Hand rehabilitation - a gaming experience

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Abstract. This research is made to aim bettering the current hand rehabilitation methodology. It is developed expressly to motivate the patients to play, as their hand is getting healthier. The system consists of a hand motion capturing device, and the game control system, that is using dedicated processing algorithms and aims to register hand movement, and also the progress that the user can make over a period of time. The game it uses is a fairly simple one that does in fact motivate the user to play longer rounds, all the more reason to attend which will always result in positive feedback from the patient.

1. Introduction

The main causes of hand disability were declared to be strokes or heart attacks, accidents (related to work or not), some hereditary causes, syndromes or traumas. Hand rehabilitation can be performed on all medically approved hands decided by a doctor.

The disability, if not completely eradicated, can be substantially reduced. Motor rehabilitation is fundamental for insuring quality of life. Grip force control is of major importance on daily tasks, mostly on maneuvering and manipulating everyday objects. The use of devices that enable automatic recording and objective measurement of rehabilitation practices are based on subjective progress evaluation and statistics.

The use of devices for training and recording hand dexterity and grip force control of a patient, is in favor of both use of feedback and progress recording, besides allowing the incorporation of games in the rehabilitation sessions. Mirror therapy is often one of the best approaches and has one of the most desirable effects when not only does the patient imagine the way their hands move, but also their nervous system can copy the connections associated to the movement from one hand to the other.

The purpose of the research is to find an original, motivating and affordable solution for hand rehabilitation. The objective of the paper is to design and implement a simple game-based hand rehabilitation system. The game considered is Rock-Paper-Scissors. As it contains three possible poses for hand, it means it has a mimic part incorporated, very important for rehabilitation purposes. As it is designed to have two players, one the patient and the other the computer represented by a mechanical hand, it has the challenging, motivating part incorporated.

2. Hand rehabilitation approaches

Hand therapy exercises after strokes, or any other trauma will help patients regain their motor skills and get their hands to work again. However, hand movement problems can become the biggest burdens, and most difficult functions to recover, thus, being very important to experiment with all the available and imaginable options, until the patients have found the solution that works best for them.
Speaking about the hand rehabilitation techniques, we can classify them in two categories as classical and game-based. Classical techniques, that are medical procedures [1], consist of kinesiological exercises [2] and electrical stimulation therapies [3].

For the patients with partial hand movement abilities, there are simple tasks that involve common household items like: stacking coins, pinching clothespins, playing board games like chess, or checkers, putting together puzzles, or even playing the piano.

There are two things that are essential ingredients that everyone's rehabilitation regimen needs in order to achieve success: neuroplasticity and the repetition of practice. These two key features of the treatment will make the most massive difference in the patient's recovery.

Neuroplasticity is the "rewiring" of the nervous system, to connect to the nerves and muscles between their rightful ends, to ensure that there will be an undamaged connection between the nerves, muscles and brain - like a bypass, so that the damaged ends wouldn't meet and do even more damage.

Repetitive practice is the best, in all perspectives, way to activate neuroplasticity and get better. This involves practicing something over and over and over which leads to after stroke rehabilitation success. As the saying goes "You are best at what you repeatedly do." [4] Because the more you repeat something, the more your brain's connections are oriented for it. And that is in fact why repetition is so important for recovery [1].

One of the major challenges of hand rehabilitation is to re-establish the natural way of activating the muscles, while they get measured and improved, through a general restoration of motor control, otherwise impairments may be compensated by the motor system, using a strategy of task control.

New technologies such as neuromuscular electrical stimulation (NES) or functional electrical stimulation (FES) are non-invasive and can restore the pattern of muscle activation, when targeting specific muscles, or groups of muscles, to restore their activation pattern.

The restorative technologies of the FES have proved themselves to be of remarkable potential in enabling and reanimating the movements even in patients with spinal cord injury. The feasibility in using FES in the clinic domain have been established in pioneering works to restore standing, walking, reaching, grasping and other functions. Alternatively, as an interventional technology, FES designed for post-stroke rehabilitation has generated controversial results. The functionality and success of the FES applications are highly depending on the translation from neuroscience and engineering principles into clinically viable paradigms.

The multitude of existing paradigms of the EFS (electrical field stimulation) therapy include the principles of human sensorimotor control. For instance, the development of EMG (electromyography) triggered FES had been oriented to synchronize the subject's movement intention with the onset of FES.

3. Game based rehabilitation system design
The game based rehabilitation systems allow the patients to be the beneficiaries of physical rehabilitation therapy that uses a human-machine interface, an auxiliary to monitor the progress of recovery and rehabilitation.

The games can be:
- With real objects, usually geometrical figures made of rubber;
- Virtual objects, implemented in mixed reality, to aid observing the surrounding environment, and also interact with the virtual objects [5];
- With movements that stimulate certain gestures, for gripping and holding objects.

The device, used to track the hand movements is in the form of a robot-like glove [6], that acquires the values that are provided by the position variation inside a set of potentiometers. The glove has to be calibrated to establish the minimum and maximum values from the closing and opening the hand, so the game can take place with preset values.

The recovery exercises help the patient to regain opening and closing movements for the fingers, all at once, and individually. The glove, positioned over the hand can sense both movements, of
opening and closing the hand, from the fingers. The difference will be given by establishing the minimum and maximum of the closing/opening of the fingers.

Figure 1. 1.a. The minimum open hand values, 1.b. the maximum open hand values, 2.a. The minimum closed hand values, 2.b. the maximum closed hand values.

