Fuzzy Logic in Heart Rate and Blood Pressure Measuring System

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Abstract— **Healthcare sector quality demands are exponentially rising to design expert systems for medical diagnosis. Likewise there is growing capture of biological, clinical, administrative data and integration of distributed and heterogeneous databases. Those previous mentioned branches create a completely new base for medical quality and cost management. In this paper fuzzy logic model is designed and practically tested. A group of 105 patients is use to develop this model and another group of same count patients was used to test it. All results are compared using fuzzy logic model in MATLB.**

Keywords-fuzzy logic; strain gauge; infrared sensor; light dependent sensor; piezoelectric sensor ;blood pressure; heart beat rate .

I. INTRODUCTION

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth - truth values between "completely true" and "completely false". It is especially suited to medical applications, since much of the information required for medical decision-making is uncertain. Kalmanson and Stegall performed an extensive analysis of medical decision-making and concluded that the classic, formal, quantitative approach to medical research and clinical decision threatens us with the danger of drowning in excessive data, and that a new conceptual and methodological approach based on the concept of fuzzy sets offers an alternative decision making path [1].

Hudson and Cohen outlined the sources of uncertainty in medical decision-making and concluded that fuzzy logic could provide the adequate approach to handle medical problems [2]. Costin, H and Rotariu, Cr described the use of fuzzy logic and semantic knowledge for edge detection and segmentation of magnetic resonance (MR) images of brain [3]. Allahverdi presented a survey of the fuzzy set and fuzzy control theory in the medicine area in general as well as on some concrete applications [4]. Gal, N. proposed a system that can mimic the thinking of a human medic. The system consists of a fuzzy frication engine that converts the numerical data into linguistic data. A medical knowledge database is implemented and a fuzzy inference engine is used [5]. Sivasankar and E. Rajesh, R.S. assessed the role of the data mining techniques namely Fuzzy Logic rule based classifier in the diagnosis of severity of appendicitis in patients presenting with right iliac fossa (RIF) pain [6].

Jionghua Teng et al. presented a fusion algorithm based on neuro-fuzzy logic, and utilized hybrid algorithm which mixes BP algorithm with least mean square (LMS) algorithm to train the parameters of membership function. Employed the data of medical image single photon emission computed tomography (SPECT) and nuclear magnetic resonance imaging (MRI) to achieve the fusion simulation, and compared with the simulation results of Back propagation (BP) neural network on the basis of the evaluation standards which are the standard deviation and the information entropy [7].

Iman and Yahia illustrated the simulation of two designs used to measure the heart beat rate and the blood pressure. The two proposed designs are built using different type of sensors and the generated results are compared to those of the (HEM-907XL) device from OMRON company. The first proposed design is constructed using either infrared (IR) sensor or light dependent resistance (LDR) to measure the heart rate; the second design is constructed using either a group of strain gauge sensors, or a group of piezoelectric sensors to measure the blood pressure [8].

In this paper design a fuzzy logic model and test it practically. This practical test is applied on patients aged between 25 and 70 years old. A model of fuzzy sets theory is based on the results derived from two designs, one for measuring heart beat rate and the other for measuring blood pressure using different types of sensors. A group of 105 patients is used to develop this model and another group of the same number of patients is used to test it. The results of fuzzy logic are compared to the results of two designs based on different types of sensors.

II. DESIGN STRUCTURE

Mamdani type to predict inputs and outputs is used and compared them. The model has relied on four steps as follows:
Step 1: Identify and name inputs linguistic variables and their numerical ranges.
Step 2: Identify and name outputs linguistic variables and their numerical ranges.
Step 3: define a fuzzy membership function for each of inputs and outputs variables.

Step 4: construct the rule base that will govern the controller's operation.

