Mathematics Lesson using Accelerometer Sensor Interaction in Handheld Augemented Reality Application for Kindergarten

Cik Suhaimi Yusof
ViCubeLab
Faculty of Engineering
Universiti Teknologi Malaysia
81310 Johor Bahru, Johor, Malaysia
suhaimi@utm.my

Nazwa Ahmad
School of Computing
Faculty of Engineering
Universiti Teknologi Malaysia
81310 Johor Bahru, Johor, Malaysia
nazwaahmad97@gmail.com

Ajune Wanis Ismail
ViCubeLab
Faculty of Engineering
Universiti Teknologi Malaysia
81310 Johor Bahru, Johor, Malaysia
ajune@utm.my

Mohd Shahrizal Sunar
Media and Game Innovation Centre of Excellence
Institute of Human-Centered Engineering,
Universiti Teknologi Malaysia
81310 Johor Bahru, Johor, Malaysia
shahrizal@utm.my

2020 6th International Conference on Interactive Digital Media (ICIDM) | 978-1-7281-4928-8/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICIDM51048.2020.9339655

***Abstract*—Handheld Augmented Reality (AR) is a combination of the virtual content and real world that gives a chance for the user to interact with virtual objects in real time using handheld device. Recent handheld device equipped with additional sensing like gyroscope, barometer, accelerometer and proximity sensor make possible to explore full potential for interaction in application. This become interesting topic to improve the human perception and to enhance the understanding of complex 3D scenarios. The traditional educational method is not necessarily effective for the children. Sometimes student's incapable to recall the ideas and it seem struggle to solve the problem in learning process. Therefore, the purpose of this project is to develop mathematics lesson using accelerometer sensor interaction in handheld AR application for kindergarten. There are four phases to complete this study. The first phase is preliminary investigation and analyse in handheld application for Mathematics lesson. Then, second phase is to design the details of application operational framework. The third phase is to develop Mathematics lesson application with accelerometer interaction. Last phase is to evaluate the user perception of the application. Unity 3D and Vuforia SDK are used as editors and library respectively through the development process. The evaluation has been done by respondents who are the ages from 6 to 9 years old. The results have proved that the application can help better to improve Mathematics learning skill by using accelerometer interaction through handheld AR application. The application enhances the teaching method for students to learn an addition and subtraction more efficiently and in interactive ways.**

Keywords—augmented reality, accelerometer sensor interaction, handheld device, mathematics lesson application

I. INTRODUCTION

Handheld devices such as tablet and smart phone are quick popular in this era and it is a part of people daily life especially for kids. The kids in this era are growing up where the handheld devices become a common part for daily communication and interaction [16]. Children mostly preferred mobile devices as media choice because of the screen size, weight, and interactive capability.

Children nowadays are not only carrying the smartphones, but the children are also mastering when using the smartphones. In fact, the kids have the skills as good as the parents or even more in some cases. Many educators believe that using technology such as mobile devices can gives a chance to promote new learning process and development for children [10].

Due to the increasing the use of mobile devices somehow has affect the young children towards the learning process, especially in the class. The best way method for learning should be more sense such as touch, sound, hear and sight [3]. In addition, the application that have in the mobile devices should be child friendly to make the learning process be more effective [8]. Moreover, with the implementation of Augmented Reality (AR) and indirect interaction such as accelerometer interaction in the application also allows the children to improve their learning skills effectively. Accelerometer interaction allows the children to feel more natural when interact with the virtual objects in AR scene [12]. This new learning environment can attract children's attention to be more focused in the class and at home.

II. LITERATURE REVIEW

A. Augmented Reality

Augmented reality can interact between the real-world with virtual computer-generated objects that appear same with the real-world space [1]. The difference between augmented Reality (AR) and Virtual Reality (VR) system which the main goal for AR is to enhance the reality with digital content in non-immersive way while VR is to create the technology that can replace the reality and allows people to immerse in immersive environment [2]. However, AR have a potential to be used to all sense such as sense of smelling, sense of touching and sense of hearing [6]. There are many researchers claimed that AR have a potential to enhance the learning and teaching process [5].

