

Classifying Hand Gestures from EMG Data

CP3403 - Data Mining Project

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1 Introduction

Since the turn of the 20th century, a lot of focus has been placed on the incorporation and integration of technology in medical fields. This relationship between medicine and technology has spawned a multitude of life-saving devices such as the Automated External Defibrillator and non-invasive diagnostic tools such as Magnetic Resonance Imaging and Computed Tomography.

With the widespread increase of data mining and analysis in recent years as well as vast improvements in computing and storage power available today, a logical question for the data science community is finding the ways in which this area has the potential of improving the medical industry. In addition to this, in what way can the Internet of Things enable this kind of technology? A field which has attempted to improve the quality of life for it's patients since the beginning is the field of prosthetics.

2 Artificial Neural Networks

The field of classification has been plagued in recent years by the popularity of the Artificial Neural Network (ANN). Constantly evolving, ANN's are machine learning systems that aim to simulate the functionality of biological networks such as the human brain. As they have a constant defined structure, they excel when compared to some other methods as they have no bias from the programmer i.e. they are defined generally, with the data forcing biases in the output of the system.

The basic functionality of ANN's remain the same between different implementations. The building block of all neural networks is the implementation of the "neuron". A neuron is modelled as a weighted function of its inputs. As given by Figure 1, the inputs x_i are weighted by a factor w_i with an added bias b . All of these inputs are then summed and passed through an activation function f_a which filters the output y .

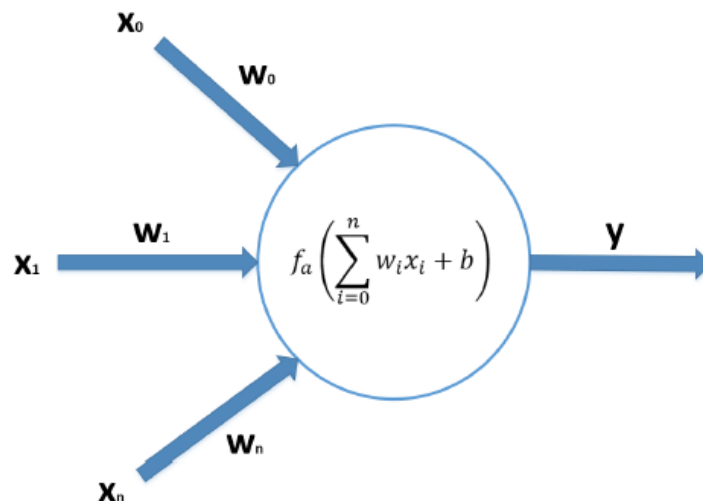


Figure 1: Simple ANN Neuron
[1]

2.1 Multi-layer Perceptron

With this simple neuron functionality, the implementation of the Multi-layer Perceptron (MLP) system can be realised. An MLP system consists of fully connected "layers" of neurons. At their most simple level, they can be realised with a minimum of three layers. The first layer, the input layer is the place in which raw information enters the network. This layer is un-weighted and each neuron fully connects to the next layer, the "hidden" layer. The hidden layer can be a single layer and up to as many layers as the developer chooses. These layers are fully connected i.e. each output connects to every neuron in the next layer. The final layer is called the output layer. This layer is the direct point in which interfacing with the neural network is performed. Depending on the task required, the function of the output layer may vary. The implementation of MLP for this project is explored in Section 2.2.

