Augmented Dodgeball: An Approach to Designing Augmented Sports

Takuya Nojima **Ngoc Phuong** **Takahiro Kai** **Toshiki Sato** **Hideki Koike**
Grad. School of Information Systems, University of Electro-Communications
1-5-1, Chofugaoka, Chofu, Tokyo, Japan
tnojima@nojilab.org, shin.phuong@vogue.is.uec.ac.jp, kai@vogue.is.uec.ac.jp, den@vogue.is.uec.ac.jp
Tokyo Institute of Technology
koike@vogue.titech.ac.jp

ABSTRACT
Ubiquitous computing offers enhanced interactive, human-centric experiences including sporting and fitness-based applications. To enhance this experience further, we consider augmenting dodgeball by adding digital elements to a traditional ball game. To achieve this, an understanding of the game mechanics with participating movable bodies, is required. This paper discusses the design process of a ball–player-centric interface that uses live data acquisition during gameplay for augmented dodgeball, which is presented as an application of augmented sports. Initial prototype testing shows that player detection can be achieved using a low-energy wireless sensor based network such as that used with fitness sensors, and a ball with an embedded sensor together with proximity tagging.

Author Keywords
Augmented Sports; Dodgeball; Ball Interface; Proximity-based Interfaces; Design; Prototyping; Gaming.

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

INTRODUCTION
Ubiquitous computing, particularly that applied in the field of sports, has become a huge part of human–computer interaction (HCI) research. The development of ubiquitous interfaces, and their intimate link with human movement has contributed greatly to the progress in tangible and embodied interaction. In sport, technology benefits all stakeholders including spectators and the general public [1], coaches and governing bodies [9, 6], and athletes [16].

Augmented sports are emerging sports that are derived from a fusion of digital technology and traditional sports. Our research group aims to add various digital elements that are used in video games into traditional sports, to make such sports more enjoyable and exciting. We specifically investigated the augmentation of dodgeball.

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Dodgeball is played as a team sport in several countries, each of which has its own locally modified rules. Commonly practiced in primary and secondary schools as a form of physical education, it is one of the very few sports in which competing players aim to attack other players rather than inanimate objects, thereby inducing critical-thinking, and strategic and competitive behavior early in the education system.

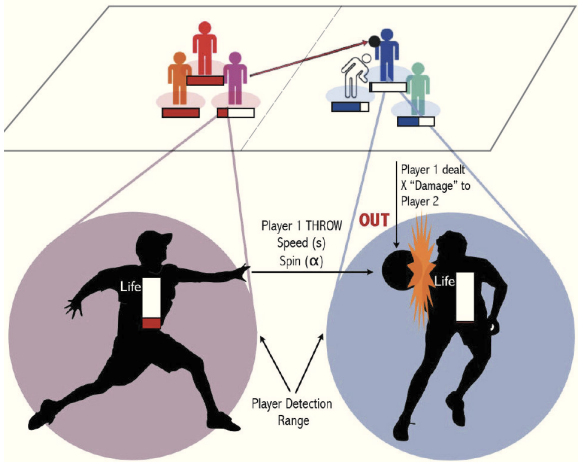

Figure 1: Augmented dodgeball preliminary design.

By adopting the approach of augmenting dodgeball as an interactive sport entertainment system, as illustrated in Figure 1, we aim to achieve the following:

- *Relationship between player and game mechanics*

  Players within the activity are aware of virtual 'parameters' used in the augmented activity. One of the typical example is 'hit points', which is often illustrated as progress bars shown in Figure 1. Each player's hit points are depleted depending on the force of impact when the player is struck. As the ball is the main object in the game mechanics, the idea of a player–ball relationship is explored.

- *Game balancing depending on player skill using virtual parameters*

Players that have difficulty throwing can do more 'damage' whereas players that have difficulty dodging can have more 'hit points'.

- *Introduction of game design elements*

  The measurement of movements that exist in the sport (throwing, dodging, and catching) can be applied to game-centric mechanics (damage, health, and defense).

For such interaction, a means to obtain contextual information during live play is required. The detection of events such as player hits, catches, and floor contact are useful for this. By obtaining real-time quantitative data from the ball and players using sensors during live play, we can determine various aspects of the ball such as impact detection and force, closest player, throwing speed, ball spin, and so on. With this information, it is possible to automate the decision process in dodgeball. In the future, it will be possible to apply these concepts to various other sports thereby contributing to sport augmentation.