Milgram defined that the continuum of real to the virtual environment in which AR is a part of mixed reality but in

978-1-7281-4928-8/20/$31.00 ©2020 IEEE

general area as shown in Figure 1 [15]. The first appearance of AR is in 1950s. It is happened when one of the cinematographers named Morton Heilig thought that the activity that have in the cinema have the ability by taking all senses with an effective manner to draw the viewer into the onscreen activity [14].

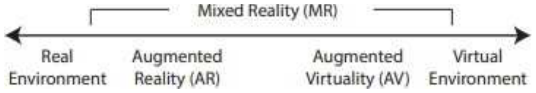


Figure 1. Milgram's reality-virtuality continuum (Rabbi, Ullah, 2013).

B. *Vision-based Tracking*

Vision based is a technique to track the position and the orientation of the camera using image information [14]. Vision based tracking for AR has becomes popular in recent times because of the minimal hardware requirements, the feature of the smartphones and tablets which have camera and screen that make them ideal platforms for AR. The available tracking techniques that used for this tracking are marker-based tracking and markerless tracking [14].

Marker-based tracking has specific properties that make it easier to track the position in the real world. Marker-based tracking usually uses QR codes or any custom template for tracking that called image target [4]. Each AR application has different marker detection and tracking requirement [14]. Marker-based tracking was presented to estimate the accurate camera pose that tracked the 2D markers. The advantage of this marker-based tracking is it can robust a large range of distance and reliability under several orientations [14]. Figure 2 below shows the example of ARToolKit markers.

Figure 2. Marker based tracking (Rabbi, 2010).

C. *Handheld Display*

Handheld display is a small device with the display where the user can use their hands to hold it. This device is using a VST techniques to overlay the graphics onto the real environment. Handheld display is a good alternative to use for AR because provided socially acceptable, minimally intrusive, highly mobile, and readily available. The available handheld displays have three distinct classes that are being used in AR which are smart-phones, Tablet PCs and PDAs [9].

According to Mohring [15], the first self-contained for AR system running is using cell phone of the consumer. It supported the correct integration of 2D or 3D graphics into the live video-stream at interactive rates and optical tracking of passive paper markers. However, there is low video stream resolution, graphics are simple and memory capabilities and a processor is slow for drawbacks. Todays, smartphones, and tablets are widely adopted and have powerful graphics processor, cameras and various sensors that can run the AR applications [19]. These handheld devices can support AR applications when running it.

D. *Accelerometer Interaction*

Accelerometer is used as a vector quantity to detect the magnitude and direction of the acceleration of the 3D objects. Accelerometer has been used in the smartphone sensor-based activity recognition [18]. The linear accelerometer measures the acceleration along with three axes as shown in Figure 3 [17]. The common usages for accelerometer interaction in mobile devices are tilting, shaking and detecting the motion [20].

The accelerometer is measuring the acceleration due to movement and gravity. When the handheld device is stable, the accelerometer returns just due to the gravity. The acceleration that measured in accelerometer sensor is in terms of g-force. The gravity force can affect the measurement of accelerometer for measuring speed or displacement of an object in a three-dimensions [11]. Moreover, the accelerometer will return with the different values based on different kind of smartphones.

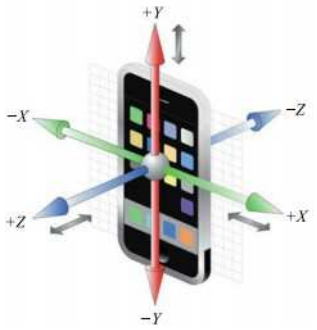


Figure 3. Accelerometer axis on smartphone (Su, Tong, Ji, 2014).

E. *Augmented Reality in Education*

AR is a new technology that has the potentials to enhance teaching and learning experiences with new methods. The emergence of the AR can give the good impression for teaching and the process of learning as well as a new way to learn. However, the educators still need to know more on how the design AR to make sure the learning experiences enhancement will become more affordable [8].

AR can help the students to improve the process skills such as critical thinking and to solve the problem [3]. In addition, the use of the virtual and real objects allows the students to view the learning content in 3D perspectives. AR technology have the effectiveness in learning process [13]. A few students reported that this technology have motivated them to achieve higher levels of learning efficiency and enjoyment. These factors make them better understanding in their lesson. Teaching abstract concepts is an effective AR application that should be used in education where students can make physical movements such as control over the virtual objects in AR environment which can make their learning process becomes easier [7].

