International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2019)
Y. Kakehi and A. Hiyama (Editors)

Visuo-Haptic Interface to Augment Player's Perception in Multiplayer Ball Game

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Abstract

We developed a system that augments the player's perception and support situation awareness for motivating them to participate in multiplayer sports in the context of a soccer game. The positional relationship of the opponents was provided using visual feedback and the position of the opponent beyond the field of view was provided using haptic feedback. Through an experiment, we confirmed that using visuo-haptic feedback and independently using visual and haptic feedback could improve the ball control skill of the player. We also found that independently using visual and haptic feedback can reduce the mental workload than the case of no feedback based on NASA-TLX.

CCS Concepts

• ***Human-centered computing*** $\rightarrow$ ***Mixed / augmented reality;***

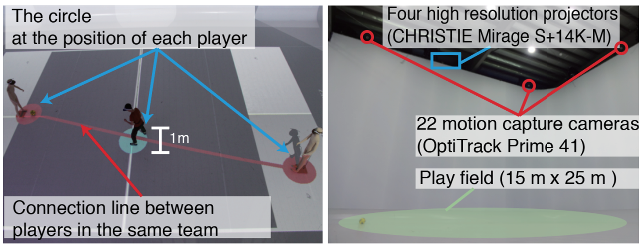
1. Introduction

Multiplayer sports such as soccer, basketball, and volleyball can create a sense of unity and accomplishment, as well as provide a wonderful experience. However, for players with little experience, psychological hurdles exist [Cha01]. For example, the sports mentioned above involve multiple players and positioning each other is important. For beginners, it is difficult to aware current situations; the movements of a ball and opponents and predict them. Therefore, it is also difficult to move to an appropriate position or intercept the ball of the opposing team, i.e. their physical skill is low. Such difficulties can hinder them from trying a new ball game or resuming sporting activities; hence, they lose the opportunity to enjoy sports.

The main motivation behind participating in sports is to develop physical skills, apart from physical health and social well-being [Aea93]. We assumed that supporting physical skill would increase motivate them to participate in multiplayer sports even if the support is temporary. Based on this idea, we developed *Ball Game Support System*; a system that supports a player's physical skill by augmenting perception and supporting situational awareness. Our system provides a similar sense of skilled player to the beginners.

Our contributions of this study are as follows:

- Implementation of a system that augments a beginner's perception and temporarily supports player skill using real-time visual and/or haptic feedback in multiplayer ball games
- Clarification of design guideline for multiplayer ball games where visuo–haptic feedback presents no significant effect if the same information is provided from visual and haptic feedback simultaneously, owing to the collision of the same information



(a) Example of visual feedback (b) System configuration

Figure 1: *Overview of Ball Game Support System.*

2. Related Works

2.1. Visual feedback for sports

Several studies have suggested that appropriate visual feedback is effective in improving sports skills. Wulf *et al.* confirmed that a higher feedback frequency resulted in a higher learning effect [Wea98]. In their system, the force applied to a user's feet was visualized as feedback for the slalom movement in ski simulation.

For multiplayer sports focused on in this study, NIKE has shown a special basketball court that can provide interactive visual feedback as a commercial purpose [Rhi]. However, it is necessary to quantitatively evaluate skill improvement by visual feedback. With regard to visual feedback in ball games, Itoh *et al.* and Sano *et*

DOI: 10.2312/egve.20191280

al. developed a system that provided the visual feedback of a ball's movement direction as a predicted trajectory using HMD or projectors [Iea16, Sea16a] and confirmed that their systems contributed to improving trajectory prediction skill.

2.2. Haptic feedback for sports

As a practical application example using haptic feedback, Feeken *et al.* developed a sole-shaped vibration device that can provide haptic stimulation for indicating where the user should place a weight while climbing [Fee16]. Furthermore, they confirmed that the device improved the climbing speed. To support climbing, haptic feedback is more suitable than other feedbacks, because the user can perceive the feedback without gazing. As another example, Shiraishi *et al.* developed a belt-type vibrator to support coaching in sports and evaluated the feasibility in ball games [Sea16b]. They experimentally confirmed that haptic feedback could indicate the direction or timing even during exercise.

