Intelligent Monitoring for Value of Blood Glucose

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Abstract

In this paper described a novel approach for monitoring the glucose value at specific range . The strategy of implementation was in two parts: firstly, modeling of physiological system of glucose value by using mathematical equations. Secondly, via fuzzy controller system that depended on the decision rules set routinely used by patients in their self monitoring activity. In other words it is a fuzzy controller having as an input variable in order to obtain there factors at desired blood glucose level.

الخلاصة

بالامكان نمذجة ما يحدث داخل جسم الانسان الى موديل رياضي مثل نمذجة تمثيل الكلوكوز للاستفادة من هذا الموديل في الكشف عن الحالات المرضية و تحليلها. في هذا البحث تم تقديم فكرة مميزة عن المراقبة الذكية لتمثيل الكلوكوز داخل الجسم ، حيث تمت النمذجة وصولا الى الموديل الرياضي و بالاعتماد على جهاز السيطرة الضبابي حصلنا على قيم المعاملات التي تسيطر على قيمة الكلوكوز داخل الجسم .

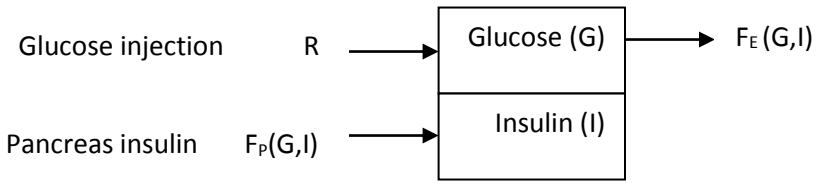
Introduction

Blood glucose monitoring is the main tool you have to check your diabetes control. Most meters test whole blood glucose, however: many meters covert the results to a plasma value, at fasting the normal range of plasma glucose value (90- 120) mg/ml and the blood glucose value (80-100)mg/ml. People with diabetes work to keep their blood sugar (glucose) as near to normal as possible keeping your blood glucose in your target range can help prevent or delay the start of diabetes complications such as nerve, eye, kidney and blood vessels damage (**Ganong, W.F.2003**, **Christopher G.P..2009**). Diabetes mellitus can subdivided in a number of classes that differ in pathogeneses. However the two most occurring types are type 1 and type2 diabetes, type 1 diabetes result of a chronic autoimmune destruction of pancreatic cell resulting in absolute insulin deficiency. The onset of type 1 diabetes is usually in children and early adult hood (<35 years) (**Christopher G.P..2009)**. Type 2 diabetes occurs in approximately 90% of all diabetic patients in the western world. The onset of the disease is usually between 50 and 75 years of age. In type 2 diabetic patient' organ are less sensitive for the action of insulin (insulin resistance) (**Christopher G.P..2009**, **Athena M..2006**). In this paper, the work achieved to simulate and relatively simple mathematical models, then applied the application of fuzzy logic for monitoring this system (glucose value). The focus of simulation is on the utilization of compartmental analysis to better understand the working of glucose in human body and obtained the necessary factors (k1 ,k2 ,k3, k4) that are control on monitoring of glucose value.

Materials &Method

There are two mechanisms for control of glucose concentration, automatic feedback involving hormonal secretion (insulin) by the pancreas and storage in the liver, will be considered. The pancreas, in addition to its digestive functions secretes insulin directly into the blood, insulin facilitates glucose diffusion (transport) across the cell membrane. In its absence, glucose transport falls into 25% of normal(referred to as diabetes), with excess amount of insulin, the blood glucose level can be driven as low as (hypoglycemia) levels that are too high (hyperglycemia). The liver acts as storage compartment for glucose

when excess amount of glucose are present, two thirds of this excess is stored in the liver almost immediately. (**Christopher G.P..2009**, **Athena M..2006**, **John D.E.2000**) Conversely, when the level in the plasma is too low, this stored glucose is released by the liver to replenish the supply in the blood. Insulin has a moderating effect on liver function. A compartment model is shown schematically, see f figure(1)



