HoverBall: Augmented Sports with a Flying Ball

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ABSTRACT
Balls are the most popular equipment for sports. To play with balls, certain physical methods, or "vocabularies," such as throwing, hitting, spinning, or kicking have been developed by reflecting the fact that balls obey physical dynamics. This feature forms the foundation of ball-based sports; however, we consider that it limits the possibility of such sports. For instance, the speed of balls could be considerably fast for small children, senior people, or people with physical disabilities. In this paper, we propose a flying ball based on quadcopter technology. This ball has the ability hover and to change its location and behavior based on the context of the sport or game. With this technology, the physical dynamics of a ball can be re-programmed by sports designers, and new ball-playing vocabularies, such as hovering, anti-gravity, proximity, or remote manipulation, can be introduced to extend the method in which people interact with balls. In this paper, we introduce this concept as a method of augmenting sports, and present our initial flying ball system that consists of a grid shell that comprises a micro quadcopter, and demonstrates new sports interactions with the ball.

Author Keywords
Augmented Sports; Interaction device; Ball; Unmanned Aerial Vehicle

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces: Interaction styles.

INTRODUCTION
Information technology and electronics are used in the field of sports, such as instant replay and electronic referee. Conventionally, there has been much effort to introduce technology to sports watching, training, and judging (refereeing), but not to sports themselves From late 1990s, some researchers have proposed extended sports by augmenting field and sports equipment using information technologies and electronic devices [6]. The augmentation of sports is intended to intervene actively in the game itself using information technology and electronics, with the goal of contributing to the realization of a new method of enjoying sports. For example, in table tennis, adding visual images and sound effects when the ball bounces on the table has allowed for the realization of highly entertainment games. In our research, we call these sports "augmented sports." For types of sports that use digital technology, electronic sports (e-sports) in video games are already known. In some games, such as action games, the ability to manipulate precise reflexes and high quality physical abilities similar to that of the sport is required during play. On the other hand, augmented sports are an extension to the base of conventional sports.

Figure 1: Playing with a HoverBall

In the field of augmented sports, there are many studies that have focused on the advancement of the ball. Balls are the most widespread sports equipment and are also used in many entertainment activities, such as juggling. With technological improvements in the digital field, many studies have been conducted to enhance balls. For instance, balls with visual effects [7] and acoustic effects [6] have been developed. In addition, a ball with multiple cameras was developed for capturing sports scenes from the viewpoint of the ball [10]. However, these balls still obey physical dynamics, and the actual behavior of the balls remains unchanged. For instance, a part of the body must remain in contact with a ball in order to control it, and it is not possible for players to interfere in the motion when they move their hands away. Therefore, non-skilled players frequently have difficulty controlling the ball accurately. Moreover, it is difficult to institute a handicap to adjust the game balance when a match is performed between non-skilled and skilled players.

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To address these problems, we propose a new ball device with flying ability based on quadcopter technology. This ball can hover and stay in the air, change its location, and change its trajectory and behavior during play. We consider that these features can be used to extend the possibility of ball games. Mueller et al. indicated that the framework of sports can be divided into a "four lens view" [8], where the four lenses are The Responding Body, The Moving Body, The Sensing Body, and The Relating Body. The Responding Body is a view of the body's internal state changes, such as heart rate. The Moving Body focuses on the players' muscular repositioning of body parts. The Sensing Body is how the body senses and experiences the world. Finally, The Relating Body encompasses the ways in which bodies and people relate to one another for social facilitation. In this framework, our research changes The Sensing Body to The Affecting Body by adding technology to a ball (Figure 2). Traditional ball games have been developed based on the fact that the ball obeys physical dynamics, and have used interaction methods (or interaction "vocabularies") such as throwing, hitting, or kicking. In contrast, sports games with our ball might not be restricted to physical dynamics, and can introduce other types of interaction vocabularies, such as hovering, proximity, weak or anti-gravity, and (remote) pushing or towing.

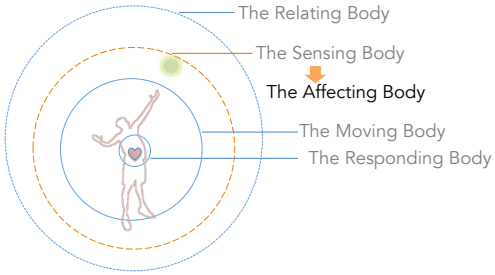

Figure 2: Four-lens view of sports

As a result, we expect that we could design new types of sports where non-expert or physically disabled players can interact with balls. We might also be able to realize new types of competitions where novice and expert players can compete seriously, because the ball behavior compensates the difference in abilities.

A BALL WITH FLYING ABILITY

There are many types of sports in the world. Among them, there are many sports that use the ball in particular and are enjoyed by a large number of people. However, there are several problems with such sports, as follows:

- It is difficult to establish an even game among players with vast differences in skill.
- The cost for learning to control a ball precisely is high.

