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Finger-Ray Interaction using Real Hand in Handheld Augmented Reality Interface

C S Yusof [1,2] *, N A A Halim[1,2], M N A Nor'a[1,2] and A W Ismail[1,2]

[1] Mixed and Virtual Environment Research Lab (mivielab), ViCubeLab, Universiti Teknologi Malaysia, 81310 Johor, Malaysia
[2] School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia

* suhaimi@utm.my

Abstract. Augmented Reality (AR) is the technology that augments the real world by using virtual information of 3D objects overlaid on a view of the real environment. This will create an immersive and intuitive experience. As handheld devices are widely used and now has climb with increasing demand of specifications, its interaction based on touch is a natural and appealing input style for the application of AR. Furthermore, most heuristic studies of interaction in AR usually focus on interactions with AR Target close to the user, generally within arm's reach. As the user's move farther away, the effectiveness and usability of the interaction modalities may be different. This study explores handheld AR interaction using real hand gesture at a distance in a room-scale setup. Our aim is to investigate the effectiveness of performing selection while being far away from the 3D object and performing selection task towards object that is being occluded. As object manipulation is one of the key features to explore for mobile handheld AR, we hope our study can give some contribution towards its practical use, especially for real-world assembly structure. Hence, our paper proposes finger ray interaction technique for real hand in handheld AR interface to work for selecting objects at distances ranging from 3 feet to 8 feet and when the object being occluded ranging from 20% to 80% occluded.

1. Introduction

In this advance technology era, Augmented Reality (AR) application in mobile devices has bloomed, making it widely spread and is used for a growing range of application. The increasing performance of computational, cameras, processors, displays, and various sensors in mobile devices, making it possible for researchers to discover the full capabilities of handheld AR. The transformation of learning caused by AR provides exciting opportunities to build learning environments that are engaging, realistic and fun [1]. For researchers and developers, the rapid development of handhelds has opened up plenty of scope to explore new and previously unattainable ways to provide mobile AR experiences [2].

Currently, people enjoy using AR because it helps to give them a better understanding of some of the information rather than just by looking at the plain view of the information. For example, the application from ARTutor [3], enables students to verbally ask questions and obtain responses based on the book's content. This implies that the framework is sufficient for distance learning and independent learning, thus encouraging students to learn and understand the subjects better.

Meanwhile, Heb@AR [4], which is not yet covered by the literature, explores the use of handheld

AR as an additional method for technical education in academic midwifery education. Another example, the usage of VR and AR in the dentistry not only use the system for learning and teaching from their perspective but also training their skill and improve the hand-eye coordinate indirectly help the user to correct the posture and skill [11].

However, there are general problem in handheld device, such as limited screen size, and one hand interaction (in which the other hand need to hold the device). On smartphones and tablets, nearly all handheld mobile AR systems are introduced. This is complicated by the fact that the tracker (the part used to monitor the AR marker), which is a built-in camera, [24] often used on the same device (smartphone or tablet) as the rendering systems linked to the display screen.

As part of a larger body of work by conducting on mobile AR authoring, Sambrooks et al. examine the impact these various device sizes have on user interaction with AR content [2]. Their experiment is to compare AR interaction for three different handheld devices which were chosen as prototypical representations of three categories: smartphone, mini tablet, and tablet. In particular, the screen size was noted as offering a clearer view of the on-screen crosshair and virtual objects. Meanwhile, in the finding of Hürst et al., some users complained that doing the motions with one hand and clicking on the touch screen when holding the computer with the other hand was uncomfortable and that it put an extra cognitive burden on them [24]. In handheld AR, pointing techniques are impaired by the instability of the augmented scene that the users interact with on screen [9].

AR head-mounted displays (AR-HMDs), such as the Microsoft HoloLens, support immersive applications which embed interactive virtual content throughout the visible environment. Nonetheless, in recent years, many commercially usable AR HMDs have like Microsoft HoloLens, has come to market including the Microsoft HoloLens, Daqri Smart Glasses, Meta 2, and Magic Leap [4-7]. For these applications to give smooth, seamless interactive experiences, creators must craft intuitive and efficient interactions with the virtual content at extended spatial scales, including virtual objects to be well beyond a user's reach [7].