In this paper, we first introduce related work in the area of fitness-based interfaces and proximity-based gaming. We then discuss the design process for dodgeball augmentation describing the design goals and prototype implementation, focusing especially on the aspect of ball–player interaction. We then present our interim results and design implications for future work, concluding with a summary.

RELATED WORK

This section first considers one of the many perspectives in designing augmented sports, that is, gaming that requires the investment of physical effort. Thereafter, ball-based interfaces, followed by proximity-based games using user and object identification, are introduced.

Exergaming and Exertion Interfaces

Exergaming and exertion interfaces are designed around the deliberate requirement of intensive physical effort [17] under the umbrella of commercial gaming systems (e.g., Wii, Kinect, and Dance Dance Revolution). Long-distance fitness interfaces such as Sports over a Distance [13] have demonstrated that social interaction can be further enhanced with physical exertion. Such interfaces provide a tighter connection between players and the game mechanics, resulting in higher motivation and involvement [3,14]. We build on an already strong foundation using a traditional sport; however, since players are also aware of the exertion and its effect on the game mechanics, much more attractive gameplay can be introduced.

Ball-based and Throwable Interfaces

To date, several throwable interfaces promoting active fitness using sport-based technology have been developed. One of these is Shootball [18] where a player throws a ball sensor at a wall to gain points. The system uses a camera to detect the location of the ball strike, but does not create a relationship between the ball and the player. Another similar project is Izuta's Bouncing Star [10], using special effects and projection mapping for entertainment. The position of the ball is tracked and given appropriate feedback in an immersive environment. Ichikawa et al. developed a ball which could altering its flight path using gas propulsion as a means of game balancing and adding extra challenges [8,12]. HoverBall is the flight path controllable ball by using quadcopter technology to adopt imaginary dynamics to ball sports [11]. Earthlings Attacks! by Takahashi et al. [19] introduced human body communication using balls coming into contact with the human body as a form of strike recognition without the use of a camera. Our system allows for relatively free movement between the ball and the player, as well as player recognition without requiring actual contact or a camera.

Proximity-based Interfaces and Gaming

User identification by means of proximity is a commonly used method in mobile computing. To achieve a close-range solution, radio-frequency (RF) tagging is often used. TagURIt [2] implements a digital game of tag using on-body displays. It promotes both contact and non-contact player detection using RF signals with the assistance of a camera. Mueller et al. proposed using the interpersonal distance between players, as a novel design resource for digital games [15]. Proximity triggered multi-player interaction has also been proposed [5] as a means to explore physical environments with movable objects using hand-held devices and short-range sensors for rich spatial interaction. Using a similar method with the notion of the ball in play acting as a movable object, we are able to detect nearby players from the perspective of the ball for the application of gameplay semantics.

DESIGN PROCESS

As dictated by Hummels, design should be led by active participation and experience that allows for appropriate contextual understanding of movement-based activities [7]. Obtaining quantitative information from an interface can be complemented further with contextual application and reasoning; we attempt to achieve this through the design process. Pilot research was initiated through participation in standard dodgeball games as well as live observation of local amateur competitions to determine the design goals. In a standard game, players who are struck by a ball thrown by a player of the opposing team are eliminated. However, in the Japanese variation of dodgeball, these players continue playing by acting as a 'flanking' party, attacking from the rear boundary of the opposing team. Through this team balancing mechanism, dodgeball becomes a more strategically challenging team-based activity. We set out to use the Japanese variation of dodgeball as our base.

Casual and Competitive Game Observations

Players in casual dodgeball games were interviewed and several comments were made concerning physical and digital game design aspects. All players verbally confirmed

that they experienced "a workout" during a dodgeball game and mentioned that it would be ideal to be able to supplement various skill levels owing to different levels of fitness, especially for children. Player information, such as "player A hits player B with force C" was also suggested to represent real-time events similar to those in video gaming. We also attended local elementary school dodgeball tournaments to observe gaming behaviors. One clear observation was the movement tactics to avoid flanking attacks with respect to the ball's position. Players would actively create a distance between the ball in the opponent's possession to allow for adequate time to dodge, while advanced players would group together in a line to optimize the chance of catching the ball and prevent flanking players from retrieving it. Moreover, the need for referees to resolve 'out' and 'boundary' decisions was seen to be paramount (6 referees were required for a 12-versus-12 match), although the strict decision process directly affects the active flow of the game owing to frequent time-outs.

