Fuzzy Inference Modeling of Risk Factors in Coronary Diseases : A Review

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Abstract- *To estimate the variation in the major risk factors for cardiovascular disease (Hemoglobin HGB; mean corpuscular volume MCV; Mean corpuscular hemoglobin concentration MCHC; Fe and Folic acid), we try preventing according coronary heart disease risk factors observed in elderly men and women in the region of Setif – Algeria. Participants.100 men and women aged 26 to 86 years for whom the physiological parameters were recorded. These parameters are risk factors for cardiovascular disease. The expected analysis was estimated using an artificial intelligence model including the principles of fuzzy logic. Risk factors are inputs of the system and the incidence of coronary heart disease is output. The observed data recorded from Analysis Central Laboratory of Setif university hospital - Algeria. Factors that promote coronary heart disease are inaccurate and uncertain. The effect of these factors varies from person to person. Their consideration as fuzzy variables is perfectly adequate. A database is established. Fuzzy inference rules are highlighted according to the recorded values. An algorithmic application is established making it possible to read instantly the number likely the person with a coronary disease just by the random introduction of the variables at the input of the system.*

Keywords: Coronary diseases, Risk factors, Artificial intelligence, Fuzzy logic.

I. INTRODUCTION

Cardiovascular disease is the cause of death in the industrialized world, and a number of well-characterized factors, including advanced age, hypertension, dyslipidemia, diabetes and smoking, contributes to cardiovascular risk[1]. Coronary heart disease continues to be a leading cause of adult morbidity and mortality in Europe. Different risk factors are widely studied. However, the weight of each factor varies according to people. The phenomenon is very complex. Modeling such factors by classical mathematical techniques becomes very difficult if not impossible. Several attempts were made. Different models are proposed, but this remains in the realm of probability and approximation.

Nowadays, artificial intelligence has found its application in solving various complex problems. The use of fuzzy logic systems as an intelligent system is a very powerful tool for solving, classifying and making decisions in an uncertain environment, especially in the medical field.

In this study, after giving an overview of the risk factors for coronary heart disease according to the literature, we conclude that these factors are analyzed numerically in all models. In order to get closer to the precision and the expected accuracy, we propose the analysis of these factors by the techniques of artificial intelligence in particular the principles of fuzzy inference. For this purpose, we give a general overview on the fundamental notions of fuzzy logic in order to facilitate the understanding of its application. Some main risk factors (Hemoglobin HGB; mean corpuscular volume MCV; Mean corpuscular hemoglobin concentration MCHC; Fe and Folic acid) are considered as input variables to the fuzzy system. The possibility of coronary heart disease is expressed in degrees as an output variable. Given the nature of the effect of these imprecise factors, we consider them to be fuzzy variables. A base rule is established according values recorded by the analysis laboratory of patient. The algorithm established allows the instantaneous reading of the degree of attack by the coronary disease. To do this, it is sufficient to randomly enter values at the input system to read the result.

II. RISK FACTORS

Some risk factors are those of birth and cannot be changed. With increasing age, the majority of these people die from coronary heart disease are 65 years of age or older. At more advanced ages, women who have heart attacks are more likely than men to die from them in a matter of weeks. Estimates of coronary prediction tend to be the most reliable when the data are most concentrated and can be particularly useful when subjects have multiple mild abnormalities that act synergistically to increase the risk of coronary heart disease[2]. With the exception of low cholesterol; all other major risk factors were higher among urban men than among rural men. This trend was also observed among urban women as compared to rural women[3]. Lipoprotein and triglyceride levels have a greater impact on the risk of coronary heart disease in women than in men. On the other hand, evidence that lipoprotein is a cardiovascular risk factor appears to be stronger in men than in women[4].