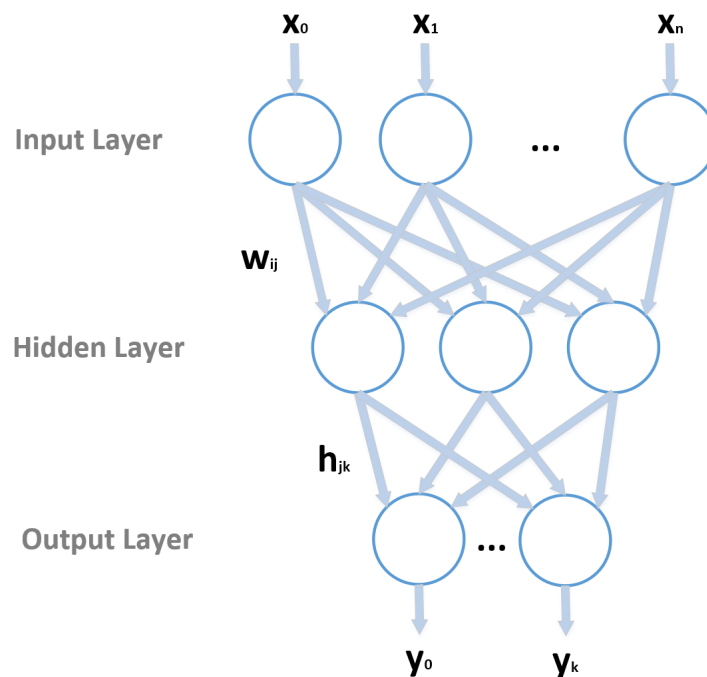


Figure 2: Simple MLP Network
[1]

2.2 MLP for Classification

3 EMG Data for Gestures Data Set

The EMG Data for Gestures Data Set (Available from: <https://archive.ics.uci.edu/ml/datasets/EMG+data+for+gestures>) was a data set created for determining latent factors in the performance of sEMG interfaces [2]. The overall achievement of this paper was identifying some potential medical influences on the use of EMG interfaces to measure gesture information.

This particular dataset was obtained through the use of the Myo Thalmic bracelet (See Figure 3). The EMG channel recordings were obtained through a Bluetooth interface to a computer. A total of eight channels are recorded with each of the sensors equally spaced around the forearm of the subjects recorded.

Table 1: Attributes of the Raw Data Set

Attribute	Description
Time	Time Step of Recording (Numeric)
Channel 1-8	Raw EMG Measurement (Double Precision Float)
Class	Gesture Performed (Numeric 0-7)

Table 2: Descriptions of Attribute Class

Class	Description
0	Unassigned
1	Hand at rest
2	Hand clenched in a fist
3	Wrist Flexion
4	Wrist Extension
5	Radial Deviations
6	Ulnar Deviations
7	Extended Palm

A total of 36 subjects were used for this experiment. Each subject performed a series of static hand gestures (a total of 7 unique gestures) with a 3 second gap between the recording of each gesture. The series were also repeated twice for each subject.

The values recorded by each channel are represented in scientific format corresponding to a double precision floating point number. The magnitude corresponds to the potential measured by the device at the skin level but units were withheld from the data. Further information about the Myo armband revealed that raw EMG data should be transferred as uint8 values corresponding to the amount of "activation" of the muscle [3] but this is not reflected in the data. Based on preliminary analysis, the data should be sufficient as the final system should adapt to incoming signals without the need of specific input data (As long as the format is known).

An important thing to note for this data set is that due to the nature of the data (different subjects), the general classification task will prove more difficult as there are physiological aspects that affect the magnitude of the readings. As explored in [2], people who have greater muscle development in their forearms generally show higher magnitudes on the EMG readings and people with higher body fat content generally have smaller magnitudes.



Figure 3: Thalmic Labs Myo Bracelet

Due to the discontinuation of the Myo armband in 2018, this dataset is unlikely to be able to be replicated or in future. However, the design of the final analysis system should be independent of the recording device used (as preprocessing should solve this problem). As is the design of many systems in use today, modularity is key for these devices to remain cost effective for the end users.

4 Preprocessing

Preprocessing is a crucial step of any data analysis task. Much like any other analysis, the quality of the outputs of the system is directly dependent on the quality and accuracy of the inputs. In addition to this, deeper knowledge of the system is also useful in mapping input data values into system values.