Figure(1), schematic a modified compartmental analysis for glucose distributed

the balance equations are:-

$dG/dt = R - F_E(G,I)$----------1

$dI/dt = F_P(G,I)$----------2

G:-is glucose concentration (mg/ml) in the plasma

I:-is the insulin concentration (U/ml)

R:- is the injected glucose rate (mg/ml)

F_E (G,I):-is the nonlinear elimination rate (loss) of glucose to the liver and tissue (mg/mls)

F_P(G,I):-is the nonlinear rate of insulin into plasma (mg/mls).

It is convenient to expand the fasting F_E and F_P with regard to their "fasting values G_F and I_F "because the system in aquasi- steady-state after the subject fasts over night, R is zero and so are the derivative terms. This gives $F_E(G,I) = F_P(G,I)=0$. Furthermore the variables are changed by using difference from the fasting values, g and p define as:-

$g=G-G_F$ AND $P=I-I_F$ the functions are linearized about G_F and I_F

$$F_E(G,I) = F_E(G,I)+g \left.\frac{\partial F_E}{\partial G}\right|_{(G_F,I_F)} + p \left.\frac{\partial F_E}{\partial I}\right|_{(G_F,I_F)}$$

$$F_P(G,I) = F_P(G,I)+g \left.\frac{\partial F_P}{\partial G}\right|_{(G_F,I_F)} + p \left.\frac{\partial F_P}{\partial I}\right|_{(G_F,I_F)}$$

Furthermore:- We define the following transport rate constant :-

$$K1=\left.\frac{\partial F_e}{\partial G}\right|_{(G_F,I_F)}$$

K1:-is independent elimination transfer rate constant which the system returns glucose to its fasting value (glucose loss in urine).

$$K2=\left.\frac{\partial F_E}{\partial I}\right|_{(G_F,I_F)}$$

K2:-is elimination transfer rate constant in which the system returns insulin to fasting value.

$$K3=\left.\frac{\partial F_P}{\partial G}\right|_{(G_F,I_F)}$$

K3:- pancreas transfer rate constant in which the system returns glucose to the fasting value

$$K4=\left.\frac{\partial F_P}{\partial I}\right|_{(G_F,I_F)}$$

K4:- pancreas metabolic rate constant in which the system returns insulin to the fasting value.

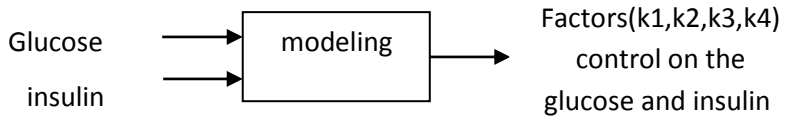
$F_E(G,I) = F_E(G,I)+g\ K1 + p\ K2$

$F_P(G,I) = F_P(G,I)+g\ K3+ p\ K4$

$F_E(G,I)$: represented the glucose loss in urine.

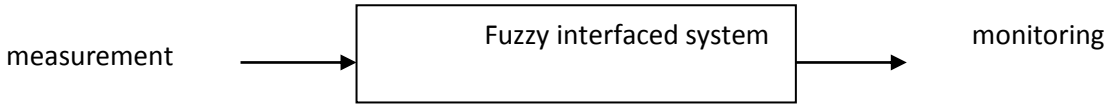
$F_P(G,I)$: represented the amount of Insulin needed from human body.

These factors (k1, k2, k3, k4) will be effected on the analysis of glucose distribution and diagnosis of diabetes mellitus disease.



Figure(2), Stage 1

The strategy of monitoring based on the modeling system (glucose distribution and analysis) to obtain the effective factors on the system and implementation via fuzzy controller (FIS) in order to detect these factors at desired glucose level, see stage (2).