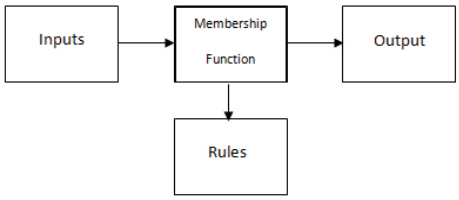


Figure 1. The block diagram of the designed structure.

A. *Identify the input and output variables and their numerical ranges*

The first step is to take inputs, outputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. Table I shows the extracted data of the heart beat rate without effort condition and table II shows the blood pressure using different type of sensors. Table III shows the recorded data of the heart beat rate with effort condition.

TABLE I. The average measurements of the heart beat rate without effort condition [8].

Average Heart beat rate (without effort)		
Reference value	***IR sensor value***	***LDR sensor value***
98	98	99
95	97	97
93	95	95
90	90	90
88	87	89
85	86	86
83	84	85
80	81	82
78	79	79
75	76	77

TABLE II. The average measurements of the blood pressure [8].

Average Blood pressure (Diastole)		
Reference value	***Strain gauge sensor value***	***Piezoelectric sensor value***
80	80	81
82	82	83
85	84	85
87	86	87
88	88	87
89	90	89
90	92	90
91	94	90
93	95	92
93	95	93

TABLE III. The average measurements of the heart beat rate with effort condition.

Heart beat rate (with effort)		
Reference value	***IR sensor value***	***LDR sensor value***
142	142	142
137	139	139
133	135	135
129	132	132
125	128	128
122	123	123
119	121	122
115	120	121
113	118	118
112	117	117

B. *Identify a set of fuzzy membership function for each of input and output variables*

Various types of membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions. In this paper using Gaussian curves to design a model.

C. *Construct the rule base that will govern the controller's operation*

The rule base is required as a matrix for inputs and outputs variables. For each matrix element in the output there corresponds a matrix element in the output. All rules are activated and fired in parallel whether they are relevant or not and the duplicate ones are removed to conserve computing time. Each rule base is defined by ANDing together with the inputs to produce each individual output response. The input and the output rules of the fuzzy inference system are illustrated from figure.2 to figure.6.

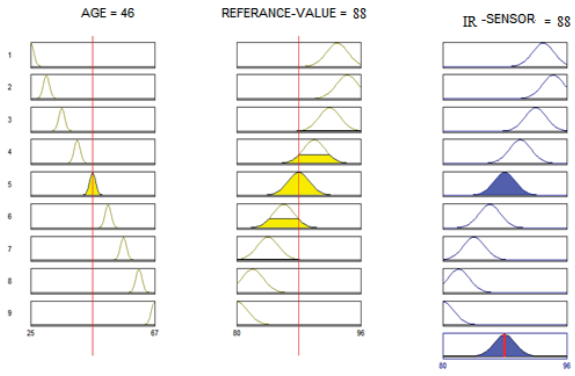


Figure 2. A fuzzy logic rules between reference results and the designed IR sensor results without effort.

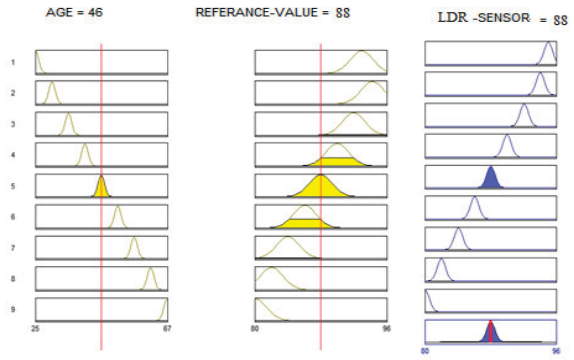


Figure 3. A fuzzy logic rules between reference results and the designed LDR sensor results without effort.

