RESEARCH

A Web-user interface design for mathematical model of glucose-insulin system

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ABSTRACT

This paper aims to present a design of a web-user interface for mathematical model of glucose-insulin system. Nurses and administrative personnel can confirm the measured parameters entered by Lab technician. These parameters include glucose and insulin concentration in the heart, the liver and tissues. Measured and estimated parameters are stored in the database, the system displays the results evaluated and calculated by the system to serve as a point of reference to allow users making appropriate, and timely decisions. The front end is designed to be user friendly and to ease the user's manipulation and the back end which is the hidden part embodies the database that stores measured and estimated parameters as well as the mathematical model which is programmed to calculate automatically the parameters and displays the results finally.

Key Words: *Web-user interface; Mathematical model; Glucose-Insulin system; Health subject; Medical Doctor tests*

INTRODUCTION (SECTION 1)

The Computer plays a crucial role in designing of Graphic User Interface (GUI) by users who manipulate and interact with it [9]. The task is complex since software application programming is needed while human interacting with computer [10]. GUI as tool of Human–Computer Interaction (HCI), it is applied by user in many activities of touch, sight, hearing, talk etc. GUI is also implemented in other different types of devices and ICT objects like smartphones, printers, TVs cars, airplanes, tablets, etc. The list is not exhaustive. Different designs of GUI have been made. The details of guidelines on designing GUI can be found in [6] and [13]. Although it is used in many applications, it is not easy when needed in designing a GUI of mathematical model especially health systems and medical oriented solutions which must convey complex data and functions through lists, tables, charts, and diagrams to visualize on user's benefits and at a global range [3], [12]. This high development cost is required if it is GUI that implements the visualization of human body system particularly one designed using the mathematical model of glucose-insulin system. Different researchers have developed the mathematical models of this system [2], [4], [5], [7], [8], [14], [15].

The objective of this paper is to design a web Interface for Glucose-Insulin System Mathematical Model (IGISMM) using the mathematical model presented in [1]. IGISMM is a tool for physicians, nurses and administrative personnel who need to review the trends of some parameters of glucose- insulin system to make appropriate, accurate, precise, and timely decisions based on the displayed results. It presents some guidelines and reviews the design of prototypes for glucose-insulin system with an emphasis on numerical test and appearance results for healthy and abnormal subjects.

This paper consists of six sections. Section 2 presents the overview of the mathematical model of glucose-insulin system. Section 3 deals with IGISMM layout. This section focuses on context and data flow diagrams, front-end side and back-end side and database design. System implementation of IGISMM is presented in section 4. Section 5 discusses the results of the test evaluation. Finally, we conclude with Section 6.

MATHEMATICAL MODEL EQUATIONS (SECTION 2)

Sorensen developed a physiologic global mathematical model to simulate metabolism and regulation of glucose [15] for healthy

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subjects. These physiological tasks are performed in human being body by two important hormone insulin and glucagon. Compared to mathematical model developed by Sorensen that results in 22 nonlinear ordinary differential equations with 42 parameters and 11 nonlinear inputs, we propose in this work a simple mathematical model of six compartments developed in [1]. It is a system of 6 nonlinear ordinary differential equations resulting from blood flow in 3 compartments which are heart and lungs, liver and tissues. The compartment of tissues includes brain, kidney, gut and periphery which includes skeletal muscle and adipose tissue. The simple mathematical model developed uses the subscripts H, L, T, and A to stand for heart and lungs, liver, tissue, and hepatic artery tissue, respectively. The glucose concentration (G) is expressed in *mg/dL*, insulin (*I*) in *mU/dL*, volume (*V*) in liters (*L*) and vascular blood flow (*Q*) in *dL*/min. The blood flow through the compartments in shown in Figure 1.

