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Hybrid Expert System for Wheat Diseases Diagnosis Using Fuzzy Logic, Neural Network and Bayesian Method

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Abstract

Expert system is a branch of Artificial Intelligence is a collection of programs which has the ability to reason, justify and answer the queries in a particular domain as a human expert would do. It can be applied to various fields. This research was designed hybrid expert system for the diseases diagnosis of wheat rust by incorporating application of fuzzy logic, neural networks and Bayesian method. The research aim is to tackling the control and remedial measures for disease management for the wheat diseases. The expert system is intended to help the farmers, researchers and students and provides an efficient goal-oriented approach for solving common problems of wheat rust. The system gives results that are correct and consistent.

Keywords: Wheat Disease Diagnosis, Expert System, Knowledge Based, Fuzzy Logic, Neural Network, Bayesian Methods**.**

نظام خبير هجين لتشخيص امراض القمح باستخدام المنطق المضبب، الشبكات العصبية وطريقة بايسن

وجدان رشيد عبد الحسين
كلية علوم الحاسوب والرياضيات- جامعة ذي قار

الخلاصة

النظام الخبير هو فرع من فروع الذكاء الاصطناعي هو عبارة عن مجموعة من البرامج التي لديها القدرة على التفكير المنطقي، وتبرير الإجابة على الاستفسارات في مجال معين كما يفعل الانسان الخبير، حيث يمكن تطبيقه في مختلف المجالات. في هذا البحث تم تصميم نظام خبير هجين لتشخيص امراض صدأ القمح من خلال دمج طريقة المنطق الضبابي وتطبيق الشبكات العصبية وطريقة بايسن. ويهدف هذا البحث إلى مراقبة و اعطاء التدابير العلاجية لا إدارة امراض القمح .هذا النظام يكون موجه لمساعدة المزارعين والباحثين والطلاب حيث يوفر النظام طريقة كفؤة وموجهة لحل المشاكل الشائعة لمرض صدأ القمح. النظام يعطي نتائج تكون صحيحة ومتسقة.

الكلمات المفتاحية: تشخيص مرض القمح ، النظم الخبيرة، وبناء المعرفة والمنطق الضبابي، الشبكات العصبية، طرق النظرية الافتراضية.

1- Introduction

An expert system is a collection of software developed for a particular area of domain aimed to suggest solutions to problems in the way as human experts pertaining to that field would solve. It has some main components, i.e., user interface, expert system database, knowledge acquisition facility, and inference mechanism. In addition, there is another component in some expert systems, i.e., explanation facility. Due to its versatility it is fast emerging as a discipline with great potential for research and development (Elaine *et.al*,2010 :Tilotma *et.al*,2013: Dan ,2010).Due to the diseases that attack the crop at various stages of its growth, it is crucial to devise an efficient way to tackle the problem. Combined with the expertise of the agricultural scientist and experience of the farmers, technology can be blended to revolutionize the agronomic practices . Disease management can be defined as the series of agronomic practices to be followed so as to minimize the produce loss due to disease. 'Integrated Disease Management' involves the selection and application of a harmonious range of disease control strategies that minimize losses and maximizes returns. Expert systems has found a wide spectrum of application across many domains such as nursing care and medicine, natural resources management, agriculture, process control, technology in design and manufacturing, remote sensing and project management- just to name a few (Zhiqing et.al 2009:Tang et.al 2009).

2-Fuzzy Logic

Fuzzy logic is a set of mathematical principles for knowledge representation based on degrees of membership rather than the crisp membership of classical binary logic. Fuzzy logic provides an appropriate framework for the representation and use of imprecise medical concepts. Inexact medical entities can be modeled by fuzzy sets. Fuzzy relations enable the representation of uncertain medical associations. In addition, fuzzy logic enables the very smooth and useful way of knowledge representation that is rule based, which is an appropriate structure for systems related to diseases. The effectiveness of this method for diagnostic support has been proved by many successful applications of fuzzy concepts in different fields such as technology, economies and medicine. The approach used in this research is aimed at improving the prediction by handling uncertain and ambiguous variations found in health parameters using a fuzzy linguistic approach. Since it is easier to convert exact information into linguistic form than vice versa, we consider the major linguistic properties small, medium, and large as the attributes of the input feature. Any input feature value can be described in terms of some combination of membership values for these properties (S.Rajasekaran et.al, 2006: George et.al,1995)

