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Summoning Method using Freehand Interaction for Occluded Object Selection in Handheld Augmented Reality

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ABSTRACT

Ray-casting is often used for object manipulation that intersects with the ray that uses the intersection between rays extending from the user and a virtual object. In Augmented Reality (AR), ray-casting has been triggered by a single touch event on the screen using smartphone or handheld device. Object selection in AR implemented in a simple single touch experience, which should be easily understandable for users. However, to select or hover the distant object or occluded object becoming one of the issues need to be solved in handheld AR. Besides, to work with real hand gesture for handheld AR may be challenging. Therefore, the ray intersection will be one of the advantages to manipulate virtual object in AR when works with bare hand or freehand gesture. As aiming a ray out of one's hand towards out of reach item is a very abstract interaction, summoning method has been proposed to confirm the object selection. In handheld AR, summoning method has not been explored, this paper aims to explore the summoning method with raycasting in handheld AR using real hand gesture. It also compares the implementation of summoning using touch-based, the conventional method in handheld AR.

1. Introduction

Summon and select was introduced by [1] which represent a new approach to freehand interaction where the user summons the object into focus before manipulating it rather than navigating to the control. The use of the hand as a substitute pointer has become commonplace in finger detection products like Kinect and Leap Motion. Virtual hands could interact physically with virtual things via Leap Motion [2, 3]. Earlier works on freehand interaction also centers on optimizing the pointing paradigm [4, 5]. It can be implemented within interaction for application of various fields such as medical [6], educational [7], renewable energy system [8], industrial application [9, 10] and many more. Figure 1 describes the mechanism for the state of summon and select designed by [1]. To prevent accidental release, it does not confuse with summoning or manipulation movements, thus the gesture for releases summoned control does not lead to unintended manipulation. An open palm gesture of a summoning hand is presented by Gupta *et al.,* [1] where the release gesture is able

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to fulfills both requirements to a very high degree. When the user summons the incorrect control, the release gesture also functions as an instant Undo. Additionally, the open palm position serves as the ideal hand reset before starting the subsequent summoning gesture.

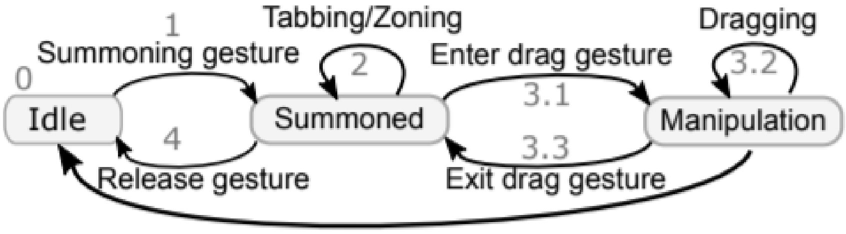


Fig. 1. Summon and Select state mechanism designed by [1]

Ray-casting is often used in Virtual Reality (VR) environments [11–14] for object manipulation that intersects with the ray [15, 16] and it is a technology to determine where rays originating from a user and a virtual item intersect. [17] has suggested a distance-free freehand virtual object handling method for augmented reality (AR). They have put into practice the straightforward notion that a user may always manipulate an object by simply grasping it, regardless of whether it is within reach or not with replicating the selected remote object in front of the user. Meanwhile, [18] ARPointer also employed ray-pointing to enable users interact with three-dimensional (3D) virtual items in the AR environment. Their study utilized the smartphone's gyro and accelerometer sensors.

The study [19] has considered corresponding physical metaphors or biases that may anchor this gesture because firing a ray out of one's hand to target something out of reach represents an abstract interaction. The movements from everyday life were utilized to bring the chosen object within direct reach for modification; a typical motion to draw something closer starts with a flat palm facing up, then swiftly curls the fingers (as shown in Figure 2).

During the testing phase, we discovered that many users would simply flick their wrists and turn their closed hand towards themselves after selecting an object with their arm extended, palm facing the distant object, and fingers curled into a grasp pose. This motion appeared to be pulling the object toward the user. Given our summoning heuristics (palm facing up, followed by degree of finger curl driving animation), performing this action really promptly summoned the object into the user's hand.

