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X-TUMOUR: FUZZY RULE BASED MEDICAL EXPERT SYSTEM TO DETECT TUMOURS IN GYNAECOLOGY

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Abstract: Medical expert systems are designed to help various physicians in diagnosis of various diseases. The medical expert system makes use of various facts about various diseases to make decisions regarding various diagnoses of diseases. The major problem in most of women is related to Tumours. The main Tumours considered in this research are: Adenomyosis, Myoma, Carcinoma, Endometrial, Sacroma of uterus, Choriocarcinoma of vagina. In this research we make use of fuzzy logic to develop the fuzzy system for Tumours in the field of gynaecology. Various results obtained showed that the diagnosis of these Tumours corresponding to the symptoms that were selected were successful. 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. The medical data and the expert comments are taken from Sanjeevani Hospital, Jalandhar.

Key Words: Gynaecology disorders, Sacroma of uterus, Cancer tumours

1. INTRODUCTION

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. From the mid -70's the research in medicine field had started by using the various techniques of soft computing. 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. The diagnosis in the field of medical science is based on the identification and recogonization 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. Expert System (ES) from the artificial intelligence field is one of the most important tools which can used to provide aid to the doctors. Expert systems can make use of user facts and rules, based on such knowledge base the results can be generated .This particular knowledge base is designed with the help of an expert. The knowledge of expert plays an important role in the case of expert system, as whatever the knowledge is provided by the expert that will be

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stored in knowledge base and that particular knowledge base is used for decision making process. The interfaces designed for such a system needs to be user friendly, as the user/doctor may need to interact with the system without wasting time in learning the system. The interface should be such that it would be easy to learn, easy to use and should be efficiently designed such that the for experts it may be provide effective results.

From the survey done in 2014 it has been found that nearly 54,870 women in the United States suffered from the Tumours(endometrial).It has been founded that nearly 10,170 women died because of late diagnosis of the Tumours[8]. So, the main aim of this research is for the diagnosis of Tumours in the field of Gynaecology.

As it is difficult to diagnose tumours related to the gynaecology field ,because in this case ,it contain the vague values, mixture of various symptoms ,which may point toward multiple further diseases and tumours. Not only diagnose of the tumour is the main goal of this paper, but also the stage at which the tumour is present in the body of women. The best way to deal with such type of symptoms and tumours 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 tumours. In many developing countries, the government are organising various free medical camps in various villages and towns. For such a diagnose their 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 students in the field of gynaecology [3].As there are various complex and typical cases in the field of gynaecology that are not understood until or unless visual work can be done on them. It will help in the better understanding of the various symptoms and corresponding tumours by the medical students. Even the professors will found very easy to elaborate the concepts using the software.

The overall diseases which are covered in this particular paper are related to the Tumours of female reproductive system. First the software will ask for the various symptoms the patient is possessing, and then the software will diagnose the tumour and the stage at which the tumour is present on the basis of the available knowledge base. 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 tumour and its stage that is diagnosed by the system. 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. 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.

2. REVIEW LITERATURE

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. 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. It precisely calculates the dosages and handles the interactions between various drugs.

Another various systems like DENDRAL, which is used by the chemists in identifying the structure of various unknown organic molecules, by analyzing their mass spectra and using the knowledge of chemistry [1], 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.

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 [9, 10]. This expert system helps in the diagnosis of gynaecology disorders. This will help various doctors, medical students in diagnosis and understanding the various diseases.

3. BACKGROUND

3.1 Tumours of female reproductive system

In the field of gynaecology tumours are the one of the most common and problematic part because diagnose of the tumours is one of the biggest challenge faced by the gynaecologist. If the proper diagnose of the tumour is not done at right time then it may even lead to the death of patient. So there is need of software which will help in the proper diagnose of the tumour at its very early stages, so that it could be treated well. There are basically two type of tumours namely: Benign and Malignant tumours.

