

Diseño y desarrollo de una terapia asistida por robot de muñeca basada en juegos serios

Design and development of a wrist robot-assisted therapy based on serious games

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RESUMEN

Al navegar a través de la red, día a día, se tiene acceso a una gran cantidad de información; sin embargo, datos sobre el autor de estos contenidos no está a la vista o de manera explícita. Por lo que, al procesar e interpretar esta información es posible obtener características que identifiquen al autor como identificación del género, el rango de edad, la variante del lenguaje, entre otras características más. En este artículo, se presenta un trabajo en progreso que permite analizar y procesar textos de comentarios en español, con el objetivo de identificar el género

(hombre o mujer) del autor. El proceso de análisis y procesamiento del sistema toma en cuenta las palabras, los emoticones de los textos y la utilización de algoritmos de aprendizaje automático. Los algoritmos empleados son Naïve Bayes y Árboles de decisión (J48), obteniendo el mejor resultado de precisión del 69.81 % con J48 para la identificación de género.

Palabras clave: *Perfilado de autor, Identificación de género, Análisis de textos en español.*

ABSTRACT

Nowadays, when browsing through the network you have access to a lot of information; however, data about the author of these contents is not visible or explicitly. Therefore, when processing and interpreting this information, it is possible to obtain

characteristics that identify the author as the gender identification, the age range, the variant language, among other characteristics. In this paper, we present a work in progress that allows to analyze and process texts of comments in Spanish, with the

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aim to identify author gender (man or woman). The process of analysis and processing of the system considers the words, text emoticons and the use of machine learning algorithms. The algorithms used are Naïve Bayes and Decision Trees (J48), obtaining the best precision result of 69.81 % with J48 for author gender identification.

Keywords: *Author profiling, Gender identification, Analysis of texts in Spanish.*

INTRODUCCIÓN

According to the World Bank analysis of disability and poverty, about 85 million people live with some disability only in Latin America and the Caribbean [7]. Diseases, including brain injury or musculoskeletal accidents, can result in disability. Physical rehabilitation has increased in demand in recent years; therefore, it is essential to design low-cost technology and easily reproducible. The World Health Organization (WHO) defines rehabilitation as "interventions designed to optimize functioning and reduce disability in individuals with health conditions and their environment interaction" [20]. A therapy session consists of repetitions of some movements that allow the user to strengthen the affected area. These exercises must be performed daily; however, this is not always possible, and the patient receives no more than 2 or 3 sessions per week.

Motivation is a crucial factor in achieving adequate rehabilitation since when patients perform repetitive routines, they risk abandoning rehabilitation. There are two types of motivation: the intrinsic one that brings, puts, executes, and activates the individual when desired [17], making it a motivation that does not depend on external factors but that the user has the initiative to do something for his convenience. The second type of motivation is the extrinsic one, which is the one provoked from outside the individual by other people or the environment [17]; this motivation is helped by incentives/punishments, environments, or people willing and able to help to achieve a particular target.

In robots that assist patients in rehabilitation, the MIME-RiceWrist [13] is an exoskeleton for wrist rehabilitation that works in passive, active, and restricted modes. Similarly, the EMUL system [6] is a platform with three degrees of freedom, in horizontal and vertical planes, with force sensors in the three-dimensional plane. In this system, the user makes the movements through the robot, and the robot offers some resistance to the patient's movement; the design allows various movements so that the user has more freedom and thus can rehabilitate the wrist and the arm. Other works in which rehabilitation techniques are proposed, such as techniques that include assisted movements and haptic simulations, such as those performed by the Pneu-WREX robot [10]. All these strategies have had good results in the rehabilitation of patients. These systems also have various routines that the patient can perform to rehabilitate himself and motivate him to continue his rehabilitation exercises.

On the other hand, virtual environments have had significant development. Despite having been crea-

ted for the video games and entertainment sectors, nowadays, they take advantage of the different advantages they present for areas such as the industrial sector, as mentioned in [8], where virtual environments are focused on the use of simulators for assembly with haptic feedback to help engineers through a different and technological environment. A virtual simulator is used to manufacture products without prolonged training [5]; in the health area, virtual environments are primarily used for the simulation of surgical methods, as mentioned in [3, 9, 11].

