Augmented Systems in Sports

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ABSTRACT

Augmented sports systems are athletic activities in the real world that are enhanced using computer technology. This is done by changing the player experience either through an embedded system or by augmenting some perceptual experience of a player. The augmented sport systems described in this paper increase participation of players with a wider range of skill, improve the experience from a training perspective, and increase the enjoyment level of these sports for participants.

Keywords

Embedded system, augmented reality, sports

1. INTRODUCTION

An augmented sports system alters the experience of an individual participating in a sport. There are a variety of reasons to consider augmenting sports. The main reason is to encourage people to be more active. Another reason is to create an enjoyable environment that all skill levels can play at. Lastly, is to improve the overall experience by increasing understanding of the game. When you understand a sport you tend to enjoy yourself, which improves your overall experience.

In this paper, we explore both how and why sports can be augmented with a system. Some augmented sport systems alter the way people experience reality through their senses by providing additional (or different) perceptual information. Such systems are designed for experiences that are generally referred to as "augmented reality". Augmented reality (AR) is different from virtual reality. AR is when the technology changes the experience of an individual in the real world, whereas virtual reality (VR) is when an individual is immersed in a world where many of the perceptual inputs are constructed by technology. AR changes only part of the experience, while VR aims to replace it.

There are a variety of ways researchers have attempted to augment sports. For example, an augmented sport system to help soccer players that projects the trajectory and velocity of the ball to help train players is described in [4]. An augmented sport system that helps enhance a swimmer's visual perceptions by creating a natural environment in a pool is described in [8]. Sometimes, the system alters how the game is played instead of the environment. For example, in Section 3.2 we describe the physical ball used in the game is implemented with an inner ball mechanism that records data and is used for the improvement of the players' physical attributes. This game uses physical in-game data to decide upon the virtual parameters based on the player's attributes. In contrast, in Section 3.1 the creation of virtual parameters of the physical attributes of players in the game are virtually augmented based on each players' role.

In this paper, we will provide a description of how and why we use augmented systems for sports. First, in Section 2 we will discuss two augmented wall climbing systems that motivate, instruct, and improve the practices of wall climbing. Next, in Section 3 we will discuss two augmented dodgeball systems that have or create virtual parameters based on physical abilities. To wrap things up, the conclusion will review what we have discussed and the importance of augmented sports systems.

2. AUGMENTED WALL CLIMBING

Climbing was generally only practiced outdoors until 1964, when a Physical Education lecturer named Don Robinson created the climbing wall [6]. A definition of indoor wall climbing is climbing an artificially constructed wall indoors with grips for hands and feet. The climbing walls are made of a variety of materials such as wood, steel, and aluminum. The climbing wall has multiple grips to mimic the conditions of outdoor rocks. The grips can be color coordinated to indicate specific routes for a variety of levels of difficulties. Indoor and outdoor climbing can differ in many ways that include environment, safety, and difficulty.

Some climbers might feel negatively about climbing. These climbers may be not be physically able to climb or climbing is not appealing to them. In the two augmented climbing systems we try to resolve these challenges of climbing by increasing the competitiveness, involvement, and physiological perceptions of the game.

2.1 Wall Climbing with Interactive Surfaces

One example of an augmented wall climbing system was created by Raine Kajastila, Leo Holsti, and Perttu Hämäläinen [1]. This research designs and implements an augmented wall climbing system that incorporates visualizations and interactive projections. To represent why a sport should be augmented, there are three main themes. The three main themes when digitally augmenting a sport are: improve variety of physiological actions and limitations, enable agile

