Augmented Sports of Badminton by Changing Opening Status of Shuttle's Feathers*

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Abstract
In this study, we propose a new entertainment system using the badminton shuttle. This study focuses on how the distance a badminton shuttle travels varies depending on how much its feathers are opened and proposes a new entertainment system using the badminton shuttle. The shuttle is equipped with a servo motor, and the rotation of the servo motor opens and closes the shuttle's feathers. Using a motion capture camera, one can open and close the shuttle feathers in the air after launching. This paper describes the specific applications of this shuttle, emphasizing measuring the changes in the distance caused by opening and closing the feathers.

Keywords
Augmented Sports, Badminton, Shuttle

1. Introduction

Information technology has been widely used in sports - for example, to determine match tactics and assist referees in making decisions during games. In addition to technology supporting sports, recently there has been a growing interest in "augmented sports", where the game itself is extended using technology. One area of augmented sports research involves changing the ball's movement in games that use balls, with various approaches, such as gas injection and ultrasound being explored [1, 2].

In this study, we propose a novel augmented sports technology using badminton shuttles. We focus on the fact that a badminton shuttle has feathers, and how opening or closing these feathers affects the aerodynamic drag on the shuttle (Fig. 1 (a)). To utilize this phenomenon to change the trajectory of the shuttle, we designed and developed a shuttle on which the feathers can be opened and closed. We also conducted a study to examine how opening or closing the feathers affects the shuttle's flying distance. Our results show that the distance a shuttle flies can be changed depending on whether the feathers are opened or closed during flight. The specific contributions of this paper are (1) We designed and implemented a shuttle whose feathers can be opened and closed, and (2) showed that opening or closing the feathers can affect the shuttle's flying distance.

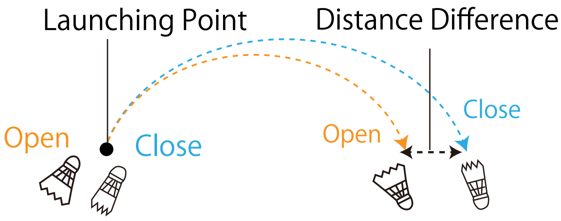

Figure 1: (a) Due to the aerodynamic drag on the shuttle, the distance a badminton shuttle travels varies depending on how much its feathers are opened.

2. Related Work

There has been research related to augmented sports. This research applies digital technology to the game field, the equipment, and the ball.

Research has also been conducted to apply digital technology to the game field or environment. Ishii et al. proposed an extended sport of table tennis by applying the technology to a table tennis table to track the ball [3]. Mueller et al. proposed an air hockey game that can be enjoyed by people in remote locations by setting up the display at the center of the table [4]. Morisaki et al. proposed Hopping-Pong, an augmented sport of table tennis in which one can change the trajectory of a ping-pong ball using ultrasonic waves [1]. Augmented Climbing Wall is a Wall-Sized Interactive Surface using the projector and computer vision technology [5].

Some researchers have proposed augmented sports using technology-enhanced equipment such as racket

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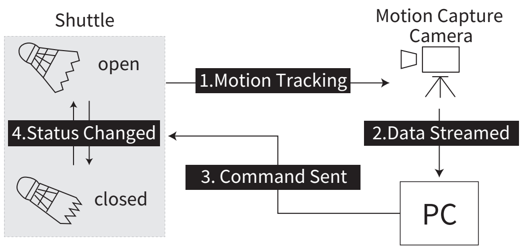

Figure 2: Schematic of our system

[6, 7] or ball[2, 8, 9]. Masai et al. proposed a new type of sports racket that can change the angle of its surface [6]. Kim et al. proposed Sonic-Badminton, an audio-augmented badminton game that can be enjoyed by the visually impaired through sound feedback [7]. About the ball, TAMA is a ball-type interface, which has a gas injection device inside that can be ejected in mid-air to change the ball's trajectory [2]. Izuta et al. proposed a game using a ball equipped with LEDs and sensors, called "Bouncing Star" [8]. In addition, some research proposed augmented sports using a drone as a ball [10, 11, 12, 13].

In this study, we apply the technology to the shuttle and try to change the trajectory by changing the opening status of the shuttle's feathers. there are previous studies for changing the trajectory of balls, but our study differs from these studies in that it uses a badminton shuttle, which has a different shape than a ball. In addition, the approach to changing the trajectory differs from other studies, which have used gas jets, drones, and ultrasonic waves, in that this study uses changes in air resistance.

3. Proposed System

In this study, we implemented a system to control the angle of a shuttle's feathers. A schematic of the system is shown in Fig. 2. The system consists of a shuttle whose feathers are open or closed, a motion capture camera, and software for detecting the shuttle's position and controlling its opening or closing motions.

