



Designing Augmented Sports: Merging Physical Sports and Virtual World Game Concept

Takuya Nojima¹(✉), Kadri Rebane¹, Ryota Shijo¹, Tim Schewe¹,
Shota Azuma¹, Yo Inoue¹, Takahiro Kai¹, Naoki Endo¹,
and Yohei Yanase²

¹ University of Electro-Communications, Tokyo, Japan
tnojima@nojilab.org, {kadri, shijo, timschewe, sazuma,
yoiknoue, kai, naoki.e}@vogue.is.uec.ac.jp

² Unity Technologies Japan G.K., Tokyo, Japan
yoheiy@unity3d.com

Abstract. It is important to encourage people to play sports and physical activities to keep their own health and well-being. However, not many people can keep playing sports regularly. In addition, people in today tend to become physically inactive. Thus, a novel way to motivate people to become physically active, by playing sports, is desired. Augmented sports are novel sports that integrates concepts of computer games into existing physical sports. Physical sports are played in our physical, real world. Thus, physical law limits the methods. On the other hand, such methods for computer games are limitless. Augmented sports are novel sports that integrates various methods to fill or reduce the unwanted gap between humans, to make sports enjoyable regardless of their physical skill or conditions. It will contribute every sports player to feel fun and enjoyment more, that should also lead to motivate people to play sports more. In this paper, detail concept of augmented sports is described. Then, we developed an augmented dodgeball, a proof-of-concept of augmented sports. The detail of the system is also described.

Keywords: Augmented sports · Augmented dodgeball · Sports
Exertion games · Video gaming

1 Introduction

The word “sports” is deemed to be etymological in Latin [18]. This word has the meaning of de (= away) and portare (= carry), distractions from what is indispensable for survival, distraction, rest and enjoyment. In other words, sports is basically a leisure activity, it is an activity that strongly includes elements as play. However, it is not perfectly equivalent to “play”. As a sociologist A. Guttmann tries to define sports by incorporating concepts such as play, structuring, and competition. The relationship between play and sports [19] is illustrated in Fig. 1. For example, fun playing just like playing the ball somehow or throwing it on the ground is classified as “Spontaneous play”. When this becomes a catch ball, some rules are applied such as the ball must not

be dropped, throwing the ball so that others can easily receive it. This is classified as “Organized play”. Catch ball does not have any competitive elements, but baseball has. Since baseball is a competitive play with physical activity, it can be classified as sports.

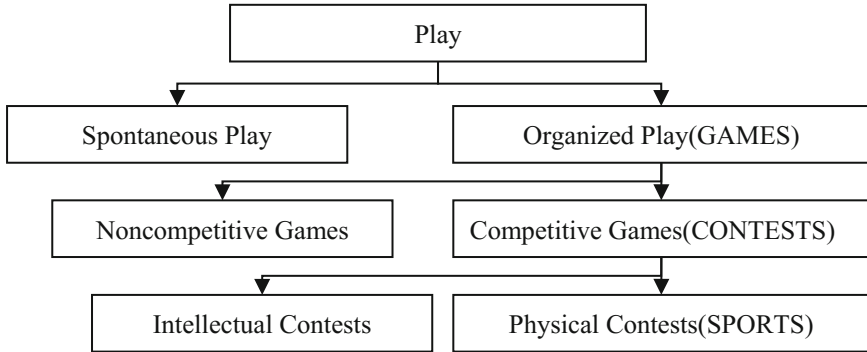


Fig. 1. Definition of sports(re-edited)[33]

One of the big question is from when human play sports. Sports have long history. About 2100 BC Gilgamesh epic poems have descriptions that thought to be about wrestling. The number of kinds of sports has remarkably increased during the 4000 years from that description. For example, in the first Ancient Olympics held in 776 BC, there were at most only a few sports events. On the other hand, at the Rio de Janeiro Olympic Games in 2016, 306 events of 28 races are being conducted. It is well known that there are lots of sports that are not adopted to the official Olympic Games. All sports currently being enjoyed were created by people of the past. In other words, sports can be created with our own hands. This seems to be obvious, but for many people today, sports is not the area of creation but the area of choosing. However, if we strongly recognize that “we can create sports by ourselves”, it will contribute enlarging the possibility of new sports. In addition, the progress of technology is expected to accelerate this movement. Motor sports and e-sports can be typical examples.

