



Real Hand Gesture in Augmented Reality Drawing with Markerless Tracking on Mobile

Ajune Wanis Ismail^{1,2}, Mohamad Yahya Fekri Aladin^{1,2} and Muhammad Nur Affendy Nor^{a1,2}

¹Mixed and Augmented Reality Research lab, Vicubelab Research Group, Universiti Teknologi Malaysia, Skudai 81300 Johor Malaysia

²Faculty of Engineering, Universiti Teknologi Malaysia, Skudai 81300 Johor Malaysia

Received 22 Jan. 2021, Revised 15 Jul. 2022, Accepted 23 Jul. 2022, Published 31 Oct. 2022

Abstract: Augmented Reality (AR) is a technology that can combine real and virtual objects. Interaction is essential in AR, allowing the user to interact with a virtual object in the natural environment. There is various type of gesture interaction that can be applied in AR. The use of gesture interaction in drawing space has become a popular topic among researchers to apply this concept to AR technology by using bare hands to interact directly with AR. However, the visual and spatial complexity of the canvas when involves a real-time drawing canvas for AR still unsolved issue and using real hand gestures on a handheld device still challenging. The implementation approach for the AR Drawing application, as well as hand gesture recognition to collect gesture input for the AR drawing space, is detailed in this paper. The gesture input needed to be conveyed to the portable device, hence the integration procedure took place over a local network. The application flows have been documented, and the user interface (UI) consists of three screens. Brushstroke, thickness slider, and colour are among the elements in this AR drawing space. For AR, ARCore has been used to enable tracking. ARCore is a motion-based tracking approach that does not require the use of a physical marker. It is also known as markerless tracking. By bringing attention to an unsolved problem that impacts a gesture inputs. The compatibility to convert from traditional drawing into digital drawing space and the use of hand gestures as input is challenging. Therefore, this paper explains the process to actualize the real-time drawing in handheld AR using the user's real hand.

Keywords: Real Hand Gesture, Augmented Reality, Virtual Reality, Drawing Tools

1. INTRODUCTION

Augmented reality (AR) technology was useful to combine both real and virtual objects with improving users' understanding of real-world compatibility [1]. It allows the users is carried out real-world jobs by getting the virtual information data by itself. Although several works have been undertaken to develop various ways of improving the experience of using AR, interaction on a smartphone often limits to a touchscreen. The user's ability to interact and control AR content is very limited and does prevent it from engaging more naturally and intuitively with it [2].

There has been a lot of research on the uses of AR technology using different types of a gesture including stylus pen, joystick and 3D hand gesture. 3D hand gesture is one of the potential inputs that can be used to control and interact with the AR virtual material to experience the naturalness. Hand gestures are among the most popular method used in Human-Computer Interaction (HCI) [3]. There are also other methods that can be used as an input form, such as depth-based input and glove-based input. However, the

3D gesture to work with handheld device and align with AR tracking system is still challenging. Robust hand tracking is required and estimate hand positions in 3D space with lack of robustness can impact the user experience. Dynamic hand gesture recognition in appropriate user interfaces (UIs) working on hand movements are still a challenge [4].

Drawing provides a rich means of exchange of information, like the paper with a rough drawing and sketching that can be easily created, without the need for detail, to align the main features of a concept. Hence, 3D drawing work has traditionally been hindered by technical difficulties in promoting basic visual and interaction capacities [5]. Case for AR and VR drawing also involve if the issues about drawing space are rising. In situ marking-up virtual and physical models with defined problems or preferable features are the case of important value for AR drawing in a certain industry [5]. Ali et al. [6] developed an AR application in engineering drawing classrooms. The AR application is for the teaching purpose where it involves 3D object content that is suitable for this class. However,

[7] agree that acceptance of handling of gestures requires a large number of degrees of freedom (DOF), a major variation of the 2D content depending on the camera point of view, specific sizes of silhouettes, and other spatial dimensional resolutions.

The gesture interaction in AR drawing space is when a user can use their bare hands to draw their desired idea and what is in their minds simultaneously [8], [9], [10]. However, the visual and spatial complexity of the canvas requires rethinking how to develop a real-time drawing canvas for AR [11], [12], and using real hand gestures on the handheld device was challenging when smartphones today still rely on conventional touchscreen instead of real hand gestures to manipulate AR content. This paper aims to actualize the real-time drawing using human's bare hands and without needed to track physical marker, it tracks real surroundings to run the drawing application on mobile or smartphone.

The study scope limits to acquire the gesture tracking in handheld device, next is to design appropriate UI to work with the dynamic hand recognition for handheld AR and finally this study has produced AR drawing space application. Three screens Brushstroke, thickness slider, and colour are among the elements in this AR drawing space that we used to implement our 3D hand gestures. Therefore, this paper provides related works and explains the methodology before it describes about gesture interaction. This paper ends with conclusion after it enlightens about a test application, AR drawing space.