Benign Tumours: Cells in the case of benign tumours do not travel to other parts of the body. So these tumours are less harmful as compare to malignant tumours.

Malignant Tumours: These are cancerous type of tumours which comprises of the cells which may grow out of control and travel and effect others parts of the body too.

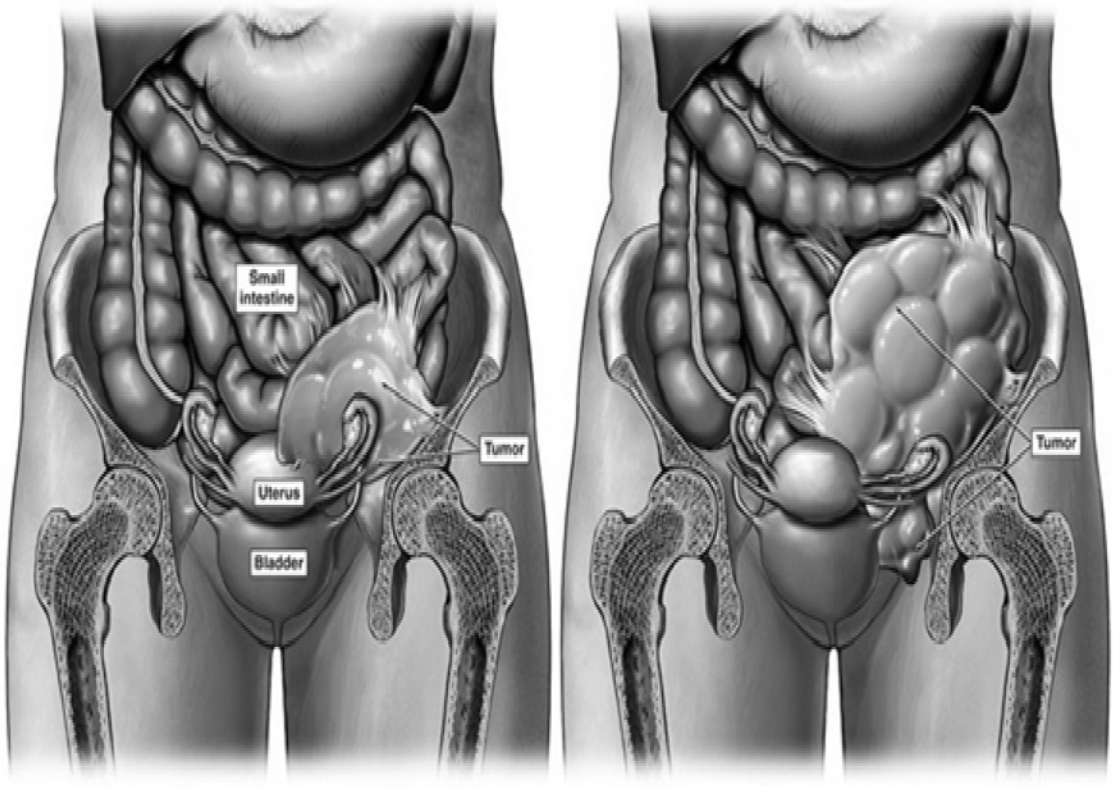

Figure 1: Showing Tumours in reproductive system of female [6]

As, Tumours are is a complex because it contain various vague symptoms ,which needs to be handle with care to diagnose various level and type of Tumour. So fuzzy logic is being employed for the development of this system.

From the gynaecology field we have worked on the Tumours which contain the various Tumours like **Adenomyosis, Myoma, Carcinoma, Endometrial, Sacroma of uterus, Choriocarcinoma of vagina.**

3.2 Expert System and fuzzy method

Expert systems can make use of user facts and rules, based on such knowledge base the results can be generated .This particular knowledge base is designed with the help of an expert. The knowledge of expert plays an important role in the case of expert system, as whatever the knowledge is provided by the expert that will be stored in knowledge base and that particular knowledge base is used for decision making process. The interfaces designed for such a system needs to be user friendly, as the user/doctor may need to interact with the system without wasting time in learning the system. The interface should be such that it would be easy to learn, easy to use and should be efficiently designed such that the for experts it may be provide effective results.

