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An Interactive Augmented Reality Architectural Design Model

A Prototype for Digital Heritage Preservation

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***Abstract*—We present study on the integration of augmented reality using Microsoft Hololens and architectural design documentation for cultural heritage application by practical evaluation method. Our goal is to understand the potential of AR implementation in architectural narration and documentation. Herein, we outlined our works: 1) Visualization of architectural forms; 2) Data visualization embedded in augmented environment; 3) Basic user interaction mechanism. Our focus of the study is on the methodology and workflows involved in the AR platform. The case study is traditional Balinese architectures that constitute issues of materiality, tectonics, aesthetics and embodied local and specific information, hence the cultural heritage. Our study found that AR and Hololens provide a promising tool for 3D visualization and experiences particularly in cultural heritage application where computer-generated objects are augmented into real and physical objects. Despite latency, limited visual field and interaction methods that are still in development, implementation of AR in the architectural field bring understanding architecture as a medium and interface where space, form, and information are combined**

Keywords—Augmented Reality, Microsoft Hololens, Architectural Design, Cultural Heritage, Traditional Balinese Architecture

I. Introduction

In 2016, Microsoft released the developer edition of the first Augmented Reality instrument dubbed Microsoft Hololens. This new tool, along with new platform promised a potential and technological step for data visualization, spatial and ambience experiences particularly in the field of architectural design where a 3D representation of design plays an important role for various purposes.

While Augmented Reality (AR) and Virtual Reality (VR) concept and technology have been around for many years [1], Microsoft Hololens brings a new potential advantages as a medium for data augmentation and integration between real and virtual world. The later issue differentiates AR from VR where AR presents combination between a computer-generated object and existing real-world objects while in VR, user immersed in a complete virtual world , isolated and separated from the real world. The application of AR into professional and academic uses has been the topic of studies of scholars particularly in the field of architectural design where this device promises as a new media to enhance the user experience of design process, production and product. Study on experiential architectural design process [2] summarized that AR/MR (Mixed reality) pioneered by hardware platform of Microsoft Hololens has capability to enhance the utility and user experience in AR/MR. The platform is anticipated to serve intriguing possibilities for exploration by a wide range of professionals across disciplines. Prior this study, [3] proposed the concept and associated enabling technologies and technical issues bringing AR into the context of the architecture and design applications. According to this result, a key issue for AR application in architectural design is the flexibility and robustness of AR system allowing work accurately in all environments without the need to learn these environments in advance.

Related to architectural design application, some studies and initiatives have been worked on an application in planning and design processes [4-6], documentation, interaction and visualization [7-12]. Most of them investigated and made an analysis of the possibilities in utilizing AR inherently with iterative-non formal and formal procedure. While the specific application for architectural narratives in education, Zarzycki [13] for example, highlighted three factors for implementing AR in architectural design: design, user experience, and content. The student perceived AR technology as highly transparent without a strong technological footprint. Thus, it naturally transitions them to explore diverse content-based topics. Another example of utilizing AR for architectural documentation and education showed by Niedmermair [14] and Kim [15] where mobile AR used to facilitate exploration and experience in urban and interior scale.

A number of case studies and findings are conducted from the developer point of view focusing on the technological complexities and technical layer. Our primary focus in this study on the methodology and framework in developing rich-content AR-based architectural narratives and documentation by taking a standpoint from architectural design perspective where, as Zarzyzki has pointed out application design, user experience, and content is our main concern. We examined ways of the emerging interactive technology, in the case of Microsoft Hololens, are being adopted by educators, designers, architects and exploited into the area of architectural design.

All standard paper components have been specified for three reasons: (1) ease of use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout a conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. METHODOLOGY

Augmented Reality using Hololens works by acquiring application specifically developed for Hololens in the Unity 3D Platform and Microsoft Visual Studio. Unity 3D is a platform for developing virtual environment including acquiring 3D geometry data from 3D modelling software and developing interactive objects. This software, which is free for personal use, is one of the most popular platform for game development. While Microsoft Visual Studio provides a platform to develop user interaction and deploy the application into Hololens (Fig.1 shows the diagram of the system and Fig.2 shows the Microsoft Hololens unit). Essentially, the quasi holographic respresentation in Hololens works by projecting data signal on the lens to an optimum distance from the user's eye while at the same time, detect the spatial configuration around the lens for locating virtual object into real world. The interaction process works by calibrating and detecting user's fingers, voice and gaze using camera and microphone embedded into the HMD.