2. RELATED WORKS

VR drawing space needs some kind of ability effect to enhance the potential of this technology. Both drawing of 3D objects and utilize AR technology to draw in the real world can break the capacity of physical drawing when performing VR drawing. Besides, it could enhance spatial visualization skills, and it sounds convincing to research its impact on these spatial capacities [13]. The need for spatial abilities in VR technology is really important, and it is the capacity to realize, understand and remember spatial among the object or space. Spatial abilities are usually being used for navigation, understanding, and estimating distance or measurement on performing on a job. [14] described that spatial visualization as "the ability to perform complicated, multistep manipulation of spatially presented information."

[15] stated that activities that proven to affect spatial included playing with the construction equipment toys, engaging in a certain form of sports, and playing specific video games. The type of activities is also have related to creativity, and it might be proven that sketching and drawing coincide with the development of spatial competencies. Several drawing practices are paired with other spatial visualization enhancing tasks, making it difficult to relate performance gains to drawing alone [16]. From the statement, it has been proven that spatial abilities can be obtained and being developed from doing the drawing

activity. The spatial concept and its relation can be achieved by combining this drawing activity with VR technology. In addition, it allows the people to observe and manipulate the virtual 3D content and help the understanding of the concept. [17] have been differentiated spatial skills development after training various 3D virtual technologies and traditional methods, the various 3D virtual technologies being in AR and VR.

With the existence of technology, VR drawing applications have been created, such as Gravity sketch pro and Tilt Brush. Both applications are room-scale 3D painting virtual-reality using HMD and its controller to draw in VR space. The provided controller enables the user to select any drawing tools and draw in a 3D virtual space. With the HMD as the display device, the user can see virtually the drawings clearly. Those applications were popular among graphical artists because they allowed creatively create 3D drawings with them. Figure 1 shows the Tilt Brush [13] application for VR.



Figure 1. Tilt Brush application for VR using HMD [13]

[18] stated that the virtual 3D drawing space comprising a plurality of the 3D objects is output. The drawing application in this study was presented in 3D instead of 2D. This 3D drawing has different perspective views for display and usually makes sense with a stereoscopic approach. However, with various camera angles, it also can be displayed. The object control is output for display within virtual 3D drawing space. The object control can be located near a side of the interface where the camera is located. [19] has implemented gesture recognition. However, they have used an HMD to run their visualization application.

Table 1 shows the related works to drawing space in handheld and input controller such as touch-screen, stylus pen and gesture. In 5 years' works, 2017 MagicToon has bring the issue on complexity screen in AR, ARGI prototype explored the gesture-based interaction, and a technical drawing has been explored in both AR and VR interfaces. However, ARGI required HMD device and the technical drawing in AR/VR has been worked on touch-screen not gesture-based. Recently, drawing and coloring applications in handheld devices have been controlled by touch-based and stylus pen. 3DCoLAR has been produced on HMD

TABLE I. Research Works

Year, Researchers	Works	Display, Input controller	Interface
2017 Feng et al. [20]	MagicToon builds 3D models according to user-drawn 2D images and interactively edit more complex scenes in AR screen	Handheld, Touch-screen	AR Space
2018 Sorgalla et al. [19]	ARGI: AR with Gesture-based Interaction	HMD, gesture	AR Space
2019 Oliveira et al. [21]	Use of VR and AR in Learning Objects: a case study for technical drawing teaching	Handheld, Touch-screen	AR / VR Space
2021 Meesuwan [22]	Drawing and coloring application by augmented reality technology	Handheld, Touch-screen	AR Space
2022 Zaid et al. [23],	AREDAPPS: Mobile AR Framework Based on AR Technology for Engineering Drawing Course	Handheld, Touch-screen	AR Space
2022 Zhang [24]	Colouring the sculpture through corresponding area from 2D to 3D with augmented reality	Tablet Handheld, Pen stylus	AR Space
2022 Lawrence et al. [25]	3DCoLAR: Exploring 3D Color Selection and Surface Painting for Head Worn Augmented Reality using Hand Gestures	AR HMD, gesture	AR Space

however used gesture-based to interact. In contrast to this study, we aim to implement gesture interaction on handheld without using touch-screen and without needed HMD or restricted to hardware. This study explores a markerless AR tracking was performed, so the workspace doesn't require a printed marker.

3. METHODOLOGY

This section explains about methodology. This study has combined AR application with real hand gesture system for drawing and more versatile we have improved the AR tracking by using the recent approach markerless tracking. With markerless tracking, AR content can be displayed respectively in a correct alignment without concern on the visible of physical marker or printed paper as a marker. Next, the important part is the display technique. The handheld display device has been chosen as the display technique. Motion-based tracking and marker-less have been implemented as the tracking technique. This is used to prevent the overlay between real objects and virtual objects and the ease of use for the users while drawing in space. In order to recognized real hand gestures and depth data, the sensor-based is also being used in this research. In order to bring AR drawing using gesture, the system overview has been identified and presented in Figure 2. There are four divisions, first is defining AR display. In this study we use handheld device which very portable and convenient compared to desktop based. Next is designing gesture interaction for AR and enabling AR tracking for the third division. Final division we have defined the appropriate content such as type of strokes, crayon or pencil styles and we have to work on texture also materials.

