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Simulation of Colonial Building Reconstruction in Jakarta Old Town Through Augmented Reality

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Abstract

Augmented reality (AR) is a trending technology with many potential applications. In architecture, AR can help visualize and document historic buildings by virtual reconstruction. Colonial buildings in Jakarta Old Town are cultural heritage buildings that are vulnerable to damage by aging and environmental factors. The mitigation of this damage as the first step toward restoration is important. The storage and maintenance of records of threatened buildings for posterity are also important. The objective of this study is to develop a methodology for AR-based reconstruction. AR technology is implemented through mobile phones or smartphones. The modeling process is simple and interactive and has potential applications in both education and tourism. The reconstruction method of colonial buildings uses markerless AR and a database of historical knowledge of colonial architecture. The architectural style is identified using the database. Then, an AR-Reconstruction prototype, which provides a visual description of the building reconstruction process using 3D graphics animation models of colonial buildings, is developed. The model reproduces the building in its original condition and actual location. In the trial run, access to building details is delayed. Therefore, in the future, the geometric details and marker quality need to be optimized.

Abstrak

Simulasi Rekonstruksi Bangunan Kolonial di Kota Tua Jakarta Melalui Augmented Reality. *Augmented Reality* (AR) sebagai tren teknologi berdampak signifikan pada kemudahan aplikasi dalam berbagai hal. Pada bidang Arsitektur, AR dapat membantu program pelestarian bangunan bersejarah dengan rekonstruksi maya. Bangunan kolonial di kota tua Jakarta yang masuk dalam kategori bangunan cagar budaya sangat rentan terhadap kerusakan, baik karena faktor alam ataupun karena faktor usia. Oleh karena itu perlu adanya mitigasi bangunan cagar budaya tersebut sebagai langkah awal rekonstruksi. Penelitian ini bertujuan mengembangkan model konsep pelestarian melalui paradigma 'aktif' dengan rekonstruksi berbasis AR Yaitu membuat simulasi rekonstruksi bangunan kolonial dengan bantuan AR berbasis mobile smartphone, yang memberikan informasi interaktif dan dapat dipergunakan dengan mudah oleh pengguna untuk keperluan edukasi dan pariwisata. Metode rekonstruksi bangunan kolonial dengan menggunakan markerless AR dan basis data pengetahuan sejarah arsitektur kolonial. Diawali dengan melakukan identifikasi dan klasifikasi melalui penelurusan sejarah arsitektur yang diakuisisi sebagai sebuah basis data pengetahuan. Hasil dari penelitian ini adalah prototype AR-Reconstruction, dimana memberikan gambaran visual proses rekonstruksi bangunan dalam bentuk animasi grafik 3D bangunan kolonial yang sama dengan kondisi di lokasi aslinya. Hasil percobaan mengindikasikan jeda pada akses detail bangunan sehingga perlu optimalisasi pada detail geometri dan kualitas marker.

Keywords: augmented reality, AR-reconstruction, historic buildings

1. Introduction

Jakarta Old Town, formerly known as Oud Batavia, is an important part of the history of the formation and development of Jakarta. Jakarta Old Town has considerable economic, social, and cultural potential. However, the function of Jakarta Old Town has not been maximized to improve its potential and achieve its objectives. At present, Jakarta Old Town is experiencing deterioration in the quality of its physical, economic, social, and cultural environments.

Heritage buildings are material sources of human culture that are vulnerable to damage by aging and environmental factors. Therefore, the thorough documentation of cultural heritage buildings is desirable so that they are not lost to history. Problems concerning the vulnerability of heritage buildings are encountered in

Jakarta Old Town. Colonial buildings, which are cultural heritage buildings, around the city station and the Fatahillah Museum to the Sunda Kelapa port of Jakarta Old Town show that 75% of the 170 cultural heritage buildings from the 16th century to the beginning of the 20th century are threatened and damaged (Figure 1) [1].

Developed countries, such as those in Europe, have utilized augmented reality (AR) technology for various purposes, including the preservation of historic buildings. The rapid development of AR also boosts the tourism sector [2]. This technology provides virtual models of the restoration, renovation, reconstruction, and rehabilitation of buildings for tourism purposes, as well as for research and development of on-site construction guidelines.

