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X-Gyno: Fuzzy Method based Medical Expert System for Gynaecology

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Abstract

Inflammatory disease is the category which is discussed in this paper, early diagnosis of these diseases will help in proper treatment of the disease. The main disorders considered in this research are, Acute Cerviticis, Chronic Cerviticis, Acute Endometritis, Chronic Endometritis, Atrophic Endometeritis, Acute Salpingo-oophortis, Chronic Salpingo-oophoritis. The method employed is Fuzzy Logic and is implemented in MATLAB. In this research we make use of fuzzy logic to develop the fuzzy system for gynaecology. For testing purpose data of nearly 144 patients has been collected to verify the system. Various results obtained showed that the diagnosis of these disorders corresponding to the symptoms that were selected were successful. The data has been acquired and verified with the help of various experts like from Sanjeevani Hospital, Jalandhar, Arora Hospital, Kartarpur. With all these findings, it makes sure that the system will be beneficial not only in the case of cost effectiveness but also help in saving time and by calculating various values 96.1% of efficiency has been achieved.

Keywords: Acute, Cerviticis, Chronic, Diagnosis, Gynaecology Disorders

1. Introduction

Various medical support systems are available that will provide an aid for decision making in medical diagnosis. Some of the systems which developed during 1970-1980 are -MYCIN (1976), INTERNIST I (1974), PIP, ABEL, ONCOCIN these all were developed using the concepts of artificial intelligence. To improve the quality of the services provided in the field of medical science can be enhanced with the help of computer bases methods. Development of expert system will be based on the human knowledge; this is one of the most emerging fields of Artificial Intelligence. The diagnosis in the field of medical science is based on the identification and recognition of the diseases and the results are based on the appearance of signs and symptoms. As more and more improvements have been done in the field of medical health care, it becomes very hard to extract the important useful information from the available huge information. But we can organize, store as well as access or retrieve the important medical knowledge that will be needed by the doctors for solving the problematic cases and also for regular diagnosis and treatment decisions. As the fields of medical science like Gynaecological diseases involve the imprecise and complicated factors which need to be diagnosed in a proper way. There are several levels of uncertainty in the diagnosis of these diseases, because in this field a single disease may be the result of various symptoms and single symptom may lead to various diseases. The best way to deal with such type of symptoms and diseases is to use fuzzy logic inferences to diagnose the diseases.

For the new practitioners in the field of gynaecology, the use of software will provide an aid to them in easy, early and accurate diagnosis of the disease. In many developing countries, the government are organising various free medical camps in various villages and towns. For such a diagnose we need a software which can work efficiently but within limited time. The software discussed in the paper will provide the efficient results within limited period of time. The software can be used by the medical

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students in the field of gynaecology[1]. As there are various complex and typical cases in the field of gynaecology that are not understood until or unless proper visual work can be done on them. It will help in the better understanding of the various symptoms and corresponding diseases by the medical students and for experts to elaborate easily the concepts using the software.

The overall diseases which are covered in this particular paper are related to the Inflammatory Diseases. First the software will ask for the various symptoms the patient is possessing, and then the software will diagnose the disease on the basis of the available knowledge base[2]. The knowledge base is constructed with the help of various experts and the data has been verified from the various experts. The data is stored in the form of IF-THEN rules, if the antecedent part of the rule is satisfied only then the rule will be fired and its corresponding consequent part will be followed. The consequent part will be the disease that is diagnosed by the system[3]. If there is no result found by the system, then the software will ask for more symptoms and signs and then on the basis of these additional symptoms and signs the system will check for the corresponding rule and again the whole process will be repeated and the disease will be diagnosed[4]. The system will simplifies the work of various gynaecologists as well as can be used for the awareness among the patients. The system is designed using the fuzzy logic toolbox from the MATLAB.