F. *Related Works*

Table 1 below shows the comparative between the existing mobile applications for accelerometer interaction and mathematics lesson. Based on the comparison table, one of these applications which is Math Worlds AR used a marker tracking by using the textbook cover as a marker and the player can used a touchscreen to perform the game. However, this apps do not used the accelerometer interaction compared to Basketball Roll and Accelerowriter that used accelerometer interaction for the games. Besides, Basketball Roll game is not AR game compared to the other both applications which are Math Worlds AR and Accelerowriter applications. Lastly, both Math Worlds AR and Basketball Roll can use a touch screen to perform the game.

TABLE I. COMPARATIVE STUDY

Characteristic	Math Worlds AR	Basketball Roll	Accelerowriter
Handheld Device	Tablet and Smartphone	Tablet and Smartphone	Tablet and Smartphone
Platform	Ios and Android	Android	Android
Marker Tracking	Yes, using textbook cover	No	No
Augmented Reality	Yes	No	Yes
Accelerometer Interaction	No	Yes	Yes
Touchscreen	Yes	Yes	No

III. METHODOLOGY

Methodology plays as an importance part of the application. Figure 4 below shows that four main segments to guide this project from analyse the project until to evaluate it based on the design and development cycles. First phase is about analyse and identify the issues in Mathematics Lesson application. The second phase is a design process that consists of the concept of Mathematics Lesson application and Handheld Augmented Reality (HAR). The process of the tracking and accelerometer interaction will be designed in this phase. The third phase is the development of the application using accelerometer interaction in handheld AR and lastly to evaluate the complete application.

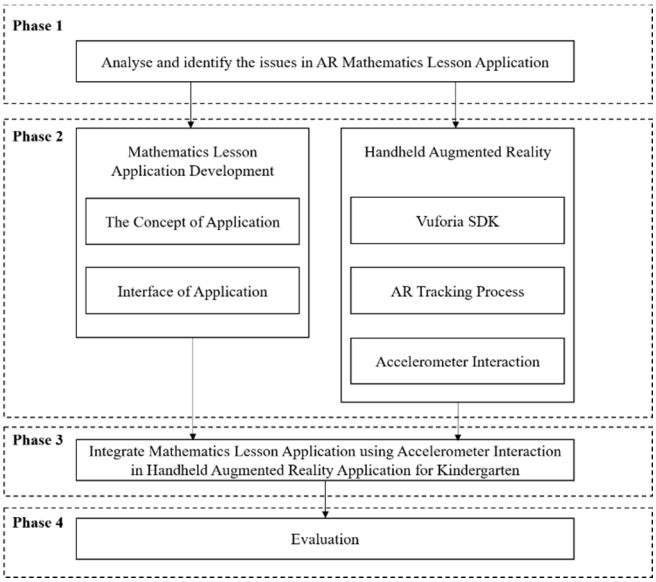


Figure 4. Project methodology.

A. *Phase 1: Analysis and Identify the Input Data in Handheld Application for Mathematics Lesson*

Developer need to understand what is handheld for AR and analysed the problems or issues that have in this AR application. Developers also need to analyse the important requirements that needed to develop the application. Furthermore, this project is to identify on how the input data will apply into this project by using accelerometer sensor interaction and marker-based tracking.

B. *Phase 2: Design the Well-suited of Concept of Application and Marker-based Tracking Technique with Accelerometer Interaction in Mathematics Lesson Application*

Design process needs to be done to overcome the major problems addressed when using handheld interaction technique to interact with AR Mathematics Lesson Application from the information that had been analysed in the previous phases. The main challenge in Mathematics Lesson application using accelerometer interaction is to ensure that the application can maintain the feeling as real as possible, smoothly and feel comfortable when using this application.

C. *Phase 3: Integrate Mathematics Lesson Application with Accelerometer Interaction in Handheld Augmented Reality*

After the design have been completed, the prototype of the handheld device for representing see-through visualization that replace on the screen for Mathematics Lesson Application is setting up. The prototype is developed in this phase. In addition, the accelerometer interaction prototype also is being developed in this phase.