Why do people play sports? According to the study in the UK, fun, enjoyment and social interaction were reported to be the key factors whether or not to get involved in the sport [2]. It is well known that playing sports contribute keeping one’s health. This also can be a reason to play sports, but not the key factors. When considering improve one’s health, playing sports are highly recommended. However, it is also known that not many people can keep playing sports regularly. In addition, people in today tend to become physically inactive. In a U.S. report, the percentage of people who work for a job requiring physical activities decrease from almost 50% to less than 20% in these 50 years [5]. As this kind of change in the human behavior has resulted in negative consequences in people’s health and well-being, it is important to encourage people to play sports. Thus, a novel way to motivate people to become physically active, by playing sports, is desired. To comply with this issue, computer games may be helpful when considering the reason why people play sports. The Olympic Movement has also acknowledged that – “The Olympic Movement should strengthen its partnership with

the computer game industry in order to explore opportunities to encourage physical activity and the practice and understanding of sport among the diverse population of computer game users” [1].

Augmented sports are novel sports that integrates concepts of computer games into existing physical sports. Competitiveness, is one of the key factor of sports as we stated in Fig. 1. To achieve this, rules must be fair. But fairness must be discussed carefully. Physical abilities of human differ from person to person. Gender, height, weight, age, presence or absence of disability, and degree of disability, of course, are different from each other. Rules of sports are required to fill or reduce the unwanted gap in an appropriate form. Most existing sports have sophisticated rules on this point, and those rules are often updated if necessary. For example, weight classification in fighting sports is a rule to reduce the impact of difference of player’s weight which greatly affects result of the match. This way of thinking is not limit to physical sports. Games (including computer games) also have the same way of thinking. A lot of effort have been done to develop enjoyable games for both novice and skilled players. The difference between computer games and physical sports is limitation of methods can be used to fulfill the purpose. Physical sports are played in our physical, real world. Thus, physical law limits the methods. On the other hand, such methods for computer games are limitless. Augmented sports are novel sports that integrates various methods to fill or reduce the unwanted gap between humans, to make sports enjoyable regardless of their physical skill or conditions. It will contribute every sports player to feel fun and enjoyment more, that should also lead to motivate people to play sports more.

2 Related Works

From the point of the view of computer games, sports are important theme fields to create new games. In addition, several computer game products that have novel interface like Nintendo Wii [16] and Kinect [12] enables people to play such games with a certain amount of physical activity. It is the same for sports area. Computer games are getting focused as a technology to motivate people to play sports. Research have been done [9, 10] on how to add exertion elements to otherwise button controlled video games. It is believed that a certain technology can induce motivation for people to become physically active. Richards et al. developed a card game on screen to motivate people who do repetitive exercises that can easily get boring [17]. Kajastila et al. developed a novel trampoline game, that uses trampoline activity as a game input [8]. This makes trampoline jumps into jumping in the game world. In the game world, it has graphical obstacles to give trainer’s feedback. Adding social elements is considered to contribute to improving enjoyment of sports. Mueller and Muirhead developed a jogging companion robot that stays with a jogger [14]. They also developed a system that enables people in remote places to play sports together [11, 15]. Such systems are intended to improve social elements when playing sports under a certain situation. Swimtrain [4] is a system that enhances a group fitness training like swimming with social elements, to motivate people to put more effort on the exercise.

It is hard to enjoy playing sports with players who have too much different skill level. Balancing among different players an important factor for being the sports more

enjoyable. Altimira et al. proposed a novel balancing way between in table tennis by limiting table size according to the player's skill level [3]. Thanks to the big interest to the field of movement based games, guidelines have also been published [7], to give game designers insights of what things have been proved to work and which things not.

In this research work, we apply concept of augmented sports to dodgeball to make augmented dodgeball as a proof of concept. It is expected to make the dodgeball more balanced, enjoyable sports. There are also many versions of dodgeball that have been developed to make the classical version more versatile, strategic and/or give weaker players some advantages. Some versions of them include giving the weaker players more "lives" so that they can play longer as an infield player. There is also a version using a "buddy" system which means that the players are also divided into pairs and when one player gets hit, actually the other one in that pair will go out of the game [13]. Some variations also use the time restriction on how long time the players can hold the ball, other ones have a doctor in the team which means that the players who have got hit can return to the game when the doctor has healed them and the game finishes when the doctor has got hit etc.