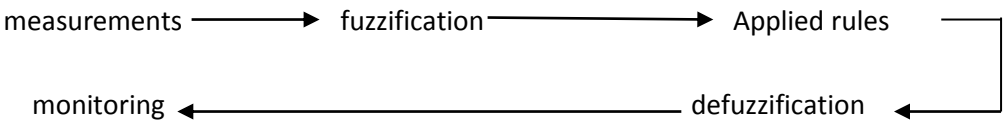


figure(3),stage 2

Fuzzy inference system are also known as fuzzy models fuzzy associated memories, fuzzy rule-based systems and perhaps the more well known fuzzy controllers. The fuzzy inference process contains the following steps:-

1- Fuzzification of input variables .
2- Application of logical, connective.
3- Implication from antecedents to consequents.
4- Aggregation of consequents from all the rules.
5- Defuzification of output variables.

An inference engine is used to evaluate fuzzy rules and performs a mapping from the fuzzy inputs to fuzzy outputs, see figure(4). (**John, 2000**, **Sven Tiffe 2003, Amid, 2009, Ahmad, 1997**)



Figure(4),shown the fuzzy inference system

The choice of membership function type is dependent on the situation at hand. For these factors obtained from the model simulation (k1, k2, k3, k4), trapezoidal membership functions are used which are represent the low and high definitions.

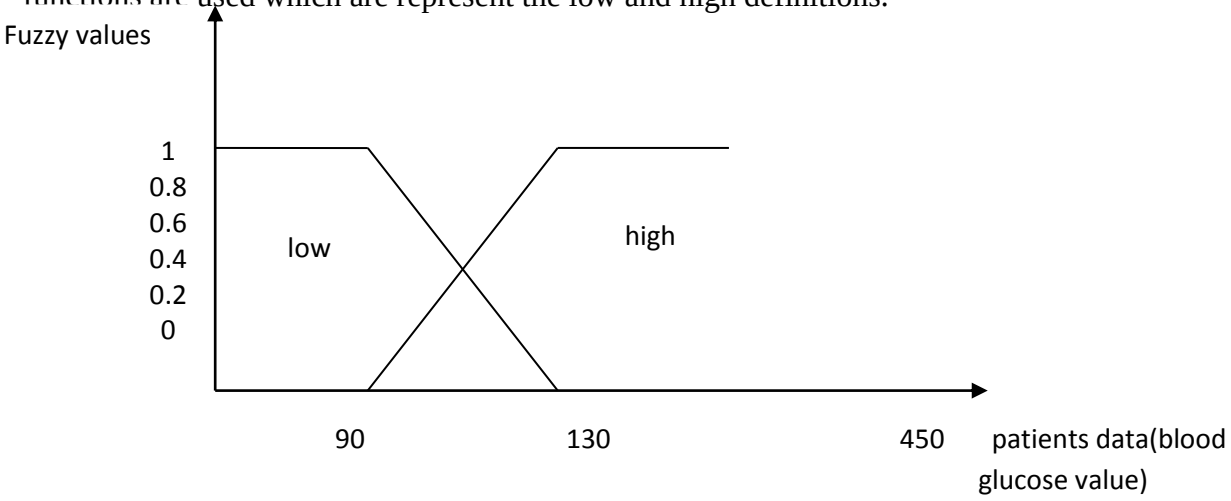


Figure (5),illustrated the membership function

The main depending of the system in the formulation of fuzzy rules. Notice that the keyword is has two differing interpretation in a fuzzy rule. For the antecedent it is used to evaluate the truth of a statement, while for consequent it is an assignment operator used to determine the value of the output variable.

A complete set of rules for (k, k2, k3, k4) is given as:-

1- If k1 is high and k2 is low and k3 is low and k4 is low then the glucose value is high.
2- If k1 is high and k2 is low and k3 is high and k4 is low then the glucose value is high.
3- If k1 is low and k2 is low and k3 is high and k4 is low then the glucose value is low.
4- If k1 is low and k2 is low and k3 is low and k4 is low then the glucose value is low.
5- If k1 is low and k2 is high and k3 is high and k4 is high then the glucose value is low.
6- If k1 is high and k2 is high and k3 is low and k4 is low then the glucose value is high.