- **Knowledge Base:** It contains the knowledge gathered from the various experts regarding the symptoms, type and various levels of the tumours. The data has been verified by various experts. So it contains the results of multiple expertises.
- **Inference Engine:** Inference engine is an invisible part of an expert system; it comes into role only when the user provides input to the system. Then, expert system comes into an active state.
- **Agenda:** It may comprise of the active rules. The rules whose antecedent part matches are queued and this particular queue is known as Agenda.
- **User Interface:** It is designed so that the non technical persons like practitioners don't feel any type of difficulty in using the expert system.

3.3 Fuzzy Inference System for Ex-Tumour System

Let the input values or input vector will be X=$(X_1, X_2, X_3 \ldots . X_n)$*A and the output values or vectors will be Y=$(Y_1, Y_2, Y_3 \ldots . Y_n)$A .In the universe of discourse U the linguistic variable i.e Xi can be characterized as :

$A_x = \{ A_{x1}, A_{x2}, A_{x3} \ldots \ldots A_{xk} \}$ and$\mu_x = \{ \mu_{x1}, \mu_{x2}, \mu_{x3} \ldots \ldots \mu_{xk} \}$ where A_x is a term set of X and $\mu_x$be the membership function of the universe of discourse U. For the linguistic variable Y in the universe of discourse W is characterized by:

$A_Y = \{ A_{y1}, A_{y2}, A_{y3} \ldots \ldots A_{yk} \}$ where A_ya term is set of Y and μ_{yi} will define the membership functions of the universe of discourse W [5, 13].

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.