To solve these problems, HoverBall extends the area where players can interfere with the trajectory and speed. The trajectories of conventional balls are determined by aerodynamics and gravity. By providing autonomous mobility to the ball itself, it is possible to program and add new artificial physical laws; we refer to such laws as "imaginary dynamics." Augugliaro et al. indicated that admittance control allows users to define the apparent inertia, damping, and stiffness of robots, thus providing an intuitive way to physically interact with robots [1]. We aim to develop a ball with flying ability by adding imaginary dynamics. By introducing this ball, our goal is to create a new sport with a HoveBall, and set an ideal handicap match between unskilled and skilled players by augmentation of player skill. There are several considerable advantages of using floating balls.

To facilitate ball control

In sports such as baseball, a skilled player can throw a trajectory-changing curve ball by rotating a ball. The existence of a breaking ball will be closely related to the results of the competition, because tactics are required to detect quickly the type of breaking ball in order to identify the trajectory of the opponent. However, to master a breaking ball is extremely difficult. When a non-expert and an expert player engage in a match, it becomes necessary to appropriately adjust the score, or a physical altercation might ensue, with the result that the game might be interrupted and not reach a climax, which is an extremely important element in enjoying sport games. The ball invented by us allows for an improvement in the weaknesses of players' abilities by adjusting the velocity of the pitch and correcting the trajectory of the ball. As a result, each player can perform at his best, and an exciting game is realized.

Designing new sports

Sports and training using a floating ball often appear in the world of science fiction (SF) and fantasy, for example, Star Wars, filmed by George Lucas, and the Harry Potter series, written by J. K. Rowling. As these examples demonstrate, by unleashing the trajectory of the ball from the conventional physical laws, the manner in which players and balls interact becomes rich, and more strategic games can be designed. For example, a ball can float and slide in the air similar to the hockey puck on ice, dodge an object and another player, and return to the player who throws it (Figure 3). These functions allow a player to pass the ball to a team member positioned far away in order to avoid an opposing player. Such functions could be set up to be limited, or only available for non-expert players. Moreover, these functions realize the tactics of The Affecting Body space. If the ability of HoverBall to auto-tune skills can result in sport games that are more independent from the players' physical strength, the strategic component of these games can become more important. Therefore, anyone from children to the elderly could participate in games equally, thus allowing more and varied participants to enjoy games as lifelong sports. In addition, it can be used as a tool for the rehabilitation of people with disabilities. Moreover, HoverBall can be used to support the exercise of children and the elderly by "traction" and "proximity."

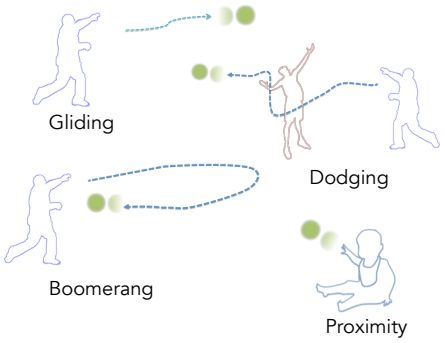

Figure 3: Interaction example with HoverBall

RELATED WORK

In many new sports, tools are added to the tool used in the conventional sports. For example, bossaball is similar to volleyball, but bossaball uses an inflatable court with integrated trampolines on each side of the net, allowing players to bounce sufficiently high to spike the ball and add great spectacularity. Bubble football is a soccer game in which players compete inside giant bubbles. The game has 14 players encased in a zorb-like inflatable bubble; the players are encouraged to bounce into each other as they fight for possession of the ball.

Augmented ball sports

Some people engage in augmented sports with the use of projectors, acceleration sensors, and so on. Ishii et al. developed PingPongPlus [6], which is an athletic-tangible interface. The interface is a Ping-Pong table that includes eight microphones and a video projector; the player can enjoy dynamic graphics and audio generated by sound-based ball tracking technology. Shootball, an original sport developed by Sugano et al., is a goal-based ball game played in a field surrounded by four screens linked to each other [11]. The ball used in this sport contains an embedded wireless shock sensor. The player throws the ball to a goal area projected on the screen in order to earn points. Mueller et al. developed a game that enables communication and play between multiple players in different locations. Using a wall screen, camera, and projector, players break blocks projected onto a screen, either cooperating with other players, or competing for the highest score [9]. The game uses a wall screen, a camera and a projector, and players break blocks that are projected on the screen in concert with other players, or compete for score. Izuta et al. created a ball for augmented sports, called Bouncing Star [7]. Because the ball has a wireless module, acceleration sensor, sound sensor, infrared LEDs, and is observed by a camera, this system can recognize the ball's motion and track its position. When the ball bounces or rolls on the field, the projected computer graphics, color LEDs inside the ball, and responsive sounds are all synchronized with the ball's state of motion. Ichikwa et al. invented a ball-type motion control device [5]. It is composed of a ball and an air-pressure tank to change its vector using gas ejection. This device is able to reappear a breaking ball, however, cannot hover. Baudisch et al. invented the imaginary Reality gaming [2]. This is a ball game similar to basketball, but without a ball. Players engage in the game with voice feedback, such as "who has the imaginary ball," "judgment of the goal," "which is the state of the imaginary ball, inside or outside of the game field." This game is executed upon common understanding. Therefore, it is difficult to import the game to imaginary dynamics that were never seen.