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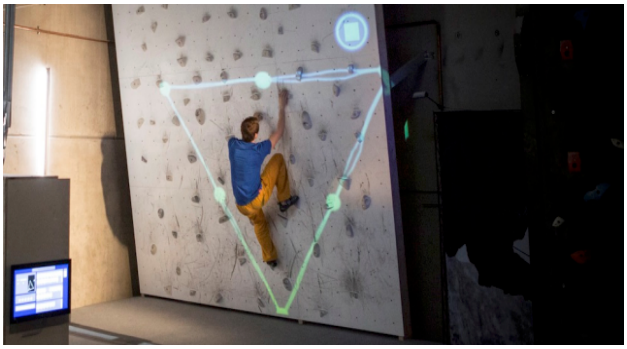
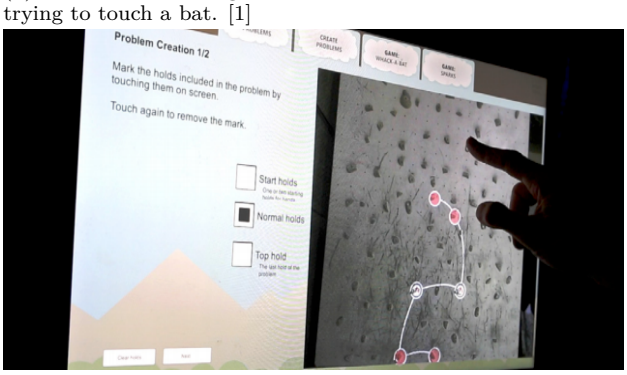


(a) A climber playing the Spark game [1]

(b) The Whack-a-bat game. The climber is trying to touch a bat. [1]



(c) The route creation interface [1]

Figure 1: The three activities described in [1]

thought processing in a risky environment, and gather useful feedback for future work. This section describes three applications: the Spark game, Whack-a-bat game, and Route creation.

2.1.1 Spark Game

The first application is a game where the climber tries to avoid overlapping or touching the electric lines that are projected onto the climbing wall (See Figure 1a). As the climber completes levels, the levels increasingly get more challenging such as moving electric lines and intermediate way points.

The three main points to the Spark game are:

1. Each game level has a clear start and end.
2. The moves can be planned before and executed while climbing, creating both cognitive and motor challenges.
3. Each level is pre-designed so it can be practiced and one can learn from the performance of others.

Method and Results

A total of 50 climbers participated in the research (29 male, 19 female, 2 other) with an age average of 27. The climbing experience of the participants was an average of 2 years. Each participant played the Spark game twice. The researchers used a questionnaire for user feedback. The researchers had participants comment on each question to their best ability after playing augmented wall climbing. The comments of each question were categorized by topic and ranked by frequency (See figure 2). This means that each comment from each of the participants was reviewed by the researchers and categorized according to a related topic. We will discuss the first 4 questions because questions 5 and 6 had unimportant feedback.

The questionnaire included six open-ended questions:

1. What did you like the least?
2. What did you like the most?
3. How does climbing in the game differ from regular climbing?
4. How does watching someone play differ from watching regular climbing?
5. Who is this most suitable for?
6. Would this help your climbing practice? How?

Starting with the positive responses, Q2 responses highlight the versatility, enjoyment, and excitement that the game adds. Some responses are “Fun, new things to do for a climber”, “Versatile and different.”, “Many routes in a small space.”, “Easy to change the wall and level of difficulty.”, “Fun endurance practice that does not feel like practice.” [1] The categorizing of topics were mainly on difficulty, fun, and variety of routes and training. This tells us that the game was not too easy nor too difficult and still fun to play.

Q3 responses discuss the differences of the Spark game compared to regular comparing. The challenges were change in speed, variety of movements, and recognizing spatial areas. “Movement is different, more sideways movement. “Faster pace makes it more addictive”, “Must look at other things besides just the holds”, “One must observe sideways and downwards directions as well, can’t rest so much.” [1] The comments that were categorized most often on Q3 were on the climbing style, position, and tempo. This tells us that the level of competitiveness changes dramatically and intensifies the experience.

Q4 highlights the variations of perceptional problems of viewing all instructional information and modifying levels. “More exciting, one could participate as a spectator by giving instructions related to the moving lines. “More interesting and nice to give guidance and warn the climber about the electricity.” [1] This gave spectators a new perception of having fun with sounds and visual effects. The categorizing of the topics tell us that the social aspect of the game made it more fun which is a goal of augmented wall climbing.