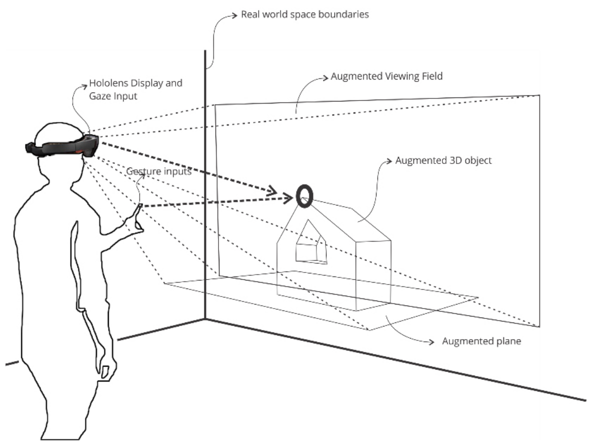

Fig. 1. Augmented Reality system with Microsoft Hololens

Fig.1 depicted a Hololens system where basically is a head-mounted Windows 10 device. Using Hololens for architectural design purpose is essentially developing an application that deployed into Hololens device. There are key features signified this AR device from other VR devices.

1) The visor is translucent, allowing the user to see both real and virtual (or, augmented) objects.

2) The system has the spatial mapping to detect and remember planes of physical objects. Therefore, a holographic application can be located or, put on any physical objects such as table top and floor.

3) The user interaction is via gaze (there is eye tracking sensor in the visor) for selecting objects, gesture inputs and voice command using Cortana, a voice-activated digital assistant in Microsoft Windows.

4) Since the Hololens is, in essence a PC, cables or support hardware are not required.

Fig. 2. Microsoft Hololens unit used for the study

Our study involves system preparation for 3D modeling, Unity3D, and Microsoft Visual studio workflow for deploying Hololens application that can be summarized in the following:

1) Modelling of architectural form of the case study using Trimble Sketchup that was exported to Autodesk 3DS MAX for texture mapping and .fbx conversion to Unity 3D.
2) Creating interaction and navigation using Unity3D based on 3D geometry (.fbx format) and set of interaction and navigation libraries. The Unity 3D scene then compiled and deployed onto the Hololens using Microsoft Visual Studio 2017.

III. PROTOTYPING

Our study intends to investigate the potential application of Hololens AR to visualize, conceptualize and communicate 3D architectural forms encapsulated in rich contents within holographic fashion. Communicating ideas of 3D forms for both professionals and common audiences is always been the main task for architects. Since the beginnings, architecture profession used projection drawings such as orthogonal and isometric as well as diagrams and scaled models to convey ideas and addressing design solution. This medium helps the audience understand and convey the notion of form dimensions and its settings. Nevertheless, projected representations and scaled models have issues of static and scaled, and the notion of not 'being there'.

Information technology through CAD and computer-generated modeling address the issue of scale through some techniques such as 'walkthrough' and 'fly-trough' where the user can locate themselves with predetermined viewing angle and elevation to move inside or around objects. Still, this technology displayed on the two-dimensional screen where three-dimensional objects remain projected into a flat surface.

Later, development of Virtual Reality (VR) enables to create an environment that encourages human sensory organs. VR technology projects the body of a user in a three-dimensional space and causes a sense of immersion in the space by the effect of the device by wearing it on his body part with images and sounds synthesized by the computer. VR technology can be considered as a medium that has three defining characteristics: interactive, where users can interact with any projected models; spatial, where all models are represented in three spatial dimensions; and real-time, where all feedbacks received by the users from actions that occurred are given without noticeable pause [16].

Nevertheless, there are issues with VR that yet to be fully resolved regarding user interaction: first, is the feeling of isolation and completely separated with real-world cause orientation problem, nausea and motion sickness. Second issues related to latency and registration of any user interaction that limited VR implementation in full virtual 3D modeling processes.