Taking into consideration diagram flow of the Figure 1, the mass balance equations are formulated as follows:

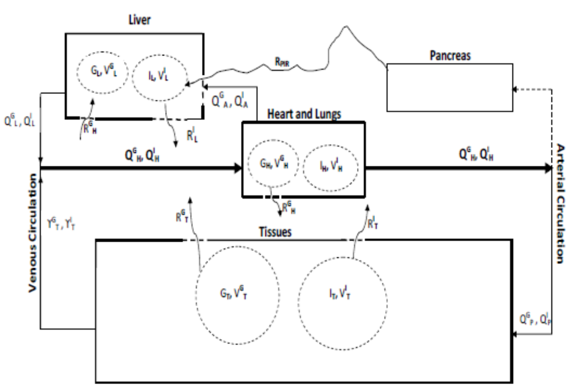

Figure 1) *Flow diagram for glucose and insulin in the three main physiologic compartments that are heart, liver and tissues. Arrows indicate the direction of blood flow and subscripts distinguish physiologic compartments.*

$$
\begin{cases}
V_H^G \dfrac{dG_H(t)}{dt} = Q_L^G G_L(t) + g_T^G (G_T(t))^a - Q_H^G G_H(t) - R_H^G \\
V_L^G \dfrac{dG_L(t)}{dt} = Q_A^G G_H(t) - Q_L^G G_L(t) + R_L^G \\
V_T^G \dfrac{dG_T(t)}{dt} = Q_P^G (G_H(t) - G_T(t)) - R_T^G \\
V_H^I \dfrac{dI_H(t)}{dt} = Q_L^I I_L(t) + g_T^I (I_T(t))^b - Q_H^I I_H(t) \\
V_L^I \dfrac{dI_L(t)}{dt} = Q_A^I I_H(t) - Q_L^I I_L(t) + R_{PIR} - R_L^I \\
V_T^I \dfrac{dI_T(t)}{dt} = Q_P^I (I_H(t) - I_T(t)) - R_T^I,
\end{cases}
\quad (1)
$$

The first three equations represent the glucose subsystem while the three last equations concern the insulin subsystem.

The Table 1 shows the nomenclature of variables and parameters. The estimated parameters are R^G(mg/min), R^G(mU/min), γ(dl/min), p, α, δ, σ and β.

The Table 2 shows the parameters from the literature [15] and the Table 3 summarizes the estimated parameters [1].

DESIGN AND LAYOUT (SECTION 3)

In this section, the researchers focus on the arrangement of predetermined items on a page as well as combining text, images, and other items into a visually pleasing arrangement. Basically, you're given the pieces and they are arranged so that they give the work structure and make it easier to navigate, from the margins on the sides to the content in between. According to [11], to manage structure of the display area, the two essential and complementary approaches/schemes where they deal with arrangement in form of tabular, illustration, and organized items in a form of hierarchical as well as concentrating on interacting step-by-step, more information and tumbling/reducing the information which are not relevant. Based on the case of Graphical User Interface (GUI) design for the mathematical model of glucose-insulin system, there is a foremost scheme amongst the two stated ones, but to avoid them to be inaccurate/inappropriate, both two of them will be combined. Table 3 indicated the estimated parameters and its estimated values to be used for the system design.

TABLE 1
Nomenclature of mathematical model

Variable	Description
V	Volume *(dl)*
G	Glucose concentration $(\frac{mg}{dl})$
I	Insulin concentration $(\frac{mU}{l})$
Q	Vascular blood flow rate $(\frac{dl}{min})$
Subscript	**Description**
H	Heart
L	Liver
T	Tissues
A	Hepatic Artery
PIR	Peripheral insulin release
s	Stored insulin
b	Labile insulin
Superscript	**Description**
G	Glucose
I	Insulin
˥	Glucagon

TABLE 2
Parameters used from literature

Parameter	Value	Parameter	Value
V_H^G	3.5	Q_L^G	12.6
V_L^G	25.1	Q_H^G	43.7
V_T^G	9.5	Q_A^G	2.5
V_H^I	0.99	Q_P^G	12.6
V_L^I	1.14	Q_L^I	0.9
V_T^I	0.73	Q_H^I	3.12
R_{PIR}	27.8553	Q_A^I	0.18
		Q_P^I	1.05

