A Low Power Optimized Wearable Insulin Delivery System

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Abstract

Diabetes patients are likely increasing day by day in the recent years due to many factors. Patients mainly prefer artificial systems to provide insulin with a glucometer in an open loop insulin system. Among the commercially updated systems the most preferably used system is the hybrid closed loop system in high power computing power. In this paper a novel insulin delivery system with reduced energy and computation requirements are considered. The information regarding patient is done in the conventional manner using a continuous glucose sensor and insulin based pump. An embedded system connected to the pump and sensor will collect glucose data and process the data. The channel is connected radiofrequency signals. So the system cannot be connected to the processor which increases overall stability of the system. Based on the patient parameter configuration, automatic control should be made by the basal infusion rate of insulin bringing glycaemic level of patients to the target level. Simulated results are implemented in Uva/Paduva simulator for the proposed algorithm.

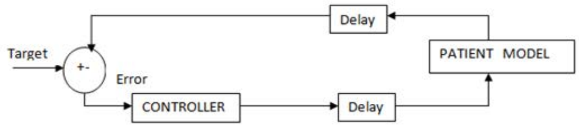
Keywords: Insulin delivery; Wearable system; Closed Loop; Embedded platform

Introduction

Among 10% of the people affected with diabetes many are subdivisions of diabetes with diseases like LADA and neonatal diseases etc. The general categories of diabetes are type 1, type 2 and gestational diabetes. The commonly affected one is the type 2 diabetes which is mainly reduced by the strict diet plan. The primary remedy is oral medication with extreme cases of diet and exercise. Type 1 diabetes patients are in the risk of suffering short and long term complications in glucose level. In recent years more accurate infusion devices are used consisting of small electrodes underneath the skin to measure glucose levels in the blood.

Nowadays the possibility of using such devices is improved with far applicable technology. The burden to reduce the diabetes is the main objective of medical companies. Most of the recent devices do not prefer glucose sensor data to find the insulin dosing.1 The current technologies paved a way to infuse insulin besides carbohydrate consumption. Now it's simple to reduce dose of insulin but when insulin is dosed, it cannot be removed from the body. The patients infusion level is suspended on the security threshold.[1,2] This is the main feature of the closed loop system. A simplified version of the hybrid closed loop system is depicted in Figure 1.

Figure 1: *Controller scenario for diabetic patient*



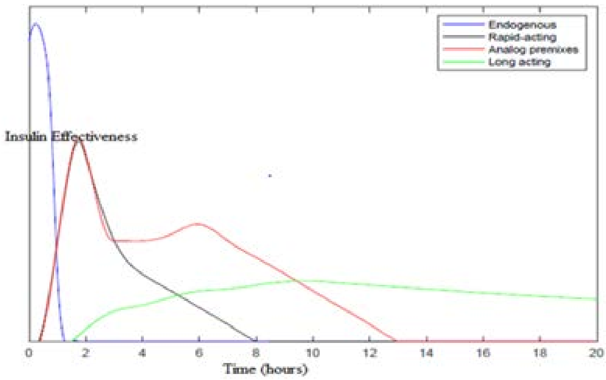
Delay in glucose scenario

The delay in the glucose process measurement is 10 minutes-15 minutes. This delay can reduce the controller speed to provide changes in glycaemic level.

Response on Insulin

Based on subcutaneous infusion strategy the patient receives insulin. With a little delay in the loop the insulin effect in the patient effect get absorbed. While a person without diabetes has no delay. In a healthy pancreas the delivery to insulin is given after an hour Figure 2.

Figure 2: *Insulin effectiveness versus time*



The delay in the closed loop system causes glycaemic level to rise to a dangerous level. A rapid glycaemic level change can be easily evaluated by the food intake changes and by means of exercise. As the glycaemic level increases due to the carbohydrate meal and so the controller responds simultaneously. During exercise the level of insulin is lowered leading to hypoglycaemia. The controller tries to drop for every 15 minutes with a reduced insulin infusion. To include the usage of controller user impacts such as meals and exercise are even incorporated in devices like smartphones. This makes smartphones adaptable for future.

The proposed insulin delivery system is depicted in the

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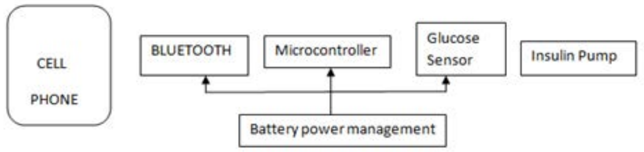
Figure 3. The insulin delivery system composed of a pump for insulin delivery, glucose sensor, and a controller included in the single silicon on chip. The proposed system includes glucose sensor integrated together with insulin pump based on a communication protocol. The glucose sensors will calibrate for every 12 hours with a specific set of rules