1.1 Background

Various areas of medical field are there where an expert system has been implemented successfully. Diagnosis of the various diseases like ENT diseases, cancer, cardio vascular diseases, diabetes, tumours, endocrine diseases, determination of the risk and diagnosis of the drug doses[5]. There are several expert systems available; one of them is MYCIN which is developed in 1970s by Feigenbaum and his team for diagnosis of the infectious diseases. It provides quick results for the diagnosis of various specimens. It makes use of LISP for implementation and consists of nearly 450 rules[6]. It precisely calculates the dosages and handles the interactions between various drugs[7].

Another various systems like DENDRAL, which is used by the chemists in identifying the structure of various unknown organic molecules, by analysing their mass spectra and using the knowledge of chemistry[8,9]. CADIAG-2 for the internal medicine, MEDICO which is used by various ophthalmologists about the management of diseases like chorioretinal, PUFF is used for the diagnosis of lung disease and also to know the severity level of those diseases[10].

Most of the expert system has been developed but there is no much focus given on the gynaecology field which is the most complex field of medicine[11]. This expert system helps in the diagnosis of gynaecology disorders. This will help various doctors, medical students in diagnosis and understanding the various diseases.

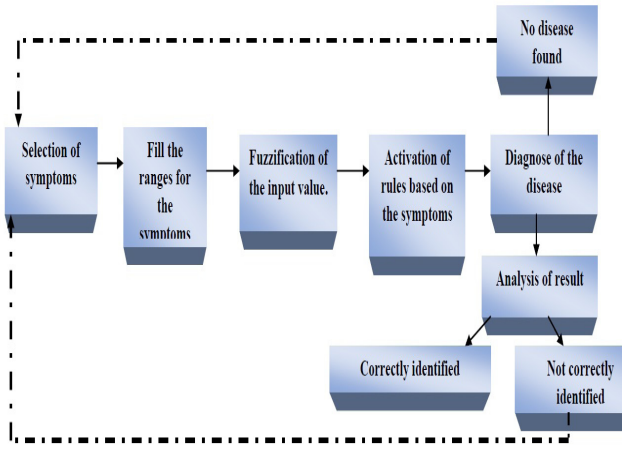

Figure 1. Essential components of ex-gyno system.

2. Material and Methods

In this paper basically we cover about the diseases related to Gynaecology, not of obstetrics[12]. Gynaecology deals with diseases[13] and functions of the women who aren't pregnant while obstetrics deals with the diseases and functions of pregnant women and their unborn children. There are various medical procedures which are used by various gynaecologists are as follows:

- **Laparoscopy:** These types of procedures are used for the diagnosis of cysts and infections of fallopian tubes and ovaries[14,15].
- **Cone biopsies:** To prevent the cancer of cervix the unhealthy cells are removed using this type of procedures.
- **Hysterectomies:** These types of procedures are used when the removal of uterus is to take place.

As, gynaecology is a complex field because it contain various vague symptoms, which needs to be handle with care to diagnose various diseases[16,17]. So, fuzzy logic is being employed for the development of this system.

From the gynaecology field we have worked on the inflammatory field which contain the various diseases like Acute cerviticis, chronic cerviticis, Acute Endometeritis, chronic Endometeritis, Atrophic Endometeritis, Acute salpingo-oophortis, Chronic salpingo-oophortis.

2. Fuzzy Inference System for Ex-Gyno System

Let the input values or input vector will be P= $(P_1, P_2, P_3 \ldots . P_n)$*P and the output values or vectors will be Q=$(Q_1, Q_2, Q_3 \ldots . Q_n)$ A[19]. In the universe of discourse U the linguistic variable i.e. Pi can be characterized as:

$X_1x = \{ X_1x1, X_1x2, X_1x3 \ldots \ldots X_1xk \}$ and $\mu_1x = \{ \mu_1x1, \mu_1x2, \mu_1x3 \ldots \ldots \mu_1xk \}$ where X_x is a term set of P and μ_x be the membership function of the universe of discourse U. For the linguistic variable Y in the universe of discourse W is characterized by:

$X_1Y = \{ X_1v1, X_1y2, X_1y3 \ldots \ldots X_1yk \}$ where A_y is set of Y and μ_{yi} will define the membership functions of the universe of discourse W[18,19].