Figure 2 shows the elements for AR Drawing Application in the project. There are four keys elements in the AR Drawing Application which are AR Display, AR Gesture

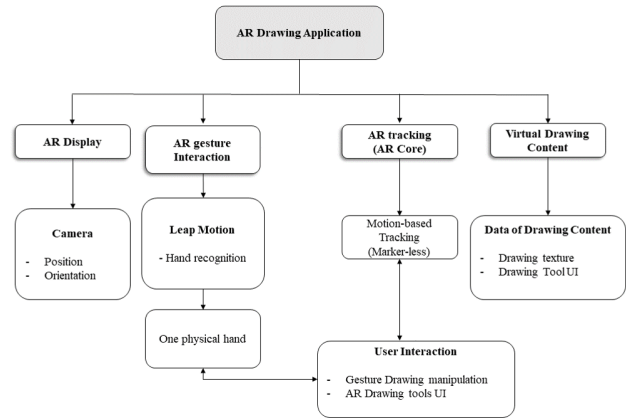


Figure 2. System overview

Interactions, AR Tracking and Virtual Content. The AR display requires a handheld camera in order to recognize the motion-based tracking technique, the input, and the user's hand. The one-hand physical hand must be recognized to perform provided gesture interactions such as gesture drawing manipulation and interact with AR drawing tools UI. The drawing texture and drawing tool UI have been registered as the virtual content that can appear in the AR environment.

A. Enabling Markerless Tracking

In this phase, the tracking technology used is the motion-based tracking technique. ARCore has been used since it has the motion-based tracking to detects visually features points at specific flat-surface and used it as the change in location as shown in Figure 3.

Motion-based tracking techniques to enable markerless tracking system has stored the collection of the data of the features point on the real flat surface for the camera to recognize it as confirmed location points or marked as the marker. As presented in Figure 3 (a) shows the real target environment. ARCore's motion-based tracking has been used along with its software development kit (SDK) in the Unity 3D engine. The process starts after the application has been compiled and been opened in the handheld device. The target must be captured first by the optical camera from the handheld device. The target environment automatically must be converted into a grayscale version, as shown in Figure 3 (b). As in Figure 3 (c), the real environment has been converted into a set of features that has been using for tracking and registering the 3D content, such as drawing contents into a real-world environment, which can be done after these processes have been completed.

Figure 4 shows the markerless detection process when see-through mobile's camera, there no physical marker captured, only the environment. This spatial detection has performed features point capturing process. The result for plane detection features points for motion-based tracking technique by ARCore. From the result, the white quad plane

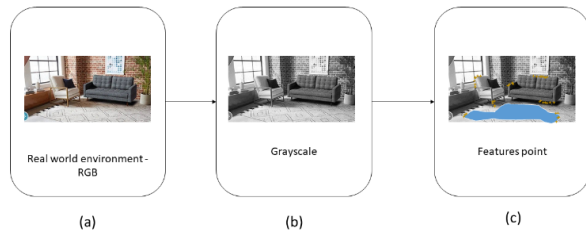


Figure 3. Markerless tracking using ARCore



Figure 4. Feature point capturing process

is the indicator for the features point. Thus, this visualization must be disabled in order to enhance the drawing performance for the user. The features point visualization might disturb if the user performs the drawing action in an AR environment.

B. Designing Drawing Application

Tools like the type of brushes, various selection of color, and the changeable thickness are the tools that were provided in this project. The tools have been added as the AR drawing tools. Since this study is required to work on AR space, the canvas is not included. The floating-like drawing tool UI can be toggled by performing the palm up and palm down gestures. Figure 5 shows the Drawing Application features.

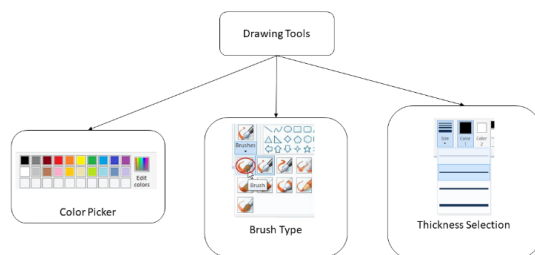
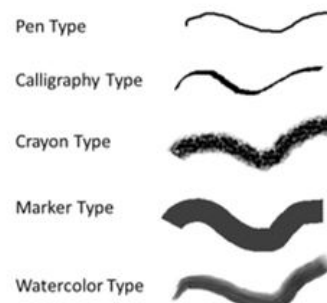
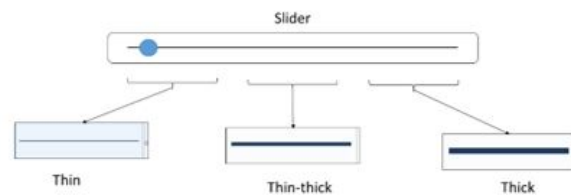


Figure 5. Drawing application features, color picker, brush type and thickness

- Color picker - users to select any color as he desired for his drawing.
- Brush Stroke Types - users to select brush types as they desired for their drawing. Various type of brush has been provided in this study such as pen type, marker type, calligraphy type, crayon type and watercolor type. Different type of brush gives a different type of texture and its strokes at the start and end of its tip's line of drawing as shown in Figure 6 (a).
- Thickness Selection - The slider method (as in Figure 6 (b)) has been chosen as the way for users to change the drawing line thickness. The changes in thickness affect the thickness drawing line if the user starts to draw.



