A Fuzzy Petri Nets System for Heart Disease Diagnosis

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Abstract

In this paper we have proposed a Fuzzy Petri Nets Expert System for heart disease diagnosis. The aim of the proposed system is simulating experience of experts in Diagnosis Heart Disease stage, based on Fuzzy Rule System and modeling reasoning operation by using Fuzzy Petri Nets. The database taken from Machine Learning Repository Center for machine learning and intelligent system. The system has 11 input fields and one output field. The accuracy of proposed system is 75%.
Keywords: Expert System, Heart disease, Fuzzy Petri Nets, Fuzzy Logic.

الخلاصة

في هذه الورقة اقترحنا شبكات بتري المضببه كنظام خبير لتشخيص أمراض القلب. الهدف من النظام المقترح هو محاكاه خبرة الخبراء في مرحلة تشخيص أمراض القلب، استنادا إلى نظام حكم غامض وعملية نمذجة المنطق باستخدام شبكات بتري المضببه.قاعدة البيانات المعتمده في هذ البحث هي قاعدة بيانات عالميه. النظام لديه 11 حقول للادخال وحقل للإخراج واحد. دقة النظام المقترح هو 75٪.

الكلمات المفتاحيه: نظام خبير، أمراض القلب، شبكات بتري المضببه، المنطق الضبابي.

1. Introduction

The Heart disease is one of risky disease and need to diagnosis in early time to surmount it's risk, use of soft computing(fuzzy logic , genetic algorithm , neural network ,supper vector machine, fuzzy Petri nets) in the fields of medicine area diagnosis, treatment has highly increased . In spite of the fact that these fields, in which the computers are used, have very high complexity, uncertainty, Imprecision and the use of intelligent systems have been developed [Tsipouras *et al.*, 2006; Abdullah, *et al.*, 2011].

Imprecision and inconsistency are the prevailing sort of incompleteness of information, that database of an expert system (ES) are suffer, whereas fuzzy logic had show its faculty of reasoning with imprecise databases. The reasoning process of the two techniques (Fuzzy set and Petri nets) is orthogonal to each other [Hamed, *et al.*, 2010].

[Robert *et al.*, 1989], presented an new probability algorithm for Diagnosis of Heart Disease ,they built discriminate function model for estimating probabilities of angiographic Heart Disease ,where this function operates based on logistic regression derived discriminated ,this study represent the reference for many later literature.

[Jayanta and Marco, 1999], proposed new approach, this approach present new model for Heart Disease ,they proposed probabilistic model based on Bayesian network which called belief network.

[Bhatia *et al.*, 2008], proposed Decision Support System for Heart Disease Classification based on Support Vector Machine, simple Support Vector Machine algorithm has been used to determined the support vector in a fast ,iterative manner .integer coded genetic algorithm is used for selecting the important and relevant feature and discarding the irrelevant and redundant ones. In this work the accuracy of the system is calculated in two case; *First* when it classify to 5-stage; second, when it classify to only two class, disease or no disease.

[Zhao *et al.*, 2009], this study was establishing characteristic diagnosis pattern for Unstable Angina with Qi-Yin deficiency syndrome based on Decision Tree. Where a

pattern, which could distinguish unstable angina with qi-yin deficiency syndrome patient from the non qi-yin deficiency. In this work decision tree was take as data mining method to the study of the relation between symptom and inflammatory factors.

Out of consist of fuzzy reasoning, we design system to construct a rule-based reasoning .Fuzzy Petri Net (FPN), which combine Fuzzy logic with Petri Net, is useful tool in dealing with Imprecision and inconsistency of the information, the graphical nature of the Fuzzy Petri Nets and it's mathematical basis can help to visualize the inference states and modify fuzzy rule bases.

Our system is developed to simulate the inference process from the antecedent to the consequent propositions, such networks are used for diagnosis, where the token of the starting place are known and the tokens of the ending places are to be evaluated.

In this paper, two techniques are used to Diagnosis Heart Disease, the first one used to approximate the experience of expert, Fuzzy Logic. The second one used to Fuzzy reasoning modeling and formalism, Fuzzy Petri Nets.

The paper is structured as follows: Section 2 introduced database .Section 3 introduced knowledge base description. Section 4 introduced structure of fuzzy system. Section 5 introduced the definition of Fuzzy Petri Nets. Section 6 describes the Fuzzy Petri Nets model based on specification of fuzzy reasoning rule and procedure of reasoning .finally, Section 7 concludes the paper.

