Global Journal of Pure and Applied Mathematics.
ISSN 0973-1768 Volume 12, Number 1 (2016), pp. 1019-1027

http://www.ripublication.com

Non-Invasive Bg Scrutinizer System

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Abstract

Diabetes is a disorder, not a disease. Now a day, many of the people are getting affected by this disorder. Diabetes is not only constrained with the adults, but also with kids. People who are affected by it have to check their sugar level before and after having their food. For it, they have to undergo finger pricks to check their glucose level. But it is a paining process. So, many organizations developed sensor-based CGM devices to measure the sugar level to supplement with the finger prick process. The aim of this paper is the implementation of the non-invasive BG scrutinizer system and alert the patient and the doctor for undergo the further medical treatment.

Keywords: CGM, diabetes, sensor, arduino, GSM board

1. Introduction

Now a day, as technology grows, we people are migrating towards hi-tech, portable, non-invasive and affordable devices. In this list, non-invasive glucose monitoring device plays a major role. It meets people's all requirements. Likewise, many non-invasive devices are available in today's market for measuring sugar level frequently. It acts as a scrutinizer system for people at the age from kids to oldies.

Legacy systems need to draw blood from test site, undergo calibration and send those values to the display devise at limited distance. These types of devices are not optimal for kids who suffering from diabetes, because they need to check out the glucose level four times a day in case of hypoglycemia. To overcome this drawback, many companies have designed their non-invasive devices for continuous monitoring of

glucose level in blood. But they are not successfully attained the fully non-invasive criteria. The proposing is using sensor, arduino and GSM modules to send data message to doctor or caretaker even they are offline.

2. Literature Survey

Many companies have launched their products with good scope, but some of them might get people's attention with bright features of their product. In this section, we are going to discuss about some of CGM devices which are playing their role successfully in diabetes world.

2. 1. **Glucose Watch Biographer** was launched in 2002. It is a watch-like device, can clasp the wrist. The backside of the watch contains AutoSensor. AutoSensor is responsible for generating electricity on the skin, brings glucose to the skin surface and enzyme reaction takes place here. Enzyme reaction generates the electrons, from which glucose estimation can be done. It generates the BG level at the interval of 10 minutes.

2. 1. 1. Advantages

- Portable ie., clasp our wrist
- Display device and sensor are implemented back-to-back. So, no separable between the transmitter and receiver

2. 1. 2. Disadvantages

- It makes some irritation over the skin because of electric charge
- This device is not to replace but to supplement with the traditional blood sugar meter. After warm-up period, user have to calibrate the BG values against the biographer values to find the MARD value, If lower the MARD, higher the accuracy of the device.

2. 2. **Scout DS**[2] do not need blood draw and fasting. The device contains the portable table-top unit where patient have to place his/her forearm on it. The results will be generated within 4 minutes. This device is optimal for patients at age 18 and older, to check whether patient undergo diagnostic test. It follows three step processes to measure the blood glucose level. Initially, patient have to enter their age and gender. Then, he/she have to place his/her arm in cradle. Finally, the results will be generated within few seconds.

2. 2. 1. Advantages

- Non-invasive
- No need for fasting
- Ease of use
- Higher sensitivity
- No need of test stripes

2. 2. 2. Disadvantages

- Cannot carry this device to anywhere.

2. 3. **AGE Reader**[3] can predict the chronic diseases like diabetes, renal failure and cardiovascular disease. It employs fluorescent technique to tissue accumulation of AdvancedGlycationEbdproducts (AGE). The device's model is similar to Scout DS. This device can be used under the supervision of physical advisor.

2. 4. **Medtronic 530G with Enlite**[5] is a mobile-sized device, can carry to anywhere. It was launched on 2011. This device comprises of display device integrated with insulin pump and receiver, Enlite sensor, transmitter. The insulin discharge patch has to keep a distance of 2 inches from the sensor. Both these have to be fixing in the abdomen area. The transmitter has to be integrated with the sensor. An Enlite sensor's work is to generate electric current of small amount on the interstitial fluid, and it passes these electric current to the transmitter attached to it. Then the transmitter converts the electric current into some sort of signal and passes the signal to the receiver. The receiver is designed to convert those signals into the numeric values, generate the trend graph for the overall calculated BG levels. If the BG level attains the minimum threshold, the CGM system has been designed to deliver the insulin via the insulin deliver system sticking onto the abdomen area.