Conventional risk factors for coronary heart disease include a Hemoglobin HGB; Mean corpuscular volume MCV; Mean corpuscular hemoglobin concentration MCHC; Fe and Folic acid. A positive correlation was observed between Gensini Score and Mean corpuscular volume, Mean corpuscular hemoglobin, WBC (leucocyte), neutrophils, lymphocytes and monocytes. Therefore, the results suggest that erythrocyte has a role in the pathogenesis of coronary artery disease, as other blood cells or factors in the pathogenesis of coronary artery disease can affect erythrocyte morphology[5]. The paired comparison of the three groups of MCH, MCHC, MCV and The erythrocyte sedimentation rateby statistical techniques showed that there was no statistically significant difference between control, generalized chronic gingivitis and chronic generalized periodontitis[6]. Red blood cell distribution width red blood cell distribution width is one of the routine hematologic parameters reported in the complete blood count test, which has been recognized as strong prognostic marker for various medical conditions, especially cardiovascular disease[7]. Also, it is considerate as a parameter, which reflects the degree of heterogeneity of the erythrocyte volume (conventionally known as anisocytosis) and is traditionally used in laboratory hematology for the differential diagnosis of anemia. Nevertheless, recent evidence shows that anisocitosis is common in human disorders such as cardiovascular disease, venous thromboembolism, etc[8].

Other studies demonstrating improved endothelial function in patients with high doses of folic acid (5 mg daily for 1.5 to 4 months) alone or in combination with other B vitamins. Folic Acid Improves Endothelial Function in Coronary Artery Disease via Mechanisms Largely Independent of Homocysteine Lowering[9]. Folic acid supplementation significantly improved endothelial dysfunction in patients with coronary atherosclerosis[10]. The analysis revealed a reduced risk of stroke and an overall cardio vascular disease risk with folic acid supplementation. A greater benefit for cardiovascular disease was observed in participants with lower plasma levels of folate and no pre-existing cardio vascular disease[11].

Women have many risk factors that predispose them to coronary artery disease; Most of which are age-related and some of which are exclusive to women[12]. It has been recognized in recent years that women are a distinct subpopulation in patients with coronary artery disease[13]. High blood pressure is considered a major factor in coronary artery disease. Coronary artery disease is a major component of cardiovascular death. Systolic blood pressure, cholesterol, body mass index, smoking, diabetes and physical inactivity are major risk factors for cardiovascular diseases[14]. Also, we can consider body mass index, gipertriglitsiridemiya, and hypercholesterolemia are the most common risk factors. In comparison with persons of fertile age arterial hypertension is more common in postmenopausal women[15].

III. FUZZY LOGIC

3.1 Principles of Fuzzy Logic:

We present in this section the summary of basic concepts. The concept of fuzzy logic was first introduced by Zadeh in 1965[16]. Fuzzy logic was proposed as an extension of classical logic. A classical logic set is a set with a crisp boundary. In contrast, a fuzzy set is a set without a crisp boundary. The transition from "belonging to a set" to "not belonging to a set"is gradual, and this smooth transition is characterized by membership functions that give fuzzy sets flexibility in modeling linguistic expressions.

The central idea of the fuzzy logic is to model the imprecise aspects of the behavior of the system through fuzzy sets and fuzzy rules. System variables are defined as linguistic variables and their possible values are linguistic terms (expressed as fuzzy sets). Fuzzy sets are used to represent linguistic variables. For example, if the temperature is a linguistic variable, it's possible values could be {low, normal, height}. These terms are called linguistic terms and each one is characterized by a fuzzy set. A possible interpretation of the linguistic variable "Age" and its linguistic terms can be fuzzyfied in three fuzzy linguistic terms. In this example each linguistic term is represented by different fuzzy sets. In general form, each fuzzy rule is written as were A_1 and A_2 are the fuzzy sets that describe the nature of the inputs, such as young, old, or very old. The linguistic control rules of this system are given by: *If* X_1 *IS* $X_1(1)$ *and* X_2 *IS* $X_2(2)$ *and…*X_n *IS* $X_n(n)$ *than* Y_1 *is* $Y_1(1)$[17].