2- Data Base Description

As an expert rule base system the main components are the data base and knowledge base. In this work heart disease diagnosis system's dataset is taken from University of California, Irvin (UCI) dataset for heart disease[Robert Detrano], the collection of data set at by David Aha, which determine the attributes that depended on to diagnosis Heart Disease, this dataset contain 13 attributes (which have been extracted from a larger set of 75), the proposed system used 11 attributes from the 13 as is explain in table (1)**.**

Table 1: The Attributes of Heart Disease

No.	Name	Description
1	Chest pain	1-typical angina; 2- atypical angina;3-non-anginal pain; 4-asymptomatic
2	Age	Real No.
3	Sex	Female(0); male(1)
4	Resting blood pressure	Real No.
5	ECG	0=normal; 1=ST-T wave; 2-hypertrophy
6	Old peak	ST depression induced by exercise relative to rest
7	Maximum heart rate	Real No.
8	Thal	3=normal; 6=fixed defect ; 7=reversible defect
9	Exercise	1=yes;0=no
10	Fasting blood sugar	1=true(>120mg/dl);0=false
11	Cholesterol	Real No.

And the diagnosis class 0=health; (1-4) the patient who is subject to possible heart disease.

We normalize the fuzzy beliefs of the input data by using a set of construct grade of membership function and construct the linguistic variable.

3 - Knowledge Base

Knowledge base in the form of fuzzy rule, depending on the attribute of heart disease there is 44 rules, each of these rules has a value represent the strength of the belief in the fuzzy rule, certainty factor, and the traditional certainty factor is a constant determined by an expert. The thresholds that connect with each symptom estimated by the experience are 0.5.

The knowledge base of this work is organize in the form of data tree having depth of three level ,where the first level represent the root of tree, starting pointer ,the second level represented the conclusion of the rule, finally, the third level represent condition of the rule ,as it explain in the figure (1),(2). Such organization helps in efficient searching in database.

