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Detailed Gait Analysis and Prediction: 24/7 Approach

Dr H S Manjula[1], Vishesh S[2], Priyanka PA[3], Nagaraj S Islur[4], Nishanth R[5]

Assistant Professor, Biochemistry, SJICS&R, Bangalore, India[1]

BE, MBA (e-Business), PGDIB[2]

Student, MBA (Business Analytics), CMS Business School, Bangalore, India[3]

Student, BE, DSATM, Bangalore, India[4,5]

Abstract: Diabetes Mellitus (DM) [1] is one the most dreaded life style disease condition which is spreading as an epidemic across the globe. Diabetes is a group of metabolic diseases characterized by hyperglycemia or hypoglycemia resulting from defects in insulin secretion, insulin action, or both. Chronic hyperglycemia is associated with long-term damage, dysfunction, and failure of different organs, especially the eyes, kidneys, nerves, heart, and blood vessels. In our assignment, we consider the effect of Diabetes Mellitus on the healing of foot ulcers, internal bleeding due to false postures and many more. So, there is a need for monitoring foot pressure and treating these conditions effectively. But each person's feet and walking pattern are different and unique. In this paper, we present a versatile and any-size-fit in-shoe sensor which is capable of capturing data as you walk in real-time; vivid and easy to understand graphics obtained, will let the subject and the doctor see what happens while walking. The graphics are displayed on the Smartphones using an Android application developed by us. It is wireless, portable and user friendly technology and also records the data or history for gait analysis by a podiatrist. The user friendly application will display the foot strikes dynamically as a movie, frame by frame. A podiatrist or the subject can use side by side comparisons of graphics before and after treatment to evaluate effectiveness or suggest correction. The acquired data consists of many pressure points values which directly or indirectly affect the fitness of the diabetic foot. Data pre-processing helps to format the data into useful form by removing redundancy and noise, eliminating missing and non-numerical values, and also by normalization. Data analysis and visualization are carried out to improve the statistical analysis of given data. Logistic regression is carried out on the data since it contains lot of columns with categorical values. Accuracy, precision, and f1 score of the model have been measured. Various conclusions can be drawn from this interdependent data set and can be stored as historical data for future analysis.

Keywords: Diabetes Mellitus (DM), hyperglycemia, hypoglycemia Machine Learning, Data pre-processing, Logistic regression, accuracy, f1 score, foot ulcers, podiatrist, Android application, pressure point values, Smartphones

I. INTRODUCTION

Podiatry or podiatric medicine is a branch of medical science devoted to the study, diagnosis, medical and surgical treatment of disorders of the foot, ankle and lower extremity. Podiatrists perform gait analysis on patients before treatment. Using gait analysis would help one determine the tools needed to control the entire environment in which the foot functions. [1] These tools may include orthotic devices, shoes, shoe modifications or even surgery. Gait analysis is also prescribed post-surgery or post injury. Pressure mapping of the feet is used for:

- Measuring degree of pronation [2]
- Determining degree of ankle joint equinus [3]
- Determining patterns of weight bearing forces [4]
- Determining amount of tibial varum [5]
- Back pain can be diagnosed with pressure mapping of the foot and gait analysis [6]
- Symmetry between feet [7]
- Determining areas of highest pressure [8]
- Identifying areas of potential ulceration in diabetics. [9]
- To evaluate surgical procedures [10]
- Gait analysis of athletes for better performance [11]

The present system of gait analysis used by podiatrists is not wireless, is restricted to podiatric centres, use bulky sensors and can be monitored using software available only at labs or hospitals. We employ a lightweight, portable, wireless and user friendly system for monitoring of gait patterns. On top of that, we make use of a thin, flexible and "one-size-fits-all in-shoe" sensors. We have also made use of an android application to represent gait patterns

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graphically and pictorially. Gait is dynamic and everything happens quickly. To make an assessment, we have to capture each movement every second one's heel hits the ground. Pressure mapping technology allows us to do that by capturing pressure data in each phase of foot motion, from heel contact to toe-off. The information it provides on how one's feet are functioning and how one is walking through abnormal pressure gradients, helps prescribe effective treatment. Using this technology reveals a host of various other conditions that cannot be seen otherwise. Whether it is to assess how effective the orthotics is, to detect limb length discrepancy, assess lower back pain, and identify potential areas of ulceration in diabetics and post-surgery help. Athletics is a key area where assessing the athlete's foot functioning gait is critical. When a person is running, his feet are striking the ground with roughly three times of his body weight and these pressures can create significant problems for body movement and functioning. With this technology, one can enhance his or her performance, choose appropriate footwear and prevent injuries.