3.1.1 Fuzzy variables

Unlike the binary variables that are defined by the two states "true" or "false", in binary the (1 and 0), the fuzzy variables present a gradation between the value "true" and the value "false". Two remarks are necessary about this representation: On the one hand, it is preferable to represent the state of the variable using its degree of truth by associating the value 1 (degree of truth of 100%) with the value "true" and the degree of truth zero at "False" value. On the other hand, we see that this way of doing things is very far from the reality and what the human being does when he solves this kind of problem[18].

3.1.2 Fuzzy intervals

These intervals define the number of fuzzy variables associated with an input variable. In the case of people's ages, for example, fuzzy intervals are used: "Adult" and "Old". Moreover, each interval refers to a membership function which allows defining the degree of truth of the corresponding fuzzy variable according to the age of the person and therefore his belonging.

3.1.3 Fuzzyfication of the membership function

Every fuzzy subset A of U can be defined by a particular mathematical function which gives a weighting to each element $X \in U$. This function is called membership function, it is denoted by
$\mu_A : x \in U \rightarrow \mu_A(x) \in [0,1]$.

3.1.4 Inferences rules

A fuzzy implication between two elementary propositions is a relation *R* between the two sets U_1 and U_2, quantifying the degree of truth of the proposition.

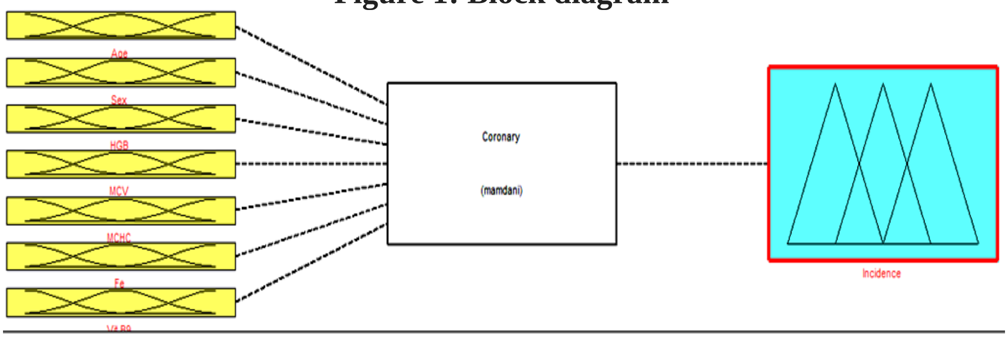
3.1.5 Fuzzification

In order to make fuzzyfication, the linguistic expressions below are used. The proposed fuzzy logic factors impact control system consists of five inputs variables.

- Fuzzy variable “Age” has the linguistic values young; old; very old
- Fuzzy variable “HGB” has (normal, middle, high).
- Fuzzy variable “MCV” has the linguistic values: lower, normal, higher.
- Fuzzy variable “MCHC” has the linguistic values normal; lower, normal, higher.
- Fuzzy variable “Fe” has the linguistic values normal; lower, normal, higher.
- Fuzzy variable “Vit. B9” has the linguistic values normal; lower, normal, higher.
- Sex variable is not fuzzyfied, we attribute (1 for male; 2 for female).

The mapping values of input variable through the membership function are the linguistic values. The linguistic values of inputs are shown as a result:
A block system is constructed (Figure 1) with five inputs and one output