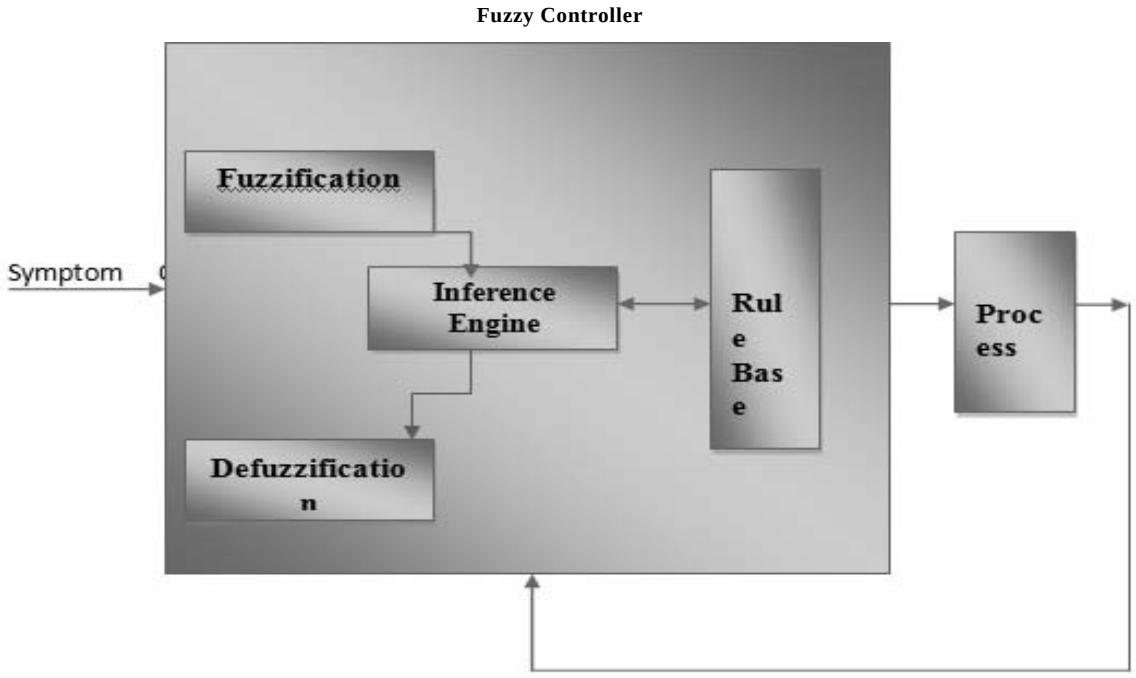

Figure 2: Showing the process of Fuzzification of Ex-Tumour System

Fuzzy Inference System is used for the vague data .It provides the mapping (nonlinear mapping) of input vectors into the scalar output values with the help of fuzzy rules defined by the expert. This mapping process involves various steps like:

1. Defining the Input/output membership functions.
2. Fuzzy logic operators
3. If then Fuzzy Rules
4. Aggregation of output sets
5. Defuzzification

The output is generated by the activation of the various rules and hence all the steps mentioned above are mapped to get accurate results.

4. PROPOSED METHODOLOGY

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

Data is gathered on the basis of various categories of the diseases and their related symptoms.

4.1 Knowledge Engineering

Data has been gathered regarding the various inflammatory diseases and their corresponding symptoms. In this paper we have shown seven inflammatory diseases. These seven diseases along with their symptoms are shown in table 1.

Table 1
Showing various Tumours and their symptoms

Tumours	*Symptoms*
Adenomyosis	▪ heavy, prolonged menstrual bleeding ▪ severe menstrual cramps ▪ abdominal pressure and bloating
Myoma	▪ Prolonged menstrual periods ▪ pelvic pressure or pain ▪ Frequent urination ▪ difficulty emptying bladder ▪ painless mass in lower abdomen
Endometrial Carcinoma	▪ pelvic pressure or pain ▪ Vaginal bleeding after menopause ▪ bleeding between periods ▪ abdominal discharge from vagina ▪ pain during intercourse
Sacroma of uterus	▪ blood stained offensive vaginal discharge ▪ palpable mass in lower abdomen ▪ pain in lower abdomen
Choriocarcinoma of vagina	▪ intermittent heavy vaginal bleeding ▪ brownish vaginal discharge ▪ Anaemic ▪ swelling of vulva ▪ pregnancy hormone(HGC) Level

4.2 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.

A notation for fuzzy sets when the universe of discourse, X, is considered to be as discrete and finite, is as follows for fuzzy set Y:

$$Y = \left(\frac{\mu A(x1)}{x1} + \frac{\mu A(x2)}{x2} + \cdots..\right) = \left(\sum \frac{\mu A(xi)}{xi}\right)$$

Set Y can also be demonstrated in the following form, if the universe X is continuous and infinite:

$$Y = \left\{\frac{\int \mu A\,(x)}{x}\right\}$$

Cosine Amplitude Method

When the data samples are collected they form a data array,

$$X = \{x_1, x_2, \ldots\ldots\ldots, x_n\}$$

In data array X, each element xi is itself a vector of length m is described as follows:

$$x_i = \{x_{i1}, x_{i2}, \ldots\ldots\ldots., x_{im}\}$$

The r_{ij} for cosine amplitude method is calculated as:

$$0 \leq rij \leq 1$$

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

where i ,j=1,2,…….,n.

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

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 as:

$$r_{ij} = \frac{\sum_{k=1}^{m} min\left(x_{ik}\, x_{jk}\right)}{\sum_{k=1}^{m} max\left(x_{ik}\, x_{jk}\right)}$$

where i , j=1,2,……,n.

4.3 The fuzzy model created for the Ex-Tumour System

The architecture of the Ex-Tumour System is shown in the Figure 2.The main part of the system is knowledge base which contain the various rules. These rules are fired according to the matching of antecedent parts. Some of the rules are as follows, which are based on the various symptoms:

Some of the sample rules related to various types of tumours are given on next page.Various further rules are illustrated in this research that comprises of various more symptoms in their moderate and severe sense, corresponding to which there are various types and stages of tumours.