In the health area, virtual environments are widely used in motor rehabilitation since they have advantages such as their capacity for precise evaluation, adaptability to each patient and disease, and repeatability. They also involve the patient by generating a greater interest in his therapy [4]. Therefore, this paper intends to join these two concepts and focus them on the rehabilitation area to achieve a more significant commitment from the patient to finish the long treatments, using serious games with which the rehabilitation routine becomes more interesting, entertaining, and safe.

Virtual reality is now adapted to the so-called serious games, which can help improve balance, posture control [2], coordination [13], and patient rehabilitation. Serious games help with problems with patient motivation and commitment [16]; according to Michael and Chen, serious games are used to educate, train, and inform [6]. This term is better known for video games and simulators, whose main objective is education or training. Serious games [10, 15] improve the sharpness of visual perception, the speed of reflexes, the memory, and the capacity to follow instructions, this being at a sensorial level. However, cognitively, advantages are also obtained, such as facilitating the development of strategies for problems and developing thought structures. As the literature points out, a serious game “can only take effect if these games are developed and designed based on an interdisciplinary understanding of the respective application field.” [19]. Therefore, this work is part of a greater effort in developing rehabilitation systems.

There are different taxonomies for the development of serious games in different areas of application; within the area of rehabilitation Rego and collaborators [14] contribute to the design of serious games by taking into account two elements: pedagogy and entertainment; likewise, they take into account nine factors that contribute to evaluating the objective and classification of a serious game based on the area of application, the technology of interaction, the interface of the game, number of gamers, adaptability, feedback, progress monitoring, and portability. There is no formal methodology for developing serious games; Esperança and coworkers propose five steps to develop a serious game [1]. The selection of therapy and interaction mechanism must be considered when developing a serious game to succeed.

Another methodology proposed in 2008 is called EMERGO, which aids in the acquisition of cognitive skills and consists of 5 cases: idea (analysis), scenario (design), development, delivery, and evaluation [12].

The EDoS (Environment for Design of Serious Games) methodology [18] shows an environment based on three models focused on creating serious games, combining learning and fun features. This methodology is focused on the creation of serious games for the teaching of engineering skills.

In this research, a serious game has been developed to be applied in robotic rehabilitation platforms, which helps motivate patients with their wrist rehabilitation routines and allows therapist interaction to adapt the serious game to every routine the patient needs. A significant advance is that the therapist can change ranges of motion, the duration of the routine, and the level of force that the patient will perform. Besides, the therapist has access to a series of data to compare the trajectory performed by the patient against the correct trajectory performed in the game and thus has an objective parameter to evaluate the progress of the patient's rehabilitation. The present work is focused on designing a serious game that, in conjunction with a rehabilitation robot, could allow the rehabilitation of the upper limb, specifically the wrist. This work is limited to the mechanical and programming part of the system therefore, no rehabilitation routines were performed.

MATERIALS AND METHODS

The present work involves designing and manufacturing a robotic system capable of assisting patients with motor disabilities of the wrist during their rehabilitation using serious games. As shown in Figure 1, the system is divided into three main sections: mechanics, electronics, and serious game programming.

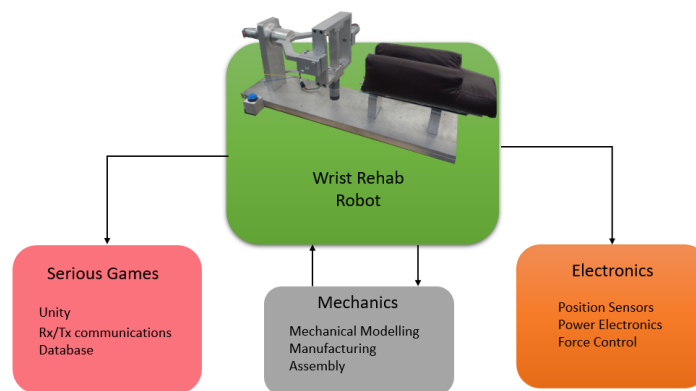


FIGURA 1. *General scheme of the Wrist Rehabilitation Robot.*

Mechanical design

The robot has been designed to have three degrees of freedom (DOF), which produces a fully actuated system capable of executing active and passive rehabilitation. Because the human wrist has the following movements: flexion, extension, abduction, adduction, supination, and pro-supination, the robot helps

with those movements of the patient's wrist, assisting them during their rehabilitation routines. The robot movements were selected based on questionnaires applied to Rehabilitation center personal.