Recent advances in AR open up new opportunities for the development of virtual urban geographic experiments [3]. Boboc *et al*. propose a mobile augmented reality (MAR) application that contains historical information [4]. Kolivand *et al*. presented a brief comprehensive survey of cultural heritage using different techniques [5]. Riboldi and Maciel [6] determined that the use of AR technology can support the resilience and longevity of cultural heritage buildings. The system developed in this study is a new AR tool, particularly for the visualization and exploration of urban historical heritage. The application has considerable potential in the dissemination of knowledge and preservation of heritage buildings. The application can be used to present cultural information, although it is still in the development stage. For example, the application could be used in interactive museum exhibits and as a historical guide for both residents and tourists.

Current conservation efforts in Jakarta Old Town are still incomplete and not fully digitized. Existing data are mostly in the form of computer-aided design (CAD) drawings, which are stored manually and partially. Communities and conservation stakeholders expect simple and interactive access to data. The AR-Reconstruction application proposed in this study provides a method for presenting building data in text, 2D, and 3D form.

The AR-Reconstruction application digitally records cultural heritage buildings. The objective is to store the data of threats from both natural and human factors [7]. The methods used to digitize existing data include photo documentation, descriptions of historical value, data of the physical elements of the building (e.g., foundations, structural supports, and roofing tiles), and condition of other substances needed (e.g., paint and plaster). A database of the architectural characteristics of heritage buildings is useful in preservation activities because reconstructing cultural heritage buildings that have been damaged or even destroyed is difficult when historical architectural data are unavailable [8]. However, CAD data used to replicate heritage buildings in 3D models must be compatible with other tools, particularly if intended for AR. As the data needed for AR are complex, the methodology should be structured effectively [9].

Figure 1. Map of Jakarta Old Town [5] and Ruined Colonial Buildings in Jakarta Old Town

Reconstruction is one of the approved conservation methods [10]. Reconstruction is a restoration activity to rebuild and repair, as accurately as possible, the buildings and environments destroyed by natural or other disasters or damaged by neglect or abandonment of the building. During reconstruction, the remaining or stockpiled construction materials are used and traditional building materials are added to ensure that the building functions properly and meets all construction standards and requirements.

This research attempts to solve an existing problem by developing a conceptual model of conservation using AR-based reconstruction. AR-based reconstruction is a conservation concept that prioritizes ease of access to data and information, interaction between users, and maintenance of artifacts. AR-based reconstruction also recreates the original environment of historical artifacts that are restored or reconstructed. The use of AR technology enables the work to be done more easily and efficiently, thereby saving money, energy, and time. Compared with the existing conservation concepts, this model presents a more innovative approach.

2. Research Methods

The AR-Reconstruction of colonial buildings was done in an information system based on MAR, with a knowledge database related to the construction of colonial buildings. The research phase starts by transforming the “real environment” object into an AR object.

The design phase of the AR-Reconstruction application is as follows:

a. 2D and 3D model creation: In this stage, the data or objects that are collected are rendered in 2D and 3D models. This process is also called data/object digitalization [11] and uses the Google SketchUp and 3DS Max software tools. Similar workflows were utilized by Albourae *et al*. [12] and Setyawati *et al*. [13]. However, this study also uses Vuforia along with Unity. The Google SketchUp software also has geolocating capabilities, which can provide precise geographical locations and even the terrain aspects of these locations through the placement of 3D models in Google Earth.

b. Establishment of a database of historical knowledge of colonial architecture: In this stage, data from each element of knowledge along with a description or an explanation are tabulated and stored. The selected database model is the relational database.

c. Forming a marker target: A markerless system is used when there is no need for markers that are identical to the black and white box area. However, the marker target can be an object or image. The target image that will be used as a marker target for pattern recognition by Vuforia is identified and recognized. The process of forming a marker target is shown in Figure 2.

