Reality (AR) improve user experience and increase learning about cultural heritages [7][8]. Many techniques are used for 3D reconstruction, such as a laser scanner to convert authentic object images or direct digitalization [9]. Many strategies implement BIM using 3D modeling software, such as Sketchup, 3DMax, and game engine Unity3D or Unreal Engine [10]. The method for developing AR varies from marker-based to marker-less-based. Marker-based image recognition uses a repetitive pattern, QR code, or unique image—marker-less-based cut-up into camera pose estimation and GPS and gyroscope [11]. Marker-based AR is based on the marker, a two-dimensional pre-defined screen, that is a square shape because the tag is accurate by using its four corner points [12]. On the other hand, marker-less based utilizes camera pose estimation for detecting a horizontal or vertical plane, GPS, and gyroscope, which can be used to determine the position in the physical world or integrate virtual objects into a 3D real environment in real-time [13].

## 2. METHODOLOGY

The application was developed using AR Foundation and ARCore in Unity3D. AR Foundation allows the user to create Augmented Reality in multi-platform [14]. While ARCore is Google's platform for building an augmented reality for android devices [15]. This research was carried out in two stages. The process in figure 2 starts with compiling the content of history and culture about Pathok Negoro Mosques and visualizing it into posters [8]. The next stage is developing a 3d model using SketchUp; then, the FBX file is imported into Unity for AR content. The method used image tracking and planar surface detection for spawning a 3d model object and archival content.



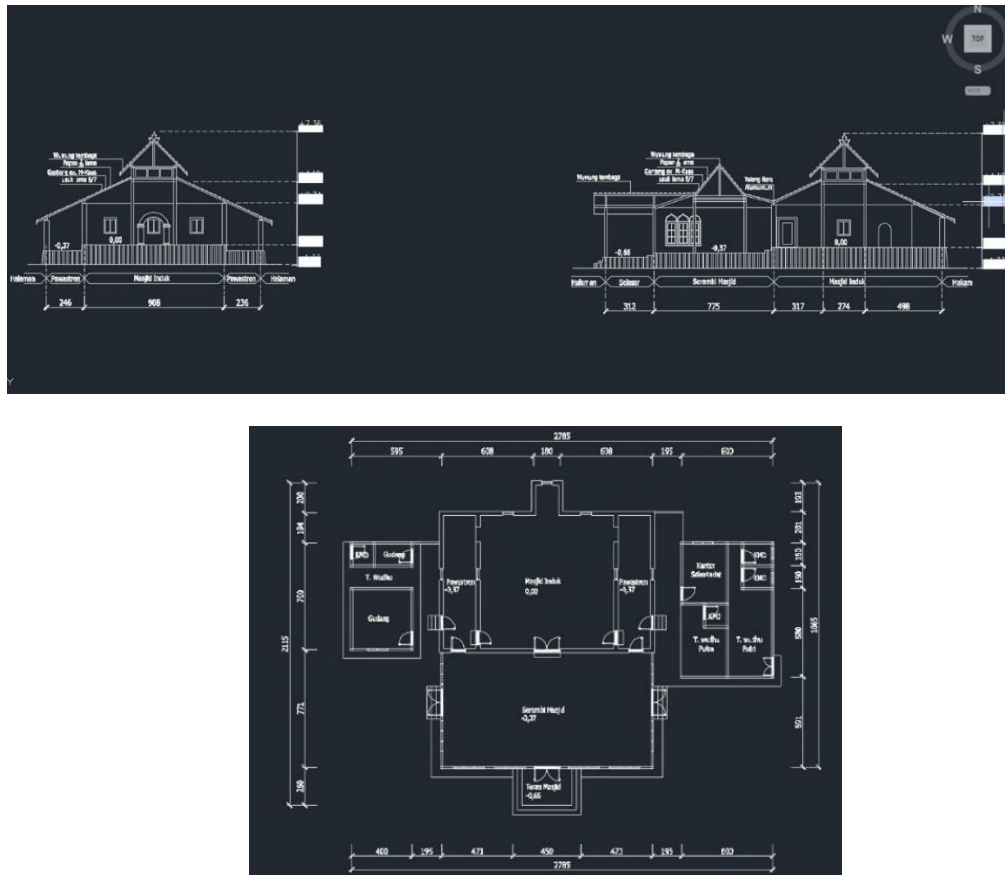
Figure 2. Process of developing an augmented reality application

