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Gait Analysis using Neural Networks

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Abstract - *Gait analysis is the systematic study of animal locomotion, more specifically the study of human motion, using the eye and the brain of observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles. Gait analysis is used to assess and treat individuals with conditions affecting their ability to walk. It is also commonly used in sports and biomechanics to help athletes run more efficiently and to identify posture-related or movement-related problems in people with injuries.*

This paper deals with trying to identify and recognize the gait patterns exhibited by humans by studying the various pressure points in the foot, with the help of a velostat pressure sensing paper placed inside a shoe. This is the simplest and best way of procuring data which can be used for future processing in an Artificial Neural Network (ANN) using the Back Propagation algorithm.

This system can also be used in different scenarios and applications – like feature extraction which can be used as a security measure in airports, banks, airbases to detect forgery and human masquerading.

***Key Words*: Gait analysis; back propagation; Artificial Neural network; biomechanics; velostat; gait patterns; feature extraction**

1. INTRODUCTION

Gait simply means the distance covered as you walk in your stance between two successive steps. Now, because different individuals possess different body features that characterize them, this gait varies from person to person.

Maintaining a healthy posture and balance are key factors in determining the efficiency of gait. The efficiency usually denoted as a percentage portrays how far a person is from maintaining the perfect gait and posture according to his/her body dimensions.

The imperfections in gait can be found and analysed in numerous ways possible. In this paper, a novel and economic method of using pressure as a medium for comparison is detailed. Values of pressure serve as basepoints in the analysis of different pressure zones- that can be mapped based on the concentration of pressure in focused areas.

Table -1: Calculation of gait

Distance to Gait	If you have a 4 foot Gait	If you have a 4.5 foot Gait	If you have a 5 foot Gait	If you have a 5.5 foot Gait	If you have a 6 foot Gait
100 feet	= 25 Gaits	= about 23 Gaits	= 20 Gaits	= about 19 Gaits	= about 17 Gaits
200 feet	= 50 Gaits	= about 45 Gaits	= 40 Gaits	= about 37 Gaits	= about 34 Gaits
300 feet	= 75 Gaits	= about 67 Gaits	= 60 Gaits	= about 55 Gaits	= 50 Gaits
400 feet	= 100 Gaits	= about 89 Gaits	= 80 Gaits	= about 73 Gaits	= about 67 Gaits
500 feet	= 125 Gaits	= about 112 Gaits	= 100 Gaits	= about 91 Gaits	= about 84 Gaits

Now, there are numerous points of contact between the foot and the shoe that is worn by one during locomotion. Varied amount of pressure is exerted at different points on the foot- for instance the pressure experienced by the toes, the heel and the crown of the foot is unique.

Studying these values and trends of pressure obtained, observations can be made about the way a person commutes on foot. Regions of high and low pressure can be identified, and consequently the person gets an analysis- of how to better his posture and gait during walk. This analysis is cardinally important to athletes and patients diagnosed with orthodontic or neuro-muscular ailments alike- because their movement needs to be monitored carefully from time to time. Gait analysis covers the walking style uniquely and many subsets of walk like angles, speed, foot intensity, leg size, etc.

Now, this entire process of gait analysis has been done in three stages:

1) Extraction and processing of data

2) Training of the ANN with the data

3) Testing the ANN and procuring results

1.1 Extraction and processing of data

The data to be processed in the neural network is obtained in this stage. The proper pressure values from the foot positions are taken and passed into the neural network for segregation and meaningful analysis of a person's gait.

This stage involves the collection of the analog data from the shoe, digitalizing the data and transmitting it to an IOT (Internet Of Things) platform where it is fed into a neural network for further processing.

1.2 Training of the ANN with the data

The back propagation algorithm is used for implementing the ANN because it a systematic and reliable method for training multi-layer ANNs. The multi-layer forward network uses the gradient descent based delta learning rule, or commonly known as the back propagation of errors rule. The network is designed in such a manner so as to strike a balance between the ability to respond correctly to the input patterns that are used for training and the ability to provide good responses to the inputs that are similar.