Mamdami fuzzy inference system is used for this research as it is widely used and is an appropriate for the work and centre of gravitation is used as a method of Defuzzification. Fuzzy Inference System is used for the vague data[20,21]. It provides the mapping (nonlinear mapping) of input vectors into the scalar output values with the help of fuzzy rules defined by the expert[22]. This mapping process involves various steps like:

- Input/output membership Functions need to be defined properly.
- Operators like AND, OR should be properly defined.
- Fuzzy Rules in the form of IF THEN should be defined.
- After defining the IF-THEN rules the output sets need to be aggregated.
- The fuzzified output is converted into the form understand by others should be defuzzified by various methods like Centroid, LOM, MOM etc[23]. The output is generated by the activation of the various rules and hence all the steps mentioned above are mapped to get accurate results.

3. Theory/Calculation

The expert system is developed with the use of fuzzy logic for the diagnosis of the human diseases and analyses of various conditions. Various rules are in the form of IF, IF THEN ELSE form. The knowledge base is built with the various symptoms and their corresponding diseases in the form of rules.

3.1 Knowledge Engineering

Data has been gathered regarding the various inflammatory diseases and their corresponding symptoms. In this paper we have shown seven inflammatory diseases. The data has been gathered from various experts as well as verified from experts and with patient's survey. These seven diseases along with their symptoms Figure 2.

3.2 Notion for Fuzzy Logic

In the rules of knowledge base of rule based systems, fuzzy properties are often connected by logical words like "and", "or", "not". In traditional set theory, these operations correspond to ∧, ∨, ‘. So, we need to extend these operations to fuzzy sets.

3.2.1 A Notation for Fuzzy Sets

When the universe of discourse, P, is considered to be as discrete and finite, fuzzy set for R is shown in Equation 1:

$$R = \left(\frac{\mu A(P1)}{P1} + \frac{\mu A(P2)}{P2} + \cdots\right) = \left(\sum \frac{\mu A(Pi)}{Pi}\right) \quad (1)$$

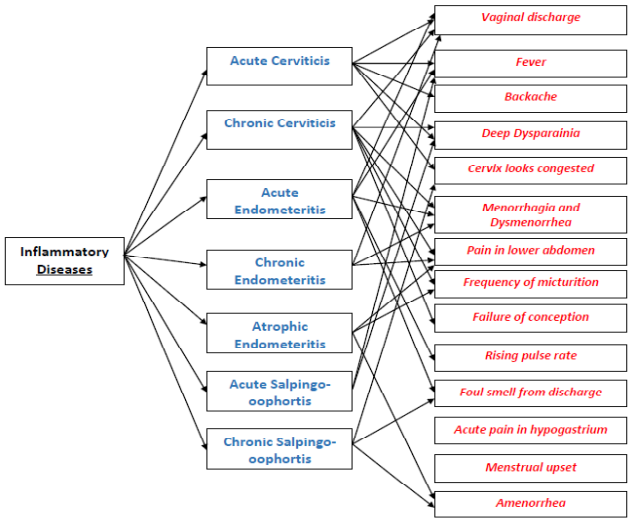

Figure 2. Various diseases with their respective

Set Y can also be demonstrated in the eq2 form, if the universe P is continuous and infinite

$$R = \left\{ \frac{\int \mu \mathbf{A}(p)}{p} \right\} \quad (2)$$

3.2.2 Cosine Amplitude Method

When the data samples are collected they form a data array, P, as shown in Equation 3

$$P = \{p_1, p_2, \ldots \ldots \ldots, p_n\} \quad (3)$$

In data array P, each element Pi is itself a vector of length m is described in Equation 4

$$p_i = \{p_{i_1}, p_{i_2}, \ldots \ldots \ldots, p_{im}\} \quad (4)$$

The Q_{ij} for cosine amplitude method is calculated in Equation 5

$$\mathbf{0} \leq Qij \leq \mathbf{1}$$

$$Q_{ij} = \frac{\left| \sum_{k=1}^{m} x_{ik}\, x_{jk} \right|}{\sqrt{\left(\sum_{k=1}^{m} x_{ik}^2\right)\left(\sum_{k=1}^{m} x_{jk}^2\right)}} \quad (5)$$

where i, j=1,2,……,n.

when two vectors are collinear then it will be unity else it will be zero.

