Development of Mobile Tracking System for Diabetes and Recent Patents on Diabetes Mellitus

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Abstract: In today’s world, the prevalence of insulin dependent patients is increasing worldwide. In light of advancing in technology at biomedical science, the new approach and methods in recent years show the potential to solve the problems. In addition, advances in biomedical instruments have led to new opportunities such as real time patient tracking for mobile healthcare purposes. In this sense, wireless tracking of diabetic patients in home environment has been proposed as an alternative to conventional tracking. It can enhance the performance of processes in terms of reduction of expert person, cost, ease of use, and decrease the compliance of patients. In this study, wireless diabetic tracking system (WDTS) is developed. The application system concerns mainly wireless tracking of diabetic patients from their home environment. It is focused on the insulin dependent Type-2 diabetic patients. Main aim of the system is to facilitate tracking of diabetic patients. Satisfactory results are obtained by applying the system to six patients. Revision and summary of the most important and prominent patents regarding diabetes mellitus management, mobile tracking and treatment are also presented in this study. The patents examined concern a period extending from the years 2000 up to date. The paper ends with a description of the future improvements expected in the subjects covered.

Keywords: Diabetes mellitus, mobile, management, patent, tracking, wireless.

1. INTRODUCTION

Advances in mobile technology and development of remote monitoring, in other words tracking through wireless technology, have led to modern facilities [1]. For instance, Bluetooth and 3G have made it possible for elderly patients to track them independent of time and place. To achieve this, biomedical data has to be acquired and evaluated to provide ease of use, quality of life. Today with aging and increasing health problem in population, remote tracking becomes very important. However, usage and compatibility difficulty have emerged. Due to the reason, an effective and reliable method has to be found. In addition, the prevalence of diabetes in the worldwide is forecasted as 2.8% in 2000 and will be 4.4% in 2030. The total number of people with diabetes is estimated to rise from 171 million in 2000 to 366 million in 2030 [2]. There are two types of diabetes such as Type-1 and Type-2 [3]. Most of diabetic patients (approximately 90%) have Type-2 diabetes mellitus [4, 5].

The population of elderly people tends to increase. As a result, chronic diseases such as diabetes incline towards a rise [6]. To treat and manage diabetes, health education and professional health care are needed [7, 8]. By using information and communication technology (ICT), it is possible to provide health care to the patients from remote location [9, 10]. Together with the ICT, mobile devices enable reliable and effective opportunities [11] Owing to these reasons; wireless diabetic tracking system (WDTS) for patients who have Type-2 diabetes mellitus is developed. In this paper, rule based method is used for addressing complicated problems employed in diabetic tracking.

This article is organized in four sections. In the first section, we present WDTS (wireless diabetic tracking system). In the second section, we evaluate most recent patents regarding the diabetes management, mobile tracking and treatment. In the third section, we give the results of the system and a discussion about the system. Finally, we give the conclusion and future works related to the development of mobile tracking system for diabetes and recent patents on diabetes mellitus issue.

2. WDTS (WIRELESS DIABETIC TRACKING SYSTEM)

Wireless tracking of physiological data is desirable in many research and clinical applications [12]. It provides a solution which can be used in different areas of healthcare. These will be available through smart phone, web browsers, or desktop clients. Different types of sensors are connected to mobile equipment through Bluetooth. Data is continually sent to a server, where it is being processed and evaluated in detail. Processing and evaluating on the server consists of receiving and saving data, monitoring in an advanced form, and automatic evaluation of the critical states with the help of advanced technologies [13].

Low-cost and effective wireless system can make life easy especially for elderly people [14]. In literature, phone-
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Based studies facilitate psychological data transfer in real-time for increasing the mobility of patient monitoring. It also provides easy critical care before the patient is on the ambulance. Bluetooth, Zigbee, WLAN, 3G, GPRS, RF technologies are used in data transfer. In these studies, different types of policy engines evaluate the data and the results will be accessible almost anytime and anywhere through mobile device web browser [15-20].

In mobile diabetes studies, GPRS and SMS are frequently used between patients and remote center as a data transmission type [21, 22]. SMS is preferred due to the store and forward options. It also facilitates self management of patients [23]. There are too many studies regarding diabetic management and treatment. Prominent studies are presented respectively. In Al-Taee and colleague study, diabetic patients are managed and tracked through PDA based Bluetooth technology. Medical data is obtained from the sensors and sent to the smart phone via Bluetooth connectivity. These technology based systems provide improvement in diabetes management [24]. The objective of another study in mobile phone based management of diabetes is to develop an application comprise blood glucose (BG) device, tailormade step counter and software. It is obtained that the system has a motivational effect on the patients [25]. Salameh “A Mobile Phone SMS-Based System for Diabetes Self Management” named study propose an SMS-based system. It enables continuous monitoring of patients and includes SMS based patient management and educational module [26].