(a) Five types of Brush Stroke



(b) Three levels of thickness

Figure 6. Drawing Stroke and Thickness

Designing the drawing application on mobile, the initial idea as presented in the illustrations Figure 7. It can be seen at the top of the device's screen; there were three buttons for UI (User Interface). The back button, the screenshot button and the gallery button. If the user taps the back button, it returns to the main menu scene. The function of the screenshot button enables the user to snap the drawing and the picture has been saved in the Portable Network Graphics (PNG) format. The gallery UI button allows the user to access the gallery to view back the drawing picture that was captured. The next section explains the gesture recognition and interaction to implement in drawing applications so users can draw freely using their hands.

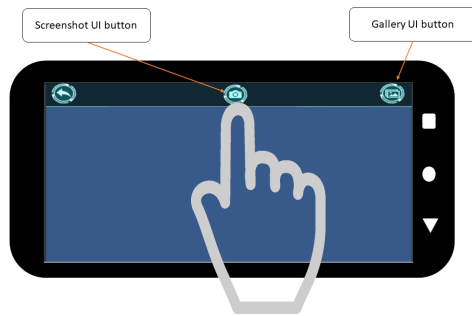


Figure 7. UI for drawing mobile apps.

C. Real Hand Gesture on Mobile

This section discusses gesture input that has used Leap Motion to track bare hands. Gestures have usually been used to manipulate virtual 3D content. The types of gestures, such as grabbing and pinching, were recognized by Leap Motion. The main focus for the use of gestures through this study is the gesture on allowing the user to perform drawing action robust and naturally using their bare hand. They toggle the drawing tool UI in the AR space environment and enjoy the drawing with their hands.

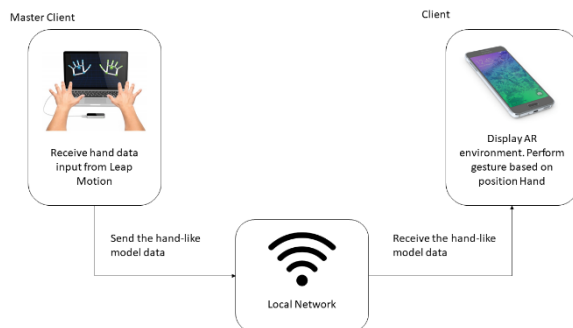


Figure 8. Shared environment, MR collaborative interface.

Figure 8 shows the process of transferring the model data over the local network was needed since the Leap Motion device to track human hands were not handheld. The data captured by Leap motion required a network connection to transfer to the application on handheld. User right-hand data captured by Leap Motion are processed at a PC or as the master client and sent to the client through the same local network that must connect by both devices to make sure the handheld receives the mapped data. The integration of gesture input in AR drawing space has been done if that process is successful. The hand-like model will be appeared to align with the user's physical bare hand at the AR drawing space by using an optical camera's device as displayed. From this point, the user can use any assigned gesture input for drawing.

Leap Motion device does not provide a practical use

for handheld, and it was designed for a computer-based system. The challenging part is to align the gesture tracker to our hands and to send the tracked data (gesture inputs) to mobile or handheld devices. To make sense of this, we have used networking to send the data or transmit the data captured by Leap Motion to mobile phones or smartphones. This study has followed suggestions in many related works regarding gesture interaction on handheld AR [26], [27]. A mobile camera is used to recognize the environment after been tracked by the motion-based tracking and the Leap Motion device to recognize the physical hand. Both devices must be set up properly, as shown in Figure 9.

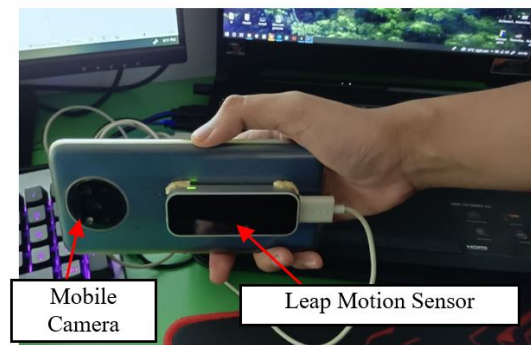


Figure 9. Leap Motion attached to the smartphone.

Figure 10 shows the flowchart to toggle between drawing mode and drawing tool UI mode. To switch between drawing mode and drawing tool UI mode can be performed by using palm up and palm down gestures. If the drawing tool UI mode is on, the drawing mode is off and the user is able to use select any provided drawing tools by pointing up the index finger and chooses as pleased. If the drawing mode is on, the drawing tool UI mode is automatically off and the user is able to draw. As for the 3D touch gesture, the user can tap only the UI button that appeared while in drawing tool UI mode on the device's screen.

4. GESTURE INTERACTION

The real human hands both first need to be captured by the Leap Motion device so it can execute the detection for hand gestures. The Leap Motion provides the detection and segmentation test to obtain the data with the raw sensors in the gestures input. The raw data were stored in the Leap Motion controller are used to understand the skeletal configuration of the hand, the process of hand tracking has carried out as in Figure 11. This standard process has been referred and derived based on [26].