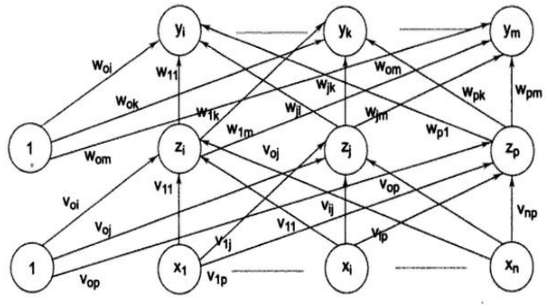

Figure -1: Architecture of the back propagation network.

A multilayer feed forward back propagation network with one layer of hidden z-hidden units is shown in Figure-1. The Y output unit has Wok bias and the Z hidden unit has Vok bias. Both the input and the output units have a bias. The input layer is connected to the hidden layer, which is in turn connected to the output layer by means of interconnection weights. Please note that only the feed forward phase is being depicted in Figure-1, but during the back propagation phase of learning, the signals are sent in the reverse direction. There can be multiple hidden layers present in the network and the computational complexity of the network increases as the number of hidden layers increase.

The training algorithm of the back propagation involves four main stages:

1. Initialization of weights
2. Forward feeding of information
3. Back Propagation of errors
4. Updating weights and biases

Now, the pressure readings that are entered as parameters into the network, all represent some characteristic features which need be specified quantitatively, but this is obviated by choosing the back propagation algorithm as it's formula can be applied to any network, irrespective of the individual features of the network. The computing time can be reduced by choosing smaller weights at the beginning of training. The batch update of weights exists, which provide a smoothing effect on the weight correction terms.

1.3 Testing the ANN and procuring results

Once the neural network is trained, when it is excited with an input, the network classifies the given input into two outputs- with a proper gait and posture or with an imbalanced gait and posture, by examining the pressure exerted on several points on the feet.

2. EXPERIMENT DONE WITH THE PROTOTYPE

The above explained procedure was carried out with the help of a prototype- that consists of:

1. A shoe with velostat paper aligned on top of the sole of the shoe.
2. Node MCU (IOT platform connectivity) source embedded outside the shoe.
3. An aurduino NANO microcontroller board placed beside the shoe lace.

Now, the prototype was targeted at identifying primary faults in gait and posture by making a candidate walk a few steps and thereby, getting the values of the pressure that he/she exerts on some key points on his/her foot.

I have used four such points on the foot- namely the mid region, heel, toes, base of the crown.

2.1 Functioning of Components used

The most principal component used in obtaining the pressure values is the velostat pressure sensing paper.

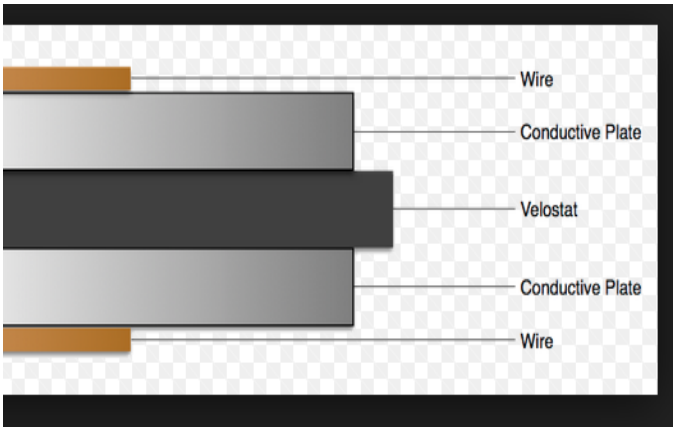

Figure -2: A rough schematic of the velostat setup

The working principle of the velostat is very simple- its resistance varies according to the pressure that is applied on it. This difference in pressure causes the dimensions of the velostat to change in the region of application of pressure.

$$R = \frac{\rho L}{A}$$

ρ = resistivity
L = length
A = cross sectional area

Equation-1: Resistance dependence on dimensions

Thus, the change in dimensions changes the resistance, which impacts the output current that is obtained on either side of the conductive plates- as illustrated in figure-2.

Now, according to the values of voltage observed as a result of the changes in current, we can gauge the amount of pressure applied at localized areas on the velostat- thereby collecting data that describes the various amounts of pressure that is exerted on different points on the foot.

But, these values of voltage are analog values, which need to be digitized for further transmission and processing.

So, we use the aurduino NANO (Atmega 328P) microcontroller's inbuilt ADCs (Analog to Digital converters) to digitize these analog values of current.