Not all the responses were positive; Q1 responses reveals future work when tracking the body of the user. The criticism the users said are “It was hard to perceive one’s body

Q1: What did you like the least?		Q2: What did you like the most?		Q3: Differences to regular climbing.		Q4: Differences to spectating climbing.		Q5: Suitablility.		Q6: Benefits for climbing practice.	
Category	**N**	**Category**	**N**	**Category**	**N**	**Category**	**N**	**Category**	**N**	**Category**	**N**
Tracking Failure	15	Different / Novelty	18	Climbing Style / Positions	9	Social / Participatory	16	Everyone	23	Endurance	11
User Interface / on Wall	13	Other	16	Tempo	8	Fun	12	Children	14	Other	10
Climbing Routes / Perceiving	12	Fun	12	Climbing Routes / Planning	8	Excitement	9	Other	7	Speed	8
Physical Environment	5	Variety (of routes / training)	12	Concentration / Focus	7	Other	8	Beginners	7	Movement Variety	8
Cheating	5	Motivates Movement Variety	6	Other	7	Nothing	5	Youth	4	None	6
Soundscape	3	Moving Routes	5	Competitiveness	4	Soundscape	3	Groups	3	Concentration / Focus	4
Climbing Routes / Planning	2	Motivates Endurance Training	4	Endurance	3	UI	2			Warm-up	3
Tempo	2	Idea	4	Fun	3					Training small holds	3
Visual Design	2	Fear of Heights	3	Fear of Heights	2					Dynamic moves	3
Difficulty	2	Competitiveness	2	Social	1					Technique	1
Other	2	Excitement	2	Excitement	1						

Figure 2: Questionnaire for the Spark game. Ordered by frequency.[1]

on the wall, "Electricity borders are imprecise, difficult to estimate whether one's head or limb will hit the electricity." [1] The system shows that the there is unpredictable behavior. The categorization of the topics tells us that tracking failure and projections on the wall need to be improved.

Some Q3 responses highlight the negative conditions of the Spark game and how it is changing climbing. "The game does not force one to work on the route and develop one's technique." [1] The game is more useful for endurance and strength training or for more of a warming up exercise.

The most intriguing feedback claims are "I forgot the fear of heights and falling" ,"Excitement provided by the game at one meter above the ground". [1] The application created a more focused environment that made the climber literally forget she was climbing instead of playing a game. This shows that the digital augmentation expands and limits a sport's target audience. Overall, augmented sports systems expand the participation of the game but some people would prefer to play without the system.

2.1.2 *Whack-a-bat and Route Creation*

The Whack-a-bat application is designed for when a user attempts to touch a projected bat that is sitting on the grips which are mounted on the climbing walls before the timer runs out. When touching a bat it flies to a random location on the climbing wall and the bat's timer restarts. The locations are randomized so the bat's projection is not being overlapped by the climber's body. As the climber persists playing the game, more bats appear, this escalates the difficulty of the game. To help track multiple bats, the bats produce a visual beacon so that the climbers can view more than one bat. The beacons are small expanding circles that allow the climber to see the directions of where the bats are (See Figure 1b).

The Route Creation application uses a climbing wall that projects graphic coordinates by using 3D coordinate information and censored projected calibrated data [1]. The routes are created on a touchscreen interface shown in Figure 1c. Touches on the phone's screen are mapped on the interface screen that project the graphic coordinates on the climbing wall. Touching a grip on the screen adds or removes a grip mark. The created routes can be viewed by difficulty, ratings, and how many times climbed [1].

Setup and Results

The results for Whack-a-bat and Route Creation are combined because Whack-a-bat incorporates Route Creation in its application. In this study 10 participants were recruited from students and staff members from Aalto university. Each participant played the game with and without the beacons. After experiencing the game with and without the beacons, all the users were asked to rate the level of difficulty of knowing where the bat is on a Likertstyle scale (1=very easy, 4=not easy or difficult, 7=very difficult). The results when the users played with the beacons was rated as easy (mean=2.7, standard deviation=1.4), and when the users played with no beacons was rated as difficult (mean=4.7, standard deviation=1.4). After the experiment, the users were asked how the two versions of the game were different. All participants noticed and started to use the beacon's information after the first bat appeared, indicating that the beacons are very useful.

