ABSTRACT

A hand amputation is a major life event that has a significant impact on a person's physical capabilities, psychological health, and general quality of life. Losing a hand causes a decline in dexterity and fine motor control, making even easy tasks more challenging to complete daily tasks become difficult or impossible without the aid of a prosthetic device. Hand prosthetics are equipped with advanced mechanisms and cutting-edge technologies that empower users to regain a wide range of hand functions. These innovative devices enable individuals to perform tasks such as grasping, gripping, and manipulating objects with remarkable precision and versatility. Hand prosthetics come in various designs, ranging from simple cosmetic covers to highly advanced myoelectric prosthetics. The latter utilize myoelectric control, a technology that leverages muscle signals from the residual limb to precisely control the movements of the prosthetic hand. Among various physiological signals, the EMG signal, produced through voluntary muscle contractions, demonstrates remarkable capabilities in controlling pattern recognition systems. It stands out because it can be captured from both intact muscles and residual muscles that remain after amputation. Hence, the EMG signal is particularly well-suited for designing prosthetic or orthotic systems.

In recent decades, the design and development of hand and arm prosthetics have been a significant area of research and development, aimed at providing support to individuals with amputation. The improved design of prosthetic-based Human-Machine Interface (HMI) systems incorporates Pattern Recognition (PR) techniques, which extract relevant information in the form of features. Nevertheless, these approaches suffer from a significant drawback concerning the feature extraction and selection process. It requires expertise to effectively manage the dimensionality of inputs for classifiers and

overcome the suboptimal outcomes that arise from inadequate feature performance. In this context, the latest research in multifunctional myoelectric hand prosthetics has focused on analyzing the sEMG signals to achieve optimal performance of prosthetics, specifically enhancing control over multiple Degrees of Freedom (DOFs) by employing AI algorithms. Hence, the objective of this research is to create an indigenous self-regulated hand prosthetic system based on surface electromyography (sEMG). The focus is on investigating ways to enhance the performance of prosthetics by utilizing various machine learning classifiers and configuring deep learning models. Furthermore, our aim is to develop an affordable and practical prototype design for the hand prosthetic.

In this regard, the sEMG signal dataset from publicly available NINAPRO database is utilized and time domain analysis is performed on sEMG signal to obtain feature vectors of the signal and the Pearson's rank correlation test is applied to extract the significant attributes and also to scale down the unessential attributes. Further, supervised ML algorithms namely Support Vector Machine (SVM), Bayes Classifier (BC), Ensemble Classifier (EC) are employed to classify the nine different wrist gestures using the optimal feature vector. The 10-fold cross validation is imparted on the feature vector and thus helps us to achieve better accuracy percentage range between 97.1-99.6 for wrist gesture signal classification. Secondly, a Discrete Convolutional Neural Network (DCNN) based hand wrist gesture signal classification method is presented mainly to bypass the extraction of hand-crafted features used for the ML algorithms. The 1D DCNN architecture is analyzes for a definite frame size of the 1D input signal and the L2 regularization approach has been employed to avoid the data over fitting and stochastic gradient descent algorithm to optimize the CNN loss function, an average classification accuracy of 96.4% for able-bodied subjects and 94.3% for trans-amputee subjects are achieved. Next approach ,the Time-Frequency

analysis is performed on grasping hand gesture sEMG signals by applying Discrete Wavelet Transform(bior3.3 ,Coiflet4 type) to extract the hidden information about changes in muscle activity over time and frequency shifts during different movements through decomposition levels of DWT. The classification accuracy rate between 98.6% and 96.2% from Bior3.3 type DWT transformed grasping signals are accomplished. Further more, the performance of CNN algorithm in handling the increased dimensionality of 1D signal data is examined by using the real time data along with the database data for grasping signal . As expected, the CNN structure manages to work with large amount of grasping data and produces a classification accuracy of 95.4% and 93.9% for combined data set. Next approach, concentrates on the development of cost effective real time prototype structure of prosthetic. Therefore, the structure based on solid works 2021 simulation platform is modelled in this thesis. In this model the phalanxes of the finger are individually designed and then assembled to form a complete hand based on tendon-wire and actuator link and by applying von-Misses stress on the individual phalanxes and the assembled hand, the flexibility of the prosthetic hand is determined with the help of stress-strain analysis. Finally, an actuator links-based hand prosthetics design simulation model to real-time prototype by converting the acrylic phalanxes design to real components using laser cut printing technology and incorporating the micro motors and MCU controller was developed. The flexion and extension movements of the individual assembled finger of hand prosthetics is achieved through IoT technology.