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A Survey on Technologies Used in Glucose Monitoring for Diabetic Patients

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Abstract- **In the recent years, there has been a great improvement of technology in engineering as well as medical industries. Even though the technology has increased in the medical field, the patient's waiting time in hospitals and emergency appointments is extremely costlier nowadays. In the modern lifestyle many people are susceptible to Diabetes Mellitus (DM).The management and monitoring of DM is a challenge for the diabetic patients. This paper surveys about the various methods used in self-monitoring of blood glucose levels pervasively. The devices used for self-monitoring of glucose level are also discussed in this survey. These devices are very useful in the present busy life scenario. The major disadvantage of these devices is that they are expensive and cannot afford by all diabetic patients. An idea can proposed which involves the preparation of the kit which directly calculates the glucose level and automates with an alert message that includes the diet control,exercise control and medication control.**

Keywords- **Diabetes Mellitus (DM), Glucose level, self-monitoring, Devices, Internet of Things (IoT).**

I. INTRODUCTION

Diabetes Mellitus (DM), [3] which is commonly known as diabetes is a metabolic disease in which there are high blood glucose levels over a long period. Diabetes is caused due to insufficient secretion of insulin in the pancreas. Majorly there are two types of diabetes namely 1) Type 1 DM 2) Type 2 DM. The failure of the pancreas in the production of enough insulin results in Type 1 DM. Type 2 DM is due to the condition in which the cells fail to respond to insulin. Diabetes can be prevented by taking proper diet, doing regular exercise and maintaining normal body weight. The control measures for diabetes are controlling the blood pressure and maintaining proper food intake. Type 1 DM can be controlled by insulin injections.

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The glucose levels can be detected and monitored by using glucometer devices. A glucometer is a medical device which is used for approximate measurement of glucose level in the blood. The glucometer made easy for the patients to self-monitor their glucose level without the help of the doctor. The glucose meter can also be a strip of glucose paper dipped into a substance and measure to the glucose chart. A small drop of blood is obtained by pricking the skin with a lancet and is placed on a disposable test strip that the meter reads and calculates the blood glucose level. The glucose level is measured in terms of mg/dl or mmol/dl.

The Internet of Things (IoT) is the internetworking of physical devices that enable the objects to collect and exchange data. IoT offers advanced connectivity of devices, systems and services. The interconnection of these devices enables automation in all the fields and also in advanced applications. According to a research of Gartner, Inc., there will be a nearly 20.8 billion devices on IoT by 200. IoT devices can be used to enable remote health monitoring and emergency notification systems.

The glucometer and the IoT technology can be combined to monitor the lifestyle of the diabetic patients.This scenario which is based on the above said technology is depicted in the following architectural diagram (Fig.1). The glucometer calculates the blood glucose levels. The calculated glucose levels will be automatically sent to the server and the server automatically replies with the diet control information to the patient.

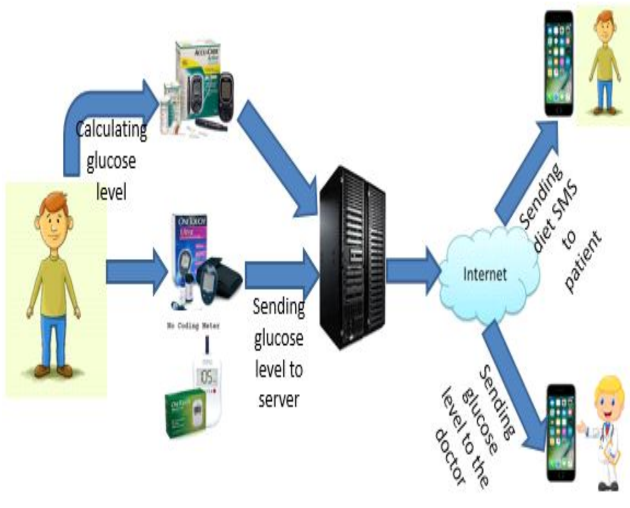

Fig.1 Architecture Diagram

The entire process is carried out using IoT as shown in Fig.1. One copy of the calculated glucose level along with the diet control will be sent to the patient's doctor. The doctor, based on the patient's history prescribes drugs manually. The server maintains the details of patient medical history, incoming and outgoing messages for future verification.