Data-tree= fuzzy _rule

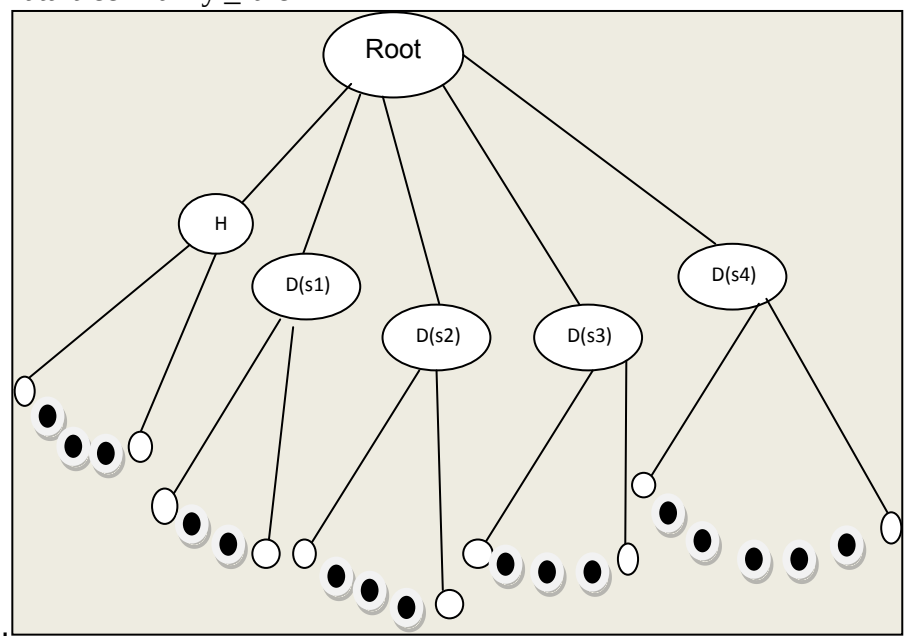


Figure (1) The Tree of Fuzzy Rule

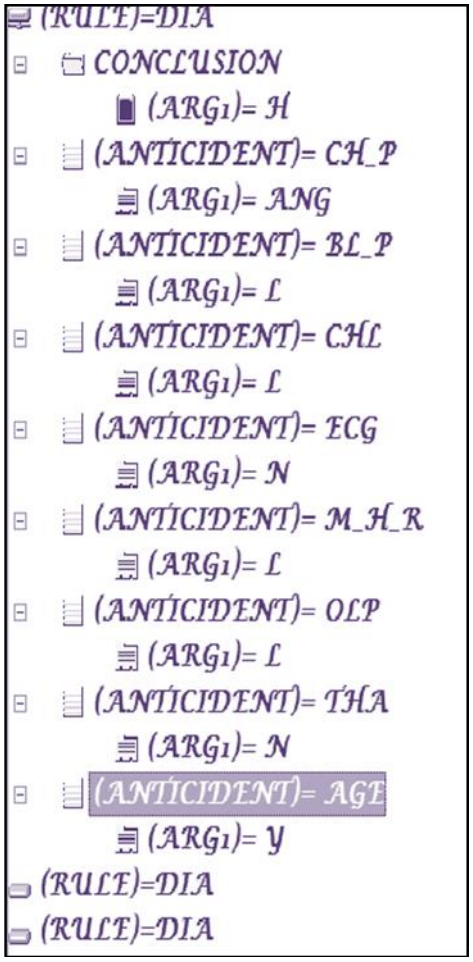


Figure (2) The Tree of Fuzzy Rule of Heart Disease

The knowledge base save in two data buffer, first one for conclusion part of the Fuzzy Rule, has a record to each diagnosis, and the second one for condition part of the Fuzzy Rule, has a record to each symptom. As it explain in the figure (3) and figure (4),where each fact, in the data buffer of condition part know his father through special ID , where the unique ID gift to fact ,diagnosis, in data buffer conclusion part and this ID give to all its antecedence, symptom.

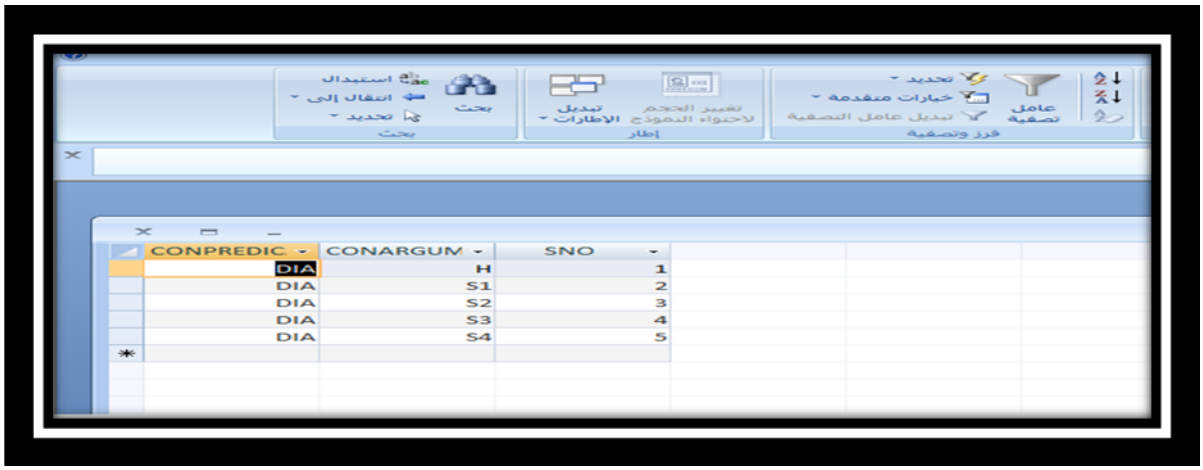
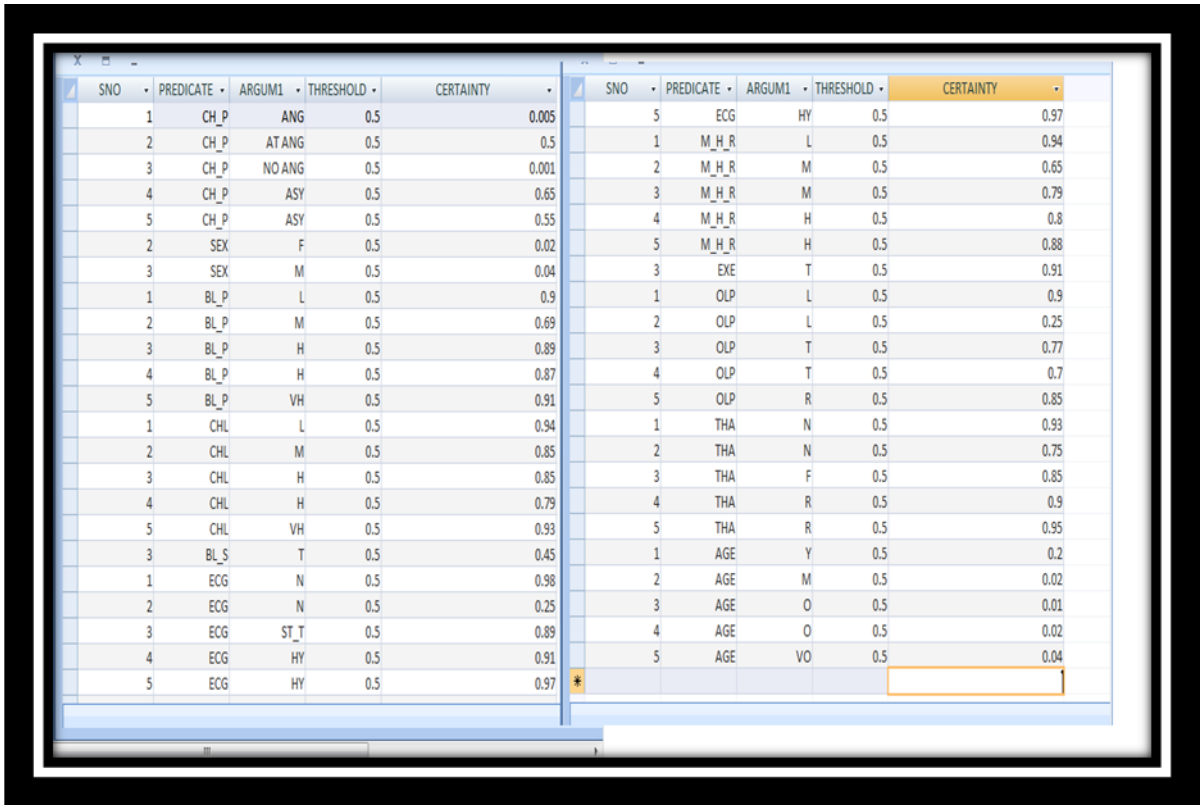


