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Diabetes Detection System Using E-Nose: A Literature Survey

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***Abstract*—Diabetes is one of the common diseases that many people have suffered especially elders. However, unfortunately only few of them are aware of this metabolic disease and most of them remain undiagnosed. Currently, urine test and blood ketone test are used for detection of diabetes. These methods are considered as invasive, inconvenient and expensive. Through research it has been observed that breath acetone can be considered as a new ketone biomarker because it is non-invasive, convenient, and accurate reflection of the body's ketone level. This paper proposes a method to distinguish between diabetic and healthy patient using breath analysis (E-Nose). The E-Nose method overcomes most of the limitations of traditional system. The detection is done in seven stages: making of e-nose using microcontroller and gas sensors, collecting ground truth data acquisitions, data preprocessing, feature extractions, feature selection, classification, and evaluation. This system can distinguish healthy and diabetic patients using K-NN classifier (accuracy: 95.0 percent).**

***Index Terms*—Diabetes; E-Nose; K-NN; Sensors; Discrete Wavelet**

I. Introduction

Diabetes is a condition where body does not produce enough insulin. In this condition the cells do not respond properly to insulin. When the pancreas cannot make insulin then the Type 1 diabetes arises. Type 2 diabetes is reported when the pancreas does not make enough insulin or the body is not able to utilize the produced insulin properly. Adults are usually affected by diabetes. Type 1 diabetes management requires insulin administration by the patient, 3-4 times a day throughout their lives and their blood sugar levels should be regularly monitored to avoid complications and risks of cardiovascular diseases.

India is one of the 6 countries of the International diabetes Federation (IDF) SEA region. According to that, 425 million people have been reported to suffer from diabetes in the world, among which 82 million people are from SEA Region. By 2045 the number of people suffering from diabetes is expected to increase to 151 million. Out of the total adult population of 829,491,000, total cases of diabetes are found in 72,946,400 adults [1].

The traditional method of diabetic test includes urine test and blood ketone test. An alternative to these traditional methods is the method of non-invasive breath analysis [2].

The distinguishing factor between a diabetic patient and a healthy patient is the gas content contained in the breath [3].

This system uses E-Nose as a tool for breath analysis. ENose can identify, measure, and analyze the compound to gain information. E-Nose is inexpensive, portable and easy to use [4].

There are seven stages to build this system: Making of E-Nose using microcontroller and gas sensor, collecting ground truth values for training set, signal processing for denoising using discrete wavelet transform and Z- Score Normalization, statistical features extraction (which includes minimum ,maximum, average and standard deviation values), feature selection for optimization, classification(using KNN), and evaluation.

II. Objectives of the Work

- To develop a non-invasive, cost effective and easy to use system, for diabetic patients.
- To design a system which can easily distinguish between healthy and diabetic patients so that they can take early preventive actions.
- To enhance the system to detect prediabetic patients.

III. Problem Statement

Diabetes is one of the common disease that many people have suffered especially elders. However, unfortunately only few of them that are aware of this metabolic disease and most of them are undiagnosed. Therefore, we propose to design a low cost, non-invasive and easy to use system that can distinguish healthy or diabetic patients so they can take early preventive action. Also, we extend this research to find out prediabetic patients.

IV. Literature Survey

1) Potential of Breath and skin analysis for monitoring blood glucose concentration in diabetes

Author: C.Turner

Description: As diabetes remain undiagnosed for most of the cases, the reason behind this situation is that the invasive methods are painful, inconvenient and expensive that makes people reluctant to monitor their blood glucose concentrations. Hence the paper proposes non-invasive methods for monitoring blood sugar concentration. There are two types of non-invasive method, the first is breath analysis and second is skin analysis. It has been observed that concentration of various biomarkers

present in the breath of a person has relation with the blood glucose. Thus breath analysis can be used to determine the blood glucose level of the person by calculating the concentration of biomarkers in his or her breath. One of the key biomarkers is acetone which is produced in the liver when not enough glucose is available. Range of acetone for a healthy person (age-24-59) is 148-2744 ppb. However, if the patient is fasting the acetone test will fail, because during fasting, the glucose level goes down however the acetone level increases which will eventually lead to false results.

