Sonic-Badminton: Audio-Augmented Badminton Game for Blind People

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Abstract
How to enhance the quality of life for the blind, in particular through sports or entertainment? HCI researchers have investigated physical games, but there is a lack of methods to improve blind people's social interaction and self-esteem through the physical exercise. To address this issue, we present Sonic-Badminton, an audio-augmented badminton game. It uses a virtual shuttlecock implied by audio feedback. We conducted a preliminary user study with the blind and sighted participants to examine the game is enjoyable to both type of participants. The results indicated that both can enjoy the game and play in a similar level. The use of real badminton racket and simple stereo sound to guide virtual shuttlecock help them enjoying the game. Based on the result, we discuss implications for further audio-based augmented badminton and other ball-based sports for the blind.

Author Keywords
Assistive Technology; audio-augmentation; blinds; game; badminton

ACM Classification Keywords
H.5.2. [Information interfaces and presentation]: Training, help, and documentation

Introduction

Recently there has been growing attention on how to improve blind people's quality of life[16]. Assistive technology addresses how technology can support social interaction with others, confidence, and physical activity for the blind[7]. Also in HCI areas, games[1], sports[6] and interaction technique[5] have been suggested.

Current methods to help blind people enjoy physical activity can fall into three groups—by sound, tactile and human aids[10]. However, research is lacking on helping the blind enjoy physical activity with the sighted without concern for their physical limitation.

One way to help the blind socially engage with the sighted through physical activity is to use audio-augmented physical motion-based game. Lumbreras et al. showed that audio augmentation of computer games' interfaces for the blind can make the overall experience richer[11]. We consider audio-augmentation can naturally assist blinds' physical activities because blind people are familiar with audio-based interactions.

In the paper we present Sonic-Badminton, a prototype system of, an audio-augmented badminton game. It was to help blind people enjoy physical activities and social interaction with the sighted. We report the result of preliminary user study. Based on it, we discuss implications on audio-augmented sports system and interaction issues to provide blind people rich experience.

Related Works

There had been research on assistive technology to help physical activities of blind people. Lieberman et al. reported physical activities have positive effect on blind people's self-esteem[9]. Buell emphasized people to have positive attitude and teamwork rather than focusing on limitations in blind people's physical activities[3]. Although the blind have games like goal ball, tandem-cycle, and spinning[15], it is rare to find sports the blind and sighted can enjoy together on an equal level.

Games with movement and sound as their main interface are related to this research as such games can be easily appropriated for the visually impaired. Such games often use VR[4] or mixed reality settings[14]. Researchers have presented guidelines on how to design movement-based games[13]. Baudisch et al. showed that people effectively interact with invisible balls while playing games that mimic real-world sports[2]. These examples imply that players can interact with virtual objects in mixed reality.

There are examples of games using audio as a main interface. Huggard et al. developed a game combining sound sources and virtual world navigation[8]. Another game allows blind players to control keys based on right/left balance and rhythm of different sound sources[12]. Another research made a prototype which induces physical activity based on sonification and suggested its application[6]. The main difference between these games and the system we suggest is that they propose totally new system. Whereas our approach is to augment existing daily sports, helping the blind and sighted play together.

Sonic-Badminton

Sonic-Badminton uses audio-augmentation to help blind people enjoy physical activity and social

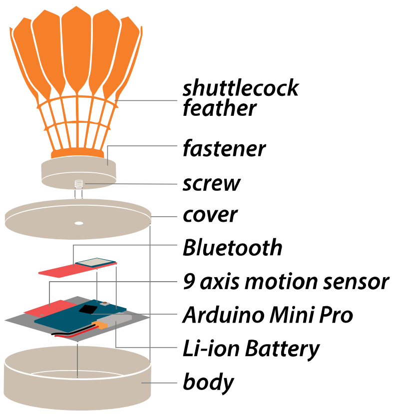

Figure 1. Exploded View of Wireless Sensor Module

Figure 3. How the Wireless Sensor Module Is Combined to the Racket

interaction. The system replaces real shuttlecock to localized audio output, so players can interpret the direction and the movement. The system use wireless sensor module attached to a conventional badminton racket. The audio output is given through stereo headphone or speakers.

Hardware

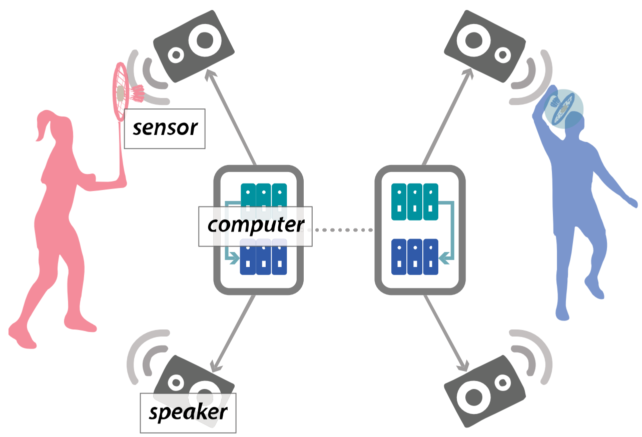

Figure 2. System Overview of Sonic-Badminton

Sonic-Badminton consists of a wireless sensor module attached to the racket, a host of each player and an earphone or speaker. The sensor module and earphone/speaker are connected to a host computer.