II. RELATEDWORKS

Andrea Facchinetti et.al. [1] proposed the importance of continuous glucose monitoring in various applications. This work demonstrated the real-time algorithms can make CGM smarter by improving accuracy and their ability to give alert messages during abnormal conditions. The authors focused on smart CGM sensor concept which consists of commercial CGM sensor. The output of the sensor enters into three software modules. These modules are able to work in real time for prediction, enhancement and denoising. The results of these three software modules were: **1)** prediction module predicts hypo and hyperglycemic events at an average of 14minutes ahead of time **2)** the enhancement module produced the reduction of mean absolute relative difference from 15.1 to 10.3% **3)** the denoising module improved the smoothness of CGM time by an average of ~57%. The above three software modules improved the performance of CGM applications. The advantage of using smart CGM was the delay between CGM reported glucose and BG can be overcome and the prediction of hypoglycaemia is carried out within time horizon. The disadvantage is that it was not possible for the smart CGM sensor algorithms to be implemented directly into the software which are used by commercially available CGM systems.

Andrea Facchinetti [2] reviewed about the algorithmic challenges of CGM used in the past and present. The work in this paper showed the identification of possible future trends in the CGM. In the past, the main challenges were linked with the quality improvement in the data received from CGM devices through signal processing methods. This challenge has been overcome by creating "Smart" CGM sensors. At the time of their research, a new challenge is being focused i.e.) the demonstration of CGM sensors for non-adjunctive use which ensured safety and efficiency. The solution to overcome the above challenge is the use of ISCT (in silico clinical trials). The challenges expected in the future are linked with the improvement in the usage of CGM sensors and the exploitation of large amount of data receiving from CGM devices. The overview of the paper reviewed the algorithmic challenges and it was presented in detail about the methods used to overcome by the research group.

Emmanouil G Spanakis et.al. [4] stated that the technologies are having the potential to assist healthcare professionals, patients, support self-management. The work proposed in this paper is the introduction of REACTION project. It is a service-oriented architectural platform based on individual services and the implementation of novel care models. These models are used to perform various functions such as patient monitoring, distributed decision support, health care workflow management and clinical feedback provision. This resulted in the ability to support diabetes management in different healthcare regimes. This gave rise to the development of Glucose Management System. It had the ability to monitor parameters from different sources that included glucose levels, nutritional diet intakes, drugs and patient's insulin sensitivity. The major advantage of this project is there was a good control over diabetes. It may reduce the risk and complications of the patient.

Jerome Place et.al. [5] proposed a work in the development of artificial pancreas (AP) for patients with Type-1 diabetes. This work had allowed performing outpatient clinical. In this paper, a new tool was used which allowed multiple patients to monitor artificial pancreas using home environment. The tool which was presented in this paper is called DiAs Web Monitoring (DWM). The DWM tool is a web based application which ensures reception storage and displays the data that is sent by AP systems. The DWM tool consists of a user interface design, software platform, bench test and clinical test. This paper developed a remote monitoring system which contains two components namely 1) Network Service (NS) which is an android application embedded in DiAs and is responsible for transmission of data 2) Web Based Application titled as DiAs Web Monitoring (DWM). The advantage of this tool is that it is a powerful tool which assists in transition of AP to outpatient use.

Jesper Thestrup et.al. [6] focused on the project titled REACTION which is a mobile and cloud based platform. This project was developed due to two major challenges: 1) Health care delivery and 2) Cost. The authors proposed this project which provides health care services to diabetic patients. The author also viewed about the services which were provided by the REACTION project. The applications based on REACTION is developed targeting type 1 DM patients. The REACTION platform is connected to sensors wirelessly and the devices used for monitoring the patients as well as to the health care professionals. This project was also implemented in clinical field trials such as Safe Glycemic Control in hospitals, Automatic Glycaemic Control. The advantage of REACTION project is that it will provide integrated, professional, management and treatment services to patients. The main disadvantage is the insufficient data about how mobile technologies are used in influencing health outcomes, creating challenges to identify. This evolution was influenced by factors such as financial incentives, development in the technologies and clinical R&D.