Research Aim

From our observations of live dodgeball games, we focused on ascertaining which gameplay elements could benefit from technology. In the context of a dodgeball application, we determined that (1) situational awareness of ball motion, and (2) player possession are key factors in the decision process determining these elements. Real-time computer-assisted event detection (strikes, catches) would then be required to establish augmented dodgeball.

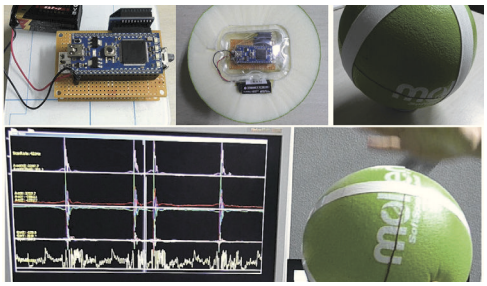

Figure 2: Ball system hardware prototypes. The inner core of the ball (top left), embedded into the ball case (top center), and the constructed prototype (top right). Visualization of the ball sensor during impact (bottom).

Prototyping

The prototype ball was designed to be a modified soft, commercial sponge ball (Molten STS21). The internal mechanism is installed in a hollow crevice cut out of the ball core to act as a wireless "brain". Embedded sensors such as inertial (ADXL345 & ITG3200) and vibration sensors, as well as wireless transmission modules (ANT+ AP2 & XBee) are controlled by the core micro-controller (mbed LPC1768) powered by a 9V battery (Figure 2). The system modules are separated into two channels of communication: one represents the ball–player interaction; the other handles communication between the ball and a host computer, for event handling and application logic, as illustrated in Figure 3.

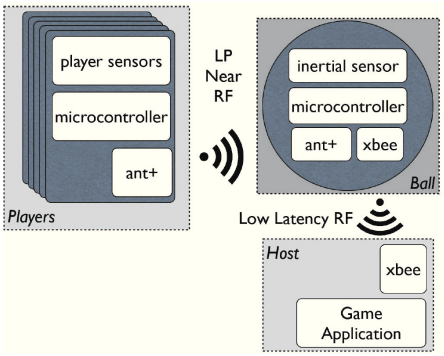

Figure 3: Simple architectural overview of the system.

Wireless Channel Separation

The decision to separate the information channels between Player and Ball, and Ball and Controller was deemed to be an important factor in the design as the requirements for each relationship differ substantially. The ball device acts as a master node that communicates with the currently detected player (from a scalable number of max players limited only by the computational power). Our proposed player detection method uses a solution based on a wireless sensor protocol, ANT+ [4], to establish a 1:N relationship between the ball and players. ANT+, which provides the base protocol for wireless sensor networks, was considered a good candidate for ball–player interaction because of its relevance to human-centric fitness. The ball emits a periodic beacon every 10 ms in search of player tags, which once in range, respond accordingly with player information. For real-time feedback and data acquisition, the prototype was fitted with an XBee wireless communication module to allow sending event-based data to a host computer. The ball information can be determined either by streaming real-time data to the host for concurrent analysis, or using deterministic methods on the microcontroller. It is possible for our system to do both within certain limitations, depending on the application scenario.

Prototype Application

We concentrated on investigating player recognition and bound-detection as an interim goal to detect ball–player collisions. By implementing sound events on activity detection, as well as player proximity detection, a test application for automated dodgeball was developed (Figure 4). Players accumulated "damage" based on the impact force (determined by an accelerometer) and this information would be displayed on an external screen to show the players' remaining life, as well as the currently detected player.

INTERIM DISCUSSION AND FUTURE WORK

Using a design approach to sports augmentation, we obtained an understanding of the elements of dodgeball and proposed an enhanced gameplay by means of computer-assisted detection. Beneficial aspects of our prototype can be exploited in future iterations in terms of detection, ball activity and gameplay design with proper user studies.

The use of scalable wireless networks offers both the game controller and player access to quantitative information that can be used for augmentation. With the current generation prototype, players can be detected by the incoming ball up to a distance of 10–30 cm. Although player information is currently limited to IDs only, there is the possibility of incorporating other player-sensitive data such as heartbeat, caloric measurements, and movement.

