Boccia Court Analisys for Real-time Scoring

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Abstract: This paper aims to develop a tool to increase the engagement and commitment of the elderly population in the Boccia game. This tool is based on the implementation of a real-time computer vision algorithm that analyses the Boccia court field and displays the score in a graphical user interface. In Portugal, physical inactivity is associated with 14% of deaths per year, higher percentage than the world average, which is less than 10%. In this paper, the Boccia game is used for promoting physical activity in the elderly, due to its simplicity and adaptability to their physical impairments. This system intends to encourage the elders to lead a more active lifestyle, providing a healthier life and possibly reducing the risk of major diseases and injuries.

1 INTRODUCTION

Physical inactivity is known to be the fourth leading risk factor for death worldwide (WHO, 2010). Regarding disease burdens, according to the World Health Organization (WHO, 2015), 5% from coronary heart disease, 7% from type 2 diabetes, 9% from breast cancer and 10% colon cancer are estimated to be the consequence of a deficit in physical activity practice, thus resulting in 1 million deaths (10% of deaths) only in the WHO European Region.

In Portugal, it is estimated that physical inactivity is associated with 14% of deaths per year, which is a higher percentage than the world average (lower than 10%) (Direção-Geral da Saúde, 2017). Besides, it is estimated that in a country with 10 million inhabitants, which is approximately Portugal's population, if 50% are insufficiently active, there is a cost associated with physical inactivity of €910 million per year (WHO, 2015), which is approximately 9% of the Portuguese Ministry of Health's budget in 2017 (Direção-Geral da Saúde, 2017).

Amongst all age groups, the elderly is one of the most physically inactive. (Matthews et al., 2008) have identified adults older than 60 years to be the most sedentary group in the United States and, moreover, it is suggested that 50% of sedentary adults have no intention of starting an exercise plan (Schutzer and Graves, 2004). According to (Instituto Nacional de Estatística, 2016), this reality is not different in Portugal. In a country where the majority of the population aged more than 15 years does not practice any form of physical activity on a regular basis (5,8 million), only 19% of the population aged more than 65 years practices physical activity regularly.

Facing these concerning statistics, along with the current increase in older population, comes the need of developing new strategies for motivating the elderly to engage more frequently in physical activity, which can be very beneficial at such age. Amongst the panoply of benefits that physical activity can offer, the prevention of functional loss (Stessman et al., 2009), reduction of the risk of falling (Gillespie et al., 2012), blood pressure control (Westhoff et al., 2007), improvement of the bones and joints' health (Lee et al., 2012) and maintenance of mental health (Salguero et al., 2011) are particularly important for the elderly, along with lower risks for all-cause mortality (Landi et al., 2004).

The (WHO, 2010) recommends adults aged 65 years and above to engage in moderate-intensity aerobic physical activity for at least 150 minutes or engage in vigorous-intensity aerobic physical activity for at least 75 minutes throughout the week. Alternatively, an equivalent combination of moderate and vigorous intensity activity can be done. However, when such amounts of physical activity cannot be reached due to health conditions, which happens often at a late age, the individual should be as physically active as his/her limitations and abilities allow. As mentioned in (Landi et al., 2004), even simple everyday activities, such as walking,

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gardening or housekeeping seem to offer considerable benefits for frail and older individuals.

Bearing this in mind, there are several examples of sports and games that are not physically demanding and can be played by the elderly with reduced mobility, such as darts, *pétanque* or even bowling (using a plastic ball). Another excellent example is the Boccia game, a simple precision ball sport similar to *pétanque* that was initially designed to be played by individuals with cerebral palsy. Due to its easy adaptability to the physical limitations of the players, later it became a game played by persons with other disabilities affecting motor skills. Furthermore, as a team sport, it promotes social interaction and motivates individuals to participate more often (Estabrooks and Carron, 1999). All these characteristics make Boccia an excellent game to encourage physical activity practice amongst the elderly.