II. PROBLEM STATEMENT

To construct a lightweight, portable, wireless and user friendly system for monitoring of gait patterns. On top of that, we make use of a thin, flexible and "one-size-fits-all in-shoe" sensors. To build an android application to represent gait patterns graphically and pictorially. Data has to be acquired from reports. Data analysis and visualization needs to be carried out for statistical and graphical analysis of the acquired data. Logistic regression needs to be carried out on the data set (categorical). Accuracy, precision, and f1 score of the model to be measured. Conclusions to be drawn from the prepared report.

III. EXISTING DEVICE

The existing system is bulky and employs CRO's which seems to be out-dated corresponding to today's improving technology and miniaturization. Figure 1 shows the existing podiatric monitor. The device is not portable and is fixed. To monitor one has to sit long hours, as a result few minutes of monitoring is possible. Since the number of patients suffering from DM is huge, and the people who are affected by ulcers are very high a robust and 24/7 monitoring system is essential.

Figure 1 shows the existing podiatric monitor.

Figure 2 shows the technicians monitoring the foot pressure values at that instant. Another drawback of the existing system is the use of PPGs for foot monitoring, which can only measure the vascular condition of the foot. Figure 3 shows PPG Vascular Doppler procedure on a subject. Figure 4 shows people standing in a queue for their turn, for treatment of ulcers and other foot conditions due to DM. We found out that most of them are from faraway places and villages. If the government along with elite researchers, put efforts for the same, most of them can be treated at an affordable price and even footwear designed and distributed.

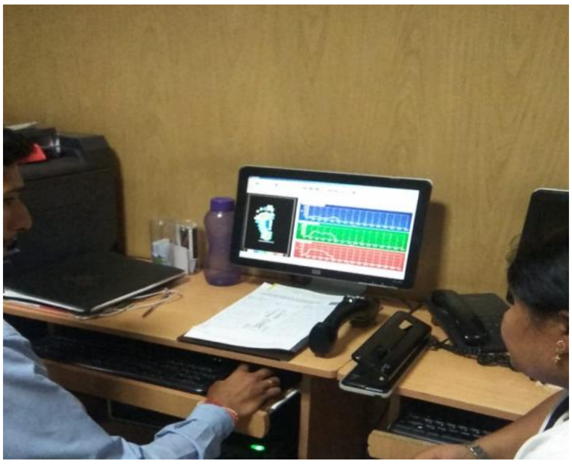

Figure 2 shows the technicians monitoring the foot pressure values at that instant.

Figure 3 shows PPG Vascular Doppler procedure on a subject.

Figure 4 shows people standing in a queue for their turn, for treatment of ulcers and other foot conditions due to DM.

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IV. PROPOSED DEVICE

Figure 5 shows the block diagram of the foot pressure mapping technology. We make use of a sensor that is thin, flexible and which can be cut into any shape depending on the size of the foot and can be placed in shoes. Figure 6 shows the in-foot sensor. Figure 7 shows how the sensor can be cut to fit inside the shoe of a specific person thereby eliminating the use of different sized sensors for the same application because of the varying foot sizes of people. The subject, by wearing the shoe with sensor can continue the daily routine activities. The input to the pressure sensor is the pressure applied on it by the foot of the subject which is continuously processed by the microcontroller and sent to the Smartphone via a Bluetooth device for the monitoring of gait. Wireless data transmission eliminates the hindrance caused due to long wires and Smartphone interface helps the subject for user friendly, self-analysis and anytime-anywhere analysis of foot movement. In fact these gait patterns can be monitored in real time and can also be stored in the SD card for comparing results before and after treatment. We have developed an android application which displays graphical and pictorial data of the feet in real time. Also points of highest pressure are indicated in a square box. The regions are colour coded. Red indicates highest pressure; blue indicates lower pressure and white indicates no pressure. Figure 8 shows the screen shot of the android application developed by us.