2.3. Visuo–haptic feedback for sports

Some studies apply visuo–haptic feedback to sports such as the choreography of dance and rowing lessons. Nakamura *et al.* and Ruffaldi *et al.* concluded that visuo–haptic feedback is effective compared with standalone visual or haptic feedback [Nea05, Rea09]. However, because these studies focused only on individual sports, the effectiveness of visuo–haptic feedback in multiplayer sports has not yet been clarified.

Because multiplayer sports require team effort and are often competitive games unlike individual sports, it is still not clear whether the results of these studies using standalone visual, standalone haptic or visuo–haptic can be applied for multiplayer sports or not. Thus, in this study, we designed and implemented a visuo–haptic feedback system for multiplayer sports. In addition, the effectiveness of the system was evaluated experimentally by simulating soccer as an example of multiplayer sports. The cases involving no feedback, standalone visual or haptic, and visuo–haptic feedback were compared.

3. Proposed System: *Ball Game Support System*

In multiplayer sports such as soccer, it is necessary to be aware of the positional relationship between the opponents and the teammates. However, it is difficult for beginners to predict such movements and situations especially outside of the view. For example, in soccer which is the primary application of the proposed system in this study, the player attempt to intercept a opponent's pass; therefore, the player must consider the movement and position of the other players especially outside of the view. This is the remarkable difference between individual sports and multiplayer sports. Therefore, in this study, we propose *Ball Game Support System*; a system that provides visual or haptic feedback on the position of the opponent and teammates in real time for supporting the player's skills temporarily. We assumed that if the system reduces the mental workload on human information processing that is related to the other players' position information, and the player can focus on the ball control, thus improving the performance of the ball game.

The proposed system allows for the player to recognize such an opponent's movement by visual and haptic feedback. Because it is necessary to acquire the position and orientation of the players in real time, we developed the system using a large-scale immersive display "LargeSpace," [Tea15] comprising 22 motion capture cameras to track player movement (Figure 1(b)).

Unlike HMD, Large Space can provide visual feedback on the floor without a heavy device for VR/AR. Large Space provides wall and floor projection using 12 ceiling-mounted projectors. Figure 1 illustrates an example of visual feedback in the proposed system. By connecting players in the same team to each other using lines, a player can visually recognize the positional relationship between the opponents and the teammates.

Figure 2(a) shows the belt-type vibration feedback device utilized for haptic feedback. In the proposed system, the vibrator of the belt attached to the waist of the player provides the position of an opponent on the player's back in the form of haptic feedback. The players are required to wear the device on their waist (Figure 2(b)). As shown in Figure 2(c), the direction of the player outside his/her field of view is divided into three directions— behind, on the right, and on the left. This device vibrates the actuator of the same direction of the opponent, and feedback the position information of the opponent to the user.

4. Experiment

Previous studies have failed to evaluate the effectiveness of visuo-haptic feedback on player skill in a ball game. Therefore, we conducted an experiment using 18 healthy participants (23.0 ± 1.6 years old, 17 males, 1 female). With regard to the experience of the study participants with soccer, 16 participants were beginners without experience, and two had previously played soccer but were playing after a long break (> 10 years).

We assume that intercepting an opponent's pass is an important aspect of playing soccer. Therefore, we evaluated the effectiveness

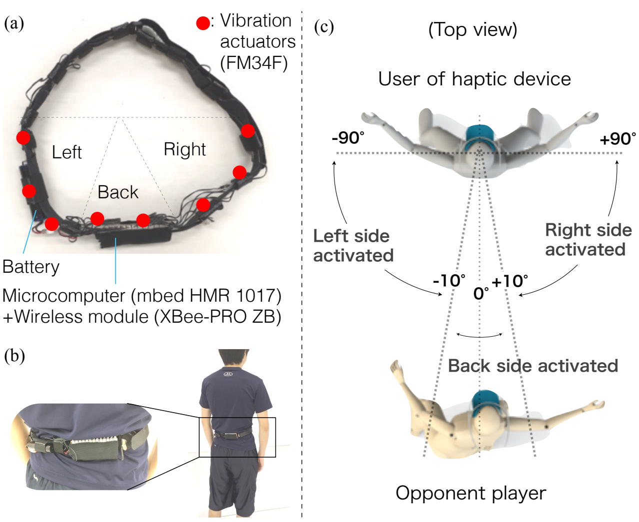


Figure 2: *Configuration of the vibration feedback device*

of the proposed method based on the player's performance in terms of pass interception.