## 3. DISCUSSION

Histories of Yogyakarta's city phenomena can still be traced today. It has become one of the attractions for researchers who have produced exciting findings from city life [16]. The results are an exciting inspiration to be developed continuously. Considering the Pathok Negoro mosque's age is crucial to know the durability, construction, and architectural materials. The strategy to maintain building sustainability needs to continue. Then in this study, a review of the architecture and structure of the mosques was carried out as an identification effort to plan sustainability strategies. Numerous research found integrating digital heritage, VR, and AR for preservation, documentation that utilizes BIM, such as digital documentation [10], research, education [17], reconstruction, tourism [18], and exploration of AR in architectural and urban design [19]. AR implementation is also in the historical context [20], which developed for an outdoor mobile AR [6]. In addition, there is an AR for historical storytelling [21], which is a mobile tourist guide [6] for cultural heritage sites with a video image of the actual site [22]. The development of the AR application uses a modern and widely accessible game engine technology such as Unity3D [8], [10]. Furthermore, the system must be

compatible, widely used, natural to interact with, and precisely detectable. On the other hand, AR technologies have migrated from marker-based methods to markerless methods [23], which conducts a GPS location tracking system that connects to an online database [24].

In this research, the 3D models were constructed from the original collected and integrated data (Image-based, range-based, CAD modeling, and survey methods). The survey resulted in photographs and size dimensions of the Pathok Negoro mosques. In addition, we conducted a study of literature related to the approach and history. As a result, we produced a collection of information to be used to analyze, interpret, and summarize the architectural characteristics of the Pathok Negoro mosques. Finally, 3D models of Pathok Negoro were created by utilizing a survey document. The process started from converting data into a 2D plan and elevation, as seen in figure 3.



**Figure 3.** Plan and section of Dongkelan mosque

The 3D model in figure 4 was created in Sketchup by implementing layering and components for clearing up the mosque building elements. The layering tab consists of the central and porch area of the mosque, such as roof, roof insulation, roof structure, and column.

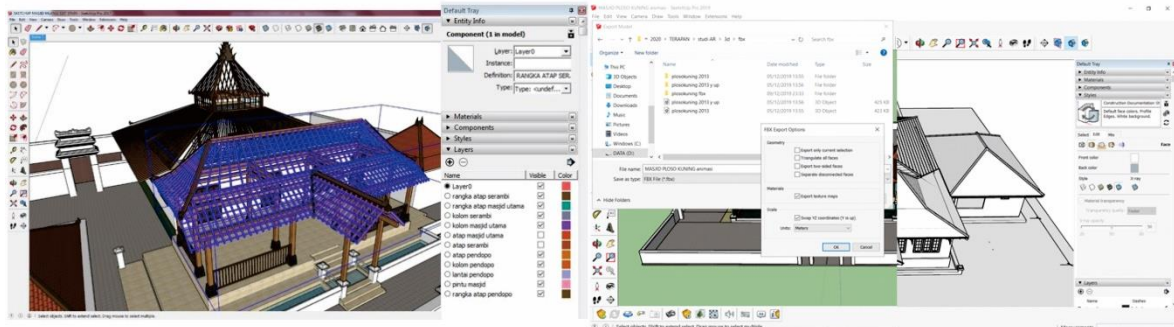


Figure 4. Layering, component, and export FBX file in Sketchup

The surface on the 3D model should be in front color, as shown in figure 4 so that the surfaces showed up on Unity3d after being imported. The next step divided the building into several components to animate in Unity, such as roof, roof insulation, roof structure, and building columns. The last step for the 3D modeling exported the file to the FBX file. Therefore, all geometry and materials were exported into a folder. The unit for the FBX export option used meters. The Y coordinate was up. We used Google ARCore 1.6. SDK package for Unity for developing AR in Unity 2018.3.14f1 in figure 5 by importing the package into unity3d [14]. We used the augmented image from the example folder, utilizing the image tracking method to bring up the 3D model for a specific image. The images were imported to an augmented image database. The photos were made from the collected data that visualized into a poster.

