IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper | Vol.-7, Issue-8, Aug 2019 | E-ISSN: 2347-2693

Blood Glucose Values Prediction Using Breath Analysis: A Literature Review

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DOI: https://doi.org/10.26438/ijcse/v7i8.320322 | Available online at: www.ijcseonline.org

Accepted: 26/Aug/2019, Published: 31/Aug/2019

Abstract — Diabetes Mellitus is one of the chronic diseases affecting the world's population. The development of diabetic patients is expanding step by step because of the ways of life. It is a significant issue influencing an excess of individuals today, and if it is left unchecked it can create enormous implications on the health of the population. Hence, diagnosing diabetes is extremely fundamental to spare human life from diabetes. Among the different non-invasive methods of finding, breath examination exhibits a simpler, increasingly precise and suitable technique in giving extensive clinical consideration to the illness. It is a well-known fact that Acetone focus in breath has an immediate connection with blood glucose level. The grouping of acetone levels in breath for monitoring blood glucose levels and is possible to predict its values with the use of feature extraction and classification techniques in the machine learning. The paper reviews different methodologies used to identify the presence of acetone in breath samples. Also, the various sensors technologies used in computing the acetone in breath are reviewed.

Keywords— Acetone, Blood Glucose Level, Breath, Sensors

I. INTRODUCTION

Diabetes is a chronic disease that affects an increasing number of people in developed countries. The World Health Organization (WHO) predicts that by 2030 there will be roughly 350 million individuals worldwide influenced by diabetes [1, 2]. Diabetes Mellitus (DM) is defined as a gathering of metabolic disorders mainly caused by irregular insulin secretion, or action. Insulin deficiency results in high blood glucose levels and impaired metabolism of carbohydrates, fat, and proteins. Diabetes Mellitus can be split into three kinds. The first is Type 1 DM which starts in youth and is brought about by the harmed pancreases which don't deliver insulin. It might be the defective beta cells in the pancreas which ordinarily produce insulin. The second is Type 2 DM. It is a metabolic issue that is generally described by the absence of insulin. About 90% of diabetic cases have a place with this category [3]. The third type is gestational diabetes which resembles the type 2 DM. It is a condition wherein ladies without recently analyzed diabetes display high blood glucose levels during pregnancy. Diabetes is a disease by which blindness, nerve damage, blood vessel damage, kidney disease, and heart disease can be developed [4].

The diabetes patients are advised to check the glucose intensity four to six times each day. In the invasive process, Glucose testing is done with the help of a needle called a lancet. The needle is utilized to prick the fingers, and the blood sample thus obtained is placed on a glucose testing strip. The strip comprises of a concoction called glucose-oxidase and this response with the glucose in the blood. The glucose level in the blood test is then determined to utilize a glucose meter. This invasive procedure is accurate, but it is painful and may cause infections and bruising. Thus there is always a need for an accurate, safe and a lesser amount of painful technique for blood glucose measurement.

Nowadays researches show that tears, saliva, urine, and breath also contain hints of glucose in them. The parameters provide a way for non-invasive blood glucose level prediction. The investigation of a person's breath poses as a good non-invasive technique for monitoring the levels of blood glucose. Section I contains the introduction of Diabetes Mellitus, Section II contains the breath activity, Section III contains the Acetone detection techniques, Section IV contains the sensor technologies, feature extraction, and selection techniques, Section V contains the methodology and Section VI has a conclusion.

II. BREATH ACTIVITY

Breath analysis has received endlessly increasing attention because of its potential as a non-invasive strategy for illness determination and metabolic standing recognition. This technique allows the deduction of blood glucose levels by just exhaling into the monitoring device. Among thousands of breath volatile organic compounds (VOCs) [5], Acetone is one of the volatile organic compounds which is available in the breathed out-breath has demonstrated a high relationship to the blood glucose levels. Table 1 shows the range of variation in the acetone levels [6] for a healthy subject, Type 1 diabetic and Type 2 diabetic subject.

Table 1: Range of variation in acetone levels (ppm – parts per million)

Type of Samples	***Acetone values (ppm)***
Healthy Subject	0.22 to 0.80 ppm
Type2 Diabetic Subject	1.76 to 3.73 ppm
Type1 Diabetic Subject	>21 ppm

III. ACETONE DETECTION TECHNIQUES

This section reviews all the techniques which have been used in detecting acetone concentration from the breath.
Gas Chromatography-mass spectroscopy (GC/MS) is one of the old methods used to collect gas concentrations. In breath investigation, this strategy was utilized to anticipate the acetone focus levels. The standard utilized here is that the distinction in the synthetic properties between the various atoms in the vaporous blend and their relative partiality for the stationary period of the part advances the division of the particles. This technique is highly accurate and shows high sensitivity and selectivity in the blood glucose level [7]. Due to its complex working, lower portability and its high cost, this process is not viable in household Blood Glucose Level monitoring and diabetes screening. Another drawback is that this detection practice cannot be done in actual time analysis.
Selected ion flow tube-mass spectroscopy (SIFT-MS) is a mass spectrometric method used to analyze the trace of gas [8,9]. In this method when the neutral analyzes the molecules of a sample vapor meet the precursor ions they may undergo chemical ionization which depends on their chemical properties, such as their proton affinity or ionization energy. The advantage of this method is that high accuracy detection can be done in real-time analysis. High cost, low portability, and complex usage are the disadvantages of this method.

