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IoT Enabled Non-Invasive Detection and Classification of Diabetes using Breath Acetone

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Abstract:-Diabetes is a metabolic disease that is characterized by high glucose level in the blood. It is a major problem affecting millions of people nowadays. Regular testing and accurate determination of glucose levels is essential for diagnosis and treatment of diabetes. Though the test involving the collection of blood sample from finger pricking may not pose any risk to a healthy adult, but it can be very painful to the diabetic patients. A noninvasive, accurate, easy-to-use and low cost diagnostic tool for diabetes is on high demand. Acetone in the exhaled breath can be estimated for the detection of blood glucose levels. Artificial Neural Network can be used to calculate the glucose levels. It is a non-invasive technique that measure blood glucose levels and the discomfort to the patients can be minimized. Finally, to provide a global connectivity Internet of things can be enabled.

I. INTRODUCTION

One of the leading non communicable diseases affecting the human health is diabetes. When the body is not able to appropriately utilize glucose as a form of energy, diabetes occurs. The body can be effectively operated and a vital form of fuel for cell function can be provided when glucose is at a normal level. Damage of cells in the pancreas and insufficient production of insulin are the major complications of high sugar levels in the blood. Also it can internally damage the body and lead to critical health conditions such as hardening of the blood vessels. Permanent organ damage can also occur as a result of hyperglycemia. Uncontrolled diabetes can lead to complications such as renal failure, liver failure, heart-attack, loss of sight or foot problems if not diagnosed, monitored and treated on time. Blood glucose level should be periodically monitored to avoid these complications.

There are two types of diabetes based on the onset of the disease as well as the complications. In type 1 diabetes mellitus, pancreas will not be producing any insulin and thus the body stops regulating the blood glucose levels. Type 1 diabetics must regulate their blood glucose levels through insulin injections. When the body is unable to produce sufficient insulin or is unable to process insulin properly, type 2 diabetes occurs. This form of diabetes is usually onset due to lifestyle and has fewer complications when compared to type 1 diabetes. The diabetes has to be classified accurately to provide an appropriate treatment.

Conventional methods has a risk of infections to the patients as it uses sharp needles to prick the finger , which leads to loss of blood and can be very painful for the patients. To minimize the discomfort to the patients, current invasive method uses a thin needle. To avoid these painful situations, a non-invasive technique has to be developed that measure blood glucose levels without taking the blood sample. At the same time the cost has to be minimized and also the method should be reliable.

Over the last decade, non-invasive diabetes detection has been gaining more importance. Among many human serums examined, human breath emerges as a promising option. Acetone levels in breath exhibits a good correlation to blood glucose levels. We can make use of feature extraction and classification algorithms to analyze this bio-marker in breath for disease detection.

A non-invasive technique of determining blood glucose levels from thedetection of the acetone in the breath is being proposed here. Exhaled breath contains many volatile oraganic compounds. One of such VOCs is acetone. Low levels of acetone are formed in the body as a result of breaking down of fat. Acetone is a colorless liquid with a distinct smell and taste. This acetone is exhaled or excreted through urine after reaching the lungs. So, the breath acetone levels could definitely be a measure of the blood glucose levels. Nanostructured optical fiber films can be used for detecting VOCs.

Parameters such as temperature, pressure and humidity can be considered in estimating the acetone because these parameters affect the quantity of acetone sensed by the sensor. For the same person breathing for different times, the acetone concentration will not be the same because of the different flow rates. This can lead to a wrong diagnosis. Therefore, specified time duration for breathing should be there. A neural network system can be used to calculate the glucose levels as well as to classify the diabetes. Finally, Internet of Things can be enabled for global connectivity and exchange of data.

II. LITERATURE REVIEW

A qualitative review of noninvasive glucose sensors including their operating principles, advantages and limitations has been presented here. The most representative non-invasive glucose sensing techniques are described below.

