glucose concentration,
telemedicine, artificial organs

Rafal DONIEC*, Kalina DONIEC*,
Jolanta DONIEC-WOLNIK*, Krzysztof GOWOREK*

WEBSITE CONTROL SYSTEM OF THE HUMAN BODY INSULIN LEVEL

The following research characterizes the system for remote data collection of blood glucose concentration. Based on the data an algorithm was introduced in order to determine the infusion of insulin. This paper presents a glucose measurement method using the test strips, instructions for collecting the source data, as well as the process of adjusting the insulin dosage.

1. INTRODUCTION

The following study is consistent with the thesis that medicine and technology have undergone many transformations for centuries, and especially over the last few years. There is invariably a need to replace, copy or to model the biological processes.

The necessity for carrying out regular check ups and preventive screening tests requires a demand for not only precise or fast, but first of all cheap analytic and diagnostic methods, which can also support the decision making process. Development of technology, chemistry, biology, etc. enables us to create examinations that combine all the mentioned fields. The biggest influence on that has the microprocessor technology, as well as the still increasing significance of the global network Internet.

The most important task of this research is to develop an artificial pancreas model based on the concepts of telemedicine and AI algorithms. Its main elements are: measure of blood glucose concentration based on the reflection converter which is adapted for the Accutrend glucose test strips, artificial intelligence (AI) as the part of a decision making process, as well as the description of nowadays available applicators and insulin pumps as the elements closing the feedback loop of the glucose-insulin system. Medium that combines all the elements to become one is the data collection application which is placed on the Internet.

2. METHOD

Glucose measurement method using the test strips with the help of reflection reader is based on defining the radiation stream that is being absorbed by the test field. Reflection (R) will be defined as the ratio of the reflected radiation stream (Φ_r) to the falling radiation stream (Φ_o) that is (1):

$$R_\infty = \frac{\Phi_r}{\Phi_o} \tag{1}$$

Luminous parameters (Φ) are generally determined in special optoelectronic converters which work on the basis of a device called the Ulbricht sphere. The test strip is put in the central part of the reading field. Electric signal from a photodiode is being transformed to a voltage signal by a converter. Value of the measured voltage is proportional to the reflected radiation stream and can be converted into reflection according to the relation (2).

$$R = \frac{U_p - U_{cp}}{U_w - U_{cw}} \tag{2}$$

In practice, each of the glucose meters' producers adjusts them to specific strips, which can read one or more parameters.

The strip test is classified as an invasive method that is connected with the inconvenient and painful procedure. It is a serious problem since many diabetics face due to this fact low resistance. Nevertheless, it is still the most popular method of quasi permanent monitoring the diabetics.

Data collection. In order to collect the necessary data a special web site was created, namely http://virtual-net.pl/DiabLab/personData.html. On the web page a patient is supposed to write his or her weight, age, gender and of course the level of blood glucose concentration obtained by the strip test method. Furthermore, the system saves the data and enables

* Polish Telecomm, Francuska 101, Katowice , *rafal.doniec@telekomunikacja.pl*
Silesian University of Technology, Akademicka 16,
Gliwice Polish Pharmaceutical Chamber, Kryniczna 15, Katowice

the patient to view the history of measurements. There is also a possibility to refresh the results. After having collected the necessary data, the system will determine the required amount of insulin, as well as a blood glucose curve.

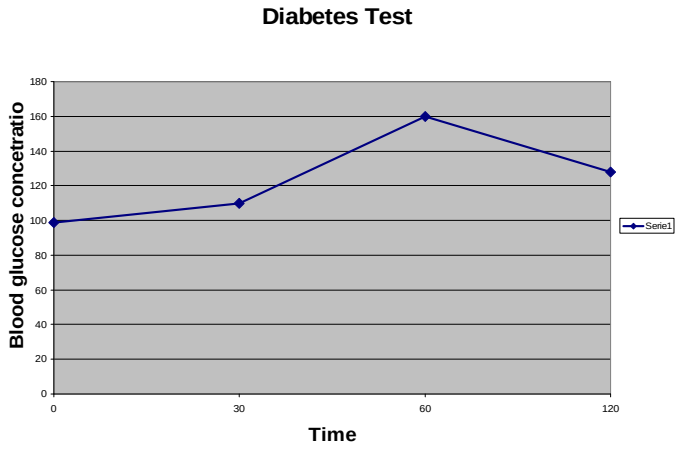

Fig. 1. Graph of the blood glucose concentration within given time periods for the research trial in diabetes test

The example of results, diabetes test, (Fig.1) which have strictly a research character and are based on the trial of 56 patients from different age groups, suppose to identify the problem and find the best solution determination of insulin injection.