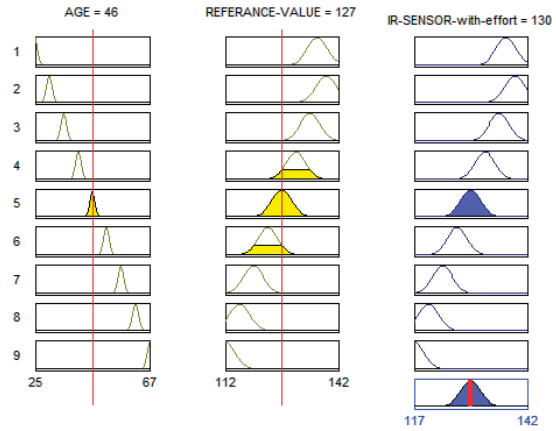


Figure 4. A fuzzy logic rules between reference results and the designed IR sensor results with effort.

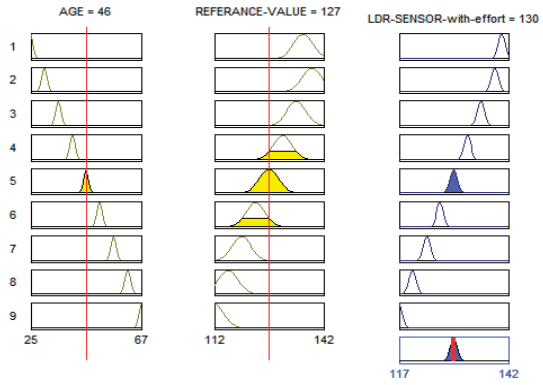


Figure 5. A fuzzy logic rules between reference results and the designed LDR sensor results with effort.

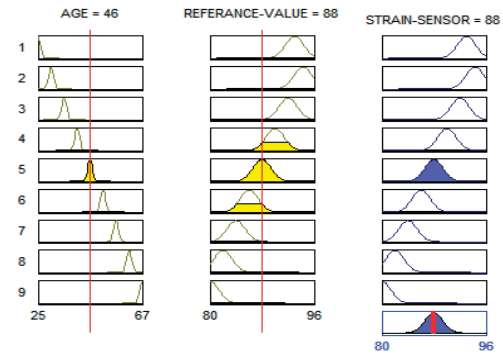


Figure 6. A fuzzy logic rules between reference results and the designed strain gauge sensor results.

Compared with the human brain, computers are well suited in make rapid calculations and recalling large numbers of facts, permitting the creation of decision networks that support near limitless complexity. For many situations, however, the variable nature of disease and patient characteristics makes it is difficult, even impossible, to decide exactly what should be done in every conceivable set of circumstances. In such situations, the physician must depend on intuitive decision making, sometimes described as the art of medicine. Intuitive decision making is usually described as being poorly suited to computerization. Certainly, subjective judgment generally description in terms of the kinds of deterministic mathematical equations that computers are well suited to solving.

Tests are applied of fuzzy logic to detect the accuracy. If the reference value is 88, and the result using IR sensor and LDR sensor is 88 as shown in figure 2 and figure 3. Which show the comparison among the reference results, the designed IR sensor results and the LDR sensor results using fuzzy logic for measuring heart beat rate which indicates that all results are close to each other (without effort). Figure 4 and figure 5 show the comparison among the reference results, the designed IR sensor results and the LDR sensor results using fuzzy logic for measuring heart beat rate which indicates that all results are close to each other (with effort).

A value of reference is 127 and the result is 130 from using IR sensor. A value of reference is 127 and the result is 130 from using LDR sensor. To confirm the validity of the fuzzy logic model, a random value on the curve results has been chosen, and a comparison has been done for this value between the reference value and the proposed fuzzy logic model. Figure 6 shows the comparison between the reference results and the designed strain gauge sensor results using fuzzy logic for measuring blood pressure (Diastole). A value of reference is 88 and the result is 88 using the strain gauge sensor as shown in Figure 6.

