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Original Research Article

Continuous blood glucose level prediction of Type 1 Diabetes based on Artificial Neural Network

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ABSTRACT

Recent technological advancements in diabetes technologies, such as Continuous Glucose Monitoring (CGM) systems, provide reliable sources to blood glucose data. Following its development, a new challenging area in the field of artificial intelligence has been opened and an accurate prediction method of blood glucose levels has been targeted by scientific researchers. This article proposes a new method based on Artificial Neural Networks (ANN) for blood glucose level prediction of Type 1 Diabetes (T1D) using only CGM data as inputs. To show the efficiency of our method and to validate our ANN, real CGM data of 13 patients were investigated. The accuracy of the strategy is discussed based on some statistical criteria such as the Root Mean Square Error (RMSE) and the Mean Absolute Percentage Error (MAPE). The obtained averages of RMSE are 6.43 mg/dL, 7.45 mg/dL, 8.13 mg/dL and 9.03 mg/dL for Prediction Horizon (PH) respectively 15 min, 30 min, 45 min and 60 min and the average of MAPE was 3.87% for PH = 15 min, knowing that the smaller is the RMSE and MAPE, the more accurate is the prediction. Experimental results show that the proposed ANN is accurate, adaptive, and very encouraging for a clinical implementation. Furthermore, while other studies have only focused on the prediction accuracy of blood glucose, this work aims to improve the quality of life of T1D patients by using only CGM data as inputs and by avoiding human intervention.

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1. Introduction

Type 1 Diabetes (T1D) is a chronic disease characterized by immune-mediated destruction of pancreatic β-cells resulting in insulin deficiency by reducing the ability of the pancreas to produce sufficient insulin [1]. T1D has been steadily increasing worldwide (3% per year) [2]. Unfortunately, the only treatment for T1D is the subcutaneous insulin therapy. This injection requires knowledge of the exact insulin dose to avoid hypoglycemia and hyperglycemia. Hyperglycemia causes long-term complications, such as retinopathy, neuropathy and cardiovascular diseases. Hypoglycemia can rapidly lead to dangerous events, such as hypoglycemic coma and nocturnal hypoglycemia, which is critical because of the difficulty for patients to recognize its symptoms during sleep. Consequently, an optimal dose of injection is required to ensure human health care. To guarantee this need, clinicians generally resort to Continuous Glucose Monitoring (CGM) to get a more complete picture of the blood glucose level, which can lead to better treatment decisions and better glucose control. The CGM devices began to be developed in the 1980s and from 2000, the first commercial one was available [3]. Indeed, the CGM technology has opened several horizons in the analysis of T1D [4]. As a common glucose monitoring solution, CGM provides blood glucose value in real-time throughout the day and night, with predefined time intervals.

Practically, as shown in Fig. 1, CGM can become smarter by providing them with prediction and control algorithms that are able to generate alerts if there is hypo/hyperglycemia. Specifically, an accurate prediction of blood glucose prevents T1D complications and improves the quality of life and health. The aim of this work is the development of an algorithm that predicts with maximum accuracy the future blood glucose levels.

In the literature, various approaches have been proposed to predict blood glucose levels. One of the first investigations was proposed by Bremer and Gough [5] in 1999. The authors showed that blood glucose values could be predicted based only on previous values, so no need to involve models of glucose and insulin distribution for the prediction of blood glucose.

Thanks to the great and fast development of computers and microelectronics technologies, several advanced techniques have been used in the last decade. Sparacino et al. [6,7] compared the predictive performance of a first-order polynomial model with a first-order autoregressive model (AR). These two models were evaluated based on data of T1D patients wearing the GlucoDay CGM System, which provides glucose levels every 3 min. Experimental results showed that the AR model was more reliable for obtaining a clinically significant performance, even with prediction intervals of 30 and 45 min.

In 2005, Palerm et al. [8] used the Kalman filter to predict blood glucose levels based on glucose estimation and its rate of change. Authors predicted hypoglycemia with data from a CGM system (Medtronic) and used a variable PH from 1 to 30 min. Thereby, an alarm threshold of 70 mg/dL was defined to alert patients. Statistically, the Kalman filter hypoglycemia prediction was 90% sensitive and 79% specific. On the other hand, because of the non-linearity of glucose measures, the optimal solution with minimal variance was not defined.

A few years later, Pappada et al. [9,10] proposed an Artificial Neural Network (ANN) approach generated from the NeuroSolutions software package to predict glycaemia over 50 to 180 minutes. The network was a feed forward one trained using the backpropagation algorithm, thereby the learning phase was slow and the network convergence was assured after several training times. The data were acquired from 18 T1D patients using a CGM over a period of 3–9 days for each patient, at a sampling rate of 1–5 min. The ANN was trained using 17 patients and the test was performed on the last one. Experimental results showed that prediction of blood glucose level was more accurate in the hyperglycaemic and normoglycaemic ranges than those in the hypoglycaemic despite that 17 patients were used in the training mode. It was also demonstrated that an increase of predictive horizon resulted in a decrease of predictive accuracy and this is the major drawback of this work.

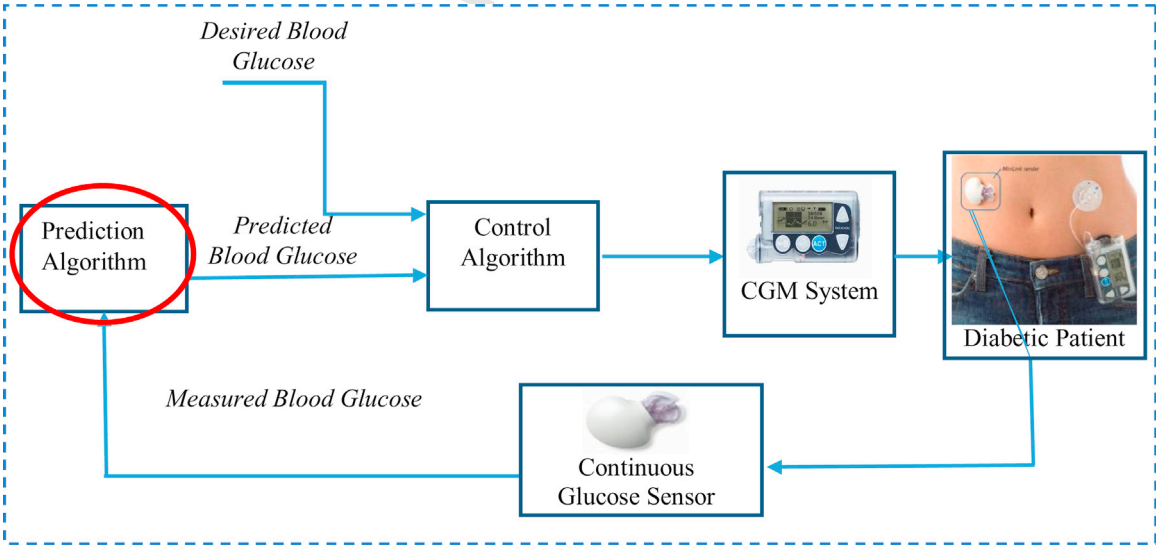

Fig. 1 – Blood glucose control system for T1D.

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