Realistic Boccia Game Simulator Adapted for People with Disabilities or Motor Disorders: Architecture and Preliminary Usability Study

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Abstract. Over the last decades, Serious Games have gained increased importance, mainly due to the evolution and expansion of video games and its application in multiple areas. Integration in the world of sport is one of the solutions that individuals with disabilities or motor disorders develop to feel more socially integrated, more independent and confident with themselves. Boccia is a Paralympic sport that is increasingly getting more attention around the world. This has contributed for the objectives of this project since it attracts these patients a lot more easily and including it in the Serious Games category enables them to develop and rehabilitate their cognitive capabilities. It will allow the users being dynamic, holding their attention and motivating them instead of the traditional cognitive rehabilitation processes that quickly become repetitive and discouraging. This paper describes a realistic Boccia game simulator adapted for people with disabilities or motor disorders still on development that aims to integrate a set of features that include real physics, multimodal user interface and social features (diversion, rehabilitation, competition and improvement). These features can be used to enhance the interest of non-practitioners of the sport and to improve the training conditions of Boccia athletes. Results observed in an experiment with real Boccia game components indicate that the simulator offers great similarity to the reality with the maximum difference between the measures obtained in both being 10 cm.

Keywords: Boccia · Simulator · Realistic · Serious games · Games · Rehabilitation · Game engine · Multimodal interface · Health informatics

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1 Introduction

This document shows a first approach to the subject of an ongoing work, in which the primary goals of the project are defined as well as the work done so far. It is also presented the subject contextualization and motivation that led to the choice of developing this project.

Over the last decades, the quality of life has increased, causing the increase of life expectancy and therefore, the increased number of people with a disability or impairment, especially in terms of mobility [1]. This problem causes the level of autonomy of these people to be very small. Due to technological advances in the fields of artificial intelligence, robotics simulation and graphic and physical computations, it is possible to develop simulators capable of enabling advances to help solve this increasingly recurring problem. The importance and concern for such problems has been increasing over the years, and one of the major focus points is the integration into society [2].

One of the solutions developed for these individuals to feel more independent, more autonomous and more confident with themselves, both socially and vocational level, it is the integration in the world of sport. The Boccia is a Paralympic sport that has generated a lot of attention around the national level due to the great results achieved by the Portuguese federation [3], which led to the aspiration of developing a simulator of the sport. This tool was thought so that athletes can make their practice more independently and without the help of a coach.

The main motivation of this work comes directly from the problem described above, and is an effort to help close the gap between people with lack of mobility and people without mobility problems. As the athlete does not have sufficient autonomy to move the launch pad of the ball without help or even put the ball in the top of the ramp, he is extremely dependent on their coach. Through the simulator, is expected to greatly increase the athlete's autonomy to control the ramp, since it will be a robot that will move based on the athlete's orders, taking into account their limitations.

These aspects allow the removal of the athlete's coach during training, thus reducing costs involved in these (as the dislocations to the training camps or the constant presence of the coach), allowing the training from home and possibly enhance the performance of athletes in competitions. Because it is a simulator, it also allows the attractiveness of other users who are not athletes of this sport, encouraging social integration. Another reason is the fact that this is an innovative project with great social impact, which can be upheld by Boccia associations to benefit the training of their athletes.

In a previous study was made a literature revision on Serious Games [2, 4], Game Engines [5, 6] and User Interfaces [7] that was used to decide which ones had the best features allowing a successful achievement of this work's main objective. The goal is the development of a simulated game of Boccia adapted for people with disabilities or motor disorders using a realistic virtual environment with the physics accessories as similar as possible with the real ones (created with the help of the resources provided by the game engine chosen).

The game should be aimed at the entertainment of casual users (developing their social interactions and interest in the Paralympic sport) and to allow the training of the athletes from the comfort of their home without the need of a coach to provide constant help they need. It should also favour the athlete's training to achieve better results. It will allow the participation of at least two players and these players will be able to control the launching pad of the ball (through the virtual joystick or by using the multimodal interface (MMI)) in the most appropriate way to their limitations.