Based on the aforementioned remarks, this paper proposes a system that uses a computer vision algorithm based on object tracking to automatically compute and display the game score of a Boccia match in real-time. The main objective of this system is to make the experience of playing Boccia more fun and enjoyable while promoting its practice, therefore motivating the elderly to engage in physical activity.

In a later stage, the proposed system will be tested during a Boccia match played in an actual nursing home, thus its development was based on the modified game rules used by the caregivers, along with the characteristics of the room where the game is usually played.

In future work, the proposed system will also be integrated in the iBoccia framework (Figueira et al., 2017; Silva et al., 2018) which features the use of inertial sensors along with Microsoft Kinect to monitor the player's physical activity throughout a game of Boccia. The extracted data will be stored in a database and processed afterwards to help enhance the player's performance in the game and provide relevant information for the caregiver such as the detection of physical or cognitive decline.

This paper is organized as follows: section 2 offers a state-of-the-art regarding object tracking in sports. It also presents a brief description of the Boccia game and its rules, along with the modified rules that are used in the nursing home. Section 3 presents a thorough description of the system's architecture. Section 4 describes the preliminary results from the tests performed using the proposed system. Finally, section 5 presents the conclusions taken from the obtained results, along with future work.

2 BACKGROUND

The Boccia game has been used as the context for a limited number of studies regarding motion analysis of the throwing movement involving individuals with cerebral palsy (Huang et al., 2014; Tsai et al., 2014), as well as individuals suffering from other disabilities affecting motor skills (Arroxellas et al., 2017). Regarding Boccia scoring systems, (Wang et al., 2017) developed a computer competition system and a computer scoreboard system to be used in official Boccia events and competitions. However, within the Boccia context, no literature was found concerning object tracking or real-time game score computation. Nevertheless, in the last years there has been a growing trend for using computer vision in sports analysis.

Object tracking is particularly relevant for sports analysis and different tracking techniques have already been used in various works. For instance, (Pingali et al., 2000) implemented multi-camera estimation for tracking the motion of a tennis ball in 3D. In this technique, six fixed cameras are placed around the area of play and the resulting images are processed afterwards to mount a 3D image which allows the tracking of the ball's entire trajectory. This technique is also used by the Hawk-Eye system ("Hawk-Eye", 2018), which is currently applied in a wide variety of sports, such as football, cricket and tennis.

(Wu et al., 2006) developed an algorithm for the detection of a basketball based on its colour and shape, using clustering. If the detection was succeeded, then, the ball tracking would start in the next frame. This algorithm was successfully used in videos of a basketball tournament, thus eliminating the need of additional cameras as in multi-camera estimation.

Another tracking technique, called mean-shift, was used by (Kim, 2015) by detecting the colour and edges of a curling stone.

On the other hand, (Yu et al., 2003) have used trajectory-based optimization for the tracking of a football in a broadcast video. In this case, the algorithm does not evaluate if an object is a ball, instead, it evaluates if a candidate trajectory is a ball trajectory.

More advanced approaches include the use a physics-based algorithm for predicting the ball's trajectory in 3D. This algorithm exploits the 2D ball trajectory, along with the court lines, to reconstruct the 3D trajectory and compute the shooting location. This technique has been successfully used in videos

of basketball (Chen et al., 2009) and volleyball (Chen et al., 2011) matches.

In sum, the implementation of object tracking techniques, such as the one presented above, in sports can offer a panoply of advantages, as improving the spectators' experience, enhancing the training process of professional athletes, providing valuable information for the referee's decisions, presenting richer statistical analysis (Wang et al., 2006) or, as the authors of this paper propose, motivating physical activity.

2.1 The Boccia Game

Boccia is a strategy-based precision ball game that is not as physical demanding compared to other sports. The player only has to perform a throwing movement, which allows the participation of individuals with different levels of impairments.

Boccia can be played individually, by pairs or by teams. In the latter, which is the case considered in this paper, players are divided into two teams, the red and the blue. Each team features three players and each of them receives two balls of the respective team colour. Briefly speaking, the main goal of the game is for the players to place their team balls as close as possible to a white ball, called the *jack*.