3-Fuzzy Expert System

The success of a Fuzzy Expert System depends upon the opinion of the domain experts on various issues related to the study. The domain experts identified were from Specialist. The developed Fuzzy Expert System for the Management of diseases has an architecture presented in Figure 1 below:

The development system involves fuzzification, inference engine and defuzzification. The Fuzzy Expert System is a decision support system that provides decision support platform to health care researchers in tropical medicine. The designed system is a rule based system that uses fuzzy logic rather that Boolean logic. It was developed based on the following key components (Michael ,2005).

- Knowledge-Base component.
- Fuzzification Component.
- Inference Engine Component.
- Defuzzification Component.

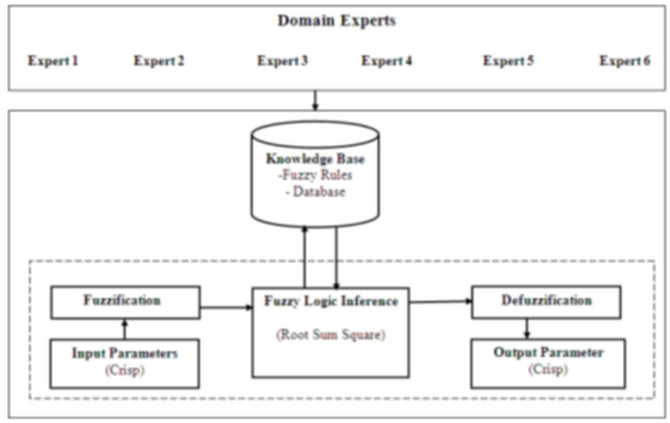

Figure 1: Architecture of the System

4-Data Collection

The data is collected from various sources including agricultural institutes, research institutes and farmers. The photographs taken can be uploaded as a tool for visual confirmation to clearly identify the disease rather than the verbal description of the disease. This is the striking feature which helps the expert system to focus on the disease and hence proceed to the recommendations (http://kenanaonline.com/users/abeer1254/posts/107868 , http://wheat.pw.usda.gov/ggpages/wheatpests.html)

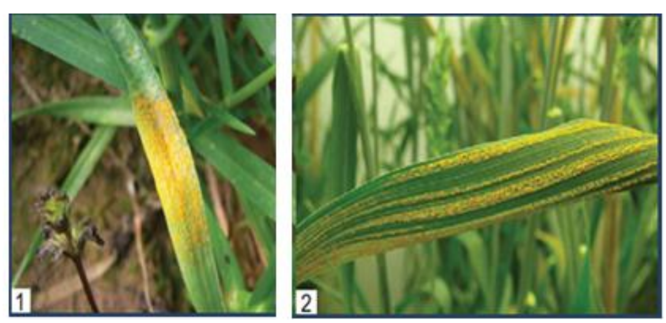

Figure 2.Yellow rust

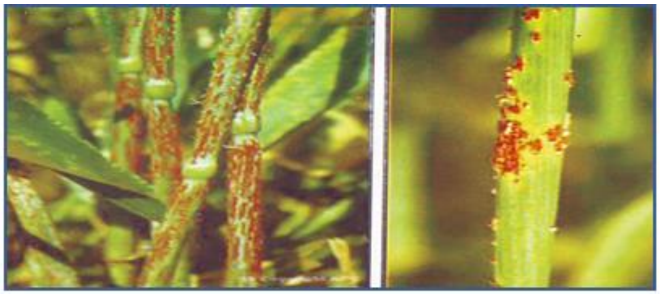

Figure 3.Steam rust

Figure **4.**Leaf rust

4.1 Sample of input variables with their membership functions

1- Pimples Color(Y)

Table 1. classification of pimples color

INPUT FIELD	RANGE	FUZZY SETS
Pimples Color	0-3 2-7 6-10	Yellow(B1) Brown(B2) Sepia(B3)

