MR-Deco: Mixed Reality Application for Interior Planning and Designing

F E Fadzli [1] *****, **A W Ismail** [1], **R Talib** [2], **R A Alias** [1,3], **and Z M Ashari** [2]

[1] School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia

[2] School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, 81310 Johor, Malaysia

[3] Azman Hashim International Business School, Universiti Teknologi Malaysia, 81310 Johor, Malaysia

*fazliaty.edora@gmail.com

Abstract. Over the past few years, Augmented Reality (AR) and Virtual Reality (VR) have become a phenomenon in this new era and nowadays smartphone device can enable these technologies quickly and seamlessly through downloadable applications. Some of them are to benefits community and others just for entertainment purposes such as movies and games. Despite their goal, researchers take the opportunity to use Mixed Reality (MR) technology as it is suitable for real-life usage by users as its low cost and it can replace the conventional way of rearranging the furniture for interior design application. MR also brings design and planning, interior design, and engineering into a digital world where people can operate the prototype without having to physically involve in real life. A user should be able to interact intuitively with the virtual content in real-time. This paper identifies the integration for both AR and VR fusion for the MR environment. It also discusses the suitable user interaction technique can be applied in interior design in the MR environment, called MR-Deco.

1. Introduction

Mixed reality (MR) is a technology that either supplement or replace real-life with computer-generated data to facilitate user interaction through the natural senses which including augmented reality (AR) technology and the virtual reality (VR) technology. VR and AR have been useful for exploration, logical training and the development of new models of understanding in complex data systems [1].

As defined by [2], MR in the field of human and computer interactions involves the superposition of virtual reality graphs and enables users to interact with the virtual world tangibly. For the user to have an immersive experience in MR, the virtual scene generated by the computer must be composed with the actual world scene without the sense of incompatibility by three cohorts, which are geometry consistency, consistency of time and optical consistency [3].

Furthermore, for users to have an immersive experience in a VR environment, a user should be able to interact intuitively with the content through three-dimension (3D) space. The application should support several VR environment techniques for interaction and object manipulation such as rotation,

translation and user interface (UI). As [4] stated, a key component is the development of appropriate AR application interaction techniques that allow users to interact intuitively with virtual content.

Nowadays, many applications such as games and simulations are using AR and VR, and there is no doubt that these technologies have been on a long journey of research and development. However, still, there is more need to be done to make sure it is reliable, robust and most importantly, convenience and economical to reach a higher market value in this digital era.

As defined by [5], MR is a cutting-edge technology, which connects real and virtual worlds seamlessly. The AR and VR technologies, therefore, naturally immerse users in 3D environments [5], and this may improve the user experience when 6 Degree-of-Freedom (DOF) controller can provide immersive user interaction [6]. ARDeco has demonstrated an interior design for AR environment [7]. Researchers have studied for an advanced user interaction and a comprehensive review has been presented in [8] to show MR has potential for intuitive user interaction. MR interface has proven can enhance user experience depending on the hardware and MR devices [9]. Ray pointing primarily used when the user needs to use HMD with the motion controller, it works similarly with hand rays. Real hand gesture required specific hardware and the accuracy may need to study further in-depth [10]. However, this research chooses to use a ray pointing because the proposed interior design application aims for far pointing in MR. Furthermore, the only reliable MR device nowadays is Hololens, and it is very costly to enable user interaction in such an immersive merged reality environment. Thus, this research attempt to discard the hardware restriction by utilizing the holographic projection as the display technology. Augmented Virtuality (AV) environment works with hologram display has been proposed for MR environment [11]. Therefore, this paper proposes an interior design MR application called MR-Deco that should be able to integrate AR and VR using holographic projection in the MR environment. As agreed by [12], the approaching new advanced technologies have encouraged to implement interior design in MR environment.

2. Interior Design Application Development

Interior designing is chosen as this research application to test the interaction in the MR environment. The interior design application for user interaction and 3D object manipulation such as rotation, translation and also duplicate and remove.

2.1. Defining input controller

This section describes the user interaction in AR and VR technologies for the proposed MR framework. It is essential to identify the integration for both AR and VR fusion for the MR environment.