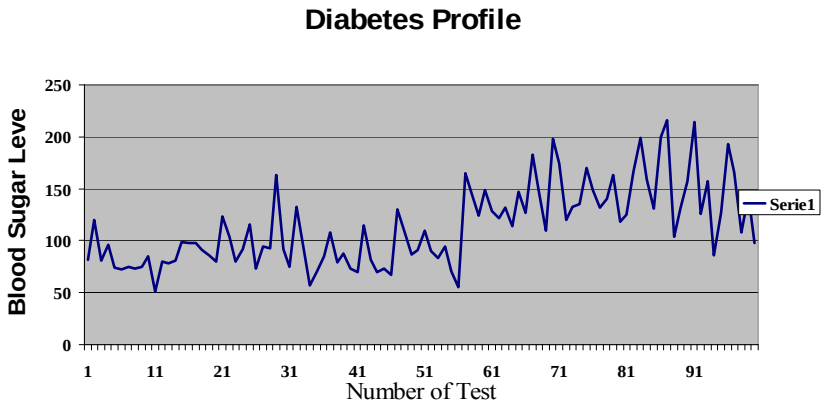

Fig. 2. Graph of the blood glucose concentration within given time periods for the research trial in diabetes profile

Next graph (Fig.2) data, diabetes profile of the blood glucose concentration for patient for implementation optimal neuron network structure for support medicine diagnose. Therefore, three different methods were specified:

3. COMPARING METHODS

3.1. PROPORTIONAL-DIFFERENTIATING CONTROL METHOD

Infusion is determined approximately by the algorithm of non-linear proportional-differentiating relation glucose-insulin, which was worked out in Toronto by the Albisser's research team:

$$I = \frac{1}{2} I_{\max} \left[1 + tghS_I \left(G_p - B_p \right) \right] \tag{3}$$

$$D_F = K_1 A^3 + K_2 A \tag{4}$$

$$A = \frac{\left(4G_0 - G_1 - G_2 - G_3 \right)}{10} \tag{5}$$

where:
$G_p = G_0 + D_F$; B_p – blood glucose level
S_I, K_1, K_2 – constant
G_0, G_1, G_2, G_3 – glucose meter

3.2. EXPERT METHOD

The most important element in this particular method is the table of dosage insulin medicines. Decision about the infusion is taken by a specialist – doctor, based on the results and his or her knowledge of insulin medicines, which are shown in table 1.

Table 1. Insulin medicines

Infusion of insulin			
	Blood glucose level (70-130mg)	Blood glucose level 70mg	Blood glucose level 130mg
Data [n] from 1-10	0	0	4
Data [n]>10 and 50% [n] more than 130mg	2	0	+ 2 to next

3.3. AI ALGORITHM METHOD

From the researcher's point of view neuron networks are simple (thanks to that it is easier to understand and to model with the help of computers), but at the same time rich and interesting model of a real, biological nervous system. They consist of a combination of objects called neurons. The most essential feature of these networks is the possibility to learn, i.e. to modify parameters that characterize neurons in order to increase the effectiveness of networks while problem solving process.

Neuron networks can serve as a useful calculative device that solves complicated tasks – mostly too complex for a standard computer or a standard programme. The reason is that neuron networks have two significant features. First, calculations are made simultaneously; therefore, less time is spent than when using sequent calculations. What is more, there is a possibility to get the solution without even defining the problem.

There is no need to programme the network, as there are methods of learning and self-learning that enable effective operation without even knowing the adequate algorithm. Not only programme or information, but also database and the calculation process are fully dispersed in the network.

The network always works as a whole and all the elements have their contribution to the problem solving process. One consequence of this fact is the ability to work properly in a situation when some of the elements are damaged.

The network structure is formed in such a way that inputs of one neuron are being joined with outputs of the other. Of course, the network typology depends on the specific task. Nevertheless, the decisions concerning the network structure have no big influence on working, which is mostly determined by the learning process and not by the structure or number of neurons.