3.2.3 Max-Min Method

The simpler method than cosine amplitude method, which we had used is Max-Min method. Consider the pairs of the data points, x_{ij} , and can be expressed in Equation 6:

$$Q_{ij} = \frac{\sum_{k=1}^{m} min\,(x_{ik}\, x_{jk})}{\sum_{k=1}^{m} max\,(x_{ik}\, x_{jk})} \quad (6)$$

where i, j=1,2,……,n.

3.3 The Fuzzy Model Created for the Ex-Gyno System

The architecture of the Ex-Gyno System is shown in the Figure 1. The main part of the system is knowledge base which contains the various rules. These rules are fired according to the matching of antecedent parts. Some of the rules are described above, which are based on the various symptoms.

Above mentioned in Figure 3, are some of the sample rules related to chronic cerviticis, which is the diseases related to the category of inflammatory diseases. In Figure 4, the representation of rules is shown which is having various symptoms with their different values as input and corresponding to which output will be the different level of disease. In the following figure, we have shown that Vaginal discharge is at level 3.4, Deep dysparania at level 4, Menorrhagia at level 7, Pain in lower abdomen at level 9, Frequency of micturition at level 1 and failure of conception at level 9 then the corresponding disease Chronic Cerviticis at level of 5.67.

Sample membership function has been shown in the following Figure, which shows the various levels of the output membership function. The output membership function for this particular sample is chronic cerviticis.

Different membership functions are used to represent these like for normal, moderate and medium the membership style used is triangular, for severe the memberships function used is trapezoidal.

Furthermore, the following Figure 6 shows the rules for the Atrophic Endometeritis along with the symptoms and their levels and in Figure 7 we have shown the various symptoms like vaginal discharge at level=2, pain in lower abdomen at level=6.1, frequency of micturition at level

Sample Rules

- If (vaginal_discharge is moderate) and (deep_dysparainia is moderate) and (menorrhagia_and_dysmenorrhea is moderate) and (pain_in_lower_abdomen is moderate) and (frequency_of_micturition is moderate) and (failure_of_conception is moderate) then (**chronic_cerviticis is low**)
- If (vaginal_discharge is moderate) and (deep_dysparainia is moderate) and (menorrhagia_and_dysmenorrhea is moderate) and (pain_in_lower_abdomen is moderate) and (frequency_of_micturition is moderate) and (failure_of_conception is severe) then (**chronic_cerviticis is low**)
- If (vaginal_discharge is moderate) and (deep_dysparainia is moderate) and (menorrhagia_and_dysmenorrhea is severe) and (pain_in_lower_abdomen is moderate) and (frequency_of_micturition is severe) and (failure_of_conception is severe) then (**chronic_cerviticis is moderate**)
- If (vaginal_discharge is moderate) and (deep_dysparainia is moderate) and (menorrhagia_and_dysmenorrhea is severe) and (pain_in_lower_abdomen is severe) and (frequency_of_micturition is severe) and (failure_of_conception is moderate) then (**chronic_cerviticis is moderate**)

Figure 3. Sample rules.

=5 and amenorrhea at level =9, corresponding output for these level of symptoms is Atrophic Endometritis at level of 5.69.