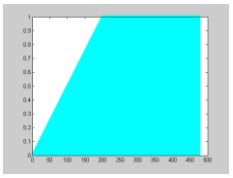
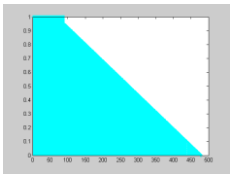
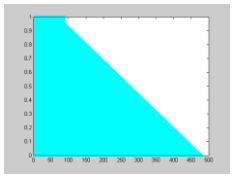
Discussion & Results:-

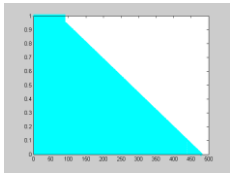
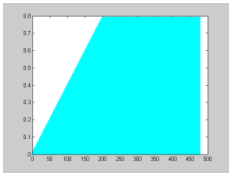
The input data take it from measurement of glucose values into more patients, these data transferred from the real world into the fuzzy world through using membership function as shown in fig(5). After applied the rule on the inputs variables, the minimum value of each antecedent is selected, corresponding to the scale method of implication from antecedent to the consequent. This value is then passed to the inference engine and next rule is selected. The method of aggregation used by the inference engine corresponds to the maximum method. The process of aggregation is complicated by the representation of membership functions as a list of vertices. Each vertex from the consequent must be added and serially to the graph to form the final output fuzzy set. The defuzzifucation takes the final output of the inference engine and converts the membership function into a crisp value by finding the center of gravity or centroid of the function. The system definition is written using MATLAB language which is used to optimize the factors values at specific glucose range (90-200) mg/ml are represented low & high value of glucose respectively. The fuzzy inference system which applied on the patients data, for example, when

k1=350, k2=20, k3=50, k4=30. At firstly, we fuzzification the input data & achieving set of rules for (k1,k2,k3,k4).

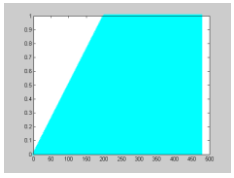
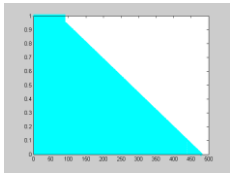
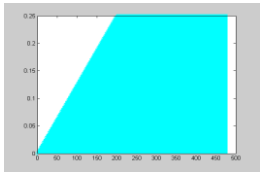
Rule(1):- If k1 is high and k2 is low and k3 is low and k4 is low then the glucose value is high.

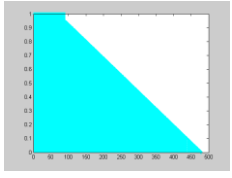
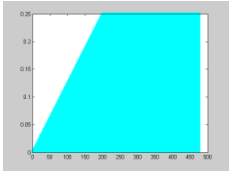
Means that:-

