

PAPER • OPEN ACCESS

Augmented reality battleship board game with holographic display

To cite this article: F E Fadzli *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **979** 012013

View the [article online](#) for updates and enhancements.

A promotional banner for the 240th ECS Meeting. The banner features a colorful striped border at the top. On the left, the ECS logo is displayed in a green circle. To its right, the text reads "240th ECS Meeting" in large blue font, followed by "Digital Meeting, Oct 10-14, 2021" in a smaller blue font. Below this, it says "Register early and save up to 20% on registration costs" in bold black font, and "Early registration deadline Sep 13" in a smaller black font. At the bottom left, there is a red "REGISTER NOW" button. On the right side of the banner, there is a photograph of a diverse group of people in a professional setting, smiling and interacting. A white diagonal line separates the text from the photograph.

ECS **240th ECS Meeting**
Digital Meeting, Oct 10-14, 2021
**Register early and save
up to 20% on registration costs**
Early registration deadline Sep 13
REGISTER NOW

Augmented reality battleship board game with holographic display

F E Fadzli^{1,2*}, **A W Ismail**^{1,2}, **M F A Rosman**^{1,2}, **N M Suaib**^{1,2}, **M S M Rahim**²
and I Ismail³

¹Mixed and Virtual Environment Research Lab (miviellab), ViCubeLab,
Universiti Teknologi Malaysia, 81310 Johor, Malaysia

²School of Computing, Faculty of Engineering, Universiti Teknologi Malaysia,
81310 Johor, Malaysia

³Faculty of Informatics & Computing, Universiti Sultan Zainal Abidin, Kampung
Gong Badak, 21300, Terengganu

* fazliaty.edora@gmail.com

Abstract. The board game is a game that played on the board, and the Battleship board game is one of the examples. While developing the virtual board game, multi-user interaction is essential as a board game played by more than one people. To enhance the user experience, the board game has been implemented with Augmented Reality (AR) technology. AR can superimpose it into the real-world since it has the capabilities to overlay the virtual game on the top of the real world. However, AR handheld has limited perspective viewing for the viewers to see the battleship game. Therefore, this project aims to develop an AR battleship board game with a holographic display. Three phases have been carried out, first is to study the multi-user interaction for the AR battleship board game and holographic display with a different perspective. Second is to develop the multi-user interaction for AR Battleship board game. Finally, the third phase is to integrate the AR Battleship board game with a pyramid holographic display. The evaluation has been performed, and the result is based on the usability and user acceptance have been recorded. Based on the result, this project has successfully produced AR Battleship board game with holographic display application and significantly enhance the user experience.

1. Introduction

The board game is generally any games of strategy or chance played on a specially designed board and involved two or more opponents moving pieces, and using dice or cards [1]. Some examples of the board game are checkers, chess, snake and ladder, and monopoly as the board games involve more than one people, players able to explore and interrogate the knowledge in a fun and interactive way by working in groups or provoking the players [1]. This paper describes the implementation of the multi-user interaction of the board game by using the Photon Unity Networking (PUN). Augmented Reality (AR) is a combination of the real and virtual object in a real environment, interactively run and in real-time, and registered or aligned real and virtual objects with each other [2]. AR tracking is the main components in application development. One of the tracking methods applied is marker-based tracking. The AR can serve to display three-dimensional (3D) objects and their information when scanning the marker [3]. To implement the AR marker-based tracking, Vuforia SDK has been implemented during the application development. The implementation of AR provides a gaming experience for the player. The developed



board game had integrated with the holographic display to give the gaming experience for the non-player. The hologram is an image that can appear or display in the form of 3D and can be seen by naked eyes. The holographic display becomes more enjoyable when multiple points of views of the display shared by multiple users at the same time [4]. The sharing process can occur when using the four-sided hologram pyramid based on Pepper's Ghost Illusion concept.

This paper explains the phases to develop AR board game with a holographic display. This work needs to produce game elements for battleship and multi-player algorithm to execute the battle. Therefore, this paper discusses the proposed multi-user interaction before implementing the holographic setup for non-users. This research needs to obtain non-user experience if the battleship game can be displayed to see by non-users openly. While the multi-user interaction also collected to know the user experience with the AR interface.

2. AR Board Game

People already familiar with the AR during this modern era. It is a technology that allows the users to have an interactive experience with digital or computer-generated information and overlays over the real-world environment. That digital information can be either images, audio, video or gesture [5]. Kipper and Rampolla [5] stated in their book that AR is the combination of many types of technologies that bring digital information into visual perception. The augmented perception of reality and the creation of an artificial environment are those functions of the AR. Based on the book written [5], AR act as a tool designed to enhance the surrounding environment from the perception of the user. They also claimed that in some cases, AR is not only for the entertainment process, but it is beneficial to assist users in the process of decision-making. This is a significant element when AR has used in a game, especially a battleship game which required decision-making [6]. Figure 1 shows the AR battleship game.