Intelligent and alert system also facilitates management and treatment of diabetic patients. Ichimura and colleagues develop an intelligent web based system to support diabetic patients [27]. Ren-Guey and colleagues propose and implement intelligent diabetes management system. System comprises PDA, patients and alert mechanism. It is shown that this system provides fast and reliable help to the patients [28]. Mougiakakou and colleagues design a platform to assist the monitoring, management, and treatment of Type-I diabetic patients. System comprise patient and patient management unit [29].

In this study, development and applying of WDTS to diabetic patients in home condition are described. The system comprises a portable glucose measurement device, a weight scale, a smart phone, an XML web services, a web server and mobile web pages. System architecture is shown in (Fig. 1). Firstly, glucose and weight data are acquired with Bluetooth virtual serial port protocol and health device protocol respectively. The obtained data are handled in real time on the smart phone with the rule based algorithm. Threshold values are defined for every patient in the assessment. The rule based algorithm evaluates measured data that is obtained from the patients. For instance, if the blood glucose level is out of the threshold values, the status of patient is labeled as emergent. The results are sent by the means of SMS and web service. The XML Web service is employed to store the measured data to the remote database.

The measured data regarding the diabetes diseases can be tracked on mobile web pages. The mobile web pages for tracking of diabetic patients are designed as shown in (Fig. 2). With these pages, smart phones that have small screen and limited data transfer can retrieve the related data from the server.

Fig. (1). WDTS Architecture.
The evaluation flow chart of the wireless diabetic tracking system is shown in the (Fig. 3). This flowchart and the developed system are designed with respect to the doctor recommendations. All steps of flowchart are performed by the smart phone. Initial setting (first three steps) has to be done for every patient. In the evaluation process, if there is an emergency condition, SMS is sent to the doctor for management purpose such as directing of ambulance to the patient. In all condition, the measurement results are sent to the remote database with the web service.

Wireless diabetic tracking android application is developed with Java programming language. This application software acquires diabetic data from the measurement device to the mobile phone by means of the Bluetooth virtual serial port protocol. Weight scale sends measurement data to mobile phone through the Bluetooth health device protocol. If there is no problem, the data set is parsed and the measurement data are achieved on the mobile phone. This data is also shown in real time with the smart phone.

3. RECENT PATENTS OF DIABETES MANAGEMENT AND MOBILE TRACKING

The main aim of the diabetes mellitus management and the mobile tracking is to control the blood glucose value in an acceptable level. The diabetes mellitus management has to cover tracking of blood glucose value, controlling of nutrition level, managing of weight and stress, using of medication and injection of insulin. Furthermore, management of diabetes mellitus can be achieved by changing lifestyle such as nutrition type, exercise etc. In literature, there have been numerous patents about the diabetes management and the mobile tracking. These patents can be divided into four main categories. These categories are about the devices, wireless tracking and management, implantable units, algorithms and monitoring systems. In the device category, devices have network connectivity, portable usage and therapy features. They also check diabetic feet. In the wireless management category, improved diabetes data management is accomplished through wireless connectivity. The innovative algorithms, the diabetes management and planning system are summarized in the algorithms and monitoring systems category. In the implantable unit’s category, the implantable glucose monitoring and the control of a subject’s glycemic state are realized. Remarkable patents regarding these fields are summarized respectively.

Fig. (3). Flowchart of Wireless Diabetic Tracking System.

The first patent included in this review concerns early detection of neuropathy on the foot. It sends images of foot to the doctor for consultation purposes. The device comprises sending means and images of the sole of the foot to
expert person or doctor in a hospital [30]. Other inventions on this field, computing device and an insulin delivery device are used to manage blood glucose level. These devices provide diabetes care management. It is shown in (Fig. 4) [31]. Braig and colleagues found a glucose monitoring instrument called “Glucose monitoring instrument having network connectivity”. This device sends the measurements between patients and practitioner [32]. Another patent included in this paper concerns with the medical device and testing procedure. It comprises a combination of hardware and software [33].

![Handheld device for monitoring](image)

Fig. (4). Handheld device for monitoring.

In Galley and colleagues’ patent, a device is used for managing of the blood glucose measurements. In the measurement, a handheld diabetes management device is used. The method involves configuring of the database and identifies specific ones of a plurality of the blood glucose test values [34]. In another patent, Anderson and colleagues’ invented diabetes care host-client architecture and data management system. In this model, a client or local database stores the diabetes care data and system manages them [35].

