Pronosupination Device to assist Pronation and Supination Movements of the Forearm Rehabilitation with Virtual Interface

Ríos-Hincapie J.A[1], Contreras-Calderón MG[1], Porras-Ramirez O[1], Gomez-Nava A[1]

[1]División de Tecnologías de la Automatización e Información, Universidad Tecnológica de Querétaro, Querétaro, México, {ma.gpe.contreras.c@gmail.com}

ABSTRACT

1 Introduction

The development of technological devices for rehabilitation as new alternatives for therapies has brought solutions for assistance in physical rehabilitation. Robotics improve patient outcomes by promoting neuroplasticity, helping the brain rewire and relearn lost motor skills, and accelerating functional recovery in conditions like stroke. Robotic systems also enable continuous tracking progress, allowing for personalized treatment adjustments, which further supports efficient rehabilitation and recovery speed compared to traditional methods [1]. These devices allow repetitive movements with specific trajectories that generate exercises such as flexion-extension, adduction, pronation, and supination, among others, whether passive or active therapies. Also, they provide optimal rehabilitation; stand out reproducibility, programs oriented to specific tasks, and a quantified progression. With the previous benefits, an increase in strength, improved coordination, modifications in muscle tone, motor reeducation, and greater functional independence, among others, are obtained, although some studies show controversial results [2]. The aim of rehabilitation is not therapist substitution; it's a tool to assist so that he can provide optimal rehabilitation to all their patients. In rehabilitation, pronation and supination exercise improve flexibility, strength, and the overall functionality of the forearm and hand, making these movements key focus areas in restoring upper limb mobility and independence for patients [3]. Fifty relevant devices have been reported [4], twenty-four of which are end-effector devices and only six consider pronation and supination exercises. The best known are InMotion Arm [5], Gentles [6], Braccio Di Ferro [7], and Adler [8], all above are of end-effector type. Only the InMotion Arm considers pronosupination, however, this movement is carried out independently of the rehabilitation exercises, while the others are limited to execute movements of flexion-extension, adduction, and abduction. The exercises assisted by these devices can be complemented by pronosupination to perform more complete therapies. In this paper, a pronosupination device design is proposed and implemented. A user interface developed in Unity was implemented that allows the user to interact with the mechanism while playing a game, with trajectories using in rehabilitation.

2 Pronosupinator CAD Design and Prototype

The pronosupinator consists of five main parts: A forearm holder, a cylinder with a circular rack, a pinion, a cd motor, and an optical sensor (see figure 1). The forearm holder has motor support and a hole where the bolt can be placed to fix the position of the cylinder. The union of the end effector and optical sensor has a bearing to allow it to rotate on its axis and adapt the arm to the mechanism's movement. The cylinder has a grab bar with a strain gauge and a circular rack that matches the pinion to form a motion transmission system. The motor is attached to the holder; the pinion is fixed to the motor shaft to make permanent contact with the cylinder circular rack. The cylinder rotates freely inside the holder through two circular guides (cylinder) and two grooves (holder). The mechanism has one degree of freedom, and can slide on the XY plane, in order to provide movements such as abduction, flexion and, extension of the arm.

