AN APPLICATION FOR MONITORING AND DIAGNOSIS THE HEALTH OF A HUMAN SUBJECT

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ABSTRACT

The paper presents an application developed for monitoring the health of a human subject, respectively for monitoring a set of critical medical parameters (blood glucose, cholesterol, blood pressure, pulse and oxygen saturation) while the diagnosis is made based on the application supplied results. The field of artificial intelligence is a very wide one, providing to the user a set of various techniques such as: fuzzy logic, artificial neural networks, adaptive neuro-fuzzy systems, expert systems, data mining, genetic algorithms. To develop the application software (the necessary decision rules, in fact the fuzzy rules) was used one of the most efficient (due to the multiple advantages supplied by the usage of fuzzy logic together with artificial neural networks) artificial intelligence technique, respectively the neuro-fuzzy inference systems, while the application interface was developed using the Visual Studio programming environment (respectively the C# language). A set of simulation results related to the developed application are presented for different test cases, such as: a healthy human subject, a human subject with diabetes, a human subject with high cholesterol, with high blood pressure, with lower level of blood oxygen and also with hypoxemia.

Keywords: monitoring, diagnosis, neuro-fuzzy inference systems, fuzzy rules, medical parameters

INTRODUCTION

Due to the fact that nowadays, unfortunately, pandemics still occur, the permanent monitoring and diagnosis of the human health is an important aspect. For this purpose, an important tool is represented by those dedicated applications that can immediately supply basic information about the human health, so that people can have at least one idea about what will happen after consulting a specialist in the field.

The interest of applying artificial intelligence (AI) techniques (fuzzy logic, artificial neural networks, adaptive neuro-fuzzy inference systems, machine learning, expert systems, multiple linear regression, etc.) in medicine has grown rapidly, due to the fact that numerous tasks from different branches of medicine can be solved efficiently, sometimes the usage of AI algorithms surpassing the performance of a physician [5, 2, 9]. AI techniques found their utility in: emergency medicine [10], radiotherapy and oncology [11], pediatric critical care medicine [3], triglyceride and cholesterol assessing of overweight people [6], prediction of blood glucose level for diabetic persons [7], hypertension predicting and managing [4], estimation of the carotid-femoral pulse wave velocity [8], pulse oximeter neonatal specificity improvement [1], and others.

The purpose of the proposed application is to monitor a set of important medical parameters (blood glucose, cholesterol, blood pressure, pulse and blood oxygen levels) and also to obtain an accurate diagnosis based on the supplied data. The application software developed with this goal uses a set of decision rules (in fact, fuzzy rules) obtained using the so-called neuro-fuzzy inference systems (ANFIS); the implementation was performed using the Visual Studio programming environment.

The paper has the following structure:

- A short description of the analysed medical parameters (blood glucose levels, cholesterol, blood pressure, pulse and blood oxygen levels or oxygen saturation) and the associated measuring devices; also, it is presented the working procedure specific to ANFIS;
- The developing of the proposed monitoring and diagnosis application using Visual Studio environment (C# language), respectively the application software (the implementation of the decision rules - fuzzy rules- obtained using ANFIS) and the user interface presentation; it is also presented a selection of the application simulation results for different test cases (for human subjects with high cholesterol, with high blood pressure, with lower level of blood oxygen, with hypoxemia and also for those with a good health).

THE MONITORED MEDICAL PARAMETERS

As it was mentioned, the monitored medical parameters are the following: blood glucose levels, blood pressure, pulse, blood oxygen level and the cholesterol. These parameters are easy to measure using specific devices.

According [12], the blood glucose represents the concentration of glucose in blood, being the main type of sugar found in it. It is supplied by the foods a human subject eats and it represents the body's main source of energy. For the majority of healthy individuals the normal blood glucose limits are between 72mg/dl and 108mg/dl (on an empty stomach) and up to 140 mg/dl (two hours after the last meal). Blood pressure is the pressure at which blood is forced to circulate throughout human circulatory system. Blood pressure measurement consists in measuring the systolic and diastolic blood pressure. A normal blood pressure value is somewhere below 120/80mmHg and above 90/60 mmHg. The blood glucose level testing (also known as serum glucose monitoring) it is made using a so called glucometer, while the blood pressure is made using a tensiometer (Fig. 1).

Figure 1. Glucometer, tensiometer and a pulse-oximeter [13].

The pulse represents the movement of blood through the human body blood vessels. This is the number that indicates how many times the human heart beats in a minute. The pulse can be felt in all places where an artery can be put next to a bone such as the carotid artery in the neck, the radial artery in the wrist and others. The pulse can also be measured directly by counting the heart rate. The normal pulse values are in the range of 60 beats to 100 beats per minute.