   The tracking process is done by recognizing the pattern in the image captured by the camera sensor. The Vuforia Library as a 3D Unity support tool can detect images using a standard camera. The position information obtained is used to place the object in the markerless position. After the image pattern is recognized and/or detected, the information appears on the screen of the Android mobile phone.

d. Designing the AR-Reconstruction application: An intuitive user interface is built for this purpose. This interface displays various menus to facilitate interaction. The system built is a mobile application that serves as a medium for information on colonial architecture using an Android platform with AR.

Figure 3 illustrates the system flow and activity diagram of the AR-Reconstruction application.

The system architecture of the AR-Reconstruction application is as follows:

a. Mobile software: The software is installed on an Android mobile that has a mobile camera, as a tool to detect images when the camera is directed to the marker.

b. Target image (marker target): The target image or object, which is a Google Earth map, will be detected by the system.

c. Marker detection: The existence of a pattern in the image or photo that has been captured by the camera is recognized. Then, the pattern is used as a tracker object. Afterward, pattern recognition is done by introducing image patterns that will be made markerless, with data in the system. Then, the pattern is detected and adjusted to determine whether the AR marker object can provide information or not.

The sequence in the designed AR-Reconstruction application starts when the user presses the AR presentation button. Then, the application detects the camera that is already active. The camera is pointed at the object to be used as a marker. Then, the system captures the image. Afterward, a tracking marker is applied to determine whether the object pattern is detected or not. If detected, then the information appears on the mobile phone screen.

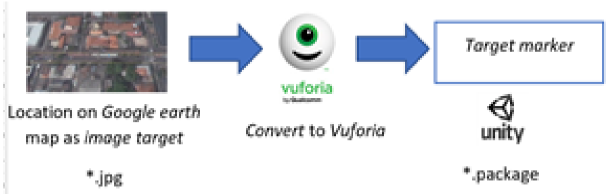

Figure 2. Process of Forming a Marker Target

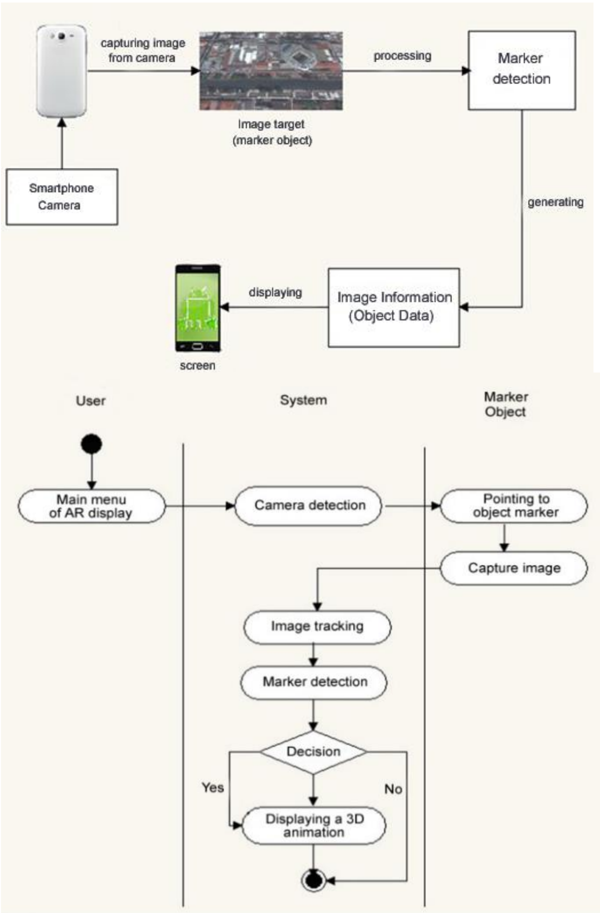

Figure 3. System Flow and Activity Diagram of the AR-Reconstruction Application

3. Findings and Discussions

In this study, the simulation model for the reconstruction of heritage buildings focused on the shipping office building of Samudera Indonesia Limited. The building was once the shipping office of Office Premises, Maintz & Co., founded in the latter part of 1927 by Architect FJL Ghijsels, with Art Deco style. Currently, this building is unoccupied and nonfunctional. On February 1, 2008, half of this building was destroyed by land subsidence. Figure 4 shows the existing condition of the shipping office building of Samudera Indonesia Limited.