Sample Rules

- If (heavy,prolonged_menstrual_bleeding is moderate) and (severe_menstrual_cramps is moderate) and (abdominalpressure_and_bloating is moderate) then **(Adenomyosis is stage_1)**
- If (heavy,prolonged_menstrual_bleeding is severe) and (severe_menstrual_cramps is moderate) and (abdominalpressure_and_bloating is moderate) then **(Adenomyosis is stage_1)**
- If (heavy,prolonged_menstrual_bleeding is severe) and (severe_menstrual_cramps is severe) and (abdominalpressure_and_bloating is severe) then **(Adenomyosis is stage_3)**
- If (blood_stained_offensive_vaginal_discharge is moderate) and (palpable_mass_in_lower_abdomen is moderate) and (pain_in_lower_abdomen is moderate) then **(sarcoma_of_uterus is stage_1)**
- If (blood_stained_offensive_vaginal_discharge is severe) and (palpable_mass_in_lower_abdomen is moderate) and (pain_in_lower_abdomen is severe) then **(sarcoma_of_uterus is stage_2)**
- If (blood_stained_offensive_vaginal_discharge is severe) and (palpable_mass_in_lower_abdomen is severe) and (pain_in_lower_abdomen is severe) then **(sarcoma_of_uterus is stage_3)**
- If (pelvic_pressure_or_pain is moderate) and (vaginal_bleeding_after_menopause is moderate) and (bleeding_between_periods is moderate) and (abnormal_bloody_discharge_from_vagina is severe) and (pain_during_intercourse is moderate) then **(Endometrial_Carcinoma is stage_1)**

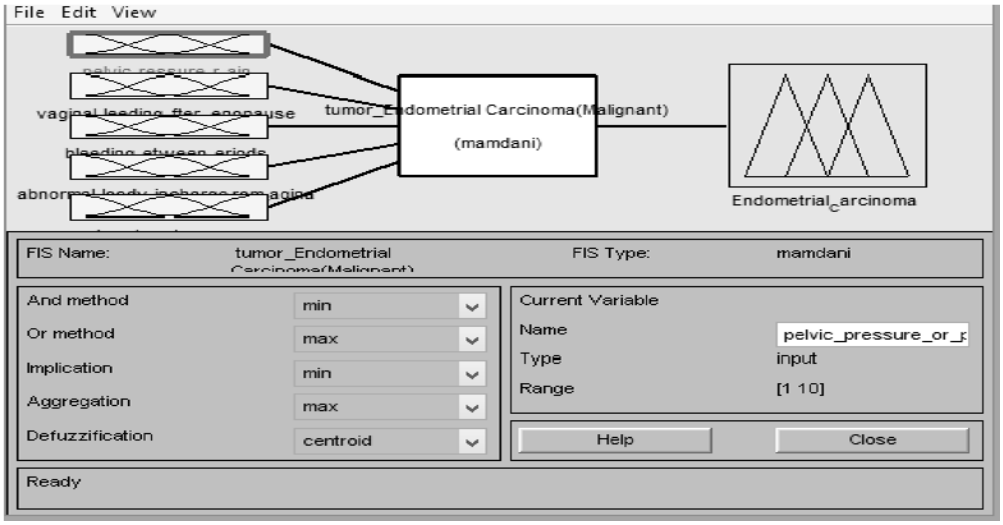

Figure 4: Showing FIS Editor(Inputs as Symptoms, Output as Tumour)

In **Figure 5 ,** 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 tumour.In the following Figureure, we have shown that **pelvic pressure or pain** is at level 2, **Vaginal bleeding after menopause** at level 3, **bleeding between periods** at level 6, **abdominal discharge from vagina** at level 9.5, **pain during intercourse** at level 8 then the corresponding disease **Endometrial Carcinoma** at level of 5.67.