if  &  &  &

 then 

Rule(2):- low and k3 en the glucose value is high, mea

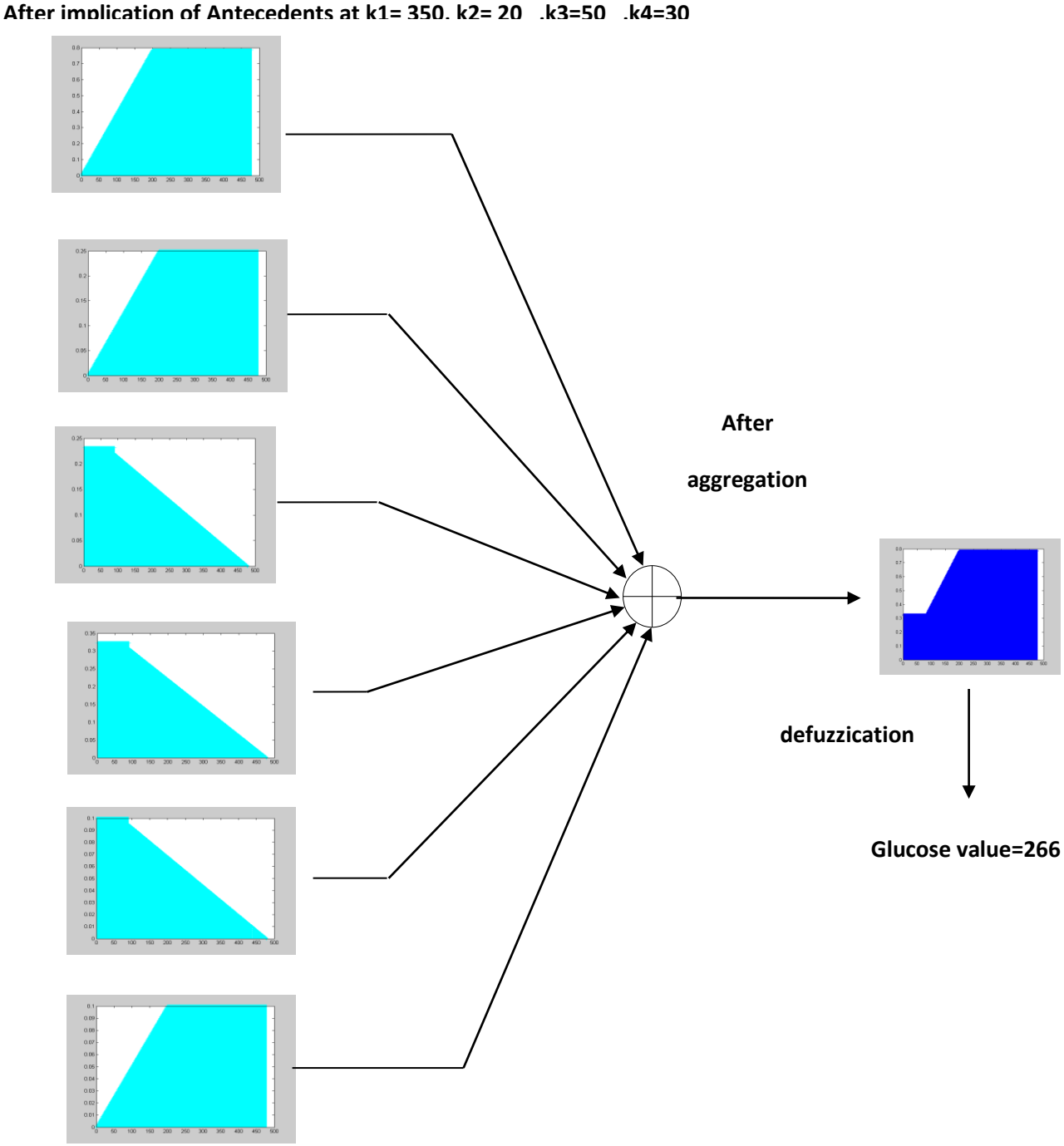
if  &  &  &

 then 

In the same met les in order t s.