Figure 12 shows the results of real hand gestures captured by the Leap Motion device and the data has been transferred over the network to the handheld device. Sphere represented the fingertip to start the drawing. The stroke drawn in a purple color has corresponded to hand movement. From the result, the hand data was spawned and aligned with the physical hand in the AR environment

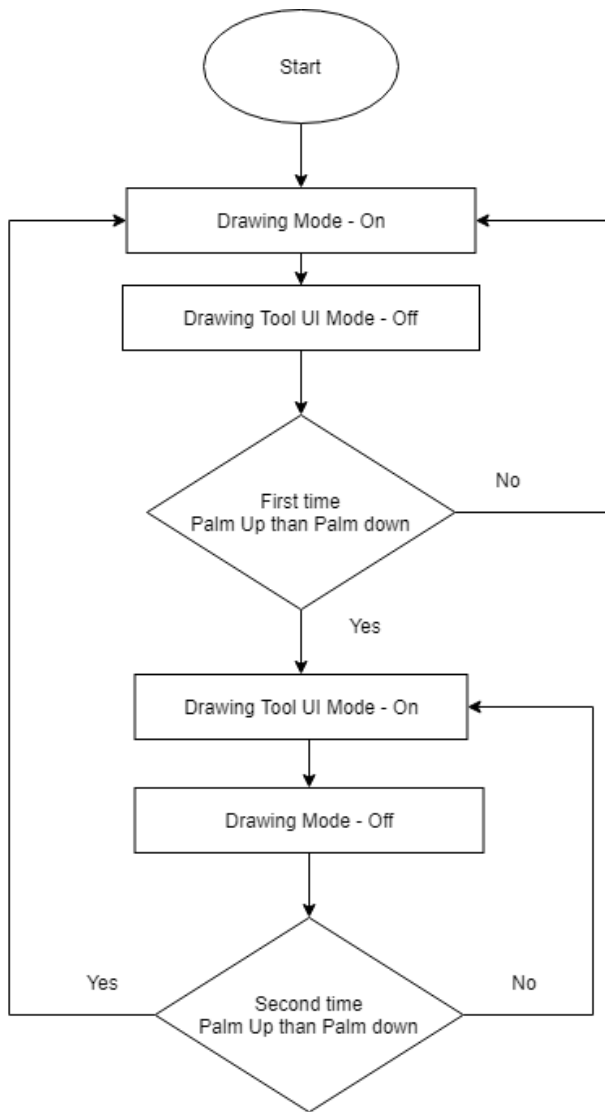


Figure 10. The real hand gesture in mobile for drawing.

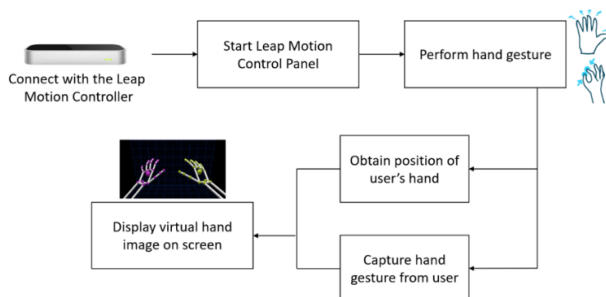


Figure 11. The robust gesture recognition process.

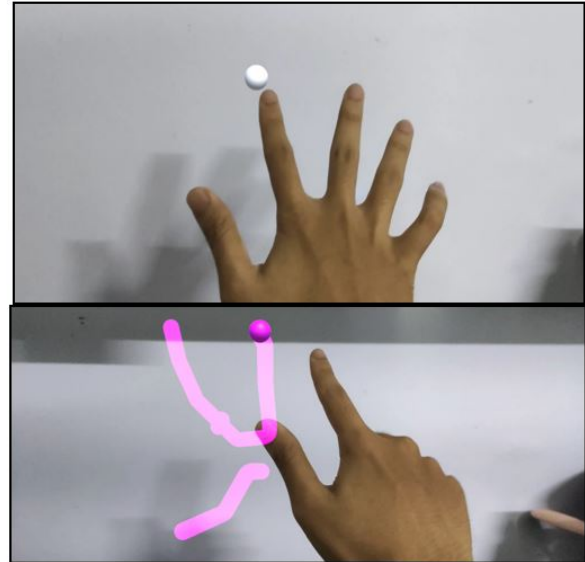


Figure 12. Purple stroke is drawn by real hand in AR.

after the transferring data was succeeded. One sphere was spawned at the tip of the index finger as the indicator to perform the particular gesture. At this point, the user is able to perform any assigned gestures drawing in AR environment.

The gesture input for this application consists of 3 types of gestures which are palm up and palm down gesture and index finger gesture interaction. While using mobile, this study also using the touchscreen. A combination of real gestures and touchscreen can provide the users with more significant hand movement because the touchscreen assists on-screen events such as press the virtual button. The hands have been captured and tracked, and for precise drawing action, the user uses their fingertips to move the strokes or point. User also is able to their hands to trigger the three drawing features and interacts with the UI drawing menu. Based on Table 2, the index finger gesture as drawing action instead of the pinch gesture that usually use in much VR drawings software must be questioned in this project. As the pinch gesture can act as the gesture if it is like holding the pen brush that accepts the naturalness, the index finger can also be used, because the use of the index finger is usually used on wide-surface either in the device such as smartphones or flat canvas, so it is not uncommon if it is used in this project. In this research, the movement of the Index finger, if and only if it was pointing up, will spawn the drawing line only in drawing mode.