The blood oxygen level (oxygen saturation) represents the ratio of oxygen-saturated hemoglobin to total hemoglobin. The normal level of oxygen in blood is between 95% - 100%, values below 90% meaning hypoxemia [12]. The measurement of blood oxygen level is called oximetry. A pulse oximeter (Fig. 1.) is a non-invasive device that measures oxygen saturation in a person's blood as well as heart rate. Pulse oximeters are easily recognizable due to clip-type probes, usually applied to the patient's finger. A pulse oximeter can be an independent device, part of a measuring system or integrated in a portable fitness tracking device [12].

The cholesterol is produced by the human body and it represents the level of fat in blood. It is also brought into the body (in some proportion) by foods high in animal fats (meat, dairy products, eggs, etc.). As long as it does not exceed normal values (200mg/dl-optimal cholesterol), the cholesterol is beneficial for the human body functionality, while a cholesterol between 200mg/dl and 240mg/dl is a value at limit and over 240mg/dl means a dangerous level of cholesterol [12].

The domains for each monitored medical parameters, are those presented in Table 1, domains used in developing the application decision rules (fuzzy rules) using ANFIS (respectively the Neuro-Fuzzy Designer from Matlab/Simulink). These types of systems through training (using artificial neural networks, ANNs) generate a fuzzy inference system (FIS), whose membership functions (triangular MFs) for each input (the measured parameter) and output (diagnostic code) use the domains presented in Table 1. The FIS input it is given by the measured medical parameters values, while the output it is represented by the diagnostic code (encoded with value 0-normal parameter value which means no healt problems and value 1-high or low parameter value whict means that there are some healt problems).

The application decision rules obtained using ANFIS and the application software development (the rules implementation) in C# language (Visual Studio environment) are then presented.

Table 1. *Input and output MFs domains*

Measured parameter	Inputs MFs domains		Output MFs coding (diagnostic_code)	
	Normal value (NV)	**High value (HV)**	**Normal value code (NVC)**	**Abnormal value code (AVC)**
Blood glucose[mg/dl]	[72 – 108]	>108	0 ([90 – 140])	1 (>140)
Cholesterol [mg/dl]	[40 – 200]	>200	0 ([100 – 240])	1 (>240)
Blood pressure [mmHg]	[90/60 - 120/80]	>120/80	0 [90/60 – 125/85]	1 (>125/85)
Pulse [beats per minute]	[60-100]	>100	0 ([70 – 110])	1 (>110)
Oxygen saturation [%]	[95 – 100]	<95	0 ([97-100])	1 (<97)

THE MONITORING AND DIAGNOSIS APPLICATION DEVELOPMENT

For the application development Microsoft Visual Studio was used (respectively C# language), an integrated development environment (IDE) used for computer programs, web sites, web services and mobile applications development. It uses Microsoft software development platforms such as: Windows API, Windows Forms, Windows Presentation Foundation, Windows Store și Microsoft Silverlight [14].

The purpose of the application with the user friendly interface presented in Fig.3 is to monitor the health of a human subject and to provide a diagnosis based on the supplied information. The monitoring and diagnosis application is a simple one, but quite effective for the purpose for which it was created. The application interface was created in Visual Studio using forms and different objects such as buttons, text boxes, labels arranged in such a way that it is easy for the application user to identify the monitored parameters and to interpret the supplied results. The application operation is quite simple: data processing starts when the *Analyze button* is pressed, in this way the rules (under *if-then* form) obtained after processing some data training sets using the Neuro-Fuzzy Designer from Matlab are applied to the parameters values displayed into the text boxes.

The rule base was automatically generated by activating the *Generate Fis* option from the Neuro-Fuzzy Designer, option that also generated the entire FIS system with the structure presented in Fig. 2.

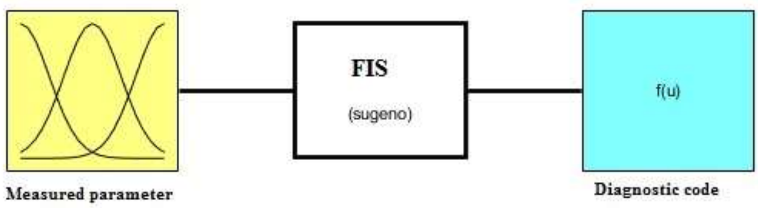

Figure 2. FIS architecture.

To generate the FIS a set of training data was used (training.dat) for each measured parameter, set composed from a thousand input (measured parameter value) - output (diagnostic code) data sets. It must be mentioned that the available training data were collected through testing a human subject, respectively measuring the monitored parameters over the course of two months. The training of the obtained FIS (Fig. 2) was made in a number of twenty thousand epochs and it was used a hibrid training algorithm (feedforward-propagation and back-propagation).

