Closed Loop Insulin Delivery System Based on Non-Invasive Glucose Measurement

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Abstract— Diabetes has become a serious health issue of this century. To overcome this situation Continuous Monitoring of glucose is necessary which is quite challenging task. The use of Non-invasive technique for measuring Blood Glucose level is a better way for Continuous Monitoring. Automation in Insulin Delivery to the patient has also become a boon to Diabetes therapy. This paper aims to combine the concepts of continuous monitoring and automated insulin delivery. The proposed work is to design a completely automated diabetic therapy system which can be used by the patient himself/herself without assistance. The measurement of glucose level is achieved with a Near Infra-red (NIR) Light Source and the required amount of insulin is delivered to the patient with the help of Micro-Actuator controlled by a Stepper Motor.

Key words: Continuous monitoring system, Diabetes, Insulin pump, near infra-red Measurement

I. INTRODUCTION

Diabetes Mellitus, commonly referred to as Diabetes, is a group of metabolic disorders in which high blood sugar levels over a prolonged period occurs [1]. Symptoms of which are frequent urination, increase in thirst and hunger, if left untreated then it may lead to serious consequences which include failure of kidney, stroke, eye damages, etc. [2]. The cause of diabetes is inability of pancreas to generate the amount of insulin required by the body, as a result insulin has to be delivered to the patient externally. The reason for which there is a need to supervise the blood glucose level. Presently, the most common way for the patients to measure the glucose level is to prick their finger and then use the capillary blood to measure the glucose level, it is obvious that it causes a lot of pain and displeasure to prick the extremities every time to measure the glucose level, hence it is necessary to come up with a non-invasive method [3].

Insulin Delivery is also an important issue to be considered because if more content of insulin than required is delivered to the patient then it leads to hypoglycaemia. Severe hypoglycaemia leads to risks such as coma and death [4]. In order to overcome this situation it is better to use Automated Control System for Insulin Delivery [5]. Interfacing both Insulin Delivery system and Non-invasive Glucometer helps to find a solution for problems occurring by manual interpretation and therapy. This project forecasts a closed loop insulin delivery technique which can work without human intervention. The Block Diagram and Working Methodology are described in next Chapter. Interpretation and Experimental Results are described in preceding Chapters.

II. METHODOLOGY

A. Overview:

The glucometer proposed here uses NIR (Near Infrared) light as a source. The light source is placed in the region where only minimum interference of tissues takes place and such a region is the Ear Lobe (otherwise known as Pinna). The delivery system proposed here is a simple one which uses a stepper motor and a Micro-actuator for accurate delivery purpose. A very simple yet diverse system is proposed for efficient functioning.

B. Block Diagram:

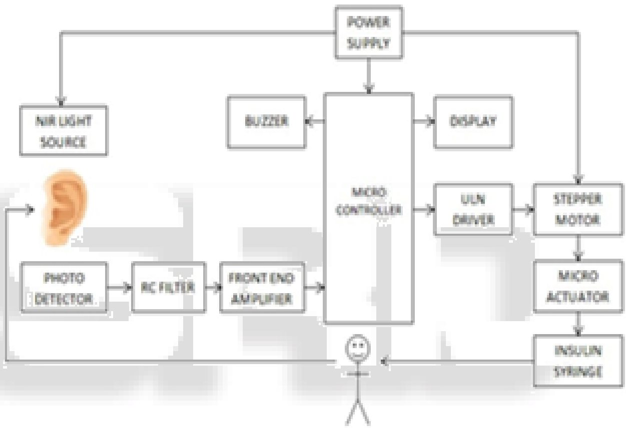

Fig. 1: Block Diagram of Closed Loop Insulin Delivery System

The light source used here is an LED source of wavelength 1550nm and in the other end is a photodiode of Spectral Range 1300 – 1700nm. The LED and the photodiode are placed across the Pinna. The purpose of connecting a RC muscle filter is to remove the high frequency components (noise). High frequency components may be as a result of tremors, power line interference, etc. As the biomedical signals are very low in amplitude it is inevitable to get any meaningful data from those data without using a high gain front end amplifier, primarily used to increase the amplitude of biomedical signals. A microcontroller is used in order to process the signals which have an inbuilt ADC.

Microcontroller is programmed in such a way that the sensor output is converted into the relevant glucose value and the value is displayed in the LCD display. If suppose the glucose value is high (more than the normal threshold) the controller commands the stepper motor to rotate thereby pumps the insulin inside the syringe. After completing the insulin delivery to the patient the system alerts through a buzzer.

C. Interfacing Both the Systems:

After both the setups have been completed it is highly necessary to provide a proper interfacing between them so as to avoid any errors and have an automation system in place. The coordination of the system was achieved by removing the bugs from program and manually calculating the distance the actuator moves with every step taken by the motor. After repeated tests the distance that the actuator moves can be added with the program for complete automation.

III. CALCULATING THE DOSAGE

The right amount of insulin dosage to be given can be calculated in two ways:

- A bolus dose that is pumped to cover food eaten or to correct a high blood glucose level.
- A basal dose that is pumped continuously at an adjustable basal rate to deliver insulin needed between meals and at night [6].

The set inversion via interval analysis algorithm has been applied to obtain the feasible set of basal and bolus doses that, for a given meal, mathematically guarantee a postprandial response fulfilling the International Diabetes Federation (IDF) guidelines (i.e., no hypoglycemia and 2 h postprandial glucose below 140 mg/dl). Hypoglycemia has been defined as a glucose value below 70 mg/dl. A 5 h time horizon has been considered for a 70 kg *in silico* T1DM (Type-1 Diabetic Mellitus) subject consuming meals in the range of 30 to 80 g of carbohydrates [7].

IV. EXPERIMENTAL RESULTS

The use of 1550nm NIR LED as a light source in this technique has resulted in greater accuracy than other non-invasive techniques. The Non-invasive technique used in this paper for Glucose Measurement is compared with prevailing Invasive technique and showed better results.

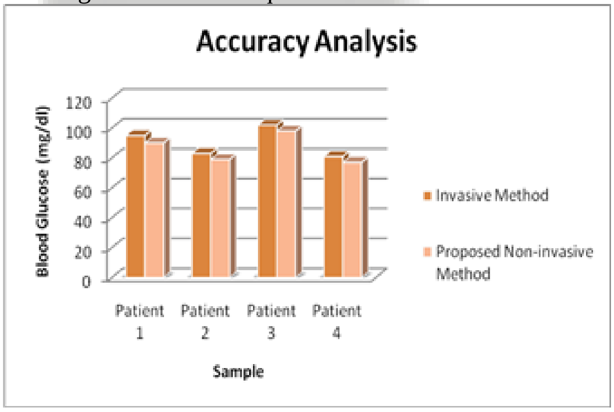

Fig. 2: Comparison Chart

The micro-actuator in delivery part works precisely so that amount of insulin delivered is more accurate. On together a completely automated system was designed and tested.

V. CONCLUSION

In this Closed loop Insulin Delivery System, complete automation in Diabetes therapy has been achieved. This system can be used by Diabetic patients in spite of literacy since handling this system is simple.

VI. Future scope

With some modifications the system can be made more compact and user-friendly. Usage of different wavelength of NIR light sources may increase the accuracy of Glucose Measurement thereby increasing system performance.

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