The proposed prototype for interior design has developed, and user interaction in this prototype used a typical VR interaction. Between real hand gesture and motion controller, as shown in Figure 1, the interaction designs are symmetry. When a user wears an immersive headset and interacts with 3D objects via motion controllers, it will shoot out rays for pointing and manipulating far objects
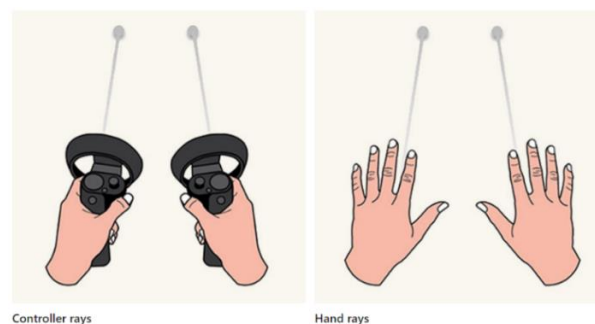

Figure 1. Controller rays and hand rays [13].

. There are buttons on the controllers for further committing different actions. In our proposed MR-Deco, we did leverage the interaction model of rays and attached them to one-handed hand only. Ray pointing is suitable for far pointing and manipulation, primarily when the user uses HMD with the motion controller, it works similarly with hand rays.

The interaction for MR-Deco includes rotation, translation, and also texture manipulation, where the user can change the texture of the object. HMD is essential in this development. There are several interaction controllers can be used with the HMD such as Oculus Touch, Oculus Remote and also Joystick. As illustrated in figure 2 (a), the workspace to set up VR display technology, there are listed the computer desktop, Oculus Sensor, Oculus Rift and Oculus Touch. Oculus Rift is chosen as the display device for users to experience and interact with the MR environment, and Oculus Touch used for the user interaction. Oculus Touch allows users to interact with the virtual object such that their hands are pointing a ray to hit the object (as in figure 2(b)), to be precise the controller rays produce a ray pointing using Oculus's touch controller. Then, for the translation and rotation, the user uses the right-touch controller.
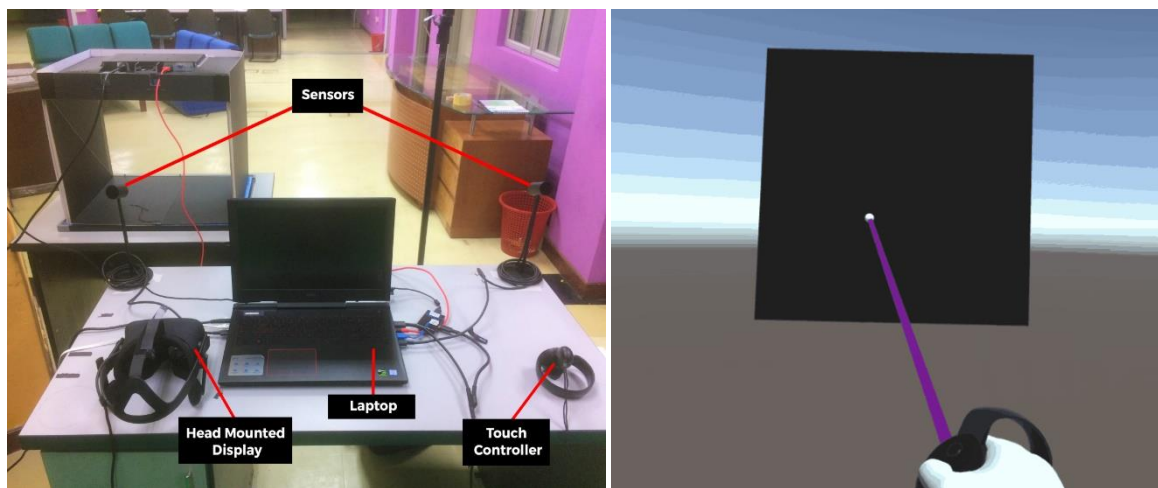
(a) Hardware for workspace setting   (b) Ray pointing in VR scene using controller ray
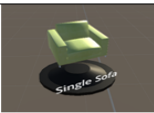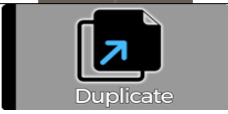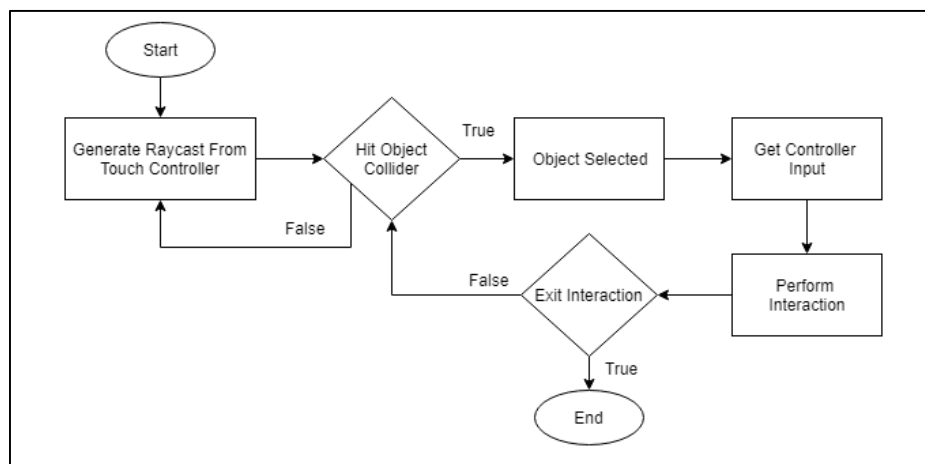
Figure 2. VR workspace.