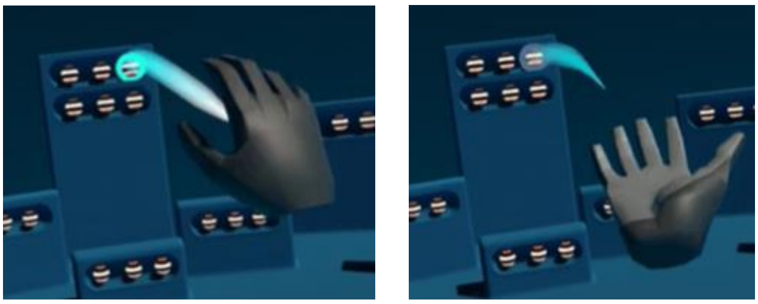


Fig. 2. Summoning Method designed by [11] in VR

A single touch event on the screen, according to Mossel *et al.,* [20], activated ray-casting. These 2D screen coordinates were then back projected into 3D space, and from the virtual camera's position a virtual ray was then cast with the direction of the back-projected 3D point into the handheld AR scene. Using the device's 6 degree of freedom (DOF) position, which the portable AR implicitly provides, one might estimate this direction. The ray selects the first thing it encounters. Therefore, object selection results in a direct single-touch experience that should be easy enough for individuals to understand. Freehand gesture in handheld device has been explored to allow users for the manipulation on the virtual object with their bare hand in AR [21, 22]. Besides using ray-casting in touch-screen, it also be utilized in freehand gesture for the occluded object and distant object [23]. AR combines the VR with the real world in real-time, summoning method in AR has not been explored and using handheld device to work with real hand gesture interaction has been the advanced interaction technique in AR. Therefore, this paper aims to explore the initial experiment to work with summoning method.

2. Handheld Augmented Reality

This section discusses the structure to prepare handheld AR interfaces. In order to work with AR, tracking one of the fundamental in enabling AR technology [7], [24]. Vuforia is one of the tracking libraries that capable to track a marker and bring VR content into a real world.

Table 1 shows the handheld that uses as a display device, it also can be used as interaction device if people use device-based method [25]. In order to enable gesture, it requires tracking library to track human hands. The device such as Leap motion comes with their own SDK to execute the tracking algorithm. Photon SDK is a TCP networking library that can be used to send the gesture data into handheld device. This structure has been recommended in [26]. Using networking, the internet needs to ensure in a stable bandwidth to avoid transmission of data encountered delays.

Table 1
Architecture handheld AR with freehand gesture

Handheld AR (Display)		
Leap Motion SDK (Gesture)	Vuforia SDK (AR)	Unity (Rendering)
	Photon SDK (Network)	

The occlusion positions of objects in complex environment settings may be divided into four groups, according to a study by Elmqvist and Tsigas [27]: closeness, intersection, enclosement, and containment. When two objects are near but not touching, proximity exists, making it possible to perceive occlusion from certain angles but not from others. In terms of interaction, it happens when two items partly cross and are hidden from all angles. Other than that, enclosement takes place when an object is inside one another, such as a room and an object in it. When an object is totally surrounded by another object and is obscured from all angles, this is known as containment.

Meanwhile, as target selection for the distant object, being a far away from the user, the condition would make it hard for the selection process as the target object would appear smaller [28, 29]. The most popular method for selecting the distant target object is using a handheld device to control a cursor on the AR display to indirectly point to the target object. However, this method is not a natural and efficient method [30].

Target selection while dealing with an obscured and distant target object has repeatedly been addressed in prior studies [31–33]. It is, nevertheless, frequently raised up in relation to interaction in VR environment. However, the proposed approach for target selection can be used in the AR environment due to the nature of its action. As a result, in the section that follows, we discussed into further detail on the approaches used by earlier researchers to address the difficulties that were highlighted above.

As a baseline technique to be contrasted with the proposed novel target selection techniques on the obscured object, Yin *et al.,* [34] have included Go-Go technique. I it allows a virtual hand to point to the desired target with a single touch, conduct swipes up and down to change the arm length, and press button on the screen for confirmation on choosing the target which has intersected with the virtual hand, as shown in Figure 3. Despite that, as Go-Go technique limits the desired target size with a point cursor, it is difficult to use the virtual hand to point at and touch the tiny or occluded target object. Meanwhile, the enhance Go-Go interaction system by Jung *et al.,* [17] enable a trigger motion to switched on and off for interaction within AR environment setup.

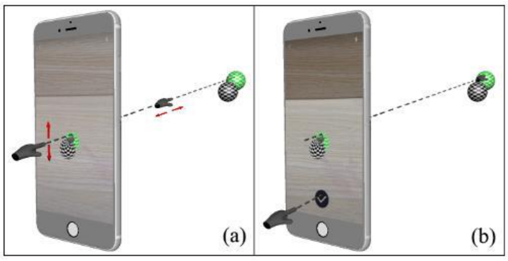


Fig. 3. The selection process for Go-Go which consist of two subtasks: (a) indicating and (b) the optional step of confirming the selection [34]

As shown in Figure 4(a), the virtual hand avatar functions just like a real hand, with the exception that it may be dispatched far into the distance to enable the selection for a distant virtual object. Other than that, in other implementations such as Halim *et al.,* [35] and Yusof *et al.,* [23], the selection is triggered when the ray meets with the desired object as illustrated in Figure 3(b) and (c).