In the real world, AR apps also use virtual content to augment objects, so this decontextualization can generate cognitive challenges. Instead, to test accuracy and ease of use in communicating with distant objects in AR, we concentrate on selecting and manipulating material that remains at a fixed distance and building on previous findings in these spaces [10]. Through the use of head-mounted displays and monitoring devices, such as data goggles, and on desktop VR settings with a keyboard and mouse, three-dimensional interaction techniques have been extensively studied in interactive virtual environments. Several researchers have studied 3D interaction techniques that, particularly for desktop and large-scale interactions, approach the richness of reality. The benefit of controlling 3D objects using mobile devices in augmented reality scenarios is the ability to use physical gestures for interaction. This technique is a normal way of placing objects in the scene, as it mimics the actual behavior [14].

The field of interaction and display is restricted due to the limited size of the display. During interaction, users often cover the target with their fingertips when using multi-touch input [16]. The size of the target on the limited screen that user can touch is really small. This constrain is becoming a crucial problem with the growing of complexity of AR scenes. Another case is that when the targets are obscured from each other in a 3D AR environment due to the variation of its spatial depth, the selection by touch becoming hard to be perform. Depth is also the main issue when we do interaction using 2D interface for 3d environment. Thus, an accurate of pixel-level selection in occlusive or compact areas with various sizes of the targets making it difficult to perform [17].

For these purposes, although they are partially or entirely obscured by other virtual targets, the selection performed must include the possibility to disambiguate and able to select desired targets with preciseness. With current selection techniques, choosing a target can be hard or even difficult with targets of strong visual resemblance in compact virtual worlds. It should retain some spatial information which will enable disambiguation. It also includes the interactions of a single touch to ease the user interaction and eliminate faults conveyed by incorrect feedback of touch input in order to have a unique selection of a target. We use ray-casting selection technique for the handheld AR interface to resolve these interaction issues, although the target is in small sizes or being occluded, it can precisely select

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targets.

2. Related Works

In 3D user interfaces (3DUIs), selection is one of the universal interaction tasks [12] and has been extensively studied by researchers and developers. While several guidelines have been created for developers of 3DUIs, the research has clearly shown that there is no best selection technique for all situations. Natural and intuitive interaction techniques such a spatial gesture input are required by user instead of simple pointing and clicking and manipulating 3d content from a 2d interface to have better experience with AR [18]. Manipulating 3D objects is a complicated task that requires multiple degree-of - freedom (DoF) control for object selection, translation, rotation and scaling in AR environments. In addition, virtual objects are intangible, and only by whole-body observation or moderate by a mobile device can contact with them be accomplished [12].

Metehan et. al. [20] presented a novel concept for AR in cultural heritage sites: Distant Augmented Reality in which they explore a new possibility; proposing drones as a medium to communicate through AR. Based on the relevant task criteria (i.e., distance and size of the target) and the layout of the environment, such as occlusions of the target and the density of the scene, the efficiency and usability of a selection technique vary greatly, as seen in the literature. It often consists of two sub-tasks: determining the goal and the verifying step of the optional collection. For virtual environments (VEs), as there are several selection methods that have been developed, we set apart the related works into selection with handheld mobile touch interface (device based) developed for VEs that can be modify to AR, and with mid-air gesture-based interaction technique selection. The fact that almost all handheld mobile AR systems are implemented on smartphones and tablets by means of the tracker (used to monitor the AR marker) is the built-in camera that has also been used as the rendering device associated with the display screen, all together on the same platform, complicated the implementation of 3D object manipulation of virtual objects in handheld mobile AR.

Ray-Casting [13] is a frequently utilized technique of pointing-based where a virtual ray projecting from the input device or real hand when user points to target in the scene. For Ray-Casting, this is a bigger problem than for other methods because at the tip of the rays, small hand motions are amplified allowing Ray-Casting to be less accurate as targets get farther from the consumer. These issues make Ray- Casting difficult to use when the targets have a small visual size [14], as selecting such targets by pointing requires high levels of precision. In order to address these issues, a number of improvements have been proposed. Even though such techniques improve selection performance in general, they can have a negative effect in very cluttered environments. Cone-Casting [15], for example, extends ray casting by adding a cone-shaped volume to the ray to make it easier to select distant targets.