Atrophic Endometeritis is basically caused by infection and it is inflammatory condition of the lining of the uterus. The input membership functions are moderate and severe. The FIS Editor is Figure 6 which is represented with various inputs namely: Vaginal discharge, Pain in lower abdomen, Frequency of micturition, amenorrhea. The symptoms has been classified into various categories like moderate and severe, but in case of signs like the congestion of cervix is categorized into the membership function like belief, disbelief or plausibility. Similarly, the output membership functions are also described in Normal, low, medium and severe functions. These functions will describe the level at which particular disease is present and normal will be displayed in those cases where there is no disease. The 3-D representation is shown in Figure 8.

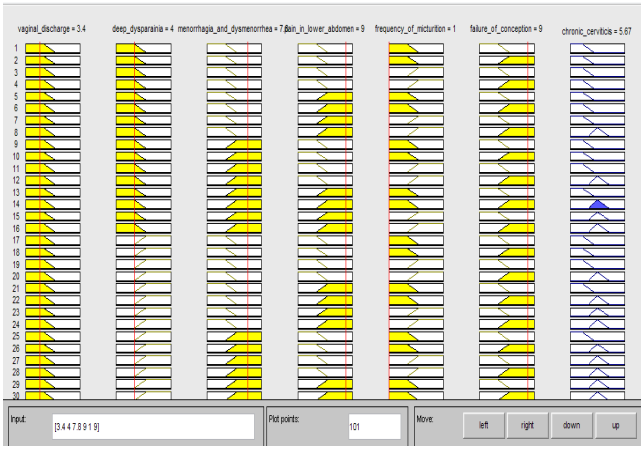

Figure 4. Rule editor for Chronic_Cervicitis.

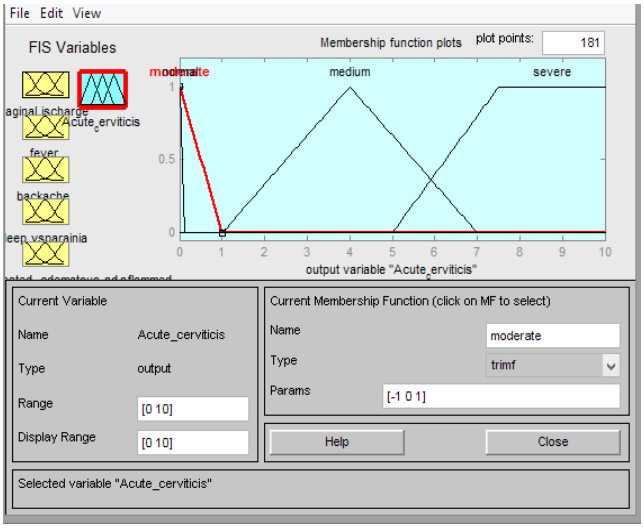

Figure 5. Plot of output membership functions.

4. System Interface

The interface for the Ex-Gyno System is designed in Matlab, various signs and symptoms are listed for which specific values need to be filled by the doctor. The output is obtained in the output box. For this particular scenario, the output obtained is Chronic Cerviticis with level of severity (8.61). User Interface is designed in such a way, that the system can be easily used by the gynaecologist Figure 9. At the left hand side Symptoms are shown whose values need to be filled by the user and output will

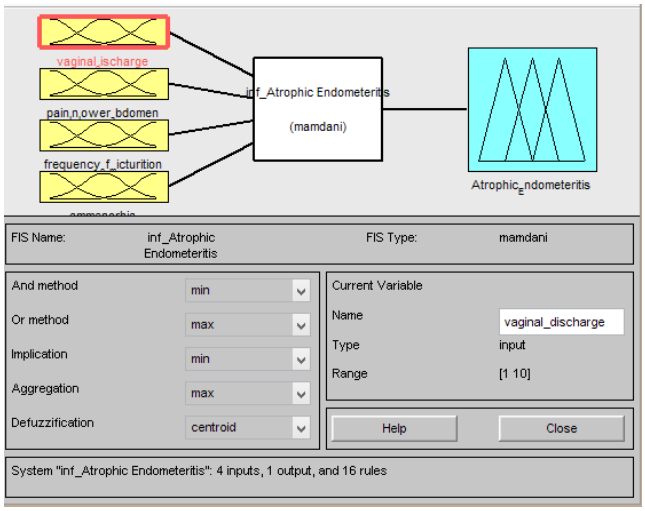

Figure 6. FIS for atrophic endometeritis.

