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


Submitted by

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# CHAPTER1: INTRODUCTION

## 1.1 Background

Stroke is a life-threatening condition caused by the death of brain cells, often results in paralysis, affecting approximately 55% to 75% of survivors. The type and severity of paralysis can vary widely depending on the location of the brain damage. Similarly, spinal cord injuries can lead to hand paralysis, significantly impairing both physical function and emotional well-being. The extent of hand paralysis is influenced by the level of the spinal cord injury and the specific nerves affected. Both stroke and spinal cord injuries can have long-lasting effects on a person's quality of life, requiring ongoing rehabilitation and support. Physical therapy can improve muscle strength and help individual to regain motor functionality. The mirror therapy is the traditional method for improving hand motor function, in which mirror is placed between the affected and non-affected hand, and patient imagines the movement of non-affected hand by observing the movement of the affected hand. The rehabilitation system will help them to regain their muscle strength and improve their ability perform daily task.

## 1.2 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] discussed about 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] reviewed 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] presented 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] presented the design of 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] presented 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] 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.

Xiaoshi Chen et al.[11] proposed the human-machine interaction system based on the concept of mirror therapy. Surface EMG was used to collect data from non-affected hand which classify the hand gestures using machine learning model. The STM32F103 was used to integrate DC motor and other sensors. Flex sensor and pressure sensors were used to process the signals coming from the sEMG. Machine Learning algorithms like Support Vector Machine (SVM), k-NN, and subspace k-NN were used for pattern recognition.

Xiaoshi Chen et al.[12] designed a tendon-driven motor glove driven by linear actuator powered by DC micro motor. Flexion sensors and force sensors are also mounted on each finger. Wi-Fi interface was implemented to send and receive control signals. The paper is the continuous work of the previous paper.

Alireza Mohammadi et al.[13] designed the portable tendon-driven soft exoskeleton glove for hand rehabilitation and assistance. Thermoplastic polyurethane (TPU) was used for a 3D printing of the exoskeleton. DC motors were implemented on each finger which was controlled using ATmega2500 microcontroller. The pinch, cylindrical grasp force, and maximum grasp size were measured using two flat surface resistors and two force surface resistors.

Waqas Ahmed et al.[14] developed a robotic hand controlled by the soft glove placed on the healthy hand. The goal was to perform mirror therapy on the robotic hand. Two experiments were performed, the one was feature extraction and gesture recognition, and other was real-time performance for sensing actuation combination of the glove. The output of the flex sensor was evaluated using Arduino and sent it to servo motor to perform the same action.

Xuanyi Zhou et al.[15] developed a tendon-driven robotic finger using servo motors. The robotic finger was controlled by a soft glove worn on a human hand, consist of 14 pressure sensors and 5 bend sensors to collect the data of a human hand. The finger consists of a base, servo drive wheels, and servo motors placed on a base far away from the finger joints.

### 1.3 Problem Statement and Definition

Stroke is a life-threatening condition that can lead to loss of motor function, affecting various parts of the body, including the face, arms, and legs. The loss of hand function, in particular, can significantly hinder daily activities and have a devastating emotional impact. However, with appropriate rehabilitation, many individuals can regain some or all of their lost motor function. The proposed system aims to assist in regaining hand functionality by facilitating fine-motor activities. The system will mimic the movements of the operator's unaffected hand.

### 1.4 Significance of Proposed Work

The proposed rehabilitation system aims to assist individuals with hand paralysis in regaining motor functionality, enabling them to perform daily activities more independently. By mirroring the movements of the unaffected hand, the system offers a novel approach to rehabilitation, potentially improving patient outcomes and offering a more effective rehabilitation system.

### 1.5 Objectives of the Proposed Work

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

### 1.6 Orientation of the Proposed Work

The proposed rehabilitation system will be designed to assist individuals with hand paralysis caused by injuries or stroke. The system consists of two primary components: a sensor phase and an actuator phase. The sensor phase utilizes an electromyography (EMG) sensor connected to a microcontroller on the unaffected hand to capture muscle activity. The actuator phase employs servo motors and a microcontroller to control the movements of the paralyzed hand, mirroring the actions of the unaffected hand. The Wi-Fi module can be used to receive the signals from the non-affected hand.

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