(a) (b) (c)

Fig. 4. (a) Projection of virtual hand into the distance [11] (b) Pointing raycast for target selection [23] (c) Pointing with gesture [35]

3. Freehand Gesture

3.1 Real-Time Gesture on Handheld Device

To enable real-time hand gesture on handheld device, Leap Motion device is utilized; it is connected to the computer, provided the 3D hand orientation, gesture, and direction to the system running in the computer. Figure 5 illustrates the motion-based procedure and depth threshold used to recognize the hand. Leap Motion is a device that can identify, track, and provide information about the positions of hand elements [36]. As the hand inputs may be utilized to build the interaction methods, this common tracking mechanism provided the position and orientation to establish a coordinate system. This allows the device to follow a user's hand's movement as it moves. These unprocessed data are used by the Leap Motion device to calculate the hand's skeleton calibration, which is subsequently used for skeletal hand tracking.

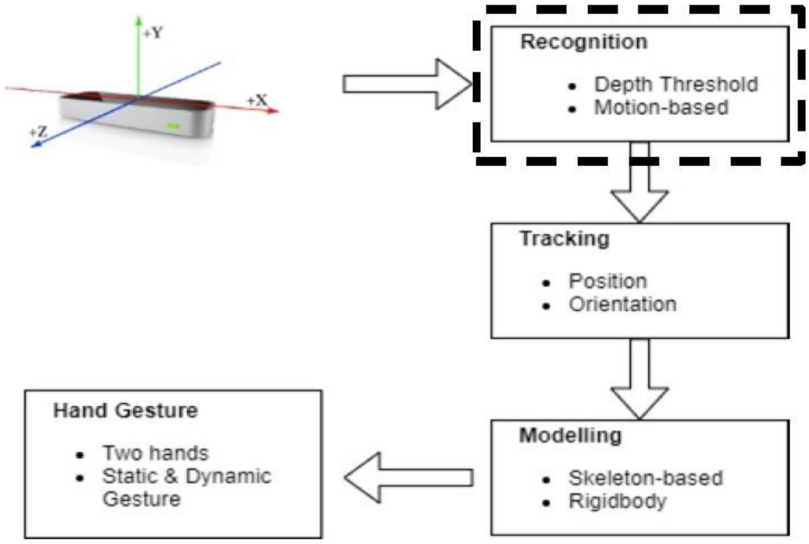


Fig. 5. Freehand tracking for palm close gesture detection

Due to the device's limits and lack of design for portable use, the Leap Motion device cannot be directly linked to a handheld device. Leap Motion's gesture data must thus be sent over the internet to the AR scene. The multiplayer networking is allowed in the system as referred to the study by Nor'a *et al.,* [26]. In this study, data transfer between devices is made possible through Photon Unity Networking (PUN) as shown in Figure 6. The computer which served as a Sender, transmits the position of the user's fingers to the PUN server dedicated for the system. The systems on the handheld device known as Client then retrieves the hand data from the server across the network. The hand data from the Leap Motion device may be effectively shown on the Client side through internet access due to this real-time synchronization through PUN. Additionally, it enables the user to engage further with the target object seen through the handheld display by performing the right-hand gesture.