2. 4. 1. Advantages

- Integrating display into the pump screen
- Downloaded software is a universally accessible
- Integrating software with the pump, meter and CGM data
- If we are in out of range from receiver, transmitter can store 40 minutes of data
- Having alert features and insulin suspension based on BG level

2. 4. 2. Disadvantages

- Can't hear the alarm properly
- Transmitter range is short
- Need to charge the transmitter every week
- Need high degree of adhesiveness required to stick sensor to skin

2. 5. **Dexcom G4 Platinum**[4] is a powerful CGM, got FDA approval on 2012. It comprises of two modules; one is a sensor part and another one is a portable display monitor. The sensor part is a sticky one; a user can patch it over their abdomen area or forearm. The sensor implemented with transmitter at its both sides to transmit the measured BG values from sensor to the receiver at the display monitor. The sensor and the display monitor connected over wireless network; it can operable at some considerable range. The sensor can measure the BG level every 5 minutes; the sensor is a disposable one (7 days). The

display monitor generates the trend graph for the corresponding BG values over the corresponding set of time instances.

And a user can set the threshold BG level; for an instance 250mg/dl. If the sugar level crosses above this threshold the alarm will ring. It can monitor sugar level even during night time also. In case of emergency, it alerts the user with the melodious sound. Finally, the sugar level is calibrated against the traditional finger pricking meter for every 12hrs to ensure the accurate results.

2. 5. 1. Advantages

- Using alarms to alert the user while the BG level reaches its maximum or minimum level
- Provides high accuracy of results
- No need to charge the transmitter
- Displays BG level graph while we are downloading results
- Sensor life is between 12-14 days
- Calibration can be done at any time
- Device simplicity

2. 5. 2. Disadvantages

- Have to carry an extra device ie., receiver/display
- PC only supports the download software
- Software does not support the integration of data from other devices
- Need to charge the receiver between 1-2x/week

3. Comparative Study on Different CGM Devices

Table 1 briefly explains the features and properties of the sensors. **Glucowatch Biographer** uses AutoSensor. The sensor should be disposed after every 13 hours. And every 13 hours, patient should take finger prick test to compare its output against the sensor value. Alarm is set for BG threshold. This biographer can hold 4000 readings and should be clasped in wrist to measure the BG value. The biographer provides values every two hours in its in-built monitor, after removal from wrist.
ScoutDS do not use sensor. Instead, it use light rays to measure the BG level. There is no particular interval of time to perform calibration. An alarm can't be set as this is a testing device used in medical centers; it is not a scrutinizer system; **AGEReader** is a testing device used in medical centers; not a scrutinizer system. This device is as similar as ScoutDS; **Medtronic 530G with Enlite** is a scrutinizer system which uses Enlite sensor. The sensor should be disposed after 6 days. The calibration should be done after every 12 hours. An alarm can be set for one high and one low BG threshold. The size of this device is as similar to mobile-phones. The optimal place to keep this device is Abdomen and arm. The MARD value of this device is 13. 0%; higher the MARD value lower the accuracy of the device.

Dexcom G4 Platinum is also a scrutinizer system. It comprises of Dexcom G4 platinum sensor and Glucose sensor. The sensor should be disposed after 7 days. The calibration should be done after every 12 hours. We can set one high and one low alarm. The size of this device is 2. 4 ounces. The MARD value of the device is 9%, lower the MARD value higher the accuracy of the device.

Table 2. Explains the devices and the technology they implement in it. Where Glucowatch Biographer displays its stored data when it is connected to the system; And Medtronic 530G with Enlite generates the trend graph based on the stored data inside the system; Dexcom G4 Platinum also generates the trend graph based on the stored data inside the system; Finally Symphony tCGM generates the trend graph based on data stored in smart phone, it uses wi-fi technology to transfer the data from sensor to the smart phone.

Table 1: Features and properties of sensors

Device Name	**Glucowatch Biographer**	**Scout DS**	**AGE Reader**	**Medtronic 530G with Enlite**	**Dexcom G4 Platinum**
Sensor	Autosensor with Biosensor	No sensor / uses light rays	No sensor / uses fluorescent technique	Enlite Sensor	Dexcom G4 platinum sensor combined with Glucose sensor
Sensor Reliability	13 hrs	-	-	6 days	7 days
Calibration	After 13 hrs	When we need	When we need	12 hrs	Every 12 hrs
Alarms	One high and low alarm	No alarm	No alarm	One high and one low alarm	User can set one high and two low
Memory	4000 readings	-	-	-	-
Size	-	-	-	Nearly mobile phone size	2. 4 ounces
Applicable Places	Wrist	Place forearm on table top unit	Place forearm on table top unit	Abdomen, arm	Abdomen, arm
Warm up period	2hrs	-	-	-	-
BG Monitor	In-build display	In-build BG monitor	In-build BG monitor	-	-
MARD	-	-	-	13. 0%	9. 0%

Table 2: Features of CGM devices

DEVICE	TECHNOLOGY USED (DATA)
Glucowatch Biographer	Connect to system and view the data
Medtronic 530G with Enlite	Manipulate the trend graph based on stored values
DexcomG4 Platinum	Manipulate the trend graph based on stored values
Symphony tCGM	Manipulate the trend graph based on stored values in smart phoneUsing wi-fi technology

Non-invasive BG Scrutinizer System

A system which do not involve in measuring the BG level by drawing blood from patient is generally called as **non-invasive** device. The proposing system consists of four major hardware devices. They are sensor, arduino, GSM board and a computer system. **Sensor** is a hardware device to detect the glucose level. The function of **arduino** is to feed the glucose value to both the computer system and as well as GSM board. **GSM board** sends the glucose values to the patient or patient's caretaker as a text message. A **computer system** is used to maintain the database and to display the trend graph for the set of BG levels we have found. Each and every hardware device performs its own functions as per algorithm. All of these hardware devices were explained below.