Current 3D target selection approaches in AR for mobile generally use the basic specifically pointing metaphor activated on the mobile screen by a single contact case. [16]. However, these methods lack accuracy due to the finger size of users in a cluttered mobile world. Selection techniques of 2D that able to control the issue of finger being occluded on the screen have been confer to improve accuracy in 2D touch interface [19]. Dual-Finger Offset and Dual-Finger Midpoint. Both of these needed the precision selection of two hands and resulting of it's to be not suitable to be applied in a scenario of mobile AR where there is just one hand accessible for input. Two selection techniques specifically outline were proposed in reference for handheld AR [19], using two fingers to pick the targets that is small and partially occluded in dense AR. The procedure is encouraging but cannot be extended to the extreme screen corners to select targets. As this reduces the already small space for interaction, this is not an ideal solution for a handheld device, for example smartphone. In addition, in [19], by differentiating the selection point from the physical touchpoint, the selection in dense mobile AR using a single touch was explained by the authors. Thus, the occlusion of the target by the finger can be evaded, but statically calculated for the offset.

3. Implementation

Realism [15] is a crucial factor in determining the right measurement of distance and perception of depth. There are significant variables that affect efficiency and ease of use when developing a selection

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system for handheld AR.

On these displays, manipulation directly suffers from minimal preciseness, issues of being occluded, and restrictions of the scene element's size due to the physical constraints of the mobile device size and the constraints posed by human fingers. We discuss the criteria for accurate selection of one-handed, handheld AR setting in the compact environment for this section. Then we will use the ray casting technique to compare the interaction between the handheld mobile app and the actual hand gesture. This is to equate the techniques' efficiency and usability with the increasing in distance, rendering the target 3D object smaller. Mid-air free-hand gesture interaction has been considered as a promising input method for MAR systems to solve the above problem while providing a richer interaction experience [23].

3.1. Requirement and User Setting

Our aim is to achieve selection that is precise for handheld AR in dense environment with one-handed, even though the distance makes the 3D object smaller. We summarize the requirements as follows. A built-in camera of the handheld device is used as display technique. This camera is used for video streaming the target marker. A few configurations have to be made before it can be used. If the target marker is recognized as a registered marker, the AR 3D object will appear at the center of the marker on the display screen of the unit. In order to run the application on the handheld device without any problems or errors, the right API is required. We use Leap Motion, a depth sensor device to track the gesture input.

The Leap Motion Controller is a device for optical hand tracking that captures with unprecedented precision the movements of your hands. During recognition, Leap Motion enables the process to read depth data for the application. Then orientations and positions were generated by the computer. The technique for tracking presented is focused on functionality. Figure 1 display a natural feature tracking (NFT) process, which also the feature-based tracking technique. The tracking technique includes the registration in the real world of the virtual object over the actual marker.

Figure 1. Standard marker for NFT.

Compared to immersive VEs, independent monitoring of the interaction device from the user is not obtainable with the head. Thus, a single device combines input and output devices. The gesture interaction is analyzed at this point to engage between the user with the virtual space of AR. A form of interaction using hand motion can be done to engage with the virtual object naturally. The user will use their finger to touch the virtual elements directly. By pointing their finger towards the 3D object that is visible on the marker, users may perform a gestural interaction. In the project, therefore, as a metaphor, the method of hand gesture recognition for feedback are necessary for the engagement of the user with the virtual object in AR space.

3.2. Leap Motion Gesture Tracking

As a tracking device, Leap Motion enable the process to read depth data from the application, thus the user hand location can be detected in the actual world and mapped to the virtual world [22]. Below in Figure 2, it displays the gesture tracking standard flow of Leap Motion, which enables to read depth data during recognition of the application. Then, positions and orientations were generated. It observed the location of the user's hand in the actual world and maps it to the virtual world. The modelling method is needed to show a virtual hand skeleton and to allow interaction signals, and the rigid body was applied to the virtual hands 3D model. After this phase has been completed, both the gesture input and the dynamic gestures will be produced.

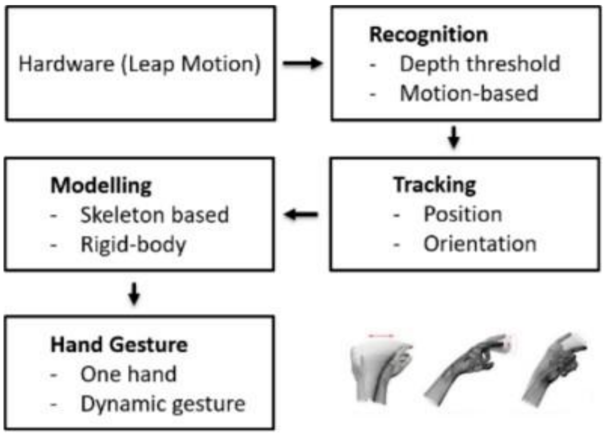

Figure 2. Gesture tracking standard flow [22].

