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Research article

Interactive device for the treatment of pediatric neuromotor deficiencies using personalized recovery programs

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Abstract: Modern rehabilitation procedures use devices that provide physical therapists with various types of information to improve assessment of patient progress during rehabilitation plans. The new trend of these technologies is the development of safe, portable and comfortable wearable devices with extensive applications in various environments (medical clinics or at the patient's home). The present work presents a portable and safe device for hand rehabilitation, consisting of five finger force sensors and a palmar sensor arranged in the ball, capable of capturing pressure signals during the execution of movements guided by the physiotherapist or by a video game/virtual reality. A 3-axis accelerometer was used to spatially monitor the patient's movements. A series of games with different levels of difficulty were created, through which the degree of mobility of the patient can be monitored depending on the game he chooses and at the same time reflected by the score obtained at the end of the game. Also, to be more interactive, the interface was chosen to play with 2 players simultaneously. So that they can choose to play in the team or as competitors. The system allows users to show different routines to guide them in their use and also evaluates pressure signals and response time.

Keywords: microcontroller, games interactive, physiokinetotherapist, rehabilitation, health improvement.

1. Introduction

Each game in recovery has its own specifics, more precisely it pursues a goal and is a means to reach a goal. In an educational game setting, subjects learn how to solve complex problems. The problems within a game usually start at a minimum level and then become progressively more difficult as the players' skills develop.[1] The most commonly used new recovery strategies are based on play elements and game design principles that enhance learning and the development of relationships and social skills.

Currently, there are a large number of applications that allow children to familiarize themselves with geometric shapes, colors, numbers. The paper simultaneously approaches the use of two game styles (competitive and cooperative) that have their impact on the motivation and communication of users.[2] Pressure sensors applied to human-machine physical interfaces should exhibit linearity, low hysteresis, low drift, low temperature sensitivity, flexibility, thin construction, large measurement range, repeatability, ease of use, and cost-effectiveness. Each technology has its own advantages and disadvantages. [2] According to the multiple requirements of sensors for wearable applications, piezoresistive sensors, capacitive sensors or force sensing resistors seem to be applicable.

However, the performance of force sensing resistors is known to be improved in terms of linearity, stability and repeatability. [3]

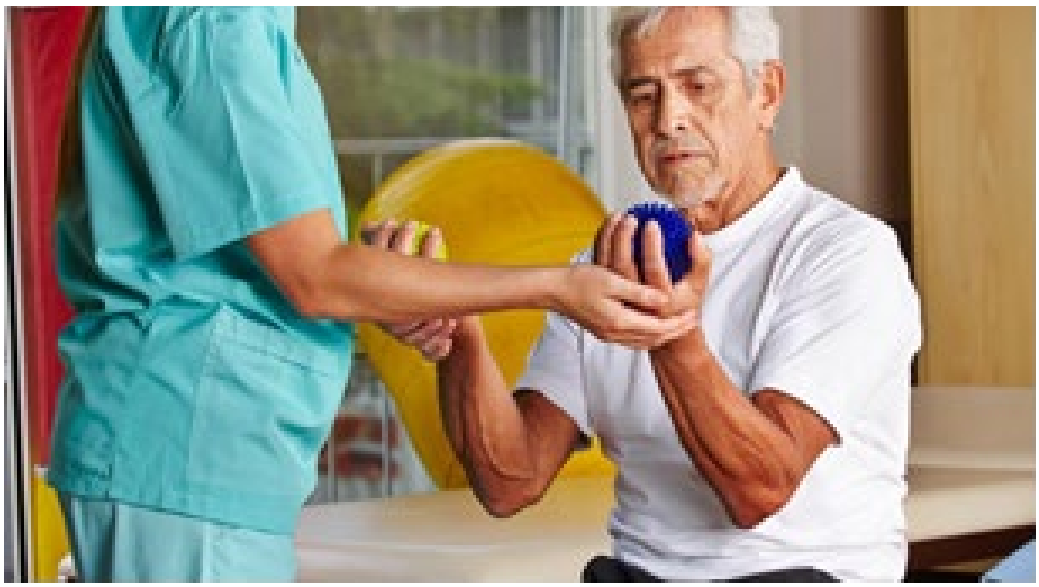

Fig. 1 Recovery through games with a physiotherapist

2.MATERIAL AND METHOD

The design opted for a small, comfortable device capable of monitoring the pressure level, in close correlation with the pressure sensors, which capture the force with which the ball can be tightened. The values are analyzed by the microcontroller and then transmitted via Bluetooth to the laptop on which the interactive application is located.