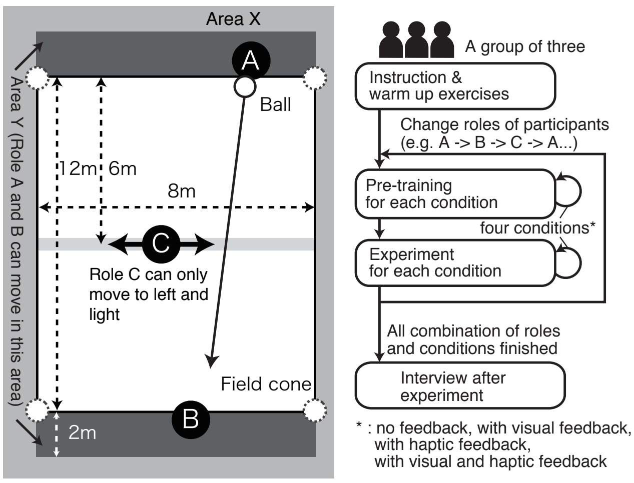
As shown in Figure 3(a), role A involves passing the ball, role B involves receiving a pass, and a role C is the interception of a pass; the three roles were arranged in the experimental environment. All the roles were assigned to the participants. Roles A and B were required to be inside the area Y, and role C was required to move only along the left and right directions. We evaluated the number of interceptions made (role C). Participants assigned role C were instructed to intercept a pass and maintain possession of the ball; participants assigned roles A and B were instructed to pass a ball such that they avoided an interception. In addition, we instructed role A participants to not make aerial passes.

Figure 3(b) illustrates the experimental procedure. The participants performed the pass interception 20 times under each condition (single experimental block). After performing the experiment under four conditions: *noFB* (w/o Vis, w/o Hap), *H* (w/o Vis, w/ Hap), *V* (w/ Vis, w/o Hap) and *VH* (w/ Vis, w/ Hap), the role C participants were asked to respond to the NASA-TLX [Hea88] Japanese version. To eliminate the order effect, we counterbalanced the trial order for the four conditions.

In this experiment, we evaluated the effectiveness of the proposed system using the following indices:

1. Pass interception score: The total score was determined over 20 trials (Max. 20 points).
2. Workload: It is evaluated using NASA-TLX; the scale was set to 20 levels (Max. 100 points).

We defined the score of the pass interception as; 0 (A or B kept the ball), 0.5 (C could intercept the ball, but could not keep it), 1 (C could intercept and keep the ball). To evaluate both the improvement in ball control as well as situational awareness in terms of pass interception scores, we instructed role C participants to hold the possession of the ball after intercepting the pass and used a score weight based on whether the role C participant could hold the ball. In addition, in the case where role A or role B participants kept the ball, regardless of whether role C intercepted the pass, the trial was counted as a failure.



(a) Experimental environment (b) Experimental procedure

Figure 3: *Outline of experiment.*

5. Result

Figure 4(a) shows the pass interception score. Error bars indicate the standard deviation (SD). We analyzed the all data by a one-factor analysis of variance (ANOVA) with Bonferroni correction as a post-hoc test in this experiment. ANOVA revealed that there was a significant difference between conditions $(p < 0.001, (F(3,51) = 6.74)$. The post-hoc test revealed that there was a significant difference in *noFB* and *H* $(p < 0.001)$, in *noFB* and *V* or *VH* $(p < 0.05)$.

Next, Figure 4(b) shows the results of the workload as evaluated using NASA-TLX. ANOVA revealed that there was a significant difference between the conditions $(p < 0.01, (F(3,51) = 5.535)$, and the post-hoc test revealed that the workload was significantly reduced in *V* or *H* $(p < 0.01)$ than *noFB*.

From the average of the pass interception scores shown in Figure 4(a), we confirmed that feedback (i.e. with visual/haptic/visuo-haptic feedback) was effective for supporting player skill compared with the case without feedback. On the other hand, no significant score improvement was observed between the feedback types (with visual/haptic/visuo-haptic feedback). Based on this result, we assume that the combination of visual and haptic feedback could not reduce the mental workload significantly for beginners compared with standalone visual or haptic feedback. The cumulative scores obtained using NASA-TLX also support this assertion; the workload was significantly reduced in the condition with only visual feedback or only with haptic feedback.