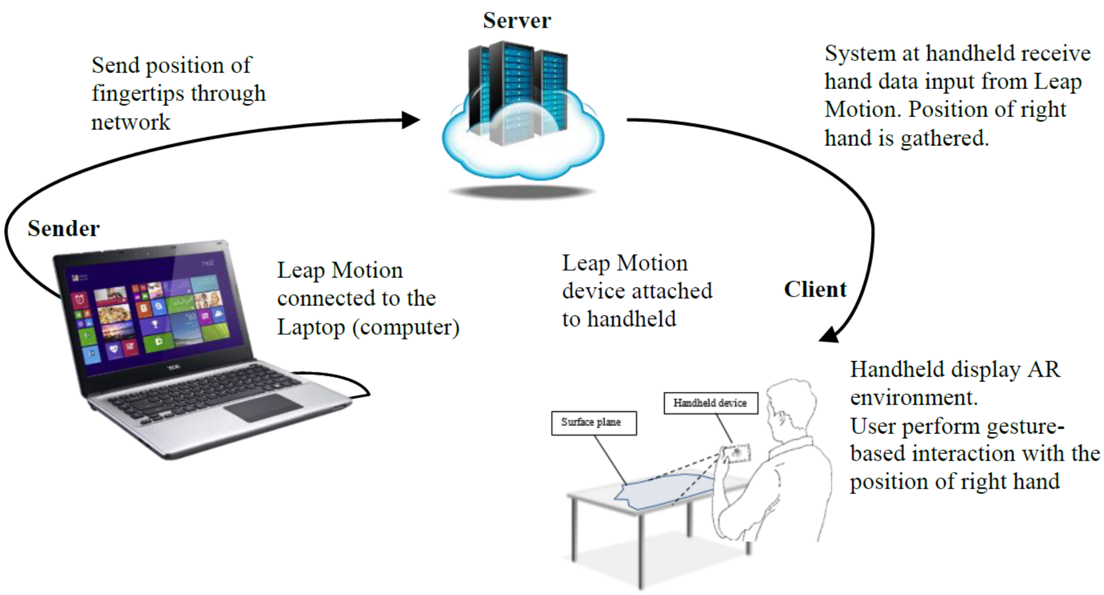


Fig. 6. Gesture inputs have been sent to handheld device through PUN

In order to provide fluid and reliable gesture movement, the portable device must guarantee that internet performance is in a steady bandwidth. Otherwise, if the network is poor, the data transfer might be postponed to acquire real-time hand movement.

3.2 Determine Range and Distant

Figure 7 shows the user stands 5 feet from a tangible table, the marker was placed on the top of the table to be captured by handheld device, and once it performs the recognition. The marker becomes a target or reference point to register 3D content to merge with the real world. The setup where the user was standing in front of a table with the height 0.75 meter. The interaction space (arm-reachable area) is set to 0.3 meters in front of the user.

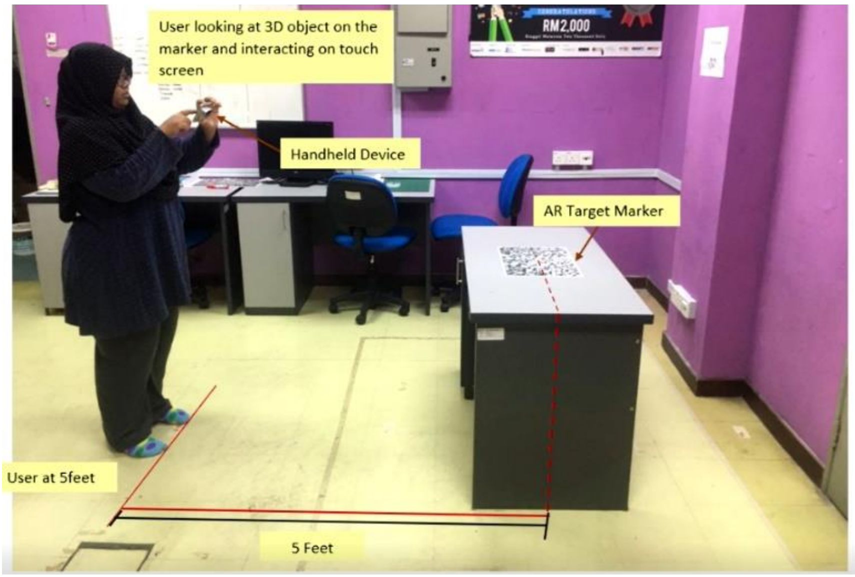


Fig. 7. User with experiment space

Using the formula for the surface area of a cube as given in equation, the occluded area of the targeted object is determined. The blue and yellow cube is the disruptor that obscured the target object in the scene, while occluded target object in red color is for selection.

Cube surface area = 6*a*2 where *a* = width; (1)

Through the perspective view of human eyes, in maximum, only three surfaces of a cube are visible to the eyes. Therefore, to calculate the visible area of the occluded object is as described in Eq. (2).

Visible surface area = x $3a^2$ = 2.4 (2)

In this study, the occluded range for occluded target object is set as referred to the study by Yin *et al.,* [34]. We implement ARCore SLAM which only requires an RGB camera (red-green-blue camera) to recognize 3D feature points from overlapping frames taken while the user looks about. To model both horizontal and vertical surfaces depicted as 3D planes, it searches for clusters of feature points that exist on typical horizontal surfaces such tabletops and desks, as illustrated in Figure 7. The figure depicts how the device only supplies and visualizes a mesh of dots and triangles that adapts with a high degree of accuracy to the surface that is being scanned when it estimates that the plane recognition is accurate. As the camera processes the input stream (see Figure 8), apart from the feature points, it also looks for horizontal surfaces, and the detected surfaces are called planes. Once the plane is defined, the user is able to place the virtual object in the scene by attaching it to the anchor. By attaching it to an anchor, the object's position and orientation can be tracked accurately over time. Therefore, the virtual object appears as if it is within the actual world.

(a) (b)

Fig. 8. Plane surface tracking with SLAM (a) horizontal (b) vertical

Although it allows development without requiring external computational capabilities, it is limited by the capabilities of the device. It also allows environmental understanding, allowing the virtual object to be put on real-world surfaces (such as on top of a table) and tilted in accordance with the angle of the surface after being able to recognize flat surfaces. The surface detection process work as the device's camera looks for the distinct feature points in the real world. By identifying the edges in the camera pictures, it also reveals the plane's bounds. Figure 9 shows the flowchart of the SLAM tracking process of the system.