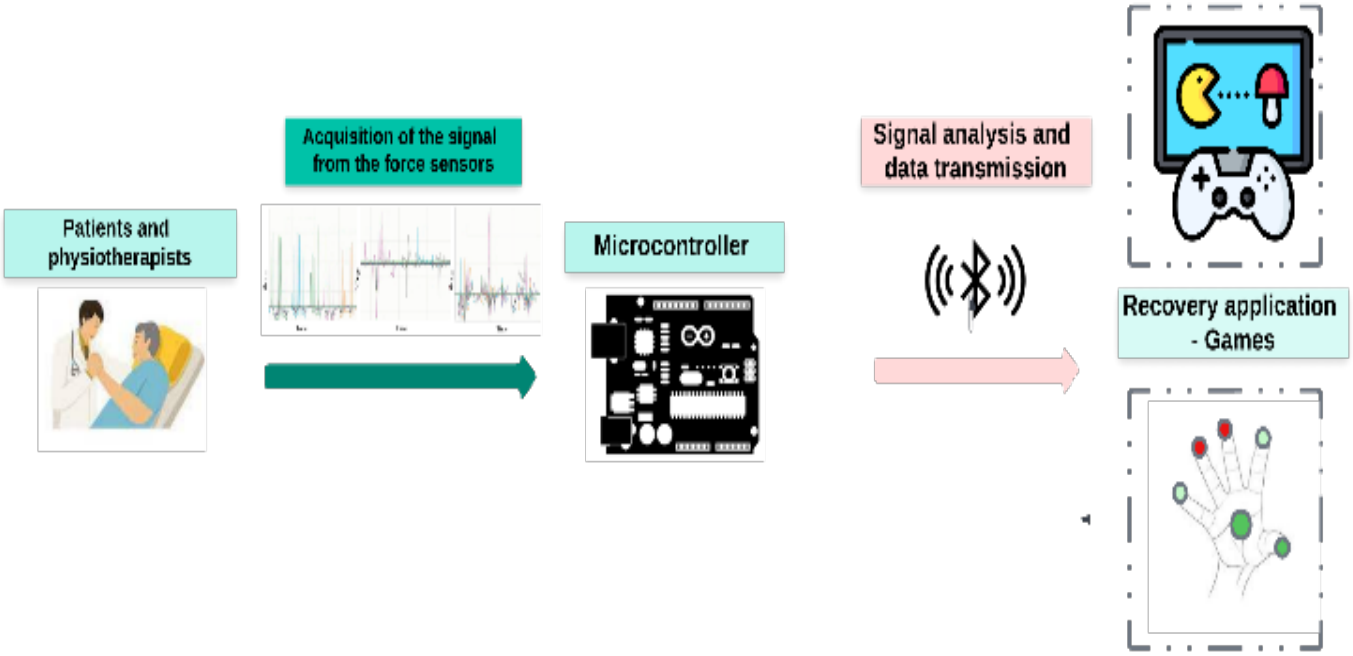

Fig. 2 Block diagram

The designed and built system consists of an Atmega328 microcontroller located on the Arduino Nano development platform, which is defined as an analysis and control unit according to the component connection diagram. (Fig. 3)