Figure 2 shows the mechanism design for each of the three DOF; the combination of these movements executes the entire wrist movement. This robot also has a mobile base to support the patient during rehabilitation exercises, ensuring that the user always has a comfortable position regardless of the type of movement with the wrist, as illustrated in Figure 3.

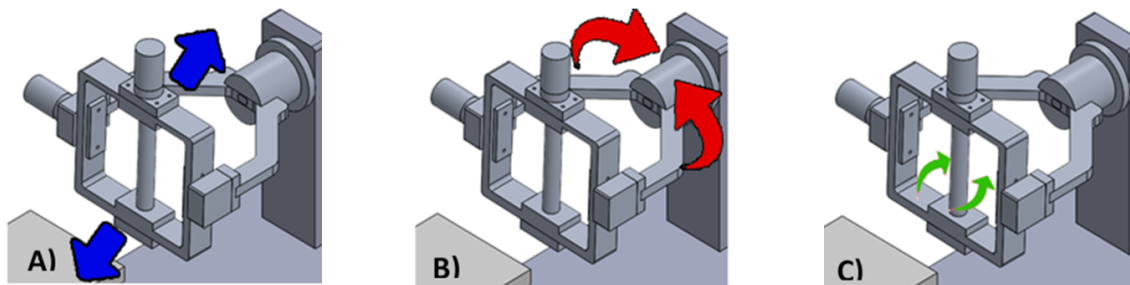


FIGURA 2. *Schematic representation of robot movements, A) abduction and adduction. B) pronation and supination. C) flexion and extension.*

Passive rehabilitation aims to avoid rigidities, promote blood and lymphatic circulation, prepare the muscle for better active work, prevent adhesions and contractures of the tissues, maintain their elasticity, maintain joint mobility, or restore it in the joints presenting limitation. Therefore, the proposed robot carries out the complete movements of the patient's wrist.

Conversely, active rehabilitation aims to recover muscle tone, reinforce joint movements, recover their amplitude range of movement to the maximum, improve neuromuscular coordination, and increase dexterity and speed when carrying out the movement. In this case, the robot carried out an impedance control to generate resistance during the movement performed by the patient's wrist.

Electronic design

The position sensors, the DC motors, the power electronics module, and the control module integrate the electronic system. Two-channel hall effect encoders conform the position sensors. H-Bridge boards conform the power electronic module for controlling three gear motors of 250 oz-in torque with a gear ratio of 131:1. Finally, the control is carried out by a MyRIO platform board from National Instruments that contains an FPGA XILIX Zynq-7010 and a 667 MHz dual-cortex ARM Cortex-A9 processor. Figure 4 illustrates the information flux in generating the impedance control. This scheme is reproduced for each of the DOF in the robot.

Serious Games

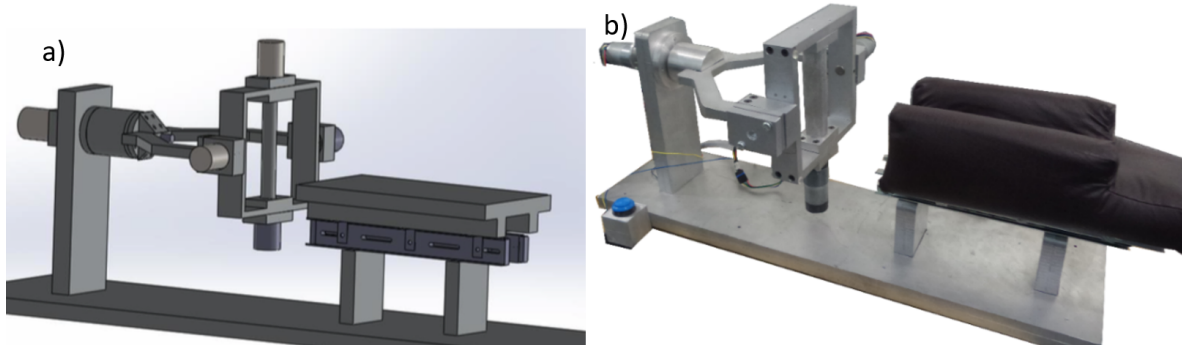


FIGURA 3. *Integration of mechanical components and actuators to the wrist rehabilitation robot a) conceptual design, b) real system.*