There are many examples of structures that were formed completely by chance (e.g. at random) and still the network was able to solve complicated tasks.

Neuron networks are able to gain their knowledge only during the learning process. What is more, it is not necessary for them to have a precisely specified structure. The network must, however, be complex enough in order to "crystallize" the necessary connections and structures.

Network that is too small is not able to learn anything as the problem is its "intellectual potential" – it is not the structure that determines that, but the number of elements.

Another useful tool that is helpful when it comes to the problem of control and data collection are wavelet functions.

From a historical point of view, wavelet analysis is a relatively new method, even though its mathematical principles descend from the work of Joseph Fourier in the 19th century. Fourier focused in his study on the frequency analysis, which was an essential and important approach.

In practice, the aim of wavelet analysis is to find the "mother wavelet" functions and ways of gaining them with the help of the numerical methods. It was proven that every task using Fourier transforms can be formulated with the wavelets, which, in fact, give more information about the location and frequency. Hence, it is possible to receive wavelet spectrum instead of creating intensity / frequency spectrum. Wavelet analysis is an extremely useful tool in the analysis of non-periodic or non-stationary signals and for accurately deconstructing and reconstructing original signals. Wavelets are functions that satisfy the mathematical needs and that are used to represent other functions and data. The idea of approximation itself is not new after all. This feature offers a possibility of an excellent data compression. Basis functions are easier to explain in the vector space. Every vector can be represented on the plane by the combination of elementary vectors, which are indeed base

vectors as every other vector can be expressed by the linear combination of vectors. What is more, base vectors are also orthogonal.

When it comes to function spaces (instead of vectors there is a set of functions), they will be exemplified by a given function f(x). Function f(x) can be constructed by the combination of sinus and cosine, as well as by using various amplitudes and frequencies, which in this case are not only base functions, but at the same time elements of the Fourier series. There is also a possibility for trigonometric functions to be orthogonal by choosing the right combination of functions so that their scalar product is zero. Such a set of functions which are all simultaneously orthogonal and form the main function, are exactly orthogonal basis functions. For example, a given segment is divided into two or more parts. Then, each part is analyzed with the help of the specific scale. Thanks to that, information about the signal is more precise.

4. ARTIFICIAL PANCREAS MODEL

Based on the collected data a graph of changes and trends of the blood glucose concentration for different age groups within 2h by 2h per years was formed (fig. 2.).

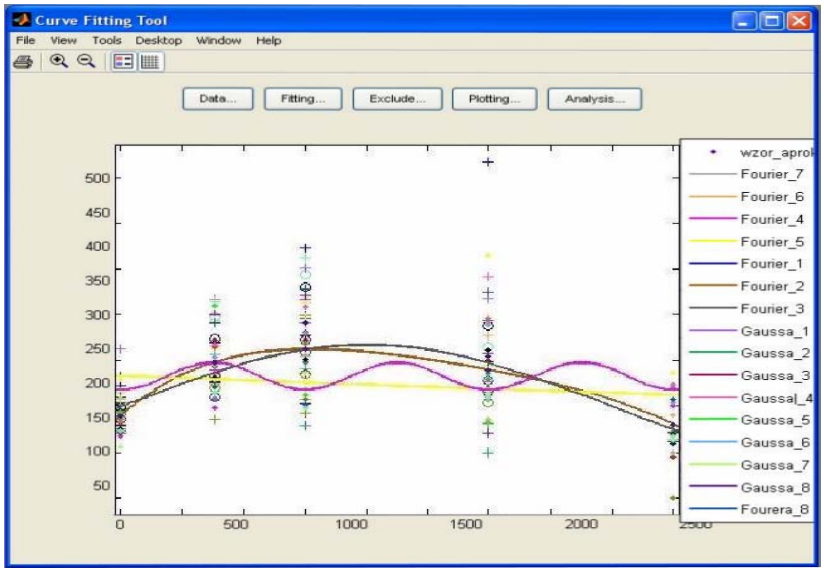

Fig. 3. Graph of changes and trends of the blood glucose concentration with approximation curves for different age groups within 2h by 2h per years.