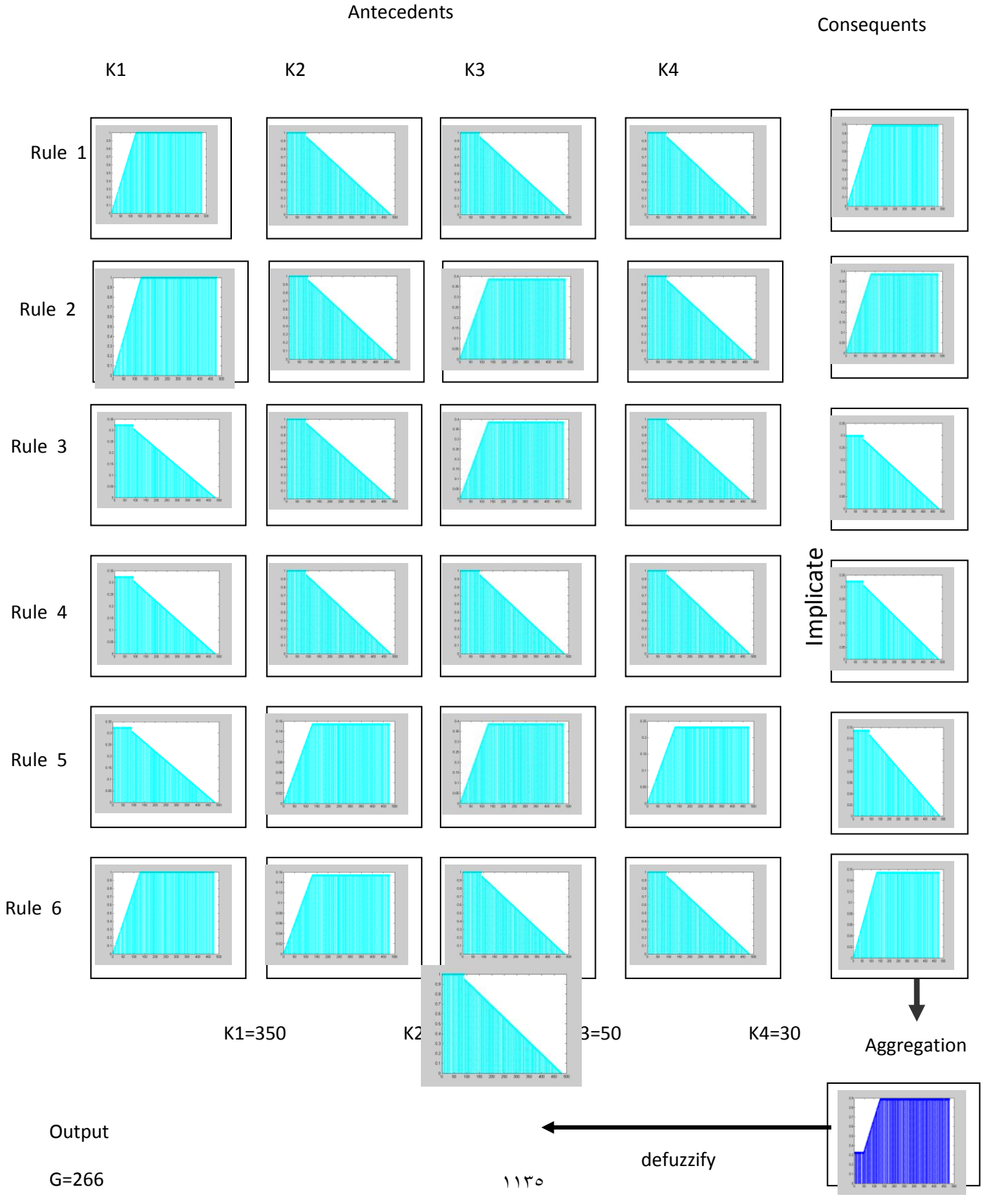
Secondly: Aggr from all rule

Here, we shown how the aggregation process representation in order to perform the glucose value at specific factors.