FIGURA 4. *The electronic scheme applied to sensing and control.*

Following the methodology proposed by Alcover and collaborators [1], the therapy selection is based on the statistical data exposed elsewhere devoted to wrist rehabilitation. Also, a specific design robot focuses on the rehabilitation of the segments as described by De Mauro [4]; this robot constitutes the mechanism of interaction, while the elements of interaction are the serious game, the rehabilitation robot, and the information provided by the sensors that the robot has.

UNITY and the MyRIO platform were used to develop and design the serious game. A classic game of a spacecraft that follows trajectories, evades collision, and shoots objects was designed; it was programmed to perform certain routines determined by the therapist. The robot selects and programs the force and range of movements exerted by patients at each DOF. Figure 5 shows a schematic diagram of the serious game programming methodology focused on the wrist rehabilitation platform.

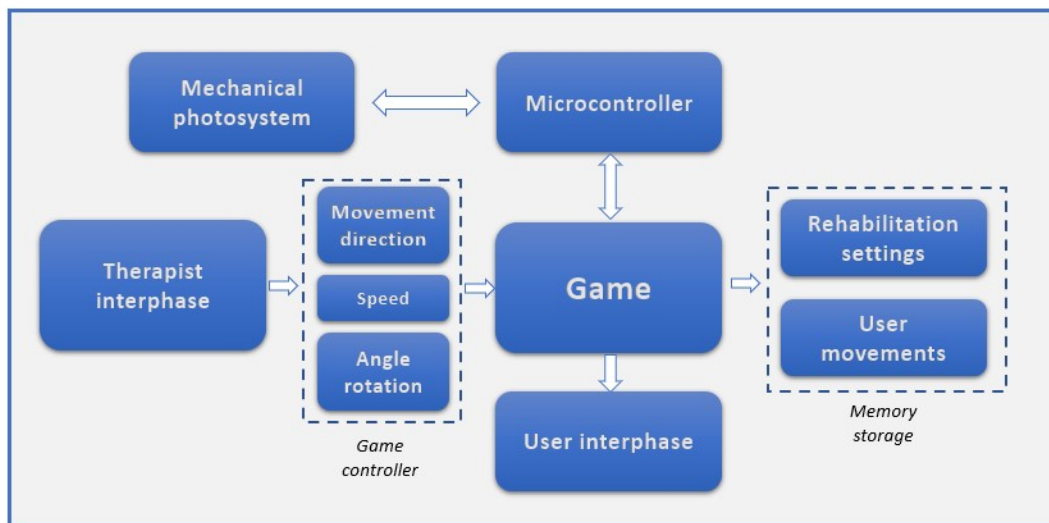


FIGURA 5. *Methodology for serious game development and design.*

This game's goal is for the patient to execute one or more combined movements -like pronation, supination, flexion, extension, adduction, abduction, and circumduction. Four training sections were designed for the game; each corresponds to a movement type, such as pronation-supination, flexion-extension, or adduction-abduction, and the last section is configured to use all three movement types. All movements can be programmed in a specific range of movement and a specific force programmed by the physiotherapist. Although the range of movements and the force are programmed, switching the game between two options is possible. The game can be programmed to move freely or follow a specific trajectory and speed required in specific rehabilitation routines.

Rehabilitation routines feedback

A tracking system was also developed to analyze the patient's performance and give feedback to the physiotherapist. Figure 6 shows a flowchart of developing a tracking system to determine the patient's routine to help the patient perform prescribed movements employing a system of movement patterns.