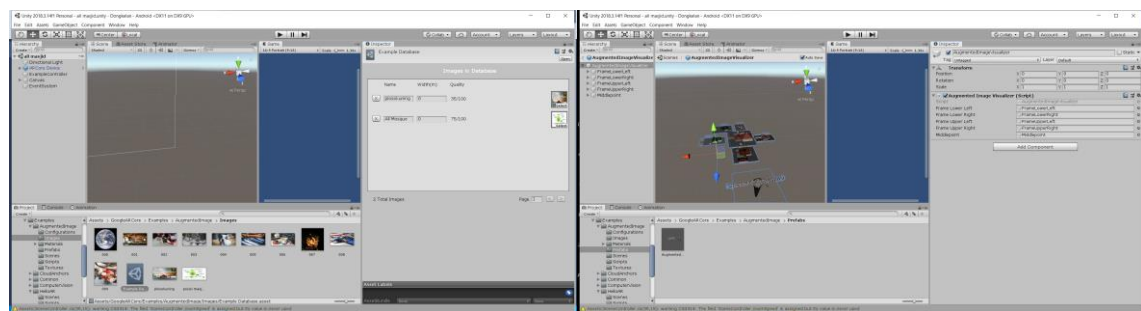


Figure 5. Augmented image databased and augmented image visualizer

The imported images in the example database display the quality of the picture. As shown in figure 5, the image quality is 75. The quality score of the image depends on the unique feature points on the image [25]. In contrast, the repetitive image gives a lower score for quality. However, this image will trigger the 3D model to show up. We modified the augmented image visualizer script in figure 6 by adding a public GameObject called Middlepoint. This GameObject consists of a 3D model of all Pathok Negoro Mosques. The script shows the 3D model in the middle of the image by the modified script.

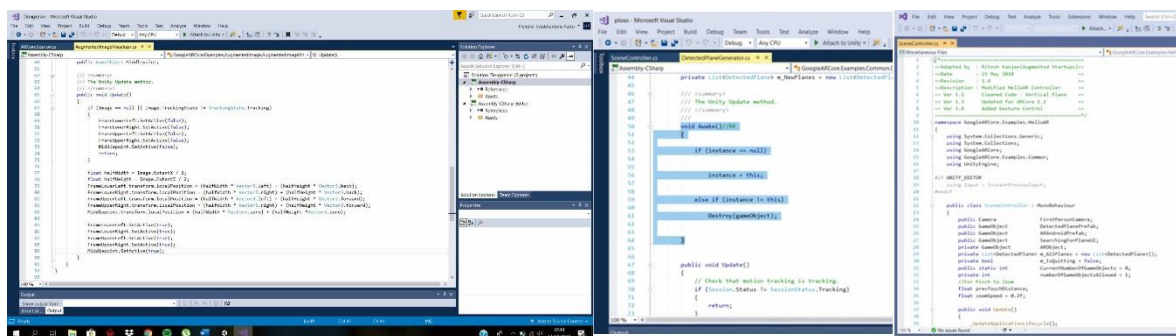


Figure 6. Modified script in Unity3D



We developed the augmented reality app by implementing the plane detection method using google ARCore 1.6 SDK in figure 7. We used the HelloAR scene from the example folder, utilizing the plane detection generator script. We used the detector plane from HelloAR. We used the modified detected plane generator and scene controller script so that the visualization of the plane detector was gone after the touch screen and 3D model came up. Moreover, we used gestures to control the 3D object, such as pinching for zooming and dragging to rotate the object [26]. The setting on Unity followed the minimum requirement of ARCore for android. The automatic graphics API and multi-threaded rendering in figure 7 were unchecked. The minimum API level was Android 8.0 or Oreo, and the ARCore supported on XR settings were checked.