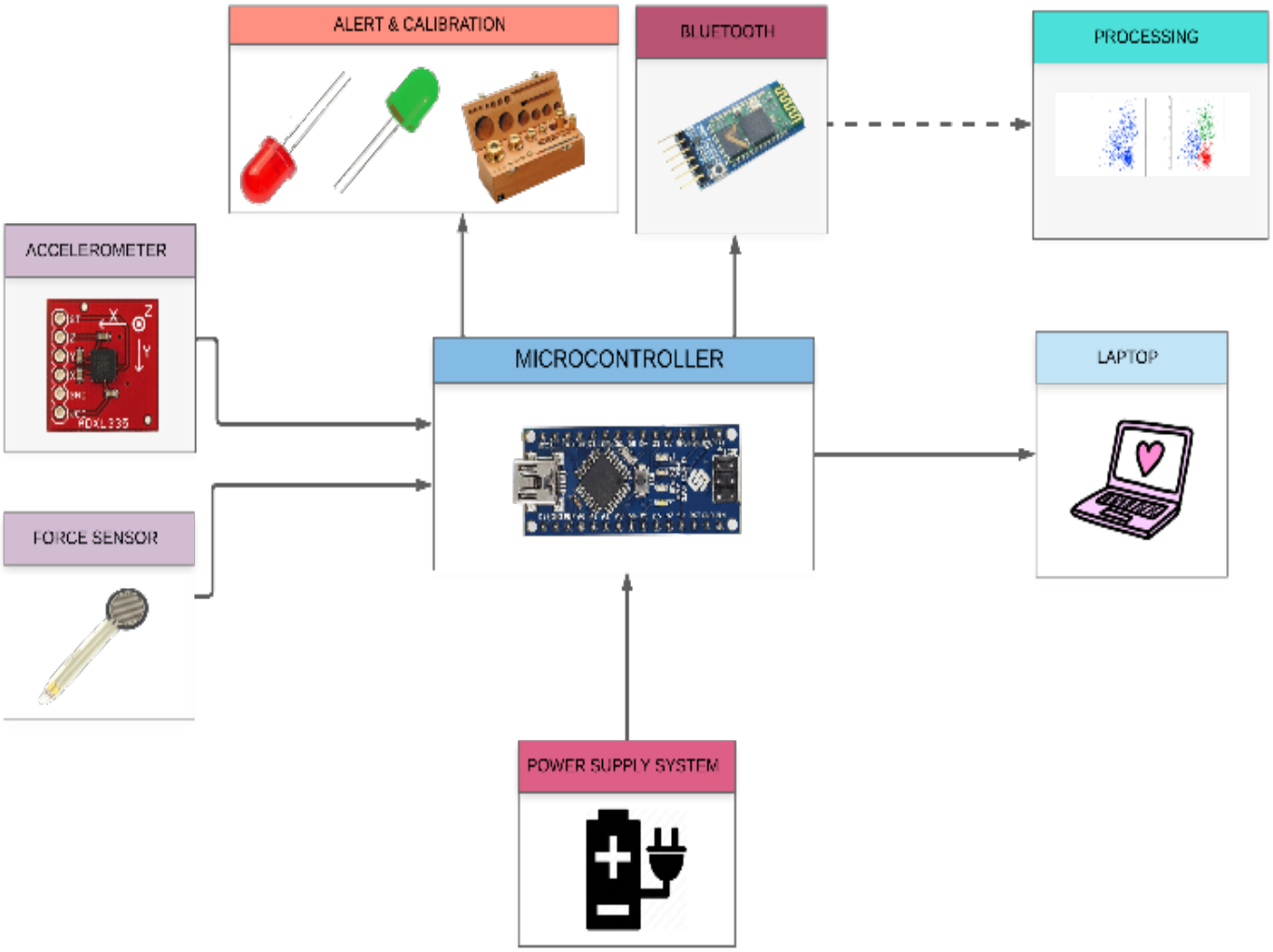

Fig. 3 Device component connection diagram

The main components of the system are represented by: pressure sensors, accelerometer, Bluetooth module, and on the warning side we opted for a two-color LED, all of which are managed by the microcontroller located on the development platform. On the software side, the interface between the proposed system and the virtual rehabilitation applications was made. [4]

Arduino Nano is a processing platform that uses the Arduino IDE application through which programming, compilation and uploading of the program to the microcontroller can be done. It has 14 digital inputs/outputs of which 6 are PWM type, analog inputs/outputs, a 5V and a 3.3V power supply port. Since there is no external power supply, a Mini USB connection can be used. [5]

The main sensor to be able to analyze the degree of pressure from the fingers, it was decided to use pressure sensors of different sizes. The sensor has two connectors, and the resistance measured between the two varies depending on the degree of pressure. The sensor is made of a conductive polymer and is designed to reduce temperature dependence, improve mechanical properties and increase surface durability. A 10KΩ resistor is mounted on the sensor's GND pin coupled in a resistive divider configuration with the sensor. [6] According to the connection diagram of the pressure sensor in the resistive divider configuration, the port named OUT will connect to an analog port of the development platform. (Fig.4).

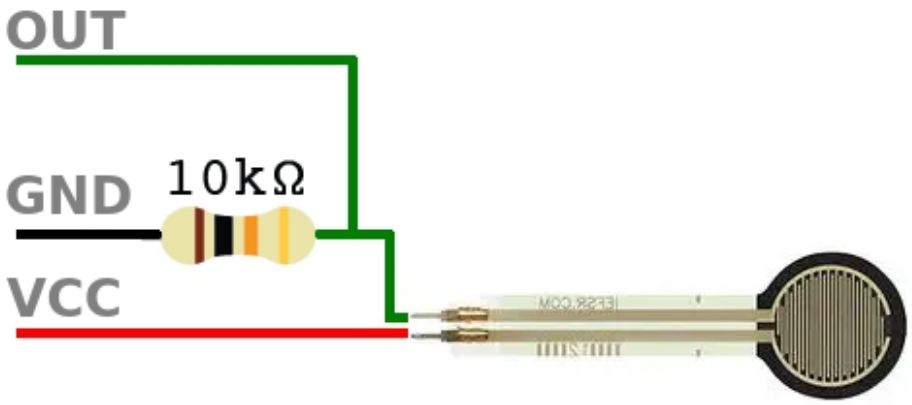

Fig. 4 Principle of operation of the bending sensor

Accelerometer used can detect the movements of the hand, relative to the 3 axes. The mobility of the Y-axis is determined according to the position it will take at the time of calibration, allowing the measurement of tilt changes of less than 1 degree. It works at a supply voltage between 2.8 and 3.3V. (Fig.5). [7]