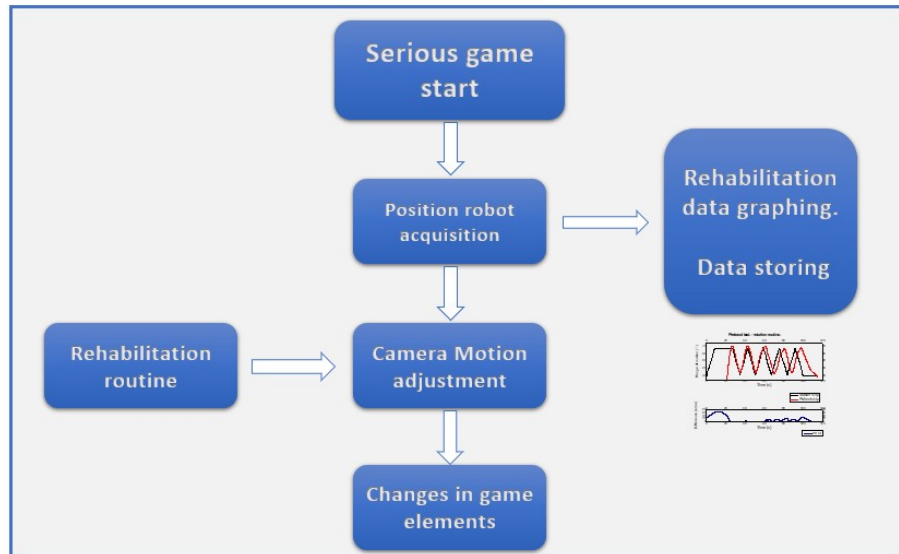


FIGURA 6. *Methodology for the development and programming of the follow-up routines of the serious game.*

Within each level are a series of points marked by spheres of white material; these spheres are placed within a marked path depending on the desired movement to be performed. In Figure 7 a) are supination and pronation movements, indicated by the blue arrows; in Figure 7 b) are performed adduction-abduction movements. For the camera movement, adjustments were made to make translation movements along the area of the game. The movements of supination-pronation and abduction and adduction of the pattern element leaving a tracing guide to advance to each of the points established also shows the interaction between the ship that commands the patient to touch one of the points established upon reaching a point is a change of material to make the patient notice reaching the indicated point.

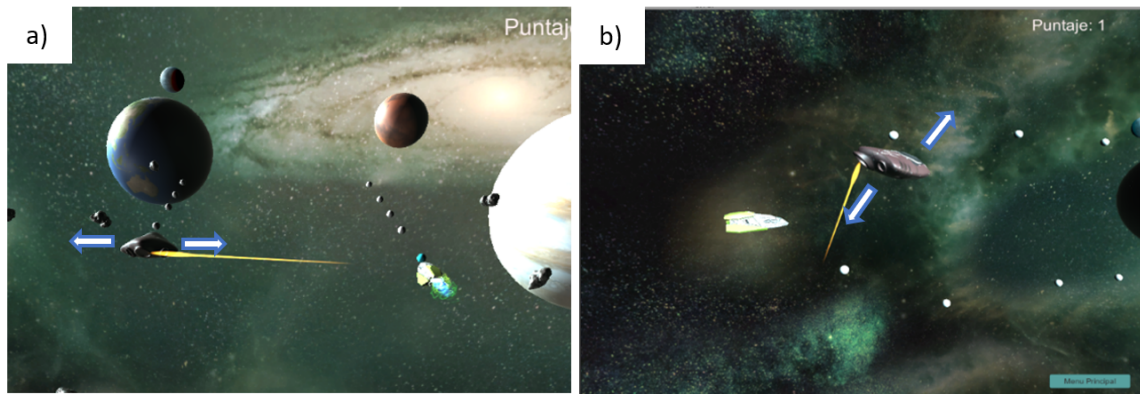


FIGURA 7. View of the serious game for follow-up rehabilitation routines with a) supination-pronation and b) abduction and adduction movements.