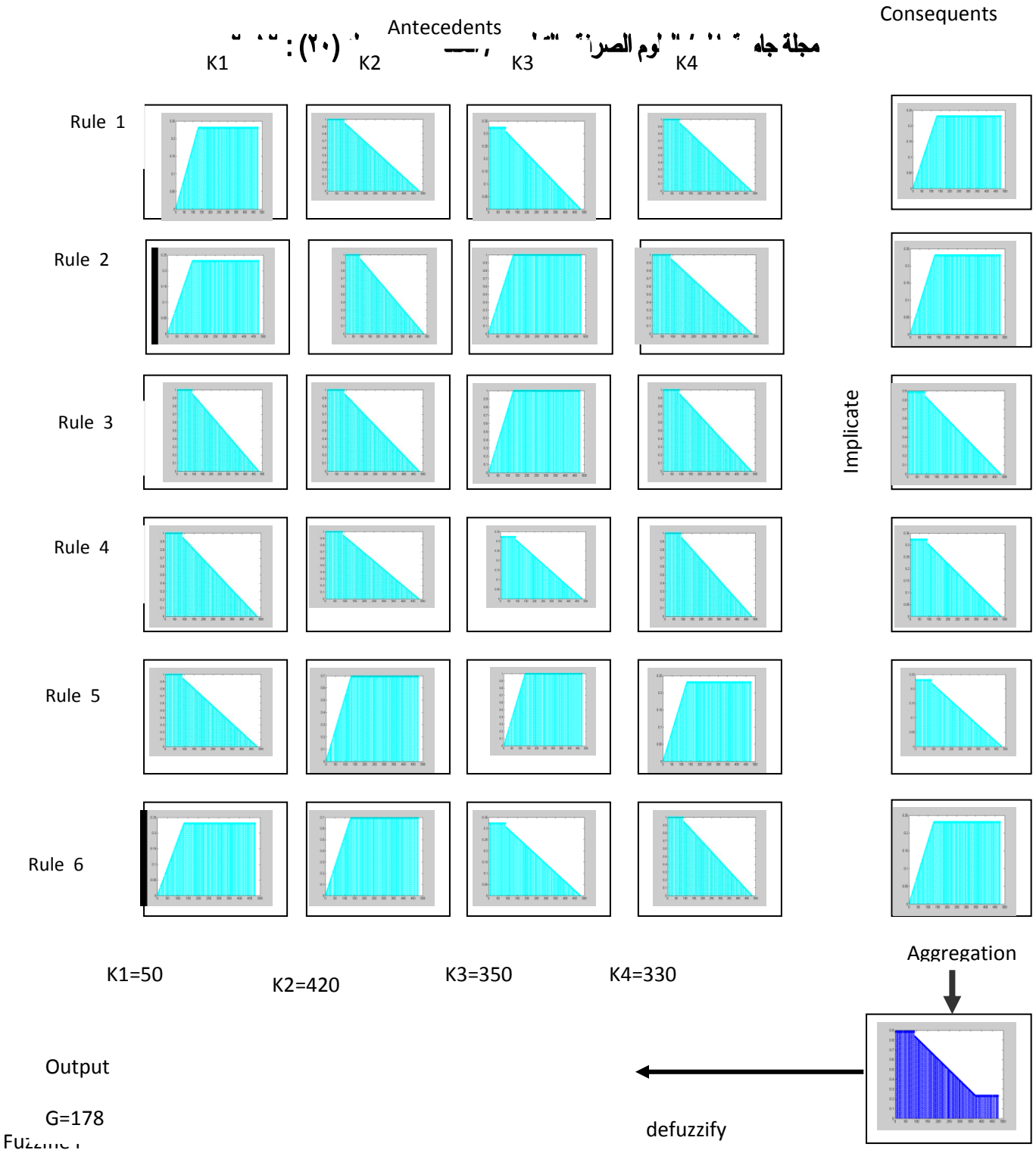
The defuzzification takes the final output of the inference engine & converts the membership which are obtained after performing aggregation methods into a crisp value by finding the center of gravity or centroid of the function. Notice that, in this system the glucose value =266 when k1=350, k2=20, k3=50, k4=30. These factors are really effected on the glucose value; therefore, we can depended on this point for developing & addition

the new idea on the equipment of glucose value measurements. The following figures 6(a,b) illustrated glucose value monitoring at specific factors.



Figure(6a)

Figure(6a)



Figure(6b)

Conclusion

The technical of fuzzy controller system achieved to obtain the main factors (k1, k2,k3,k4) , these factors effected on the increase or decrease the glucose value in the blood depending on the fuzzy rules , the results illustrated it

In the future, we can be developed the idea of intelligent monitoring in order to support the equipment of glucose value measurements.

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