Because of the wide space occupies on the display due to the user's fingertip, finger's input of touching can be imprecise. Since only one hand is required for contact, it is not possible to apply complex multi-hand movements to increase the preciseness of selection.

Figure 3 below shows the system workflow of our current prototype in details. One of the problem that we face, is regarding the data calibration between build in camera of the handheld device and the Leap Motion itself. To avoid this issues and have better result of finger tracking, we attach the Leap Motion behind the mobile device and near the build-in camera of the handheld device. Leap Motion, a hand tracking device for Virtual Reality (VR), will provide us the information of hand tracking which the most important information is the depth. Leap Motion is used in our interaction system for marker-less Augmented Reality to detect the hand.

By using Leap Motion, 3D hand location, gesture and direction can be obtained and transferred to the Unity 3d game engine. We are using Photon Unity Networking (PUN) library to transmit the finger tracking data between devices. For better understanding we divide the process into 4 phase which are 1) Master Client will create a session to receive hand tracking information from the Leap Motion, 2) Using photon library, the data of hand tracking collected from Leap Motion will then be transmitted to the Handheld Client(mobile device) application 3) User now can view the finger movement from both Master Client and Handheld Client 4) User now can do the selection process by selecting the item that appear on top of the AR Target Maker.

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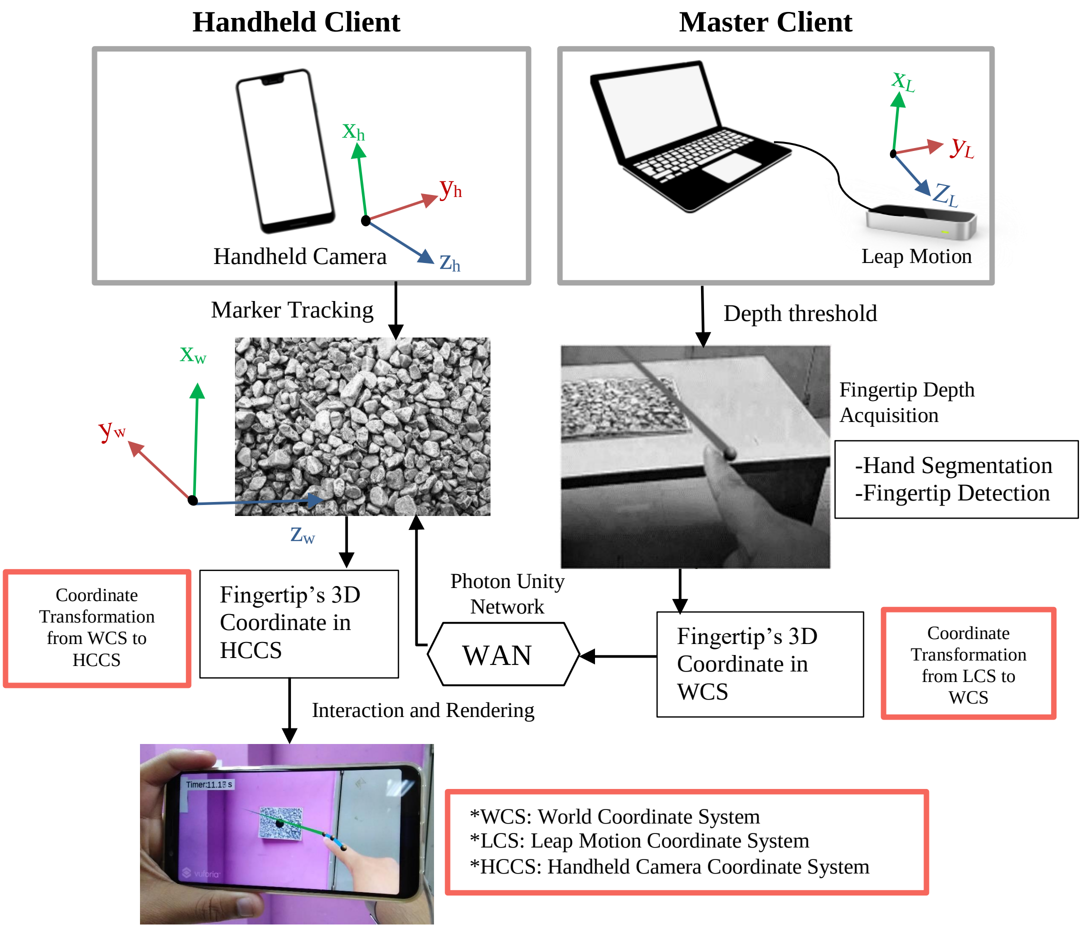

