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# DEVELOPMENT OF SERIOUS GAMES FOR A ROBOTIC DEVICE TO ASSIST AT WRIST REHABILITATION

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*Abstract. The purpose of this paper is to describe the serious games that are being developed to work together with a robotic device in the assist of the human wrist rehabilitation. As the dispositive permits the main movements of the wrist, the serious games must receive the user movements and understand whether the player is able to move the device or not, helping the player in the case of some difficulty.*

*Keywords: physiotherapy, rehabilitation robotics, serious game.*

## 1. INTRODUCTION

Since the emergence of the first electronic games, with William Higinbotham's "Tennis for Two" in 1958 (Leite, 2006), humanity has sought to improve these systems in an attempt to be more and more useful to a machine entertainment. It estimated that, over the years, there was an increase in the production of these games and in their purchase as well, showing that the world accepted them in a hegemonic way as an entertainment tool. With advances in technology and the growing need for improvement of the electronic tools used to help man for his daily and scientific activities, electronic games present themselves as a possible alternative to complement this reality, increasingly growing in concept and lacking new devices and adaptive systems.

To fit these new needs, the concept of serious games was created, first mentioned by Clark C. Abt (1987). Serious games are games in which there are a mental challenge for the player, with the use of a machine, for improvements in health, education, public policies, corporate or governmental training, among others (Rego et al., 2010; Michael Zyda, 2005).

From this conceptualization, the serious games began to use as a possible alternative to entertainment, but also to help in other spheres of human life (Azevedo, 2012; De Morais et al., 2015; Gonçalves et al., 2019; Pereira et al., 2019) like in the rehabilitation field.

Rego et al. (2010) show that since traditional approaches to treatment in rehabilitation, use often boring and repetitive exercises, the use of computer games for the same purpose of rehabilitation offer a potential therapeutic benefit. The serious games require the movement physics and cognitive work of the patient in rehabilitation, demanding a level of attention and interest that these games can captivate. In addition, these games give the player a sense of challenge and, as they reach the goals of the games, the sense of progress and adaptation is generated, as well as being a mechanism of pain management. Then, in conjunction with the previous idea, it's remarkable that gaming can turn a common and repetitive activity into something more enjoyable for the patient, therefore motivating it to continue evolving to get better (Finco, 2010).

It is important to emphasize that these games, although developed with the general purpose of rehabilitation, focus on adaptability, that is, that the patient, at his level of injury or difficulty, can play in a system that suits his demand, working with assisted as needed control (Ibarra, 2014; Hogan, 1985) to give a dynamic interaction to the patient.

In a study on the application of serious games with people who suffered a stroke, Rego et al. (2010) and Bechkoum (2008) found that stroke patients might present several cognitive and motor weaknesses after the accident. The use of serious games that stimulate these patients had, in general, significant results, in which improvement in the rehabilitation process occurred.

Therefore, the intent of this paper is to talk about the serious games developed to work with the robotic device prototype to be applied at wrist rehabilitation.

## 2. WRIST KINESIOLOGY AND REHABILITATION

Rehabilitation is a dynamic process of adaptation planned from the change in the lifestyle of a person, in reaction to the traumatic situation, be it physical or cognitive. In a first moment, the concept "restoring to working order" would be the main goal of rehabilitation. However, from further studies, it was proposed that the focus of rehabilitation would not be on healing, but in living with as much freedom and autonomy as possible, so that this injured patient would adapt with the available resources (Gunasekera & Bendall, 2005).

In this way, robotic training can offer several potential advantages in rehabilitation, including good repeatability, precisely controllable assistance or resistance during movements and quantifiable measures of subject performance. Moreover, robot training can provide the intensive and task-oriented type of training that has proven effective for promoting movements rehabilitation (Barbosa et al., 2018; Gonçalves and Krebs, 2017; Gonçalves et al., 2016; Gonçalves et al., 2013; Ribeiro et al., 2013).

The wrist is the joint that connects the hand to the forearm, having two degrees of freedom, which makes possible the movements of flexion-extension, Fig. 1(a), and abduction-adduction Fig.1(b). In addition to these movements, the hand can also be rotated, using the forearm and elbow joint, characterizing the pronation and supination movements, Fig. 1(c), (Kapandji, 2000).