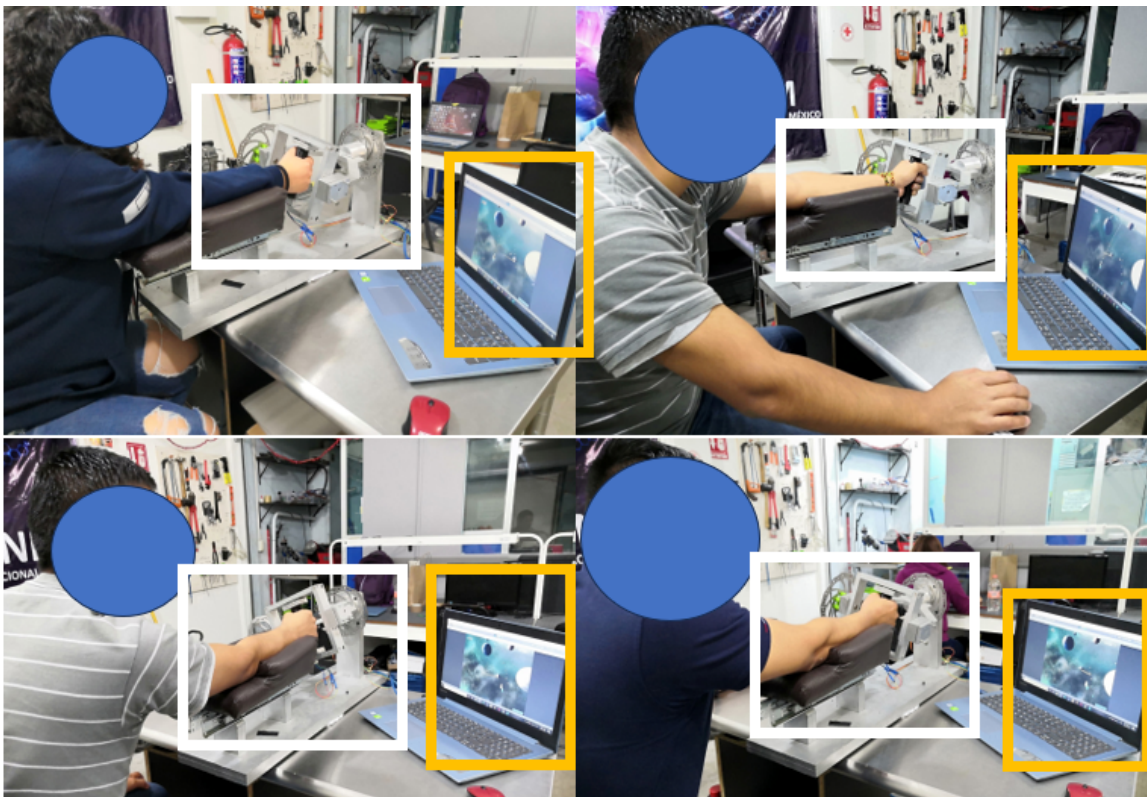


FIGURA 8. Rehabilitation system during use, white squares show the system and yellow squares the serious game screen.

RESULTS

An experimentation protocol was carried out to organize and validate the tests of the robotic system. Ten healthy participants without motor or visual disabilities were selected (18 - 35 years old) for the preliminary experimental tests as Figure 8 shows.

At the beginning of each test, the person's forearm was placed on the robot's armrest, adapting a neutral and comfortable position. Once his arm was placed on the platform, the volunteer was instructed to grab the robot's end-effector. At this point, the data transfer between the MyRIO platform and the Unity program begins. The routine starts with the pronation-supination, then the abduction-adduction, and finally, the flexion-extension stages. Each stage has a time of 120 seconds, with three different strength levels. In between each test, a 120 seconds rest period was performed.

The comparison of a proposed path and the voluntary performance with a robot force set to zero force impedance is presented in Figure 9. The proposed trajectory was designed to reinforce the pronation-supination movements mainly.

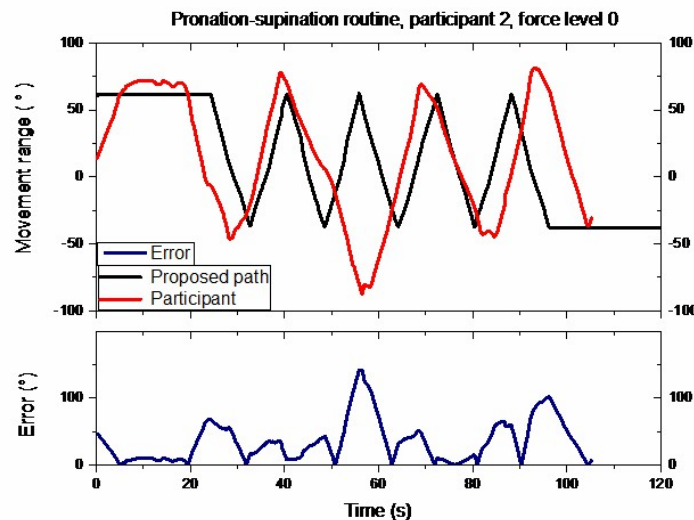


FIGURA 9. *Tracking path results of a voluntary #2 performing the pronation and supination routine with a zero force level.*

Because the volunteer is healthy, he tries to anticipate the robot's movements, as shown at the beginning of the routine. After the first cycle, the participant misses one of the cycles. The error shown in the figure is the difference between the proposed trajectory and the robot's actual position.