Our research focuses on using virtual parameters known from computer games. This method is considered to enable players with different skill levels would be able to play together and enjoy their activity. In addition, this method is expected to used as more sophisticated way of balancing, by adjusting parameters. In the next chapter, detail of our approach and developed system is described.

3 Augmented Dodgeball-The Proof of Concept Augmented Sports

3.1 Basic Concept of Augmented Sports

Our research group has focused on developing augmented sports which could be enjoyable for everyone, regardless of their physical skills and abilities. People tend to feel the sports as enjoyable if it provides right amount of exertion, feeling of contribution to the outcome of the game. It is often difficult to maintain this condition when people with too much different physical abilities play together. Traditionally, analogical handicapped methods are pursuit to balance players, such as adding extra scores to the player or team that assumed to have lower abilities before playing the game. Such kind of explicit handicap methods can be thought to be an unfavorable label that the player/team is not skillful.

The basic concept of the augmented sports is making use of virtual parameters and abilities that are common among computer games. People plays (existing) physical sports that have rules modified to use those virtual parameters. Those parameters are affected by the physical event such as hitting and/or a physical ball, running to/from a certain place, etc. Then, a certain kind of special effects are generated based on those events and parameters, to support and/or entertain players.

Those virtual parameters and abilities are also used to fill or reduce the unwanted gap between humans. At the same time, such virtual parameters never harm the fairness of the game. The fairness is the key factor to make the sports enjoyable. In augmented

sports, a person's playing ability depends on the person's actual physical playing ability and virtual parameters and abilities. In other words, although a person has low physical ability, the person's ability for play can be augmented by the effect of virtual parameters and abilities. This is a kind of implicit handicapping method to improve competitiveness of sports. In addition, such virtual parameters and abilities can be used to increase fun for play.

To realize the augmented sports, major research topic will be (a) rule design to motivate people with different physical abilities to play while keeping fairness of game, (b) systems to detect physical events during play to support the rule, which is necessary to make a certain effect to virtual parameters, (c) feedback systems to show the status of virtual parameters and abilities for players and audience.

3.2 Development of Augmented Dodgeball

In this section, detail of augmented dodgeball (Fig. 2) is described. This is a proof of concept of the augmented sports.



Fig. 2. Playing augmented dodgeball

Dodgeball is a ball game mostly played in elementary and junior high schools all over the world. Although detail of rules may differ from place to place, the basic rule is common: “throwing a ball against opponents to hit”. Dodgeball is not only a sports of personal physical abilities, but requires a cooperation with their team members and a certain strategy to win. One of the typical strategy is keep passing the ball between infield players and outfield players to keep moving opponents in their field. While passing the ball, they try to find a target and throw a ball against the player. When throwing a ball, the thrower often assesses physical abilities of thrower's own and that of opponent's who is about to be thrown against. In this condition, a physically weak

player often has difficulty continue playing as an infield player. By making existing dodgeball as a kind of augmented sports, it is expected that all players could enjoy playing “the modified version of dodgeball” without depending on their own physical abilities. We call this “modified version of dodgeball” as “Augmented dodgeball”. Augmented dodgeball is designed to use virtual parameters which is mainly used for balancing the physical skill levels between different players. Following subsections show how to modify the existing dodgeball into augmented dodgeball.

Rule design

Firstly, rules must be modified to use virtual parameters while playing dodgeball. To achieve this, we added a virtual point named “life points” to each player to indicate their virtual life status. This is a well-known concept in computer games. When a player gets hit in the Augmented Dodgeball game, they will lose a certain amount of points from their life points. This enables all the players to keep being an infield player until the player loses all life points. In addition, players are also assigned virtual parameters named “attack points” and “defense points”. Attack points indicates the level of offence, and defense points indicates the level of defense. The Eq. (1) shows the points to be reduced from the player’s life points when they got hit. In this equation, m, n, u, v are natural numbers to identify players and teams. T_m denotes a team, P_u denotes a player. $AP(T_{n(\neq m)}, P_{v(\neq u)})$ denotes an attack points of the thrower, $DP(T_m, P_u)$ is a defence point of a player who is hit by the ball. If a player P_u in team T_m got hit by a ball thrown by the player $P_{v(\neq u)}$ in team $T_{n(\neq m)}$, the life point of the player P_u in team T_m , which is denoted as $L(T_m, P_u)$ will be updated as follows:

$$L_d(T_m, P_u) = \frac{AP(T_{n(\neq m)}, P_{v(\neq u)}) - DP(T_m, P_u)}{2} \quad (1)$$

