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Original Research Article

Accurate prediction of continuous blood glucose based on support vector regression and differential evolution algorithm

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ABSTRACT

Type 1 diabetes (T1D) is a chronic disease requiring patients to know their blood glucose values in order to ensure blood glucose levels as close to normal as possible. Hence, the ability to predict blood glucose levels is of a great interest for clinical researchers. In this sense, the literature is rich with several solutions that can predict blood glucose levels. Unfortunately, these methods require the patient to specific their daily activities: meal intake, insulin injection and emotional factors, which can be error prone. To reduce this burden on the patent, this work proposes to use only continuous glucose monitoring (CGM) data to predict blood glucose levels independently of other factors. To support this, support vector regression (SVR) and differential evolution (DE) algorithms were investigated. The proposed method is validated using real CGM data of 12 patients. The obtained average of root mean square error (RMSE) was 9.44, 10.78, 11.82 and 12.95 mg/dL for prediction horizon (PH) respectively equal to 15, 30, 45 and 60 min. The results of the present study and comparison with some previous works show that the proposed method holds promise. The SVR based on DE algorithm achieved high prediction accuracy while being robustness, automatic, and requiring no human intervention.

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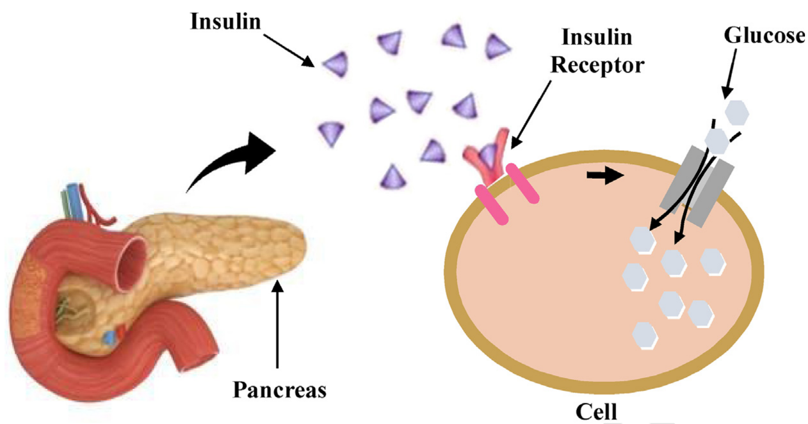

Fig. 1 – Cycle of insulin on glucose uptake.

1. Introduction

In the human body, the regulation of blood glucose is controlled by the action of two hormones: glucagon and insulin. The loss or destruction of β cells in the pancreas is known to causes Type 1 diabetes (T1D). Consequently, a reduction in insulin production leads to an increase of blood glucose and hyperglycemia [1]. Insulin has a significant role in the ability of cells to metabolize glucose [2]. Fig. 1 describes the cycle of insulin on glucose uptake.

Hyperglycemia is generally associated with complications such as: long-term micro-vascular complications (diabetic neuropathy, retinopathy and nephropathy), in addition to macro-vascular issues (stroke, peripheral arterial disease, and coronary artery disease). In addition, a decrease in blood glucose (hypoglycemia) can rapidly turn into critic situations, such as nervousness, sweating, rapid heartbeat, headaches and even coma. The remediation of these diabetic complications is the use of multiple doses of insulin injections (generally 2–3 injections per day) to supervision and control glycemic levels [3].

The latest technological advances in diabetes provide patients the ability to monitoring their blood glucose levels continuously (every few minutes). Hence, users can assess their response to insulin treatment in a more effective way [4]. Based on these technologies, a clinical goal has appeared: Is it possible to predict accurately blood glucose levels and give the opportunity for T1D patients to stabilize their blood glucose excursions?

To address this question, researchers have developed a number of techniques. In the open literature, two directions have extensively validated their efficiency:

- Mathematical modeling: these methods could be used and implemented in electronic devices. However, in practice they have not fallen short in their performance expectations due to limited precision and their dependence on measuring patient activity.
- Artificial intelligence and advanced signal processing techniques: although more difficult to implement in a run time system due to their complexity in described by mathematical models, tend to have higher performance.

Bremer and Gough (1999) exploited blood glucose levels [5] by recording data every 10 min. The experimental results obtained from modeling blood glucose data, allowed a prediction horizon (PH) equal to 10 min. This study demonstrated that blood glucose levels could be predicted by exploiting past blood glucose values. Since then, numerous methods have been proposed using continuous glucose monitoring (CGM) data and larger PHs.

The works of Sparacino et al. in [6,7] compared the predictive accuracy of a first-order autoregressive model (ARM) with a first-order polynomial model. For each model, the inputs were past blood glucose levels. These approaches assessed data from T1D patients recorded every 3 min using the GlucoDay CGM system. The results showed that the ARM model was the most consistent for obtaining a significant performance with PHs of 30 min and 45 min.

In [8], Palerm et al. exploited a Kalman filter to forecast blood glucose levels based on reconstructing the derivative of the glucose level. They predicted hypoglycemia using data from a CGM system (Medtronic) with an alarm threshold of 70 mg/dL, and they used a variable PH from 1 to 30 min. Experimental results of predicting hypoglycemia were sensitive to 90% and specific to 79%.

Pappada et al. [9,10] proposed an artificial neural network (ANN) engendered from the ''NeuroSolutions'' package software to predict blood glucose for a PH of 50–180 min. The training data set was acquired from 18 T1D patients based on CGM for a period of 3–9 days. Furthermore, the authors used an electronic diary to record hypo/hyperglycemia symptoms, meal intake, insulin doses, emotional states and activities. Experimental results showed that the predicted blood glucose levels were more accurate in the hyperglycemia and normoglycemic stages than those in the hypoglycemic stage. The authors reported that the cause of the discrepancy was that the training database employed fewer samples of hypoglycemic events. Consequently, one can conclude that ANN prediction results depend heavily on the quality and the

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