Design and Study of Human-Human Interaction System to Control the Movement of Paralyzed Hands

Submitted by

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Introduction

In rapidly changing world, many people are facing muscle and joint problems due to unhealthy lifestyles. These issues can slow down or stop body movement, sometimes leading to paralysis. Arm and hand paralysis can also result from injuries, illnesses, neurological disorders, and sudden strokes, with strokes causing 29% of these cases. Different therapies are used to relieve pain and help hands move again. Various stimulators are used for muscle pain relief, helping patients move hands more easily. The stimulator is device that activates weak muscles by sending electrical impulses to the nerve and manage pain to activate muscle contraction. Stimulators are often used in physical therapy and rehabilitation to help strengthen muscle, improve blood circulation, and reduce pain.

Aim

The aim is to develop a system that allows therapists to help patients with hand movements by replicating the therapist's own hand motions. A machine learning model will be used to recognize and interpret therapist hand moves. These signals will be processed by the microcontroller which will control a stimulator device to trigger the patient's muscle contractions.

Objectives

The objectives of the proposed system are as follows:

- To design a rehabilitation system for an individual with hand paralysis to regain functionality of their hand
- To design a system that senses electromyography (EMG) signals of the hands of the therapist
- To train a machine learning model to recognize hand movements
- To mimic the hand movement of the therapist to increase flexibility of the patient’s hand

Literature Review:

Franceso Di Nardo et al.[1] studied the dataset of 2880 simulated sEMG signals for signal-to-noise ratio and time to train a hidden single layer fully connected neural network. DEMMAN's performance was used to evaluate sEMG signals and provide reliability prediction of muscle onset/offset in simulated and real sEMG signals. The present work predicted onset/offset timing of muscular recruitment of the machine learning based methods.

Ankita L. Dharmik et al.[2] designed an exoskeleton to assist a person with disability to perform routine tasks. EMG sensors were used to acquire the signals from the muscles of the hand and convert them into voltage and then fed to a signal conditioning circuit. Microcontroller was programmed to rotate servo motor according to the voltage received from the EMG sensors. The exoskeleton works effectively for normal functioning of the daily activities of an exoskeleton for hand rehabilitation.

Mailyn Calderon-Diaz et al.[3] the paper represented the Hamstring strain injury, the most prevalent type of injury among professional soccer players. These injuries are challenging to pinpoint the most crucial risk. There is an increasing need for advanced injury detection and prediction models that can aid doctors in diagnosing or detecting injuries earlier and with greater accuracy. The study focuses on identifying biomarkers of muscle injuries through biomechanical analysis. The study employes several Machine Learning algorithms like Decision Tree, Discriminant method, Logistic Regression, Support Vector Machine (SVM), Artificial Neural Network (ANN), and XGBoost. The integration of machine learning models with fuzzy logic can be investigated to create a hybrid model and improve accuracy.

Ching Yee YONG and Terence Tien Lok SIA [4] proposed a system that implemented Neuro-muscular Electrical Stimulator (NMES) integrated with Human-to-Human Interface (HHI) in the rehabilitation process for stroke patients from which a controller can control the motion of the subject by injecting his own signal to subject. The EMG detects the electrical signals transmitted from the motor neurons when there is muscle contraction. The signals were detected at the receiver's side by NMES and send to the actuators which helped subject to move their hand by mimicking the movements of the controller. The NMES is a device was used electrical impulses to activate muscle contraction. These impulses were delivered through electrode placed on the skin near targeted muscles.

Nestor J. Jarque-Bou et al.[5] reviews the studies of EMG to characterize the muscle activity of the forearm and hand. The paper focused on human hand behavior, improve rehabilitation, control of prostheses, and biomechanical models. Myoelectric hand prostheses used the electrical action potential of the residual muscles in the limb emitted during muscle contractions. The methods like detection, decomposition, processing, and classifications were used to acquire EMG signals.

Yassine Bouteraa et al.[6] presents a remote rehabilitation system that integrates a IoT based connected robot for wrist and forearm rehabilitation which uses Support Vector Machine (SVM) to classify the design for the estimation of muscle fatigue based on the features extracted from the EMG signal acquire from the patient. The rehabilitation robot integrates the biomechanics of the forearm and wrist joints into rehabilitation protocol. The SVM classifier was used to estimate muscle strain based on feature extracted from the EMG signal acquired from the patient.