Wireless channel separation allows both player and ball information to be handled without any latency limitations. This can also be seen as a method for abstracting the game logic into a ball and player tag system without the need for an external system. Given that this research is still in its infancy, the current proof-of-concept provides a strong foundation for rule-automation and subsequent augmentation for various augmented sports in the future.

Figure 4: Player detection using low power wireless networks. Player 1 throws the ball (top). Once out of range of both players, the player indicator displays zero (middle). When the Player 2 holds a ball, the indicator displays two (bottom).

CONCLUSION

This paper presented an overview of designing an augmented sport by initially augmenting the game of dodgeball. By offering a ball–player-centric approach to interaction, it described the design of a proof-of-concept process of seamlessly integrating technology into sport for enhanced embodied interaction through physical activity. This design approach has proved to be an attractive, novel approach to human fitness and interaction. By adopting this approach, quantitative data from moving bodies within an activity can be used to enhance the activity intrinsically, and create a much greater embodied experience.

REFERENCES

1. A dual-screen sporting phenomenon. http://www.businessspectator.com.au/article/2012/2/28/technology/dual-screen-sporting-phenomenon. Accessed: 16-02-2015.
2. Cheng, S. H., Kim, K. and Vertegaal, R. TagURit: a proximity-based game of tag using lumalive e-textile displays. In *Proc. CHI EA*, (2011), 1147-1152.
3. Consolvo, S., Everitt, K., Smith, I. and Landay, J. A. Design requirements for technologies that encourage physical activity. In *Proc. CHI*, (2006), 457-466.
4. Dynastream Innovations Ltd. ANT+. http://www.thisisant.com/. Accessed: 16-02-2015.
5. Falk, J., Ljungstrand, P., Björk, S. and Hansson, R. Pirates: proximity-triggered interaction in a multi-player game. In *Proc. CHI EA*, (2001), 119-120.
6. Hawk-Eye. http://www.hawkeyeinnovations.co.uk/. Accessed: 16-02-2015.
7. Hummels, C., Overbeeke, K.C. and Klooster, S. Move to get moved: a search for methods, tools and knowledge to design for expressive and rich movement-based interaction. *Personal and Ubiquitous Computing*, 11(8), (2007), 677–690.
8. Ichikawa, T. and Nojima, T. Development of the motion-controllable ball. In *Adj. Proc. UIST*, (2010), 425-426.
9. Infomotion Sporting Technology. 94Fifty Sensor Basketball. http://94fifty.com/. Accessed: 16-02-2015.
10. Izuta, O., Sato, T., Kodama, S. and Koike, H. Bouncing star project: design and development of augmented sports application using a ball including electronic and wireless modules. In *Proc. AH*, (2010), Article No. 22.
11. Nitta, K., Higuchi, K., and Rekimoto, J. HoverBall: augmented sports with a flying ball. In *Proc. AH*, (2014), Article No.13.
12. Ohta, T., Yamakawa, S., Ichikawa, T., Nojima, T. TAMA: Development of Trajectory Changeable Ball for Future Entertainment. In *Proc. AH*, (2014), Article No.50.
13. Mueller, F.F., Agamanolis, S. and Picard, R. Exertion interfaces: sports over a distance for social bonding and fun. In *Proc. CHI*, (2003), 561-568.
14. Mueller, F.F., Edge, D., Vetere, F., Gibbs, M. R., Agamanolis, S., Bongers, B. and Sheridan, J. G. Designing sports: a framework for exertion games. In *Proc. CHI*, (2011), 2651-2660.
15. Mueller, F., Stellmach, S., Greenberg, S., et al. Proxemics play: understanding proxemics for designing digital play experiences. In *Proc. DIS,* (2014), 533–542.
16. Nike. Nike+. https://secure-nikeplus.nike.com/plus/. Accessed: 16-02-2015.
17. Sinclair, J., Hingston, P. and Masek, M. Considerations for the design of exergames. In *Proc. GRAPHITE*, (2007), 289-295.
18. Sugano, Y., Mochizuki, Y., Usui, T. and Okude, N. Shootball: the ball sport using dynamic goals. In *Proc. ACE*, (2007), 262-263.
19. Takahashi, M., Fernando, C. L., Kumon, Y., Takeda, S., Nii, H., Tokiwa, T., Sugimoto, M. and Inami, M. Earthlings Attack! In *Proc. AH*, (2011), 1–4.