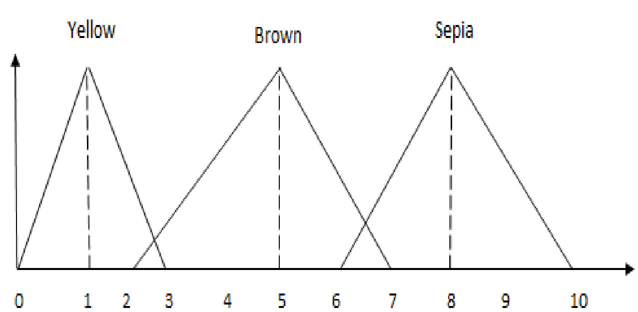

Figure.5.Membership Function of Pimples Color

2-Pimples form(Z)

Table 2. Classification Of Pimples Form

INPUT FIELD	RANGE	FUZZY SETS
Pimples Form	0-4 3-7 6-10	Irregular(C1) Semicircular(C2) Circular(C3)

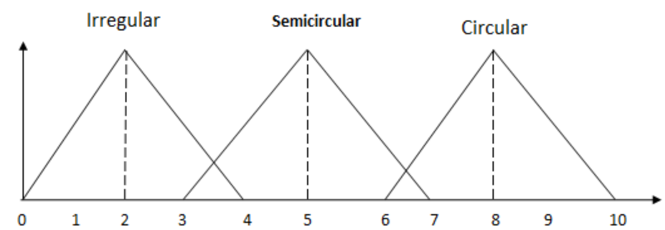

Figure.6.Membership Function of Pimples form

3-Temperature(X)

Table 3. Classification Of Pimples Temperature

INPUT FIELD	RANGE	FUZZY SETS
Temperature	<20 15-30 25-40	Low(A1) Avg(A2) High(A3)

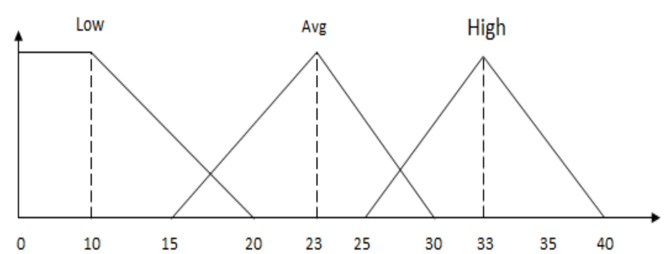

Figure.7.Membership Function of Temperature

5-Adaptive Neuro-FuzzyInference System

The advantage of the fuzzy inference system is that it can deal with linguistic expressions and the advantage of a neural network is that it can be trained and so can self-learn and self-improve. The idea behind neural network and fuzzy inference combination is to design a system that uses a fuzzy system to represent knowledge in an interpretable manner and has the learning ability derived from a neural network that can adjust the membership functions parameters and linguistic rules directly from data in order to enhance the system performance. A network-type structure similar to that of a neural network, which maps inputs through input membership functions and associated parameters, and then through output membership functions and associated parameters to outputs, can be used to interpret the input/output map. The ANFIS architecture contains a five-layer feed forward neural network as shown in Figure 5 (Elif ,2008 : P.Aruna *et.al*,2003).

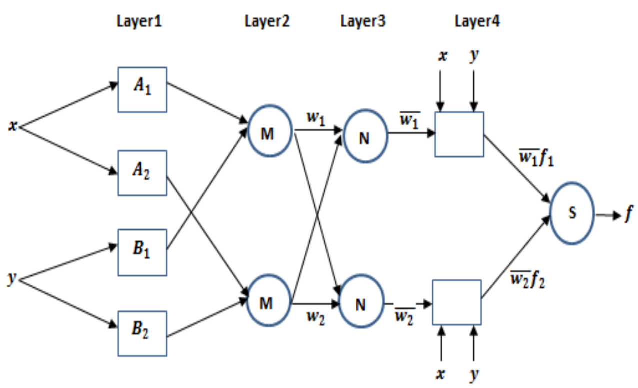

Figure 8. ANFIS architecture

Layer 1: known as a fuzzification layer, define the membership grades for each set of input and depends on the fuzzy membership function chosen.

$$\theta_i^1 = \mu_{A_i}(x), \qquad i = 1,2,3$$
$$\theta_i^1 = \mu_{B_{i-2}}(y), \qquad i = 3,4,5 \qquad \textbf{(1)}$$

Where x is the input to node i, A_i is the linguistic label (small, large, etc.) associated with this node function, and where $\mu_{A_i}(x)$ and $\mu_{B_{i=2}}(y)$can adopt any fuzzy membership function.