The Augmented Reality (AR) suggests that instead of replacing real world with a virtual world, the data and information are augmented and situated in real context. In architectural design point of view, this notion allows architects to explore the way of communicating his idea to the audience, either by scaled 3D model, or full-scale 3D model without leaving the grasp of reality.

Our case of study being developed into an application is the design of traditional Balinese houses located in a rural area of Central Bali (Fig.3 and 4 show our model of case studies). In such traditional architecture, some values are considered as our focus on rich content development in AR such as: structural elements and its construction, building elements and textures.

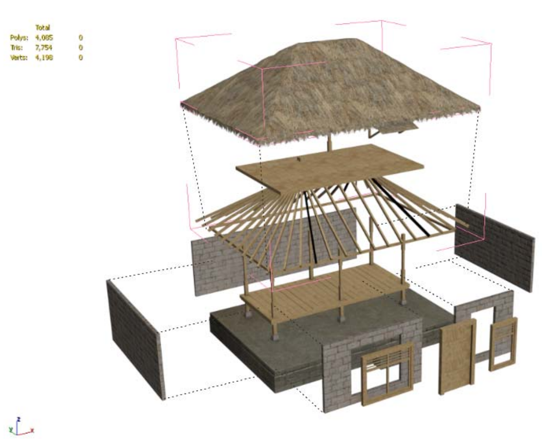

Fig. 3. Model of Bale Adat

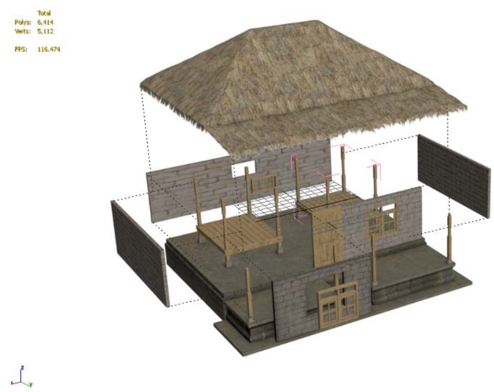

Fig. 4. Model of Bale Meten.

Depicted in Fig.3 and 4 are two vernacular house of Balinese Pengotan Village. This village is considered as one of the oldest in Bali island where inhabitants live in groups in a secluded compound area. Each group has its own territory consists of several house units and a granary. The house is approximately 6 x 4 meter with 2.5m height, using paddy's straws or palm leaves as a roof material, where solid timber and clay bricks are main material for frame and walls. Layout and arrangement of houses are depicted partially in Fig.5 where main orientation is North-South and aligned with the Mount Agung, the biggest volcanic mountain in Bali island.

Fig. 5. Partial Site Plan of Pengotan Village

The two distinguished house of Bale Adat and Bale Meten serve as food and offerings preparation room and a common kitchen for their regular rituals respectively. Each group has their own Bale Adat and Bale Meten and the houses also a representation of guardian value of the family. Typologically, the simple form, material, and construction of the house is a common practice in the traditional people of Bali where the main structure of the 4m long-span house is solid timber by local forest.

IV. Application Development

We are able to gather data on geometry and materials as well as non-graphical information such as the history of the dwelling in Pengotan Village, video of house construction process and others that were included into AR application. This richness of information is encoded in the application via structured interaction mechanism displayed below:

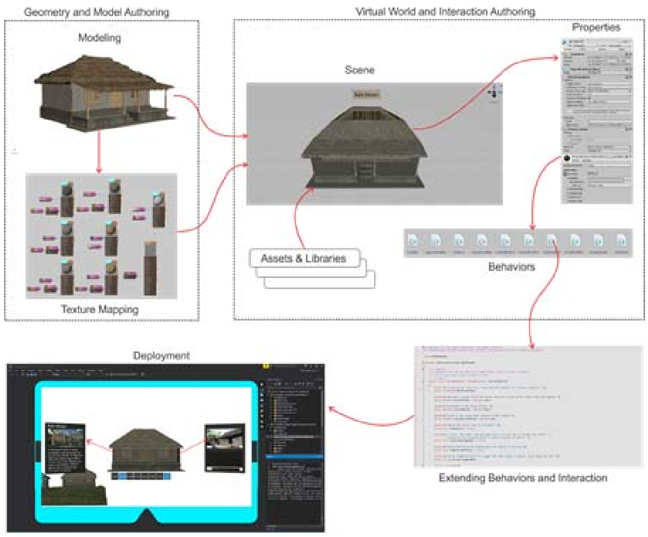

Fig. 6. Application Authoring Workflow

As displayed in Fig. 6, our application development can be characterized into three stages:

1) Geometry and 3D model authoring: The general models were completed in Sketchup while material setup and texture mapping were completed in 3DSMAX. Completed models then exported to Unity for virtual world and interaction modeling. There is no significant issue related with the integration of geometric models in Unity including texture mapping and its properties.

2) Virtual environment, AR camera navigation and interaction authoring: In AR authoring software using Unity 3D, we set up two main interaction mechanism: a) navigation using AR camera, used as a camera for Microsoft Hololens; and b) Interaction and information extraction using Microsoft Hololens interaction features.

We are focusing on the AR application that provide user experience to examine a building model using features such as: zoom-in/out, exploded building components and orbital camera movement, as well as extracting some information in form of text, images and video.

There are three interaction mechanisms specifically applied using Microsoft Hololens: Object Selection, Object Location and Action Trigger. We experimented and developed user interaction mechanisms using C# scripts embedded into these following objects:

a. Object selection via gaze. Gaze input is used to select (focus) object. The Inertial Measurement Unit (IMU) of Hololens providing data of head movements that can be used as gaze control. This procedure is conducted via Unity program where main camera (AR camera) of Unity scene is assigned or mapped to head movement. The heading/forward vector that indicates user view is programmed to search for intersection with target surface to activate focus or "selected object". This sensor happens to receive noise of raw data received from IMU processor that sometimes cause jitter effect when displaying the cursor. To overcome this we applied GazeStabilizer script provided by HoloToolkit to smoothen the data received by application.

b. Object location via gesture control. Upon object selected, user can put object to real world flat/ planar surface by utilizing Spatial Mapping feature that reconstruct triangle meshes that represents viewable surrounding environment. In our case, we only intend to use real flat surface to put our 3D model. By using standard HoloToolkit script, it is possible to convert the meshes into plane to which we use for this purpose.

c. Action Trigger via gesture control. We utilized gesture control using air tap method as a trigger for action of retrieving information from selected object and bloom method to go to the Home Screen or back to Start Menu. We developed information hierarchy for this purpose as determined in Table 1 below:

TABLE I. Information Hierarcy

Actuator/ Trigger	Action
Name banner	Text, image, video and sound of the description of selected object.
Whole house	Object explodes, revealing building components
House Component	Text, image, video and sound of the description of selected object.

Meanwhile Fig.7 depicted our interaction scheme using combination of Gaze and Airtap features of Microsoft Hololens.

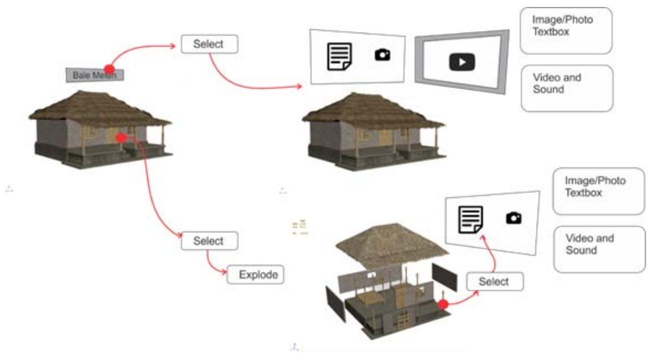

Fig. 7. Interaction Scheme

3) Deployment preparation and in Microsoft Hololens: following the model and application development, the deployment and porting procedure into Microsoft Hololens application is a straightforward approach as been guided in the Microsoft Hololens website.