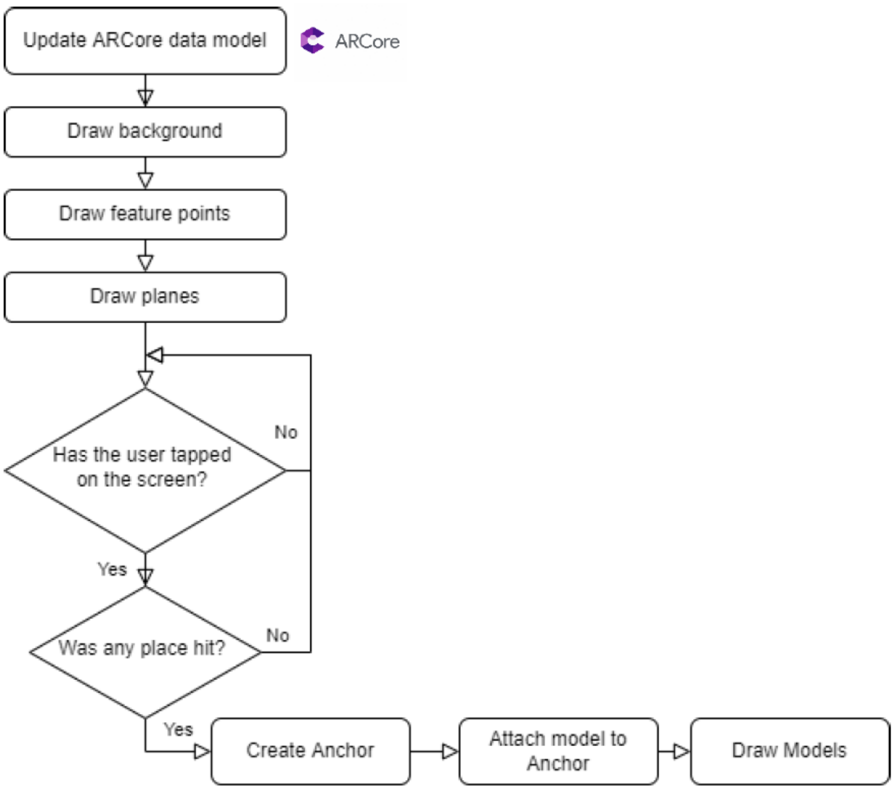


Fig. 9. Markerless Tracking for AR handheld

4. Proposed Summoning Method

This section explains the summoning methods to test for object selection using gesture interaction and the conventional technique, touch-screen.

4.1 Designing Summoning Method

Instead of create gesticulating to reach distant object come closer, the condition may extend the extended arms and grasp the distant object with the fingers. The summonable items in this study were physics-enabled, allowing the distance-free hand motion in AR to reach. This suggests they were most likely lying on the ground rather than sitting up at eye level on a shelf. To make them easier to choose, adjust the selection mode hand stance from overhanded, open palm-facing-the-target to a more comfortable open palm-close with fingers close to summon the targeted object from far and close up to the user. Figure 10 shows as the user stands far away from the scene, ray-cast was projected until it hit the object. Hand snapped to the object through physic with collision detection to hit the object. This behavior triggered the hover, once ray-cast hit the point the object snapped to the actual reach point. Leap hand space is the leap motion device interaction space. The basic cube was used to test the summoning method.

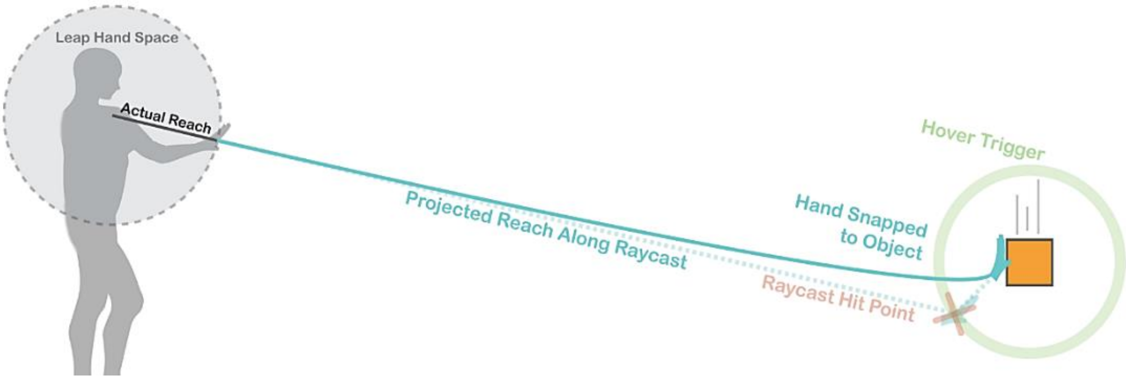


Fig. 10. Summoning Method

There are two metaphors have been proposed to implement the summoning method in this paper, Freehand Gesture (FH) and Touch-screen (TS). The test cases were defined to perform object selection tasks using both FH and TS. Table 2 presents the FH and TS. There are two subtasks: indication the selection and confirming the selection.