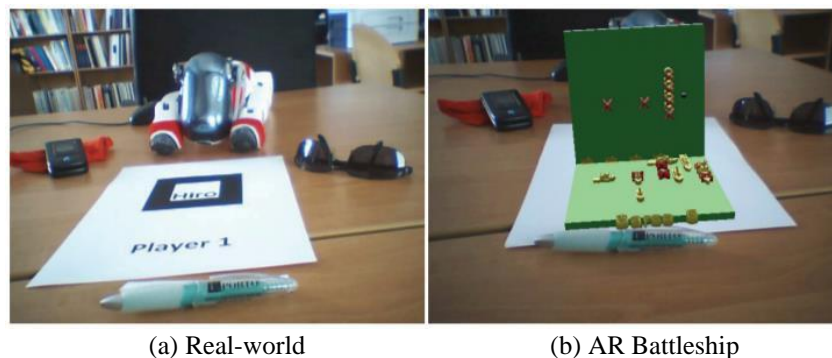


Figure 1. AR Battleship [6].

Battleship consists of four grid board, and the interaction was the ballistic shots. There was an interactive cursor based on the grid cell definition; it allows a visual hit. The application is defined in [6] by using ARToolkit tracking system which black and white marker was used as in figure 1 (a), while figure 1 (b) shows the whole game scene appeared on top of the marker.

Besides ARToolkit, marker detection can be performed by Vuforia SDK, especially for mobile application [6]. Camera images are making use of marker tracking to find square optical markers and estimate their relative pose to the camera [7]. It was also able to superimpose the camera image and the virtual object by using the camera image as the background in their display, which is the real world and using the marker pose. The augmentation stays on the marker although either the marker or camera moving.

The board game is commonly any games of strategy or chance played on a unique design board and involved two or more opponents moving pieces and using dice or cards [1]. Some examples of the board game are checkers, chess, snake and ladder, and monopoly as the board games involve more than one people, players able to explore and interrogate the knowledge in fun and interactive way by working in

groups or provoking the players [1]. While sitting around the table, board games can be played by several people [8]. Majority of the board game is the multi-player game. Multiplayer is the involvement of multiple players to play the same game and interact within the same game environment [9]. This approach is in contrast with the single-player.

Table 1. Differences between single-player and multi-player [9].

	Single-player	Spacing
Number of players	One	More than one
Form of social play	The player can play with a friend, but the game environment cannot interact	More than one player can interact with the game environment
Type of rule	Formal rule	Social rule
Data-intensive suitability	More	Less
Data-intensive outcome	More predictable and less diverse	Less predictable and more diverse
Type of interaction	Linear interaction	Nonlinear interaction
Present of pressure	No, unless played with a friend	Yes
Type of learning	Individual learning	Social learning

Table 1 shows the differences between single-player and multi-player. The result indicates that multi-player can involve more than one player than single player. The form of social play of multi-player is where more than one player can interact with the game environment, but for the single-player, the player can be interacted by a friend but not with the game environment. The rule applied in multi-player is the social rule but the formal rule for single player. Less data-intensive suitability for multi-player as the outcome is less predictable and more diverse, but those factors were opposite with single player. At the same time, playing with multi-player, the pressure and be present but not in single-player, unless they played with their friend. Multiplayer involved social learning but individual learning involved in single player.

Besides the board game, battleship game also can be classified as a location-based game [10]. Battleship game usually can be played by two players [11]. Each player has marked game board that looks like checkerboard square. The players had to select any one or more square on their board by marking, covering or designating the selected squares as each selection being called a “shot” for each turn. The objective of the game is to locate and sink the other player’s ship. The selected panel squares are corresponding with other player’s panel squares. The ship is usually consisting of the straight line of square arranged, which can be either horizontal, vertical, or diagonally on the plane. The game concept remains the same during 2019. Each player must place their ship secretly on a 10-by-10 grid [12]. Based on the article written by [12], the grid was noted by a row and column indicator. Each player has two grids, and those grids were one with their ship and the other used for their opponent’s grid hits record. By placing missiles, which is small pegs on the chosen location on the grid or cells, each player takes a turn to hit and sink their opponent ships. The first player, who managed to sink all the opponent’s ships become the winner.