According to the BISFed International Boccia Rules (BISFed, 2017), each Boccia match is divided into six "ends". Each end finishes whenever both teams have thrown all of their respective balls and the game score is noted as it follows:

- The team that placed the ball closer to the *jack* scores one point for each ball placed at a shorter distance from the *jack* than the closest opponent's ball to the *jack*.
- If two or more balls of different colour are equidistant from the jack, each team scores a point per ball.

The sum of the points of all the six ends determine the winning team. If both teams finish with the same number of points, further ends will be played until the tie is undone.

In previous work developed by the authors of this paper (Calado et al., 2018), the game score was computed according to the aforementioned rules. Although these are the official game rules, Boccia can be easily readapted for a nursing home environment. In the nursing home where the system will be tested, the game rules have been changed by the caregivers in order to simplify it as much as possible. This has been done due to some of the residents having serious cognitive disabilities.

Having this in account, during each end, each time a team throws a ball and hits the jack, this team scores one point. Similar to the official rules, the winning team is determined by the total of points from the six ends. In case of a tie, the team that has the ball closest to the jack after the sixth end finishes wins the game.

3 PROPOSED SYSTEM

In this section it is described the proposed system that allows the graphical user interface (GUI) to display the real-time score of a Boccia game. The score was calculated using rules suited to the specific features of the nursing home, as previously described.

3.1 Experimental Setup

The system's architecture (Figure 1) consists of a camera, a computer and a graphical user interface (GUI).

Figure 1: System Overview.

The RGB webcam used was the Microsoft LifeCam VX-1000, with a resolution of 0.3 MP (640 x 480), a field of view (FOV) of 50º and a maximum frame rate of 30 fps.

3.2 System Description

Figure 2 shows the block diagram of the developed system.

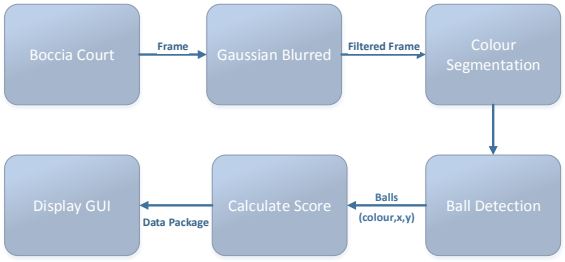

Figure 2: Block diagram of the developed system.

The webcam captures the Boccia court and provides a stream of frames, at 30 fps. Each individual frame is analyzed to detect the ball

position. Initially, the frames go through a pre-processing stage, where a Gaussian blurred filter is applied to reduce image noise.

The computer runs an application developed in Python programming language that implements a colour segmentation technique to detect the balls positions. To detect all the three ball colours (blue, red and white), a colour mask was defined in HSV (Hue Saturation and Value) space. In order to be dependent on the light conditions, a sensitivity margin was implemented, by trial and error, to cover the desired range of colours.

Next to the colour segmentation, a few computer vision techniques such as erode and dilate were performed as well as the evaluation of some ball metrics, such as radius and circularity in order to create a set of valid balls. Then, each ball was categorized with its colour, center, radius, *x* and *y* positions.

When the balls were correctly detected, the algorithm computed the distance between each of the blue and red balls and the *jack*. If this distance was less than a threshold value and the *jack* ball had moved, it would be considered a valid point.

Finally, a data package was created with the current score and sent to the developed GUI to be displayed.

3.3 Communication

The communication between the algorithm that calculates the real-time score and the GUI is done using JSON format over the TCP/IP protocol.

An example of a JSON message to send/receive the score can be seen below:

```
{
    "instruction": "SCORE_INFO",
    "red_points": <[0, 3]>,
    "blue_points": <[0, 3]>
}
```

3.4 Graphical User Interface

The Qt framework was used for the development of the GUI, which can be seen in Figure 3.

The GUI was developed with the goal of being intuitive and to be easily understood. It can be described in three parts: left side, centre and right side, where the left side concerns the red team and the right side the blue team.