For measuring body composition, the measurement of bioelectrical impedance has proved useful as a noninvasive method [2]. In red blood cells, variations in plasma glucose concentration induce a decrease in sodium ion concentration and an increase in potassium ion concentration. This cause changes in the membrane potential of red blood cells. Through a dielectric spectrum, these changes can be estimated by determining the permittivity and conductivity of the cell membrane. Main advantage of using this method is that it does not require the use of population specific prediction models. It is able to differentiate between extracellular water and intracellular water. It provides an estimate of body cell mass and characterizes the blood bioimpedance properties. The instrument is easy to use and low in cost compared to other devices. The limitation is that it requires an equilibration process, where the user must rest for 60 minutes before taking the measurements. Effects of temperature and body water content on readings are not considered in this method.

Ultrasound technology is another non-invasive method for the determination of blood glucose levels. For blood glucose monitoring a low-frequency ultrasound penetrates the skin [3]. For measuring the resulting acoustic response, photoacoustic spectroscopy is used, which is based on the use of a laser light for the excitation of a fluid. By a short laser pulse, the fluid is excited with a wavelength that is absorbed by a particular molecular species in the fluid. A microscopic localized heating is caused in the medium by the absorption of the light. Accordingly an ultrasound pressure wave is generated that is detected using a microphone. By measuring the changes of the peak-to- peak value of the signal, which varies according to the glucose content of the blood, glucose level can be detected. This technology provides higher sensitivity than traditional spectroscopy. But, the technology is sensitive to interference from temperature fluctuations and pressure changes. Also, when the laser light transverses a dense medium, scattering phenomena can be caused by the photoacoustic signal . Another disadvantage is that the instrumentation is expensive as well as sensitive to environmental parameters.

Blood's dielectric parameters such as its conductivity vary in accordance with the blood glucose concentration. Due to changes in the electromagnetic field, an electromagnetic sensor based on Eddy currents can determine the concentration of glucose through these variations [4]. The principle of the sensor is based on two coils separated by 40 mm apart. Coil's output signal varies with the conductivity fluctuations as a result of the change in glucose concentration. To the primary coil signal with a frequency 4 MHz is applied. Secondary coil measures the output signal. A specific frequency range is used to isolate the effect of blood glucose and minimize the characteristics of other substances, such as cholesterol. This technique is safe and will not ionize the molecules of the body. Temperature has a strong effect on this method. Also, blood dielectric parameters depend on several components other than glucose. Therefore, more study is needed on this field before considering this method to be reliable.

For the detection of glucose concentrations, polarimetry has existed for several years. Parameters involved are the specific rotation of the light source, the sample pathlength and the observed rotation of linearly polarized light caused by the glucose. For a known pathlength inside the sample, glucose concentration will be directly proportional to the observed rotation in polarization [5]. This technique is not accurate in measuring the detected signal consistently over long periods of time. Complicated shape of the cornea is another limitation. Also, there are other biomolecules in it that contribute to the optical rotations.

Fluorescence-based sensors use fluorescence reagents to track the presence of glucose molecules in blood. One of the techniques is based on the measurement of cell auto-fluorescence due to NAD(P)H and signals the changes in extracellular glucose concentration by fluorescent markers [6]. However, these experiments have been performed using in vitro cell models, thus requires further investigation for monitoring. Another approach is based on the monitoring of tear for blood glucose level determination. The technique relies on colorless contact lenses with boronic acid probes containing fluorophores and provide a glucose-sensing mechanism through the lens color variations [7]. This can be monitored using different techniques such as fluorescence, colorimetry and polarization.

This method is reversible in nature and sensitive. But the photonic sensing can suffer from strong scattering phenomena, especially in fluorescence technology. There are limitations such as short lifetimes and biocompatibility.

None of these technologies have produced a commercially available, clinically reliable device. Therefore, much work remains to be done. It is relatively simple to measure and find correlation with blood glucose levels under the controlled conditions of research laboratories. But measuring these variables in a normal environment is challenging. This requires understanding the physical and physiological factors that may affect blood glucose measurement.

III. PROPOSED SYSTEM

For analysis of glucose levels from the breath, consider a total of five parameters: voltage, resistance, pressure, temperature and humidity. Sensors can be involved to obtain the values of these parameters. Design a mouth piece and the sensors can be placed inside the mouth piece for analysis. All the sensors data can be given to the controller board. Microcontroller board reads the data from the sensors and sends back to the artificial neural network model.