Sensor

The sensor we used here is **Moisture sensor**. It calculates the BG level by considering the amount of water content present in our body. The amount water content in our body is directly proportional to the amount of BG in our blood. Various sensors are available in market. Moisture sensor is of cheap cost while compared with other sensors. For better results and high accuracy, we can go for salinity sensor also. Moisture sensor is only for testing purpose only.

Algorithm:

Start
Hold the sensor device
Until you leave the sensor
Sensor continuously measures the BG from body
Arduino_sec() will be invoked
End

Arduino

Arduino[6]is a microcontroller based board. It consists of 14 digital pins and 6 analog pins. And it has a power jack and serial port. By using serial cable, we can arduino sends the BG value to computer system that will be stored on database in computer system. At the mean time, arduino sends the BG value to the GSM board. The remaining processes have explained in GSM section (7. 0). Arduino follows the following algorithm

Algorithm:

Arduino_sec()
Start
Continuously feed BG values to computer system and GSM board
Compares the BG values with the threshold values
Invoke **GSM_sec()**
Invoke **comp_sec()**
End

GSM Board

GSM board[6] is Global System for Mobile communication. From the name itself, it implies that this module is used to send the BG values and the alert message to patient or patient's caretaker mobile. This message will be sent as a text message with the current status of the patient.

Algorithm:

GSM_sec()
Start
Receive the BG values from Arduino
Recieves the alert message from Arduino
Sends message to the patient/caretaker
End

Computer System

A computer system is used to store the BG values in Database maintained in it. And it is used to display the trend graph. For every 10 entries, the alert_alg() will be invoked. Finally the result will be displayed on the web page and as a trend graph.

Algorithm:

alert_alg()
Start
Receive values from Arduino
Store BG values into database
For every 10 entries
Count the no. of entries greater than max. threshold and min. threshold
If **max. count > max. no. threshold**
Send the alert message to doctor
else if **min. count > min. no. threshold**
Send the alert message to doctor
Otherwise
Send health notification to doctor
End

Performance Analysis

The performance of the device is measured by its throughput time. The throughput time is inversely proportional to the performance of the system. This system is optimal for single-user and multi-user system. But now it is designed for single-user system. If it is a single-user system, the performance of the system is high.

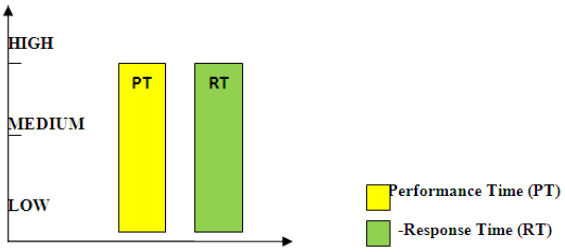

Figure 1: For single user.

The above figure1 depicts the performance time and response time against amount of time.

9. 1. Performance Issues

There are many factors that may affect the performance of the system. Network failures, data traffic, number of users are the major factors that affect the performance of the system.

a) **Network Failure** is, the network do not work properly due to hardware or software failures. In this situation, a user cannot able to access the system for

trend graph and the alert. But the presence of GSM module does not bother about the network failure. It can send notification even though the network failure occurs. Because it uses mobile communication (Sending text messages). Even though a user is offline.

b) **Data Traffic** is, if multiple user is accessing or fetching the data from the database, traffic may occur. It may degrade the performance of the system.

c) **Number of User** is, number of users accessing the network and the database. If the number of user increases, data traffic and network traffic also increases.

Result

The system sends the BG values at an interval of 1 second. The database in the system stores vast amount of data. The sensor provides less accurate results. The performance time of the system is considerably at good rate.

Conclusion

The system is optimal for single user and provides maximum performance under good network facilities. The system sends the BG values between the intervals of 1 second. Though the database can store vast amount of data, the number of users and data traffic is less in this system. But the moisture sensor provides less accurate results and therefore for better accuracy, IR sensors are prefered.

Future Enhancements

Currently, the system is designed for single user. In future, we can design the system for multiple users, that is, we can store the multiple users' information also. It may leads to the proper data integration and data utilization. An effective data mining process leads to an effective system.

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