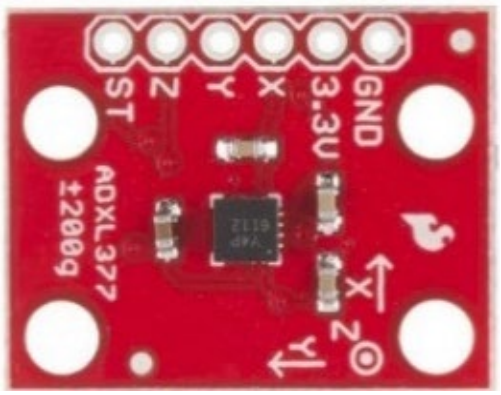

Fig. 5 Accelerometer ADXL 377

In order to warn the patient if he holds the device in the correct position and if he executes the movements correctly, he opted for the visual warning. Visual signals were generated by attached LEDs, one red to warn of incorrect position and one green to highlight correct position. [8]

Fig. 6 Module Bluetooth HC-05s

The Bluetooth module is used to establish a connection between the device and a laptop for the transmission of data to be interpreted in order to create a pressure map. (Fig.6)

3. RESULTS AND DISCUSSIONS

Many rehabilitation system interfaces are not designed to be fun or motivating for users and only have the tasks present in a repetitive way. Thus, it is very difficult to sustain the interest of patients during prolonged exercise with such an interface. Therefore, it was developed in an interactive way by creating age-appropriate games for patients using the Scratch Environment and Oracle Java. These applications can bring a high input in support of game achievements with icons, sound and motion graphics and simple support for Arduino open source hardware platform programming. [9]

Fig. 7 Exercises required of the patient performed using the device

A database was created, which was used to evaluate the type of game chosen together with the score displayed after the completion of the game to have an overview of the patient's evolution. (Fig.7)

The maximum time to complete the activity was 15 minutes, which, on the one hand, can be considered a limitation, and on the other hand, a factor that has an impact on the level of motivation during the procedure. The needs and rehabilitation capabilities of patients vary greatly between individuals and during therapy progression, all this information being stored for analysis by the system.[10]

Name	Name games	Performance level	Score	Task accomplished
Recovery interval – 04.04-22.04.2022				
AL	GOING BALLS	1-2	18	50%
MB		1-2	16	45%
AL		1-2	35	85%
MB		1-2	40	90%
AL		2-3	59	33%
MB		2-3	62	55%
AL		2-3	72	44%
MB		2-3	120	100%
AL		4-5	140	19%
MB		4-5	215	15%
AL		4-5	232	85%
MB		4-5	285	23%
Recovery interval – 10.05-30.05.2022				
MB	GRANDPA RUN 3D	-	16	-
AL		-	19	-
MB		-	72	-
AL		-	77	-
MB		-	36	-
AL		-	189	-
MB		-	256	-
AL		-	261	-
MB		-	265	-
AL		-	270	-

Fig. 8 The results obtained after testing the device on the 2 games

4. CONCLUSIONS

According to the results obtained, the games that were selected were adapted to the age and level of neuro-motor development are satisfactory for them because they trigger states of mind such as enthusiasm, pleasure and curiosity, at the same time increasing the degree of involvement, from a low level, at the beginning , towards a state of well-being, at the end.

As healthcare services are an important part of our society, automating these services reduces the burden on people and eases the measurement process, also the transparency of this system helps patients to trust it. This paper introduced a hand-held device to be used for hand rehabilitation, which is small, portable, lightweight, and easy to adjust to either the right or left hand according to the user's need. The device can be used together with a video game, the interaction of which generates the motivation of the user while performing finger movements. This indicates the great potential of the device to be used in hand rehabilitation routine. In the specialized literature, many cases of successful rehabilitation are reported when serious games and gaming platforms are integrated traditional rehabilitation. Different visual and audio feedback modalities can also be integrated with our device for use in rehabilitation routines aimed at learning different motor tasks.