The objective of another patent in wireless tracking and management field is to develop a system comprising of diagnostic testing devices, medication delivery devices and wireless connectivity components. [36].

McAleer and colleagues’ “wireless diabetes management devices and the methods for using the same” named patent propose a diabetics management system. System uses a wireless smart phone and provides a remote counseling service. It can also be utilized to alert a caretaker [37]. Another invention on wireless management field deals with treatment of health condition. All data are stored and managed through the PDA. Proposed health management program deals with diet, daily activities and medication delivery [38]. In another patent that is invented by McAleer and his colleagues, diabetics are managed by means of wireless phone. There is an interface to the diabetics' glucometer and providing remote counseling service to the diabetic patients [39]. Serge finds out a patent that is called “method and system for detecting location of fixed wireless asset”. It identifies the location of wireless devices. It consists of device tracking number, mobile device, communication link, and a database [40]. Lau and colleagues’ invention is about the mobile device user behavior analysis based on tracking purposes. It tracks motion behavior of the mobile device, and generates a user profile [41]. In Pakzad’s patent, system tracks the location of a mobile device. The graphical representation of routing area is covered in this patent [42]. In Furey and colleagues’ invention, tracking unit, system, and method are presented. It use SATCOM and GPS network as shown in (Fig. 5) [43].

![Tracking System](image)

Fig. (5). Tracking System.

L.M. Wolfe and colleagues’ “monitoring, diagnostic and tracking tool for autonomous mobile robots” named patent propose a system and method for managing and prioritizing of mobile robots. System comprises mobile robots, home-based servers, central server that processes the obtained data [44].

An invention related to the algorithms and monitoring systems concerns evaluation of changes in glucose levels. It is tried to determine the pre-event measurement and post-event measurement for each of the plurality of occurrences of the repeating event [45]. The following patent included in this review concerns glucose behavior. Developed system analyzes glucose behavior around meal events by using pre and post-meal analysis period. The system has graphical interface that highlights the pre-meal analysis period, the post-meal analysis period, and shows the plurality of glucose.
readings for the time period. In Dahlin and colleagues’ patent, disease management algorithm integration that is composed of medical order and healthcare provider interface is presented. Galley and colleagues’ patent propose a method. It comprises handheld diabetes management device’s entry, adherence, and exit criteria. Another invention on this field, diabetic patient’s carbohydrate to insulin ratio, carbohydrate to blood glucose ratio, insulin sensitivity factor are determined. In the determination process, blood glucose values, carbohydrate consumption and insulin doses are used. A network based healthcare management system is provided in Cha and colleagues’ patent. System composed of a plurality of client workstations and health space service processors.

Another patent of implantable units in diabetic management concerns glycemic state. It is controlled with implantable glucose monitoring system. Main important component of system are sensors, catheters, insulin reservoir. Doron and colleagues design an implantable system to control an insulin pump or store and transfer the data for monitoring purposes. In another patent that is invented by Osorio and colleague, implantable glucose monitoring and a glycemic state of a subject controlling method and system is presented.

4. RECENT PATENTS OF DIABETES TREATMENT

There have been numerous patents regarding the diabetes treatment in literature. These patents can be divided into two main categories. These categories are about the herbal composition, methods and systems. In herbal composition category, different types of herbal species and composition are used to treat diabetic patients. In methods and systems category, advanced diabetes treatment is achieved through video game, statistical results, and wireless based system. Prominent patents regarding these fields are summarized respectively.

The first patent about herbal composition provides methods for treatment diabetes mellitus by using extract from a fruit of genus elaeis. It also facilitates treating and preventing of diabetes mellitus. The objective of another herbal composition patent in diabetes treatment field is to provide regulation of glucose level with the leaves of gymnema sylvestre. Aqueous ethanol is used in extraction. With this way, blood glucose value is maintained at a predetermined level. In another invention by Wang reveals fruit/vegetable nutritive buckwheat powder and a preparation method from it. With this product, unsatisfying taste of the food for diabetics is changed. Wen and colleagues’ patent concerns with health beverage that has not got the toxic and side effects. It has green and natural in raw materials.

Another patent of the methods and the systems in diabetic treatment concerns a treatment of diabetes by supplying brown adipose tissue to a subject. Antony and colleagues’ invention on treatment proposes a method for preparation, process and a regeneration and technique for prevention, treatment and hyperglycemia of diabetes mellitus. In Genkin and colleagues’ patent, a method for treating diabetes is invented. Treating is accomplished with DNAse enzyme injection into a systemic blood circulation in doses. With this way, qualitative and quantitative composition of blood extracellular DNA is changed. Kircher and colleagues’ patent proposed a method and a system. They automatically adjust parameters for predicting blood glucose levels and/or controlling the dispensing of insulin.