Now, the project also encompasses these virtues which makes it unique and adaptable:

1. Ability to trigger the request gait status at will using a smart virtual assistant. (Amazon Alexa).
2. Remote cloud-backup of all data for live monitoring.
3. Easy way to identify the pressure points by just wearing a shoe.

Now, to facilitate all these cloud related services, the IOT platform connectivity is taken care of by the node MCU device. This node MCU facilitates internet connectivity, and enables these values to be transferred to the bluemix IOT platform.

Figure -3: Picture of the prototype

Table -2: Data set obtained for processing at different areas of the foot

S.no	Toe	Heel	Crown base	Mid region
1.	845	670	921	880
2.	769	540	1081	844
3.	591	611	1004	581
4.	617	620	982	688
5.	957	538	897	716
6.	702	577	1020	591
7.	535	690	1010	604
8.	839	623	861	838
9.	630	544	972	648
10.	919	519	886	886

The data shown in Table-1 represents the analog data that is perceived by the ADC, according to its design. Now, since we have used the aurduino NANO's inbuilt 10bit ADC which deals with 5 volts, these readings can be interpreted as divisions in voltages, the maximum value of 1024- corresponding to 5V.

So for eg., by using simple unitary arithmetic, we can say that

1024 - > corresponds to 5V

670 -> corresponds to ?V

⇨ (670*5)/1024= 3.271 V

In this way, the analog voltage readings can be interpreted.

It is also inherently evident that since V=IR (Ohm's law),

the voltage increases, when the resistance increases and vice versa.

From Equation-1, it is clear that whenever the pressure is applied on the velostat, it's cross section area 'A' increases and hence the resistance decreases. In turn, the voltage observed also decreases.

This is evident from the table, as the heel and the toe are the two major areas where the most amount of pressure is exerted during walking, and thus they exhibit the least magnitudes of voltages.

Finally, these analog values get digitized and get transmitted onto the Bluemix IOT platform, where they are coded to represent different pressure points.

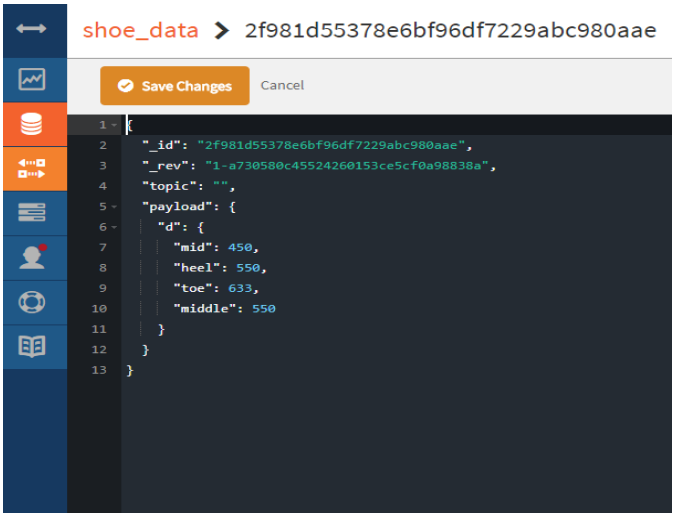

Figure -4: Code for the different pressure points

The experiment still needs to connect the hardware to the cloud monitoring and processing of data.

We use the NODE RED flow for achieving this goal.

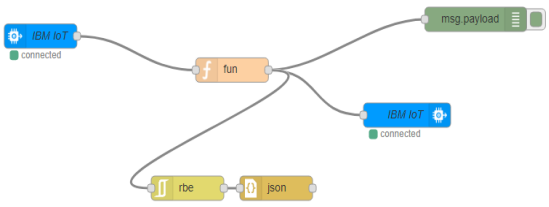

Figure -5: NODE RED flow

Now, the trained neural network gets the input data and plots the non-linear curve that depicts the boundary between satisfactory gait and posture and improper gait and posture. The Back Propagation algorithm has been implemented by using Matlab 2017.