Figure 3. Interaction workflow.

Collision detection has implemented when a ray hits the collider that bounds the object if the collider does not hit the object, the system will return to search for the ray-cast coordinates based on the controller movement as illustrated in figure 3. Once the object is hit, the interaction can be performed. Interaction is typical with the select and the release function. The release will end the interaction; select function will trigger the selected object. There is some crucial component such as ray-cast and collider, to enable interaction between the virtual object and input controller. A button has long been a metaphor used for triggering an event in the 2D abstract world. In the 3D MR world, anything can be an interactable object that triggers an event. Next section will describe the list of interactable objects that have been designed to form a user interface for our proposed MR-Deco application.

2.2. Designing UI for MR-Deco

This application consists of several user interface (UI) designs which each of the UI executes different operation functions such as to open menu panel, to spawn new virtual object and also to remove all the virtual object from the environment. This UI interaction enables the user to customize the environment according to their desire preference. There are many virtual objects in the environment. However, this prototype only focusses on four objects which are furniture, including single seat sofa, double seat sofa, coffee table and torcher lamp, to allow user interaction with the UI design. Those UI designs are as shown in Table 1.

Table 1. Interactable objects.

User Interface	Descriptions
	Button to spawn a new single sofa object in the VR room space.
	Button to spawn a new double sofa object in the VR room space.
	Button to spawn a new coffee table object in the VR room space.
	Button to spawn a new torcher object in the VR room space.
	Button to delete all objects in the VR room space.
	Icon for object's properties to duplicate selected object.
	Icon for object's properties to remove selected object.

This application consists of six UI designs which are button to open menu panel, spawn the different type of furniture and also destroy or remove all the virtual object from the virtual environment. To

interact with the UI design, the user has to perform a particular gesture to enable the menu panel. There are also object's properties UI for the user to duplicate or remove the selected object.

2.3. Implementing User Interaction
There are three main interactions implemented in this MR-Deco application which includes selection, manipulation and also UI interaction.

2.3.1. Selection
For object selection, the user used a touch controller, and a ray-cast is the crucial component for object manipulation. It allows the user to perform the interaction of object selection on a particular virtual object in the virtual environment and perform the manipulation on the selected object, as shown in figure 4. To complete the selection interaction, user can hover the pointer of the ray-cast to any object which is the furniture and perform the selection by pressing "A" button, as in figure 4 (a). The user has to press "A" button to trigger the selection interaction on the object, and the object change material with a light blue colour as an indicator of the selection has been performed on the selected object, as in figure 4 (b). The ray-cast with a line renderer from the origin of the virtual hand in the virtual environment, as shown in figure 4 (c).
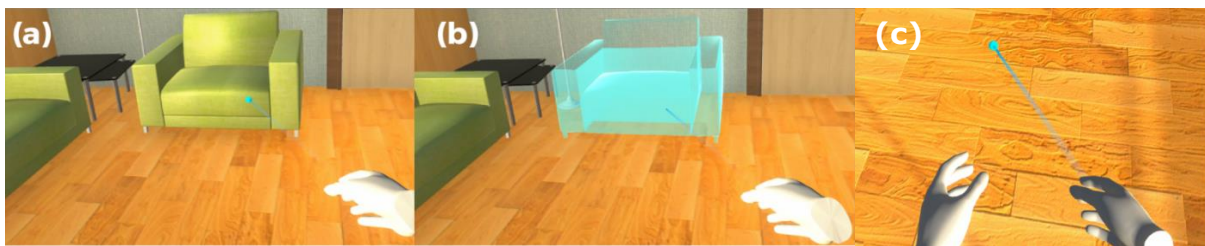

Figure 4. (a) shows the object is deselected in the virtual environment, (b) shows the object is selected in the virtual environment (c) shows a ray-cast with a line renderer for pointing

2.3.2. Manipulation
Based on figure 5, the user can interact with the menu panel and perform the selection. The user can choose any available objects from the listing to spawn a new object into the virtual environment or remove all object from the virtual environment. The user used touch tapping to interact with the menu that consists of an array of objects. There are four initial objects, *Single Seat Sofa*, *Double Seat Sofa*, *Coffee Table,* and *Lamp Torch* have been defined as the interactable objects.