$$L_{new}(T_m, P_u) = L_{prev}(T_m, P_u) - L_d(T_m, P_u) \quad (2)$$

$L_{new}(T_m, P_u)$ in the Eq. (2) denotes the life points of the player P_u in team T_m after being hit, $L_{prev}(T_m, P_u)$ denotes that of before being hit. To use this concept as a balancing method, three player roles who have different virtual points are designed: Attacker, Defender and Balanced. Attacker players have greater attack power but lower defence power than other player roles. On the other hand, defender players have greater defence power but lower attack power. Balanced players have moderate attack and defence power. All the player roles have the same life points. Then, based on a computational game simulation, detail virtual points of each roles are defined to achieve fair and competitive game as shown in Table 1. Those roles are assigned only to infield players. If the player becomes outfield player, the role will be changed to balanced type automatically. The reason behind developing these roles was to give players to act as those roles such as aggressive attacker players or less aggressive defence players. Such method is expected to add enjoyment of “playing the assigned role” in the game.

Table 1. Roles and parameters used in the augmented dodgeball game

Player role	Points		
	Life points	Attack power	Defence power
Attacker	120	140	120
Balanced	120	120	160
Defender	120	110	180

System Development

In the augmented dodgeball, life points must be updated in a real time. However, the rules behind the game is too complicated to calculate mentally in a real time. Thus, a supportive system is required.

To make virtual parameter rules effective, the supportive system should equip functions as follows: (I) detecting a player who throws the ball, (II) detecting a player who got hit by the ball, (III) updating life points. The main goal of this paper is to prove the effectiveness of the concept of augmented sports through developing augmented dodgeball. Thus, a system with minimum functions (I) and (III) are developed.

In this subsection, we describe a helmet type system to register the thrower, and a point management application. When playing the augmented dodgeball, all the players wear a helmet system as shown in Fig. 3 left. Then, players “register” the ball to the point management application through the helmet just before throwing against an opponent. The occurrence of the hit and identifying who got hit is done by a human referee. If appropriate hit occurs, the referee input the information of the player who got hit into the point management application. Then life points of that player will be updated.

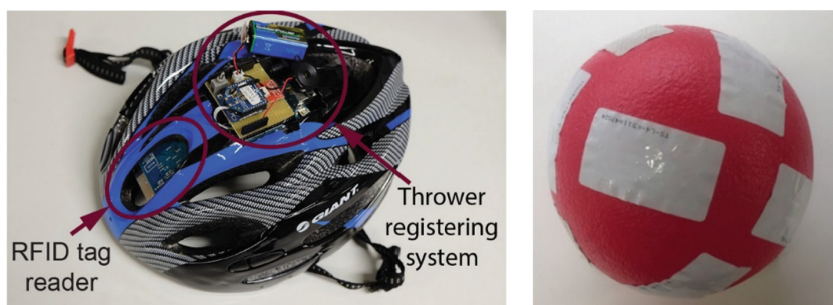


Fig. 3. Left: The helmet system for players to register the thrower. Right: The ball covered with RFID tags.

The helmet system is equipped with a thrower registering system. The system consists of an RFID tag reader, an Arduino UNO board, an XBee [8] wireless module, a small speaker and a battery. The helmet system has unique ID to identify the player who wears it. The tag reader is installed in front of the helmet to make it easier for the players to register the ball that the player has. The ball used in the augmented dodgeball

is a sponge ball (ϕ 160 mm) covered with RFID tags as shown in Fig. 3 right. To register the ball, players hang it on the RFID tag reader area of the helmet for a second until beep sound is generated as shown in Fig. 4. In the world of augmented dodgeball, we explain this action to players as “pouring special force into the ball”. This registering event and the helmet ID are transmitted to the point management application wirelessly. The whole system is powered with a 9 V battery.



Fig. 4. Registering action

The point management application receives the helmet ID, which represents a player who holds the ball. Then, if the human referee inputs player ID who got hit, the life points of the player will be updated based on Eqs. (1) and (2).

3.3 Feedback Systems

Virtual parameters must be shown all to players and spectators. Otherwise no one can understand the current status of the game. At this moment, a scoreboard is placed in the center of the play field to show life points of all players as shown in Fig. 5.