Figure (3) Data Buffer of conclusion Part of the Rule



SNO	PREDICATE	ARGUM1	THRESHOLD	CERTAINTY
1	CH_P	ANG	0.5	0.005
2	CH_P	AT ANG	0.5	0.5
3	CH_P	NO ANG	0.5	0.001
4	CH_P	ASY	0.5	0.65
5	CH_P	ASY	0.5	0.55
2	SEX	F	0.5	0.02
3	SEX	M	0.5	0.04
1	BL_P	L	0.5	0.9
2	BL_P	M	0.5	0.69
3	BL_P	H	0.5	0.89
4	BL_P	H	0.5	0.87
5	BL_P	VH	0.5	0.91
1	CHL	L	0.5	0.94
2	CHL	M	0.5	0.85
3	CHL	H	0.5	0.85
4	CHL	H	0.5	0.79
5	CHL	VH	0.5	0.93
3	BL_S	T	0.5	0.45
1	ECG	N	0.5	0.98
2	ECG	N	0.5	0.25
3	ECG	ST_T	0.5	0.89
4	ECG	HY	0.5	0.91
5	ECG	HY	0.5	0.97

SNO	PREDICATE	ARGUM1	THRESHOLD	CERTAINTY
5	ECG	HY	0.5	0.97
1	M_H_R	L	0.5	0.94
2	M_H_R	M	0.5	0.65
3	M_H_R	M	0.5	0.79
4	M_H_R	H	0.5	0.8
5	M_H_R	H	0.5	0.88
3	EXE	T	0.5	0.91
1	OLP	L	0.5	0.9
2	OLP	L	0.5	0.25
3	OLP	T	0.5	0.77
4	OLP	T	0.5	0.7
5	OLP	R	0.5	0.85
1	THA	N	0.5	0.93
2	THA	N	0.5	0.75
3	THA	F	0.5	0.85
4	THA	R	0.5	0.9
5	THA	R	0.5	0.95
1	AGE	Y	0.5	0.2
2	AGE	M	0.5	0.02
3	AGE	O	0.5	0.01
4	AGE	O	0.5	0.02
5	AGE	VO	0.5	0.04

Figure (4) Data Buffer of Condition Part of the Rule

4. The Structure of Fuzzy System

Rule based system has been successfully used to sampling human problem-solving where much of human reasoning deals with imprecise ,incomplete ,or vague information. The important aspect of design any information system are sound theoretical , capability, accuracy and ease of use. The figure (5) shows the primary element of Fuzzy system. Fuzzy system can take a decisions according to its crisp input (value from real world) ,transformed to the form linguistic variable, that emerge from membership functions , which can be used to determine the fuzzy set that input belong to and it's truth degree, then the linguistic variables are processed with Fuzzy rule IF- THEN rule ,the response of each rule is weighted ,truth degree of its inputs, that deduce from Fuzzy implication. The output of this step is expressed in output fuzzy set after it's defuzzification into crisp value[Hamed *et al.*, 2010; Konar and Mandal, 1996].