A selection of the application decission rules (fuzzy rules) is:

- if *blood_glucose* is NV then *diagnostic_code* is NVC (0);
- if *cholesterol* is HV then *diagnostic_code* is AVC (1);
- if *blood_pressure* is NV then *diagnostic_code* is NVC (0);
- if *blood_glucose* is HV then *diagnostic_code* is AVC (1);
- if *pulse* is NV then *diagnostic_code* is NVC (0);
- if *oxygen_saturation* is NV then *diagnostic_code* is NVC (0).

The first step in programming the application was to declare the necessary variables (string, integer and a variable type timer), folowed by the data retrieval, data that was stored in individual text files for each parameter. Data reading was done line by line using the string type variables.

The timer was initialized such that the data to be retrieved and displayed into the text boxes at an etablished time interval. The data processing was coded so that when the *Analyze button* is pressed, the parameters measured values are processed using the obtained decission rules.

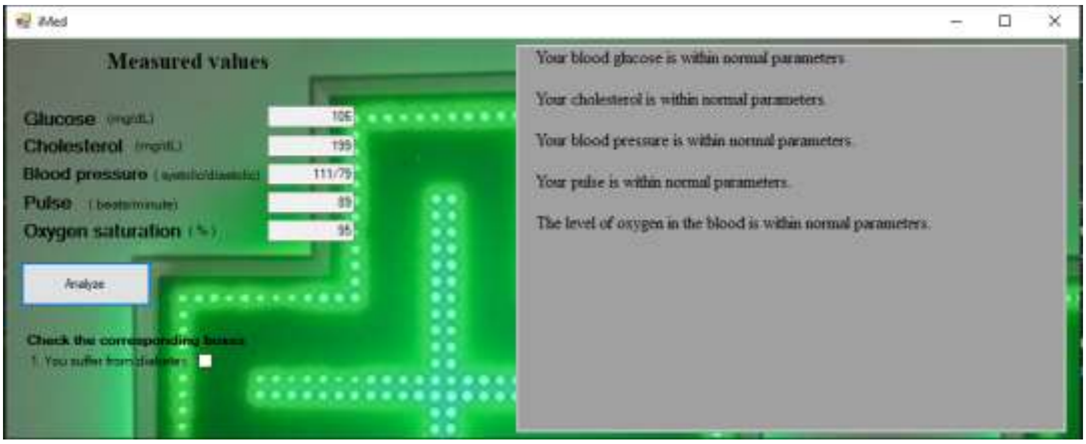

Figure 3. The application user-friendly interface.

A selection of the application source code implemented in C# language with the obtained decission rules (fuzzy rules) implementation is presented next:

```
private void Button6_Click(object sender, EventArgs e)
{ textBox1.Clear();
if (checkBox1.Checked == false)
{if (Int32.Parse(blood_glucose.Text) <= 108) {textBox1.Text = textBox1.Text + g2 + "\r\n";}
 else if (Int32.Parse(blood_glucose.Text) > 108 && counter < 6)
     {textBox1.Text = textBox1.Text + g1 + "\r\n";}
      else if (Int32.Parse(blood_glucose.Text) > 108 && counter >= 6)
          { textBox1.Text = textBox1.Text + g3 + "\r\n"; } }
......................
if (Int32.Parse(cholesterol.Text) <= 200) {textBox1.Text = textBox1.Text + c2 + "\r\n";}
else if (Int32.Parse(cholesterol.Text) > 200)
     {textBox1.Text = textBox1.Text + c1 + "\r\n";}
.....................
if (Int32.Parse(blood_pressure) <= 120 && Int32.Parse(blood _pressure) <= 80)
{textBox1.Text = textBox1.Text + t2 + "\r\n"; }
else if (Int32.Parse(blood_pressure) > 120 && Int32.Parse(blood_pressure) > 80)
{textBox1.Text = textBox1.Text + t1 + "\r\n";}
............................
 if (Int32.Parse(pulse.Text) <= 100 && Int32.Parse(pulse.Text) >= 60)
 { textBox1.Text = textBox1.Text + p2 + "\r\n"; }
 else if (Int32.Parse(pulse.Text) < 60 || Int32.Parse(pulse.Text) > 100)
 { textBox1.Text = textBox1.Text + p1 + "\r\n"; }
............................
if (Int32.Parse(oxygen_saturation.Text) < 95) {textBox1.Text = textBox1.Text + o1 + "\r\n";}
else if (Int32.Parse(oxygen_saturation.Text) >= 95) {textBox1.Text = textBox1.Text + o2 + "\r\n"; }
  ..........................
 }
```

Next, in Table 2 it is presented a selection of the simulations results, supplied by the developed application.