Acetone levels can likely be used for detection of type-1 diabetes because the level of acetone in type-1 diabetes is more as compared to type-2 diabetes. Also, it has been observed that level of acetone varies with age group and body mass as well.

The paper suggests the use of Gas Chromatography (GS) for gas analysis in order to obtain accurate results. However, Gas chromatography is not a suitable choice for a personal diabetes monitoring device as the method is quite expensive, requires skilled labour and takes more time to estimate the level of diabetes and not portable. The second method that is skin analysis uses the acetones excreted from the skin to determine the diabetes level.

Through various experiments, it has been observed that analysis of skin acetone shows strong correlation with the blood glucose. Thus, it can be said that in current events the analysis of acetones in the breath proves to be very strong candidate to detect diabetes.

2) Non- Invasive Diabetes Detection and Classification Using Breath Analysis

Authors: Lekha .S and Suchetha .M

Description: The paper uses Support Vector Machine classifier to classify the different acetone concentration levels into three class labels that are healthy breath, type I diabetic and type 2 diabetic which is then displayed as the output. The proposed analysis system operates in five stages.

Initially the patient's breath sample is collected. The acetone concentrations from various samples are taken as input in the further steps. The SVM classifier then classifies the acetone concentration levels based on the thresholds.

Thus the diabetic and the healthy breath samples are detected in the proposed model. The paper uses the samples collected from 10 subjects to classify the acetone concentration levels.

The SVM classifier is a supervised learning model that is used to analyze a given data set and help recognize patterns that is used for the classification of the samples. These model generates hyperplanes used for the classification and the regression of the data. The classifier chooses the hyper planes that has maximum distance from the nearest trained sample point to maintain accuracy. The acetone concentrations are distinguished based on given threshold by the SVM. There is an order in the levels of acetone concentrations Tl greater than T2 greater than H, where H for healthy breath, T 1 for type 1 diabetes and T2 for type2 diabetes. However it uses only one gas sensor to measure the concentration of acetone which reduces the accuracy of the system because other gases present in the breath e.g CO, CO_2 and temperature has effect on the concentration of acetone hence concentration of these gases should also be considered.

3) Gas Concentration Analysis of Resistive Gas Sensor Array

Authors: Dedy Rahman ,Wijaya Riyanarto Sarno, Enny Zulaika

Description: Although the gas chromatography and using mass spectrometry for gas analysis provides accurate results but it has some disadvantages such as high-cost, needing special skills, and unsuitable for online or real-time systems.

As an alternative to this techniques, the paper proposes to utilize gas sensor. Even though the Metal Oxide Semiconductor (MOS) gas sensors is less accurate than mass spectrometry or gas chromatography, it provides advantage to perform gas monitoring and analysis and portability. The sensors are low cost, easy to use and has wide range of gases target. The paper aims at classifying whether the meat is fresh or rotten depending upon the odor i.e. Concentration of gases released from the meat.

The proposed system uses the 6 Metal Oxide Semiconductor (MOS).For the MOS sensors the resistance of the senor changes with change in the gas concentration. The values sensed by the sensors have various types of noise which create problem in further analysis, these noise needs to be eliminated or reduced to some extent in order to achieve accurate results. So Discrete wavelet transform is used to denoise the signal. MOS gas sensor is an analog sensor, so the response values should be converted to digital response.

A mathematical model is proposed to determine the concentration of gases and it also takes in to consideration the errors introduced in the sensed values. For this a root mean square value is calculated to reduce those errors.