Within this research, the pinch gesture is implemented as the hand gesture to confirm the target selection (refer to Figure 11) as it is our natural daily motion equivalent to grabbing or picking. In an interactive system, it offers a natural cue for choosing or moving an object, assuring accuracy and high productivity.

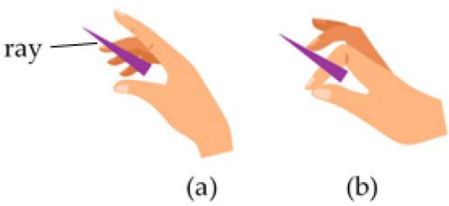
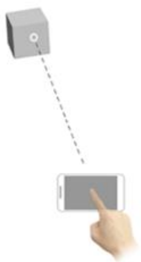
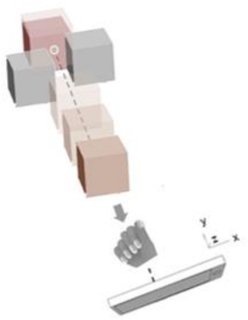
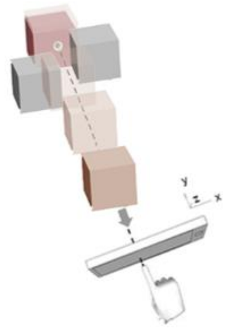


Fig. 11. Pinch gesture

Raycasting often necessitates a disambiguation mechanism among multiple possible targets, particularly in densely populated virtual environments. A virtual ray is cast from the point of origin, normally a tracked hand or handheld joystick, along a specified pointing direction is in the default implementation. The most common approach, on the other hand, is to implement it with a button to validate the selection. Another important distinction is the ray's form, which may either be a straight line in 3D space or have an aperture angle that basically configures a cone [37]. Table 2 describes the selection process for freehand gesture and touch-screen.

Table 2
Object Selection using freehand gesture compared to touch-screen

Freehand Gesture	Touch-Screen
Subtask 1: Indicating the selection 	Subtask 1: Indicating the selection 
Subtask 2 : Confirming the selection 	Subtask 2 : Confirming the selection 

4.2 Implementing Summoning Method

There are two metaphors have been designed, Freehand Gesture (FH) and Touch-screen (TS). The summoning method is recursively running until the cube come forward to the screen. By hitting the virtual button, the summoning is running, by releasing the virtual button, the summoning method will stop. As in the Figure 12(a), the virtual button stated "Pick" and the yellow wireframe was drawn as a visual appearance to give user feedback. Figure 12(b) shows the sphere in a yellow wireframe when gesture FH has performed selection and the summoning happens when the user closes their palm. Palm close was a gesture input to confirm selection and trigger summoning.

(a) (b)

Fig. 12. Summoning Method (a) touch-screen (b) freehand gesture

5. Test Application

Raycasting against a distant object’s proxy collider, sending a projected hand out and snapping it to a position directly in front of the object ready to grab it. As an alternative, this Sending a projected hand out and snapping it to a position directly in front of the object, ready to grab it, via raycasting against the proxy collider of a far-off object. As a substitute to snapping, this way avoids snapping in which the user hovers the ray over a distant object and projects a ray-casting while retaining full control of their hand. The objective was to provide remote objects complete object manipulation flexibility, including gentle touch. To do this, remapped the user's accessible range onto a pre-set projective space wide enough to contain the furthest item. Then, if the raycast struck a proxy collider on an object, this function would simply send out the projected hand to its appropriate place within the projective space, allowing it to travel freely as long as the raycast was still striking the proxy collider. Two alternative scenarios in three distance ranges in 3D space to address diverse selection conditions. In the particular range, the duties of remote object selection and occluded object selection. Thus, occlusion and visual similarity as task design factors. The order of the two selection methods, touch-screen (TS) and freehand (FH), the workspace for experiment setup has first been look up.

Figure 13 shows the user has to select a red cube with ray-casting projected by their hand touch the handheld’s screen. There is AR marker, used to register the scene contained with spheres and boxes also capsules. Figure 14 also demonstrates the occluded-object was the red color has been hit by touch-based interaction. There are raycast direction and position have been annotated in the illustration for AR environment, there was AR marker need to be captured and recognized by the handheld using the built-in camera.