3.1. A Shuttle with Controllable Feathers

We implemented a shuttle that can be opened and closed using an internally mounted servomotor. This changes the shuttle's flying distance. Fig. 3 (a) shows the mechanism used to control the opening and closing of the feathers. Sixteen strings are passed through a gap in the shuttle, and the strings are pulled closed by the rotation of the servomotor.

To implement this mechanism, a servomotor, a microcontroller, and a battery need to be mounted inside the shuttle. At first, we tried to make a prototype with a shuttle that would normally be used in badminton games, but this was impossible due to the size of the shuttle. Therefore, in this study, a commercially available shuttle with a total length of approximately 18 cm was used for the prototype.

As shown in Fig 3 (b), the servomotor(DS-929MG), microcontroller(Arduino Pro mini 3.3V and Xbee for wireless communication), and battery were attached to the shuttle with parts made using a 3D printer. The original weight of the shuttle was 21.1 g, the parts created by the 3D printer 13.1 g, the Arduino Pro Mini 3.3V 20.8 g, the battery 8.6 g, the servomotors and wiring 23.2 g, and the markers for motion capture recognition 8.6 g, for a total weight of 95.4 g. Four markers were attached near the cork of the shuttle for recognition by the motion capture camera, as will be shown later. The markers are shown in Fig. 3 (c).

3.2. Motion Capture Camera

An OptiTrack V120 Trio motion capture camera was used to acquire the shuttle's position. Markers attached to the shuttle enabled the shuttle's position to be identified at approximately 60 fps. This enabled detection of the shuttle's launches and the tracking of its trajectories.

3.3. Software

To track and open or close the shuttle, we developed a system that captures its positions and streams the values to a PC, and controls the servomotor's angle. Motive, a dedicated software of the OptiTrack, is used to stream the motion capture camera data, and the coordinate data were acquired in Python. During Experiment 2, when the acquired coordinates changed beyond a certain level, the PC communicated wirelessly to the microcontroller mounted on the shuttle to change shuttle should be opened or closed. A separate program was also prepared to open or close the shuttle using a keyboard operation.

4. Evaluation

To evaluate how opening and closing the shuttle affects the shuttle's flying distance, we conducted two experiments. Experiment 1 investigated the effect of the shuttle's servomotor angle on the flying distance, while Experiment 2 investigated the effect of opening or closing the shuttle during injection on its flying distance.

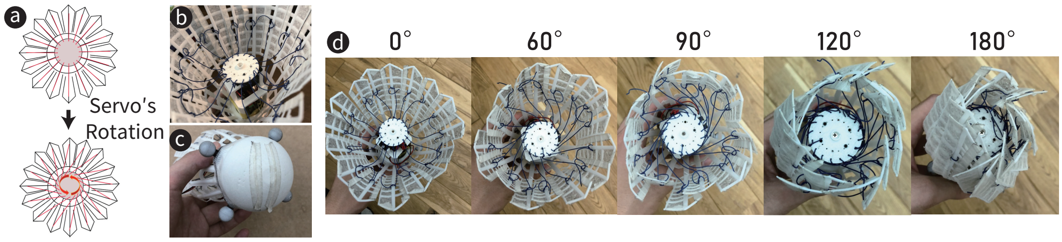

Figure 3: (a) Mechanism used to open and close the feathers (b) 3D-printed parts and actual opening and closing mechanism (c) Marker on the shuttle (d) Relationship between an angle of servo motor and feather status

Figure 4: (a) Launching device in Experiment 1 (b) Launching device in Experiment 2 (c) Distance measurement

4.1. Launching Device

In both experiments, the shuttle was launched by a launching device of our design. The design of the launching device was based on the mechanism used by Umetani et al. [14] to launch paper aircraft. A mobile desk, camera clamp, rubber strap, and board called an MDF board were combined to create the launcher, shown in Fig. 4 (a). The rubber strap was attached in a double layer to increase the launching force. By pulling the rubber strap the same distance and launching the shuttle with this device, it is possible to fly it at a constant distance. In Experiment 2, one new rubber strap was added to the launcher used in the previous experiment to increase the launching distance, and the position at which the rubber strap was pulled was at the bottom of the slope of the board (Fig. 4 (b)). This improvement succeeded in increasing the average flying distance in Experiment 2 by more than 200 cm compared with an average distance of about 520 cm in Experiment 1. As shown in Fig. 4 (c), the flying distance was measured by marking the drop-off point with tape and using a tape measure.

4.2. Experiment 1

In Experiment 1, we investigated the relationship between the angle of the servomotors on the shuttle and its flying distance.

4.2.1. Method

In this system, the opening and closing of the wings are determined by the rotation angle of the servo motor. In the experiment, as shown in Fig. 3(d), the shuttle was launched 10 times each at 5 different rotation angles (0°, 60°, 90°, 120°, and 180°), and the flying distance was measured. The state of the servomotor was defined as 0° when the string connecting the servomotor to the shuttle's wings was radially tied without twisting; the states were set at every 30°, but 30° and 150° were excluded because visual inspection showed little difference between feathers at adjacent angles. A motion capture camera was not used in this experiment, as the rotation angle is fixed.