3. Holographic Display

3D image reproduced from interference pattern by a coherent light beam is the definition of hologram [13]. When a point source of the light, which is the reference beam of fixed wavelength encounters light of the same fixed wavelength arriving from an object, which is object beam, recording of the hologram in a 2D or 3D medium of the interference pattern is formed. Based on the article written by Ratan & Akshay [13], holography is the making holograms science which was usually intended for displaying

3D objects or can be simplified as a process of reconstructing and writing a hologram. Holography also a physical structure that diffracted the light source into an image. By shining a laser through a hologram and projecting an image on the screen, the holographic image can be seen looking into an illuminated holographic print. Some of the technique to display the holographic image is using an illusion of hologram on the screen, such as Pepper's Ghost.

The holographic display became enjoyable if the display can be shared by multiple visitors at the same time exploiting its multiple points of view [4]. Based on the article written by [4], multiscreen projection especially when using the pyramid glass allows visualization of a projection that proves to be just like a hologram, and it can view from different viewpoint simultaneously. Visualization pyramid was designed as the reflective materials that reflect the light from the holographic projection system on the monitor to display the 'floating' object. Holographic can be displayed using the four-sided pyramid. The method also can produce a 3D object as the holographic result in the real-world environment [14]. Moreover, the method also allowed the user to see the view from different angles and different perspective of the hologram. The object can be displayed from four distorted views, which are front, back, left and right and it is displayed as a floating object in the middle of the pyramid when implementing it with four-sided faces. While developing it in Unity 3D, four cameras used to render the texture facet and placed at four viewpoints of the object, which are front, back, left, and right view to project on each side of the pyramid. Besides that, four reflective side holographic pyramid and a monitor used as the main hardware for this holographic setup. The monitor displayed the texture facet, and the image reflected at the 45 degrees angle on the reflective surface.

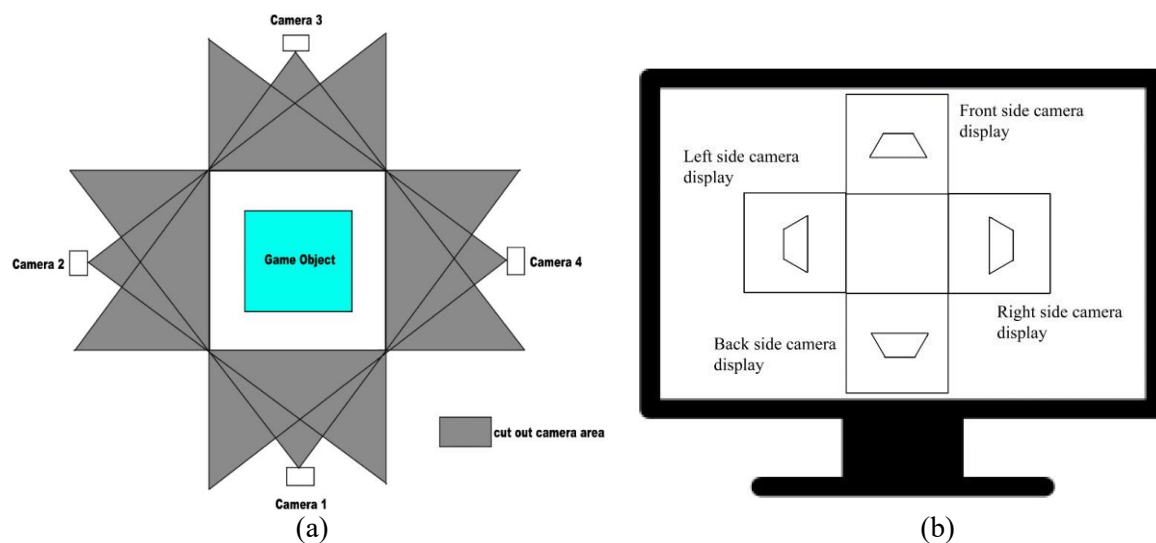


Figure 2. Holographic setup.

The proposed holographic display in this project is based on Pepper's Ghost prototype. There are four cameras, which had used and placed at a different side of the game object. Those sides are front, back, left and right sides. Those cameras displayed those four views at the same time inside one desktop monitor to test the setup. Figure 2 (a) shows the camera placement during the holographic setup. The cut-out camera area indicates the area that had cut out from the camera view. This method is used to change the camera view, the changes from a perspective view to the parallel view. Figure 2 (b) shows the projection of the holographic on the desktop monitor.

The other component such as a holographic pyramid or pyramid glass also one of the essential parts for holographic display, as this method applied the Pepper's Ghost concept. The pyramid then turned upside-down and placed at the centre of the previous holographic setup, on the desktop monitor. Each side of the pyramid must be facing straight to each screen that displayed on the monitor screen, respectively.