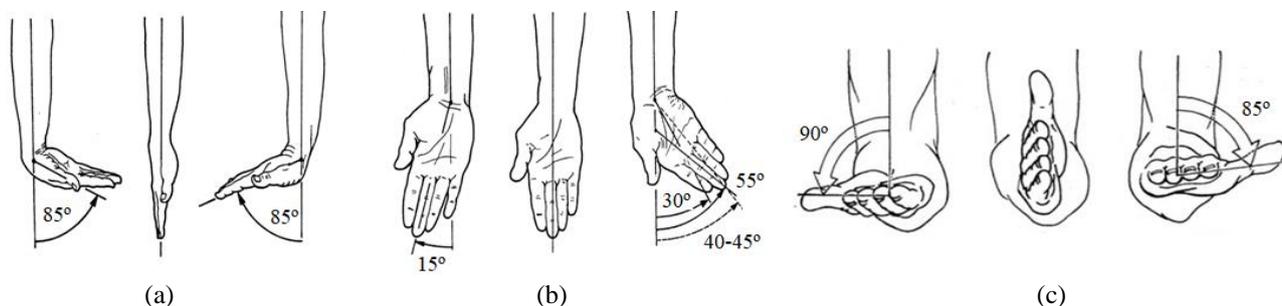|     |     |     |
| --- | --- | --- |
| (a) | (b) | (c) |

Figure 1. (a) Movements of flexion-extension; (b) Movements of abduction-adduction; (c) Pronation and Supination (Kapandji, 2000).

## 3. DEVICE

The robotic prototype, Fig. 2, is composed of a servomotor (model MX-106, Dynamixel), which has an internal PID controller that stores its position, speed and the torque applied to the motor. The control of the prototype was made using the software Matlab®.



Figure 2. Image of the device assembled without the electric/control system.

Connected to the MX-106 servomotor has a mechanical flexible coupling that connects to an aluminum plate (mobile platform) in which the patients hand stands.

The mobile platform can be configured to use in all individual wrist movements, Fig. 1, in this way the device can be adjusted, Fig. 3, accordingly to the type of lesion from the patient.

A high compression elastic orthopedic band was used to attach the patients' hands to the mobile platform. This orthopedic tape provides more comfort, as well as avoid slipping of the patient's hand on the platform and keep it stretched during the test.
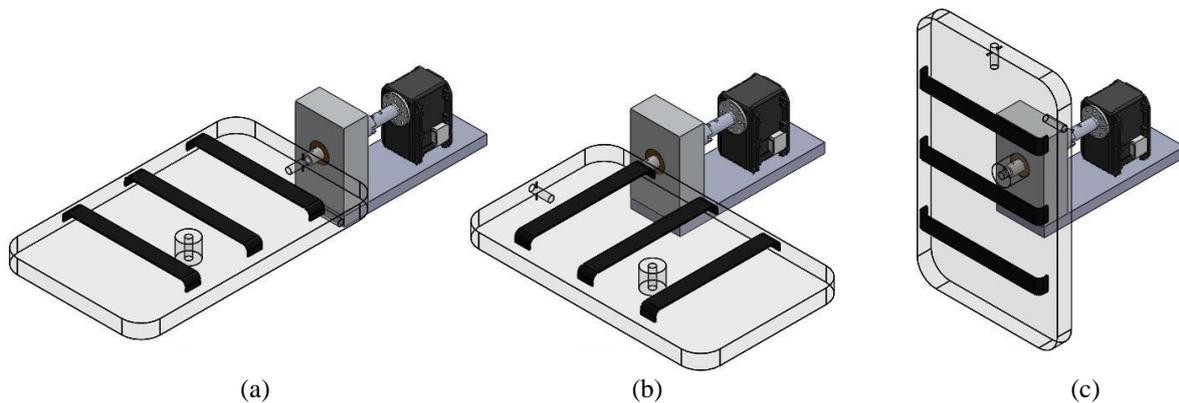
Figure 3. Mobile platform configurations. (a) Pronation and Supination; (b) flexion-extension; (c) Movements of abduction-adduction.