TABLE 3
Estimated model parameters

Parameter	Value

γ_T^G	5.1575
α	0.0354
R_H^G	9.9966
β	1.0422
γ_T^I	2.1056
R_L^G	1042.1509
R_L^I	7.6076
R_T^G	40.8085
R_T^I	1.0013

Context and data flow diagrams

According to the design of Client-Server and Web-based Graphical User Interface design for the Mathematical Model of Glucose-Insulin system (IGISMM), the design is composed of two main parts namely Front-end and Back-end interfaces which are demonstrated by the system and users who are cooperating/interacting with it. The figure 2 indicates the contextual diagram of IGISMM which is also sometimes referred to as Level 0 dataflow (DFD) diagram or Context-Level Data Flow Diagram where one part is accessed only by the system administration and on the other hand, it is accessible only by the users of the system.

The figure 2 shows how information will be flowing through the process. The users of the system who can be either administrator, doctor, nurse, receptionist or laboratory worker will have to be authenticated to to enter in system and will also have the possibility of filling in forms for registration and view graphics as result on the interface as a Front-End side which shows how things look, on the other hand the process will be having a database to record all information to be used in the computational process, and this is the Back-End Side that shows how things work.

To draw the Context-Level Data Flow Diagram, it is done in the context that it describes the boundary between the system, or part of a system, and its environment, showing the entities that interact with it, and this is a high-level view of a system. For this case, the diagram indicates the IGISMM system's clear edge. It is drawn in order to define and clarify the boundaries of the system designed by identifying the flows of information between the system and external entities where the entire system is shown as a single process. As far as the main focus of the level 0 DFD is concerned, it shows the scope and boundaries of a system at a glance including the other systems that interface with it. However, no technical knowledge is assumed or required to understand the diagram as well failing to give details about the sequence or timing of project processes and not accommodating all users who try to view and access the content. People who have interests and who are skilled in health systems and the medical doctors are the beneficiaries of the IGISMM system and also those who are familiar with glucose-insulin system. The registration for the users must be done first in order to get the system's credentials (password and username). The users will be allowed to access the system once they got the username and password. Hence, they can enter the parameters to view the results from the system. The administrator controls the system by viewing the the content registered by the users as well as controlling the whole system performance and functionalities to make sure that the system continues to operate. The system requires the security features to maintain the authorization and authentication of data recorded and managed/controlled so that it will be used for the research purposes. That is why to access the system, the users will be required to be registered to get the credentials (username and password). After getting the password, the user will be allowed to access the GUI of the system to enter the data about glucose-insulin system interface pages. The use case diagram which illustrates how system and medical users interact is show in Figure 3. It shows the interaction of users and the Interface of Glucose-Insulin System.

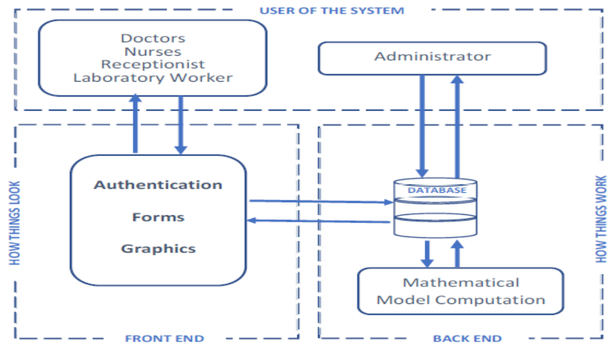

Figure 2) *Dataflow diagram, level 0 DFD of IGISMM*

The Figure 3 represents a use case diagram of the system. The system has five main users:

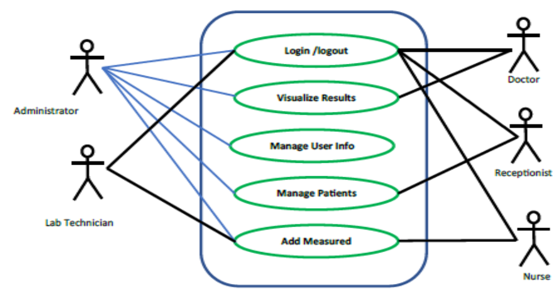

Figure 3) *Use case Diagram*

Administrator, Doctor, Nurse, Lab Technician and Receptionist. Receptionist is the first person to meet the patients when they come to the hospital. Receptionist can serve them by greeting, welcoming, assisting patients in finding the needed service, announcing them, answering phones and adding basic information of patients to the system. A Nurse can assess, observe, speak to patients, record some details and symptoms of patient medical history and current health. A nurse can also add some measured parameters such as height, weight and so on to the system. A Lab Technician is in charge of executing laboratory exams and adding the results to the system. Doctor analyzes and interprets the result displayed from the system. The administrator is responsible for managing users, troubleshooting and security of the system. He can add new users, assign roles, change them and delete if necessary.

Front-end side and Back-end side

The part of IGISMM system which is visible is front-end side which is also the part where the user interacts directly with the system. It is also referred to as the client side of the application where it includes everything that users experience directly. As this part contains the general information of the system, the responsiveness and performance are two main objectives of the Front-End and it represents a point of entry for users who will be requested to authenticate to get into the system and use it. For instance, on the system in the case of accessing the record, entering the data, and visualize the information regarding the users, the system administrator could do these tasks but after being authorized.

A login page is an interface that allows a user to enter username and password. In IGISMM system, login page can allow an administrator to enter in entire system and remaining users can enter in some parts of the system depending to their privileges. The login and access to IGISMM system is as illustrated in Figure 4.

Figure 4) *Screen layout to login IGISMM*

The IGISMM page contains forms where the user must enter related parameters for calculations which will be executed by the back-end programs once the user clicks on the calculate button. It is in this same side that the Doctor should view the results once the calculation process is made. This content also contains the programs (Mathematical functions and programs) used for calculating the parameters recorded by the Nurse. Once calculations are done, the results are sent back to the front-end side to be visualized and seen by the user as needed results of glucose-insulin system. The back-end side is invisible and it is not directly accessed by all users. It is only controlled by the system administrator and contains the database which keeps all information related to the user names, passwords, parameters, constants as well as all kind of settings which makes the glucose-insulin system running correctly.

Database Design

An Entity Relationship Diagram (ERD) is a graphical representation of database. ERD shows the relationship between entities. The Figure 5 consists of three tables: Patient, Consultation and Staff. The first table contains the information of patients such as names, telephone, gender, age and ID. The second table has the information related to consultation and the last one contains staff identification.

SYSTEM IMPLEMENTATION (SECTION 4)

The login page facilitates a registered user to enter username and password in order to be authenticated. The screenshot is shown in Figure 4.

Apart from the main job of receptionist such as greeting patients or visitors, welcoming and directing them, in Figure 6, a receptionist can add basic patient's information such as names, age, gender to the system.

To run IGISMM, the measured parameters need to be entered in database. This task is per- formed by a Lab Technician a nurse who can view a list of customers after being logged in the system, then he/she can choose a customer to whom he/she wants to insert the values. In Figure 7, a Lab Technician adds some IGISMM parameters which include glucose in the heart (GH), glucose in liver (GL), glucose in tissues (GT), insulin in the heart (IH), insulin in liver (IL) and insulin in tissues (IT). The filled form of measured parameters by Lab Technician are transmitted to Nurse for confirmation. The Figure 8 shows that the nurse can get the list of all patients and he /she can confirm some measured parameters related to glucose and insulin in the heart, the liver and the tissue in IGISMM.