This way, if monitoring the opening or closing degree of the fingers is desired, then the maximum values for opening will be a minimum for the progress evaluation start and the monitored data will tend towards the nominal minimum which, in time will become a maximum of closing. In return, if the desired effect is opening the fingers, the starting point is the minimum value for closing, towards the maximum of opening. The values connected to the states of minimum and maximum for the glove will provide data for the rehabilitation progress [7].

Figure 2. The gestures made by fingers, correlated to the fingers of the glove.
The exercises can be included in repetition series, which the patient repeats multiple times, or can be included in special game packs that include combinations of the movement types. The movements can be general, which include the mobility of the entire hand, or can be particular, for every individual articulation. In our case, we're referring to the rehabilitation movements of the fingers, and these can be based on gestures [8], that imitate the gripping of certain objects, or to reproduce movements, made by another person or an artificial hand [9], connected to a computer.

With the help of the artificial hand, rehabilitation procedure specific movements that the patient would exercise, will be presented. The glove transmits to the computer, the motion values, and they will be compared with the required values, for progress to be monitored.

The hardware configuration was implemented using the Wearable Mechanical Glove Wireless Somatosensory Controller, that is attached to the user's hand. The acquired data from the 5 potentiometers, determine their further use, by case, what movement was done, the data being transmitted through Bluetooth or USB - to the computer.

Figure 3. The patient performs a hand movement with the robot glove.

On the other side of the connection, there is a computer, also connected to a microcontroller and a 5DOF Robot Five Fingers Mechanical Hand that's driven by an Arduino Development system. The system chooses a random motion and the Arduino system controls the motors, in conformity with the chosen model. At the end of each round, the data from the two devices is compared, the winner is declared and the progress is being highlighted.

The software is now a collection of programs that communicate with each other through multiple protocols. The Glove communicates with the computer via Bluetooth Terminal and sends serial data to a COM port - in the Arduino IDE, from where the data is being accessed via Visual Studio, which is also the software package - responsible for the game's interface and decision making rulebase, then to the Arduino Board that controls the Robotic hand, to make the move which the character "ROBOT" in the game had chosen as an opposing move, versus the "HUMAN". The well-known Arduino IDE, allows the user to read values from the glove’s fingers and also send commands to the robotic hand. The robotic hand has a set of motor movement combinations with the calibrated motors for each finger, individually pre-set.
That also means that no movements outside the pre-configured movements for the “rock, paper and scissors” are the only movements the robot hand can make, for the time, being. But for the sensor the computer receives the data from the Bluetooth Serial Terminal into the Visual Basic application, then compares the computer’s random generated choice to the received data, in order to establish working combinations for the game.

The lines of code for the program, developed for the glove show how every finger of the glove has an analogic value (in this case - electrical impedance), then transformed (thorough and ADC module) into digital data with the combinations of binaries for each finger, in the Visual Basic Application, you can see the binary codes at the bottom of the human’s choice, above the “Read Value (Space)” button.

The game was developed to chose a random object from “Rock, Paper and Scissors”, then to check if the chosen object beats the object chosen by the human, the ROBOT chooses before the HUMAN, then the Match (M) button is pressed to determine the winner of that round.

For the human, there are multiple steps to determine which the chosen object is. A first step is that the hand’s situation generates numeric values, sent from the glove to the software, then the software reads the values, and after the specific set of values are being read, and the chosen object is recognized, the user can continue the game by pressing „Match (M)‟.

The game, being developed for rehabilitation, allows the patient, who’s in game nickname is „HUMAN‟, to press certain keys on the computer keyboard (the Space bar for reading the glove’s values, and picking an object, the M key for the Match operation, the N key for a New Game, that restarts the application, and X to Exit the game).
Figure 5. The game interface of the “Rock, Paper and Scissors” early version.

There are also a set of labels that show the player’s identity and score, after 10 rounds the game will show the scores and a message that says who the winner is, by what score they won, or in some cases if it’s a tie, if both players have the same score after 10 rounds [10]. The patients could leave the game at any moment and have full control over their choice, by the degrees of movement they can achieve with their hands.

4. Results
The system can be used for hand rehabilitation, and motivates the patients to keep trying, as they feel rewarded when they win [2].

Figure 6. The medical technician or patient clicks Read Value (or presses the Space bar), after that, they click Match (or the M key). The application will randomly choose one of three action variants and will compare the two and display the round score.
Everyone is attracted to the recovery process when instead of the exercises that would get them to feel bored, being associated with the idea that most of them would start having the feeling that the progress is not going very well, the patients would have a relaxing and enjoyable time, with a gaming experience, and would be interested in the levels of progress they would reach, and try to set new records every time they would engage in the game that they play to recover, without even realizing that they themselves are the real key to their recovery.

Figure 7. The Visual Basic Application’s code lines, that assign the combinations between the computer’s generated value and the human’s choice - a logical winner, based on a rules base, and creative logic.

The connections between the hardware and software that make the „Rock Paper and Scissors” hand rehabilitation game, possible.

5. Conclusions
From a gaming point of view, it hasn’t been determined what the winner’s prize would be for winning the game, but it’s certain, that no game is about its ending, but about the in-game experience, that’s why, for future developments, augmented reality will be employed for developing such games, applications and environments.

Mixed reality will play an important role in the clinical areas, where the robotic hands that replicate the movement would not have to be real anymore, and will be an animated 3D object that could run a series of scenarios, adapted to the patient’s needs. The patients would copy the movement of an artificial hand, or would interact with it. The correctness of the movement and the progress that each patient would make, could be monitored by the mixed reality - implemented system.

6. References
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