For this system, the following is known about the nature of the data:

- **Values** - The values recorded in the data can generally be represented in scientific notation with up to 5 decimal places.
- **Data Nature** - According to the data sets provided information[2], the data recorded are raw EMG values measured by the Myo armband. As such, special treatment of these values is required to generate reasonable predictions.
- **Data Bias** - As 36 subjects were used to conduct this experiment and the overall goal of this system is to generalise a system for classification, special consideration was required to obtain an accurate representation of the whole data set.

With these goals in mind, a system was designed to both format and clean data as well as prepare it for an MLP system. To design the system the most efficiently and allowing the ability for further experimentation, the system was to be designed in two steps. The first step was the formatting and cleaning of the data files

into a format that could be directly imported into a Relational Database Management System (RDBMS). The second section was then the direct mapping of values into a format conducive to making classifications by the MLP system.

4.1 Data Format Tool

The first section of the overall preprocessing system was to develop a system to interface between raw data values and the RDBMS system storing all the training data for this project. For the sake of reproducibility, this section was designed to interface directly with the EMG Data for Gestures Data Set. Although a reasonably trivial process, it was important to structure the output data in such a way that all systems are able to interpret. The following flow chart describes the functionality of this section.

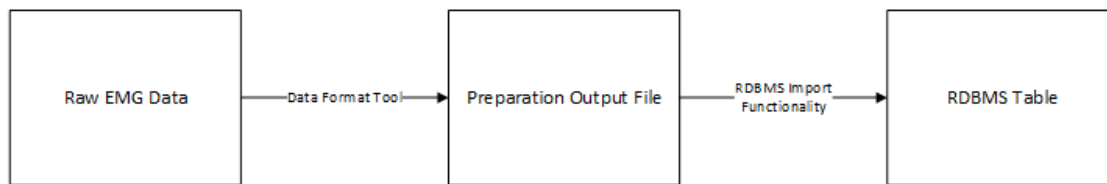
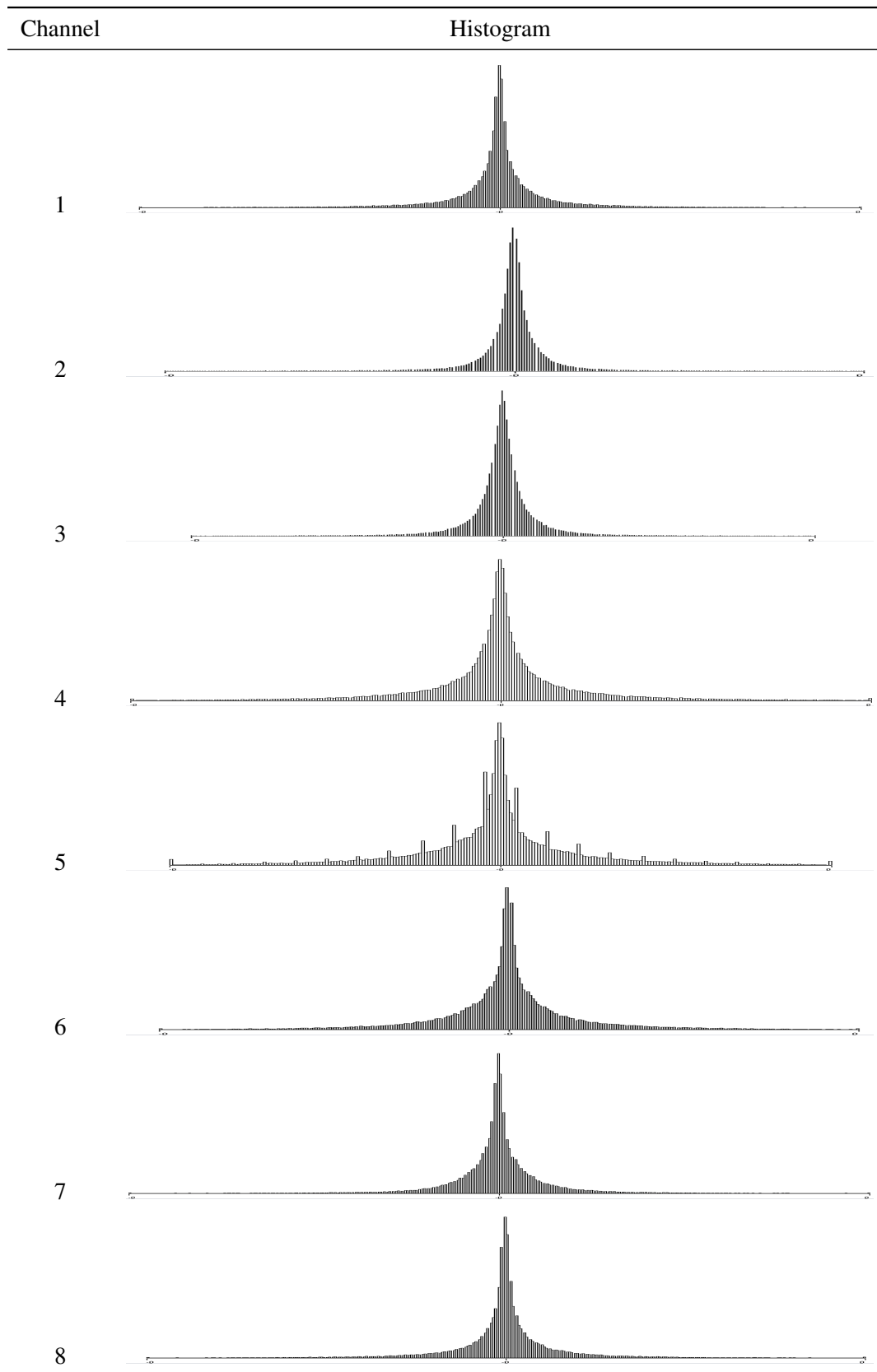