Figure 3. System workflow in details.

3.3. Proposed Selection Method

As stated previously, we come to develop the below selection methods in enabling the selection to be perform precisely although in handheld AR with dense environment of one-handed.

1) As in dense virtual scenes the targets might be invisible or partly occluded, it is crucial to have a technique that hold up the process of selecting these target. Moreover, targets can be extremely indistinguishable in figurative display. Therefore, multiple selected targets need to be described as proper spatial sense which encourages disambiguation of the target while considering the minimal display available.
2) In viewing context of mobile use, process of interaction does not presume that supplemental of physical resources (for example, extra devices of 3D pointing) are present for the interaction
3) In comparison to inexplicably (outside-in) approaches to 3D tabletop processes, the egocentric perspective should be based on handheld mobile AR interaction techniques.
4) The interactive methods should provide the consumer with sufficient input, either visually or in another type. For instance, the user should experience constant visual / physical connections during the manipulation. [21].

A finger-ray has been proposed based on these design for selection, where a ray is generated based on the finger-pointing using user's bare hand. The user achieves this method by moving a ray-cast point projected from the central position of the field of view; the finger detected will produce the ray where it was corresponding to the user's finger movement. This enables the user to manipulate a 3D object appeared on the AR marker right away in a similar manner to manipulating a close object. However, this paper needs to execute a test system to the feasibility of our proposed method before implementing the method in the AR application to manipulate the 3D object. The interaction is a simple selection, just

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to test the ray precisely hit the object based on the distance.

The most popular target pointing technique in VR is ray-casting, and AR has been implemented the VR interaction which introduced to be accessible in augmented environments. The downside is that output is influenced by the precision of the pointing technique and the controller on small and distant targets. Current pointing facilitation techniques are currently only used in the sense of the virtual hand and pointing is done using their bare finger in AR by users.

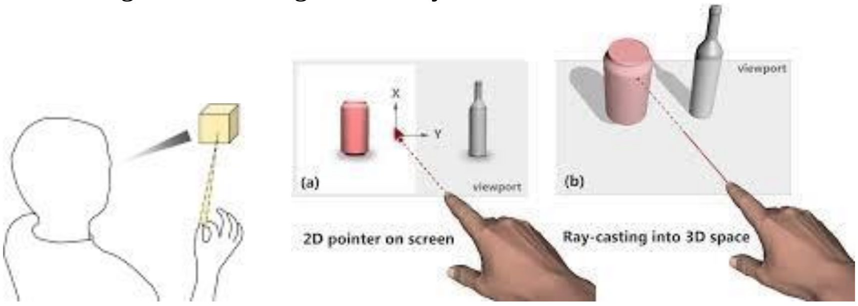


Figure 4. A finger-ray selection method.

Pointing a ray same like a laser pointer behavior. The origin and orientation are defined by those of the input device with 6 degrees of freedom. Figure 4 shows a user uses their finger to hit the cube by projecting the ray to perform a selection. Figure 4 (a) shows a 2D pointer on the screen relative to the x-axis and y-axis for handheld, however Figure 4 (b) shows the ray- casting into the 3D scene.

4. Finger-ray Interaction

In this section, we present the development of our project in progress. Figure 5 exhibited that Ray-Casting is an effortless, method of one step selection and used in VEs (immersive) and 3D computer very actively. In the virtual scene, a virtual ray is cast into; when it crosses them, targets are chosen. Ray-Casting is quick and effective for targets in near-range, however with targets that is small and occlusions at a greater distance, it has issues.