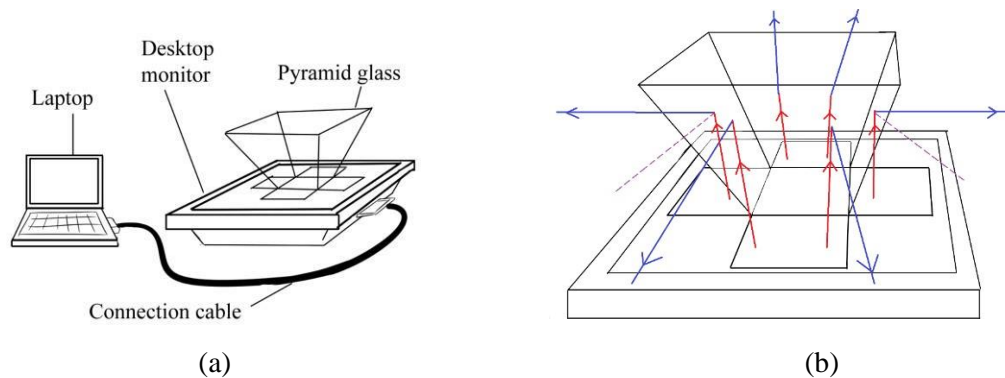


Figure 3. The light ray from holographic projection reflected on the holographic pyramid.






The holographic pyramid displays with the laptop attached to the monitor are in Figure 3 (a). Based on Figure 3 (b), it shows that the light ray reflected on the pyramid glass from the holographic projection. The light ray from holographic projection (red line) hit the pyramid glass and then reflected toward the viewer (blue line). The angle of incidence and the reflection is equal, and the value of both angles depend on the normal line (cutting line) on the reflected faces.

4. Implementation

4.1. Game Elements

The board had made up by 6x6 or plane objects. Table 2 shows the battleship models for the battleship pieces; it was available as a free source on the internet.

Table 2. List of battleship models in the proposed battleship board game.

Kriegsmarine Schiffe (KMS) Bismarck	United State Ship (USS) Enterprise	Her Majesty's Ship (HMS) Belfast	Imperial Japanese Navy (IJN) Atago	Imperial Japanese Navy (IJN) Shimakaze
				

The interaction between the player and the game object had performed to apply the board game's gameplay. For example, when the player presses the directional arrow key as in Figure 4, the game object also moved the same as the selected direction.

- Controller: To control the ships or cursor left, right, up and down
- *Next* button: To place the ship and select the next ship
- *Rotate* button: To rotate the ships horizontally or vertically

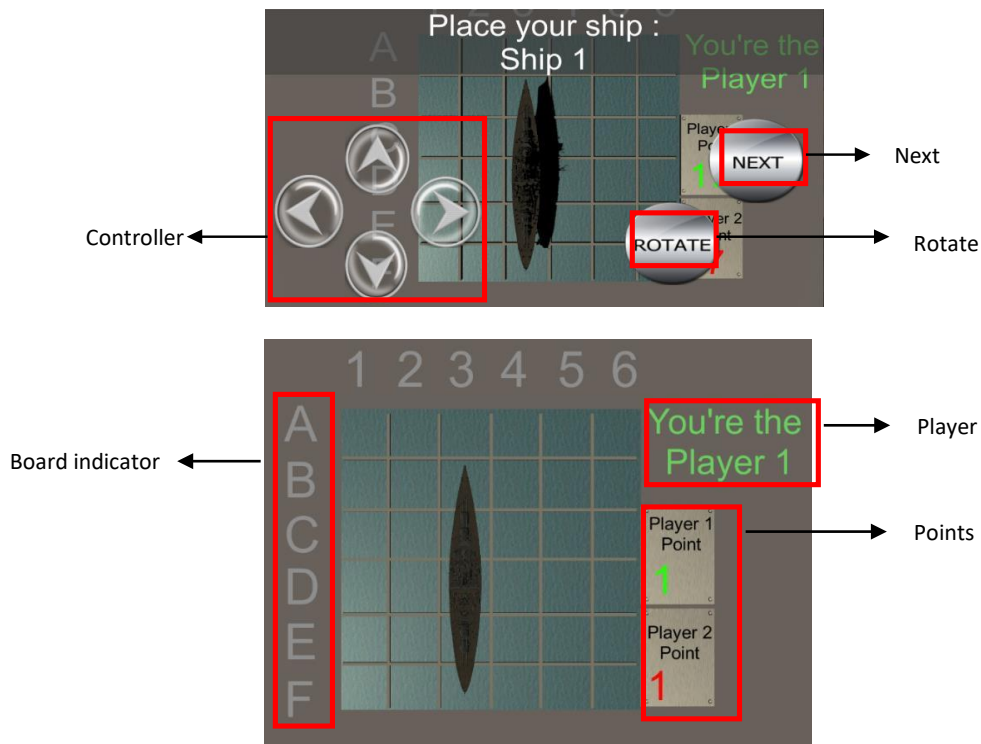


Figure 4. Controller and buttons in the battleship board game.