2.2 betaCube - Self Calibrating Camera Projection Unit

Another example of an augmented wall climbing system was created by Frederik Wiehr, Felix Kosmalla, Florian Daiber, and Antonio Kruger [5]. The design goal of the betaCube is for it to be a system that is easy to set up, solve climbing problems, and change the way climbing is practiced. This research proposes a self-calibrating camera-projection unit that features tracking and distortion-free projection [5]. The features of the betaCube help climbers improve their training and skill for climbing.

2.2.1 *Implementation*

The betaCube is a cube made out of wood containing a Kinect V2 camera, laptop computer, a WIFI router, and an Arduino Fio. The Arduino Fio is the interface that helps control the multiple physical buttons on the betacube. The

Android app is used for as both a remote control and input device for the betaCube. [5]

Figure 3: The betaCube unit placed in front of a climbing wall. Holds or grips are highlighted by the projector. [5]

2.2.2 Setup

The setup for the betaCube is simple and easy. First, a climber has to move the cube in front of a climbing wall and connect it to a power source. The climber simply pushes a button to start the betaCube calibration process. The projection of horizontal and vertical lines on the climbing wall ensures for accurate and distortion free projections. The purpose of calibrating is that every climbing wall is unique and the cube needs to scan the wall for differentiations.

2.2.3 Route Creation

The first step is to connect the Android smartphone with the cube. Creating a new route, the user selects route creation mode and is presented with an image of the back-facing camera of the user's smartphone [1]. When pointing the phone towards the wall and touching a hold on the users' phone camera, the image gets sent to the cube. The server inside the betaCube receives the information and determines the image's features in the sent image [1]. The resulting projection translates the coordinates of the user's touch on the user's phone image to a coordinate on the camera image.

2.2.4 Shadow Climbing

Shadow climbing is when a climber imitates the movements of a previously recorded climb. This is used in a practice environment when one wants to understand the movements of other climbers. When climbing a created route as described above, the betaCube recognizes the climber using a body tracking camera. However, the camera tracking the climber's body is inaccurate because of the differential shape and type of body postures of the climbers.

Results

While building and testing the current prototype of the betaCube in a climbing gym, the researchers analyzed multiple conversations with the route creators and climbers. The feedback was very promising and informed the researchers for the design of the current prototype. The work of the current prototype is still in progress and future work is promising when implementing the many designs and computer human interactions.

3. AUGMENTED DODGEBALL SYSTEMS

Dodgeball is a game where players on two teams throw balls at each other while trying to avoid being hit. The objective of dodgeball is to eliminate all of the members of the opposing team. To eliminate a player on opposing teams, a player will need to throw a ball and hit the opposing player on the body. [7]

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, inducing critical thinking, and strategic and competitive behavior [3]. Dodgeball is a great game to play not only because of its great health benefits from jumping, sprinting, and throwing, but is because it is fun to play with others.

However, dodgeball may not be enjoyable to players with a lower skill level, which makes them not want to play. When playing dodgeball, getting hit once means you're out of the game no matter your skill level. This makes it tough to improve your skill. This also can become frustrating and not enjoyable to play for lower skill level people.

The augmentation of dodgeball aims to explore how to make the game more fun for players with less skill and how to keep the game more balanced between players of varying skill levels. In this section, we describe two different approaches to augmenting dodgeball. The difference between the two sport systems is that in Section 3.1 the aspect of the game is augmented rather than in Section 3.2 where they augment the physical ball of the game and use data from the live game to determine parameters.

3.1 Game Parameters Based on Chosen Role

One example of an augmented dodgeball system was created by Kadri Rebane, Takahiro Kai, Naoki Endo, Tomonari Imai, Takuya Nojima, and Yohei Yanase [3]. The goal for this augmented system is to create an enjoyable environment that would allow players to increase their skill and involvement in the game by physiologically leveling the playing field. To do this, the researchers created three virtual player roles to even the playing field; Attacker, Defender, and Balanced. These player roles are based on the player's physical attributes. To calculate how the virtual parameters were decided, a game simulator was created. Two teams of five were simulated with teams consisting of two attacker roles, two defensive roles, and one balanced role to make the simulation level for both teams. 10,000 games were simulated and the best parameters were chosen from the data created as seen in Table 1.