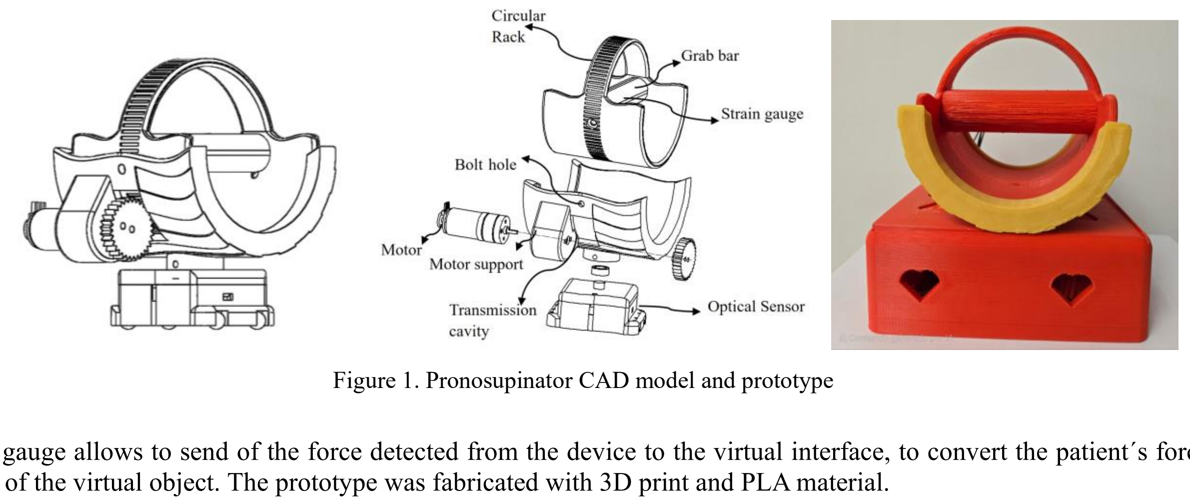

Figure 1. Pronosupinator CAD model and prototype

The strain gauge allows to send of the force detected from the device to the virtual interface, to convert the patient´s force in the movement of the virtual object. The prototype was fabricated with 3D print and PLA material.

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3 Virtual Interface for Arm Rehabilitation

The virtual interface purpose is patient interaction with dynamic games through the pronosupinator. The patient holds the device grab bar and moves virtual object. Thanks to the strain gauge attached to grab bar, which is used to measure the force exert by the patient during the game, the object in the virtual interface jumps depending on the force. A series of games were developed for helping patients to perform rehabilitation therapies actively while playing.

Games are designed so that patients, during the game, perform pronosupination, adduction, and flexion-extension movements in a controlled way, while the mechanism slides in XY plane. The software used for development of the games was Unity with C# language [9]. The features considered for the virtual interface are, patient must be able to follow the therapies trajectories while playing, stimulate strength in the muscles involved in the movements with the gauge, game's purpose is to improve patient precision and motor control, and therapist must be able to select the game level. Interface must display or save the game score to use as a patient's progress.

Games that are included in the interface are, see figure 3, jumping the river and cook pizza. The pizza game movements depend on pronation and supination angles during the device rotation, the pronosupination angle is automatically measured and send to the interface to virtually manipulate the objects (ingredients to cook a pizza). In the jumping the river, the animated character jumps depending on the force exert by the patient and walk side to side depending on the rotation. Figure 2 shows the device used by a volunteer and the board of two games.

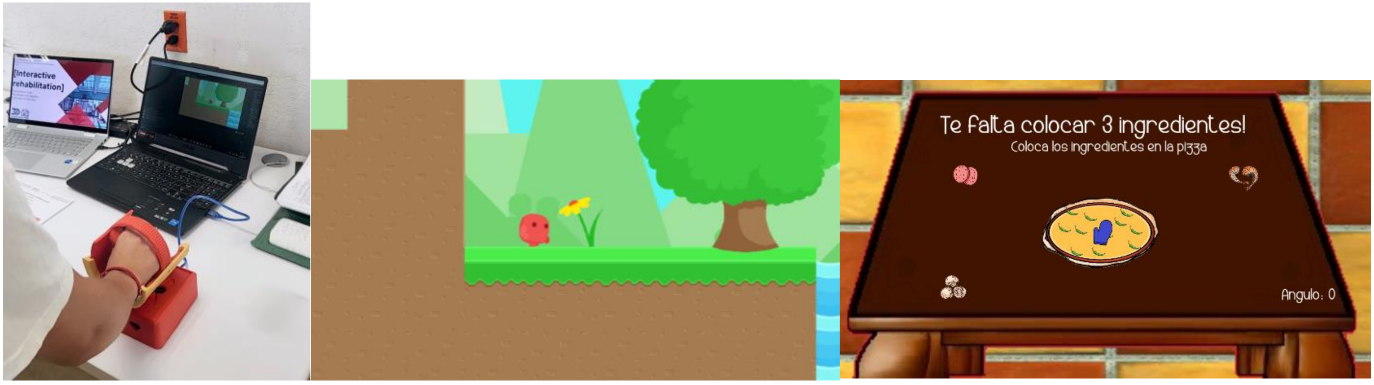

Figure 2. Pronosupinator with games

4 Conclusions

The pronosupination exercise is one of the most important for arm rehabilitation. A pronosupinator device, was developed and tested with some volunteers. The device assists the pronosupination movement and allows the patient arm to rotate according with natural arm movement during the trajectory's execution. Two games were developed to allow a dynamic patient interaction with assisting active rehabilitation therapies. To play the games, the patient must perform movements of pronosupination of the forearm and apply force in the sensor. On the other hand, during the game, the patient feels the need to improve his score and has a tendency to perform wider and precise arm movement. In this way, the game represents an incentive for the patient not to abandon therapies and thus reduce recovery time.

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