Controller: To control the ships Board and user feedback, as shown in Figure 5, there are three indicators:

- (a) Board indicator: the cells on 6X6 board ([A, B, C, D, E, F] X [1, 2, 3, 4, 5, 6])
- (b) Player: who was active in the game
- (c) Player Point: the player 1's scoring
- (d) Enemy Point: the player 2's scoring

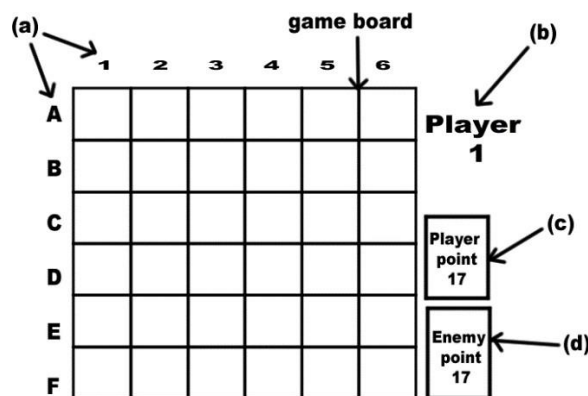


Figure 5. Board and feedbacks in the battleship board game.

The opponent's coordinate passed from the opponent to the player, and the Player 1 is indicated as an active player (in Figure 5). Figure 5 also shows the Points indicator when the player selects the target and the target same as the opponent's ship coordinate, the reduction of opponent point happened.

Battleship board game has its own game rules. The lists below some are the game rules that had followed:

- The ship must be placed within on the board only. The ship cannot move out of the board area. The ships only allowed placing horizontally and vertically. The ships cannot be replaced after the game starts
- The player that gets the turn must select the board square and say, “shot”. Both players must mark the selected board square.
- If the opponent’s selected board square has his/her battleship, the opponent must say, “hit” to tell that the target hit the target. Otherwise, the opponent says “miss” if the target hit the opponent.
- The winner is based on the player that manages to sink the entire opponent’s ship first.

As the game involve multi-player, the social rule had applied, which mean that the gameplay can play variously, but the game concept has remained the same. The only changes that applied to the gameplay are for each turn, the player able to select three locations at the same time. After choosing the targets, the player ends the turn, and the opponent gets the turn.

4.2. Multi-players Interaction

As the developed Battleship board game played by two players, the game had integrated with multi-user interaction. Multi-user interaction is crucial to enable multi-players’ interaction to allow the board game is playable for multi-player and allow the communication to occur between the players [15].

Game information had sent and retrieved between the players. Inside the same game room, there are only limited to two players at max. So, the interaction happened between both players; Figure 6 shows two players used two handheld devices to track a marker.

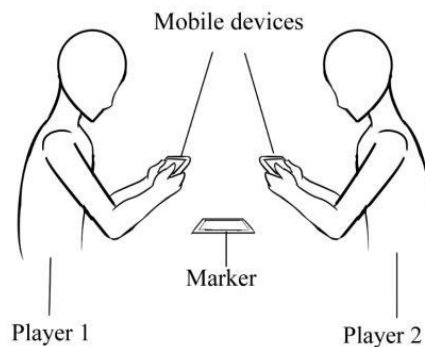


Figure 6. Two users in AR battleship board game.

Using networking to connect two players in the board game, the multi-player connection has been connected using internet protocol TCP, to send and retrieve the data in real-time. Implementing multi-user interaction, the Photon library is invoked into the game logic. A player was able to play with other players within the same room. The players had joined the room randomly. If there is a room available, the player joined the room but if no room available, the player has to create the new room. The player, who creates the room need to wait for any player to join the room before starting the match. The flowchart to implement this Photon Cloud service is in Figure 7. Based on Figure 7, when the player gets the turn, the player can interact with the application while the other player deactivates. After the player ends their turn, then the other player’s turn has activated. Before the player creates the game or a room, they either can be a player or non-player. The holographic display or display hologram is setting up for non-players so they can see the battle.

When the player selects the board tiles, the tiles turned to blue, and the opponent tile turned to red. The opponent’s ship coordinates shared with the player, so when the player selects the target and the

target same as the opponent's ship coordinate. It affected the enemy point. When the player's ship had attacked, the player's point reduced and the point sent to the opponent.