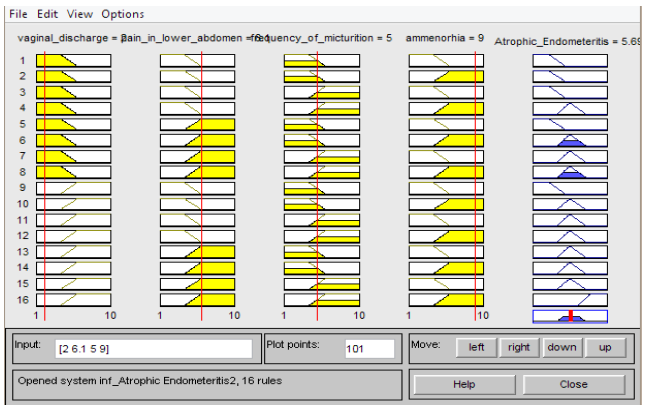

Figure 7. Various rules for atrophic endometeritis.

be displayed on the boxes given at right hand side. The input ranges are also shown on top right hand side.

5. Results

In the field of medical proper diagnosis is one of the most important parts. Various diagnosis tests are performed which are used for the diagnosis of disease and become an essential part of decision making. The decisions are made regarding the medical treatment of such diseases. The various kinds of tests which can be performed are like positive and negative predictive values, sensitivity test and specificity tests. In this particular section the results from various diagnostic tests of Ex-Gyno System are discussed:

5.1 Sample Data

Table 1 represents the result showing the First Stage, Second Stage and Third Stage of the disease corresponding to various symptoms with their specific values as used for Eyes, liver and ENT[24,25]. Tested data is shown in Table 2, 3, 4 and 5, this is a patient data collected from various hospitals.

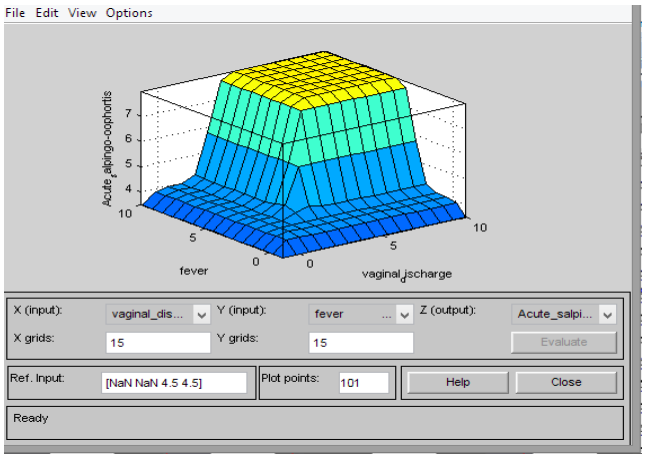

Figure 8. 3D representation for acute Salipango-oophortis.

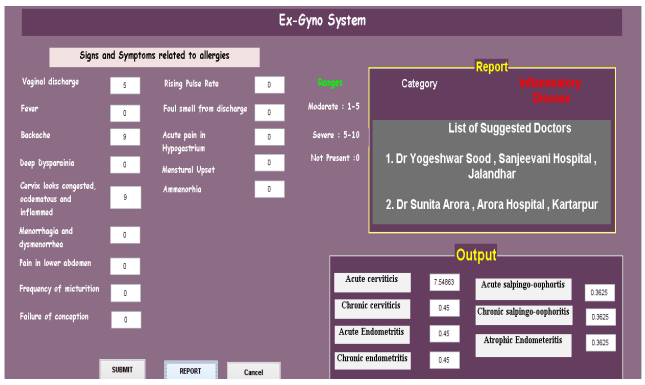

Figure 9. User interface for ex-gyno system.