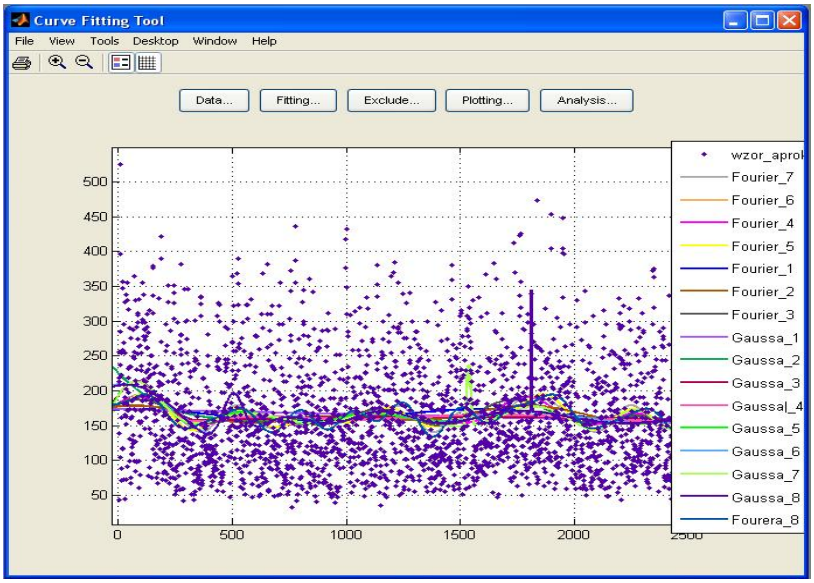

Fig.4. Graph of changes and trends of the blood glucose concentration with approximation curves for different age groups within 2h by 2h per years.

In the interactive environment for algorithm development, Matlab, an individual neuron network (SN) was created that fully reflects the profile, which is the basis for the model blood glucose concentration in the human body. Currently, an attempt

is made to set apart individual features that affect the results, to create a model curve and to estimate with others collected data (Fig. 3,4).

With the help of the Continuous Wavelet Transform (CWT) an algorithm classifying the processes was worked out.

Table. 2. Data for neuron network.

Profile	280	150	140	115	45
Net generalized regression	280	149,76	140	115,33	45
Net generalized regression-error	0	0,0288	0	0,05445	0
Net linear layer	280	150	140	115	45
Net linear layer-error	-5,6E-13	-2,84E-13	-2,56E-13	-1,99E-13	-4,26E-14
Standard regression *1000	0	57,6	0	108,9	0