4.1 Fuzzification

The first step in Fuzzy system, the crisp value, input to the system from real world, convert to fuzzy value, and (Fuzzy degree of membership) by evaluating a membership function. The crisp inputs (x) that belong to universe of discourse of fuzzy set convert to linguistic term with degree of belong[Hamed *et al.*, 2010; Konar and Mandal, 1996].

4.2 Defuzzification

The task of this step is convert the fuzzy output of the system in to crisp value, there are number of schemes that used for defuzzification, the method used in this work is Maxima Methods Maxima methods consider values with maximum membership[Hamed *et al.*, 2010; Konar and Mandal, 1996].

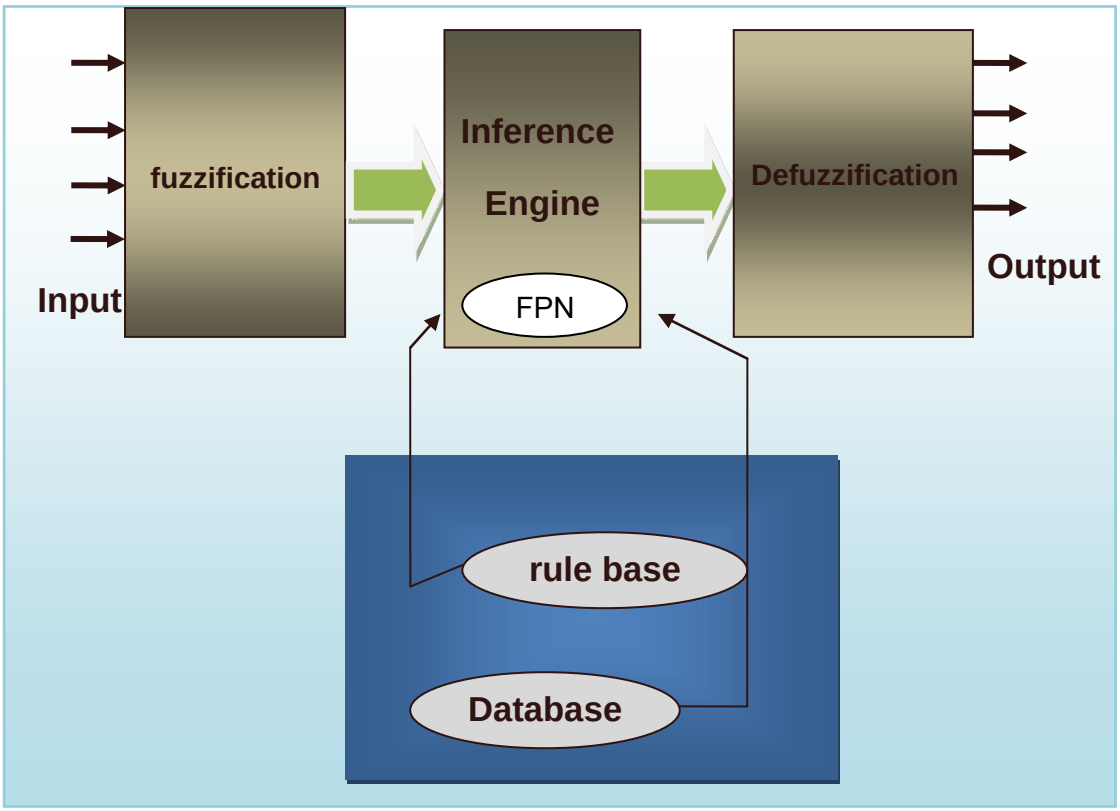


Figure 5.The Proposed System

5- Fuzzy Petri Net

The modeling of Fuzzy Petri Nets are involve; get the information from experts and from database ,then fuzzifier the real data from crisp set into fuzzy set by defined member ship, then construct a Petri Net depending on fuzzy rule and inference rule, finally defuzzifier the result, as it explain in the figure(6)[Hamed *et al.*, 2010; CHEN and CHANG, 1990].