On both the left and right sides, it is possible to see – on top – the score of the current game scenario – on the middle – the registry of the scores from the six ends – and on the bottom – the total number of points accumulated during a game.

Figure 3: Developed GUI in Portuguese language. Dashed in blue – current score; dashed in green – number of the end being played; dashed in yellow –registry of the score from the six ends; dashed in white – total score.

On the centre, the number of the current partial being played is displayed. There are also two buttons, one to increment the partial and another to reset the system.

4 PRELIMINARY RESULTS

The proposed system was tested in a nursing home, where the elders were familiar with the Boccia game with adapted rules, in S. Torcato, Guimarães, Portugal. As referenced by the caregiver, these rules state that, at beginning of the game, the *jack* is placed at an arbitrary distance from the players, according to the individual's impairments. Moreover, a team scores when a ball is thrown and collides with the jack ball.

In previous work, the authors have recorded several videos from different perspectives of simulated game situations, along with the actual playing of four ends. From the latter, only three of the videos contained situations where a coloured ball collided with the *jack*. Thereby, the algorithm was tested in each of these three recordings and the computed score was compared with the real score corresponding to that situation.

Considering the three videos, the algorithm computed the score from two of them correctly. In the last video, the score was calculated incorrectly due to an issue with the camera's perspective, which caused the algorithm to assume falsely that a collision had occurred. In this case, a collision between a red and blue ball caused the red ball to jump in the air and partially occlude the *jack*, thus misleading the algorithm to compute a false result by awarding one point to the red team. In spite of the small number of cases, the algorithm showed promising results.

Figure 4 depicts a game situation, contained in one of the videos, where a blue ball collides with the

jack. As it can be seen in Figure 4 (a), the blue ball has a yellow arrow signalling the motion direction towards the *jack*. After the collision, Figure 4 (b) displays the correctly computed game score.

(a)

(b)

Figure 4: Example of one of the recorded game situations. In situation (a), no previous scoring events have occurred, and the blue ball is going to hit the *jack*. Later, in situation (b), the blue ball had collided with the jack ball and the score of one point for the blue team is computed correctly.

5 FINAL REMARKS

In this paper, the authors proposed a system based on a computer vision algorithm that allows the automatic computation of the game score during a Boccia match and its display in a GUI. The purpose of this system is to enhance the playing experience of the Boccia game and to encourage the elderly to engage in physical activity on a regular basis.

The computer vision algorithm was tested in three videos, recorded in the nursing home, containing Boccia gameplay with ball collisions. The obtained results showed that all collisions were detected correctly, except for one. False positives, such as this one, can occur due to the limited 2D perspective, which may induce the algorithm into assuming that a collision occurred when the *jack* becomes occluded by another ball or vice-versa.

Regarding ball detection, luminosity conditions are also an issue because they can affect the colours reproduced in the camera's image, leading to false positives, thus affecting the game score. The detection based on colours, by itself, is also an issue due to the need of manually adjusting parameters if the recording environment is changed. A solution for this issue could be the implementation of a calibration method, hence making the system more flexible.

Regarding future work, the developed system is going to be evaluated in a real-time scenario during a Boccia match played by the resident elders of the nursing home in S.Torcato in order to assess its performance. This evaluation will be based on several metrics, in a first phase, the algorithm will be tested to reduce false positives and improve the detection rate, and, in a second phase, a usability test will be performed. The objective of performing such tests is to infer if the elders can easily understand the graphical display containing the score. It is also important to comprehend the level of trust of the users in the proposed system, along with their degree of satisfaction. Regarding the promotion of physical activity, as can been seen in serious games, in most cases a rewarding system is implemented. This could be done by simply including the photo/name of the player on the GUI when he/she wins. It would also be interesting to include in the GUI the photo/name of the user while he/she plays.

The usage of machine learning for ball detection and tracking is also a possibility to be explored in the future. Such techniques could help improving the system's performance by having a more robust detection rate and a more stable tracking.

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