The rest of the paper is structured as follows. Section 2 presents the importance of Serious Games and some of the main features of the Game Engine and the User Interface chosen that were essential to the development of the simulator to be the most realistic and adaptive as possible. It also presents some of the existing game simulators and their main characteristics making the comparison possible between those simulators and the one under development. Following, Sect. 3 describes the final aim that the simulator should achieve as well as its features and the work developed so far. Section 4 describes the experiment used to compare the simulator with a real Boccia game and Sect. 5 presents the results of user testing using the experiment described in the previous section. Section 6 presents the major conclusions and some directions for future work.

2 Problem Characterization and Proposed Solution

Serious Games are games that do not have entertainment as their main purpose. They are more of a mental contest, played with a computer in accordance with specific rules with the main objective of further improve the knowledge, skills and aspects related with education, healthcare, defence, training and other pedagogic components (although they are not necessarily deprived of entertainment, enjoyment or fun) [8].

This term is becoming a lot more popular since video games are getting increasing audiences with an expanding age range, they can be of any genre, use any game technology and be developed for any platform. As they can have many applications, the main focus of the current research is the rehabilitation area for patients with impairments and disabilities. That happens because it has been shown that the patients function can be improved with intensive training, however, the problem is that the lack of the patient interest in performing repetitive tasks significantly increases over time [2].

Since the traditional treatment approaches include exercises often considered repetitive and boring for patients, using computer games to improve physical and cognitive rehabilitation can offer the potential for a significant therapeutic benefit (even in the management of pain since it distracts the patient's attention) [4].

One of the main technologies used in the rehabilitation of cognitive and motor deficits is the application of Virtual Reality (VR), since the VR based-methods can offer the patients really immersive experiences that are engaging and rewarding for them [2, 4].

Based on the literature review made until now, below are presented some of the existing game simulators that represent virtual environments of the game Boccia and their main characteristics:

- *"Virtual Boccia"* – Puts the user in the perspective of the ball thrower and by using the Wiimote, he can control the ramp inclination and throw the ball using arm movements, although the ramp is not visible. Was developed to prove that the simulated practice of this sport can influence its real practice. It has no cost and is available to install in any personal computer [9];

- *"Boccia o simulador"* – A project developed in "Universidade Técnica de Lisboa", in Portugal, and it is a very basic version with unintuitive graphics and without proper interfaces for its users (since it only allows its control by mouse, keyboard or joystick) [10];
- *"BocciaSim"* – A project developed by two high-school students and is a very basic simulator that can only be controlled by the mouse and keyboard. This simulator was to be updated but the project was left in a final version without much characteristics that highlight it. It is in 2D and has no advantages or even possibilities to be played by patients with physical disabilities [11].

As can be seen that there are not many Boccia game simulators, and the ones that exist cannot adapt to the various users with different physical and psychological conditions.

That is the reason why it is so important to implement a user interface that can aid the simulator to adapt automatically to the various disabilities. Thus allowing a bigger range of people to play the game and even help the practitioners practice without having to dislocate to the training fields and without the constant help of the trainer.

The idea for this project appeared from a previous work of a Master's Degree that had the objective of developing and implementing a virtual representation of some adapted sports [12]. The major purpose were *Motorized Wheelchair Football* and *Boccia* involving adapted electronic devices. For this purpose, it was integrated a MMI capable of controlling the games components, providing flexibility and adaptability. When the project described above was finished it focused more on the *Motorized Wheelchair Football.* Were created various variants of the game such as: a game that had the objective of driving a ball from an initial point to an ending point through a map with multiple walls where the user had to go around them; a game where the user had to bring the ball into the goal various times along the map until reaching the ending objective; a game where the objective was the placement of multiple objects with different shapes in the holes with the right shapes; and, by last, was created the football game itself, that had two players against each other and they had to put the ball into the goal of the opposing player [12].

As can be seen with the work described above, the *Boccia* scenario was not developed so much. Therefore it was only created an arena with an objective square in the floor where the player had to drive the designed ramp to it and aim the balls against the three existing objective targets. Since its main goal is not much related to the Boccia sport itself, it served only as a base to what was needed to be developed in the project of this dissertation [12].

With what was said above in mind, the ongoing work aims to develop a realistic Boccia simulator, so that the practitioners that carry the various physical and psychological conditions, can practice this sport in a more autonomous way.