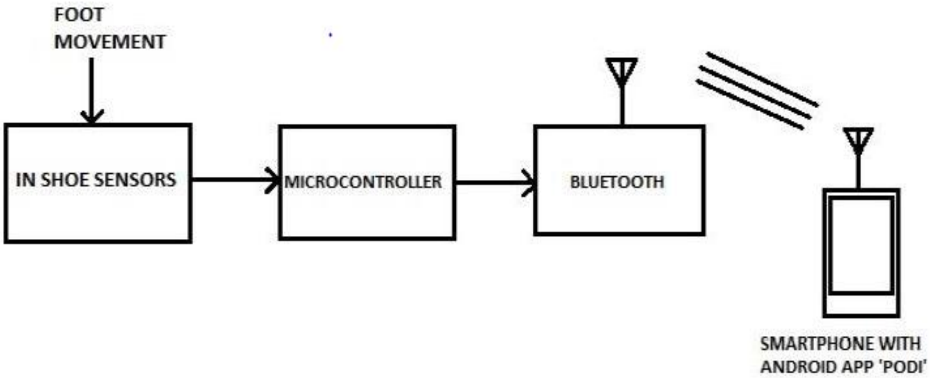

Figure 5 shows the block diagram of the foot pressure mapping technology.

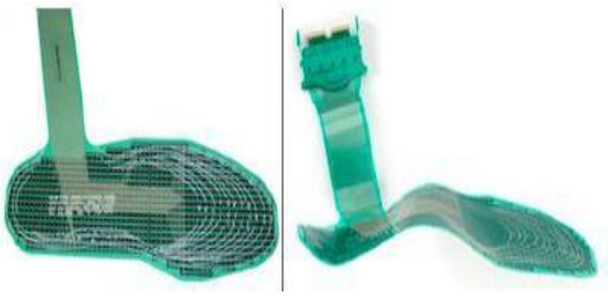

Figure 6 shows the in-foot sensor.

Figure 7 shows how the sensor can be cut to fit inside the shoe of a specific person

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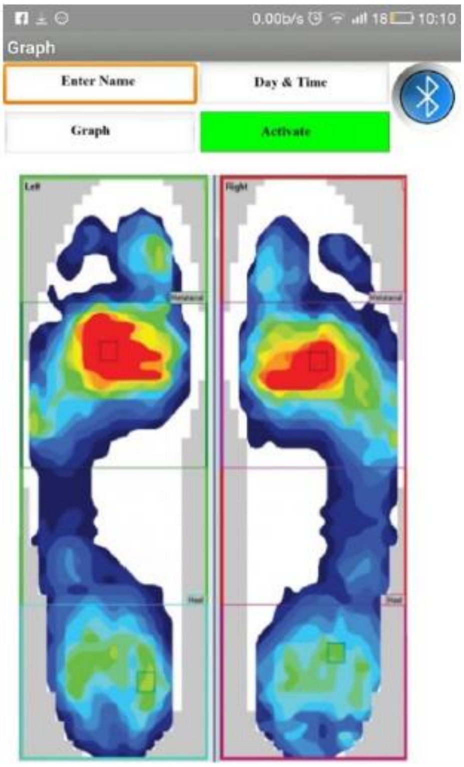

Figure 8 shows the screen shot of the android application developed by us.

V.METHODOLOGY

A. Importing Libraries

Figure 9 shows the Python code to import libraries. We have used three libraries

- 'numpy' is a package for scientific computing with Python. This library is imported as 'np' and will be used throughout the project.
- 'pandas' is for data manipulation and analysis. panadas is an open source, BSD- licenced library providing easy-to-use data structures and data analysis tools. pandas is imported as pd.
- 'matplotlib.pyplot' is a collection of command style functions that make matplotlib work like MATLAB. It is imported as plt
- 'seaborn' is a Python data visualization library based on matplotlib for attractive and informative statistical graphics.

B. Importing data

Data from respective directory/ file is imported and assigned to DataFrame df. The data stored in CSV format is being imported.

C. Checking for NaN and noise

It is very essential in data pre-processing to check for NaN. In this attempt we could identify few NaN.

D. Manipulating NaN values

It is essential to remove the NaN values. This can be done by

- Removing the entire column containing many NaN values
- Forward fillna method
- Backward fillna method
- Mean method

E. Data Visualization and data exploration needs to be carried out, which is explained in the next section.

F. Plotting a Heatmap

Correlation between the fields of the recorded data is analysed by plotting a heatmap. The values may be negative or positive and the magnitude plays a key role in designing various predictive models in AI.