4) Non-invasive blood glucose monitoring for diabetics by means of breath signal analysis

Authors: Dongmin Guoa, David Zhanga, Lei Zhanga, Guangming Lu

Description: The paper employs a specially designed chemical sensor system in order to collect and analyze breath samples of diabetics. These are then analyzed to test the possibility of chemical-sensor-based blood glucose monitoring. Breath samples as well as blood glucose values provided by the blood test are collected simultaneously.

In order to achieve highly accurate results, novel regression technique, Support Vector Ordinal Regression (SVOR) is used. SVOR classifies the diabetes samples into four ordinal groups marked with well controlled, somewhat controlled, poorly controlled, and not controlled, respectively. At last, the outputs of SVOR are map to probabilities to decide which levels the input sample belongs to.

After testing the system, it has been observed that the accuracy of the system can be up to 68.25 percent which is less

as compared to the recent diabetes monitoring devices available in the market.

The proposed system uses an array of 12 gas sensors, in an attempt to detect other diseases as well from the breath of the patient. As a pre-processing step the system use Discrete

Wavelet Transform (DWT) for signal denoising. Also the system uses base line manipulation to remove variations and get a constant signal which can be used for further processing. There are various errors that may occur while classification of the samples but the paper proposes various mathematical expressions to reduce them so that the accuracy can be increased.

V. System Requirements

- Arduino MEGA 2560 (E-nose)
- Sensors
- MQ-7 (Carbon Monoxide)
- MQ-135 (Carbon Dioxide)
- MQ-138 (Acetone)
- DHT-22 (Temperature-Humidity)
- MiCS-5524 (Volatile Organic Compounds)

VI. System Architecture

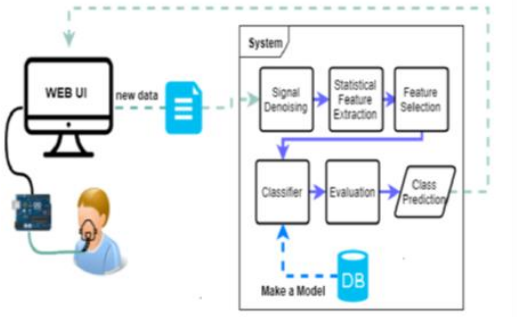

Fig. 1. System architecture

VII. Algorithm Analysis

Support Vector Machine is a supervised machine learning algorithm that looks at the data and sort it into one of the two categories as well as deals with classification challenges.

In this algorithm we plot each data item as a point in n-dimensional space (where n is equal to number of features you have) with value of each feature being the value of particular coordinate. Then, we perform the classification by finding the hyper-plane that differentiate the two classes.

This technique is useful when we have no idea about the data. This technique also uses kernel trick, so that one can build expert knowledge about the problem via engineering the kernel. This technique is not suitable for large datasets as it takes long time to execute and it is difficult to implement on web system.

Neural Network is a system or hardware designed to operate like a human brain. Neural network stores information on entire network. Neural network is fault tolerant. But it is hardware dependent and it is difficult to implement into web system and is slower.

K-Nearest Neighbor is a supervised algorithm used for classification. It classifies data point based on classification of neighbors.

Based on the study of above three algorithm, it is observed that the K-NN classifier gives the best accuracy among all i.e. approximately 95.0 percent. Also, this algorithm can be simple to implement and is effective if the dataset is large. This technique can also be used for web development.

VIII. Conclusion

Based on the literature survey we can successfully use breath analysis for monitoring diabetes. The system considers the gas concentration for analysis. E-Nose provides a non-invasive diabetes detection and classification system.

K-Nearest Neighbor algorithm is used for classification which is more accurate than the other algorithms discussed. The data preprocessing stage is considered as one of the major factor for higher accuracy, because when K-NN is performed without preprocessing stage, its accuracy falls.

For the future, diabetes detection system will be developed which can detect prediabetic patients. Also, the analysis can be done on a larger sample data which will consider fasting as well as non-fasting patients. A similar system can be developed which can detect other diseases using breath analysis.

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