5.2 Definition of Tests

- **Predictive Value:** These values are the measure in percentage of the times the false positive values or false negative values[24,25]. False Positive means when there is no disease but the system is diagnosis the disease in true terms then it is false positive where as

Table 1. Results for tested data

Sample Testing									
Symptoms(input)						Diseases (Actual output)		Expected output	
Vaginal Discharge	Deep dyspareinia	Menorrhagia and dysmenorrhea	Pain in lower abdomen	Frequency of micturition	Failure of conception	Chronic cerviticis	Chronic endometritis	EPpert's Observaton	Performance
1	4.5	3	7.5	2.05	1	2.63	2.53	cervitics at stage 1	True
9	8.5	7	2.2	2	2	8.61	5.67	cervitics at stage 3	True
5.5	3	0	7	0	0	2.63	4.65	endometeritis at stage 2	True
4	2	2	7	8	9	5.67	2.53	cervitics at stage 2	True
7	2	4	8	2	2	2.53	5.67	endometeritis at stage 2	True
9	0	9.9	0	0	0	2.53	5.67	endometeritis at stage 2	True
8	2	8	8	1	1	5.67	8.61	endometeritis at stage 3	True
1	4.5	3	7.5	2.05	1	2.63	2.53	cervitics at stage 1	False Negative
9	8.5	7	2.2	2	2	8.61	5.67	cervitics at stage 3	True
5.5	3	0	7	0	0	2.63	4.65	endometeritis at stage 2	True

in False Negative when there is a disease but the system is diagnosis no disease then it is consider as False Negative[26].

Mathematically,

Positive Predicitive Value (PPV)

PPV = TP / (TP + FP)

Negative Predictive Value (NPV)

NPV = TN / (TN + FN)

- **Sensitivity:** It can be measured as the percentage that patients with disease present who have a positive test.

  Mathematically,

  Sensitivity = TP / (TP + FN)

- **Specificity:** It can be measured as the percentage of the patients without disease who have negative test.

  Mathematically,

  Specificity = TN / (TN + FP)

The system will be accurate only if it will always give a positive result only in the presence of the diseases, it should not be the case that there is no disease but the system is returning with the presence of disease. As well as the system should show negative results even when there is no disease[5]. But in reality there are some types of errors which may occur and leads to the false positive and false negative errors, to deal with such type of errors the various test like predictive value test has been conducted for the Ex-Gyno system to deal with the false positive and false negative values.

Probability a patient has a disease under consideration of a given test result has been calculated and which is used in the interpretation of diagnostic tests. The 2*2 table has been used to show the diagnostic test results. Table 5 shows the result from an experiment conducted on various patients' data to evaluate the accuracy of the test.

Positive Predicitive Value (PPV)

PPV = TP / (TP + FP) = 88 /(88 + 4) = 0.956

Negative Predicitive Value (PPV)

NPV = TN / (TN + FN) = 50/(50 + 2)=0.961

Sensitivity

Sensitivity = TP / (TP + FN)= 88/(88 + 2)=0.977

Specificity

Specificity = TN / (TN + FP)= 50/(50 + 4)=0.925

By referring the Table 6 the results can be illustrated about the sensitivity, specificity. The PPV value of the test is 95.6%, the NPV value for test is 96.1%, and specificity of the test is 92.5% and sensitivity 97.7%.

Table 2. Sample testing data on inflammatory diseases Part-1

SAMPLE TESTING – Gynaecology Inflammatory Diseases (Part-1)	Symptoms(Input) Diseases												
	Vaginal discharge	Fever	Backache	Deep dysparainia	CerviP looks congested	Menorrhagia and dysmenorrhea	Pain in lower abdomen	Frequency of micturition	Failure of conception	Rising pulse rate	Foul smell from discharge	Acute cerviticis	Chronic cerviticis	Acute Endometritis
	5	9	4	8	4	0	0	0	0	0	0	7.914	0.45	4
	7	0	0	0	0	7.8	4.5	9.9	8	0	0	0.45	0.45	3.97
	9.8	6.9	4	6.7	1.2	0	0	0	0	0	0	7.56	0.40	4.01
	8.7	0	0	6.8	0	7.9	8	0	0	0	0	0.45	0.4	4.21
	9	8	7	1	1	0	0	0	0	0	0	5.01	0.453	4.016