G. Splitting the data into train and test sets. Figure 10 shows the python code to split the data set into train and test data.

H. Applying logistic regression on the split data. Figure 11 shows logistic regression on given data set.

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```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split
```

Figure 9 shows the Python code to import libraries.

```
In [20]:
from sklearn.model_selection import train_test_split

In [77]:
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=12)
```

Figure 10 shows the python code to split the data set into train and test data.

```
In [82]:
from sklearn.linear_model import LogisticRegression

In [85]:
logmodel= LogisticRegression()
logmodel.fit(X_train,y_train)
```

Figure 11 shows logistic regression on given data set.

VI. DATA VISUALIZATION

Data visualization is an integral part of data analytics and Machine Learning. When there is a huge data set, manual analytics becomes almost impossible. Data visualization plays a vital role in analysis in such situation. It involves use of various plots – bar graph, pie charts, box plots, line graphs and many more. Figure 12 shows a bar graph of FBS. Figure 13 shows the line plot of age v/s. fbs.

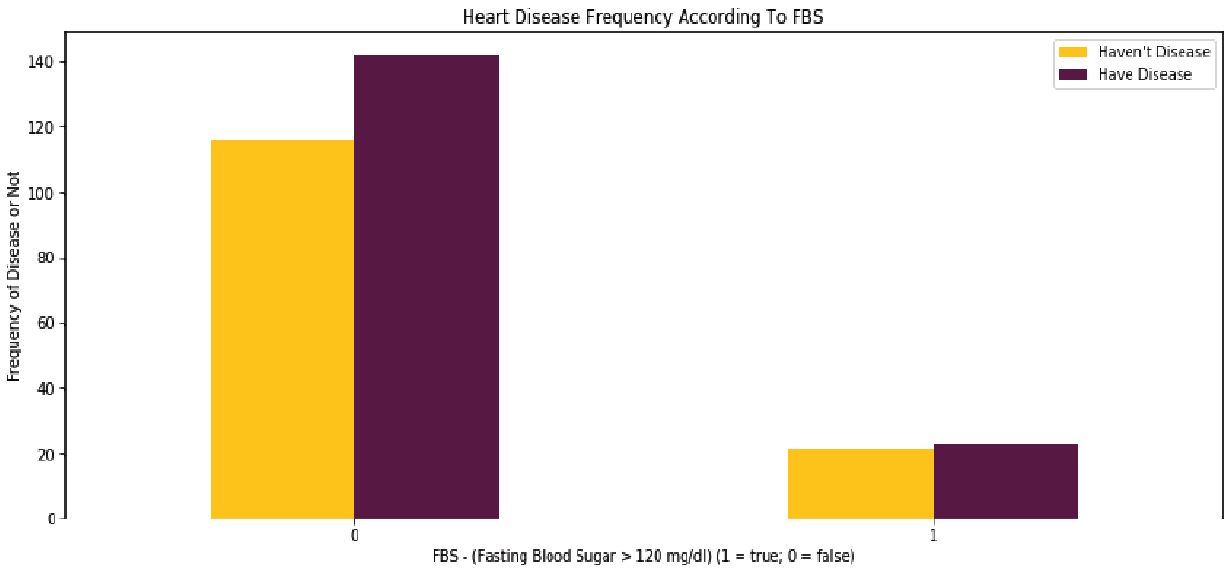

Figure 12 shows a bar graph of FBS.