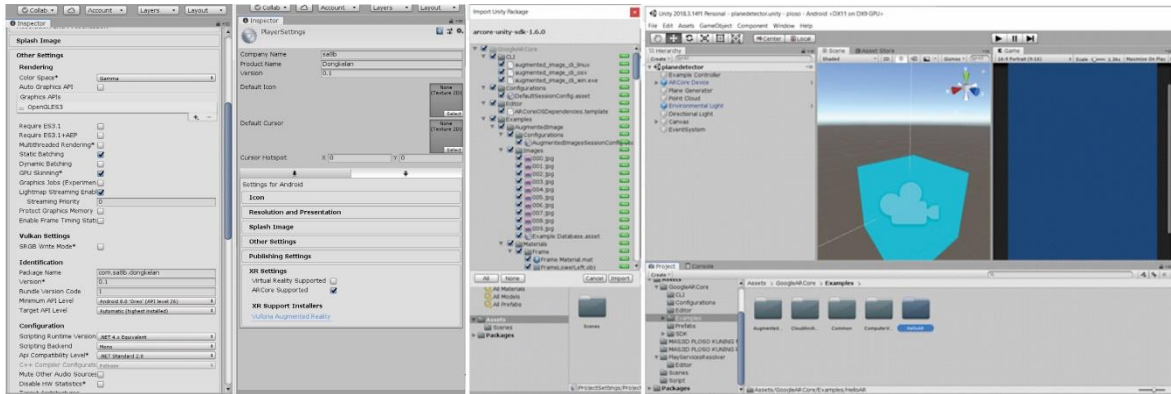


Figure 7. Build setting and importing HelloAR scene from Google ARCore 1.6 SDK

We put the recorded narrative voice into the application in three different languages in figure 8 such as Indonesian, English, and Javanese [8]. The narrative voice is automatically played when the application starts for the selected building. We recorded a narrative voice explaining the brief history of each Pathok Negro Mosque. Furthermore, in the app, we developed a short documentary of the history of Pathok Negro Mosques from several periods, such as the building element of Ploso Kuning Mosque that had changed from 1724 to 1984.

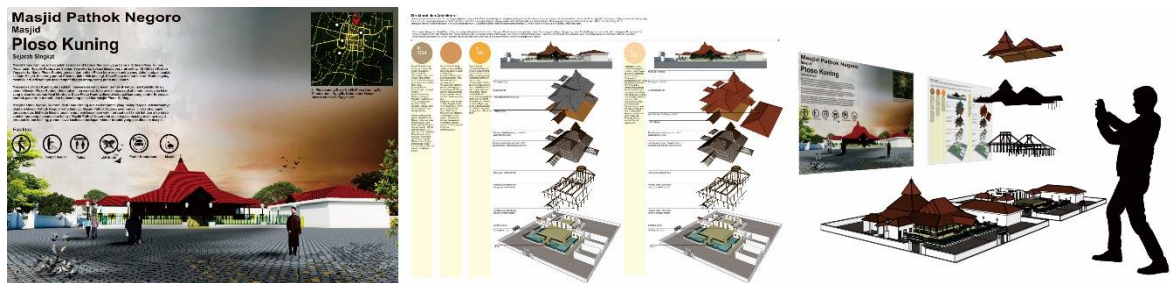
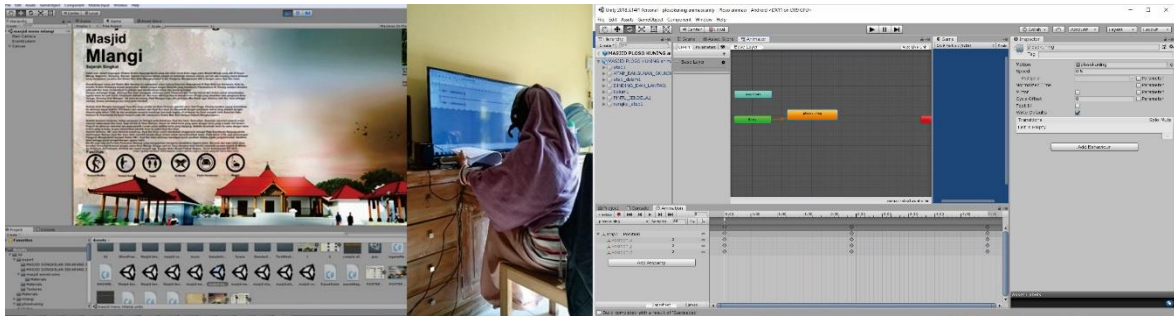