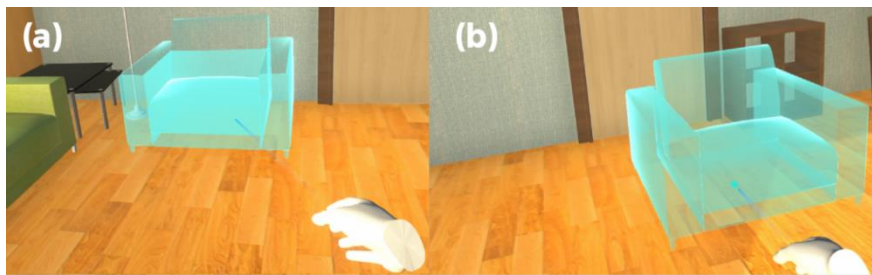**Figure 5.** Menu panel to spawn the initial objects

Figure 6. (a) shows the object is selected, (b) shows the selected object has been translated to a new position

Figure 6 shows the user performs the object selection and the selected object has been moved to a new position, translation is performed by hovering or moving the controller to a desired position within the room space. The object can be rotated in clockwise and also anti-clockwise depends on the interaction input of the thumbstick. In order to rotate the selected object clockwise, user can move the thumbstick on Y-axis to the right while moving the thumbstick to the left rotate the selected object anti-clockwise. Thus, the object rotation, as presented in figure 7.
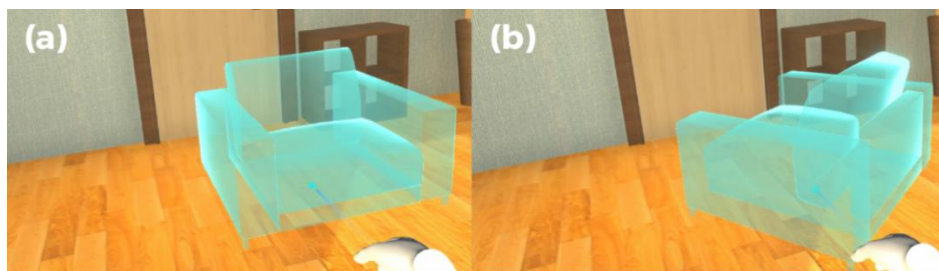

Figure 7. (a) shows the object is selected, (b) shows the selected object has been updated with the new angle for object rotation

2.3.3. Duplicate and Remove

User can perform intuitively using the touch controller the duplicate function on the desired object, and also can remove the selected object. Duplicate event is an alternative way for a user to spawn the same object in the room; the designing activities would be much faster or less time taken. Although there is remove all object function in the main menu panel, the user might also want to delete a specific object that they do not wish to enter the room space. Thus, duplicate and remove functions have designed to affect the selected object. The functions to duplicate and remove the selected object, as shown in figure 8; it is a toggle menu will enable and disable the selected menu.
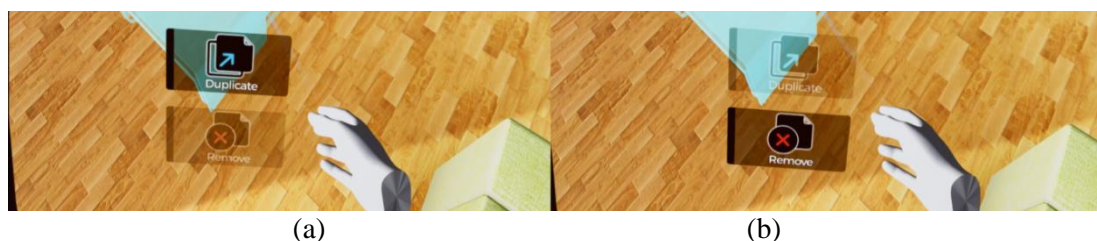

(a)   (b)

Figure 8. shows a toggle menu when the duplicate button is enabled, and the remove button is disabled.

