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AR FPS Game using Static and Dynamic Physical Obstacles

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Abstract

In this paper, we propose an AR FPS game that allows a player to use physical obstacles for avoiding enemy attacks and defeating enemies. The use of physical obstacles is intended to make the game more fun and immersive. Physical obstacles are classified into static obstacles that do not move and dynamic obstacles that can move. The game design for utilizing real space includes placing game objects in consideration of static obstacles, using physical obstacles as shields to prevent enemy attacks, and using projectiles to attack a player hiding behind obstacles. We prototyped the game using HoloLens2 and conducted a user study using a questionnaire (N = 14). The results showed that the game itself was highly evaluated, as well as the exercise promotion effect by the use of real space.

CCS Concepts

• ***Human-centered computing*** → ***Mixed / augmented reality;***

1. Introduction

VR and AR technologies have made significant progress in recent years. In particular, head-mounted displays (HMDs) such as HTC VIVE, Meta Quest, and Microsoft HoloLens have high performance and give highly immersive experiences.

Existing studies propose VR and AR games to promote exercise and to support learning [PMLD17, LvdSHF17]. In particular, research on the use of video games to promote exercise have been studied in the field of HCI and are called exergame [SHM07]. The challenges of exergame are to provide exercise benefits, to be fun, and can be played continuously [SHM07]. One factor of game fun is related to the immersion in the game; Yao et al. showed that VR games provide more immersive and improve physical exercise performance compared with non-VR games [YK19].

To enhance the immersive experience, VR experiences using physical environment have been proposed [COHW19, YHOW19]. In these VR experiences, users can actually walk and move through the VR space which is generated based on real space information.

Based on these studies, we propose an AR first-person shooter (FPS) game, in which a player defeats enemies that appear around the player. The game is expected to provide an immersive experience by using real space as the stage and physical objects as obstacles. AR is used instead of VR because it is easier for players to recognize the real space.

2. AR FPS Game

In this game, physical obstacles are classified into two categories: static and dynamic obstacles, referring to the real space recognition method of Yang et al [YHOW19]. Static obstacles include large room elements such as walls, floors, and desks. Dynamic obstacles include things that can move, such as chairs and boxes. Static obstacles are used to protect a player from enemy attacks, to hide from enemies, and to restrict enemy movement. Dynamic obstacles are used by a player as shields against enemy attacks. In contrast to static obstacles, the player can move dynamic obstacles to actively bounce back enemy attacks.

The game is designed to achieve a highly immersive experience and effective use of real space. Enemies and items are placed naturally on the floor, like a person standing on the floor. In addition, the game design, in which multiple enemies appear simultaneously and items appear in random locations around a player, encourages a player to actively move around in real space. Enemies have a visibility range based on distance and viewing angle. When an enemy can directly see a player within the visibility range, the enemy attacks the player. If a player is hiding behind a static obstacle, an enemy will not be able to see the player and will not attack. There are three types of enemy attacks: normal bullets, follow-up bullets, and grenades. Normal bullets are white balls that move in a straight line. Follow-up bullets are red balls that follow a player and have a slower velocity than normal bullets. Grenades are used when an enemy loses sight of a player. A player can use dynamic obstacles as shields to bounce back attacks. Shields only work against follow-up bullets to prevent the need for a player to move from being reduced by the use of shields. The purpose of grenades is to discourage a player from continuing to hide behind obstacles and to encourage him to move.

We created a prototype game based on the game design using Microsoft HoloLens2, an optical see-through HMD. Unity was

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used as the game development platform. Screenshots of gameplay are shown in Figure 1.

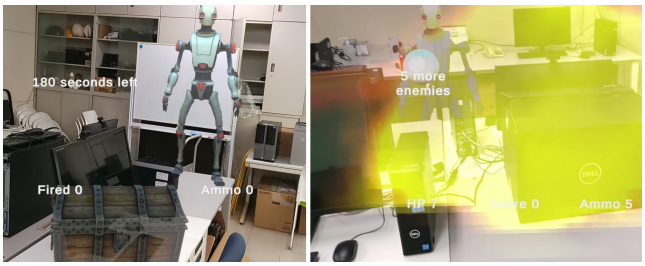

Figure 1: *Game objects placed according to the layout of static obstacles (left), An enemy attacking a player hiding behind an obstacle with a grenade (right).*

3. Evaluation

We invited 14 participants (4 females, ages 21-24, M = 22.5, SD = 0.9) from our university students to experience the FPS game we had created. A rectangular shaped room was prepared with desks and chairs along the walls and in the center of the room. The experimenter explained the experimental procedure and the rules of the FPS game to the participants. After practicing learning the game operations, the participants played the game for 3 minutes. Participants then answered a questionnaire. In the questionnaire, the game itself was evaluated on a 5-point Likert scale on four items: fun, immersion, whether a player wanted to play again, and whether the game promoted exercise. The same four items were also evaluated in terms of how much the use of real space contributed. The questionnaire included open-ended comments about the experiment.

The results of the questionnaire are shown in the Figure 2. The left graph shows the evaluation of the game itself. All participants were positive about the fun and immersive nature of the game. On the other hand, two participants scored 3 for continuity and one participant scored 3 for exercise promotion. The right graph shows the evaluation of the contribution from the use of real space to the game. Thirteen out of 14 participants answered 5 or 4 for the fun and exercise promotion. Immersion and continuity had a higher percentage of 3 or less compared to the other items, with one participant scoring 2 for continuity.

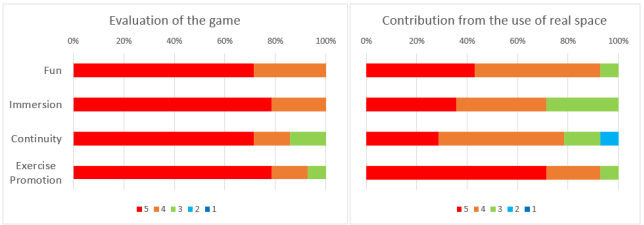

Figure 2: *Questionnaire scores about the FPS game itself (left), Questionnaire scores about contribution from the use of real space to the game (right).*

4. Discussion

One of the participants gave an opinion on how to make the game more interesting: "*I thought it would be interesting to do it in a more complex place*" (P3). The following comment shows the relationship between difficulty in viewing the game screen and continuity: "*I felt that if the screen is hard to see, it lacks fun and continuity*" (P12). Due to the limitations of the HMD's rendering range, players may not be able to see game objects even though they are within their field of view. The introduction of indicators to show the position of game objects is one way to solve this problem.

Figure 2 (right) shows the usefulness in terms of fun and exercise promote: "*I thought it was very innovative and interesting because I had never experienced playing a game using real things*" (P2). Immersion and continuity scored lower than the other items. One participant commented that items appeared near walls and were difficult to acquire. It is necessary to design games that take real space into account for games that use real space. There were no negative comments regarding the sense of immersion provided by the use of real space. Little relationship may exist between the use of real space and immersion.

5. Conclusion

In this paper, we proposed an AR FPS game to promote exercise. This game aimed to achieve a highly immersive experience by recognizing physical obstacles and incorporating them into the game. The experimental results showed that the game was fun and promoted exercise. On the other hand, no relationship was found between the use of real space and immersion. Quantitative evaluation including clarification of this relationship should be conducted in the future.

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