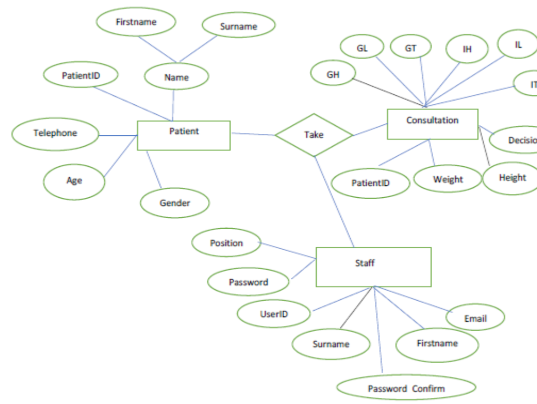

Figure 5) *Entity Relationship Diagram of IGISMM*

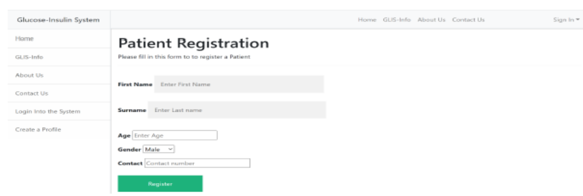

Figure 6) *Receptionist page*

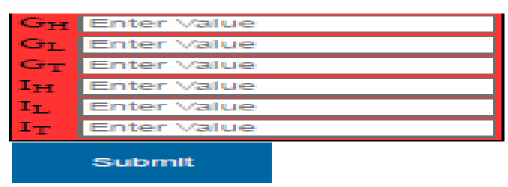

Figure 7) *Lab Technician page*

ID	FIRSTNAME	SURNAME	AGE	GENDER	TELPHONE	G_H	G_L	G_T	I_H	I_L	I_T	STATUS
1	Mcr	Nwmg	23	Male	2147483647	84	80	76	58	56	63	Approve
2	Mrth	Mgn	35	Female	258963	69	77	78	69	59	65	Approve
3	bn	jki	25	Male	2563987	63	66	98	38	36	34	Approve
4	bhy	hjk	29	Female	2365897	69	78	77	65	62	61	Approve
5	bnni	mnbg	19	Male	245879654	74	71	69	75	58	68	Approve
6	frt	lstn	32	Male	23658	125	130	110	6	7	8	Approve

Figure 8) *Nurse page*

The designed IGISMM also has option to enter the new user, to update/change the data of existing users such as username and passwords and to remove any user from the existing list. Using IGISMM, this task is performed by an administrator. In Figure 9 an administrator can view the list of users. He /she can change the position of a user, rename or he can delete any user who is not working in the hospital.

ID	FIRSTNAME	SURNAME	GENDER	POSITION	EMAIL	UPDATE	DELETE
14	Gd	Gza	Male	4	gd@yahoo.fr	Edit	Delete
21	bab	Tty	Male	1	th@yahoo.fr	Edit	Delete
22	aibb	mab	Male	3	mgwiz@gmai	Edit	Delete
23	jy	gce	female	2	jb@gmail.com	Edit	Delete
24	Fce	Kma	Male	5	mn@gmail.com	Edit	Delete

1- Administror
2- Doctor
3- Lab Technician
4- Nurse
5- Receptionist

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Figure 9) *Admin page*

In Figure 10, the medical doctor can get the list of patients and can click on compute to set parameters of mathematical equations in order to get the plot and he /she can make interpretation. This will be plotted after getting a matlab program. This task is performed by clicking on the calculate button. The example for a list of five customers is shown in the Figure 10.

ID	FIRSTNAME	SURNAME	AGE	GENDER	TELPHONE	G_H	G_L	G_T	I_H	I_L	I_T	Compute
1	Mcr	Nwmg	23	Male	2147483647	84	80	76	58	56	63	Compute
2	Mrth	Mgn	35	Female	258963	69	77	78	69	59	65	Compute
3	bn	jki	25	Male	2563987	63	66	98	38	36	34	Compute
4	bhy	hjk	29	Female	2365897	69	78	77	65	62	61	Compute
5	bnni	mnbg	19	Male	245879654	74	71	69	75	58	68	Compute
6	frt	lstn	32	Male	23658	125	130	110	6	7	8	Compute

Figure 10) *View of the list of patients and calculation of results by a medical doctor*

To test IGISMM, the results of customer are compared to ones known as healthy after compu- tation using that values given in the Table 4. heart (G_H), glucose in liver (G_L), glucose in tissues (G_T), insulin in the heart (I_H), insulin in liver (I_L) and insulin in tissues (I_T).