4.1 Selection by distance

We use the following adaptation in using Ray-Casting for a handheld AR environment: with a single touch event, Ray-Casting is provoked on the display; coordinates of the 2D display are projected back into 3D space, and a virtual ray is cast from the location of the virtual camera in the direction of the back-projected 3D point in the handheld AR scene.

(a) User selecting 3D object using Ray-Casting technique (b) A button will be displayed after the object has

Figure 5 Selection experiment using a finger-ray interaction.

A timer is shown on the top left of the device's screen, providing information on the time taken for the 3D object to be selected by the user. A 'Start' button is displayed on the screen for the user to touch, which will then start the timer. This will give us a suggestion of estimation on time taken for the user to select the object as the distance increases. The camera will then display the index finger skeleton that is being retrieved from the leap motion attach at the back of the handheld device.

To select the desired virtual object, our ray casting technique project a ray-casting pointer from the tip of the index finger skeleton. When the pointer ray-casting hit the object, it will select the object, and the timer will be stopped. When the object has been selected, the user will receive sound feedback, and it will also trigger haptic feedback to notify the user that the object is being selected. This will provide a better AR experience for the user in digesting the information given.

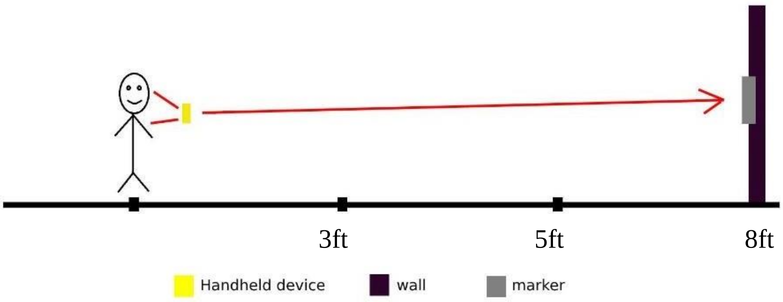
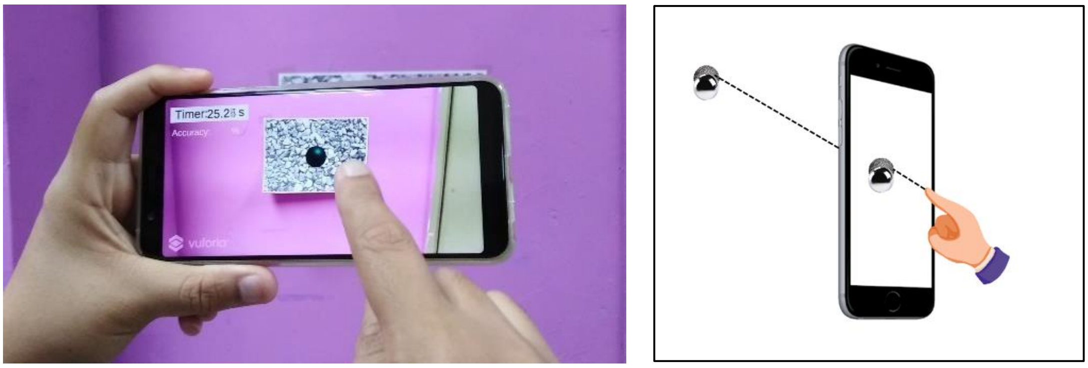


Figure 6. The distance setting for the experiment.

As shown in Figure 6 above, we test the finger-ray interaction with three different distance, which is 3 feet, 5 feet and 8 feet. As the distance decreases, the user's speed is faster in selecting the object as compared to selecting the object at a further distance. As shown in Figure 7, the selection of 3D object with handheld mobile touch interface is more familiar for the user. However, due to the small surface area for the object (the object being smaller as the distance increases), the object selection becomes harder. User needs to touch the mobile screen a few time, before able to select the 3D object.



(a) (b)

Figure 7. (a) common touch-based interaction (b) ray casting selection process.

4.2 Selection by occlusion condition

Occlusion reduce the surface of object that will be available to detect. As referred to Figure 7, the user touches the touch screen. Ray-Casting is quick and precise for targets in near-range, but it has issues with small targets and occlusions at a greater distance. Thus in our project we test the finger ray interaction towards the occluded object at 20%, 50% and 80% occlusion as shown in Table 1. For occlusion, user will be standing 3 feet from the marker. As shown in Figure 8 below, probability for user to touch more than once to select the object increases as the percentage of the object being occluded increases.