The simulator will consist on the representation of the field, the rules and ball throwing platform (Intelligent Robotic Ramp (IRR)). The ramp will be a robot that will move according to the user's orders, positioning as the user wants (both position and inclination parameters). The main focus will be on the user's ability to manage as independently as possible the launch pad. The system must be provided with a MMI, which allows the user to create his most appropriate usage profile.

After all the research made for the proposed project it was defined that it was needed at least a game simulator, a robotic simulator and a user interface. Using all the comparisons made between the available solutions, it was relatively easy to reach a decision on which ones to use and learn more about their capabilities and how to use them. The fact that some of them have already been used in a similar project targeted for people with CP (made by another student about simulated serious games using multimodal interaction) [12], helped with this decisions.

Speaking first of the game engines they are applications that allow graphic processing in real time that through the abstraction of physical and graphic concepts facilitates the creation of virtual games. Its objective is to remove from the user the responsibilities of understanding the low level architecture, such as the mathematical and physic formulas that are responsible for the visualization and collision detection of the objects in the virtual space [5]. The best one for this work was definitely the "Unreal Engine" (UE4). It is ideal to represent realistic environments and objects due to the high graphics and physics accuracy, realistic collision detection, which is very important for this project. The sub-editors that it provides allows a realistic object creation and personalization [6].

As it was needed the development of the IRR for the Boccia simulator, was needed a robotic simulator (a development platform that represents the robotic behaviour in a virtual environment allowing the representation of real robots in simulated environments). Also allows a detailed analyses of the behaviour that the robot must have bearing in mind his ultimate goal. This kind of simulators are a very important part in this project because they allow the creation of applications for robots without actually having a real robot [5].

The best choices were the USARSim and the V-REP. The main feature of USARSim is that it uses the UE4 so there is no need to worry about the adaptation between the robotic simulator and the game engine while still having high accuracy representing simulated robots [13]. Comparatively, the V-REP has the capability of a really realistic robot simulation, probably better than the USARSim, and a great development environment with much more functions. The V-REP has to import and convert the data to be used by the UE4, despite of having a low complexity on that level [14]. So, based on the study made, the V-REP was chosen because it had a low complexity and it was more realistic, which is the main goal of the project.

Regarding the user interface, it supports the interaction between a human and a computer, because it allows the users to control the machine in an appropriate manner to their physical and psychological limitations. The main feature of these Interfaces is the adaptability, which can improve the interfaces capability to interact with a user based on the experience with that user. Using that experience data and some tests it is possible to adapt the interface according to the limitations of its user, optimizing the communication Man-Machine [7].

As a user interface, it was chosen a MMI because it allows multiple input methods what grants the possibility to make the interface adapt automatically to the users easily and to create specific and customizable profiles for each. This feature is really important to the project since the main target users are people with physical and psychological conditions. The fact that an application can adapt to its users so a vast group of conditions can be covered allows most people to practice the sport without problems. It also removes the necessity of moving to the training field in the case of official athletes or even prevent users from getting frustrated in the case of casual players [15]. Of all MMIs, the one already developed for the project *IntellWheels* (one of the main projects associated with this one), will probably be the chosen one because it was carefully thought and it adapts perfectly to this work [16]. The project quoted above consists in an intelligent wheelchair simulation and visualization platform that can be adapted to any commercial wheelchair and thus assist any person with special mobility needs [17–29].

Finally, all these choices were decided by thinking in the main characteristic of the game, which is to create the most realistic Boccia Simulator possible. To make that achievable, was provided access to a real Boccia ramp so that physical measurements could be made, both of the several balls available as the different trajectories attainable by the many positions of the ramp, since the ramp can have multiple angles vertically and horizontally.

3 Realistic Boccia Simulator: A Simulator of Serious Games for Athlete Training and Casual Users Inclusion

A Simulator adapted for use by the Boccia athletes to train and by casual users for recreation or to enhance their interest in the sport has been developed. In this section is described the development process of this solution.