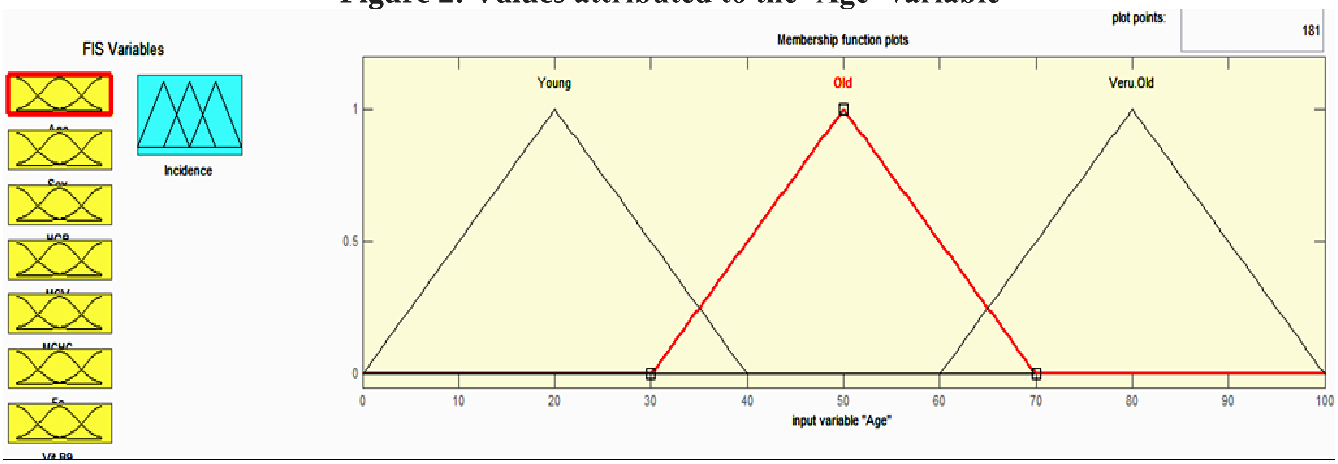
Figure 1: Block diagram



3.2 Fuzzyfication of the input variable "Age"

The input that represents the age is expressed by three fuzzy intervals and membership functions defining the young; old; very old (Figure 2).

Figure 2: Values attributed to the ‘Age’ variable



In the same way, the other input variables are fuzzyfied except the sex variable where a numerical value 1 is given for the male and the value 2 for the female gender.

3.3 Fuzzyfication of the output variable "Incidence"

The output variable that represents the incidence of coronary disease is expressed by three fuzzy intervals and membership functions defining the: low risk, Middle risk, high risk (Figure 3 & 4).