The object's properties menu implemented as UI design interaction technique where the user can duplicate and remove the selected object. The interaction menu can be opened by pressing the "B" button on the Touch Controller and "A" button to close the menu. To select the option in the menu, the user can press the "B" button again to select the option. User can also scroll between those two options in the properties menu by using the thumbstick of the Touch Controller. However, the object's properties menu can only be opened if only an object is selected in the room space of the VR environment. Thus, the results when the user removes and duplicates the object as in figure 9 and figure 10.
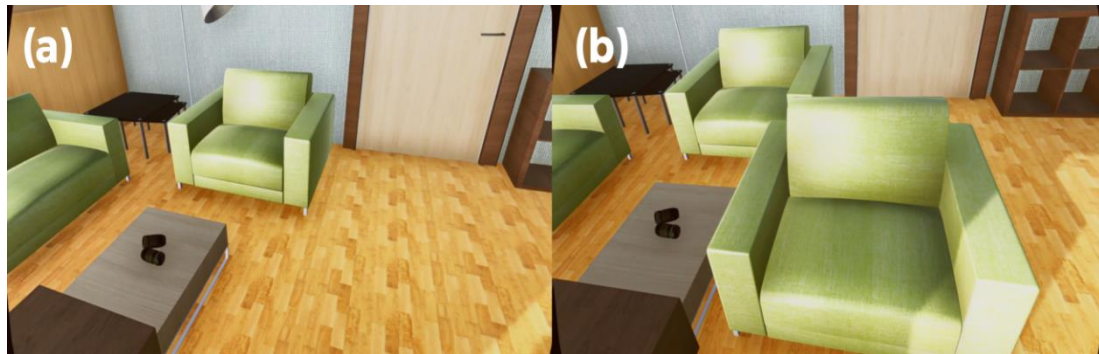

Figure 9. (a) shows the object before the interaction of object duplication while (b) result after the object duplication performed.
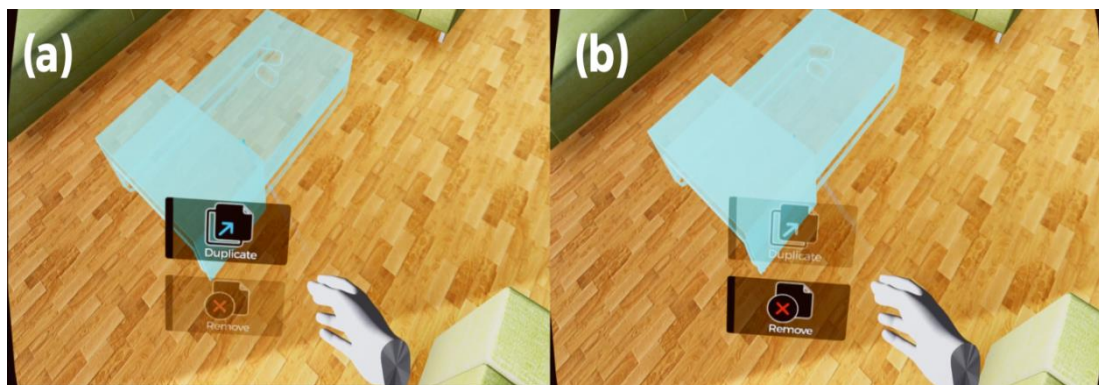

Figure 10. (a) shows the object is selected with the object's properties menu while (b) result after the remove object option is selected.

3. MR-Deco Application in MR

The third phase is to integrate the holographic projection with the Interior Design application in MR. At this phase, it involves the integration the AR holographic projection that corresponds with MR Capture (MRC), Z-hologram and High Definition (HD) external camera is used with the controller to migrate the VR interaction into MR environment.

3.1. Mixed-Reality Capture

VR works with MRC components for this study. MRC needs camera calibration and chroma key composition to be set up manually and accurately to produce a robust camera composition in the MR environment. The workspace has to be set up before the user executes the application such that the camera, Touch Controller and chroma green screen are positions correctly as shown in figure 11.

To enable MRC in the application, a Touch Controller has to set as a VR Object which acts as an anchor of the camera transform properties from the real world into the virtual environment. Then, the