2D and 3D modeling. On the basis of the architectural data of colonial buildings obtained at the study site, a basic model was made. The data are in the form of blueprint images, photos of historic buildings, and photo documentation of the location. Then, the data are drawn in the form of 2D and 3D models (Figure 5). After the drawing process, the 3D model of the location is displayed in Google Earth (Figure 6).

Results of knowledge database establishment of colonial architecture. In addition to displaying 3D images, the application displays a database of historical knowledge of colonial architecture, particularly of the buildings that are being investigated. The history of architecture is the study of events, architectural products, and figures in the past that are related to the development of architecture in the present and future. This concept is used in the context of presenting the knowledge database in the application. Therefore, the application serves as a learning model that can be used to improve the quality of architectural buildings and the environment (i.e., physical and social) in the present and future. "History" is usually investigated on the basis of "time" and "place," whereas "architecture" is investigated on the basis of "usability" and "image." Figure 7 shows how the knowledge database is established after an object is detected and tracked by a marker. The knowledge database presents an example of the relation

Figure 4. Existing Condition of the Shipping Office Building of Samudera Indonesia Limited, with Half of the Building Destroyed by Land Subsidence

of "architectural history," specifically to the investigated colonial architecture buildings. In the knowledge database relation of "architectural history," colonial architecture is divided into nine master tables (Figure 7) consisting of location, zone, subzone or a part of "place," period or a part of "time," function category, building function or a part of "function," style category, building style, and architectural elements or a part of "image."

Figure 5. Results of the 3D Modeling of Colonial Buildings in Jl. Kali Besar, Jakarta

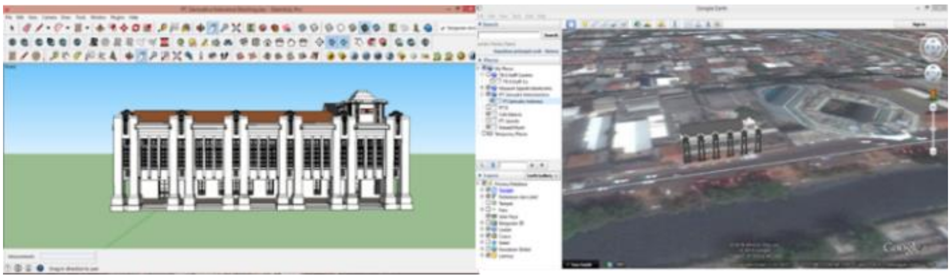

Figure 6. Position of the 3D Object Model of the Shipping Office Building of Samudera Indonesia Limited in Google Earth