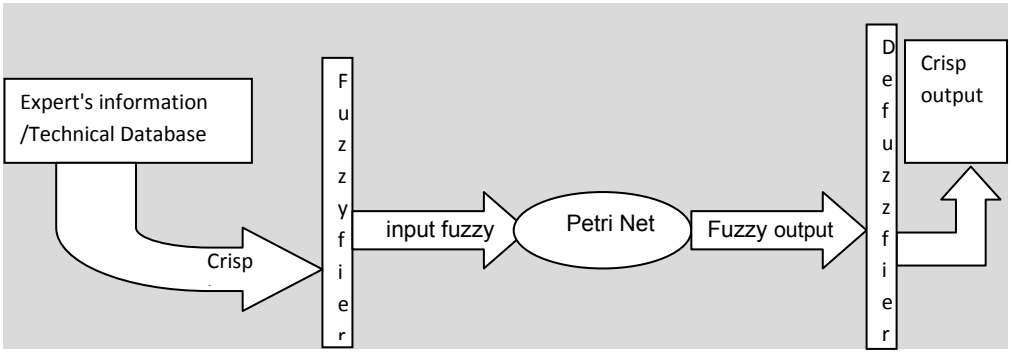


Figure (6) Methodolog`y of modeling Fuzzy Petri Nets

The formal definition of Fuzzy Petri Nets was proposed in 9-tuple FPN= (P, T, D, I, O, F, α, β, λ) as it explain in Table (3.3)[Hamed *et al.*, 2010].

Table (3.3) Formal Definition of a Fuzzy Petri Nets

FPN= (P, T, D, I, O, f, α, β) where:
P= {p_1, p2,……, p_n} was a finite set of place.
T= {t_1, t2,……, t_m} was a finite set of transition.
D= {d_1, d2,……, d_n} was a finite set of proposition, that interprets fuzzy linguistic variables .P ∩ T ∩ D = ∅, |p|=|D|
I: P→T was the input function, a mapping from places to transition, input incidence matrix
O: T→P was the output function, a mapping from transitions bags to places, input incidence matrix.
f **=$\{\mu_1, \mu_2, \ldots\ldots \mu_n\}$ where μ_i denoted the certainty factor (cf) of rule R_i, which indicate the reliability of the rule R_i ,$\mu i \in [0,1]$ where in some case this value depended on experience of professional.**
A: **P →[0, 1] was an association function, a mapping from place to real values between zero and one.**
β: **T→D was a bijective function, a mapping from place to proposition.**
λ: T →[0, 1] is the function which assigns a threshold λi between zero and one to a transition t_i
These FPRs can be classified into four types as follows:

1. Simple rule: If d_j Then d_k , (CF= μ).
2. Conjunction rule: If d_{j1} AND d_{j2} AND d_{j3} AND……AND d_{jn} Then d_k , (CF= μ).
3. Discojunction rule: If d_{j1} OR d_{j2} OR d_{j3} OR……OR d_{jn} Then d_k , (CF= μ).
4. If d_j Then dk1 AND d_{k2} AND d_{k3} AND……AND d_{kn} , (CF= μ).

Figure (7) explain represented this class with Fuzzy Petri Nets and reasoning with it [Hamed, *et al.,* 2010].