6. Discussion

In this study, we assumed that it is difficult for beginners to allocate mental resources to ball control when the players are also required to have situational awareness during the game. According to the results of the NASA-TLX total score, we confirmed that by using the visual or haptic feedback alone, the workload required for situational awareness can be reduced considerably compared with the case without feedback (Figure 4(b)), thus improving the ball control and player skill (Figure 4(a)). From the result of the interview, four participants commented that the activity with the system was enjoyable, and it is possible that our system motivates the beginners. For future work, we are planning to quantitatively investigate the improvement of motivation.

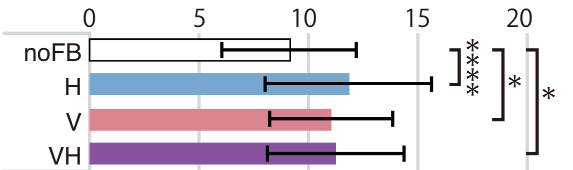
Based on the participant's comments, it was difficult to pay attention to both visual and haptic feedback. In this study, both feedbacks indicated the relative position of the opponent player. On the other hand, the dance learning system, which was proposed by Nakamura *et al.* [Nea05], provided haptic feedback for indicating timing, and visual feedback for indicating ideal movements. Therefore, similar to Nakamura's system, by designing feedbacks such that each feedback provides different information, there is a possibility of reducing workload. We intend to investigate this effect in our future work.

In this study, we demonstrated that the proposed system is effective for supporting player skill in multiplayer sports. We believe that the proposed system will also be effective for sports training and coaching, because a previous study suggested that the effectiveness of the training environment for sports is improved if it is identical to the actual environment [Mea12]. Given that the proposed system provides visuo–haptic feedback in the real environments, it is in accordance with this suggestion. For sports training applications, retention tests are necessary, and we must also confirm whether and how long the skill improvement effect persists when visual or haptic feedback using the proposed system is disabled for a player who practiced using the system.

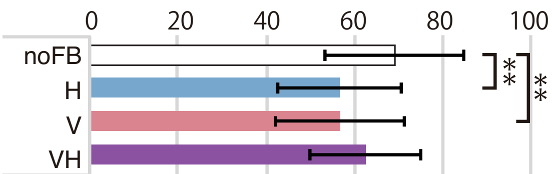
In our future work, we will conduct a real-environment user test. For example, when the current system is applied to a 3-on-3 soccer game, the triangles connecting the players in each team will be visualized on the field. Regarding visual feedback, we assume that an increase in visual information will correspondingly increase the mental workload of information processing. Regarding haptic feedback, it will be difficult to perceive the positional information owing to the vibration phantom sensation [VB17] when the number of opponent players is increased. To reduce these effects, we are considering providing the direction of each opponent individually using haptic feedback.

Several studies have extended the existing sports framework by implementing AR technology [Bea13, Nea15]. Baudisch et al. realized a basketball game without a visible ball. Nojima et al. proposed a new dodge ball game using additional sensor information obtained from the ball. Along with these trends, our platform of the visual/haptic feedback system allows for new strategies and new rules to be created in sports. For example, feints with shared visual feedback, or new rules such as the addition of handicap to impede the perception of the advanced player.

In addition, we believe that this system is applicable to other types of multiplayer sports, such as tennis doubles, basketball, and volleyball, etc. where the player's position outside the field of view is vital. Thus, we are planning to develop a support system for these sports, as a part of our future work.



(a) Interception score



(b) NASA-TLX total score

**** : p < 0.001 ** : p < 0.01 * : p < 0.05
Error bar: standard deviation

Figure 4: *Result of Experiment*

7. Conclusions

To motivate them to participate in multiplayer sports, we proposed a visuo–haptic feedback system for a ball game that supports player's physical skill by augmenting perception and supporting situational awareness. We evaluated the effectiveness of the proposed system in terms of skill improvement in ball game by visual, haptic, or visuo–haptic feedback, which was not clarified in previous studies. The experimental results confirmed that the intended effect could be obtained using visual, haptic, or visuo–haptic feedback. Meanwhile, the combination of visual and haptic feedbacks could not significantly reduce the mental workload on the players compared with visual or haptic feedback alone, but had still contributed to improvement in player skills.

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