V. FINDINGS AND DISCUSSION

Our early hands-on experience and experiment with Augmented Reality (AR) application using Microsoft Hololens have been proved that there is an opportunity for experiencing architectural design accompanied by rich information in a different approach. Experiencing AR where spectator or subject is not only able to interact with the virtual object, but also still feels surrounded by real environment gives an advantage over immersive Virtual Environment (VR).

Based on our experiment, our application was able to detect a planar surface, where our model then can be located. User can interact with the model using gaze and gesture controls while in the context of visualization, a semi-transparent and detailed AR model gives two sides of concerns: as written in the following section, there is a technical issue related with the surface material that affecting how we model the object. The brightness and clarity of the object depends on the surface material. Level of detail still becomes another issue as it goes with the limited viewing range. On the other side, a semi-transparent mode of AR gives a sense of being in real-world as opposed to VR application. This lead to the impression that user feels more engage and enjoy interacting with the application.

After all, we summarized some findings on issues related with the implementation being focused on the methodology and workflow as follow:

a. The spatial mapping on surface material was found varies depends on some factors such as light intensity in the room where surface is located. The darker the environment, the harder it can be scanned by the camera, so user should come closer to the surface. Another finding was the reflectivity of the surface. The more reflective the material is, the harder it can be scanned and apparently, it should be viewed frontally and not from low angle from the camera.

b. Virtual object is found to be best viewed in a semi empty room or, little variation of objects, texture, lightings or colors in order gives more brightness, contrast and highlight visual feedback of the virtual object against real world.

c. The optimal distance placement for virtual object is in the range of 1.2m to 2.25m. In this range of distance, level of details of the models, readability of text and other form of information is convenience and enjoyable. Given the normal situation of an office room where this experiment was conducted, our experience of optimal distance is different than the optimal zone for hologram placement as indicated by Microsoft Hololens website .

d. The determined rendering rates at minimum 60 frames per second (fps) gives optimum performance although at some points, there were uneven motion, glitch or double images caused by sudden movement of user or if the were changing their headset.

e. The gaze targeting was proved to be the main procedural mechanism for AR user. Our experience shows that user experienced differently to try out the gaze mechanism for the first time. In theory, the further distance of the object placement the larger target angle from the camera (1.5^o-3^o). In our experiment, the easiest gaze targeting was when the object located at 1.5-2.25m from the camera with tilt degree around 1.5^o-4^o.

f. Interaction and event trigger using gesture control using Air Tap and Bloom. The main issue is the recognition of gesture movement including time delay between fingers in tap and bloom method. As with gaze targeting mechanism, the gesture control is proved to be experienced differently among users. In some cases, the both hands recognition by the camera took some time and it was depend on the particular position of the hands that are visible by the camera. User then been taught of the gesture frame where the gesture movements outside this boundary were unrecognizable.

Our first hands-on application development and experiences using Microsoft Hololens for architectural design, particularly for documenting architectural heritages as our case or as a new method for experiencing architectural forms and elements proved to be convincing with some technical issues stated above. The quasi-holographic media at some degrees was responsive and enjoyable with optimum image resolution capable in handling static and animated rendering processes (Figure 8).

Unlike VR experience, the intention of AR application in our case is to embed virtual 3D objects into the real world where user still experiencing being presence while interacting with a 3D virtual object as if it is in real world. This new method open possibility for new media not only for passive interaction and experiencing visual contents, but also active interaction with data in dynamic and speculative design scenarios and/or analysis.