## 4. SERIOUS GAMES

The serious games developed for use with the robotic module device uses the Matlab software to communicate with the device's servomotor by reading the data sent by its sensors. Among these data, it is possible to read the current delivered to the motor, applied torque, position and velocity. It is possible send to the servomotor the data of the position, velocities and torque to be reached. After exchanging the data between the servomotor and Matlab a User Datagram Protocol (UDP) connection is used for the transmission of this data to the serious games, which is responsible for storing packets containing data on the computer's network ports. This method is extremely efficient, since it does not require wait for confirmation of data reception, therefore being able to send large amounts of data quickly.

The graphic interface of the serious games are made using the game engine Unity3D, which uses the programming language C# to compose the behaviors of the objects present in the games. The development of the gameplay has as main concept to be of simple understanding to the patient and to have characteristics with which it can relate, in order to establish proximity between both. The rationale for this is that once the patient is in some form of disability, the need to gain their attention and interest in the treatment using serious games is greater due to the aches and discomforts naturally caused by that disability make the exercise of some activities unattractive (Burke et al., 2009; Pereira et al., 2019).

Using these guidelines, two serious games are developed in the Laboratory of Automation and Robotics (LAR) at Federal University of Uberlândia (UFU), to be used in conjunction with the wrist rehabilitation device. Each of the games can be used in any of the configurations of the mobile platform, Fig. 3.

### 4.1 Basket Balls

The serious game Basket Balls (BB) was make focused on the flex-extension movement. In it, as the patient rotates its hand, the same movement is transmitted to the game, rotating the wooden board that is in the center of the screen. This movement of the board is used to direct, due to the balls being able to collide with it, the different colored balls to the baskets of the same color. These balls are the scoring of the game, in which, for each ball correctly placed in your basket, the patient is rewarded with a point. Although there is only one blue and one red basket, which implies the existence of only the blue and red balls, there are also the special balls of green color, which give more points to the player if they are placed in the basket opposite that the patient put the last ball correctly. In this way, the patient is stimulated both physically and cognitively.

In addition, the BB presents a non-punitive mechanics, so that there are no penalties for errors within the game, just the non-award of points. This is to make the patient stay more relaxed in relation to the game, reducing the pressure on him. In fact, not only does the game present non-punitive mechanics, but it also has an aid system that aims to detect whether the patient is able to continue playing. Otherwise, the software developed sends commands to the servomotor so that it can perform the movements alone.

In the first version of the game, this aid system was activated if the software developed noticed that after a verification routine, the player's average speed was below an initially defined speed constant. At this point, the software changes its behavior according to the modes:

- *Unassisted movement*: The patient can freely move the mobile platform device while the game captures these movements and reproduces in the object controlled by it. Meanwhile, Matlab software developed stores the instantaneous velocities of the player in a time interval, after which it compares the average of

those velocities with a predefined value. If this average is less than the default value, after five checks, this game mode ended for the start of Slightly Assisted Movement Mode.

- *Slightly Assisted Movement Mode*: The patient no longer moves the device freely, having only to make a slight movement in the desired direction so that the software detects the direction in which it should make the servomotor move. Thus, the motor prints a speed and torque in the desired direction of rotation, to aid patient movement. If after a new verification routine it is found that the patient has performed fewer movements than expected in a time interval the Automatic Motion Mode is started.

- *Automatic Motion Mode*: Matlab software developed assumes full control of the movement of the device, defining which ball must be generated in the game, so that it sends both the trajectory to be executed by the servomotor and the trajectory of the board in the game.

In the game modes that give Matlab control of device movement, there is always a check on the amount of current being transmitted to the motor to perform the motion. In case that this value is above the expected values for normal execution of the movement, the assisted mode is stopped and returns to the Unassisted Motion Mode. This occurs because it understands that the motor is applying more torque to the patient's hand due to the patient applying torque contrary to the movement, which may mean that the range of rotation supported by the patient has been reached, thus avoiding discomfort for the patient.

After tests performed with healthy people, it was verified that the system used to detect the need to use the assistive modes left margins for many improvements, making it necessary to update them to version two.