The first step in the development of the simulator consisted in defining features to be included in the environment created so that it could be as realistic as possible. It was decided that the simulator should contain rehabilitative features (capable of stimulating at least one cognitive function), as well as some proposed features in this research as a way to improve the motivation of patients within the rehabilitation process (use of natural interaction interfaces and social features as competition). The implementation of rehabilitation characteristics is a complex task. Not only because it depends on the limitations of each patient but because its design must be made effective by a multidisciplinary team composed by professionals from various fields (such as physicians, psychologists and therapists, among others). In this work, it was decided to integrate a MMI, used in a previous project, to allow the simulator to adapt to each user and to his limitations. This is made by creating a profile for each player that indicates the more adequate way of interaction with the simulator [30, 31]. The available choices are keyboard, joystick, head movements, voice recognition, facial expressions or hand movement. After that, the step to be taken was the creation of a realistic Boccia field (Fig. 1) so that the users could feel like they were in a real field instead of just a basic floor with the markings on the ground. So the markings were made in the floor of the field using the real measurements, which are a field (with 12,5 × 5 m) with play boxes (that are 2,5 × 1 m) from where the players have to throw the ball from [3]. Posteriorly, it was made an approximate representation of a sports hall and was added standings, doors, windows, spotlights to recreate the lighting, benches for the player's teams, a scoreboard, a clock and even two referee models. All this was made with one of the main objectives in mind which was to develop the simulator as real as possible when compared to a real game of Boccia including its tools and components.

Fig. 1. On the image to the left is a representation of the environment of the Boccia field developed and on the image to the right is the Boccia ramp created for the simulator.

The following objective to accomplish was the development of a realistic Boccia ramp where first was created a mobile robot using the robotic simulator chosen (V-REP). This allowed the ramp to be moved around and to change its inclination realistically. So that the ramp could be as realistic as possible, all the measures of a real Boccia ramp, provided by the Portuguese Association of Cerebral Palsy (APPC), were taken (which were 95 × 12 × 80 cm with an inclination angle of 45 degrees). Then, using the mesh editor MAYA 2016, was created the ramp with those measures and added to the robotic model with a mechanic arm serving as connector. When the development of the IRR was done (Fig. 1) it was programmed its forward and backward movement in the robot as well as its rotation. These allowed the ramp to be moved inside the play boxes and to aim the balls with precision to where the user wants them to go. For the ramp itself, it was added the change of its inclination from 40 (lowest height) to 50 (highest height) degrees by rotating the ramp and changing the length of the mechanic arm. The ramp was coded to not allow any kind of movement after the active ball is thrown until the next ball becomes active. Regarding the Boccia balls, they were also added with their real specifications measured from balls provided in conjunction with the ramp, where their weight was 250 g and their diameter was 8,6 cm [3]. As there are many types of balls relatively to their toughness, it was decided to include three different types: soft, medium and hard. Was developed a function so that could be controlled its acceleration and friction allowing an easy creation of balls with different toughnesses (was designed taking in consideration the results obtained from the comparison tests explained in the next section). Was also added the possibility of changing the spawn position of the ball in the ramp where the user can chose between three different positions: Top, 3/4 and Middle. These were the positions used in the comparison tests so that when the simulator is used it will produce results really approximate to reality. Finally, were allowed two different viewpoints of the field with: a camera behind the IRR (that allows aiming the balls) and another one on the ceiling (that allows the user a view of the whole field from above for strategic purposes). Besides those two points of view, when the ball is launched the camera changes to a chasing-camera attached to said ball.

Notice that the UE4 allows the use of a Blueprint-based coding which means that no hard-code was referenced since it was not applied. This blueprint-based coding recurs to graphic blocks which are equivalent to hard-code functions. These blocks can either be very simple functions or complex algorithms [6]. The settings of the project were changed in order to equalize a centimetre to an Unreal Unit (UU).