```
f=plt.subplots(figsize=(15,5))
sns.lineplot(x="age",y='fbs',data=df)
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x1e1b2010b38>
```

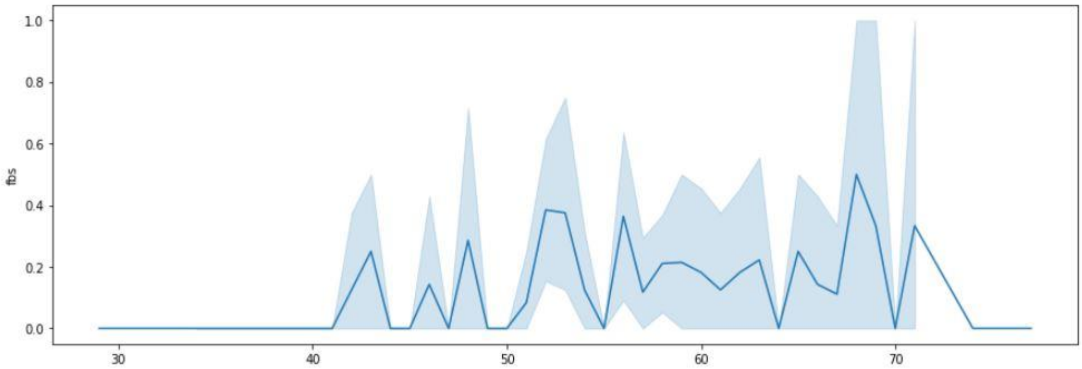

Figure 13 shows a line plot of age v/s. fbs.

VII. RESULTS

After analysing the heatmap and figuring out the correlation between different columns/ physiological parameters, Logistic regression needs to be carried out to create a prediction model. Figure 14 shows the results of logistic regression model. Figure 15 shows the Accuracy score of the designed model. From this data, precision, f1 score and reliability can be calculated. Figure 16 shows the confusion matrix of Logistic Regression to calculate accuracy, precission and f1 score.

```
Out[85]:

LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
          intercept_scaling=1, max_iter=100, multi_class='warn',
          n_jobs=None, penalty='l2', random_state=None, solver='warn',
          tol=0.0001, verbose=0, warm_start=False)
```

Figure 14 shows the results of logistic regression model+

```
In [86]:

predictions= logmodel.predict(X_test)
predictions
from sklearn.metrics import confusion_matrix
confusion_matrix(y_test,predictions)
from sklearn.metrics import accuracy_score
accuracy_score(y_test,predictions)

Out[86]:

0.9833333333333333
```

Figure 15 shows the Accuracy score of the designed model.

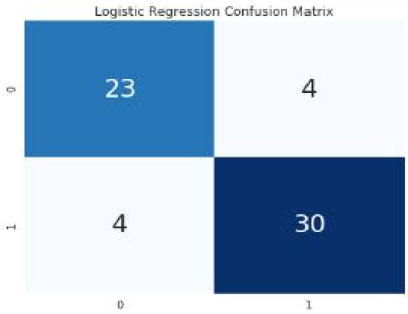

Figure 16 shows the confusion matrix of Logistic Regression to calculate accuracy, precission and f1 score.

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VIII. CONCLUSION

The paper and the system built can bring about a drastic change in the field of podiatry. With this any subject will be able to analyse his or her gait on-the-go: whether he or she is exerting right amount of pressure on the foot. Also, monitoring lower part of the body can be achieved post injury or post-surgery. It would be a boon to diabetic patients to monitor their foot frequently. Gait is dynamic and everything happens quickly. To make an assessment, we have to capture each movement every second one's heel hits the ground. Pressure mapping technology allows us to do that by capturing pressure data in each phase of foot motion, from heel contact to toe-off. The information it provides on how one's feet are functioning and how one is walking through abnormal pressure gradients, helps prescribe effective treatment. Using this technology reveals a host of various other conditions that cannot be seen otherwise.

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OUR GUIDE

VISHESH S (BE, MBA, PGDIB, (MTech)) born on 13th June 1992 hails from Bangalore (Karnataka) and has completed B.E in Telecommunication Engineering from VTU, Belgaum, Karnataka in 2015. He also worked as an intern under Dr. Shivananju BN, former Research Scholar, Department of Instrumentation, IISc, Bangalore. His research interests include Embedded Systems, Wireless Communication, BAN and Medical Electronics. He is also the Founder and Managing Director of the corporate company Konigtronics Private Limited. He has guided over a thousand students/interns/professionals in their research work and projects. He is also the co-author of many International Research Papers. He has recently completed his MBA in e-Business and PG Diploma in International Business. Presently Konigtronics Private Limited has extended its services in the field of Software Engineering and Webpage Designing. Konigtronics also conducts technical and non-technical workshops on various topics. Real estate activities are also carried out under the guidance of Siddesh B S BE (civil). Vishesh S along with his father BS Siddesh has received various awards and applauses from the scientific and entrepreneurial society. He was appointed as the MD of Konigtronics Pvt Ltd (INC. on 9th Jan 2017) at an age of 23 years. His name is indexed in various leading newspapers, magazines, scientific journals and leading websites & entrepreneurial forums. He is also the guide for many international students pursuing their Masters.