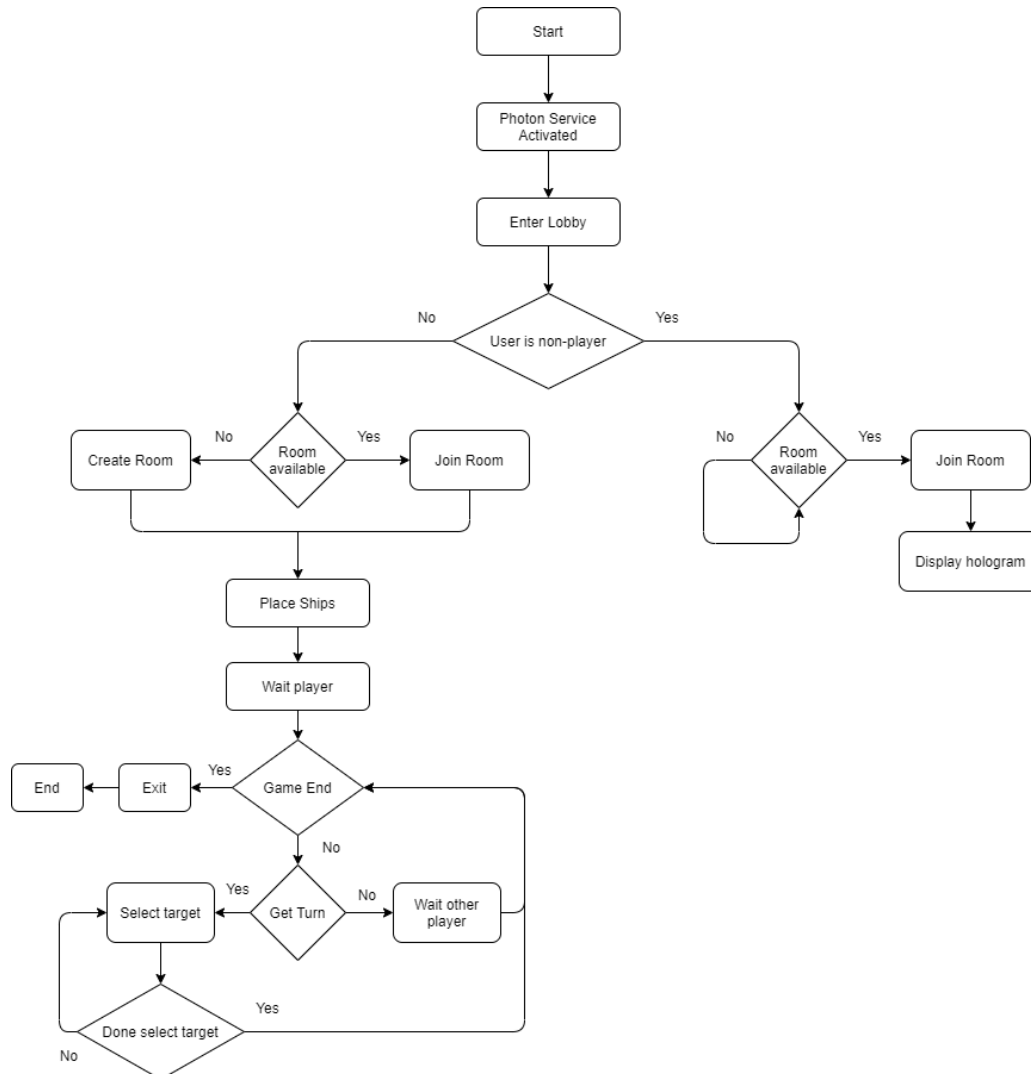


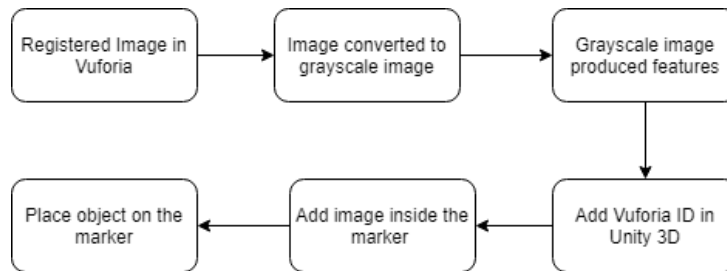
Figure 7. Battleship board game AR with holographic display flowchart.