Figure 5 below shows the operational framework for the application. The marker is scanned by the camera to display the virtual objects. Then, the interaction between accelerometer sensor and virtual objects happens after the object has been selected. Then, shaking effect is used to interact with the virtual objects and stop when release the virtual object. The output is displayed as shown in Figure 5.

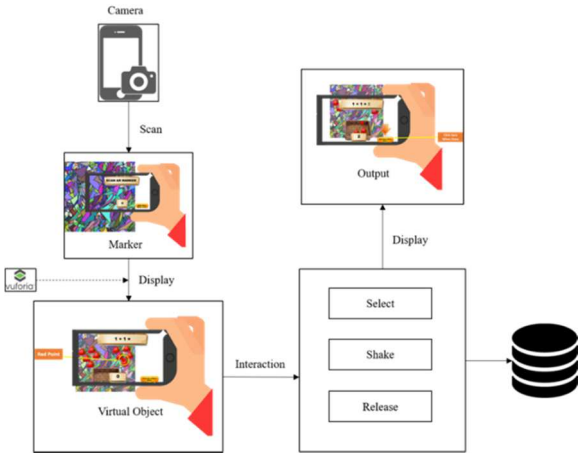


Figure 5. Operational framework.

D. *Phase 4: User Evaluation of the Augmented Reality Application*

AR Mathematics Lesson application is tested and evaluated using accelerometer interaction. This phase is focus on user testing and the feedback from the testing to make an improvement if required. This phase included the process to find the errors and bugs and to improve the application if needed.

IV. DEVELOPMENT DESIGN

This section explains the development design in Mathematics Lesson Application for Kindergarten. This section will be includes concept of application, AR Tracking process and user interface (UI).

A. *Concept of Application*

This KindergMath Kids application provided the random questions for each topic. There are consists of two main topic in Mathematics Lesson for Kindergarten which are Addition and Subtraction. The range number that used in this application is from 1 until 10. After the user hover the camera to the marker, the random number of the question will be displayed automatically. The virtual objects also will be pop up to represent the number of the question. Figure 6 and Figure 7 below show the project diagram for Addition and Subtraction.

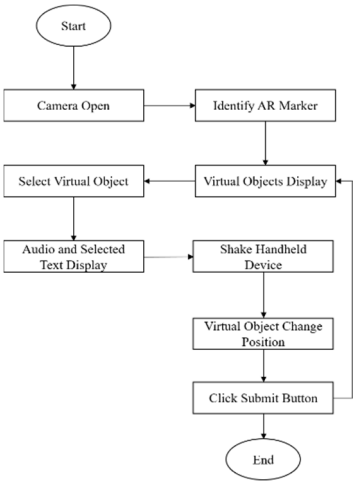


Figure 6. Project diagram for addition.

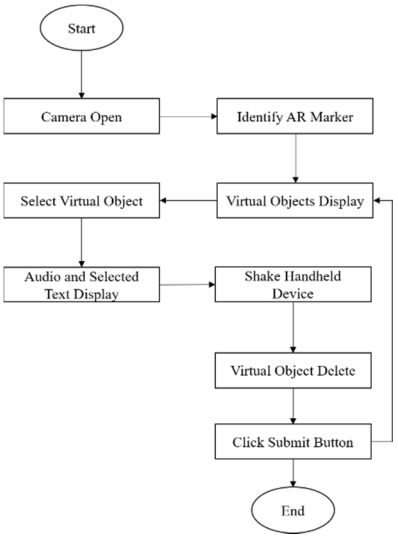


Figure 7. Project diagram for subtraction.

B. *AE Tracking Process*

Figure 8 shows the process of the tracking marker is applied to display the 3D objects in the real-world. The first process for this tracking is to search the suitable input marker. This tracking process to identify the marker pattern to make sure that the marker pattern is same with the marker in Vuforia database. Next, the marker is calculating the viewpoint of the position and orientation to display the 3D objects on the marker. This process happens when the user hovers the camera of the handheld device to the printed marker given.