Md. Latifur Rahman et al.[7] the present work design a low-cost muscle stimulator integrated with IoT to make it more user friendly. The feedback system was developed to receive voltage and send to the IoT device which could be used to determine muscle strength. The IoT device then sends data to a cloud server and stored against the ID of each user so that physiotherapist can monitor the patient. The advantage of this system is that it's affordable, so everyone can use it without spending a lot on hospital bills.

Nat Wannawas and Aldo Faisal [8] presents a method which uses Reinforcement Learning to observe muscle fatigue. The method is based on Gaussain State-space Model (GSSM) that utilizes the Recurrent Neural Network (RNN). The GSSM functions filter that converts an observable environment into a state representation vector. Reinforcement Learning learns a task through reward signals collected from interactions with an environment., occurs in a discrete time. RL-GSSM was trained to control arm movements through muscle stimulation under progressive muscular fatigue.

Dr. G. Sophia Reena [9] the research discussed the design, development, and testing of a tiny wearable interface that uses an array of sensors to monitor and notify a person's back position in real time. The device was capable of detecting and correcting improper posture using wearable EMG and flex sensor. Tiny Machine Learning to monitor human posture and categorize postures in real time. The data fed to the Arduino UNO for further processing of the signal. Flex sensor was used for deflection or blending of the body and EMG sensors record the electrical activity produced by skeletal muscles. LCD was used to display improper posture to the user.

DERVİŞ PAŞA [10] developed a stimulator for drop foot syndrome where a person faces difficulty in lifting the front part of the foot. Functional Electrical Stimulator (FES) uses Force sensitive Resistors (FSR), programmable microcontroller, transmitter, receiver, and electrodes. The system helped many patients with foot drop problem to move easily and comfortably. It worked by supplying electrical pulses to the nervous system to stimulate paralyzed muscles by producing muscular contractions.

Methodology

The proposed system will detect muscle signals from the hand, transmit them to microcontroller, to filter out the noise, and send them to the stimulator. The stimulator will use actuator to mimic the hand movements for the patient. The actuators will ensure that the patient’s hand perform exact movement as directed by the therapist. A machine learning model will be trained to recognize specific hand movements of the therapist and facilitate the patient in performing the exact movements.

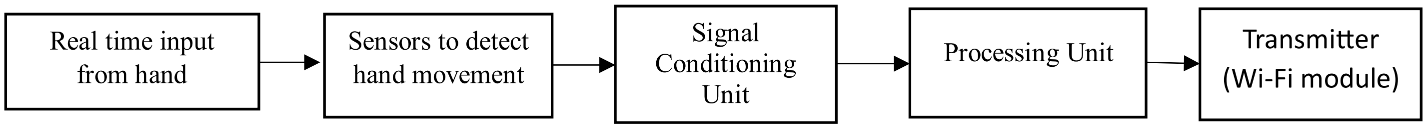

Fig.(a) Real time input from hand using sensor

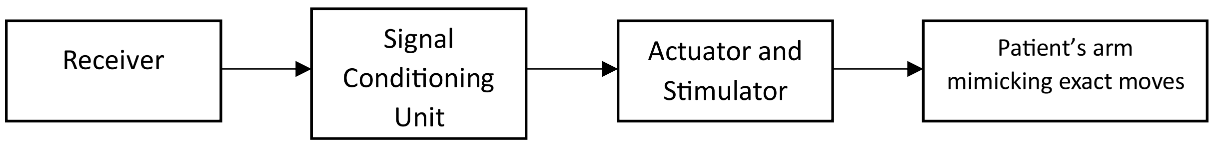

Fig.(b) Patient's hand replicating exact moves

Fig. Block Diagram of the Proposed System

Excepted Outcome

The developed system will be able to mimic the hand movements of normal person's hand to the paralyzed hand by using EMG sensors to sense the muscle contractions and actuators to accelerate the motion of the weak hand.

Significance

The developed system can be used for rehabilitation of the partially or completely paralyzed hand, allowing a therapist to control the patient's hand movement. The therapist can ensure accurate and effective rehabilitation exercises, that can lead to better recovery. The system can help patient regain functional abilities and increase independence in daily activities. Additionally, the system can be used remotely, enabling therapist to assist patients without needing to be physically present.

Social Impact

The human controlled rehabilitation system can help individuals with hand paralysis, regaining hand functionality can enhance their daily life activities. This rehabilitation system reduce healthcare cost as there will not be any need of costly machinery or robotic hand for exercises. It will also reduce long term healthcare cost and enable individual to return to their work.

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