Figure 3: *Proposed Insulin delivery system*



The glucose sensor will coordinate with the perusing from the sensor with a glycaemia gave by the patient. This glycaemia esteem should be acquired with a glucometer following the means gave by the maker, commonly: wash and clean hands prior to getting the blood test and dispose of the main drop of blood to stay away from outer specialists from the skin. Due to the postponement between the glycaemia estimated straightforwardly in the circulation system and in the interstitial liquids, alignments should be just performed while the patient's glycaemia is steady. This way the blunder is decreased as the two readings should coordinate after the time comparable to the postponement. This interaction is important to keep the coherency between estimations in the interstitial liquid (given by the glucose sensor) and in the circulation system (gave by a glucometer during alignment).[3] The alignment of the sensor turns out to be truly significant in a shut circle framework: if the sensor is corrupted or on the other hand not aligned effectively, the utilization of wrong information could cause a hypoglycaemia or hyperglycaemia to the patient. Once the patient is utilizing a solid and controllable insulin mixture framework alongside a glucose sensor, the following stage is to acquire a wearable stage that will empower the patient to close the circle: acquire constant glucose information and patient's boundaries and follow up on the insulin imbuement. Different stages utilized for DIY shut circle insulin conveyance frameworks utilize incredible chip running working frameworks as Linux, Android, or iOS.[4] These stages are not arranged to a low force utilization and they should keep the framework running, having different cycles. Behind the scenes that could burn through power in an undesired manner.[5] This is the justification for why these stages can't be considered as "wearable." In request to keep these frameworks running on batteries for no less than 24 hours, the patient should convey generally enormous batteries with the framework, making it less compact and, possibly, not solid for a drawn out timeframe.[6] At the point when the regulator runs on a cell phone there are two extra issues: the patient's telephone can't run out of battery.[7,8] All things considered the patient will open the circle. Other characteristic issue is the security hazard of being hacked. Cell phone security has to be worked on in the following ages of OS for cell phones. These two issues made this work face the regulator's concern according to an implanted stage perspective. In the proposed arrangement, with low force utilization as an objective, another custom board was planned. This board is separated into four different parts: Power and battery the board: as this will be a battery fuelled module, some gadgets are added to have the option to charge the battery and to monitor the battery. Low Power Microcontroller: the control calculation is coded to run in Low Power utilization profoundly. As the regulator will get glucose information each 5 min, the regulator can rest the processor during the stand by period and diminish the force utilization. Although this microcontroller utilizes innovation from a long while back, its low force utilization makes it the optimal stage for this framework. Bluetooth Low Energy Communications has a Bluetooth interface board to have the option to speak with a cell phone. Utilizing a cell phone, the client can arrange the regulator and tell outer occasions (Figure 3)

Glucose sensor and Insulin pump communications

This is the interface used to recover data from the sensor and the siphon, just as order activities to the insulin pump.

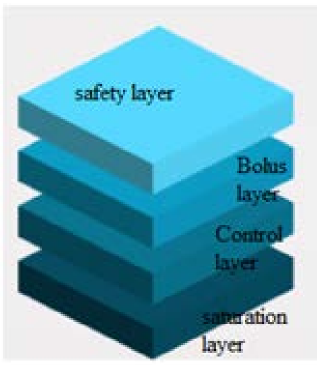
Layers of Controller Operation

Safety layer

In safety layer (Cg) denotes current glycaemic level, eventual level of glycaemia (Eg) and trend glycaemia (Tg). The controller in the proposed model will resume the insulin infusion when the glycaemic level is below the threshold level (Ts). As soon as the hyperglycaemia disappears this layer gets resumed off Figure 4.

$$\text{Safety layer exists=}\begin{cases} C_g \leq Ts \\ E_g \leq Ts \\ T_g \leq Ts \end{cases} \quad (1)$$

Figure 4: *layers of controller operation*



Bolus layer

The controller if confirms that the hyperglycaemic level is not attained then the controller checks for the insulin bolus rate. If the bolus is infused controller calculates active rate of insulin. The controller can able to compensate food intake by the patient and calculates the bolus rate of metabolism.

Control layer

Using patients parameter for the current time in the controller calculates the error between eventual and the target glycaemia.

$$\text{Error}=\text{Eg}-\text{Tg} \quad (2)$$

Insulin infused into the patient last for the period of 30 minutes will result in the basal rate maintained for a period of time.

$$\text{Correction}=\text{Error}/\text{Sensitivity factor} \quad (3)$$

Saturation layer

The controller controls all the actions performed in the control layer. The minimum and maximum basal rates are controlled by the controller. The maximum basal rate is noted and the basal rates above that value will be reduced to the basal rate maximum value.[2,9]

In closed loop system the patients can follow the meal scenario for patients. Post hyperglycaemic effects can be reduced if the patient's glucose level is in the given range of time. The simulation results give the value of general ratio as 93.69%, adult 97.99%, child 89.96%. The real nature of the closed loop systems are they really allow glucose level within the range as in Figure 5.

Conclusion

The controller integrated with fine tuning and activation provides closed loop control activation. The parameters can also be modified using patient control strategies giving control in food intakes, exercise and stress, hormonal disorders. The glycaemic control with high transparency is obtained with this new approach.

Acknowledgment

None

Conflicts of Interest

None

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