4.2.2. Results

The resulting measurements are shown in Figure 5 (a). The results confirm the correlation that the greater the angle of the servomotor (i.e., the more the shuttle is closed), the greater the flying distance. However, no significant difference in shuttle distance was observed when comparing 120° and 180°. From this experiment, it was concluded that increasing the angle of the servomotor beyond 120 degrees does not make a difference to the flying distance.

4.3. Experiment 2

Experiment 2 measured the difference in flight distance when the shuttle was dynamically changed from open to closed during launch. The hypothesis was closing the shuttle immediately after launch would increase the flying distance compared to the open state due to decreased air drag, while opening it immediately after launch would decrease the flying distance due to greater air drag.

4.3.1. Method

In this experiment, flying distances were recorded for the following four conditions:(a): The feathers are always open, (b)The feathers are open before launch but closed immediately after launch, (c)The feathers are closed before launch but opened immediately after launch, (d)The feathers are always closed. Ten flights were made in each condition, and the flying distances were measured. In conditions b and d, the system described in section 3.2

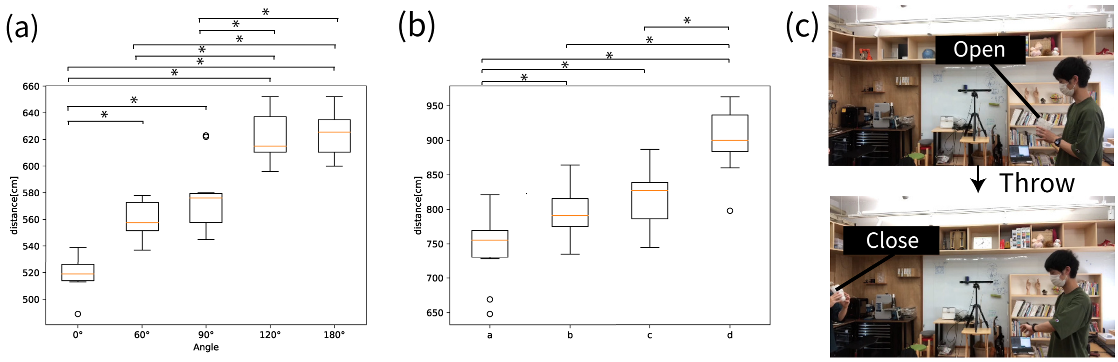

Figure 5: (a) Results of Experiment 1 (b) Results of Experiment 2 (c) Two players playing catch

was used to detect the ejection and open or close the shuttle.

In this experiment, the open condition was defined as a servomotor rotation angle of 0° and the closed condition as 120°. The closed state was defined as 120° because it was found in Experiment 1 that closing the wings any further made no difference to the flying distance between 120° and 180°, and forcing the wings to an angle close to 180 degrees would be hard on the servomotor and require extra time to complete the closing process.

4.3.2. Results

The results of the measurements are shown in Figure 5 (b). The results of the Bonferroni-corrected t-test showed that there were significant differences other than between conditions (b) and (c). It should be noted that the distance covered in condition (c) was significantly less than in condition (d), and the distance in condition (b) was significantly longer than (a).

5. Discussion and Future Work

5.1. Possible Appilications

The shuttle used in this study was larger and heavier than those used in actual games, so it is difficult to hit it with a racket as in normal badminton. Future developments in smaller sizes could lead to a badminton-based augmented sport, in which players can open and close the shuttle during games to change its trajectory.

In addition, as a way of applying the current shuttle's size, we propose playing catch games using this shuttle. The user can choose whether to change the state of the feathers at any given moment. This enables a new way to enjoy playing catch games, in which the person receiving the shuttle does not know whether the shuttle will come in its original state or change in mid-air. Furthermore, when playing catch between people with different throwing abilities, such as adults and children, it is necessary to play at a distance that the weaker person can cover. if a closed shuttle is thrown by the weaker thrower, so that the distance increases, and the stronger thrower throws an open shuttle, so that the distance decreases, the need for the stronger thrower to adjust is reduced, and the difference in ability can be taken into account when playing catch. Fig. 5 (c) shows an actual catch game.

5.2. Motion Tracking Accuracy

The tracking of the shuttle by motion capture sometimes failed. If the speed of the shuttle could be accurately captured, for example, by changing the equipment, it might be possible to adjust the opening and closing of the shuttle feathers based on the speed. In other words, it may be possible to achieve some consistency in the final flight distance, even at different launching velocities.

6. Conclusion

In this study, a badminton shuttle with a built-in servo motor was developed that can open and close its wings, and the changes in flying distance due to the opening and closing of the wings were measured. It was also found that the opening and closing of the wings in the air affected the flying distance. In the future, we will work on creating further differences in the distance by reducing the weight of the shuttle and on practical applications for competitions.

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