Collect the breath samples. Each person has to blow into the mouth piece for a specific duration of time continuously with the same flow rate. Record the sensor data on MATLAB tool. In each of five parameters maximum and minimum values were taken in the specified time duration. Invasive test can also be performed immediately after taking the breath test. To analyze and get the relation between the recorded parameters and glucose levels Neural Network Tool can be used.

Gas sensor having good sensitivity towards acetone must be used. The basic principle of operation of these gas sensors is the change in their conductivities due to interactions with oxidizing and reducing gas molecules. However, in addition to the quantity of the gas, natures of both the gas and the metal oxide determine the degree of response of the sensor. The sensor accuracy depends on the temperature and relative humidity in addition to the nature of the gas. But in most cases, the acetone sensing application is used when the ethanol is absent in the breath. So in order to detect the presence of acetone even in the presence of ethanol, an analytical column which separates the ethanol from the acetone can be placed near the acetone sensor.

Flow rate and volume of breath blow into the mouth piece can't be controlled and are different for each person. To compensate this, the effects of pressure, temperature and humidity levels have been considered for each and every person apart from the actual parameters (voltage and resistance).

Then the samples can be classified using ANN classifier and can be divided into T1D and T2D. Acetone concentration from various samples taken each as input in the next stage. The ANN then separates diabetes breath samples based on the some threshold. Finally, Internet of Things can be enabled for global connectivity and exchange of data.

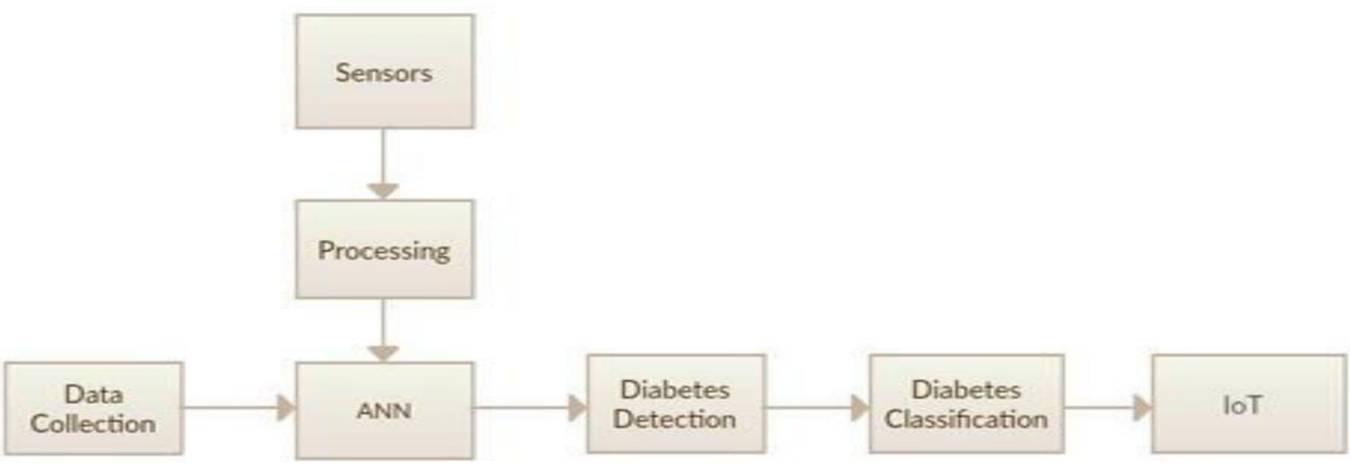

Fig. 1. Block Diagram of the System

IV. CONCLUSION & FUTURE SCOPE

The applicability of the breath acetone sensing method for the determination of glucose in human blood can be demonstrated. For this, an acetone sensor can be used to monitor acetone levels in the exhaled breath and compare with actual blood glucose levels. We also considered The effects of the pressure, temperature and humidity parameters can be considered on the acetone sensing because these parameters affect the quantity of acetone sensed by the sensor. This can be applicable for non-diabetic and pre-diabetic persons. For analyzing the data Artificial Neural Network model. Based on the acetone levels, the diabetes can be classified into T1D, T2D. Finally, for global connectivity and exchange of data Internet of Things can be enabled. Possible factors that could further influence detection of breath acetone, including stress level, and exercise, can be considered and models accounting for them could be a subject of future research. By conducting studies with a larger sample size, richer and more accurate data can be prepared.

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