Figure 8. The building timeline of modification and building appearance

The AR app is completed with a narrative sound and interactive animation object. The animation object consists of four elements: roof, roof insulation, roof structure, and column. These elements in figure 9 were animated in unity3d in 5-second looping animation, moving up and down to start position.



**Figure 9.** Recording the narrator voice of Mlangi mosque and animate object in Unity3D.

The application was tested in an Android device compatible with ARCore, at least Android 8.0 [27]. The application was tested on an android device, Xiaomi Pocophone F1, with Oreo 8.1 Android Version. It showed a smooth transition for presenting a single building in Augmented Reality but became slower when tested on image tracking with more objects of 3D models, as shown in figure 10. The image tracking process was also not optimal because of the inadequate quality of the image database.



**Figure 10.** Spatial concept of Pathok Negoro mosques position in Yogyakarta

The plane detecting for AR worked well, as shown in figure 11. It showed a well-ordered animation of a building structure with clear history and culture displayed in several posters in the augmented reality app. Unfortunately, the daylighting and material reflection is inadequate. Yet, the use of Unity3D as software for making an AR application is beneficial, especially for the possibility of cross-platform development. The Google ARCore SDK package for Unity is considerable for developing Augmented Reality. It has many benefits in the technical aspect. Moreover, the following work may involve examining other AR methods, such as creating a markerless or GPS location-based augmented reality application. Future work will investigate the method efficiency and the user experience based on the academic background.



**Figure 11.** Application test on Android device.

#### 4. CONCLUSION

We have developed a mobile augmented reality application in Unity 2018.3.14f1 for android devices that consists of the culture and history of the Pathok Negoro Mosques. We have presented the step clearly from gathering data, converting it into 2d by using AutoCAD, making the 3d model using Sketchup, and then importing the FXB file to Unity. This project utilized the google ARCore 1.6 SDK package for Unity by modifying the script of plane detection generator and image tracker from the example file. The current project was limited to the Android device with the Android oreo 8.0 version.

The application was tested in a Xiaomi Pocophone F1. The plane detecting in the AR app worked well. It showed a smooth transition for presenting a single building in AR but became slower when testing image tracking with more objects of 3dmodels. It showed a well-ordered animation of a building structure with clear history and culture displayed in several posters in the augmented reality app. The daylighting and material reflection was inadequate. Yet, the use of Unity3D as software for making an AR application is helpful, especially for the possibility of cross-platform development. The Google ARCore SDK package for Unity is sufficient for developing AR. It has many benefits in the technical aspects.

This research opens the opportunities to bring AR for digital heritages and building simulations. The following work may involve examining another AR method, such as developing a markerless or GPS location-based AR application. Future work will investigate the method efficiency and the user experience based on the academic background.

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Endang Setyawati	Endang Setyawati focuses on the typology morphology of heritage buildings and cultural heritage. Her latest research explains the Pathok Negoro Mosques as the form of territorial defense region of Mataram Kingdom of Islam Java in Jogjakarta. She is a lecturer in the bachelor architecture study program at the University Technology of Yogyakarta. She joined as a team teaching at the design studio, architecture history, and building structure. She holds a doctoral degree from Diponegoro University. Her doctoral thesis explains the Form, Function, and Architectural Meaning of Pathok Negoro Mosques as Defense of the Yogyakarta Sultanate.