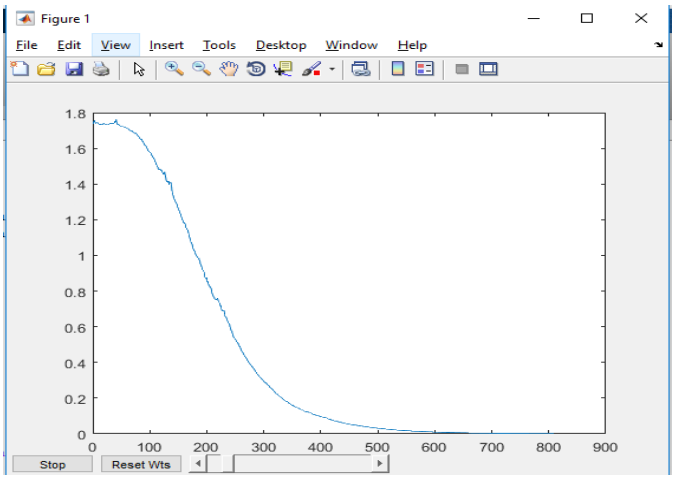

Figure -6: Neural network analysis and final result

Figure-6 shows the graph of a regressive non-linear separative region denoting the difference between the optimum and high pressure region.

This is obtained after the completion of the back – propagation algorithm in Matlab. The X- axis represents the analog values as referenced by the ADC. The Y axis represents the absolute voltage values.

The area beneath the curve bounded by the X and Y axes represents the portion of acceptable gait and good posture. The area above the curve shows that too much pressure is being exerted on the foot, which reflects bad gait and posture.

Now, the information this graph displays needs to be explained to the common people who use this project. So, the voice assistant Amazon Alexa has been trained to voice out the Gait Status for the points that fall on this graph.

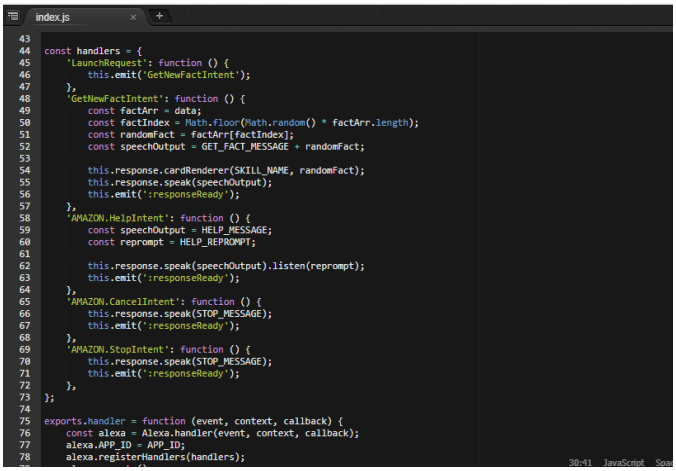

Figure -7: The Amazon Alexa code window

Finally, the following is spoken out by Alexa, to the user.

The user can also see how much his/her posture has improved by comparing the previous results with the latest ones obtained.

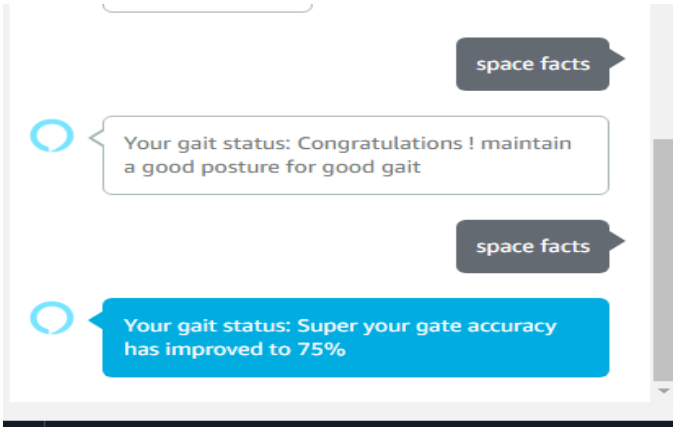

Figure -8: Amazon Alexa voice output

3. CONCLUSION

The gait status is thus effectively calculated by means of just wearing a shoe and walking a few steps. The accuracy and the features served by implementing this experiment can be improved by incorporating more sophisticated technology into the prototype.

Thus, this paper effectively summarizes the importance of maintaining a good posture and gait by carrying out an experiment, which despite being novel in technique, is easy and economically viable to implement.

4. REFERENCES

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