Figure 3: Values attributed to the 'Coronary degree' variable

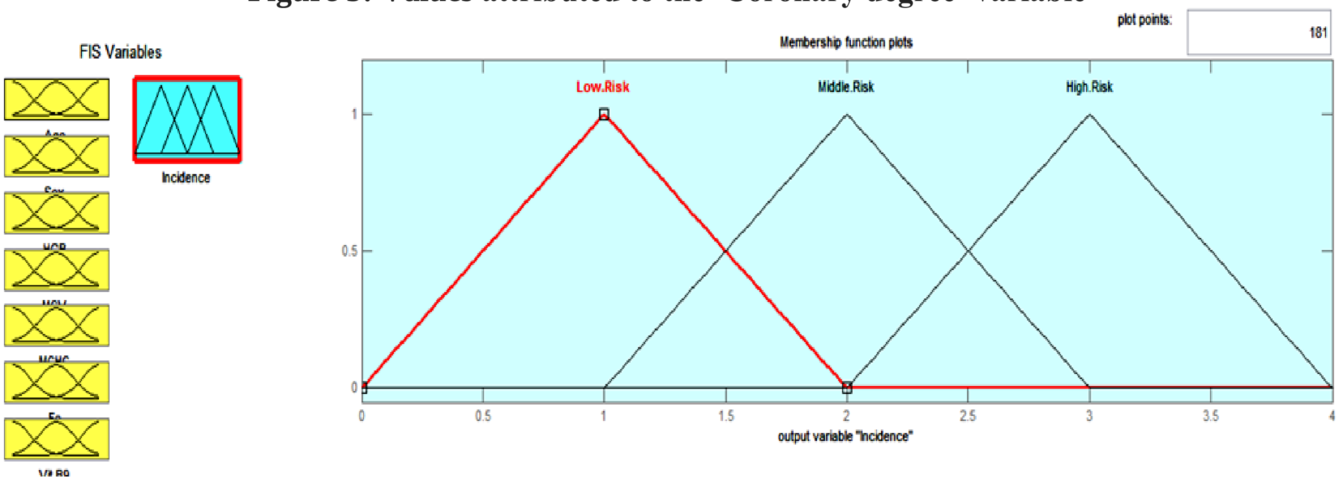
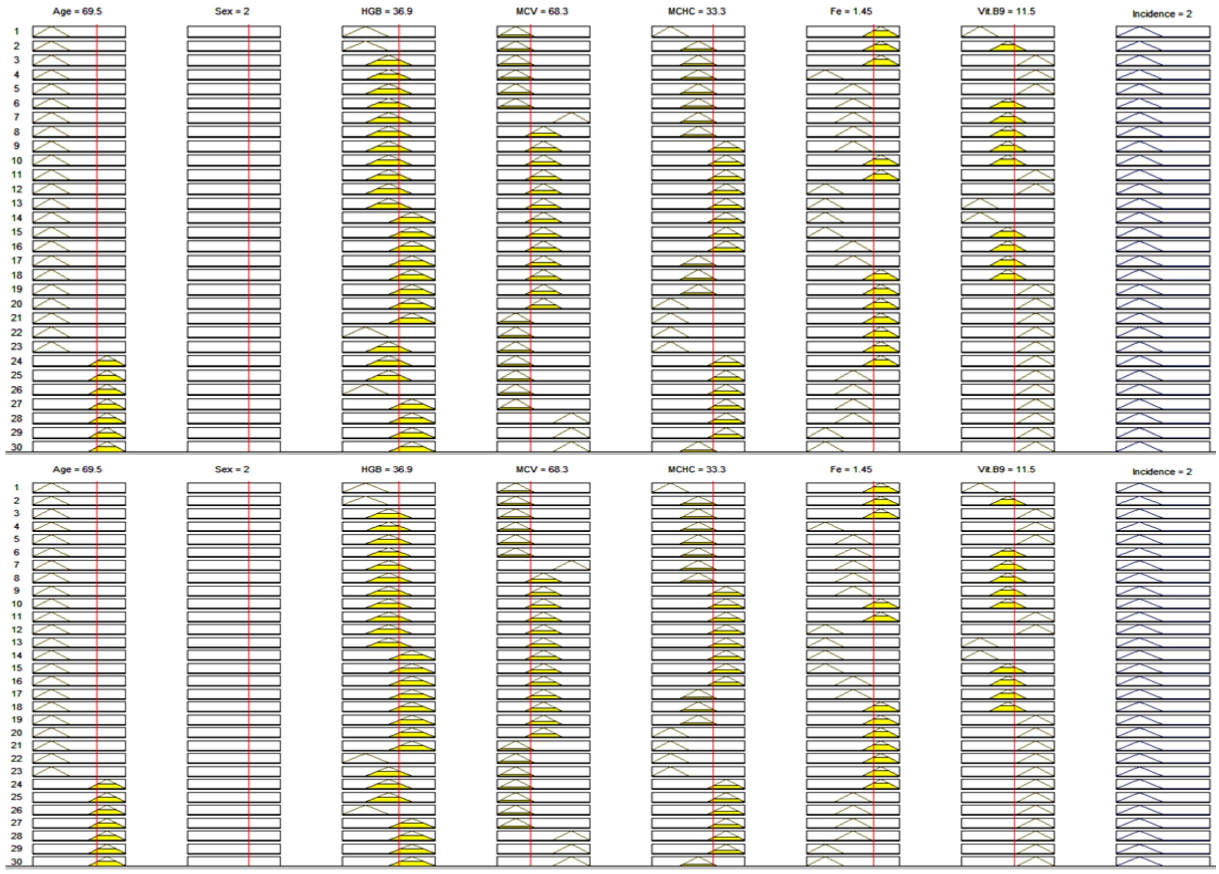


Figure 4
Reading the incidence of coronary disease at the output by fixing random values at the inputs



In according with the recorded values (Table 1), the fuzzy rules are established. These rules are in the form:

IF ‘Sex’ is X_1, **AND** ‘Age’ is X_2, **AND** ‘HGB’ is X_3 **AND** ‘MCV’ is X_4, **AND** ‘MCHC’ is X_5, **AND** ‘Fe’ is X_6, **AND** ‘Vit.B9’ is X7, **THAN** ‘Incidence of coronary disease” is Y.