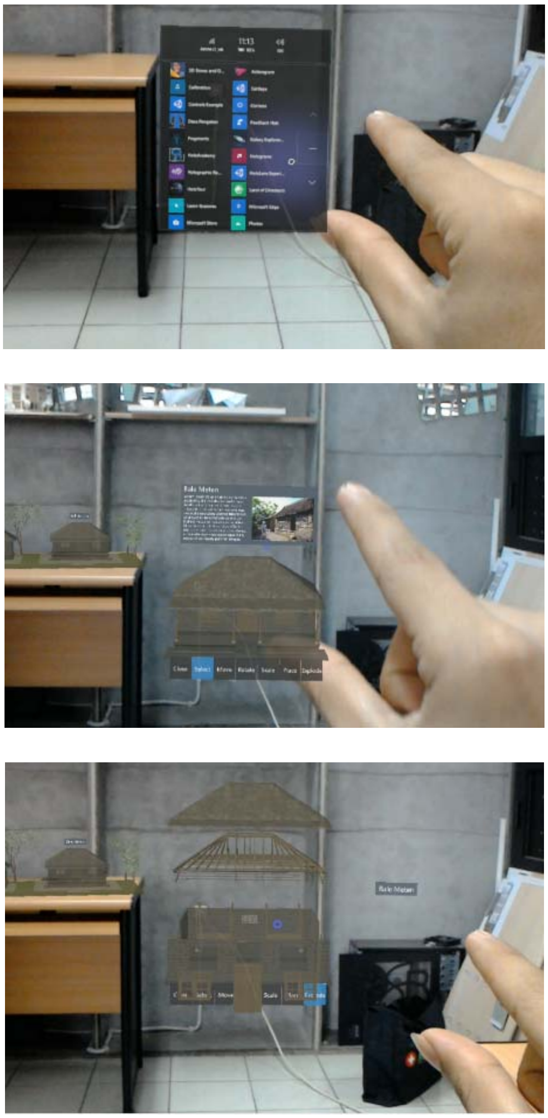

Fig. 8. User Interaction with Virtual Object

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REFERENCES

[1] Mann, Steve: Mediated Reality. MIT-ML Percom TR-260, MIT Press, (1994).

[2] Hockett, Paul & Tim Ingleby: Augmented Reality with Hololens: Experiential Architectures, arXiv:1610.04281, Cornell University Library, (2016).

[3] Wang, Xiangyu: Augmented Reality in Architecture and Design: Potentials and Challenges for Application, International Journal of Architectural Computing 02, Vol. 07, pp. 309-326, (2009).

[4] Gross, Mark D. & Ellen Yi-Luen Do: Architectural Augmented Reality, University of Washington, (2011).

[5] Abboud, R: Architecture in an Age of Augmented reality: Opportunity and Obstacles for Mobile AR in Design, Construction and Post-Completion, Codessi, (2014).

[6] Schubert, G., Schattel, D., Tonnis, M., Klinker, G., & Petzold, F: Tangible Mixed Reality On Site: Interactive Augmented Visualizations from Architectural Working Models in Urban Design, Communications in Computer and Information Science, Springer Science Business Media, pp.55-74, (2015).

[7] Radnia, Noushin, et al. : Augmented: reality, Architecture, Interface, Semanticscholar.org, (2017).

[8] Wojciechowski, Rafal, et al.: Building Virtual and Augmented Reality Museum Exhibitions, Proceedings of the 9th International Conference on 3D Web technology. ACM Digital Library, pp.135-144, (2004).

[9] Redondo, Ernest, et al.: Visual Interfaces and User Experience: Augmented Reality for Architectural Education: One Study Case and Work in Progress. Proceedings of the International Conference on Digital Information and Communication Technology and Its Applications, Springer, pp. 355-367, (2011).

[10] Avila, Lisa, and Mike Bailey: Augment Your Reality, IEEE Computer Graphics and Applications 36,1, pp.6-7, (2016).

[11] Caudhari, Aunsh et al.: Transforming the World using Holograms. International Journal of Computer Applications, 01, Vol. 130, pp. 30-32, (2015).

[12] Tomas, Bruce, et al.: Using Augmented Reality to Visualize Architecture Designs in an Outdoor Environment. Design Computing on the Net, University of Sydney, (1999).

[13] Zarzycki, Andrzej: Teaching and Designing for Augmented Reality. Proceedings of the eCAADe Conference, (2014).

[14] Niedmermair, S. & Ferschin, P.: An Augmented Reality Framework for Architectural Application. Proceedings of the 8th International Symposium on Location-Based Services, ed. Georg Gartner and Felix Ortag, pp. 192-205, (2011).

[15] Kim, K. et al.: Augmented Reality Tour System for Immersive Experience of Cultural Heritage. Proceedings of VRCAI, Yokohama, Japan, (2009).

[16] Whyte, Jennifer: Virtual Reality and the Built Environment. Architectural Press, (2002).