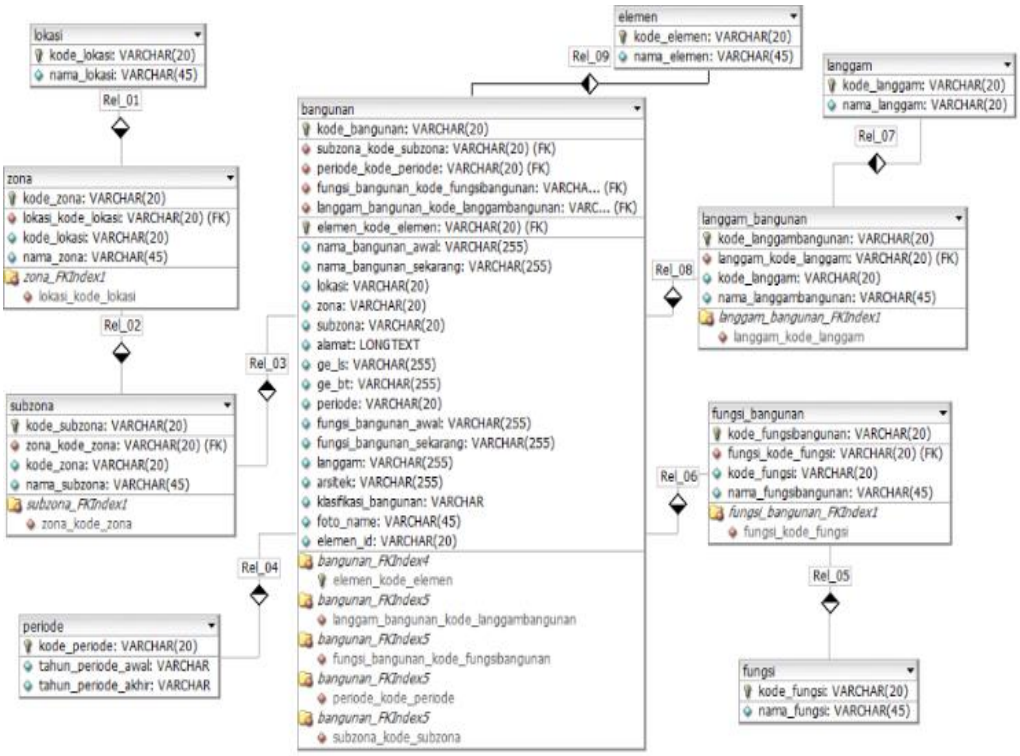

Figure 7. Entity–relationship Diagram of the Information System of Colonial Buildings

Results of marker formulation. Markers are taken from the position of the reconstruction site of the heritage building. Location maps are taken from the Google Earth map. Figure 8 shows a marker map of the location of the building to be reconstructed. The marker map location quality level of the shipping office building of Samudera Indonesia Limited is medium quality, indicated by three stars. Maps taken from the Google Earth map with 1:1,000 scale magnification yielded images with an average sharpness level.

a. Development of AR-Reconstruction

The reconstruction of the building was done by combining the architectural elements of the building that had been selected and designated as a colonial building. The output is stored in the 3D graphics animation database of the building reconstruction process (Figure 9).

The application has been developed with a user interface that contains menus of buildings in Jakarta Old Town as part of the Indonesian colonial architecture. The AR-Reconstruction application was created on the basis of the user's requirements when selecting a colonial building for reconstruction, which was adjusted using the knowledge base of the history of the architecture, i.e., the location of the subzones of the selected city, the period of construction of the colonial building, the function of the building, and the building style. The architectural elements are obtained from the database. Once the menu selection process for the building style on the main menu page is completed, the user can click submit (Figure 10). Afterward, the information on the building being searched will be displayed. The information displayed on the page includes the historical data of the building, a map of the location, and photos of the building (Figure 11).

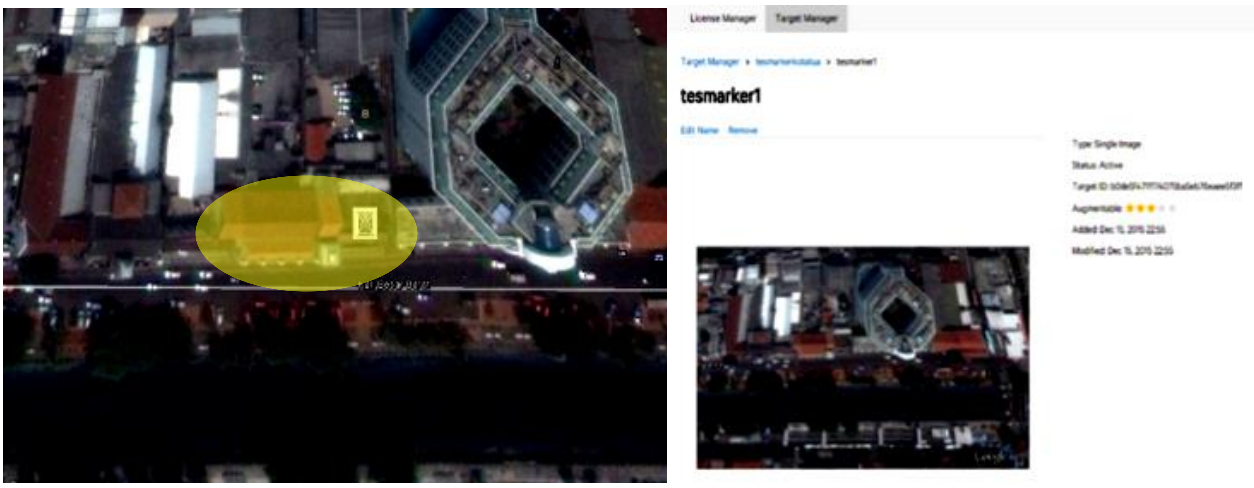

Figure 8. Marker and Marker Quality of the Location Map of the Building of PT. Indonesia Ocean Truck