5. TEST APPLICATION

There are five buttons in Brush selection for the brush types, which are Pen, Marker, Crayon, Calligraphy, and WaterColor, as shown in Figure 13 (a). In the Color section, eight colors have been provided for drawing and the colors have been sorted into two columns and four rows, as shown

TABLE II. List of gesture input

Gesture	Interaction Description
Index Finger's Movement (right hand)	Choose provided tools in drawing UI panel and perform draw.
Palm Up/Down Gesture (right hand)	To switch for enable/disable the drawing UI panel and drawing action
3D Touch Gesture	Tap the UI button that appeared on the device screen, such as Screenshot Button.
Touch and Fist Gesture (right hand)	Touch the slider thickness and adjust the slider with a fist gesture.

in Figure 13 (b). The panel of color picker presents eight colors only as an initial. The colors definition is Red, Blue, Green, Yellow. The second row shows Cyan, Magenta, Black and White colors. The slider, as shown in Figure 13 (c), was being used for the thickness adjustment. If the user chooses a particular type of tool, it will affect the drawing line if the user performs it.

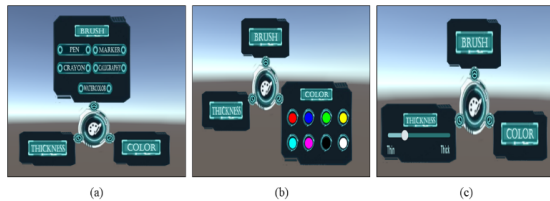


Figure 13. (a) The selection UI for the Brush section. (b) The selection UI for the Color section. (c) The selection UI for the Thickness section

The trail renderer is used because it can easily manipulate and the texture can be changed. It also can be seen as the 3D drawing line trails. The trail renderer acts as the drawing line; as shown in Figure 14, the brush types have been used to test the trail renderer. While Figure 15 shows the setup for the experiment, and it required a handheld device attached with the Leap Motion. It also needs the local network to connect both devices. The proper environment for AR is also being set up for this experiment. The user holds the device while the other hand performs the drawing. Markerless AR tracking has been performed, so the workspace does not require a printed marker, the drawing floating in the real world without needed to find the marker. The environment has been captured in a set of features and it cannot be seen by the user's naked eyes.

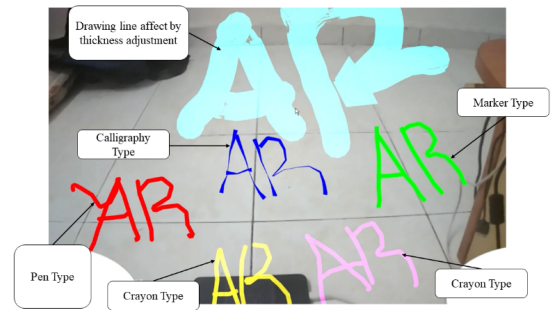


Figure 14. User workspace for AR drawing using real hand gestures with AR markerless tracking.

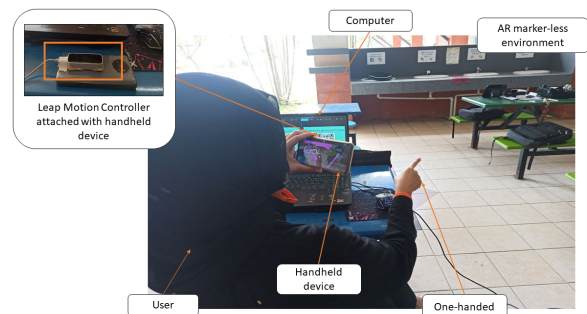


Figure 15. User workspace for AR drawing using real hand gestures with AR markerless tracking.

The data from Leap Motion starts to receive if the Start Server is click. The client-server starts to search the compatible client-server with the same IP address that is being auto-generated by tapping the button and after the IP has been shown in the input field, the user must tap the button again to connect with the master client. Index finger gesture input is if the recognition start, the position of index finger position will be taken. Based on the position value and the collider of others' fingers with palm, it can trigger the starting point to spawn the drawing line. The drawing line will spawn and it corresponds to the movement of the fingertip of the index. A pinch gesture is applied to the object after meeting a condition of colliding thumb and index finger. Pinch detector enabled the condition through On Activate and On Deactivate functions. If the pinch gesture collided with a particular object, the object followed the transformation of hand movement. This process also triggered the rotate interaction as the hand could rotate around the palm. If the palm is in positive value and the count is equal to zero, this will toggle back to drawing mode. They demonstrate the actual representation of how the palm up and down gestures have worked, as in Figure 16.