In the version two of BB, the different game modes are being exchanged for a single fluid mode of movement, which begins with the acquisition of parameter data of the patient passive amplitudes of movement and initial angular position of the system (initial position of mobile platform). This unique mode is possible due to the greater interaction between the game platform and Matlab, by making them both exchange data, not just sending Matlab commands to the game. Among the data sent by the game to Matlab are the color of the ball currently in the game, in addition to the player's net error amount, which minimum is zero.

As the amount of errors goes up, Matlab sends commands so the robotic module executes progressive torque and speed, taking control of the game more and more dynamically. This pattern repeats itself until the fifth error, in which Matlab takes full control of the game, moving correctly to ensure the score. Thus, the control system allows an understanding of whether the patient is playing really and having difficulties or if he is not trying to play.
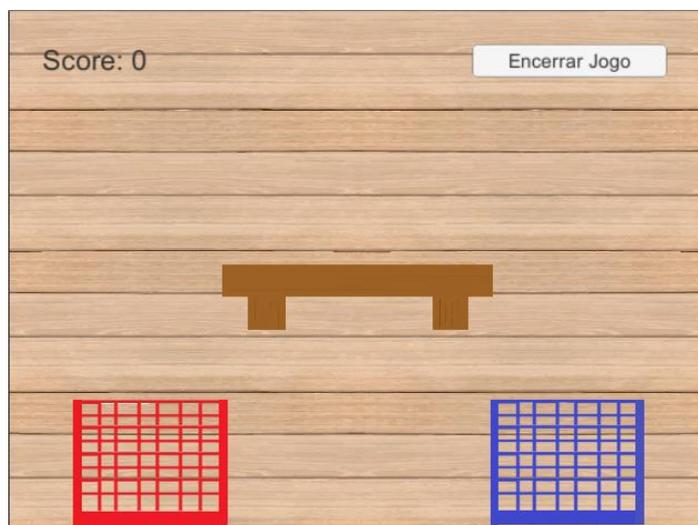


Figure 4. Sample of the game main scene, where the player controls the wooden plank and there are two baskets, one red and one blue, and the main objective is to put, inside the basket, the ball that matches its color.

To end of a serious game session is necessary click on the upper right button of the screen, as in Figure 4. This will display the patient's final score, as well as the number of errors and the duration of the session. To assist the physiotherapist the game is programmed for store this data, along with the patient's name and session date, in a separate file for easy reference.

## 4.2 Coinllector Cars

The game Coinllector Cars (CC) has as a preferred movement the abduction-adduction. The goal of the game is to use the car to pick up the coins that are generate at the end of the street in the intention that the patient, when carrying out the movements, has a sensation similar to that of controlling the car by moving its steering wheel.

Like BB, the CC also stores as parameters the patient's maximum passive amplitude and the central angular position of the device. This information is translated into coordinates along the X axis, whose origin is at the center of the screen, moving the car horizontally to the left or right according to the patient's movement. For this, the central angular position is place as the 0-coordinate of the X-axis, and the maximum amplitudes of motion are define as the X-positions in which the car is at the boundary of the street. The translation of this data is make from a simple cross-multiplication, which uses the angular variations of the servomotor.

In Figure 5, the scenario of the game is presented, as well as an example of the coin to be collected by the player to score. To be collected the car controlled by the patient must contact the coins that are generated at the top the screen, region corresponding to the end of the street. There are five different coins, all with the same value for the score. This difference exists as a visual element, with the intention of drawing the player's attention more closely to the symbols that appear on the coins. Both the coins, the car model and the streets were taken from the free Animated 2D Coins files, by All Star developer, Race Cars 2D, by Looneybits developer, and Jacek Jankowski's Simple Modular Street Kit, respectively.