4.3. AR Marker Tracking

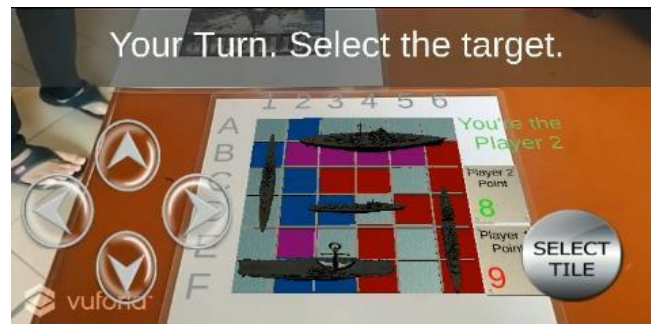
Figure 8 shows before adding the AR tracking and creating the marker is when the tracker had registered. After registering the marker, the features on the image had produced. The process of converting the RGB image into greyscale, as illustrated in Figure 8, and the greyscale image has used to create the features. This process is known as feature-based tracking. The Battleship works with AR only after the handheld device captures the marker, and the application has recognized the feature to project the battleship board game on the top of the real-world (as in Figure 9). After integrating the Battleship board game with AR tracking, the AR board game has combined with a holographic display.



(a) RGB image was converting process into features

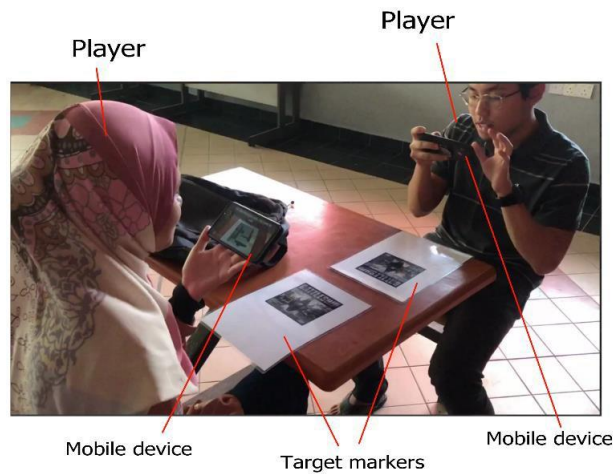


(b) Feature-based tracking process

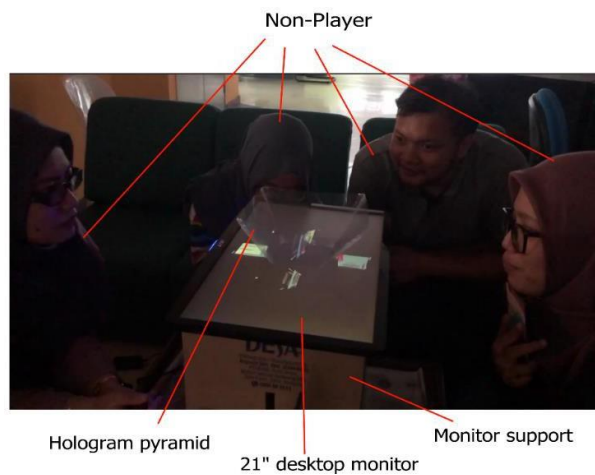
Figure 8. Enabling AR for Battleship Board Game.**Figure 9.** AR Battleship Board Game overlaid on the real-world.

5. Results

Figure 10 demonstrates the application required two players and at most four non-players. The physical markers have placed on the table, and the direction is facing the player (as in Figure 10 (a)). For the players, they used the mobile devices that have a built-in camera that used to track the AR marker while for the non-players, they used the desktop monitor, which connected to the laptop to display the hologram and pyramid glass placed on it. The 12-inch desktop monitor placed on the box, as shown in Figure 10 (b), and there is a cable connected horizontally. When the game has started, both players need to place the ships. After the first player was placing the ships, he needs to wait for the second player. After both players have finalized the ships, the battleship has initiated.



(a) AR Battleship Board Game with two players



(b) Non-player with the holographic display

Figure 10. AR Battleship Board Game with users.

The player who gets the turn can select three tiles in one turn as shown in Figure 11 (a), while the second player needs to wait as shown in Figure 11 (b) until the first player's turn ended. The 'blue' colour of the tiles indicate that the player had selected the tile. The 'red' colour of the tiles indicate that the other player had selected the tile. The 'purple' colour of the tile indicates that both players had selected the tile. The player's point that reached 0 will be defeated, and the other player announced as the winner. For the non-player, they can watch the live game match through the holographic display. Only information about the ships position and changes of board tiles colour send from both players for holographic display. The location for players or non-players can be anywhere since the application has enabled internet connection and handheld devices can be portable for both players.