A similar experimentation protocol was followed by each participant using four different force levels

starting at zero force. Figures 10 to 12 show a test made by the same participant using three different force levels. It is possible to see an error reduction at higher force. Error reduction can be attributed to the more effort needed to anticipate the robot's movement.

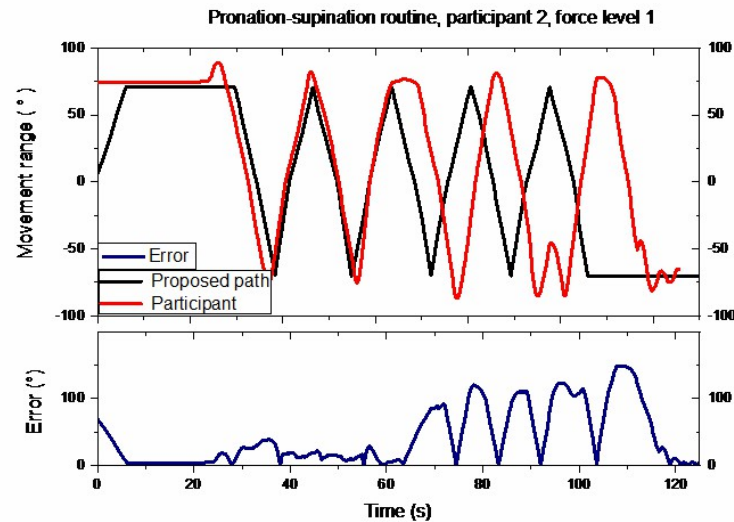


FIGURA 10. Tracking path results of a voluntary #2 performing the pronation and supination routine with a force level 1.

Figure 13 shows a comparison of rehabilitation routines using three different force levels. As previously stated, the error decreases as the force increases. No information about the force was given to the participant before the test. Additionally, the forces were selected in a pseudorandom sequence to not influence the volunteer performance.

Dynamic time warping (DTW) was used to objectively calculate the distance between the proposed trajectory and the tracking path for each voluntary. Table 1 shows the distances between the proposed trajectory and the DTW distances.

TABLE 1. Euclidean distances between the proposed path and voluntary movement.

Path	DTW
Trial 2 force 0	1.019E10 ⁴
Trial 2 force 1	5.528E10 ⁴
Trial 2 force 2	1.985E10 ⁴

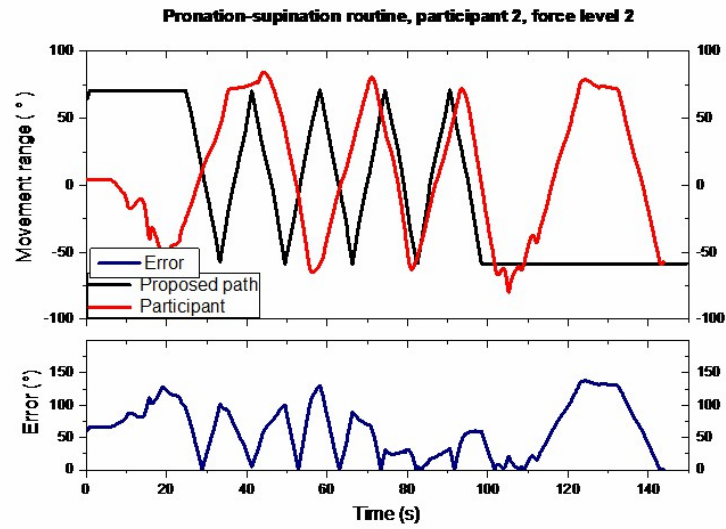


FIGURA 11. Tracking path results of a voluntary #2 performing the pronation and supination routine with a force level 2.