Cavity ring-down spectroscopy is an optical spectroscopic procedure that measures the absolute extermination by samples that absorb, or scatter light [10,11]. These detection techniques measure breath acetone using a rapidly responding and highly sensitive spectroscopic method. This method can be performed in real-time analysis. It needs a calibration procedure.

E-nose or Electronic nose [12, 13] is a sensing technology that identifies exclusive components through chemical means. The device makes use of an array of chemical sensors that react, and it detects certain chemical compounds. It also makes use of pattern recognition to identify the specific component order observation. The advantage of this technique of acetone detection is that it is less expensive, applicable in real-time, more portable and it responds fast. However, the presence of other gases and humidity in the detection process pose a big challenge.

Semi-conductive metal oxides (SMOs) shows potential for finding and checking diabetes mellitus non-invasive. This is because of their potential progressively examination, easy working rule (resistivity endless supply of acetone to the SMO's surface layers), basic gadget manufacture and prepared to scale down [14]. It measures resistivity changes based on thinning or thickening the depletion layer of n-type SMOs and hole accumulation layer of p-type SMOs around the surface when exposed to oxidizing or reducing ambient gas. The advantage is real-time analysis, portable, inexpensive and miniaturization. The drawback is comparatively low sensitivity and less selectivity.

IV. SENSOR TECHNOLOGIES, FEATURE EXTRACTION, AND SELECTION TECHNIQUES

In [6] the breath measurement device equipped with 11 sensors including 6 ordinary metal oxide semiconductor (MOS), three temperature modulated MOS sensors, a carbon dioxide sensor, and a temperature-humidity sensor. Principal component analysis (PCA) is used to extract the low dimensional features with the responses of selected sensors. It projects high dimensional data into a low dimensional subspace while keeping most of the data variance. The ratio of variance in PCA was 99.98%. The Support vector machine (SVM) has been adopted as the decision algorithm for chemical sensor systems, and it is used to discriminate between healthy and diabetes samples in the screening of diabetes. The Support Vector Regression (SVR) algorithm is chosen to forecast the Blood Glucose Levels. The sensitivity and specificity are 91.51% and 90.77% respectively.

In paper [15] the device is designed using 10 sensors of 9 MOS sensors sensitive to volatile organic compounds (VOCs) and a carbon dioxide sensor to measure the samples. The sequential forward selection (SFS) algorithm was used to extract the features which are more favorable when the optimal feature subset is small. SVR is used as the regression algorithm to predict the BGL. The mean absolute error and mean relative absolute error are 2.072 and 20.69% respectively.

In [16] the device has seven chemical sensors, which are metal oxide semiconductor (MOS) sensor, a hydrogen sensor, and a temperature-humidity sensor to measure the samples. It is used principle component analysis (PCA) for feature selection and the K-nearest neighbor (KNN) algorithm would be used for classification and to obtain the results. The sensitivity and the specificity are 91.3%, 89.86 respectively.

A device called electronic nose which distinguishes the particular segments of smell and investigates its synthetic make up to recognize it. Quartz Crystal Microbalance (QCM) sensors are used to identify and qualify a wide range of volatile chemicals. Radial Based Function Artificial Neural Network (ANN) algorithm can be used to predict the glucose parameter, and it has an accuracy of 74.76% [17].
The paper [18] states that the chemical sensors that are sensitive to the biomarkers and compositions in human breath, twelve types of sensors are used to design the device of 7 VOC sensors, a hydrogen sensor, a sulphide sensor, a nitric oxide sensor, and an ammonia sensor. K-nearest neighbor (KNN) was used as a classifier for the features that were extracted by PCA. The specificity and sensitivity are 86.8% and 87.67% respectively.

In [19] a sensory device of MOS gas sensors like MQ3 and MQ5 was used for detecting acetone from exhaled breath samples. The convolution neural network (CNN) algorithm classifies the data by adopting back-propagation and stochastic gradient descent methods.

The sensor system employs MQ 138 sensors which are very effective for the recognition of volatile compounds (VOC). It is connected with an Arduino UNO which is interfaced with LCD to show the acetone concentration in breath [20]. The root mean square error is 11.81 and the root mean absolute error is 3.106.

V. METHODOLOGY

The proposed work sequence of the prediction of blood glucose level using breath analysis is as follows:

1. Initially, the subject's breath samples are used to find the concentration of acetone.
2. The concentration of acetone in breath data from various samples is taken individually.
3. Feature extraction, selection and classification process can be done.
4. Finally, the level of Blood Glucose is predicted.

VI. CONCLUSION

In this paper, we have presented a survey of the different techniques used to predict diabetes through the breath samples has been studied. Although the analysis of the breath shows significant promise as an alternative diabetes detection technique, it becomes popular in clinical application. This paper gives valuable key points to this important research topic and supports new research.

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