The basis of the established rules must take into account all possibilities and all possible combinations according to the values recorded. The support for all variables at the system input is calculated to give the result at the output.

Table 1.
Variables recorded by patients (Sex, Age, HGB, MCV, MCHC, Fe and Vit. B9)

Patient	Sex	Age	HGB (g/dl)	MCV (fl)	MCHC (g/dl)	Fe (mg/l)	Vit B9 (ng/ml)	Patient	Sex	Age	HGB (g/dl)	MCV (fl)	MCHC (g/dl)	Fe (mg/l)	Vit B9 (ng/ml)
1	0	77	14,2	82	36,5	0,4	20	51	1	55	12,2	84,1	36,4	0,13	20
2	1	78	13,8	92,4	35,2	0,57	11,25	52	0	72	12,6	88,9	35,5	0,42	20
3	0	67	11,8	76,5	34	2,5	15,09	53	0	58	15,1	89,7	31,2	0,82	15,24
4	1	82	14,3	86,6	35,9	0,67	15,9	54	0	78	12,8	79,2	37,1	0,26	8,03
5	1	51	15,7	87,1	35	0,41	15,3	55	0	70	13,7	79,6	35,5	0,6	16,87
6	1	53	14,9	88,1	34,6	0,66	14,74	56	0	73	11,8	76,6	34	0,27	20
7	1	81	13,6	83,7	34,1	0,89	19,46	57	0	57	11,9	94,7	33,2	0,29	7
8	1	70	6,5	94,1	26,9	0,77	16,43	58	0	63	12,2	84,2	34,6	0,33	1,09
9	1	78	12,9	78,4	37,4	0,46	10,9	59	1	63	12,6	61,3	33,8	0,63	11,84
10	1	68	15,2	93,3	34	0,59	8,25	60	1	50	15,8	98	35,4	0,2	7,56
11	1	88	15,7	92,9	34,2	0,49	13,7	61	1	56	13	79	36,1	0,57	20
12	0	82	8,7	77,8	34,8	0,75	16,97	62	1	83	11,7	89,2	32	0,39	17,7
13	1	66	15,3	90,1	33,9	1,02	12,12	63	1	61	12,5	88,8	43,7	0,89	20
14	1	64	11,2	73,5	33,9	0,45	11,51	64	1	42	13,4	75,7	36,2	0,56	12,4
15	1	55	14,5	83,5	36,2	0,5	20	65	0	46	14,6	77	35,2	1,47	8,36
16	1	68	14,3	92,2	32	1,06	11,51	66	1	68	13,2	83,9	34	0,92	14,51
17	0	73	14,1	82,1	33,4	0,63	15,36	67	1	26	15,4	92,9	35,2	0,49	16,78
18	1	64	14,2	88,2	34,6	0,72	12,44	68	0	80	11,2	84,9	35,9	0,36	9,02
19	0	58	13	79,2	37,9	0,7	8,03	69	1	53	14,8	92,1	34	0,72	8,46
20	1	78	15,7	83,9	35,2	1,41	18,23	70	1	69	13,1	87,9	34,8	0,32	12,33
21	1	48	14,8	88,8	35,9	0,59	9,59	71	1	77	11	81,3	34,6	0,8	20
22	0	63	7,3	81,7	35,5	0,48	18,31	72	1	40	15,7	90,8	37,1	0,29	14,78
23	0	65	12,6	87,4	34,6	0,61	20	73	0	68	10,3	82,4	34	0,55	12,77
24	0	65	22	91,6	32	1,28	10,53	74	0	61	19,9	82,5	32,3	0,63	19,91
25	1	68	13,1	91,6	37,2	0,48	5,14	75	1	59	13,6	87,4	33	0,86	14,77
26	1	55	15,5	80,2	36,7	0,31	7,93	76	0	50	10,6	57,3	36	0,21	16,88
27	1	80	11,5	82,8	34,8	0,88	4,78	77	1	56	12,5	62,8	32,9	0,86	19,78
28	0	74	12,6	80,7	34,9	0,34	11,25	78	1	63	13,8	88,4	33,1	0,05	15,66
29	1	59	12,7	85,5	35	0,64	5,72	79	1	53	16,5	93,9	35,4	0,32	14,8
30	0	42	13	81,4	34,9	0,74	7,48	80	1	72	16,1	82,6	35	0,66	12,34