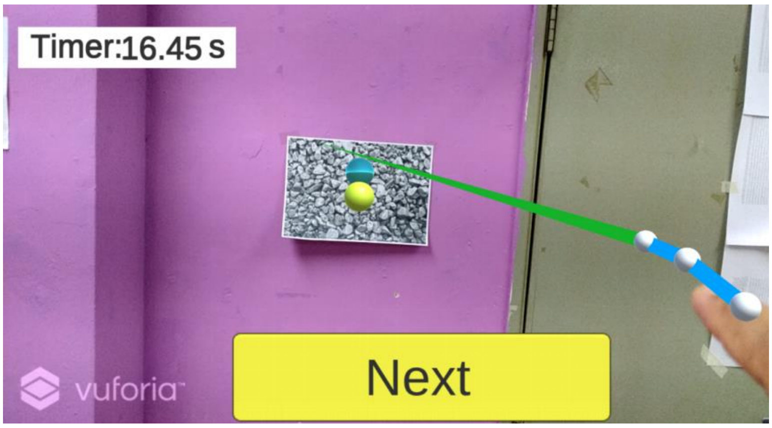


Figure 8. Selecting the occluded object (20% occluded).

Table 1. Occlusion data.

% Occluded	Distance from centre(*h*)
20	0.8
50	0.5
80	0.2

4.3 Experimental Task

As Yin et al. state in their paper [13], we also plan to invite participants who have experience with AR with three factors:

- distance of the target (Distance 3feet, 5feet, 8feet)
- selection technique of Ray Casting
- occlusion level of the target (20%, 50%, and 80%)

Participant will need to select as accurately as possible for the targets and do it as fast as they can. These variables will be evaluated for 12 participants of every technique. Therefore, in total, the design of the experiment will have resulted in 12 participants × 2 target × 3 condition × 2 techniques × 3 repetitions for each group = 432 total trials. The result would be 36 trials per participant. We will then gather the distance and level of occlusion for each chosen target to be studied. We also will obtain time and error rate for each trial.

Table 2. Post-Test Questionnaire.

#	Questions in Usability Questionnaires
Q1	I was performing well using this technique.
Q2	This interaction technique is easy to use.
Q3	This interaction technique is easy to learn.
Q4	This interaction technique is intuitive.
Q5	This interaction technique is natural.
Q6	This technique is useful for completing task.
Q7	This technique has no mental stress.
Q8	This technique has no physical stress.

A post-questionnaire will be given to participants as the experiment of the technique completed (see Table 2). The 7-point Likert scale will be used to present all the questions, where 1 was the most negative response and 7 was the most positive response. They will be asked to rank the techniques from 1 (most preferred) to 6 (least preferred) after the technical experiments were all completed.

5. Summary

We explore the occlusion and distance issue that may affect the far object in AR, and the interaction was focusing on AR. We compare the efficiency of applying our technique with handheld mobile touch interface. For selecting virtual objects, this is to analyze performance and preference. Both articulated freehand gestures and facilitated remote handheld interactions contributed to interactions that were more powerful than voice control.

People greatly favored embodied interactions, however, and considered them to be faster and easier to use. These results provide initial insight into the nature of distal interaction systems in AR, where interactive environments provide experiences with digital material embedded in the physical world on an environmental scale. Iin the future, we would like to continue and extend the experiment by considering more complex interaction such as translation and rotation, and study the efficiency of the interaction. We hope from this study, a better understanding of the finger-ray interaction technique can be achieved and thus will contribute into the growth of research on the possibilities of effective AR applications for example AR based shopping application, urban planning or any other interesting possibilities.

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References

[1] Haque, R., Islam, M. M., Salma, S., Al Jubair, M. A., & Weng, N. G. (2020, January). Extracting Relevant Information Using Handheld Augmented Reality. In Proceedings of the International Conference on Computing Advancements (pp. 1-6).

[2] Sambrooks, L., & Wilkinson, B. (2015, January). Handheld Augmented Reality: Does Size Matter?. In Proceedings of the 16th Australasian User Interface Conference (AUIC 2015) (Vol. 27, p. 30).