Although all players and spectators could perceive all virtual parameter information through this display, it is difficult to check actual game situation and the scoreboard simultaneously. Thus, appropriate information display system is necessary for both players and spectators. For the first step of display system for players, we developed a prototype of wearable parameter indicator as shown in Fig. 6. This indicator consists of four LED bars, two for each side of the body, an XBee for data communication, an Arduino UNO R3 as an LED controller. The color of LED bars changes according to the life points that the player has, which is transmitted from the point management application. Figure 7 shows the relationship between color of LED bars and life points.

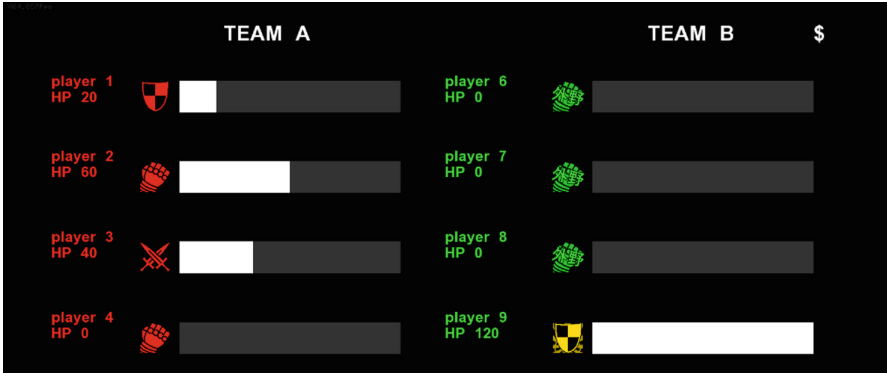


Fig. 5. The scoreboard of the augmented dodgeball



Fig. 6. A prototype of wearable parameter indicator (Color figure online)



Fig. 7. Relationship between color and life points (Left: all green indicates maximum life points, Right: most of LEDs turns red to indicate exhausted life points) (Color figure online)

Basically, sports cannot live through without considering the existence of spectators. Spectators are potential provider of psychological, material and financial support to maintain the environment for play. In addition, they are also potential players in the future. Thus, it is important designing enjoyment for spectators.

As mentioned above, the scoreboard system can be used as a supplemental information display, but not enough. For the first step to comply with this issue, we developed an AR display system. In this system, players wear specially designed bibs as shown in Fig. 8 left, which act as markers for developed AR display. Figure 8 right shows example screenshot what spectators watch. As shown in the figure, player role icon and current life points are overlaid on each players.



Fig. 8. Left: example designs of bibs, Right: prototype AR image for spectators

To achieve this system, position information of all players are necessary. In this prototype system, a web camera is placed outside of the playfield to recognize AR markers designed as bibs worn by players. Vuforia (version 6.2.10) is used to recognize the AR markers. Then, the player position information and the status information of each player are sent to the AR display device worn by spectators. Here, Microsoft HoloLens is used as the AR display device. This application was developed using Unity(version 5.6.3p4).

3.4 Preliminary Evaluation

To evaluate the concept of augmented dodgeball, a preliminary evaluation was conducted. 16 participants joined this evaluation session. Age of participants were between 20 and 26, average was 23. None of the participants played dodgeball regularly. In this evaluation, the wearable parameter indicator for players and the AR display system for spectators were not used. The scoreboard system is the only medium to indicate the status of virtual parameters. In this evaluation, two sessions were conducted. One or two games of regular dodgeball was played in the first session. Two augmented dodgeball game was played in the second session. One team consists of four players. Participants organized the team by themselves. After finishing the second session, a survey was conducted. The survey consists of 26 questionnaires to be answered by a five point Likert scale.

From the result of the questionnaire, all of the answered participants stated that they had fun playing the augmented dodgeball. 60% even strongly agreed to that claim. In addition, 93% answered that they would play the game again. The augmented dodgeball has complex rules than those of existing regular dodgeball. However, 64% of participants answered that the rule was always clear to play. Although 29% stated that they had some trouble with that.

4 Conclusions

In this paper, we propose the concept of augmented sports, which intended to be sports enjoyable for everyone, regardless of their physical skills and abilities. To achieve this concept, we claim that integrating computer game elements into existing physical sports. Then a proof of concept system was developed named augmented dodgeball, which is a re-invented version of dodgeball by using the concept of augmented sports. The augmented dodgeball utilizes virtual parameters that are well known in computer games to indicate characters' status in that world. In the augmented dodgeball, players are assigned different player roles that have different virtual parameters. Then, by throwing a physical ball against opponents, those parameters are changed according to the event in the physical world. To support this, a wearable system, point management application, display feedback system were developed. In addition, a preliminary evaluation was conducted. Through the evaluation, it is agreed that the augmented dodgeball is enjoyable sports.