31	1	56	14,1	81,6	35	0,75	14,98	81	1	61	16,1	93	34,1	0,95	13,05
32	1	76	12,6	83,7	35,4	0,03	2,1	82	1	62	15,1	84,6	31,4	0,48	18,63
33	1	63	15,5	88	35,2	0,33	20	83	0	75	11,9	83,6	35,6	0,91	15,36
34	0	80	12,7	78,9	35,1	0,72	20	84	1	80	15	88,8	33,2	0,57	9,25
35	1	61	14,5	97,7	34,6	0,71	19	85	1	58	7,9	79,4	37,5	0,38	20
36	1	30	15,2	86,4	35	0,93	9,34	86	0	53	15,2	84,5	35,4	0,69	16,5
37	0	58	7,9	65,3	30,8	0,35	17,27	87	1	57	14,8	80,6	34,9	0,05	15,03
38	0	52	13	72,5	30,5	0,65	20	88	0	44	10,7	64,6	35,2	0,36	20
39	0	65	14,1	84,2	29,5	0,56	7,22	89	0	66	14,6	81,6	35	1,17	15,1
40	0	86	14,4	84,6	35,6	0,99	15	90	1	59	14,9	88,6	34,4	0,65	18,33
41	1	77	12,9	82,9	33,5	0,32	20	91	0	49	14,2	88,3	36,1	0,01	20
42	1	76	14,8	86,6	36,1	3,6	20	92	1	40	14,7	86,6	31,2	1,4	9,5
43	0	42	12	73	34,3	0,49	20	93	0	70	12,3	88,9	33,8	0,73	16,84
44	0	64	15,1	84,1	35,3	0,33	8,56	94	1	72	12,2	87,3	36,5	0,77	7,5
45	1	61	13,4	57,7	32,2	0,67	16,57	95	0	67	7,4	74,7	35,6	0,46	20
46	1	67	11,4	78,2	35,8	0,65	17,7	96	1	81	13,5	85,4	34,3	0,24	17,32
47	1	50	14,4	80,3	35,2	0,9	20	97	0	38	13,2	87,5	33,9	0,75	13,97
48	0	84	12,7	74,6	36,7	0,49	13,28	98	1	61	16,6	87,9	34,4	0,65	20
49	1	73	15,2	85,6	35,5	0,75	20	99	0	64	13,4	79,1	35,3	0,42	13,22
50	0	89	10,9	73,4	35,1	1,32	14,7	100	1	57	14,3	95,3	35,6	0,75	9,27

IV. CONCLUSION

Once the rule base is established, it becomes possible to instantly read the degree of coronary heart disease (Figure 4). The result is the collaboration of the set of rules that support all input variables. Since the input variables are considered as fuzzy variables by expressing them by linguistic variables, this gives an analysis as precise as possible. Also the output variable is expressed in linguistic terms concerning the incidence of coronary disease. This also gives the possibility of reading a result in a wide numerical and symbolic range.

At the end, the resulting application makes it possible to randomly display values at the input to read the result at the output. If all of the factors are taken in a precise manner and the rules are established correctly and encompassing all possibilities, it becomes possible to predict the onset of coronary heart disease without making appropriate diagnoses. This tool can be considered as an aid to doctors in their diagnosis, prevention and treatment of coronary patients.

CONFLICT

None declared till date.

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