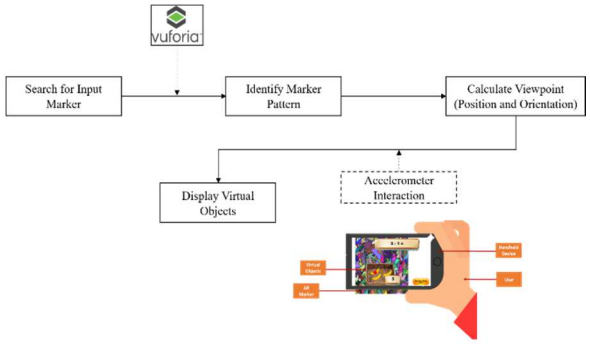


Figure 8. Tracking process.

C. *User Interface*

The project flowchart as shown in Figure 9 is the process used when the user starts using the application until the end. The user needs to enter the username and click on “Play” button to go to the next page. This process happened when user entered the first page of the application. Then, the user needs to choose either to proceed the application by clicking on addition or subtraction button at the main menu page. After that, user can read the tutorial of the application before starting AR interface by clicking on the “How to Play” button. Then, user starts AR interface by clicking on “Play” button given. Moreover, the user also can view the highest score at the scoreboard given by clicking on “Score” button in the main menu page.

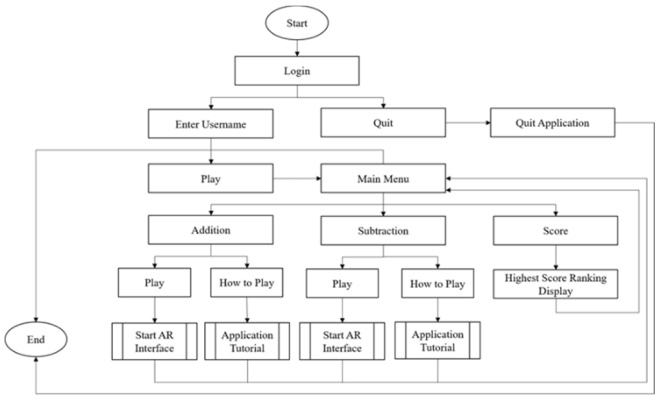
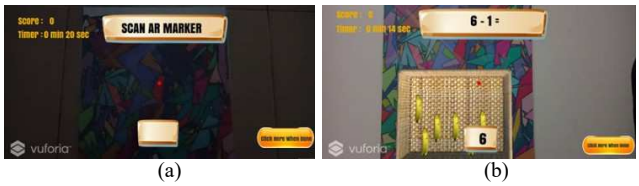


Figure 9. Project flowchart.

V. IMPLEMENTATION

A. *Implementation of Marker-based Tracking*

This section explains the marker-based tracking process that has been implemented in this project. Marker-based AR is used to display the virtual objects where the user can interact with the virtual objects in the real-world. Then, the developer needs to import the Vuforia Engine package into the Unity 3D Engine as well as a license key to activate the AR marker. After activated the Vuforia Engine package in Unity 3D software, developer needs to add AR camera and activate the target database in the scene. This AR camera can work as a main camera in the scene and the handheld device can detected and tracked the image target from the live camera view to display the virtual objects. Figure 10 below shows before and after the marker has been detected and tracked by the AR camera to display the virtual objects in digital world.



(a) (b)

Figure 10. (a) Before the marker was tracked, (b) After the marker was tracked.

B. *Implementation of Accelerometer Interaction in Handheld Augmented Reality*

This section discusses about the implementation of accelerometer interaction in handheld AR. There are multiple interactions that can be used using the accelerometer sensor interaction which are by shaking the handheld device or tilting the screen of the handheld device. This project has been used a shaking effect using accelerometer interaction to interact with the virtual objects which are fruits. There are three axis orientation for the accelerometer sensor to detect the movement of the virtual objects. A shake effect can be detected by measuring the quick changes in the accelerometer sensor. The speed also needs to assign to detect the frequency of the movement when shaking the handheld device.

Interaction of accelerometer sensor can be detected after the virtual objects has been selected by the user. In addition, a ray casting has been used in this project to select the virtual objects to enable the accelerometer interaction and release the virtual object when the interaction was completed. A red point on the screen of the handheld device has been marked as ray casting to make it easier for the user when selecting the virtual objects.