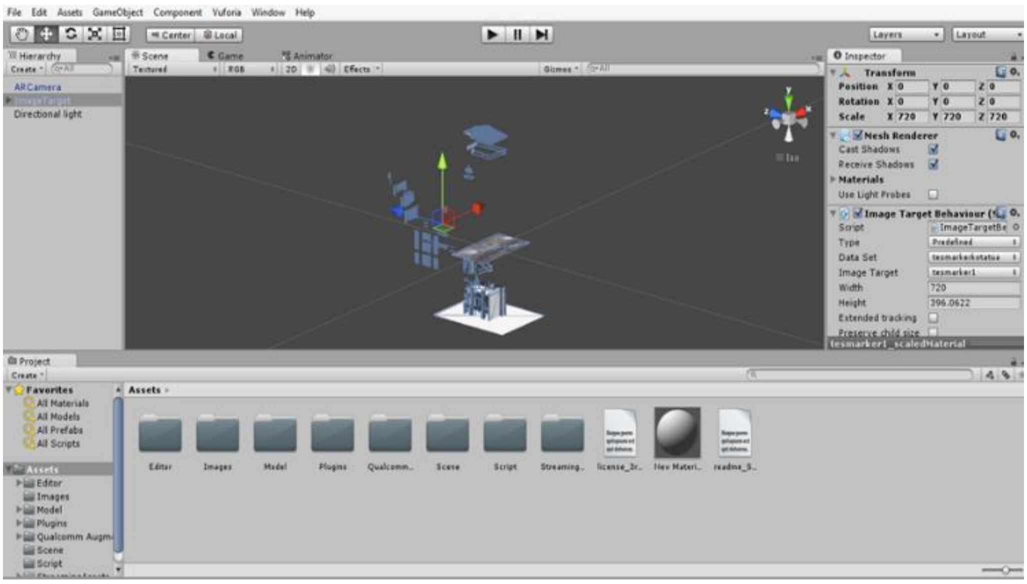

Figure 9. 3D Graphics Animation of the Building Reconstruction Process

Figure 10. Main Menu Page

After the building information is displayed, the user can continue to obtain information on the elements of colonial architecture. If the displayed information is not as intended, then the user can click "back" to return to the menu selection page to search for the information in question. Figure 12 shows a page design that displays the 2D graphics of the architectural elements of a colonial building of which the information has been presented on the previous page. From the menu of the 2D architectural elements of colonial buildings, the user can proceed to the next menu by clicking the "start reconstruction" button. Then, the menu will activate the camera to detect Google Earth map markers of the location of the building (Figure 13).

Figure 11. Building Information Page

Figure 12. Display of the 2D Graphics Menu of the Architectural Elements of Colonial Buildings

Figure 13. Display of the Google Earth Map Detected by the Camera

After the Google Earth map is detected by the camera, three buttons will appear, i.e., start reconstruction, start, and exit. To continue, the user can click "start reconstruction" to display a 3D graphics animation presenting the reconstruction process of colonial buildings according to the previously obtained information.

4. Trial Run on the Output

The application was subjected to user testing with several students. The trials focused on samples of the shipping office building of Samudera Indonesia Limited in two ways, i.e., using merged location map markers (Figure 14) and locking a camera on the Google Earth screen (Figure 15). Software testing of the AR-Reconstruction application was conducted with black box testing. Black box testing is based on the output only, which is generated from the data, or the input conditions, which are given for functions contained in the software, without the need to see how the output is obtained. Slight dynamic issues occurred because of lags. The system delay was due to the time difference between the moment that the tracking system measures the position of the viewpoint and the moment when the generated images corresponding to that position appear in the displays. However, the delay is not too intrusive, i.e., just a fraction of a second. Delays of 100 ms are fairly typical in existing systems [14].