Interaction with UAVs

Some researchers use unmanned aerial vehicles (UAVs) in entertainment, sports training, and so on. Higuchi et al. developed a sports training system using UAVs [4]. In this system, the UAV which mounted a camera tracks a user, and represents his external vision through a head mounted display. Graether et al. developed a jogging support system called joggobot [3]. The system accompanies a runner in order to motivate his exertion activities. These systems support players in recognizing and correcting their technique.

PROTOTYPE

The prototype system introduces a ball shaped micro-quadcopter and a motion capture system. The system uses Crazyflie Nano Quadcopter, which is the hand-size quadcopter (Table 1). We make a Styrofoam grid shell (16 cm) as a spherical exterior component, and put the quadcopter into its central part. The motion capture system measures three-dimensional position (x, y, and z) and orientation (pitch, roll, and yaw) to an accuracy of 1mm. Optitrack S250e as a motion capture camera can track retroreflection makers in 120 fps. We attach three makers on the exterior component. If we use a sufficient number of cameras, the system can measure the size of a tennis court. The player's position is also perceived; therefore, the trajectory of the ball is programmable, depending on the position between the players and the ball.

Size:	90 * 90 mm	Payload:	10g
Flight Time:	5min	Sensor:	3-axis gyro + 3axis accelerometer

Table 1: Specifications of the Crazyflie Nano Quadcopter

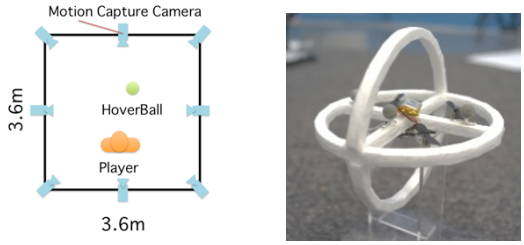

Figure 4: An overview and prototype of HoverBall

Figure 4 shows the experimental environment and the ball-shaped quadcopter At first, we tested the stability of hovering. The method for controlling the quadcopter uses a proportional-integral-derivative (PID) controller that responds to position data from the motion capture cameras. Figure 5 is a graph of altitude data.

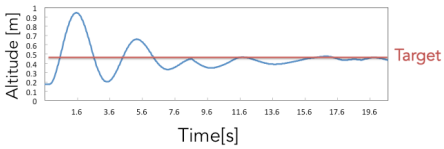

Figure 5: HoverBall altitude

Finally, we developed some basic interactions, such as "Hover & Glide" and "Boomerang." In these interactions, hand gesture is used to control the HoverBall, and a user can manipulate it once it is in the air. (Figure 6)

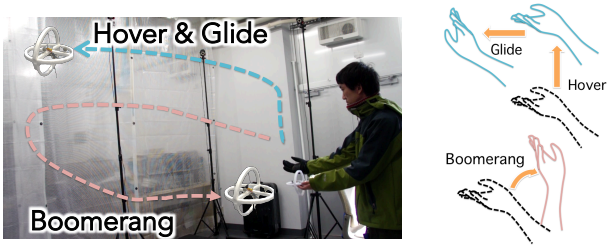

Figure 6: Image of Hover and Glide / Boomerang. When a player raises a hand, the ball floats up. When a player beckons, the ball returns to the player.

CONCLUSION AND FUTURE WORK

In this paper, we presented a flying ball device for augmenting sports. This device adopts imaginary dynamics to ball sports. The device makes interaction possible between a ball and a distant body. By extending the area in which a player can affect the ball, controlling the ball becomes easier, and the possibility for designing a new sport is realized. We developed a prototype system with a micro quadcopter surrounded by a spherical grid, and showed new interactions with players.

In our current implementation, we used Crazyflie Nano Quadcopter because of its small size, which can be embedded in a ball. However, the ball's payload is considerably limited, and it is difficult to support a spherical grid with sufficient strength to be used in sports. Thus, with the current implementation, we mainly explore non-contact interactions, such as maintaining proximity or remote manipulation. However, for use in sports, we expect the ball to frequently receive a strong impact by being hit and kicked. In order to design a ball with enough durability against such physical impact, more research is required. One possibility is to use a helicopter with a higher payload to support a stronger spherical surface. Another possibility is to use a more flexible material that can recover its shape after receiving an impact. The device also requires more power and a higher response control system. When players throw, this ball rotates severely. To control altitude, the ball requires higher thrust power. We plan to introduce powerful rotors. Second, because most radio control helicopters have no large capacity battery to fly for a long time, the helicopters should switch their thrusters to standby mode to save battery when a player is holding it.

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