VI. Result and Evaluation

The testing has been conducted user testing has been conducted with the total number of respondents were ten respondents which are nine students and one teacher. In addition, there are four of the respondents were females while six of the respondents were males. Most of the respondents did not have any experience in AR technologies. Each question was measured from range 1(negative attribute) to range 5 (positive attribute). The feedback from the respondents have been collected and was discussed based on the bar graph. Figure 11 below shows the result of respondents' feedback for their satisfaction for the application.

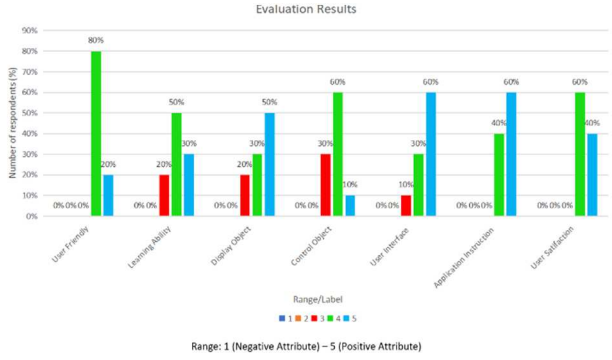


Figure 11. Results of the respondents' feedback for the application.

Based on Figure 11 above shows that most of the respondents agreed that the application was user friendly with 80% of the respondents rated as agreed and another 20% of the respondents rated as strongly agreed. Then, for user's learning ability in using the KindergMath Kids application, it shows that most of the respondents found the application was fast to learn with the percentage of 50% in total for fast and 30% in total for strongly fast when using KindergMath Kids application. Only 20% of the respondents range their ability at the third level which represented as not too fast and not to slow to learn the application. Next, the easiness for the respondents to display the virtual objects on the marker. The graph shows that a half of the respondents which was 50% in total found that it was too easy to display the virtual objects while 30% of the respondents found the virtual objects were easy to be displayed. Another 20% of the respondents found that the virtual objects were not too easy and too hard to be displayed on the marker.

In addition, the forth is the easiness for the respondents to control the virtual objects. 60% of the respondents rated as 4/5 which represented as easy and 10% of the respondents rated as 5/5 which represented as too easy to control the virtual objects by using shaking effect. Another 30% of the respondents rated as 3/5 which represented as not too easy and not too hard to control the virtual objects to complete the tasks. The fifth is about the user acceptance on user interface of the application. 30% and 60% of the respondents agreed and strongly agreed that the user interface of the application was well-designed. Only 10% of the respondents rated 3/5 for the interface of the application. User interface was important as it can attracted the kids' attention to focus on the learning process using the application and on how the kids interact with the application to achieve the goals.

Next, user acceptance on the clearer instructions when using KindergMath Kids application. Based on the bar graph, 60% of the respondents strongly agreed that the instructions were cleared and too easy to understands while another 40% of the respondents agree that the instructions provided were easy to understands the flow when using the application. Surprisingly most of the respondents were satisfied with KindergMath Kids application as 60% of the respondents rated as 4/5 which represented as satisfied and another 40% of the respondents rated as 5/5 which represented as really satisfied with the application. The overall of the satisfaction level was considered by the user friendly of the application, users' learning ability, the easiness to display the virtual objects, the easiness to control the virtual objects, how well-designed of the application interface and user acceptance towards the instructions of the application.

VII. Conclusion

This KindergMath Kids application was developed to help the kindergarten in understanding more and improving their Mathematics skills with a new learning environment method. Both Addition and Subtraction topics were chosen according to the syllabus that have learned at school.

KindergMath Kids application is limited for Android user only as it was build using android package kit (APK) file format. This application used only one target marker where the design has been fixed as it has been saved in the Vuforia database cloud. In addition, accelerometer sensor interaction which is using shaking method has been used in this application where the user can interact with the virtual objects to complete the tasks provided.

Lastly, for the future works, there are a few suggestions in improving the application in the future. Based on the usability testing, the respondents suggested that the application should

adding speech recognition to help the user easy to count the number of the selected virtual object. Secondly, to improve the application for a better learning process, the variety of color tab can be added into the application so that the user can color the virtual objects first before the user wants to select it. Thirdly, the animations on the virtual objects also can be added into the application to attract the children to play the application with a real feeling as well as attract the children's interest in learning Mathematics. Lastly, the respondents suggest that the application should have more instructions to help the children more understands when playing the application.