camera needs to calibrate using the MRCTools from Oculus SDK. The process of camera calibration captures several frames of the marker provided to produce a virtual camera depth in the VR environment. The calibration pre-defined data has saved as a file and then will be loaded when the MRC plugin has started in the application. Thus, this enables the camera in the virtual environment to move corresponds to the VR Object, which is an external camera attached with Touch Controller.
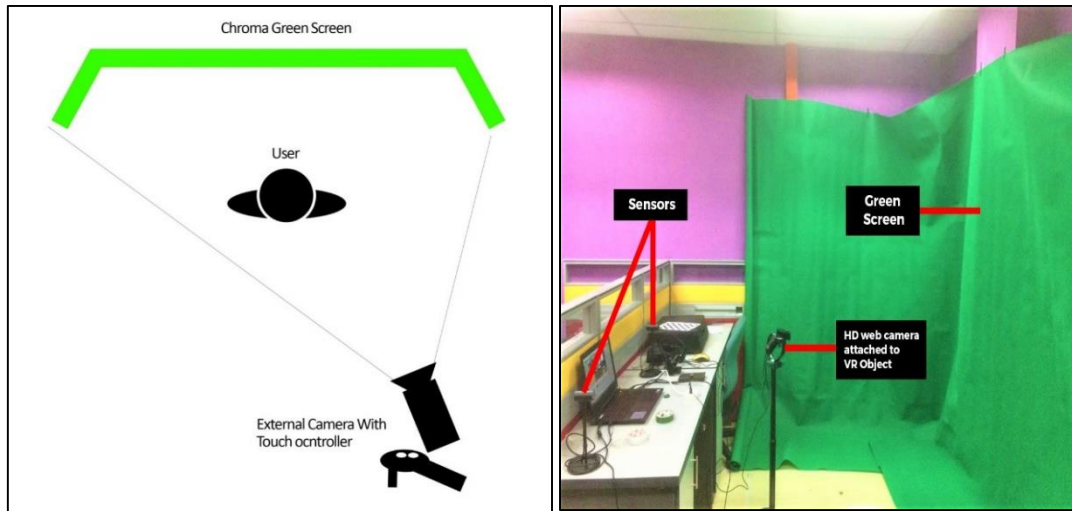

Figure 11. MRC workspace.

3.2. Integrating with the holographic projection

The application is integrated both VR and MRC with AR holographic projection using Z-Hologram for user interaction in the MR environment. In this section, the application should be able to run and execute with the HMD, which is Oculus Rift and use MRC with direct composition while synchronizing interaction with the AR projection in Z-hologram. Users also should be able to interact with the VR object through the interface and perform all the interaction technique included in the application.
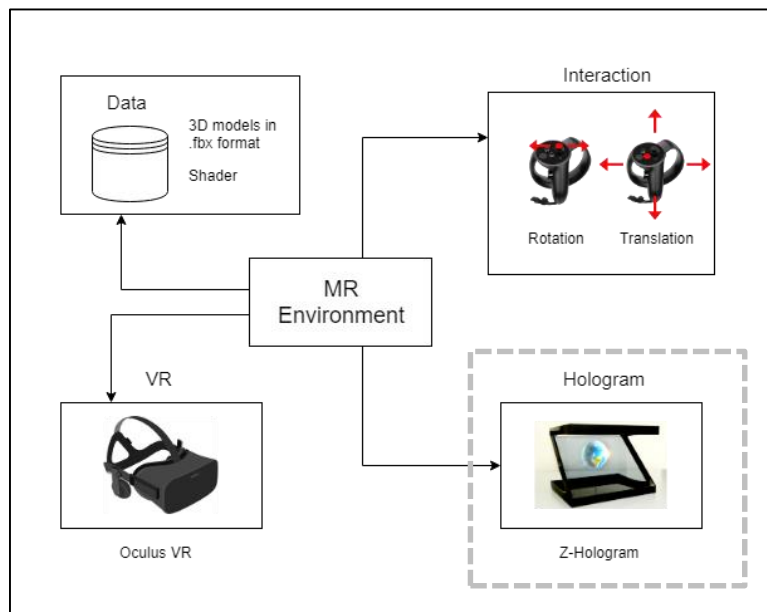

Figure 12. Components in MR environment.

Figure 12 illustrates the MR environment that the user interface consists of several components. There is a data to stores the transmitting data, and the device Oculus VR is to enable VR controller, Z-hologram presents the holographic projection and also the interaction methods such as rotation and translation. The VR object can only be manipulated if and only if the VR object is hit by raycast and selected, as explained in the previous section. MRC also needs to be enabled using direct composition to stream the real-world environment into the virtual environment in real-time. After that, users can interact with the object intuitively through the Oculus Rift controller called Oculus Touch. Therefore, the user feels immersive when interacting with the 3D object in the MR environment.