Nurul Akmal Binti Abd Salam et.al. [7] reviewed on the various methods used for blood glucose detection method and the development of blood glucose monitoring systems. The authors dealt mainly with the Non-invasive blood glucose monitoring system. The author reviewed on various invasive methods which are used over years for blood glucose measurements. In the invasive methods, a pinch of blood sample from the finger by using needles and the blood is transferred to the glucose measurement device for measuring the glucose. The other way of measuring glucose is the partially invasive method in which it uses the technique of inserting a sensor into the skin while measuring the glucose concentration. This paper also proposed a method of non-invasive technique

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for measuring blood glucose levels. The non-invasive method is done by placing sensors directly to the human targeted area without the use of any blood samples. The various techniques on non-invasive blood glucose measurement are Transdermal and Optical. The advantage of using non-invasive glucose meter and monitoring systems is that these devices are designed to be compact, wearable and lightweight with advanced microelectronics chips which can be monitored by smartphones. One of the major disadvantage of this device is it suffers from various human factors such as temperature, skin moisture and motion.

Pérez-Gandia C et.al. [8] proposed an online method for the future prediction of glucose concentration levels using the data from CGM. The method used for prediction is the artificial Neural Network Model (NNM). The values from the CGM during the preceding 20 minutes form the input of the NNM. The output was the prediction of glucose concentration within the chosen prediction horizon (PH). The assessment for the performance was done using data from two CGM systems. The accuracy of NNM is being estimated by the root mean square error and the prediction delay. The method in this paper can be used for online glucose prediction. The training algorithm is able to be executed on a PC. The NNM can assess accurately if there is any change in the glucose profile due to individual metabolic fluctuations. The limitation is that it does not allow the NNM to detect sudden changes in the time derivative of the signal.

Riccardo Bellazzi [9] focussed on the problems which occur due to the usage of telecommunication. This paper also reviewed about the solutions for diabetes management by the development of information technology. The author discussed the adoption of telemedicine in the future generation that combines new organisational models and novel technologies. According to the author, there will be two telemedicine interventions in the future which are used for short-term and long term. The long-term telemedicine intervention will be based on communications among GPs, specialists and patients. The short-term telemedicine interventions will be designed for pregnant women, type 1 DM patients. The advantage of using telemedicine is that it improves the communication among patients, health care providers and health care systems. The disadvantage is that the telemedicine can support better and faster treatments but it does not cure by itself.

SandeepKumar Vashist [10] focused on various continuous glucose monitoring systems (CGMS) which are used for diabetes management. There had been a huge development in the technology for glucose monitoring. This development lead to the evolution of blood glucose meters, non-invasive glucose monitoring (NGM) devices and continuous glucose monitoring systems (CGMS). This paper featured on the available CGMS devices such as Dexcom SEVEN plus, Dexcom G4 PLATINUM, Guardian REAL-Time, FreeStyle Navigator2, HGI-c, GlucoTrack, OrSense NBM-200G, Symphony. The author also focused on the various challenges involved in CGMS. The challenges are operational cost decrease, the detection of specific glucose, signal-to-noise ratio improvement, development of wearable CGMS, evaluation of analytical performance and the reduction of glucose measurement time. The advantage is that frequent glucose monitoring helps to manage diabetes by sustaining the physiological blood glucose level.

Shankaracharya et.al. [11] focused on the developments in machine learning algorithms as diabetes diagnosis tools. The supervised and unsupervised methods are used in detection and diagnosis of diabetes at the primary and its advanced stages. In this work, a special attention is given to the algorithms which improve diabetes diagnosis. The review paper provides a better resource for analysts who are interested in computational intelligence based diabetes diagnosis methods. The authors focused on various analysis techniques such as data analysis through logistic regression, clustering techniques, support vector machines, Neural networks, and Expert systems. The logistic regression is used when the data contains a set of explanatory variables and a binary response. The clustering techniques make use of k-means, mixture of Gaussians, self-organizing map (SOM) and neural gas (NG) used for diagnosis. The support vector machines (SVM) is operated by finding a linear hyper plane which separates positive and negative examples with maximum interclass distance. The neural network is of five types namely 1) Multi-layer neural networks 2) Back propagation neural networks 3) Radial basis function (RBF) 4) General regression neural network (GRNN) 5) Neuro-fuzzy inference systems (NFIS). The expert system using Mixture of experts and modified mixture of experts has been implemented to overcome the problem of diabetes diagnosis prediction. The advantage is that it reduces the healthcare costs through early prediction and diagnosis of diabetes.