The pilot AR-Reconstruction trial findings provided helpful insights into the actual building, including access through smartphones and final visualization on screen. The application enabled participants to use smartphones to detect images after accessing the building data. This AR system makes navigation easier by performing the association step automatically. Once the user's position and orientation are known and the AR system has access to a digital map of the object, the system can draw the object in 3D directly on the basis of the user's view. The most preferred data are 3D in 360° with high magnification of the details. In the future, more trials will be conducted using a large sample size to verify the consistency of the results obtained in this study.

5. Conclusions

This study presents a method of displaying building databases with reconstruction opportunities using the AR-Reconstruction application. The application is intended to provide a knowledge database of the architectural elements of old buildings, with the opportunity to reconstruct them. The characteristics of colonial buildings are presented in 3D animation based on AR. The application helps recreate or reproduce the building in its original condition. Building images can be constructed right at the location of the site, and its 3D objects can be rotated in all directions.

Currently, the AR-Reconstruction application is still only devoted to colonial architecture buildings. Some issues in the application, such as image detection and display, need to be optimized. Moreover, a database of building details needs to be added. However, encouraging the continuous development of a documentation system of old buildings is a strategic step. Future work needs to focus on improving image detection and display by optimizing marker quality, as well as completing and synchronizing building details in the database. More sophisticated detailing, lighting, texturing, and shading capabilities must run at interactive rates in the future.

Figure 14. AR-Reconstruction Trial Run with Print Markers

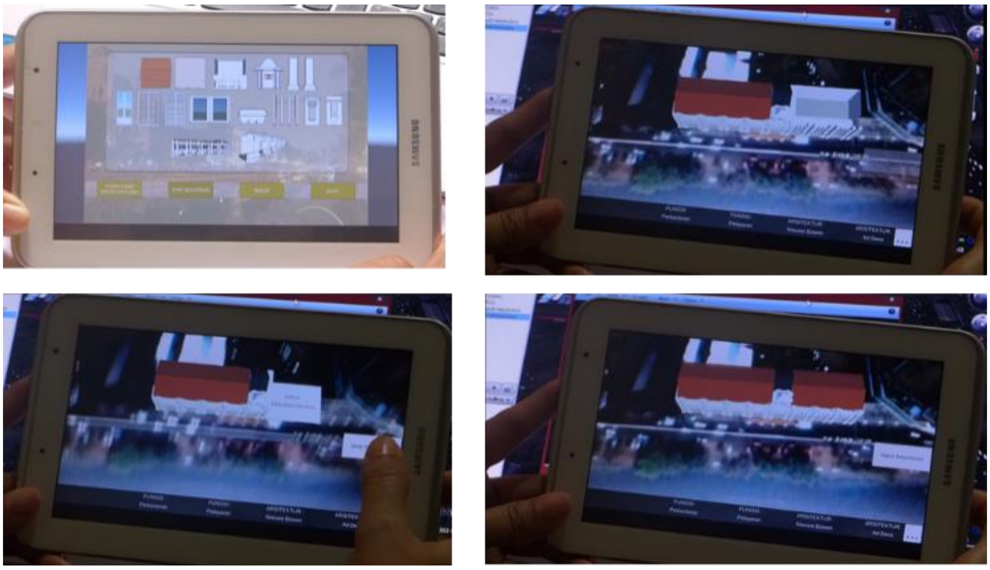

Figure 15. AR-Reconstruction Trial Run with Google Earth

Future work should include the creation of more databases of old buildings for education and tourism purposes. Through digital building model reconstruction techniques, AR-Reconstruction improves the learning process and facilitates the user in understanding the context of the building. AR-Reconstruction also connects the user to every detail of architectural elements, particularly the appreciation of the details of construction, and the chronological sequence of events in the history of past civilizations.

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