Layer 2: Output nodes are the firing strength of the rule as the product of the member-ship grades

$$\theta_i^2 = w_i = \mu_{A_i}(x)\mu_{B_i}(y) i = 1,2,3 \qquad \textbf{(2)}$$

Layer 3: Every node in this layer is a circle node that is labeled N. The ith node calculates the ratio of the ith rule's firing strength to the sum of all rules' firing strengths:

$$\theta_i^3 = \overline{w_i} = \frac{w_i}{w_1+w_2+w_3} i = 1,2,3 \qquad \textbf{(3)}$$

Layer 4 : In this layer, the nodes are adaptive nodes. The output of each node in this layer is simply the product of the normalized firing strength and a first order polynomial. Thus, the outputs of this layer are given by:

$$\theta_i^4 = \overline{w_i} f_i = w_i(p_i x + q_i y + r_i) \qquad i = 1,2,3 \quad \textbf{(4)}$$

Parameters in this layer will be referred to as consequent parameters.

Layer 5 : The single node in this layer is circle node labeled $\sum$ that computes the overall output as the summation of all incoming signals, i.e.,

$$\theta_i^5 = \sum_{i=1}^{3} \overline{w_i}\, f_i = \frac{\sum_{i=1}^{3} w_i}{w_1+w_2+w_3} \qquad i = 1,2,3 \qquad \textbf{(5)}$$

6- Bayesian Law with Neural Network

There are mistakes sometimes come with the diagnosis of some cases of disease process, these errors produced because of the great similarity between the symptoms of some diseases, Therefore in this paper the percentages have been compared to correct classification and adoption the theories that give less rate for a classification error as an assistant in the diagnostic process, by using theory of Bayesian. Bayesian methods to diagnosis because they derive classification rules based on sound mathematical principles namely, (probability theory),they can adapt easily and they have become increasingly popular for representing and handling uncertain knowledge in medicine. Typically, Bayesian rely for their construction on causal in particular (patho) physiological models of disease. The fact that Bayesian models allow for the easy incorporation of knowledge of possible disease, explains that they are also increasingly used in research on potential models of disease, associating potential with the time of agriculture, pimples coalesce, pimples scattered and injured part, when used for the prediction. The following graph shows the project work.

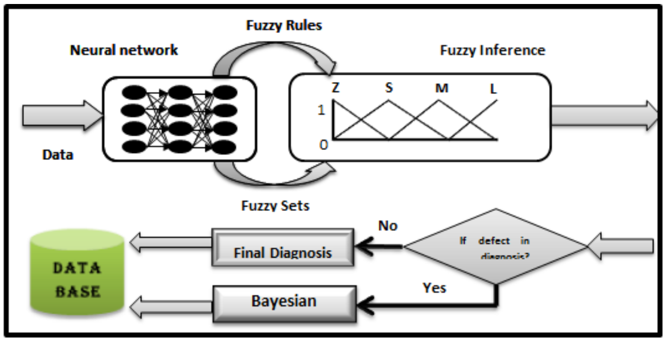

Figure 9. An architectural plan to the project

7- Bayesian Reasoning

The Bayes technique is particularly suited when the dimensionality of the inputs is high. Despite its simplicity, Bayes can often outperform more sophisticated classification methods. It shows the probability of each input attribute for the predictable state.