At this moment, the functions equipped with the wearable system is not enough unfortunately. More detail, a function for detecting a player who got hit by the ball should be equipped to eliminate human referee. In addition, more sophisticated mechanism for detecting the player who throws the ball is strongly required. In the future, this augmented dodgeball supporting system is expected to be updated as a generally applicable system to make various kinds of ball sports into augmented sports.

Acknowledgement. This work was supported by JSPS KAKENHI Grant Number JP16H01741.

References

1. XII Olympic Congress: The Olympic Movement in Society Recommendations (2009). www.olympic.org/Documents/Conferences_Forums_and_Events/2009_Olympic_Congress/Olympic_Congress_Recommendations.pdf Accessed 1 Feb 2018
2. Allender, S., Cowburn, G., Foster, C.: Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Educ. Res.* **21**(6), 826–835 (2006)
3. Altimira, D., Mueller, F.F., Clarke, J., Lee, G., Billinghamurst, M., Bartneck, C.: Digitally augmenting sports: an opportunity for exploring and understanding novel balancing techniques. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, pp. 1681–1691 (2016)

4. Choi, C., Oh, J., Edge, D., Kim, J., Lee, U.: SwimTrain: exploring exergame design for group fitness swimming. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, pp. 1692–1704 (2016)
5. Church, T.S., Thomas, D.M., Tudor-Locke, C., Katzmarzyk, P.T., Earnest, C.P., Rodarte, R. Q., Martin, C.K., Blair, S.N., Bouchard, C.: Trends over 5 decades in US occupation-related physical activity and their associations with obesity. *PLoS ONE* **6**(5), e19657 (2011)
6. FunAndGames.org: Dodge Ball Games. <http://funandgames.org/tag/dodgeball/> Accessed 1 Feb 2018
7. Isbister, K., Mueller, F.F.: Guidelines for the design of movement-based games and their relevance to HCI. *Hum. Comput. Interact.* **30**(4), 366–399 (2015)
8. Kajastila, R., Holsti, L., Hämäläinen, P.: Empowering the exercise: a body-controlled trampoline training game. *Int. J. Comput. Sci. Sport (Int. Assoc. Comput. Sci. Sport)* **13**(1), 6–23 (2014)
9. Ketcheson, M., Walker, L., Nicholas Graham, T.C.: Thighrim and Calf-Life: a study of the conversion of off-the-shelf video games into exergames. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, pp. 2681–2692 (2016)
10. Ketcheson, M., Ye, Z., Nicholas Graham, T.C.: Designing for exertion: how heart-rate power-ups increase physical activity in exergames. In: Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY 2015), pp. 79–89 (2015)
11. Jensen, M.M., Rasmussen, M.K., Mueller, F.F., Grønbaek, K.: Keepin’ it real: challenges when designing sports-training games. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI 2015), pp. 2003–2012 (2015)
12. Microsoft: Kinect for Xbox One. www.xbox.com/en-US/xbox-one/accessories/kinect-for-xbox-one Accessed 1 Feb 2018
13. Moritake, T.: Different versions of dodgeball. homepage1.nifty.com/moritake/taiiku/bo-ru/dozzi-ball.htm Accessed 1 Dec 2016
14. Mueller, F.F., Muirhead, M.: Jogging with a Quadcopter. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI 2015), pp. 2023–2032 (2015)
15. Mueller, F.F., O’Brien, S., Thorogood, A.: Jogging over a distance: supporting a jogging together experience although being apart. In: CHI 2007 Extended Abstracts on Human Factors in Computing Systems, pp. 1989–1994 (2007)
16. Nintendo: Wii. wii.com Accessed 1 Feb 2018
17. Richards, C., Nicholas Graham, T.C.: Developing compelling repetitive-motion exergames by balancing player agency with the constraints of exercise. In: Proceedings of the 2016 ACM Conference on Designing Interactive Systems, pp. 911–923 (2016)
18. Penjak, A., et al.: Sport and literature: an overview of the wrestling combats in the early literary texts. *J. Hum. Soc. Sci.* **3**(5), 49–55 (2013)
19. Guttmann, A.: *From Ritual to Record: The Nature of Modern Sports*. Columbia University Press, New York (1979)