Thus, in order to be able to highlight the degree of mobility and precision of the fingers, some subjects who had certain difficulties with the mobility of the fingers in the past were introduced. These difficulties are due to injuries during physical activities or during daily activities. Together with a physical therapist, depending on the degree of damage, the type of interactive recovery was chosen according to the person in question.

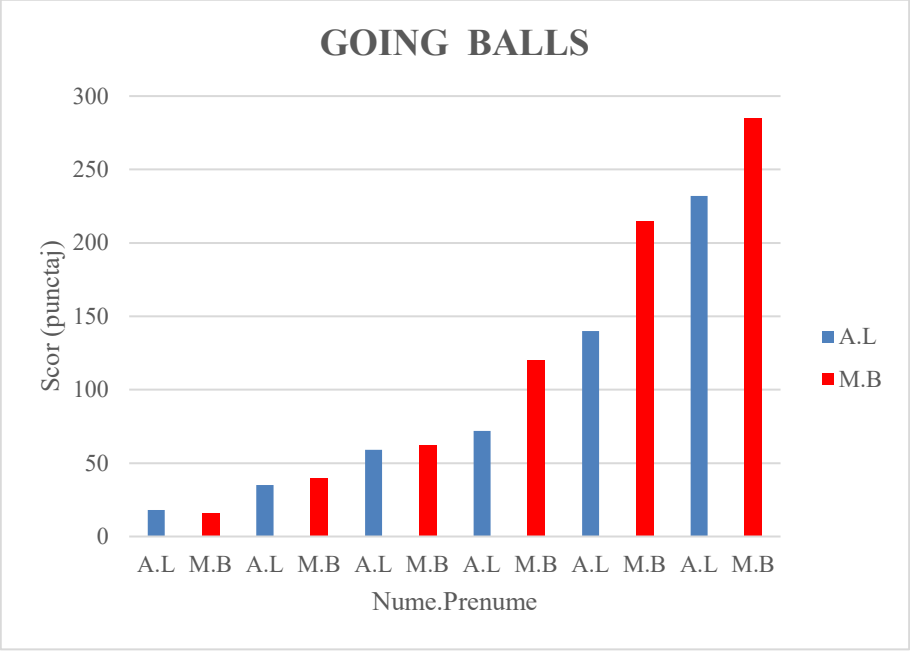

Fig. 9 The evolution of subjects during the game -Goimg Balls

Following the application of the proposed physical therapy program combined with the use of interactive games, we found that many of the initial recovery goals were successfully met in a much shorter time.

In order to highlight the evolution of the patients, initial, intermediate and final evaluations were carried out in different interactive games.

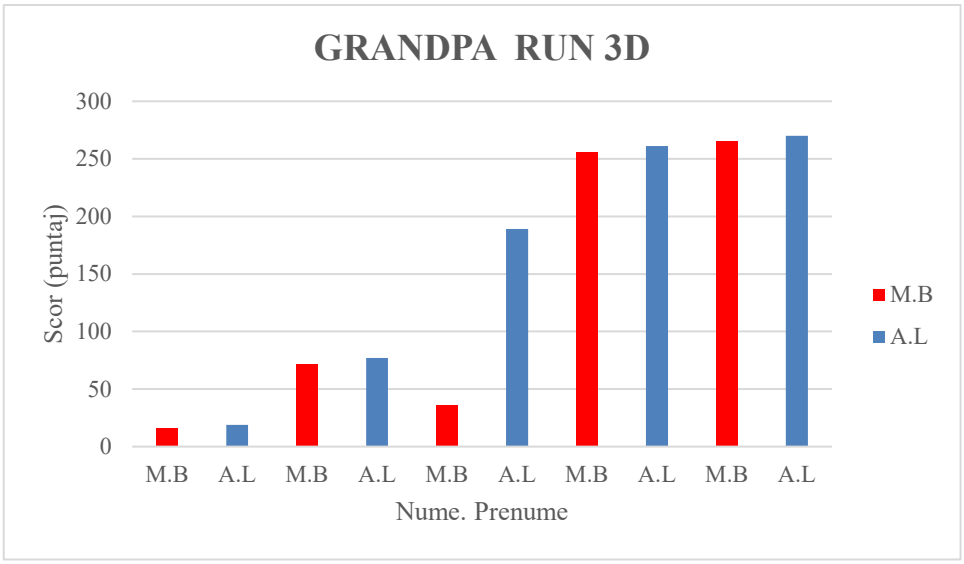

Fig. 10 The evolution of subjects during the game – Grandpa Run 3D

As can be seen from Fig. 9 and Fig. 10, which show the evolution of the subjects following the application of the recovery program chosen together with the physiotherapist.

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