Stavroula G. Mougiakakou et.al. [12] focused on type 1 diabetes patients for monitoring and managing diabetes. The authors focused on SMARTDIAB which is made of two units: 1) Patient Unit (PU); and 2) Patient Management Unit (PMU). These two units are used for data communication. Using Personal Computers, laptops and Mobile phones with Internet access the PU can access PMU. The PU consists of an insulin pump, a continuous glucose sensor and a mobile phone. The insulin pump is developed inside the SMARTDIAB frame and is programmed using the internet. The CGM devices are designed flexibly to support commercially available glucose monitoring system and novel noninvasive CGM system. The mobile phone application is used to transmit patient's data to the PMU. The PMU consists of a DSS, which provides risk assessment for diabetic complications, a diabetes data management system and an insulin infusion advisory system (IIAS). The DDMS contains a central DB and data analysis tool. The IIAS is an interface connecting the CGM device and the insulin pump. It is used to maintain glucose levels within normal range. This paper deals with various functional issues such as patient management and security framework. The authors also dealt with various evaluation strategies for MPS, DDMS and IIAS. The main advantage of this system is it connects with mobile infrastructure, WPAN and internet and also with glucose measurement devices, advanced and control techniques and tools which are used for intelligent processing of diabetes patient information. Although these results have been accepted by the users but the hardware and software modules need to be improved.

III. SUMMARY OF THE SURVEY

The summary of the survey as shown in table 1 represents the comparison between various papers based on certain attributes such as: 1) Methods used 2) Targeted area 3) Accuracy 4) Types of diabetes 5) Stages of detection. The methods used are invasive and non-invasive. The invasive method requires a pinch of blood pricked from the finger or skin to measure the glucose whereas the non-invasive method requires sensors which are placed directly to the human targeted area. The second criteria used for comparison is the targeted area. This attributes defines where the devices are placed on the human body glucose measurement. The other criterion is accuracy which denotes how exactly the devices measure the glucose level. The fourth criterion indicates the types of diabetes (Type 1 or Type 2). The last criterion denotes when the devices detect the diabetes level either primary or advanced.

Table 1: Summary of the Survey

AUTHOR	METHOD USED	TARGETED AREA	ACCURACY	TYPES OF DIABETES	STAGES OF DETECTION
Andrea Facchinetti et.al.[1]	Invasive	Skin	High	Type 1 and Type 2	Advanced
Andrea Facchinetti [2]	Invasive	-	Moderate	Type 1 and Type 2	Advanced
Emmanouil g spanakis et.al. [4]	Invasive	skin	High	Type 1 and type 2	Primary and advanced
Jerome Place et.al. [5]	Invasive	Skin	Moderate	Type 1	Primary
Jesper Thestrup et.al. [6]	Invasive	Skin	High	Type 1	Primary and advanced
Nurul Akmal Binti Abd Salam et.al. [7]	Non-invasive	Skin, earlobe	Moderate	Type 1 or Type 2	Primary
Pérez-Gandia C et.al. [8]	Invasive	Skin	High	Type 1 and Type 2	Primary and advanced
Riccardo Bellazzi [9]	-	-	Moderate	Type 1 and Type 2	Primary and advanced
Sandeep Kumar Vashist [10]	Non-invasive	Skin, earlobe	High	Type 1	Primary
Shankaracharya et.al. [11]	Invasive	Skin	Moderate	Type 2	Primary and Advanced
Stavroula G. Mougiakakou et.al. [12]	Invasive	Skin	Moderate	Type 1	-

IV.CONCLUSION

In this paper, we have surveyed some approaches for glucose monitoring. Special attention is given to the systems which helps in personal monitoring. Many glucometer systems have been developed using different techniques. Many of these systems help only in self-monitoring of glucose levels. We have suggested that a system can be proposed thatis not only used for self-monitoring but also to know the general information about the diet ,exercise ,medication to be taken for that particular blood glucose level. Additionally, the same information will be intimated to their personal doctor for further reference. The advantage of that system is that the patients need not meet their doctor personally for their check-ups, no need of prior appointments. This approach will be of greater importance and usable in the future.