Based on figure 13, the application system flow describes the process of user interaction in the MR environment. The application enables user interaction in the MR environment by using MRC plugin and updates the interaction in the virtual environment onto the Z-hologram, which augments the object manipulation made in real-time. The integration process involves combing the display technique of VR, MRC and AR holographic projection in a single scene. Thus, MRC display and holographic projection can give the immersive and intuitive experience to the user, and the user should be able to perform the interaction.
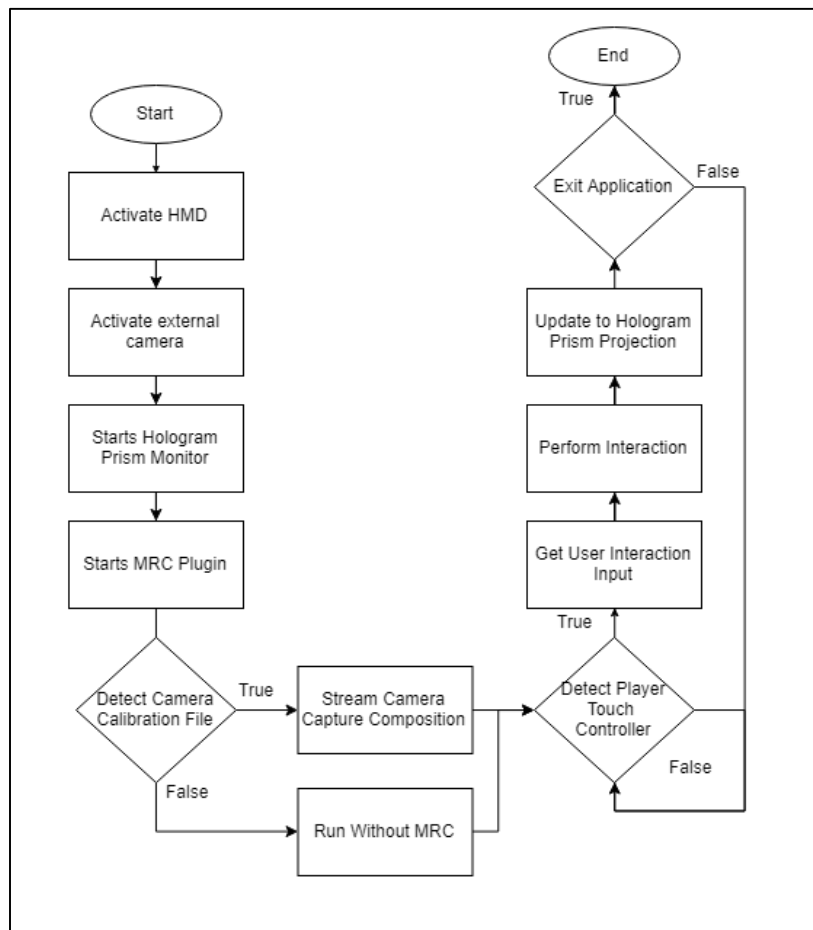

Figure 13. 3D Interior Design application system flow.

4. Results
In the setup, the application requires a laptop to run the application with the Oculus Rift connected to it to authorize the VR component used in the application. Apart from the MRC components, the HD web camera is attached to the Touch Controller and positioned slightly behind the user. The user has to face

reasonably opposite to the Oculus set up to give a real impression of the user interacting and being in the virtual environment. Other than that, this application also requires a monitor screen to project the virtual environment using holographic projection which is Z-Hologram to allow spectators to spectate the interaction performed to the virtual objects.
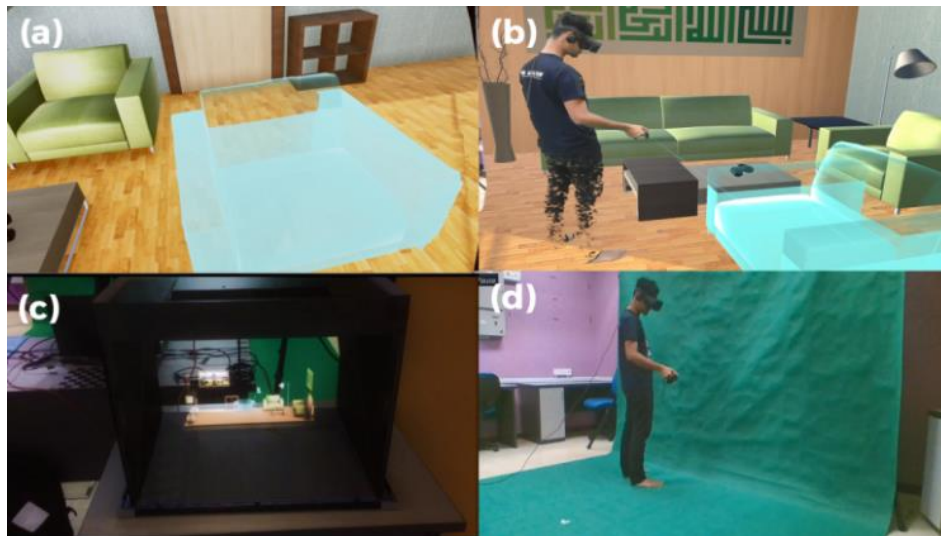

Figure 14. (a) shows the VR display view from the HMD device, (b) shows the MRC display in the laptop display, (c) shows the Z-Hologram display, and (d) actual user's activity in the real world.