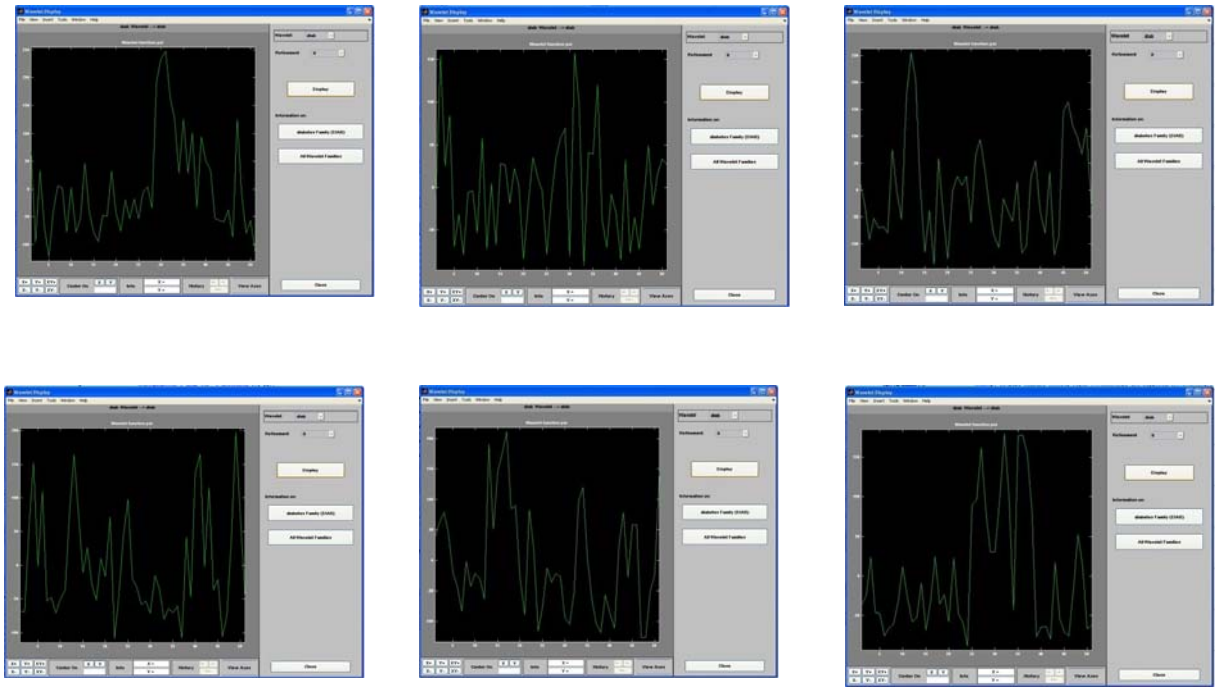

Fig. 5. Graph of the Individual Special Purpose Wavelet Family for optimal input function the neuron system learning process.

SN, which fully meets the requirements of the research, is based on the back propagation algorithm. Table 2 presents the obtained results. After having created a model, a set of functions was formed (fig. 5) that have similar amplitude-frequency parameters. The principle of the control mechanism is to compare the model with given data that are being exposed to the wavelet filtration. Taking into consideration standard deviation, the infusion of insulin can be determined likewise in the method 2.

5. CONCLUSIONS

Infusion of insulin depends on so many factors that creating only one algorithm is strictly conditional to the number of gained data. Method based on the neurone-wavelet algorithm requires a comprehensive and detailed data collection. Another significant problem is the lack of testing materials that could verify the control methods.

Insulin pump is a device that enables patient to have a constant 24-hour infusion of insulin according to the daily dosage. The level of insulin is being programmed in advance suitably to the individual requirements of the patient. Today's insulin pumps do not resemble at all those from the 70's of the past century. Nowadays they are miniaturized devices that weigh up to 100 grammas and measure 9 x 5 x 2 cm or even less, with possibilities of easy and independence website data collecting mechanism. All needed are algorithms upgrading and improvements make insulin pumps despite their advanced technology more user friendly. Therefore, this type of treatment can be offered to more and more people that suffer from diabetes, to handicapped, the elderly or small children if only they qualify for these method.

BIBLIOGRAPHY

[1] GOMEZ E.J., Telematic suport of the diabetes treatment from multi-access workspace services to personal close-loop system. Diabetes Technology and Therapeutics, Vol.5,No.5: 872-873, 2003
[2] HUBBARD B.B., The World According to Wavelets, A.K. Peters, Wellesley, 1996.
[3] MRÓZ E., Krytyczna ocena leczenia cukrzycy pompami osobistymi (CSII) w Polsce i na świecie, Medycyna metaboliczna str. 96, 1/2007
[4] NAŁĘCZ M., DĄBROWSKI M., ORŁOWSKI T., WERYŃSKI A., WÓJCICKI J.M., Sztuczna trzustka, Sztuczne narządy tom 3, Exit, str. 407-486, 2001
[5] NATHAN D.M., BUSE J.B., DAVIDSON M.B., HEINE R.J., HOLMAN RR,SHERWIN R,ZINMAN B, Managment of hyperglycemia in tape 2 diabetes: consensus algorithm for the initiation and adjustment of therapy. , Diabetes Care , str. 1963-1972, 2006
[6] TADEUSIEWICZ R., Sieci neuronowe, Akademicka Oficyna Wydawnicza,1993
[7] TATOŃ J., ŁAZ R., Intensywna insulinoterapia za pomocą pompy insulinowej w układzie otwartym: nowe wskazania i ulepszenia techniczne, Medycyna metaboliczna str. 86, 1/2007
[8] The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) Study Research Group; Intensive Diabetes Treatment and Cardiovascular Disease in Patients with Type 1 Diabetes, NEJM, 2005, 353; 2643–53
[9] CRISTIANINI N., SHAWE-TAYLOR J., An introduction to support vector machines: and other kernel-based learning methods, Cambridge University Press, 2000
[10] TKACZ E., BORYS P., Bionika, WNT, 2006