REFERENCES

[1] Andrea. Facchinetti, Giovanni Sparacino, Stefania Guerra, Yoeri M. Luijf, J. Hans Devries, Juliak K. Mader, Martin Ellmerer,Carsten Benesch, Lutz Heinemann, Daniela Bruttomesso, Angelo Avogaro, Claudio Cobelli“Real-Time improvement of continuous glucose monitoring accuracy, the smart sensor concept,” Diabetes Care, vol. 36, no. 4, pp. 793–800, 2013.

[2] Andrea Facchinetti “Continuous Glucose Monitoring Sensors: Past, Present And Future Algorithmic Challenges”Received: 14 October

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DOI: 10.21276/ijircst.2017.5.2.6

2016; Accepted: 7 December 2016; Published: 9 December 2016.

[3] Claudio. Cobelli, Chiara Dalla Man, Giovanni Sparacino, Lalo Magni, Giuseppe De Nicalao and Boris P. Kovatchev “Diabetes: Models, signals, and control,”IEEE Rev.Biomed. Eng., vol. 2, pp. 54–96, Jan. 2009.

[4] Emmanouil G Spanakis, Franco Chiarugi, Angelina Kouroubali, StephanSpat, Peter Beck, Stefan Asanin, Peter Rosengren, TamasGergely, Jesper Thestrup “Diabetes management using modern information and communication technologies and new caremodels,” Interact. J. Med. Res., vol. 1, no. 2, pp. 1–12, Oct. 2012.

[5] Jerome Place ,Antoine Robert,Najib Ben Brahim,Patrick Keith-Hynes,Anne Farret,Marie-Josée Pelletier,Bruce Buckingham,Marc Breton,Boris Kovatchev,and Eric Renard “DiAs web monitoring: A real-time remote monitoring system designed for artificial pancreas outpatient trials,” J. Diabetes Sci. Technol., vol. 7, no. 6, pp. 1427–1435, Nov. 2013.

[6] JesperThestrup,TamasGergely, Peter Beck “Exploring New Care Models In Diabetic Management And Therapy With A Wireless Mobile E-Health Platform”

[7] NurulAkmalBintiAbd Salman, Wira Hidayat bin Mohd Saad, Zahariah Binti Manap, Fauziyah bte Salehuddin “The Evolution Of Non-Invasive Blood Glucose Monitoring System For Personal Application,” vol. 8,No.1 January- April 2016.

[8] Pérez-Gandia C, A Facchinetti, G. Sparacino,C. Cobelli, E.J. Gomeez, M. Rigla, A. de Leiva, M.E. Hernando“Artificial neural network algorithm for online glucose prediction from continuous glucose monitoring Diabetes” TechnolTher 2010;12:81–88.

[9] Riccardo Bellazzi, “Telemedicine and diabetes management: Current challenges and future research directions,” J. Diabetes Sci. Technol., vol. 2, no. 1, pp. 98–104, Jan. 2008.

[10] Sandeep KumarVashist, “Continuous glucose monitoring systems: A review,” Diagnostics, vol. 3, pp. 385–412, Oct. 2013.

[11] Shankaracharya, DevangOdedra, Subir Samanta, Ambarish S. Vidyarthi “Computational intelligence in early diabetes diagnosis: A review,” Rev. Diabetic Stud., vol. 7, no. 4, pp. 252–262, Feb. 2010.

[12] Stavroula G. Mougiakakou, Christos S. Bartsocas, Evangelos Bozas, Nikos Chaniotakis,Dimitra Iliopoulou, Ioannis Kouris, Sotiris Pavlopoulos, Aikaterini Prountzou, Marios Skevofilakas,Alexandre Tsoukalis, Kostas Varotsis, Andrianni Vazeou, Konstantia Zarkogianni,and Konstantina S. Nikita “SMARTDIAB: A communication and information technology approach for the intelligent monitoring, management and follow-up of type 1 diabetes patients,” IEEE Trans. Inf. Technol. Biomed., vol. 14, no. 3, pp. 622–633, May 2010.