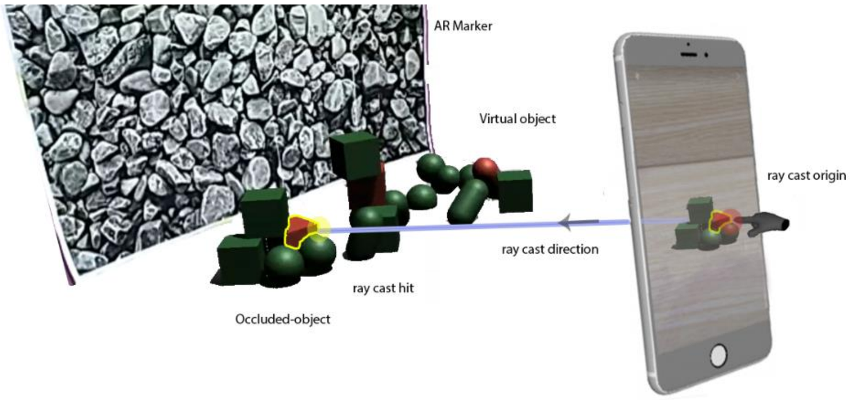


Fig. 13. Hit the occluded object (red sphere) which covered by the other objects (green spheres and boxes)

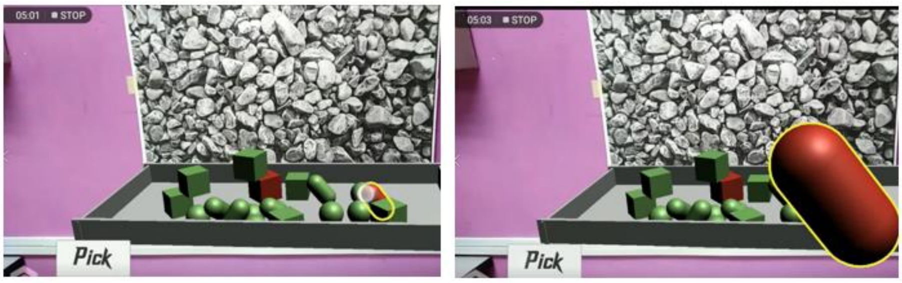
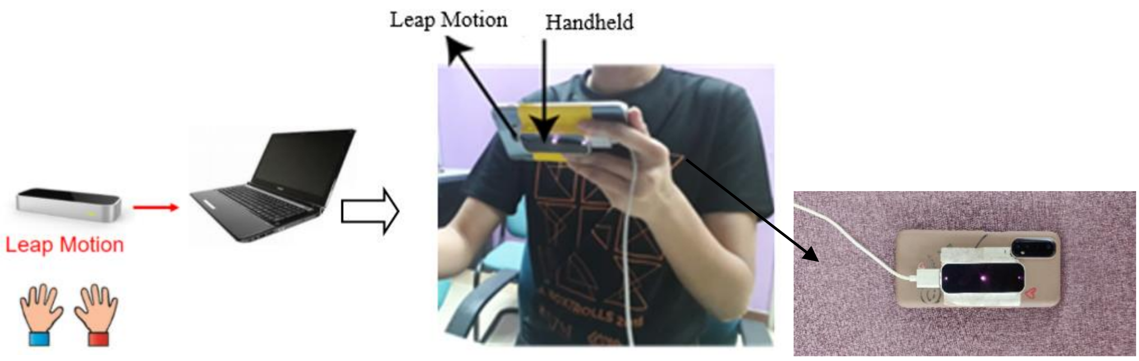


Fig. 14. Select the occluded object using Touch-Based Interaction

Figure 15 presents the application with virtual button “Pick”. Handheld device captures the AR marker, stone image and the AR scene has overlaid on the wall. Figure 8(a) shows the yellow wireframe hit the red capsule, using summoning method the capsule coming forward to the user (as in Figure 15(b)). The user performed the same 3D object selecting task. The goal of this study was also to determine the difference percentage or changes the distant object would be occluded by other objects between different type of interaction metaphor to implement the summoning method, how to determine the range and percentage will be explained in next section.