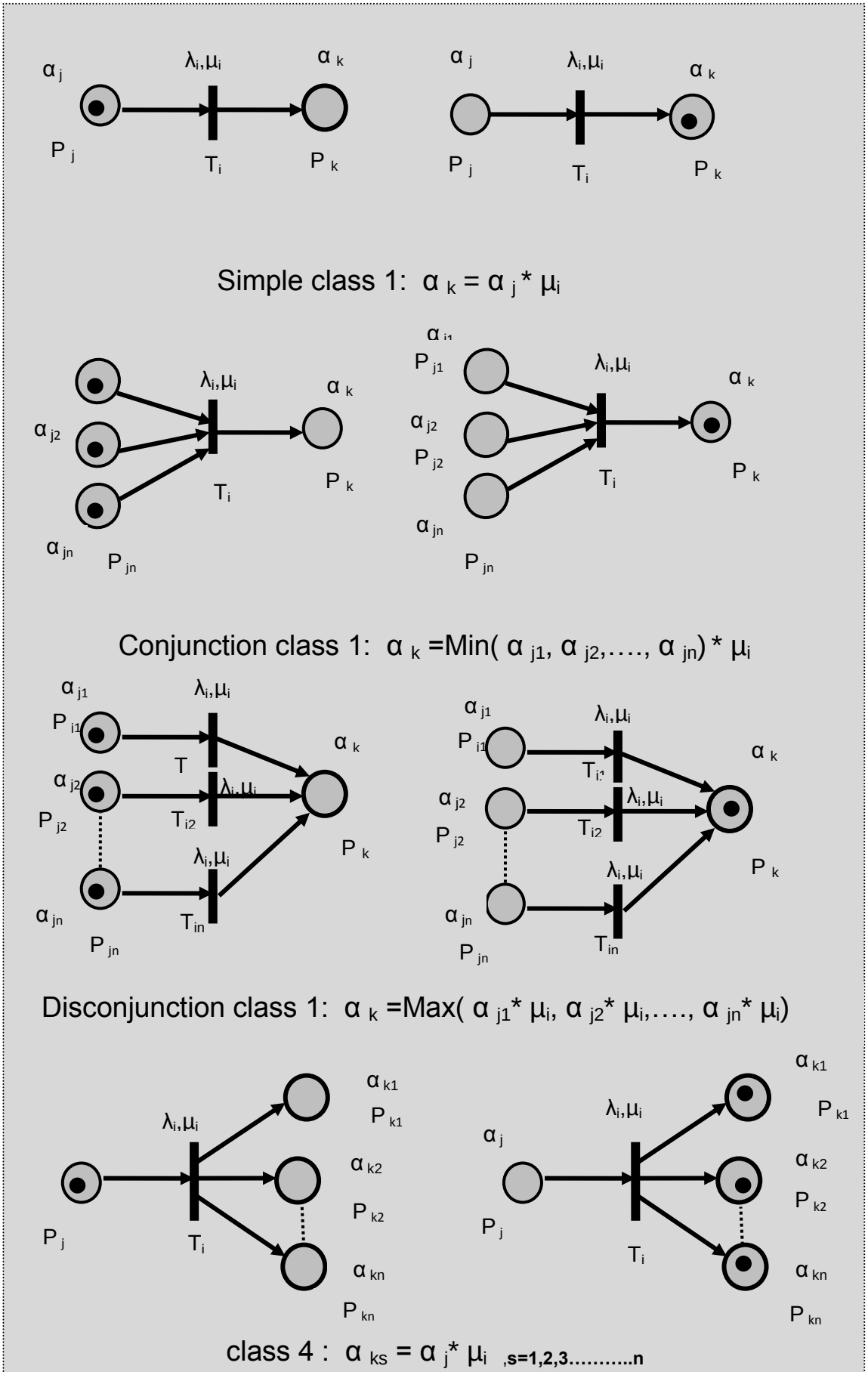


Figure (7) Reasoning and representation in FPN; right side represented before transition firing; left side after transition firing

Patient

Name of The Symptom	Crisp Value
Age	50
Sex	0
Chest Pain	4
Resting Blood Pressure	150
Serum Cholesterol	243
Fasting Blood Sugar	0
ECG	2
Maximum Heart Rate Achieve	128
Exercise Induced Angina	0
Old Peak	2.6
Thal	7
Expert Diagnosis	S4