III. RESULTS

By using MATLAB 7.9.0 results are analyzed and using the fuzzy tools to make the comparison between the different results. The linear equations from Equation 1 to Equation 3 are produced based on the comparison between the reference device results and the generated results by the IR sensor and the LDR sensor as shown in Figure 7 and Figure 8. Which indicate that the IR sensor and the LDR sensor results are very close to the results of (HEM-907XL) reference device, with a slight difference in some of the results (with effort condition).

To confirm the validity of the derived equations, a random value on the curve results has been chosen, and a comparison has been done for this value between the reference device and the proposed design. A value X representing the results of the (HEM-907XL) reference device results and a value Y is the output corresponding to the IR sensor or the LDR sensor as shown in Figure 7 and Figure 8.

Figure 7 shows the predicted linear equation between the reference values and the IR sensor results for measuring the heart beat rate (with effort condition).

$$y = 9*z + 5.51 \quad (1)$$

where

$$z = (x - 5.24) / 10 \quad (2)$$

Figure 8 shows the predicted linear equation between the reference values and the LDR sensor results for measuring the heart beat rate (with effort condition).

$$y = 8.8*z + 5.51 \quad (3)$$

$$z = (x - 5.25) / 10 \quad (4)$$

Tests are applied of all equations to detect the accuracy. If the value X from the device (HEM-907XL) is 122, the result of Equation 1 is 123 as shown in Figure 7. In Figure 8 when X is 122 from the reference device, the result of Equation 3 is 123. Figure 9 shows the comparison among the (HEM-907XL) results, the designed IR sensor results and the LDR sensor results for measuring heart beat rate which indicates that all results are close to each other.

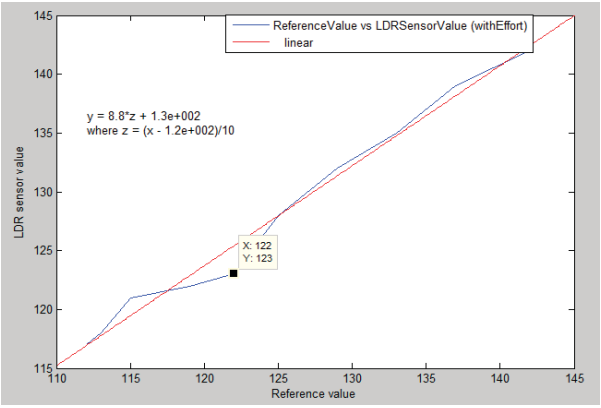


Figure 7. A comparison between the (HEM-907XL) results and the designed IR sensor results (with effort).

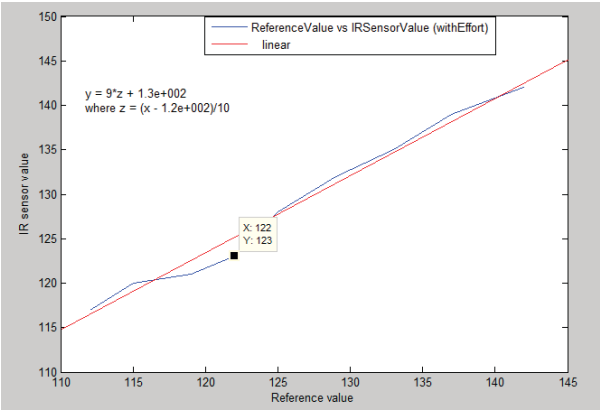


Figure 8. A comparison between the (HEM-907XL) results and the designed LDR sensor results (with effort).