The wireless sensor module consists of a main part and fastener to fix the module with a racket. The main part consists of a 9 axis gyro/accelerometer/magnet sensor, Arduino mini pro, Bluetooth and rechargeable Li-ion battery. It is attached to the racket and detects the swing and sends it to the host. Fastener part has real feather of the shuttlecock to represent visually for the sighted and to be tactile for the blind. Two parts have screw structure to fasten on each side of the net part in badminton racket. Figure 1 shows inner structure of the wireless module.

To give audio feedback to players, a stereo speaker is connected to the host computer. Two speakers control sound balance to indicate the location and direction of the virtual shuttlecock to players. It is possible to use wireless earphones. The host server gets data from the module and controls the overall game. The connected client computer sends the data to the server, which calculates audio output.

Software

Software deals with the server's wireless connection to the client and processes data from the 9-axis motion sensor. We implemented the software application using the Arduino IDE and Processing. Data value of sensor module is transferred to Processing software running on the host server. The data communication is done through Wi-Fi serial communication with osc library. The server calculates the player's success or failure, direction of virtual shuttlecock, and speed. It returns this data to the client computer.

We kept the possible movement of swing simple so the system can tell the matching motion. It only recognizes whether the racket is going from one location to another among three (left, center, right).

Since the system is playing with a virtual shuttlecock, we made an additional screen for observers to see the status of the game. It shows the location of the shuttlecock and the score of each player. Figure 4 shows the game interface on screen.

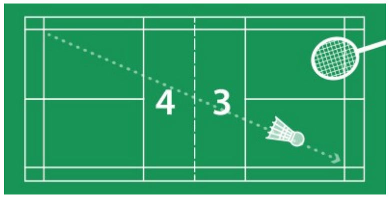

Figure 4. Game Screen with Score, Trace of Shuttlecock and Racket Direction

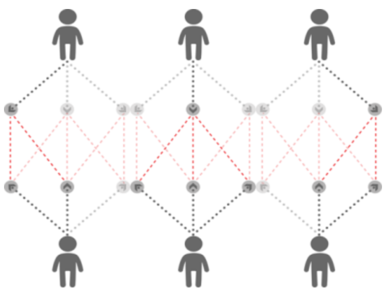

Figure 5. How Virtual Shuttlecock Moves.

Players play the system like normal badminton. Figure 5 shows how virtual shuttlecock moves during the game. They recognize the position of virtual shuttlecock through the stereo sound. If the sound is coming from the right, they regard the shuttlecock as coming to the right and swing their racket from right to left. The flying direction of the shuttlecock is randomly selected from either the direction of racket swing or the neighboring one. This is to prevent the shuttlecock direction from being fixed. If the player misses the shuttlecock, the other player gets a point. The game is finished if a player gets a certain number of points. For the study, the winning point was five.

Preliminary User Study

We conducted a preliminary user study to observe whether blind people can enjoy Sonic-Badminton with sighted people. We also wanted to identify areas for improvement with the system.

Six people, three sighted (S1, S2, and S3, all males) and three blind (B1, B2 - female, and B3 - male), participated in the user study. The three blind people were athletes of table tennis. Recruiting blind people with deep experience in other sports helped us compare the system with other sports. The sighted people had prior experience of playing sports with the blind participants. S1 and S2 taught swimming to t and S3 coached a table tennis team of blind people. The user study was conducted in the sports center, where blind people usually exercise.

The study process consisted of four sessions. It started with fifteen minutes of pre-interview asking the blind people about their daily sports or game experience. For sighted people, questions mainly focused on what kind of sports they enjoy with blind people and how often. After the interview, participants made a pair of conditions (B-B and B-S). Before playing the real game, they were asked to play table tennis. It was to compare Sonic-badminton with real sports game they are enjoying. After that, one B1-B2 group and three blind-sighted groups (S1-B1, S2-B2 and S3-B3) played with the Sonic-Badminton in the main session. Finally, a group interview of all participants asked about their overall experience on the game, its similarities and differences with other games they usually enjoy (both sports and non-sports games) and areas of improvement in the system and gameplay.

Result

From the user study, we could see that the game was playable to both blind and sighted people. In average, participants exchanged shuttlecock 8.11 times (SD=4.24, n=33), a similar rate of that of table tennis – 7.33 times (SD=1.39, n=21) played by the same participants.