The attacker has more attack points but fewer defense points, Balanced has a balance of attack and defense points, and Defender has more defense points but fewer attack points. For example, if a player was good at throwing but not good at dodging then the virtual parameters or character role they are assigned to is the Attacker. They assign virtual parameters to help decrease the player skill level gap while balancing the playing field.

3.1.1 Technical Mechanics

Technology used in this research is more about the relationship between the player and the game rather than just the game itself. In the research, RFID (Radio-frequency identification) tags attached around the ball are used to make the identification and tracking easier. The helmet

Table 1: Parameters used for augmented dodgeball [3]

Player role	Life Points	Attack Power	Defense Power
Attacker	120	140	120
Balanced	120	120	160
Defender	120	110	180

Figure 4: Three player roles used playing Augmented Dodgeball [3]

worn by every player is equipped with a thrower registering system and a RFID tag reader. The thrower registering system is on the front part of the helmet because it is easier for the camera to capture, as shown in Figure 5. The RFID tags on the ball send data to the RFID tag reader on the helmet which, sends the data to the main system where user roles are taken into account to determine points. The system knows where the ball is and who got hit with the ball at all times.

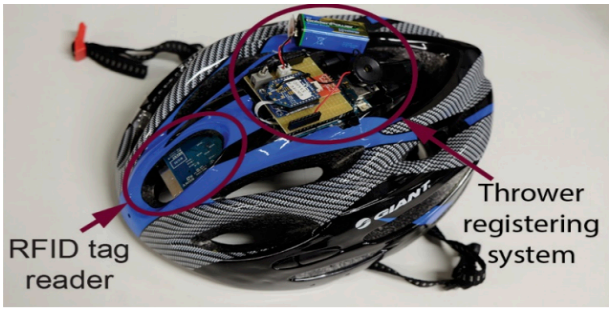


Figure 5: Helmet used for the throwing registering system [3]

The software behind dodgeball is in charge of showing the health count, role in the game and, "field" or "outfield" for all players. There is a human referee who physically has to input the information on which player was hit.

3.1.2 Procedure

16 participants (2 female and 14 male) took part in the study. Ages of the participants were between 20 and 26. The participants had never had experience playing augmented dodgeball. Two separate game sessions were organized. Each session had 8 players (teams of 4 players). The participants were explained the rules of regular dodgeball and played a match of regular dodgeball. After playing regular dodgeball the participants were explained the rules of augmented dodgeball. Each player was personally assigned one of the three player roles: Attacker, Defender, or Balanced. The teams then were separated so that each team had a balanced amount of the three player roles. The players played augmented dodgeball twice. After playing the second game of augmented dodgeball the players were asked to fill out a questionnaire about their experiences and competitiveness.

3.1.3 Results

The participants had a combined majority of 88% feeling positive when playing augmented dodgeball. Only 6% participants indicated not feeling positive and 6% participants had a neutral feeling when playing augmented dodgeball. 93% admitted to having more fun than they expected, with only 7% unsure about their experience. As seen in Figure 6, augmenting dodgeball positively increases a user's overall experience compared to playing regular dodgeball.

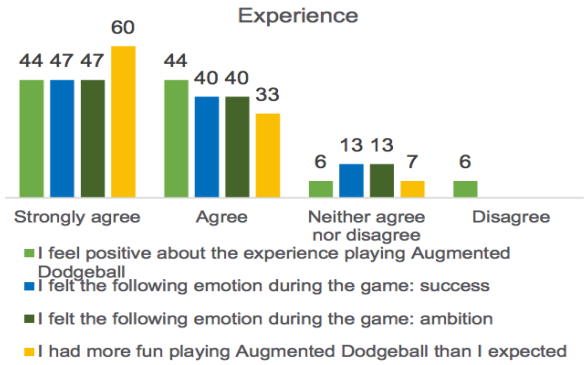


Figure 6: Player's overall experience playing Augmented Dodgeball (Represented as percentages) [3]

Augmented Dodgeball creates a competitive environment that the majority of participants found agreeable as seen in Figure 7. The participants were asked 4 questions after playing augmented dodgeball. The first question is would you think of a strategy to win again; 81% said they strongly agree or agree, and 19% neither agree nor disagree. A variety of feedback was provided when asked if the participants check the score table while playing augmented dodgeball, 76% strongly agreed or agreed while 24% were neutral or disagreed. This tells us the participants did not care who won the game and the competitive nature of the game was dramatically decreased from regular dodgeball. The positive data from Figure 6 and the variation of data from Figure 7 says that the players overall enjoyed playing augmenting dodgeball at a normal competitive level.