The application also integrates the VR interaction and display with the MRC projection display to enable MR environment and also Z-Hologram as holographic projection, as shown in figure 14. Real user exists in VR space, this condition, also known as augmented virtuality (AV). MR encompasses AR and AV, as claimed by [11]. In the real world, as in figure 14 (d)), the user's activity was moving around while holding the controller and user manipulates the VR space (in figure 14 (a)) using the see-through HMD. The participant or non-active users can see the manipulation activities through the holographic Z-projection (as in figure 14 (c)), they can see what the user had modified without needed an HMD.

Figure 15 shows the initial set up for the MR-Deco application; (1) the Oculus is set up facing to the user inside the green screen space set up, (2) the green screen is set up in front of the Oculus setup to enable Mixed-Reality Capture (MRC). (3) the user wears Oculus HMD and holds a right Touch Controller to interact in Virtual Reality (VR) environment. (4) The high definition (HD) web camera is attached to a Left Touch Controller to enable the MRC camera composition and positioned slightly at the side of the Oculus set up to give an intuitive view for the mixed reality (MR) display. (5) The Z-Hologram is set up facing opposite from the Oculus setup and positioned behind the Oculus setup for the user to evaluate the synchronization of the user interaction in VR with the AR holographic projection.
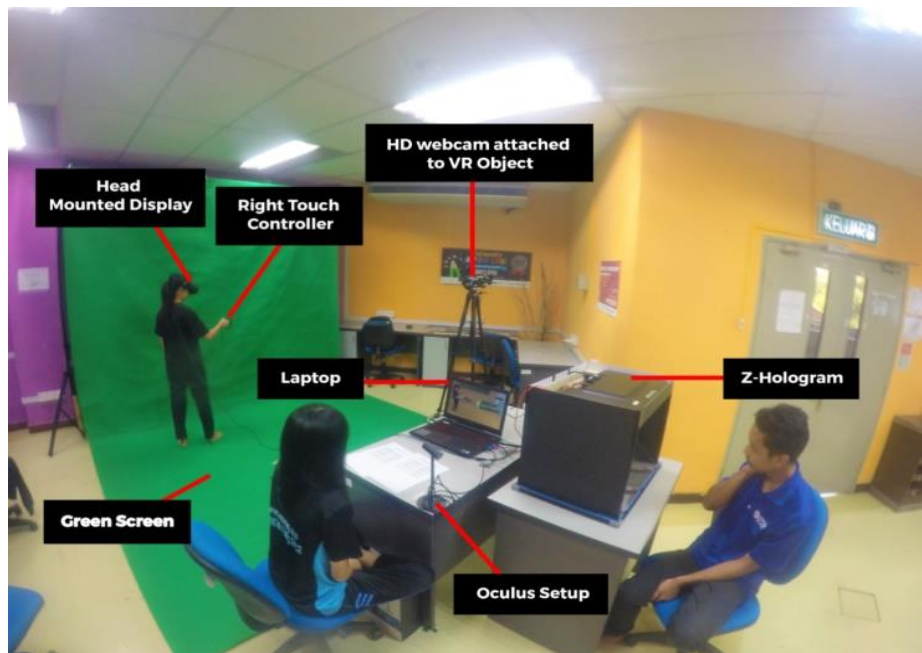
Figure 15. MR-Deco Setup.

5. Conclusion

This paper has discussed the user interaction technique implemented in MR environment for interior designing application called MR-Deco. The interaction input and method applied in the application has been explained as well as the interaction workflow. Throughout this research, there are two limitations faced during the development phase. Firstly, the application can only allow single-hand interaction to utilize only the right Touch Controller rather than both controllers. Thus, the tasks can be performed in a much longer time if compared to both hands used. Other than that, the holographic projection technique used is Z-hologram which not project on all sides and angel in 360 degrees which limit to only the user in front of the hologram who can see the display.

As a suggestion, remote collaboration for multi-user can be the future work to enable multiple users to collaborate in designing the virtual space together in a different set of places remotely. This study can make the application more intuitive and interactive to the users. Besides, user interaction using both hands can be considered instead of just with the right hand so that the tasks can be performed faster and easier by utilizing two Touch Controllers on both hands. Other than that, the holographic projection can use a prism shape as the projection technique rather than Z-Hologram, which enable users to view the projection display from all side and angels.

Acknowledgement

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