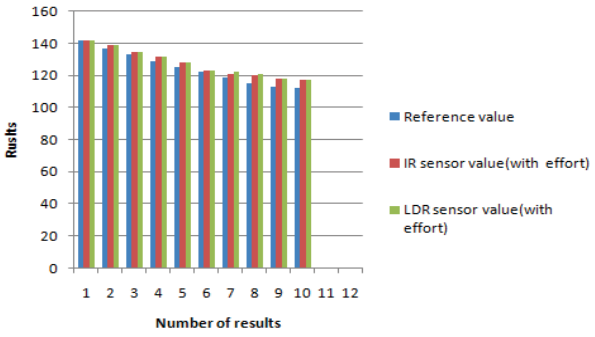
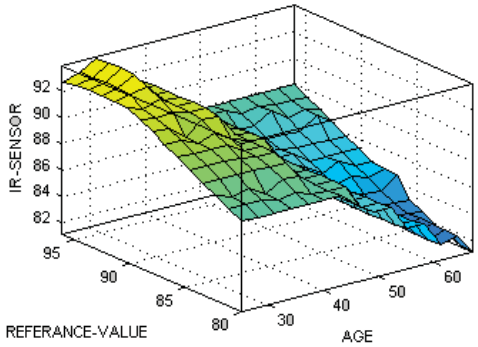
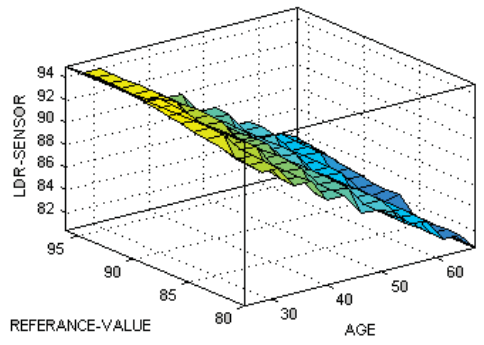


Figure 9. The comparison between the (HEM-907XL) results, the designed IR sensor results and the LDR sensor results for measuring heart beat rate (with effort).

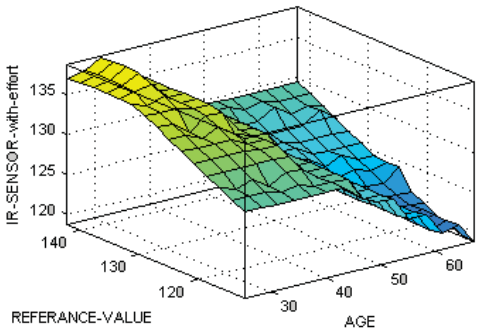
This surface reveals the effect of rounding and approximation processes on the result and also shows the accuracy of module with respect to the MATLAB-Based design. These statistics show that the surfaces generated by the fuzzy inference system more close among themselves. The input and the output surface of the fuzzy inference system are illustrated from figure 10. to figure 12.



Figures10. Relation between age, reference value and IR sensor results.



Figures 11. Relation between age, reference value and LDR sensor results.



Figures 12. Relation between age, reference value and IR sensor results with effort.

From the previous table I, table II and table III the percentage error between the reference value and the other values can be calculated.

TABLE IV. The percentage error between reference values and results using sensors [8].

Sensor type		Percentage Error
IR	Without effort	0.9249%
	Effort	0.9448%
LDR	Without effort	1.6185%
	effort	1.985%
Strain gauge		0.911%
Piezoelectric		0.1138%

IV. CONCOLUSION

Using the statistical analysis technique, the average data measurements results from designs for each sensor are recorded; the output results are close to the reference readings. The use of fuzzy sets theory in the medical field is to solve some medical problems. The model is developed using more than one hundred patients and is tested with a similar number of patients. The model is found to be accurate for classification and, when compared; it is proved to be at least as accurate as the reference values. By comparison the predicted output using fuzzy logic values, and the reference values of IR sensor for measuring heart beat rate, gave a the percentage error of 0.1116%. But when comparison the predicted output using fuzzy logic values and the reference values of LDR sensor for measuring heart beat rate, gave a percentage error of 1.511%. From this comparison conclude that using IR sensor is achieving the required accuracy. While by comparison the predicted output using fuzzy logic values and the reference values of strain gauge sensor for measuring blood pressure, gave a percentage error of 0.812%. The usage of fuzzy logic rule-based classifiers is an effective tool for accurate diagnosis of heart and blood pressure measurements.

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