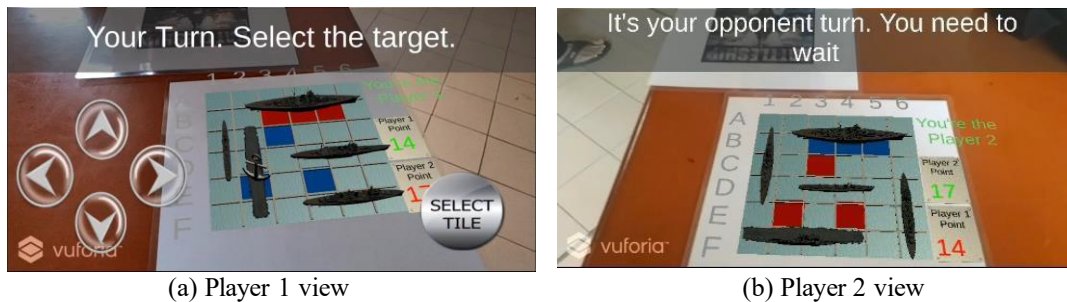


Figure 11. AR Battleship Board Game in two handheld devices.

6. Conclusion

In conclusion, the Battleship board game has its own game goal. The goal is the player, who managed to sink all the opponent's ships will become the winner. AR Battleship board game with the holographic display is the outcome of the work. The board game has chosen for this work is the Battleship board game. Players can play the game, while for the non-player, they can watch the game through the holographic display. Battleship board game has implemented with AR and holographic technology, aims to enhance the user experience. However, handheld AR interface has limited perspective viewing for the viewers to see the battleship game.

Hence, this study aims to explore the AR battleship board game with a holographic display. Three phases have been carried out; the crucial is the implementation of multi-user interaction. Integrating the AR Battleship board game with a pyramid holographic display has provided the non-players with an alternative way to see the battleship. Future work is to evaluate the usability, to acquire the user experience results.

Acknowledgement

We would like to express our appreciation to Mixed and Virtual Reality Laboratory (mivielab), ViCubeLab at Universiti Teknologi Malaysia (UTM) for the facilities and technical supports. Special thanks to UTMHIR Grants (Q.J130000.2451.04G77) for the funding.

References

- [1] Putri N, Setiyadi B and Nabila S 2018 The Implementation of Board Game to Improve Students' Speaking Achievement U-JET 7(2)
- [2] Azuma R, Bailiot Y, Behringer R, Feiner S, Julier S and MacIntyre B 2001 Recent advances in augmented reality *IEEE computer graphics and applications* 21(6), 34-47.
- [3] Haryanto E V, Lubis E L, Saleh A and Lubis N I 2019 Implementation of Augmented Reality of Android Based Animal Recognition using Marker Based Tracking Methods *In Journal of Physics: Conf. Series* Vol 1361 No 1 p 012019
- [4] Bovier F, Caggianese G, Pietro G D, Gallo L and Neroni P 2016 An Interactive 3D Holographic Pyramid for Museum Exhibition *In 2016 12th Int. Conf. on Signal-Image Technology & Internet-Based Systems (SITIS)* pp 428-34
- [5] Kipper G and Rampolla J 2012 Augmented Reality: an emerging technologies guide to AR. Elsevier
- [6] Silva D C and Vinhas V 2007 An Interactive Augmented Reality Battleship Game Implementation *Proc. Learning with Games* 213-219.
- [7] Ćuković S, Gattullo M, Pankratz F, Devedžić G, Carrabba E and Baizid K 2015 Marker based vs. natural feature tracking augmented reality visualization of the 3D foot phantom *In Proc. of the Int. Conf. on Electrical and Bio-Medical Engineering, Clean Energy and Green Computing*.
- [8] Burgun K 2012 Game design theory: A new philosophy for understanding games *CRC Press*
- [9] Hartevelde C and Bekebrede G 2011 Learning in single-versus multiplayer games: The more the merrier? *Simulation & Gaming* 42(1) 43-63.

- [10] Bidwell N J and Holdsworth J 2006 Battleship by foot: learning by designing a mixed reality game *In Proc. of the 3rd Australasian conf. on Interactive entertainment* pp 67-74
- [11] Ferreira A L S, Marciano J N, de Miranda L C and de Miranda E E C 2014 Understanding and proposing a design rationale of digital games based on brain-computer interface: Results of the admiralmind battleship study *SBC Journal on Interactive Systems* 5(1) 3-15.
- [12] Autin M A and Gerstenschlager N E 2019 Battleship and the negative hypergeometric distribution *Teaching Statistics* 41(1), 3-7.
- [13] Ratan A 2015 Holography - Working Principle and Applications 10.13140/RG.2.1.2688.4649.
- [14] Siang C V, Isham M I M, Mohamed F, Yusoff Y A, Mokhtar M K, Tomi B and Selamat A 2017 Interactive holographic application using augmented reality EduCard and 3D holographic pyramid for interactive and immersive learning. *In 2017 IEEE Conf. on e-Learning, e-Management and e-Services (IC3e)* pp 73-78
- [15] Nor' a M N A and Ismail, AW 2019, Integrating Virtual Reality and Augmented Reality in a Collaborative User Interface *International Journal of Innovative Computing* 9(2).