ACKNOWLEDGMENT

We would like to express our appreciation to the ViCubeLab, Faculty of Engineering, Universiti Teknologi Malaysia for the facilities and technical supports. Special thanks to UTMER Grant (Q.J130000.3851.19J22) for the funding. A big gratitude is dedicated to the parties that contributed the fundamental knowledge in this paper.

REFERENCES

[1] R. T. Azuma, "The road to ubiquitous consumer augmented reality systems," Human Behavior and Emerging Technologies, 2019.

[2] M. Billinghurst, A. Clark, and G. Lee, "A survey of augmented reality," Foundations and Trends in Human-Computer Interaction, 2014.

[3] I. N. M. Bistaman, S. Z. S. Idrus, and S. A. Rashid, "The use of augmented reality technology for primary school education in perlis, malaysia," Journal of Physics: Conference Series, vol. 1019, 2018.

[4] R. C. Bituin and E. C. Bautista, "Marker less hand gesture tracking using smart phones," ACM International Conference Proceeding Series, 2020.

[5] M. Bower, C. Howe, N. McCredie, A. Robinson, and D. Grover, "Augmented reality in education - cases, places and potentials," Educational Media International, vol. 51, pp. 1–15, 2014.

[6] J. Carmigniani and B. Furht, "Chapter 1 - augmented reality: An overview, handbook of augmented reality", 2011.

[7] C. S. C. Dalim, M. S. Sunar, A. Dey, and M. Billinghurst, "Using augmented reality with speech input for non-native children's language learning," International Journal of Human Computer Studies. Elsevier Ltd, vol. 134, pp. 44–64, 2020.

[8] C. S. C. Dalim, H. Kolivand, H. Kadhim, M. S. Sunar, and M. Billinghurst, "Factors influencing the acceptance of augmented reality in education: A review of the literature," Journal of Computer Science, vol. 13, pp. 581–589, 2017.

[9] D. Wagnerand and D. Schmalstieg, "Handheld augmented reality displays," Proceedings - IEEE Virtual Reality, p. 67, 2006.

[10] M. Kalogiannakis and S. Papadakis "Evaluating pre-service kindergarten teachers' intention to adopt and use tablets into teaching practice for natural sciences," International Journal of Mobile Learning and Organisation, vol. 13, pp. 113–127, 2019.

[11] M. Liu, "A study of mobile sensing using smartphones," International Journal of Distributed Sensor Networks, 2013.

[12] V. Nacher, A. Ferreira, J. Jaen, and F. Garcia-Sanjuan, "Are kindergarten children ready for indirect drag interactions?," Proceedings of the 2016 ACM International Conference on Interactive Surfaces and Spaces: Nature Meets Interactive Surfaces, ISS 2016, pp. 95-101, 2016.

[13] C. Pereral, A. Zaslavsky, P. Christen, A. Salehi, and D. Georgakopoulos, "Capturing sensor data from mobile phones using global sensor network middleware," IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC, pp. 24–29, 2012.

[14] I. Rabbi, "A survey of augmented reality challenges and tracking,", 2010.

[15] I. Rabbi and S. Ullah, "A survey on augmented reality challenges and tracking," Acta Graphica : Journal for Printing Science and Graphic Communications, vol. 24, pp. 29–46, 2013.

[16] D. Schmalstieg and D. Wagner, "Experiences with handheld augmented reality," 2007 6th IEEE and ACM International Symposium on Mixed and Augmented Reality, ISMAR, 2007.

[17] M. Skoczewski and H. Maekawa, "Augmented reality system for accelerometer equipped mobile devices," In Proceedings - 9th IEEE/ACIS International Conference on Computer and Information Science, ICIS 2010, 2010.

[18] X. Su, H. Tong, and P. Ji, "Activity recognition with smartphone sensors," Tsinghua Science and Technology, vol. 19, pp. 235– 249, 2014.

[19] T. Vincent, "Handheld augmented reality interaction: spatial relations," 2017.

[20] Z. Ma, Y. Qiao, B. Lee, and E. Fallon, "Experimental evaluation of mobile phone sensors," pp. 49–49, 2013.