Table 3. Sample testing data on inflammatory diseases Part-2

SAMPLE TESTING – Gynaecology Inflammatory Diseases (Part-2)											
Symptoms(Input) Diseases											
Vaginal discharge	Fever	Deep dysparainia	Menorrhagia and dysmenorrhea	Pain in lower abdomen	Frequency of micturition	Acute pain in hypogastrium	Ammenorhia	Chronic endometritis	Atrophic Endometeritis	Acute salpingo-oophortiss	Chronic salpingo-oophoritis
5	9	8	0	0	0	0	0	0.45	0.36	3.45	0.36
7	0	0	7.8	4.5	9.9	0	0	0.01	1.011	2.01	5.011
9.8	6.9	6.7	0	0	0	0	0	0.45	0.3	4.0	0.31
8.7	0	6.8	7.9	8	0	0	0	0.451	3.01	8.08	0.08
9	8	1	0	0	0	0	0	3.44	0.31	0.3	0.3

Table 4. Patient data on inflammatory diseases

SAMPLE PATIENT TESTING – Inflammatory Diseases (Part-1)												
Symptoms(Input) Diseases												
Fever	Backache	Deep dysparainia	CerviP looks congested	Menorrhagia and dysmenorrhea	Pain in lower abdomen	Frequency of micturition	Failure of conception	Rising pule rate	Foul smell from discharge	Acute cerviticis	Chronic cerviticis	Acute Endometritis
Severe	Modearte	Severe	Moderate	NIL	NIL	NIL	NIL	NIL	NIL	Third Stage		
NIL	NIL	NIL	NIL	Severe	Modearte	Severe	Severe	NIL	NIL			Second Stage
Severe	moderate	moderate	Mild	NIL	NIL	NIL	NIL	NIL	NIL	Third Stage		
NIL	NIL	Moderate	NIL	Severe	Severe	NIL	NIL	NIL	NIL			Second Stage
Severe	Severe	Mild	Mild	NIL	NIL	NIL	NIL	NIL	NIL	Second Stage		

Table 5. Patient's data

System Testing on Patient's data							
Symptoms(input) Diseases(output)							
vaginal discharge	menorrhagia and dysmenorrhea	pain in lower abdomen	fever	rising pule rate	Foul smell from discharge	Chronic endometritis	Acute Endometritis
Moderate	Moderate	Low	NIL	NIL	NIL	Second stage	
Low	Low	moderate	NIL	NIL	NIL	First stage	
Moderate	Low	Low	NIL	NIL	NIL	First stage	
Moderate	Moderate	moderate	NIL	NIL	NIL	Third stage	
Low	Moderate	NIL	moderate	Moderate	Low		Second stage
Moderate	Moderate	NIL	low	Moderate	moderate		Third stage
Low	Low		moderate	Low	Low		First stage
Moderate	Low	Low	NIL	NIL	NIL	First stage	

Table 6. Sample test results

Test T(Ex-Gyno)	Disease Present D+	Disease Absent D-
Test Positive (T+)	True Positives (TP=88)	False Positive (FP= 4)
Test Negative (N-)	False Negatives (FN=2)	True Negatives (TN=50)
Total	90	54

6. Conclusion

This fuzzy based approach is very helpful in the diagnosis of the diseases which contain the vague values for the symptoms, especially in the field of gynaecology. Various other parts of the gynaecology can also be covered by the same method as discussed in this paper or by some other bio-inspired methods that are appropriate to deal with. The system will help various physicians and gynaecologists in the process of disease diagnose. There are various categories of gynaecology like sexually transmitted diseases, tumours, cancers etc. which can be covered in further researches.

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