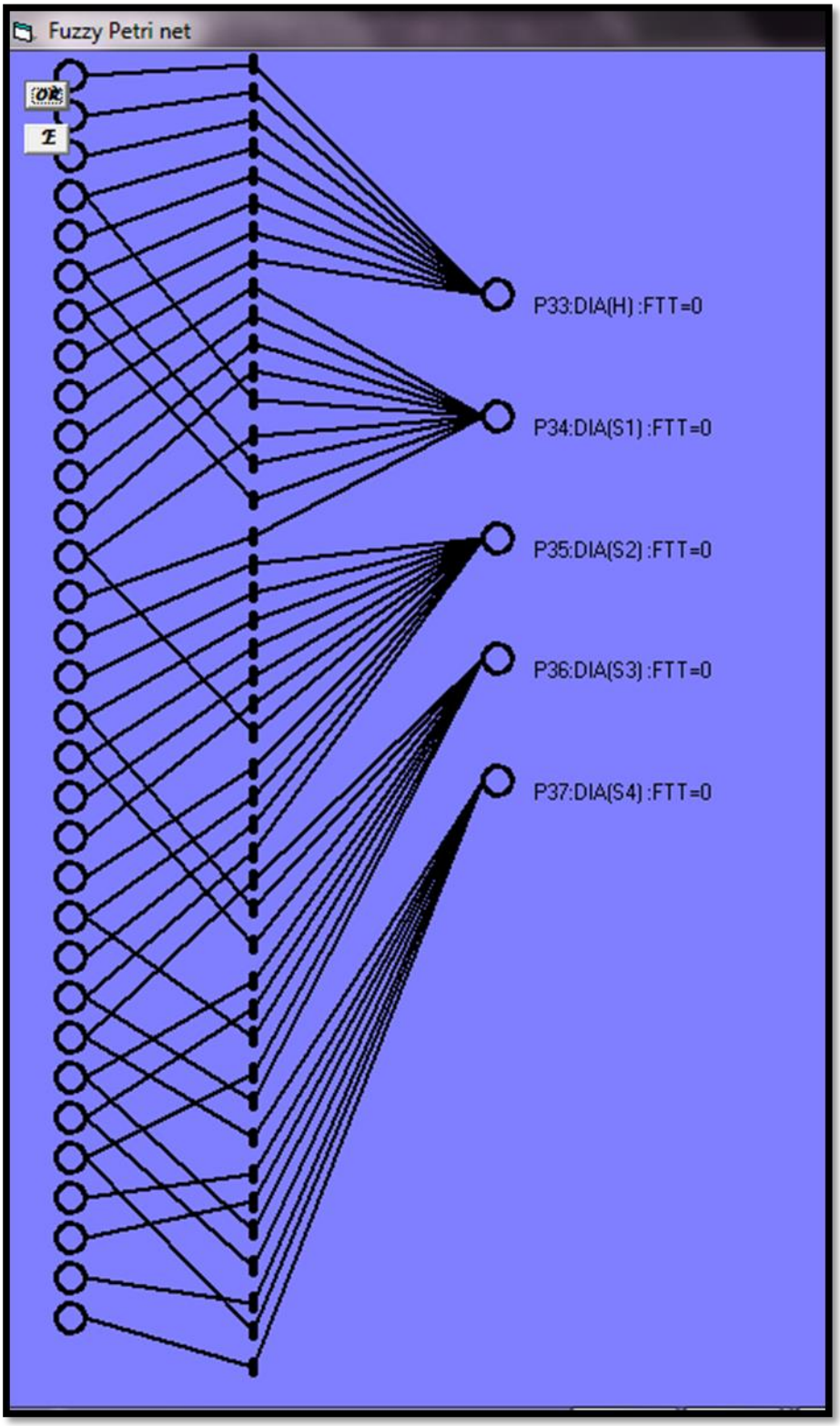


Figure (8) :The FPN Model for Proposed System

The user interface of proposed system for input the symptom of patient is explain in figure (9), this input *first*, *Fuzzification* to get its *membership Degre* and there *linguistics* term, *second*, *Match* with FPN to get the *Fuzzy Truth Token* in input place, as explain in the figure (10).While the figure (11) explain the Fuzzy Reasoning operation and fired transition and the output place's Fuzzy Truth Token.

Figure (9) User Interface of Proposed System for Enter the Symptom of Patient

Figure (10) FPN with Input Place's Fuzzy Truth Token and There Membership Value

Figure (11) FPN after Fuzzy Reasoning Operation

The Fuzzy Truth Tokens of output places are explain in the table (3). Taken Decision is act by diffizification of these values using maximum method [Konar & Mandal, 1996].

Table (3) the Fuzzy Truth Token of FPN

DIA(H)	DIA(S1)	DIA(S2)	DIA(S3)	DIA(S4)
0	0.7639	0.7073	0.8599	0.8826

The Diagnosis = Max (0, 0.7639, 0.7073, 0.8599.0.8826).
The Diagnosis =0.8826 = S4 .
Is obvious that result of the system is matching with the Doctor Diagnosis.

7. Conclusions

In this paper, a Fuzzy Petri Net model is proposed for Diagnosis Heart Disease, Fuzzy Petri Net as graphical tool able to make a visual description of the typical procedure of fuzzy reasoning, and mathematical tool, constructed the reasoning step. In a Fuzzy Petri Net model, both the truth degree of proposition, based on membership of the input, and the reliability of a fuzzy rule, based on experience of expert, should be determined beforehand. The accuracy of the proposed system is 75%. For future work, we plan to use the Fuzzy Petri Net that has ability to learn as neural network for modeling Heart Disease Diagnosis.

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