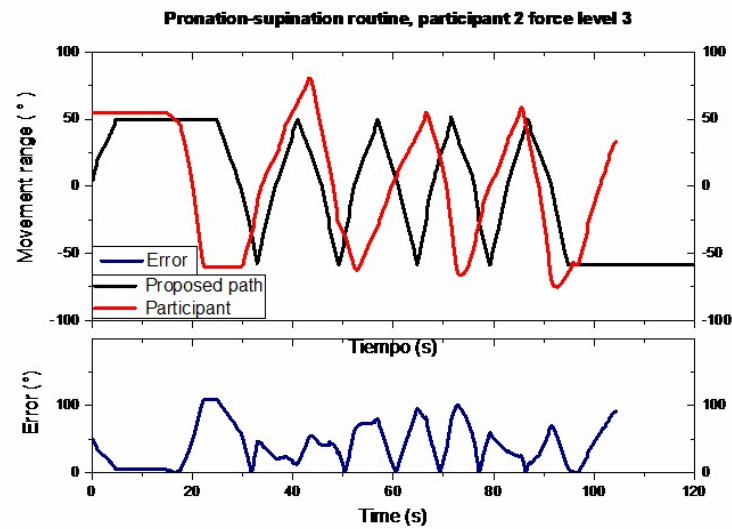


FIGURA 12. Tracking path results of a voluntary #2 performing the pronation and supination routine with a force level 2.

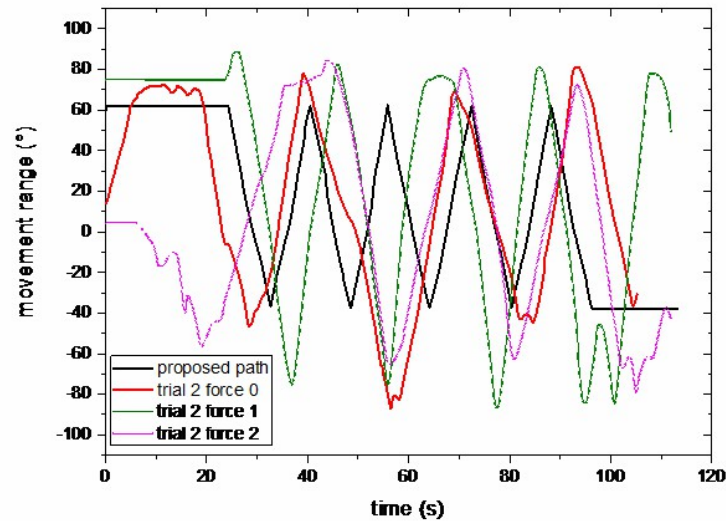


FIGURA 13. *Tracking path results of a voluntary #2 performing the pronation and supination routine with three different force levels.*

DISCUSSION

The force needed to follow the trajectories can be modified by implementing variable resistance in the robot; this is useful when the therapy requires variable effort in the subject. When the velocity of the rehabilitation routines is increased, the voluntary response needs to rise. Those two features provide the system with different force-velocity relationships to be implemented in the robot; therefore, this system can be used under different therapy requirements. Figures 9 to 12 show the system can provide different mechanical resistance levels, which leads to more strength needed to perform a movement; the resistance variation prevents the user from getting used to the robot and simultaneously follows the strength increase of the user in continuous therapy.

CONCLUSIONS

The proposed serious game follows the methodology and meets the requirements established in the taxonomy to develop a serious game focused on rehabilitation. It has interaction technology when using a wrist rehabilitating robot. The robot has a 3D interface, and its game genre is combined and adaptable. It also transmits results to the therapist to carry out therapy progression monitoring.

Because healthy volunteers performed the test, the anticipated movements were a constant along the robot-game test. No tests were performed by people needing rehabilitation because more force levels are needed to complete the requirements.

Serious game motivates and trains the patient with repetitive movements within their rehabilitation routine but only take effect if multidisciplinary approach is carried out, this work is a first step in development rehabilitation systems based on serious games. In future work, it is proposed to monitor more variables within the game, such as the response speed that the patient has within each routine, and to seek to adapt the patient's movement ranges in the game.

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