Method of preparation, process and a regenerative for prevention, treatment and glycemic control of diabetes mellitus is presented in another patent that is invented by Antony and colleague. In Angelides and colleague’s patent, a system that provide monitoring of test glucose level, advising of exercise, drug administration. It also transmits the glucose testing results with GPRS or wireless link facilities. Method and system for wound care is proposed in cha and colleagues’ patent as shown in (Fig. 6). This system consists of handheld wireless device with an integrated camera. Obtained data is transferred to the related database. In this way, tracking and analysis based on the clinical treatment algorithms is performed. This system also provides accurate assessment and treatment of the wounds.

In another Brown’s patent, methods and systems for monitoring, diagnosing and/or treating psychological conditions and/or disorders in patients with the aid of computer-based virtual reality simulations are proposed. System collects the data from the patient and analyzes the data. Apeldoorn and colleagues’ invention is about the treatment of diabetes. It proposes a method for scaffold preparation. Beta cell aggregates constitute the scaffold and they are distributed in a predetermined pattern. Boss and colleague find a method for the treatment of diabetes by controlling of blood glucose. Method provides reduction of postprandial glucose excursions by administration of pulmonary insulin in
combination with basal insulin [68]. In the Abensour and colleagues’ patent, a method is proposed to determine the degree and stability of blood glucose control in patients with diabetes mellitus via creation and continuous updating of new statistical indicators. System consists of processor that receives and computes the data [69]. Pescatore and colleagues’ invention is about the herbal extracts composition. The composition consists of different types of tea, coffee and banana extracts. This invention standardizes the individual extract suitable for health [70]. In Atienza and colleagues’ invented genetic methods for identifying a risk of type II diabetes. In addition, it administrates the type II diabetes treatment based on the presence of polymorphic variations [71]. In another patent that is invented by Boss and colleagues, method for the treatment of diabetes is presented. Postprandial glucose excursions reduction is provided with administrated insulin composition [72].

5. RESULTS AND DISCUSSION

In recent years, mobile applications for tracking and management of patients tend to increase. Thanks to the development of smart phone technology, decrease in price, increase in central processor units’ capacity, it is feasible to track patients from a remote location in real time [73]. In our study, smart phone is used as a processing unit; and weight scale and glucose meter are used as a data collecting unit. With this way, real time tracking of diabetic patients is accomplished.

An ease of use, a modular system is developed in this study. Our system has the most prominent features. Before applying the system to the patients, information is taken from the expert person regarding diabetes treatment. We applied our system to six volunteer diabetic patients in their home environment. In Table 1, the demographic characteristics of patients are presented. Primarily, the system usage information is given to the doctor and patient such as how to use the system and the web pages and how to manage SMS based information. The ages of patients are between 55 and 67. The selected patients have common characteristics. For example, they already have smart phone and they use glucose test and insulin injection in their home environment before. Besides, they have detailed knowledge regarding diabetes and insulin.

According to the patients, they will prefer the system due to the real-time tracking by doctor and emergency case. For instance, a doctor can direct the ambulance to a patient with the system. Between smart phone and web server database, 3G, Wi Fi, and GPRS/EDGE can be used for data transfer. Due to the cost priority, WLAN is preferred in this study.

6. CONCLUSION AND FUTURE WORKS

The remote tracking of patients improves safety and the quality of care. In addition, medical complications can be decreased. In this sense, wireless technology is the most common technology for tracking of patients which are widely used in the biomedical field. In addition, the measurements of blood glucose level provide effective treatment. Moreover, it prevents the occurrence of hypoglycemia. This paper presents a mobile tracking system and comprehensive analysis of recent patents of diabetes treatment, diabetes management and mobile tracking and future expectations of diabetic system. This system we designed has innovative properties such as ease of use and modular architecture. For instance, AND Bluetooth blood pressure device can be easily integrated to the system. The system uses web 2.0 technologies such as XML web service between smart phone remote servers. It also evaluates the measurement data with rule based method. It uses mobile and wireless opportunities. Developed real time system introduces self-management of diabetes care. The software allows patients to make more consistent and appropriate control in their glucose level and lifestyle. SMS based notification regarding the emergency condition realizes the remote support of patients at home comfort. It facilitates the tracking of the diabetic patients. Smart phone compatible web pages enable an accession of patients’ statistical data that also provide self-control. The system can be used as a remote tracking unit.

The performance of our system can be increased by adding different heuristic algorithm such as support vector machines. The self-management educational programs for diabetes management using distance education can be added to the system. We can also add a GPS software module to track location of patients.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.
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