3.2 Game Parameters Altered Based on Live Data from an Embedded System with a Ball

Another approach of augmented dodgeball was created by Takuya Nojima, Ngoc Phuong, Takahiro Kai, Toshiko Sato, and Hideki Koike [2]. This research creates specific virtual parameters based on each players' skill from the ball's data. This research focuses on which gameplay elements benefit from technology. The amount of movements that exist in the sport (throwing, dodging, and catching) are applied to the game mechanics (damage, health, and defense) [2]. For example, if a player wasn't good at throwing or dodging a ball, then the virtual parameters can be changed to improve

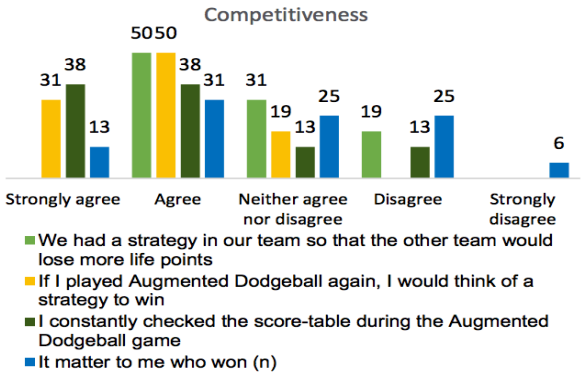


Figure 7: Player's competitiveness playing Augmented Dodgeball (Represented as percentages) [3]

a specific players' attack or defense points. The virtual parameters can be changed by the physiological advantages or disadvantages of each player. The data recorded from the ball is used for a more balanced playing field.

3.2.1 *Technical Specifications*

In this system, the technology focuses on the ball system hardware rather than the attributes of the players. The technology focused on augmenting the perception of the game rather than the perception of the player. The ball system hardware used is a sponge ball with an internal mechanism. This internal mechanism is installed in the hollow crevice cut out of the ball core, acting as a wireless "brain". The "wireless brain" is embedded with vibration sensors and wireless transmission modules controlled by the core as seen in Figure 8 .

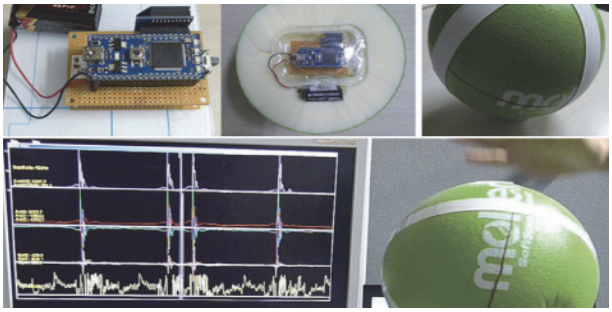


Figure 8: Ball system hardware. Inner core of the ball (top left), Visualization of the ball sensor (bottom), prototype of the ball (top right) [2]

3.2.2 *Prototype Details*

The results of the study are from the researchers themselves because the system is still in the prototype process. The study shows that the wireless networks of the internal mechanism of the ball offers both the ability to control the game and player access based on quantitative data for the augmentation of the virtual parameters. The prototype of the ball consists of an internal mechanism inside the ball that can detect when the ball is incoming to hit a player up to a distance of 10–30 centimeters. The future of augmenting dodgeball has many possibilities such as incorporating more player data such as heartbeat and caloric amounts. This research provides a strong foundation for the augmentation of various sports played with a ball in the future.

4. CONCLUSION

The paper presented an overview of the benefits augmented sports systems provide visually, physically, and mentally. The advantages consist of boosting social, physical, and mental involvement, improved experience, and an increase in enjoyability. Interactive augmented visuals increase the physiological senses of players. Virtual parameters enforced team play and communication between players, made lower skilled players see the game differently, and level the playing field. Overall these augmented sports systems create an enjoyable environment that decreases the skill gap between players.

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