[3] Blattgerste, J., Luksch, K., Lewa, C., Kunzendorf, M., Bauer, N. H., Bernloehr, A., ... & Pfeiffer, T. (2020). Project Heb@ AR: Exploring handheld Augmented Reality training to supplement academic midwifery education. DELFI 2020–Die 18. Fachtagung Bildungstechnologien der Gesellschaft für Informatik eV.

[4] Lytridis, C., Tsinakos, A., & Kazanidis, I. (2018). ARTutor—an augmented reality platform for interactive distance learning. Education Sciences, 8(1), 6.

[5] Microsoft (2018) Microsoft HoloLens | The leader in mixed reality technology. https://www.microsoft.com/en-ca/hololens. Accessed 3 Jun 2018

[6] Daqri (2018) Smart Glasses™ - DAQRI. https://daqri.com/products/smart-glasses/. Accessed 3 Jun 2018

[7] Meta (2018) Meta | Augmented Reality. http://www.metavision.com/. Accessed 3 Jun 2018

[8] Leap M Magic Leap. https://www.magicleap.com/. Accessed 6 Jan 2019

[9] Perea, P., Morand, D., & Nigay, L. (2020, September). Target Expansion in Context: the Case of Menu in Handheld Augmented Reality. In Proceedings of the International Conference on Advanced Visual Interfaces (pp. 1-9).

[10] Whitlock, M., Harnner, E., Brubaker, J. R., Kane, S., & Szafir, D. A. (2018, March). Interacting with Distant Objects in Augmented Reality. In 2018 IEEE Conference on Virtual Reality and

IOP Conf. Series: Materials Science and Engineering **979** (2020) 012009 doi:10.1088/1757-899X/979/1/012009

3D User Interfaces (VR) (pp. 41-48). IEEE.

[11] Huang, T. K., Yang, C. H., Hsieh, Y. H., Wang, J. C., & Hung, C. C. (2018). Augmented reality(AR) and virtual reality (VR) applied in dentistry. The Kaohsiung journal of medical sciences, 34(4), 243-248.

[12] D. Bowman, E. Kruijff, J. J. LaViola, Jr., and I. P. Poupyrev (2004) 3D User Interfaces: Theory and Practice

[13] Yin, J., Fu, C., Zhang, X., & Liu, T. (2019). Precise Target Selection Techniques in Handheld Augmented Reality Interfaces. IEEE Access, 7, 17663-17674.

[14] Grandi, J. G., Debarba, H. G., Bemdt, I., Nedel, L., & Maciel, A. (2018, March). Design and assessment of a collaborative 3D interaction technique for handheld augmented reality. In 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR) (pp. 49-56). IEEE.

[15] El Jamiy, F., & Marsh, R. (2019, May). Distance Estimation In Virtual Reality And Augmented Reality: A Survey. In *2019 IEEE International Conference on Electro Information Technology (EIT)* (pp. 063-068). IEEE.

[16] Goh, E. S., Sunar, M. S., & Ismail, A. W. (2019). 3D object manipulation techniques in handheld mobile augmented reality interface: A review. IEEE Access, 7, 40581-40601.

[17] H. Benko, A. D. Wilson, and P. Baudisch (2006) Precise selection techniques for multi-touch screens, 1263–1272.

[18] Yusof, C. S., Bai, H., Billinghurst, M., & Sunar, M. S. (2016). A review of 3D gesture interaction for handheld augmented reality. *Jurnal Teknologi*, *78*(2-2).

[19] C. Telkenaroglu and T. Capin (2013) Dual-finger 3D interaction techniques for mobile devices, 1551–1572

[20] Unal, M., Bostanci, E., & Sertalp, E. (2020). Distant augmented reality: Bringing a new dimension to user experience using drones. Digital Applications in Archaeology and Cultural Heritage, e00140.

[21] Lilija, K., Pohl, H., Boring, S., & Hornbæk, K. (2019, May). Augmented reality views for occluded interaction. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1-12).

[22] Nor'a M N A & Ismail A W (2019) Integrating Virtual Reality and Augmented Reality in a Collaborative User Interface, 59-94

[23] Bai, H., Lee, G., & Billinghurst, M. (2015, December). Free-hand gesture interfaces for an augmented exhibition podium. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction* (pp. 182-186).

[24] Hürst, W., & Van Wezel, C. (2013). Gesture-based interaction via finger tracking for mobile augmented reality. *Multimedia Tools and Applications*, *62*(1), 233-258.