The thickness slider can move left and right depending on the movement of the hand fist gesture. The use for this

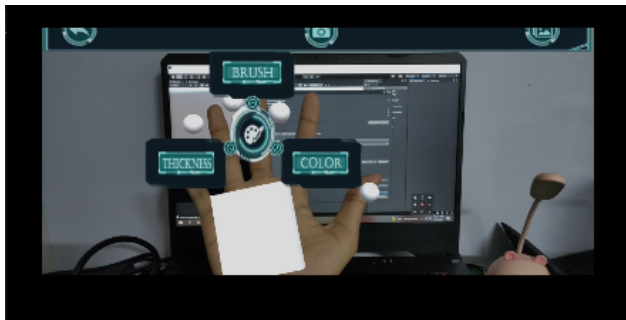


Figure 16. Palm up will bring the menu panel, while palm down will close the menu panel.



(a) Scanning the environment for markerless tracking



(b) AR Drawing app detects the user's real hand



(c) Palm up gesture brings the menu so user can pick

Figure 17. Flow of demonstration AR Drawing Application.

gesture input is also used to select any drawing tools in the drawing UI. The collider that was set at the tip of the index finger can be a function if it collides with any UI button. As for the palm up and down gestures, it is used to toggle between two modes, which are drawing mode and drawing UI mode. The palm up and down gesture have their calculation count for toggling between both modes. Figure 17 (a) shows the first screen appears to scan the environment as a captured space since we applied markerless tracking using ARCore. Figure 17 (b) shows the application has recognized the user's hand and pop-up the virtual menu. User can control the thickness by moving the slider left and right, while Brush and Color buttons the user can perform tapping gesture. Based on the demonstration, this study has brought AR drawing space in markerless tracking and control the application using real-hand gestures. The hand recognition through a Leap Motion controller has allowed user to interact with virtual UI and experience the real behavior for drawing in AR space environment.

6. CONCLUSION

This paper discusses the implementation process includes the AR Drawing application, hand gestures recognition to obtain the gesture input for AR drawing space. The integration process has happened by using a local network, where the gesture input needed to be sent to the handheld device. The application flows have been explained, and the UI has been described consist of three UI. The features in this AR drawing space are brushstroke, thickness slider and color. ARCore has been used to enable tracking for AR applications. ARCore is a motion-based tracking technique in which the tracking does not require a physical marker, and it was markerless tracking. A limitation is when the network does not stable to transfer the gesture input to the handheld device, it will affect the user experience performance. The system encounters a slow and lagging network connection. The drawing space does not smooth enough. One of the solutions, use the motion-based gesture tracking technique instead of using sensor-based for the gesture. With this tracking method, the gesture data does not require a network connection to send and retrieve the gesture on the handheld. As a future work, improvement can be done on the handheld device without transfer the hand data by using the local network. Indirectly, it can overcome the slow and lagging network connection as one of its limitations. Besides a single user can perform the drawing, the apps can invite more users and we need to concern on a communication cues when invites remote users, can be seen in this recent review [28].

ACKNOWLEDGMENT

We would like to thank the Mixed and Virtual Reality Laboratory (mivielab) in Vicubelab Research Group at Universiti Teknologi Malaysia (UTM).

REFERENCES

- [1] R. T. Azuma, "A survey of augmented reality," *Presence: teleoperators & virtual environments*, vol. 6, no. 4, pp. 355–385, 1997.