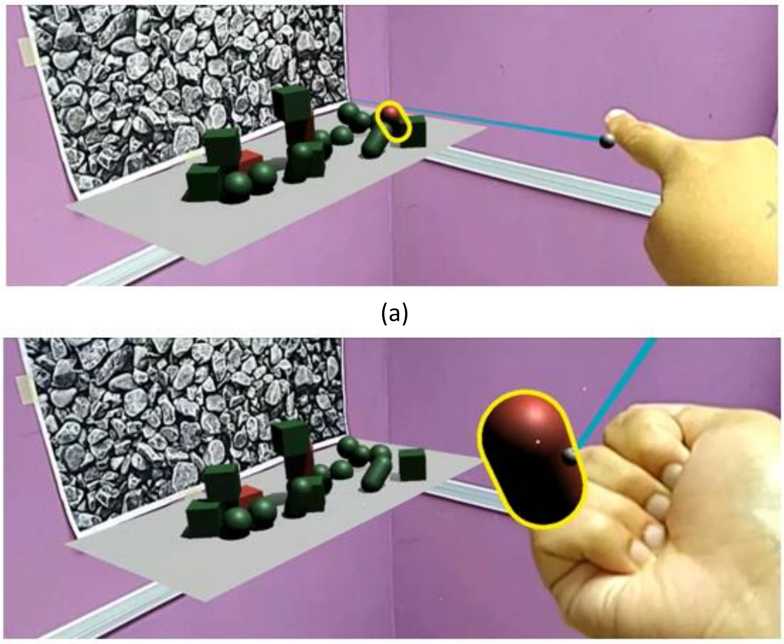
Real hand gesture was using Leap Motion sensor attached to the handheld device. The sensor is mounted to the mobile device's front. The user had to select a red capsule with their bare hand, without using touch-screen, the hand movement must stay in front of the handheld device Leap Motion device coupled to the handheld device in order for the hand to be captured (see in Figure 16). It still connected to computer, the gesture data transferred to the handheld over network.



(a) (b)

Fig. 15. User holds the handheld with Leap Motion attached to it

The condition in Figure 16 shows the red capsule was hidden by the other object, the hand has hit the capsule with ray-pointing using index finger pointing (as in Figure 16 (a)), summoning method has been performed with palm close gesture (as in Figure 16 (b)), the capsule moving forward the user to confirm the selection. This method performed in handled interface with the leap motion attached to the front camera (as in Figure 15).



(a)

(b)

Fig. 16. Summoning Method using with palm close on handheld

6. Future Works and Conclusion

The target selection using summoning method has been implemented into two interaction metaphors, touch-screen based and hand-gesture-based with raycasting technique where the AR environment is enable using markerless tracking technique in handheld setup. User is required to scan their surroundings for plane surfaces to enable the AR environment. The process continues with enabling the hand gesture tracking process in the system where the hand data is transmitted through the internet networking to enable the selection process to be in intuitive and natural manner.

The target selection process is completed in two subtasks. Firstly, the user will indicate the targeted object using raycast, by pointing the ray towards the targeted object with summoning approach the distant and occluded object has been summoned. To complete the target selection, user need to pose a pinch gesture, once the pinch gesture is detected, the outline of the targeted object will appear as green indicated the selection process has completed. Next planning for this study we will perform performance testing. The task completion time data analysis is adapted from Yin *et al.,* [34] research work which is related to target selection specifically for the occluded object. While the distance range evaluation can be referred to the study by Qian *et al.,* [38].

However, during implementation stage and pilot testing, we found and alerted a few limitations that could be address in our future work. Firstly, the target selection method proposed which implement gesture–based interaction is enabled without taking the occlusion issue for the real hand gesture into consideration. Thus, while performing selection, the virtual object augmented in the handheld AR environment always appear above the real hand gesture although the actual position for the virtual objects is behind the real hand gesture position. When performing interaction with real hand gesture recognition, occlusion issue is an inevitable problem that needs improvement.

Secondly, the target selection method is limited to the handheld AR setup. When interacting with virtual object in handheld AR environment, one hand of the user is holding the device, while the other hand is utilized to perform the interaction with the target object. Due to the handheld device weight, the user feel fatigue when holding the device for too long while performing the target selection. Other than that, summoning method is designed for single user, working with touch-screen the summoning behaviour did not fully accomplish when interacting with virtual object in AR. Meanwhile, it is suggested for future researcher to explore the adoption of different type of gesture or adding speech for target selection purposes as in this research, pinch gesture is enabled for the target selection method.

This research has built two distinct scenarios to address various selection circumstances in three distance ranges in 3D space. The order of the two selection methods, touch-screen (TS) and freehand (FH), the workspace for experiment setup has first been look up. Leap Motion, a VR hand tracking device, the device has been used to provide the AR application with gesture information. Gesture and direction may be acquired and communicated over network to the AR application. In this study, the PUN framework was employed to transport finger tracking data across devices. Summoning method has been proposed in this paper, the method has been used real hand gesture and also implemented with touch-screen to see the results. TS requires virtual button to perform summoning while FH use user's palm close gesture to perform summoning. For the future works, we will prepare for the testing and evaluation. We will compare these two metaphor, TS and FH for the summoning preferences. The usability will also be conducted.

Based on the findings in this paper, it discusses the designing and implementing process to actualize the summoning method in handheld AR. Raycasting has been utilized for object selection, it shows the user able to pick the occluded object from the distance of 5 feet. The occluded object indicated in the AR scene where the object was hidden or covered by other object. Raycasting using real hand gesture has proven appropriate method to select the distant object and it able to hit the occluded object. While summoning method was a new approach to confirm the selection. The selected object that far from user's view were approaching close up to the user when they performed summoning.

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