Figure 4: Data Flow of the Formatting System

Table 3 show the distribution of values across each channel. This table was created using the popular data-mining tool WEKA. Due to the size of the input values and the implementation of the WEKA interface, little data insights are directly available. However, the distribution of values for the raw data indicate that there is a fair chance that the data is relatively clean with small quantities of outliers and a very defined bell curve shape about the resting value (channel reading 0).

Table 3: Histogram of values across the EMG Data for Gestures Data Set



The original data file structure consists of multiple folders relating to each subject with multiple data files for each test performed. The data format module was designed such that the entire filesystem will be traversed and each file available on the system is read and converted into the desired interim format. The full exploration of the data format module can be seen in Appendix A. Beyond this, the data format tool has the following features

- Unmarked data is completely removed
- Incomplete data is ignored
- Records are randomised at the conclusion of the import (Generalising the data)
- Records are outputted to a single csv file that is directly importable into SQL Server

4.2 Data Storage

Data storage for this task is an important one, With hundreds of thousands of records available, it is important to develop a system for access and storage of this information. Being a staple of the business world for the last few decades, SQL is an appropriate choice for this task. For this project, Microsoft SQL Server Professional 2017 was chosen as the RDBMS for the gestures data. The output of the Data format tool explained in Section 4.1 can be directly imported into SQL Server through the use of Microsoft's SQL Server Import and Export Wizard.

Table 4: Gestures Table Structure in SQL Server

Field	Data Type	Data Length	Precision	Primary Key
record	int	4	10	1
channel1	float	8	53	0
channel2	float	8	53	0
channel3	float	8	53	0
channel4	float	8	53	0
channel5	float	8	53	0
channel6	float	8	53	0
channel7	float	8	53	0
channel8	float	8	53	0
class	int	4	10	0

4.3 Data Processing

Much unlike many problems in Data Mining, the preprocessing for this system lies primarily in the ability to use insights of the raw data in order to process them for a neural network. As it is inherently a signal processing problem, the following is assumed of the Gestures data based on the range of values

- DC offset is removed from the signal
- The signal has been applied with low-pass filtering and time averaged for each record
-

5 Artificial Neural Networks

6 Conclusion

References

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Appendices

A Data Format Module