- [2] M. Billinghamurst, "Crossing the chasm," in *International Conference on Augmented Tele-Existence (ICAT 2001)*. ICAT Tokyo, 2001, pp. 5–7.
- [3] M. Y. F. Aladin and A. W. Ismail, "Designing user interaction using gesture and speech for mixed reality interface," *International Journal of Innovative Computing*, vol. 9, no. 2, 2019.
- [4] R. Golash and Y. K. Jain, "Real-time robust and cost-efficient hand tracking in colored video using simple camera," in *Social Networking and Computational Intelligence*. Springer, 2020, pp. 565–573.
- [5] J. J. Dudley, H. Schuff, and P. O. Kristensson, "Bare-handed 3d drawing in augmented reality," in *Proceedings of the 2018 Designing Interactive Systems Conference*, 2018, pp. 241–252.
- [6] D. F. Ali, M. Omar, M. Mokhtar, N. Suhairom, A. H. Abdullah, and N. Halim, "A review on augmented reality application in engineering drawing classrooms," *Man in India*, vol. 97, no. 19, pp. 195–204, 2017.
- [7] V. A. Shanthakumar, C. Peng, J. Hansberger, L. Cao, S. Meacham, and V. Blakely, "Design and evaluation of a hand gesture recognition approach for real-time interactions," *Multimedia Tools and Applications*, vol. 79, no. 25, pp. 17707–17730, 2020.
- [8] J. H. Lee, D. Ma, H. Cho, and S.-H. Bae, "Post-post-it: A spatial ideation system in vr for overcoming limitations of physical post-it notes," in *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*, 2021, pp. 1–7.
- [9] P. H. Chien and Y. C. Lin, "Gesture-based head-mounted augmented reality game development using leap motion and usability evaluation," in *15th International Conference on Interfaces and Human Computer Interaction, IHCI 2021 and 14th International Conference on Game and Entertainment Technologies, GET 2021-Held at the 15th Multi-Conference on Computer Science and Information Systems, MCCSIS 2021*. IADIS, 2021, pp. 149–156.
- [10] I. Logothetis, "A toolset for physical interaction in augmented reality environments." 2021.
- [11] T. Li, J. Xie, H. Niu, and S. Hao, "Enhancing pencil drawing patterns via using semantic information," *Multimedia Tools and Applications*, pp. 1–18, 2021.
- [12] M. Fernández Camporro and N. Marquardt, "Live sketchnoting across platforms: Exploring the potential and limitations of analogue and digital tools," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 2020, pp. 1–12.
- [13] T. Chittenden, "Tilt brush painting: Chronotopic adventures in a physical-virtual threshold," *Journal of contemporary painting*, vol. 4, no. 2, pp. 381–403, 2018.
- [14] W. Bolier, W. Hürst, G. Van Bommel, J. Bosman, and H. Bosman, "Drawing in a virtual 3d space-introducing vr drawing in elementary school art education," in *Proceedings of the 26th ACM international conference on Multimedia*, 2018, pp. 337–345.
- [15] M. C. Linn and A. C. Petersen, "Emergence and characterization of sex differences in spatial ability: A meta-analysis," *Child development*, pp. 1479–1498, 1985.
- [16] S. A. Sorby, "Developing 3-d spatial visualization skills," *The Engineering Design Graphics Journal*, vol. 63, no. 2, 1999.
- [17] D. J. M. L. . I. D. Gortler, S., "U.s. patent no. 10,529,145." 2020.
- [18] . P. B. J. Cullum, A. C., "U.s. patent no. 10,529,146." 2020.
- [19] J. Sorgalla, J. Fleck, and S. Sachweh, "Argi: Augmented reality for gesture-based interaction in variable smart environments." in *VISIGRAPP (2: HUCAPP)*, 2018, pp. 102–107.
- [20] L. Feng, X. Yang, and S. Xiao, "Magictoon: A 2d-to-3d creative cartoon modeling system with mobile ar," in *2017 IEEE Virtual Reality (VR)*. IEEE, 2017, pp. 195–204.
- [21] M. P. d. Oliveira and F. P. d. Silva, "Use of virtual reality and augmented reality in learning objects: a case study for technical drawing teaching," *International journal of education and research [recurso eletrônico].[S. l.]*. Vol. 7, n. 1 (jan. 2019), p. 21-32, 2019.
- [22] W. Meesuwani, "The development of a drawing and coloring application by augmented reality technology based on the concepts of multisensory," *JOURNAL OF EDUCATION NARESUAN UNIVERSITY*, vol. 23, no. 2, pp. 295–309, 2021.
- [23] N. M. Zaid, N. H. Ibrahim, and J. Surif, "Aredapps: Mobile augmented reality development and learning framework based on augmented reality technology for engineering drawing course," in *Intelligent Technologies for Interactive Entertainment: 13th EAI International Conference, INTETAIN 2021, Virtual Event, December 3-4, 2021, Proceedings*, vol. 429. Springer Nature, 2022, p. 322.
- [24] Y. Zhang, "Colouring the sculpture through corresponding area from 2d to 3d with augmented reality," *arXiv preprint arXiv:2202.04259*, 2022.
- [25] L. M. Lawrence, G. Lee, M. Billinghamurst, and D. Rompapas, "3dcolor: Exploring 3d color selection and surface painting for head worn augmented reality using hand gestures."
- [26] M. N. A. Nor'a and A. W. Ismail, "Integrating virtual reality and augmented reality in a collaborative user interface," *International Journal of Innovative Computing*, vol. 9, no. 2, 2019.
- [27] C. Yusof, N. Halim, M. Nor'a, and A. Ismail, "Finger-ray interaction using real hand in handheld augmented reality interface," in *IOP Conference Series: Materials Science and Engineering*, vol. 979, no. 1. IOP Publishing, 2020, p. 012009.
- [28] W. Huang, M. Wakefield, T. A. Rasmussen, S. Kim, and M. Billinghamurst, "A review on communication cues for augmented reality based remote guidance," *Journal on Multimodal User Interfaces*, pp. 1–18, 2022.



Ajune Wanis Ismail Ajune Wanis Ismail is a senior lecture in Universiti Teknologi Malaysia Skudai Johor, Malaysia. She has conducted her research in Augmented/Mixed Reality and she is currently a head of UTM Vicubelab Research Group, a cross-disciplinary research group in computing whose primary focus and activities revolves around the design, implementation and application of computer graphics, vision and virtual environment, simulation and immersive visualization theories in Universiti Teknologi Malaysia.



Muhammad Nur Affendy Nor'a Muhammad Nur Affendy Nor'a received his B.S. degree in Computer Science from Universiti Teknologi Malaysia in 2017 and currently working full-time as a Senior AR/VR Programmer in UTM. He received his MSc degree, and his research is about a fusion of AR and VR, integrates with multi-user interaction and remote communication between users.



Mohamad Yahya Fekri Aladin Mohamad Yahya Fekri Aladin received his B.S. degree in Computer Science from Universiti Teknologi Malaysia in 2015, and currently working for fulltime as a Senior Engineer in UTM. He completed his industrial training with MaGICX as a game developer. He received his MSc degree and his research is about 3D Object Manipulation in Mixed/Augmented Reality (MR), integrates with 3D gesture, he successfully delivered an intuitive multimodal interaction for MR user interfaces using gesture and speech input.