The CC will also count in its final version, with a system of difficulty adjustable according to the performance of the patient, dynamically varying the speed of translation of the coins as the patient acquires more points.
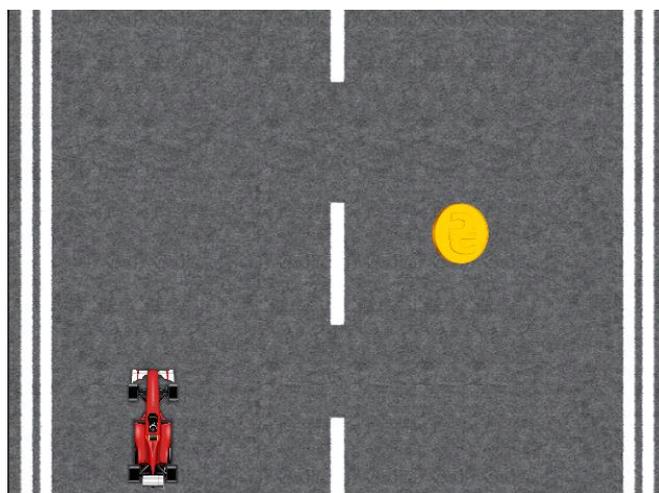


Figure 5. Main scenario from Coinllector Cars, the coins are randomly spawned within three positions at the end of the simulated street on the screen.

## 5. EXPERIMENTAL TESTS

Twelve young healthy adults (age: $19.5\pm1.57$ years, height: $1.71\pm0.07$m, mass: $69.04\pm16.52$kg) without any history of musculoskeletal or neurological disorder volunteered to participate. The study was approved by the ethics committee on human research at UFU (CAAE 00914818.5.0000.5152). The test was made using the serious game Basket Balls.

The tests consisted of, when playing the game Basket Balls, to submit the participants to perform movements of the joints with the use of the device shown in Figure 2, and the movements performed are not harmful to health, only subject to muscle discomfort and pain resulting from repetition and the amplitude of the movements. In order to obtain data that compose the research, the treatment of these data was done in a random and anonymous way, dismissing a risk of identification of the participants. An Intrinsic Motivation Inventory (IMI) was applied to understand the motivation of the players during the session, as well as their satisfaction.

Table 1 consists of the systematization of the collected data. In the first column are the healthy subjects. We chose to replace the names with the letters of the alphabet for easy reference and avoid confusion with the other numerical data. The second column consists of the final score obtained by each subject. The third column shows the number of mistakes made, which consists of placing the ball in the wrong basket or letting the ball go outside the limits of the game screen. The fourth column shows the time spent by each participant to reach the score goal imposed for the experiment, which averaged 9'12 ".

Table 1. Experimental results from tests using the robotic module together with the game Basket Balls first version.

| Subject | Points | Errors | Session Time |
|---------|--------|--------|--------------|
| A | 101 | 2 | 9' |
| B | 102 | 0 | 9' |
| C | 102 | 0 | 10'33" |
| D | 107 | 3 | 8'40" |
| E | 100 | 0 | 8'40" |
| F | 109 | 0 | 7'19" |
| G | 106 | 1 | 10'50" |
| J | 102 | 0 | 11' |
| K | 100 | 0 | 8'6" |
| L | 102 | 0 | 8'42" |
| M | 100 | 2 | 9' |
| N | 100 | 1 | 7'52" |

## 6. CONCLUSIONS

By analyzing the time spent by the participants it is possible to notice that there is a considerable variation between the times obtained in the sample, since the standard deviation of 1.16 minutes consists of more than 12% of the average time spent per subject. Since the operating conditions of the BB game are the same for all participants, this behavior is derived from the rate of generation of special balls that reward the player with the most points, causing some players to achieve the goal faster than others. From the experiment conditions, it is also important to note that the participants' average point-per-minute rate is 11.

According to the IMI applied to the participants, 67% stood in favor of the exercise, noting that they liked and had fun. In contrast, only 13% stated that the activity did not catch their attention in any way. Both pieces of information show that the game pleases visually and in gameplay, requiring no major changes.

According to observations made throughout the test, for healthy subjects, the BB game is easy to understand and play, observation supported by 67% of the participants who consider the game easy and affirming in 73% of the cases that they felt reasons to execute the movements of correct form to achieve the goal.

Finally, 80% of test participants agree that the activity performed is important because it can assist therapists in treating people with wrist problems, the main purpose of this paper.

Among the suggested future work are to develop more serious games and make experimental tests with patients.

## 7. ACKNOWLEDGEMENTS

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