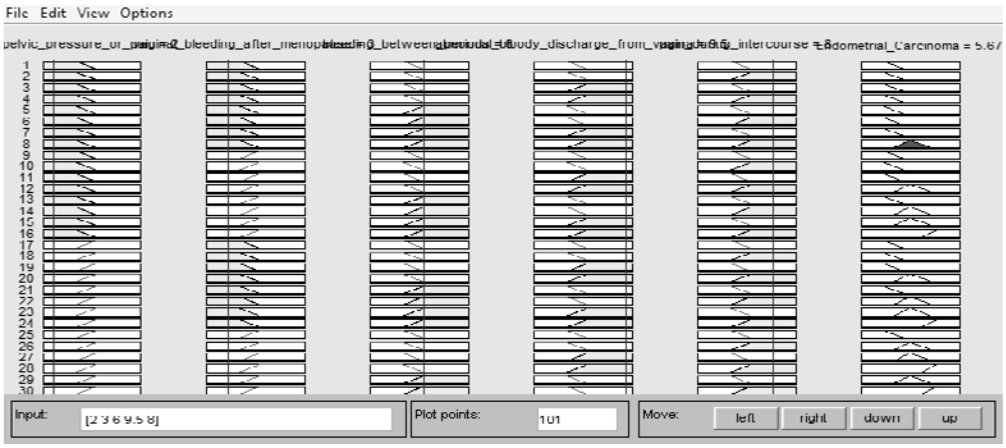

Figure 5: Showing Rule Editor for Endometrial Carcinoma

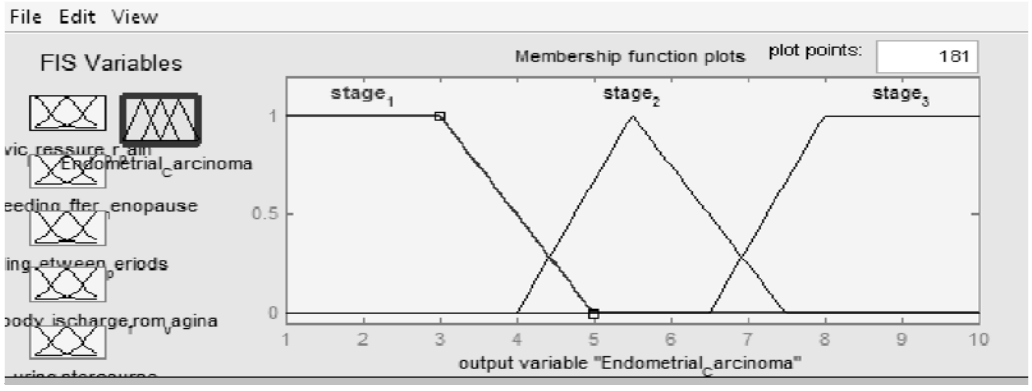

Figure 6: Showing several Stages of Endometrial Carcinoma

Furthermore,the following **Figure 6** shows the rules for the Adenomysis along with the symptoms and their levels and in **Figure 7** we have shown the various symptoms like **heavy,prolonged menstrual bleeding** at level=2, **severe menstural cramps** = 6.1, **abdominal pressure and bloating** at level =5 then Adenomyosis will be at level =3.97.

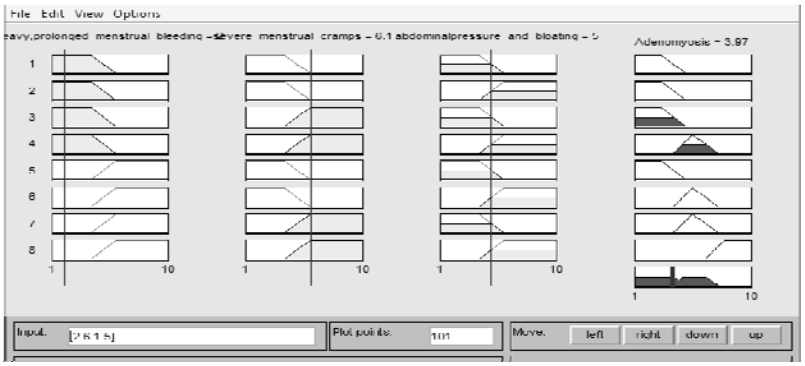

Figure 7: Showing rule Editor for Adenomyosis

5. DIAGNOSTIC POWER OF EX-TUMOUR SYSTEM

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 kind 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-Tumour System are discussed:

Table 2
Showing sample results

Sample Testing									
Symptoms(input)						*Diseases (Actual output)*		*Expected output*	
heavy,prolonged menstrual bleeding	Severe menstural cramps	abdominal pressure and bloating	blood stained offensive vaginal discharge	palpable mass in lower abdomen	pain in lower abdomen	Adenomyosis	Sacroma of uterus	Expert's Observaton	Performance
1	4.5	3	7.5	2.05	1	3	2.5	Adenomyosis at stage 1	TRUE
9	8.5	7	2.2	2	2	9	5.7	Adenomyosis at stage 3	TRUE
5.5	3	0	7	0	0	3	4.7	Sacrcoma at stage 2	TRUE
4	2	2	7	8	9	6	2.5	Adenomyosis at stage 2	TRUE
7	2	4	8	2	2	3	5.7	Sacrcoma at stage 2	false positive
9	0	9.9	0	0	0	3	5.7	Sacrcoma at stage 2	TRUE
8	2	8	8	1	1	6	8.6	Sacrcoma at stage 3	TRUE
10	4.9	9.9	3.3	6	8	7	5.7	Adenomyosis at stage 2	TRUE
1.6	4	8	7	2	1	3	4	Sacrcoma at stage 1	TRUE
4.9	1	5	9	3	7	4	5.4	Sacrcoma at stage 2	TRUE

5.1 Sample Data

Table 2 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 [2, 14]. False positive and false negative results have been highlighted

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. 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 in False Negative when there is a disease but the system is diagnosis no disease then it is consider as False Negative [4,12].

Mathematically,

Positive Predictive 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 can show negative results in which it will display the positive cases without present of disease. But in reality, there exist some type 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-Tumour 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 shows the result from an experiment conducted on various patient data to evaluate the accuracy of the test.

Positive Predictive Value (PPV)

$PPV = TP / (TP + FP) = 209 /(209 + 7) = 0.96$

$NPV = TN / (TN + FN) = 321/(321 + 21)=0.93$

Sensitivity

$Sensitivity = TP / (TP + FN)= 209/(209 + 21)=0.90$

Specificity

$Specificity = TN / (TN + FP)= 321/(321 + 7)=0.97$

By referring the table 2 the results can be illustrated about the sensitivity, specificity. The PPV value of the test is 96%, the NPV value for test is 93%, specificity of the test is 97%(321 negative results out of 328 women) and sensitivity 90%(209 positive results out of 230 women).

Table 3
Sample Test Results

Test T	*Disease Present D+*	*Disease Absent D-*	*Total*
Test Positive (T+)	True Positives (TP=209)	False Positive (FP= 7)	216
Test Negative (N-)	False Negatives (FN=21)	True Negatives (TN=321)	342
Total	230	328	558

6. DISCUSSIONS AND CONCLUSION

In this paper we had discussed about the expert system which will help in the diagnosis of various Tumours and the level of the tumour. The diagnose process needs to be an accurate one in the field of medical care. Some the computer aided expert system is widely used in the decision making process which leads to better decisions. This fuzzy based approach is very helpful in the diagnosis of the Tumours which contain the vague values for the symptoms, especially in the field of gynaecology. Other organ parts of the gynaecology can be covered by the same method as discussed in this paper as well as by some other bio inspired methods which are appropriate to deal with. The system will help various physicians and gynaecologists in the process of tumours diagnose. There are various categories of gynaecology like sexually transmitted diseases, inflammatory diseases etc which can be covered in further researches.

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