Table 2. *Simulation results [selection]*

No. simulation	Analysed parameter	Measured values	Results Diagnostic
1 (the case of a healty human subject)	**Glucose [mg/dl]**	106	Glucose is in normal parameters (0)
	Cholesterol [mg/dl]	199	Cholesterol is in mormal paramaters (0)
	Blood pressure [mmHg]	111/79	Blood pressure is in normal parameters (0)
	Pulse [beats per minute]	89	Pulse is in normal parameters (0)
	Oxygen saturation [%]	95	Blood oxygen is in normal parameters (0)
2 (the case of a human subject with diabetes)	**Glucose [mg/dl]**	111	Glucose has a value above the normal parameters; a specialist consultation in nutrition and metabolic diseases is indicated (1)
	Cholesterol [mg/dl]	189	Cholesterol is in mormal paramaters (0)
	Blood pressure [mmHg]	118/79	Blood pressure is in normal parameters (0)
	Pulse [beats per minute]	74	Pulse is in normal parameters (0)
	Oxygen saturation [%]	95	Blood oxygen is in normal parameters (0)
3 (the case of a human subject with high cholesterol)	**Glucose [mg/dl]**	106	Glucose is in normal parameters (0)
	Cholesterol [mg/dl]	205	Cholesterol has a value above the normal parameters; a specialist consultation in nutrition and metabolism diseases is indicated (1)
	Blood pressure [mmHg]	118/79	Blood pressure is in normal parameters (0)
	Pulse [beats per minute]	74	Pulse is in normal parameters (0)
	Oxygen saturation [%]	95	Blood oxygen is in normal parameters (0)
4 (the case of a human subject with high blood pressure)	**Glucose [mg/dl]**	106	Glucose is in normal parameters (0)
	Cholesterol [mg/dl]	199	Cholesterol is in mormal paramaters (0)
	Blood pressure [mmHg]	126/85	Blood pressure has a value above the normal parameters; a cardiologist consultation is indicated (1)

	Pulse [beats per minute]	74	Pulse is in normal parameters (0)
	Oxygen saturation [%]	95	Blood oxygen is in normal parameters (0)
5 (the case of a human subject with low blood oxygen levels)	**Glucose [mg/dl]**	106	Glucose is in normal parameters (0)
	Cholesterol [mg/dl]	199	Cholesterol is in mormal paramaters (0)
	Blood pressure [mmHg]	111/79	Blood pressure is in normal parameters (0)
	Pulse [beats per minute]	88	Pulse is in normal parameters (0)
	Oxygen saturation [%]	90	The oxygen level has a value below the normal parameters which can indicate the presence of a body infection; it is recomended to consult a pneumologist (1)
6 (the case of a subject with hypoxemia - low oxygen saturation)	**Glucose [mg/dl]**	103	Glucose is in normal parameters (0)
	Cholesterol [mg/dl]	183	Cholesterol is in mormal paramaters (0)
	Blood pressure [mmHg]	99	Blood pressure is in normal parameters (0)
	Pulse [beats per minute]	96	Pulse is in normal parameters (0)
	Oxygen saturation [%]	88	Low oxygen saturation; subject with hypoxemia; it is recomended to consult a specialist due to the presence of a body infection (1)

CONCLUSIONS

This paper proposes an application for monitoring and diagnosis the health of the human subjects, respectively the monitoring of a number of five medical parameters (blood glucose, cholesterol, blood pressure, pulse and oxygen saturation), parameters that were chosen due to the fact that they are easy to measure using accessible measuring devices and due to the sufficient available data. The usage of an artificial intelligence technique, respectively ANFIS, is justified by its advantages, respectively the automatic generation of a FIS that supplied the application necessary decision rules (used to develop the application software).

A step-by-step approach was chosen in developing the proposed application (that has a number of advantages and also disadvantages), the results obtained from data processing indicating the fact that the application is quite reliable and accurate.

The application has the following advantages:

- it is intuitive and easy to use;
- can accurately identify abnormal values for the monitored parameters;
- due to coding (Output MFs coding), the supplied diagnosis is easy to understand and interpret.

The application disadvantages are:

- can provide only simple diagnosis based on known information;
- the retrieval of data from files is not efficient.

So, the application performance can be improved in several ways. One of these would be the addition of more rules in order to achieve the diagnosis and also to increase the number of monitored parameters. Another method would be the collaboration with several medical experts and the collection of data in a specialized center to confirm their validity. Also, it will be preferable the real-time measurement of parameters, but to do this it is required the purchase of specific medical equipment and their connection to a PC. Connecting to a database for a better data structuring and access can also be an improvement. The user friendly interface of the application can be modified and graphs can be added with the evolution in time of the measured medical parameters.

In conclusion, the application is useful at the current stage for the human subjects that need a basic interpretation of some medical parameters values without having to go to a medical office if there are no more serious problems.

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