TABLE 4
Parameters used from literature

Parameter	Value	Parameter	Value
G_H	91.5868	I_H	15.1765
G_L	100.7137	I_L	15.1765
G_T	85.9450	I_T	16.0973

The graphs of test are shown in the Figures 11 and 12.

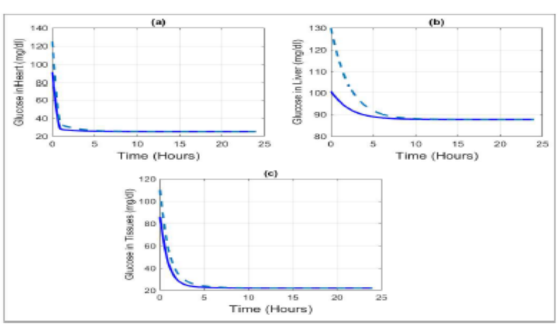

Figure 11) *Variation of glucose test in human body using IGISMM*

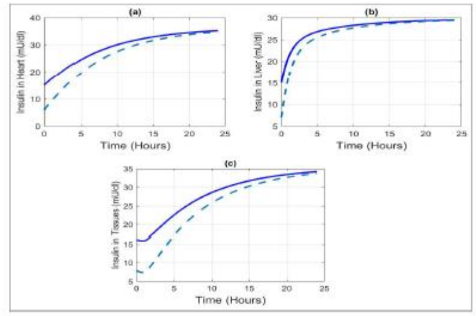

Figure 12) *Variation of insulin test in human body using IGISMM*

DISCUSSION OF RESULTS (SECTION 5)

The Figure 11 shows the trends of glucose in heart, lever and tissues respectively while the trends of insulin in the same organs is illustrated in the Figure 12. In the Figure 11 the measured values of glucose for curstomer are higher than ones for health subjet. However, the measured values of insulin for customer are less compared to ones set for healthy subject (See the Figure 12). Physiologically, this means that the body of customer doesn't make enough insulin and glucose can't get into her/his cells. It stays in the bloodstream instead. This low insulin levels can due to too much insulin released after eating (reactive hypoglycaemia or postprandial hypoglycaemia). As the time progresses, the Figures 11 and 12 show that we have homeostasis of glucose and insulin because the variation of glucose and insulin in different organs becomes close to the trends of healthy subject. This means that through its various hormones, particularly glucagon and insulin, the pancreas maintains blood glucose levels within a very narrow range. Indeed, in response to elevated blood glucose, the the pancreas secretes insulin that allows to deceasing the blood glucose by increasing glucose uptake in muscle and adipose tissue and by promoting glycolysis and glycogenesis in liver and muscle.

CONCLUDING REMARKS (SECTION 6)

In this paper, a Web-user interface design for mathematical model of glucose-insulin system has been thought-about and designed. The parameters such as Glucose and Insulin concentration, Vascular blood rate and glucose in the heart have been evaluated and calculated. Its mathematical model has also been designed. Backend and front-end of the system have also been designed. The results indicate that the parameters must be entered in the system's database. It is indicated also that based on the results from the simulation (simulation has been done using MATLAB), the glucose's values of a customer become higher than the ones of the health subject while the measure values of insulin for the customers become less comparing to the ones of the health subject. As further works, within the current trends of IGISMM, one of the recommendations is to consider some other factors (variables) not only the ones evaluated/tested during this research as well as also to adopt this system at all hospital/health institutions even though it has been applied.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest

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