Blind people replied that many different factors make the game enjoyable. They like that audio feedback—which they usually use as an interface medium. B1 and B2 compared the system to an existing computer game using beep-sound as an audio feedback and replied that having physical activity with audio feedback makes the game more interesting.

Just controlling the balance of the audio feedback gave the blind people an idea where the virtual shuttlecock was. This was a simple, imprecise but pleasing way of showing the position. Blind participants liked the balance-controlled audio feedback; "Oh, the sound is really coming from left" (B2), "This is the middle sound, this is really different" (B1).

Blind people enjoyed that they could now play games they could not before. B1 said "This is my first time to grab the racket. It's awesome." S3 said that to make sports game playable for blind people, game have had to use a rolling ball on the floor with noisy bells inside the ball. For example, table tennis changed its form to rolling ball under the net. Embedding audio-base shuttlecock into badminton, blind people did not have to change the original form of the game and were able to play with flying balls.

Sighted people enjoyed the game too, especially that the system uses some part of real badminton. S2 preferred using a badminton racket rather than other equipment designed for the blind. Sighted people, unlike blind people, had experience with audio-based games, which made the system more understandable. S1 and S2 could understand the game based on other motion-based games like Wii Sports or Screen Golf. However, S1 mentioned that playing with only sound while using the real badminton racket made the experience different from other augmented indoor games.

Sonic-Badminton was playable for blind people and sighted people at the same level. Before playing the game, participants thought that it would be hard to play the game at the same level. S1 asked whether he needed to wear eyepatches and B1 was worried that she might lose if he did not. However, the game was playable without accommodation on an equal level. Sighted people won twice and blind won once.

There were no big differences between games of B-B and games of B-S. On average, B-S pair scored 5:3.66 and B-B pair scored 5:4. The time it took for each game was 13.33 min for B-S and 15 min for B-B. B2 said that she did not feel any difference between playing with B1 and S2. From the result, the system is playable at the same level to blind and sighted people.

Discussion

From the user study, we could find out that blind people and sighted people can enjoy Sonic-Badminton, and can play it at the same level. However, we also learned some limitations in the system for further improvement.

How can blind people and sighted people interact more naturally?

Sonic-Badminton allows blind people and sighted people to enjoy physical activity together and understand each other. However, further study is needed to support this. Blind people tend to worry that sighted people would not find the game interesting regardless of their own interest (B3). The system needs to help people enjoy it more naturally, without concern for disabilities.

The system can be changed to a collaboration model rather than competition one. Instead of noticing who won, the system can assign goals like not missing the ball for two minutes. In this way, blind and sighted people can enjoy physical activity more naturally. Also, by making players choose their level of difficulty, the blind will feel less considered and enjoy the game more.

In the user study, participants knew each other. We could not check whether the system helps social interaction of blind people and sighted people who had never met. Further study is needed to verify this.

How could the experience be richer while keeping the key value of the system?
The system gets speed and direction of the players' swing and controls time and balance of audio-output based on the data. There are technical solutions to make the overall game experience richer.

First, software and hardware for stereophonic sound rendering could be more sophisticated. The current system uses realistic audio feedback. Melodies unrelated to badminton could be alternatives. Further study is needed to determine what type of audio feedback is more appropriate.

Tactile feedback was suggested by participants. Adding several vibration motors to the wireless sensor module would make it possible to tactile feedback, indicating how strong and in which direction virtual shuttlecock hits. A solenoid could provide stronger and more delicate tactile feedback. Efficient method considering the badminton context should be investigated.

One design considerations was to allow the players move their body more for active physical exercise. Connecting with cameras like Kinect, the game rule could be changed to requiring lower body movement. To do so, further 3D-sound modeling would have to determine players' position. Players also might have to control their racket more delicately based on shuttlecock speed, height and other conditions, to move their upper body more.

The system could become handy if implemented for mobile devices. A sensor module is needed to be more easily attached to badminton racket. Making the system part of an indoor game package allows for indoor play. It is not certain what kind of effect a more sophisticated system would have on the game experience especially to blind people who are sensitive to auditory stimuli. Further study is needed with refined prototype.

Badminton is not the only game applicable for this approach. Many new sonicaton game interaction with invisible ball using audio-feedback can be considered. Such games include tennis, racket ball, squash, and others. On the other hand, it could simply be a new way to enjoy real sports by augmenting sound. Further study is needed to determine the optimized structure of sensor module, means of sensing player movement, and sound effect for each sport.

Conclusion
This study we suggested an audio-augmented sport, Sonic-Badminton, for blind people. The preliminary user study shows that blind people can enjoy physical activity and social interaction with an audio-augmented sports game. It suggests a new game space showing possibility of using audio-augmentation for physical activities of blind people. This would be helpful to later studies developing similar systems.

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