4 Comparison Testing

The tests described here were designed primarily to assess a preliminary usability and the reality of the simulator, to see if the IRR developed and the physics of the balls created were approximately equal to the real ones provided. The comparison tests counted on a total sample of 270 throws using the real balls and ramp, and one throw for each position of the ball and inclination of the IRR in the simulator. It was required these throws in the simulator because it uses a mathematic model to simulate its physics so the results are always the same using the same specifications. The first test performed was in a real environment using the real Boccia equipment. It was taken in consideration the characteristics of the floor of a Boccia field during the test and so these were made in a floor with the same characteristics. The test field had a length of 10 m where was used a measure tape that allowed us to register the distance travelled by the balls in each situation. There were three different types of Boccia balls used in the tests where were used two balls of each type (with slight different specifications and insignificant to the value of the tests) and each type had a different toughness: soft, medium and hard balls. Regarding the ramp, were used three different inclinations: 40º, 45º and 50º and three different positions of the ball along the ramp as well: top, 3/4 and mid ramp. For each combination of the possibilities described above were made 10 throws, registered the results disregarding the lateral deviations as they cannot be reproduced in the simulator. Then was calculated its mean (Table 1) and standard deviation so it could be compared to the single result of the simulator (Table 2). After that, were made the simulator tests where was made one throw for each situation as well. This allowed the refinement of the values used for the physics of the balls so that the results could be as close as the real ones.

Table 1. Mean of the obtained results in the real environment tests in metres.

	Soft balls			Medium balls			Hard balls		
	40º	45º	50º	40º	45º	50º	40º	45º	50º
Top ramp	3,072	3,732	4,058	5,784	6,598	7,529	6,136	7,059	8,021
¾ Ramp	2,388	2,509	3,025	4,509	5,216	6,194	4,917	5,702	7,122
Mid ramp	1,716	1,839	2,315	3,652	4,467	4,863	3,909	5,002	6,180

Table 2. Obtained results in the simulated environment tests in metres with a measurement error of 10 cm.

	Soft balls			Medium balls			Hard balls		
	40º	45º	50º	40º	45º	50º	40º	45º	50º
Top ramp	3,1	3,8	4,1	5,7	6,6	7,5	6,2	7,1	8
¾ Ramp	2,4	2,6	3,1	4,5	5,3	6,2	4,9	5,7	7,1
Mid ramp	1,7	1,9	2,4	3,6	4,5	4,8	4	5	6,1

5 Results and Discussion

The results of the real environment tests were registered taking in consideration an inclination error of 2°, a measurement error of 5 mm and a standard deviation of 0.46 m. As can be seen in the tables below (Tables 1 and 2), the results wanted have been easily achieved since the game engine used allows a really easy change of parameters and customization of the physics related to the balls. These results were obtained using a methodology based on an iterative method of successive approximations. It follows the gradient, in order to minimize the absolute sum of errors between the distances in the simulator and the mean of the distances obtained from the tests. The acceleration and the friction of the balls were changed based on the real distances travelled measures acquired until the desired results were achieved. In the simulated environment, the maximum absolute error of the measures taken was defined at 10 cm. It happens because the values of the parameters chosen for the balls to get the right distance in a certain inclination had small deviations from the pretended distances for the other two inclinations. Possibly, this error can be shortened by choosing some different values for the parameters where, instead of only having an error in the two inclinations referred above, this error will be distributed equally for all three inclinations. The executed tests had a major importance to the development of the simulator, since they allowed the recreation of realistic balls. The ball's distances travelled and the collision characteristics were one of the focuses for implementing the simulator in the Boccia athlete's scene.

6 Conclusions

It is being developed a Boccia simulator with the objective of being realistic and integrate in the Serious Games category with its social features and user interaction via MMI. The usability and approximation to reality were evaluated based on the tests performed. The usability was considered to be the capability of the simulator to represent the reality with a high reliability as it is needed to accomplish the objectives of this work, resulting in a positive assessment which means the simulator is complying with the main objective (realism). For future work is intended to finish adding the rules of Boccia to the simulator including the player's turns as well as the score interface. Finally, if possible, integrate the MMI for the user profiling which is very important feature regarding the adaptation context because it allows its users to interact with the simulator using the most adapted way for each (such as keyboard, joystick, head movements, voice recognition, facial expressions or hand movement). Is also aimed to validate the simulator on a population with limitations (either physical or cognitive) which can be preferentially composed by casual users that never played Boccia before and by federated athletes. This validation can be effectively performed via quiz considering all the related features such as its reality, usability, adaptation, attraction and its social/cognitive rehabilitation capacities.

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