This probability is denoted as P(*H* |*E)* where:

$$P(H_i|E) = \frac{P(E|H_i) * P(H_i)}{\sum_{k=1}^{m} P(E|H_k) * P(H_k)} \dots \quad (6)$$

Multiple evidences E_1; E_2; ...; E_n and multiple hypotheses H_1; H_2; ...; H_m follow:

$$P(H_i|E_1E_2 \dots E_n) = \frac{P(E_1E_2 \dots E_n|H_i) * P(H_i)}{\sum_{k=1}^{m} P(E_1E_2 \dots E_n|H_k) * P(H_k)} \dots \quad (7)$$

By simply using H and E in expert systems, H usually represents a hypothesis and E denotes evidence to support this hypothesis.

Where:

P(H) is the prior probability of hypothesis H being true;

P(E|H) is the probability that hypothesis H being true will result in evidence E (Michael ,2005).

8- Bayesian Plus ANN with an Example

The following example is a simple demonstration of applying the ANN with Bayes Classifier. It shows how to calculate the probability using Bayes classification algorithm after applying algorithm Adaptive Neuro-Fuzzy Inference System to get more efficient output.

First step:

Table 4: Sample of diseases data

No	The Disease	Symptoms		
		Temperature(X)	Pimples Color(Y)	Pimples form(Z)
1	Brown or Leaf Rust(S1)	Avg(A2)	Brown(B2)	Circular(C3)
2	Steam or Black Rust(S2)	High(A3)	Sepia(B3)	Irregular(C1)
3	Yellow or Strip Rust(S3)	Low(A1)	Yellow(B1)	Semicircular(C2)

Second step: select input of symptoms:

Temperature: 25 , Pimples Color: 6.5 , Pimples form: 3

Third step: Applying ANFIS Algorithm.

Layer 1:

$$\theta_i^1 = \mu_{A_i}(x), \qquad i = 1,2,3$$

$$\theta_i^1 = \mu_{B_{i-2}}(y), \qquad i = 3,4,5$$

$$\mu_{A_i}(x) = \begin{cases} x - a \,/\, c - a & if \;\; a \le x < c \\ 1 & if \;\; x = c \\ b - x \,/\, b - c & if \; c < x \le b \end{cases}$$

$\mu_{A_1}(x)=0$ $\mu_{A_2}(x)=0.7$ $\mu_{A_3}(x)=0$,

$\mu_{B_1}(y)=0$ $\mu_{B_2}(y)=0.25$ $\mu_{B_3}(y)=0.25$

$\mu_{C_1}(z)=0.5$ $\mu_{C_2}(z)=0$ $\mu_{C_1}(z)=0$

Layer 2:

$\theta_i^2=w_i=\mu_{A_i}(x)\mu_{B_i}(y) \; i = 1,2,3$

$w_1= \mu_{A_1}(x)\mu_{B_1}(y)\mu_{C_1}(z) = 0 * 0 * 0.5 = 0$

$w_2= \mu_{A_1}(x)\mu_{B_1}(y)\mu_{C_2}(z) = 0 * 0 * 0 = 0$

$w_3= \mu_{A_1}(x)\mu_{B_1}(y)\mu_{C_3}(z) = 0 * 0 * 0 = 0$

$w_4= \mu_{A_1}(x)\mu_{B_2}(y)\mu_{C_1}(z) = 0 * 0.25 * 0.5 = 0$

$w_5= \mu_{A_1}(x)\mu_{B_2}(y)\mu_{C_2}(z) = 0 * 0.25 * 0 = 0$

$w_6= \mu_{A_1}(x)\mu_{B_2}(y)\mu_{C_3}(z) = 0 * 0.25 * 0 = 0$

$w_7= \mu_{A_1}(x)\mu_{B_3}(y)\mu_{C_1}(z) = 0 * 0.25 * 0.5 = 0$

$w_8= \mu_{A_1}(x)\mu_{B_3}(y)\mu_{C_2}(z) = 0 * 0.25 * 0 = 0$

$w_9= \mu_{A_1}(x)\mu_{B_3}(y)\mu_{C_3}(z) = 0 * 0.25 * 0 = 0$

$w_{10} = \mu_{A_2}(x)\mu_{B_1}(y)\mu_{C_1}(z) = 0.7 * 0.5 * 0 = 0$

$w_{11}= \mu_{A_2}(x)\mu_{B_1}(y)\mu_{C_2}(z) = 0.7 * 0 * 0 = 0$

$w_{12}= \mu_{A_2}(x)\mu_{B_1}(y)\mu_{C_3}(z) = 0.7 * 0 * 0 = 0$

$w_{13}= \mu_{A_2}(x)\mu_{B_2}(y)\mu_{C_1}(z) = 0.7 * 0.25 * 0.5 = 0.088$

$w_{14}= \mu_{A_2}(x)\mu_{B_2}(y)\mu_{C_2}(z) = 0.7 * 0.25 * 0 = 0$

$w_{15}= \mu_{A_2}(x)\mu_{B_2}(y)\mu_{C_3}(z) = 0.7 * 0.25 * 0 = 0$

$w_{16}= \mu_{A_2}(x)\mu_{B_3}(y)\mu_{C_1}(z) = 0.7 * 0.25 * 0.5 = 0.088$

$w_{17}= \mu_{A_2}(x)\mu_{B_3}(y)\mu_{C_2}(z) = 0.7 * 0.25 * 0 = 0$
$w_{18}= \mu_{A_2}(x)\mu_{B_3}(y)\mu_{C_3}(z) = 0.7 * 0.25 * 0 = 0$
$w_{19}=\mu_{A_3}(x)\mu_{B_1}(y)\mu_{C_1}(z) = 0 * 0 * 0.5 = 0$
$w_{20}= \mu_{A_3}(x)\mu_{B_1}(y)\mu_{C_2}(z) = 0 * 0 * 0 = 0$
$w_{21}= \mu_{A_3}(x)\mu_{B_1}(y)\mu_{C_3}(z) = 0 * 0 * 0 = 0$
$w_{22}= \mu_{A_3}(x)\mu_{B_2}(y)\mu_{C_1}(z) = 0 * 0.25 * 0.5 = 0$
$w_{23}= \mu_{A_3}(x)\mu_{B_2}(y)\mu_{C_2}(z) = 0 * 0.25 * 0 = 0$
$w_{24}= \mu_{A_3}(x)\mu_{B_2}(y)\mu_{C_{23}}(z) = 0 * 0.25 * 0 = 0$
$w_{25}= \mu_{A_3}(x)\mu_{B_3}(y)\mu_{C_1}(z) = 0 * 0.25 * 0.5 = 0$
$w_{26}= \mu_{A_3}(x)\mu_{B_3}(y)\mu_{C_2}(z) = 0 * 0.25 * 0 = 0$
$w_{27}= \mu_{A_3}(x)\mu_{B_3}(y)\mu_{C_3}(z) = 0 * 0.25 * 0 = 0$

$\overline{w1} = 0$	$\overline{w10} = 0$	$\overline{w19} = 0$
$\overline{w2} = 0$	$\overline{w11} = 0$	$\overline{w20} = 0$
$\overline{w3} = 0$	$\overline{w12} = 0$	$\overline{w21} = 0$
$\overline{w4} = 0$	$\overline{w13} = 0.5$	$\overline{w22} = 0$
$\overline{w5} = 0$	$\overline{w14} = 0$	$\overline{w23} = 0$
$\overline{w6} = 0$	$\overline{w15} = 0$	$\overline{w24} = 0$
$\overline{w7} = 0$	$\overline{w16} = 0.5$	$\overline{w25} = 0$
$\overline{w8} = 0$	$\overline{w17} = 0$	$\overline{w26} = 0$
$\overline{w9} = 0$	$\overline{w18} = 0$	$\overline{w27} = 0$

Layer3:

$$\theta_i^3=\overline{w_i}=\frac{w_i}{w_1+w_2+w_3} \qquad i = 1,2,3$$

$$\overline{w_1} = \frac{w_1}{w_1 + w_2 + w_3 + w_4 + w_5 + w_6 + w_7 + w_8 + w_9 + \cdots + w_{27}}$$

$$\overline{w_1} = \frac{0}{0+0+0+0+0+0+0+0+0+0+0+0+0.088+\cdots+0}$$

Layer4:

$\boldsymbol{\theta_i^4=\overline{w_i}f_i}$

F = Defuzzification

$O^4_i = \overline{wi}\mu(\overline{wi})$

O^4_{13} = 0.5* 1.5=0.75 , O^4_{16} = 0.5 * 4.5=2.25

Layer5:

$$\theta_i^5=\sum_{i=1}^{3}\overline{w_i}\,f_i = \frac{\sum_{i=1}^{3} w_i}{w_1+w_2+w_3} \qquad i = 1,2,3$$

O^5=0.75+2.25=3 : S1, S2

As notice that the network did not reach to a possible one disease because there are two diseases are similar the first disease and third disease, also note that the worth always similar, so we will resort to law Bayesian to know the possible disease. So we need to inputs other data be related with diseases and as shown in table5, table6 and table7.

Table 5: The Data related with diseases

Data		Leaf Rust	Black Rust	Strip Rust
The proportion of the disease affected the Time of Agriculture	Winter Wheat	0.8	0.4	0.5
	Spring wheat	0.5	0.7	0.3
part injured	Leaf	0.9	0.8	0.7
	Stalk	0.01	0.9	0.01
	Sheaths	0.01	0.5	0.6
	Sanibel	0.01	0.4	0.3
Are pimples coalesce with each other when the juxtaposition?	Yes	0.01	0.9	0.01
	No	0.9	0.2	0.9
Are pimples scattered?	Yes	0.9	0.8	0.01
	No	0.1	0.2	0.9

Table 6: Suppose inputs of infected plant

Are pimples scattered?	Are pimples coalesce with each other when the juxtaposition?	**part injured**	Time of Agriculture
No	Yes	Leaf	Winter Wheat

Table 7. Conditional probabilities of observing each evidence for all possible hypotheses with depending on Table5 and Table6 where S: symbol to disease and A: symbol to data of infected plant

Probability	**Hypothesis**	
	i=1	i=2
$P(S_i)$	0. 5	0.5
$P(A_1\|S_I)$	0.8	0.4
$P(A_2\|S_I)$	0.9	0.8
$P(A_3\|S_I)$	0.01	0.9
$P(A_4\|S_I)$	0.1	0.2

Now applying law of Bayesian as in the Eq. (6, 7):
P(Si| A1, A2, A3, A4, A5)=(P(A1,A2,A3,A4,A5|Si)*P(Si))/∑2K=1 P(A1,A2,A3,A4,A5|Sk)*P(Sk)
P(S1|A1,A2,A3,A4)=(0.8*0.9*0.01*0.1*0.5)/((0.8*0.9 *0.01*0.1*0.5)+(0.4*0.8*0.9*0.2*0.5))
=0.00036/(0.00036+0.02880)=0.00036/0.02916=0.012
P(S2| A1,A2,A3,A4)=(0.4*0.8*0.9*0.2*0.5)/((0.4*0.8*0.9*0.2*0.5)+(0.8*0.9*0.01*0.1*0.5))
=0.02880/0.02916= 0.988

When comparing the results we note that the rate of the second disease is greater than the rate of the first disease, so the more likely disease is second disease.

9- Implementation

Implementation module is used to determine disease and stage based on the user selected symptoms. Some of the system interfaces is shown in Figures 10, 11,12,13,14 and 15.

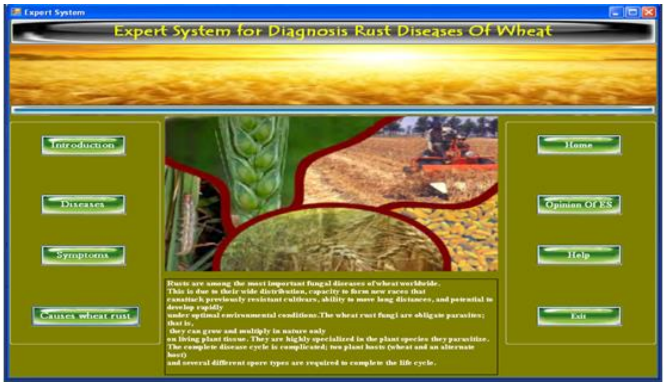

Figure 10.The Main Form

Figure 11.The Form of Symptoms

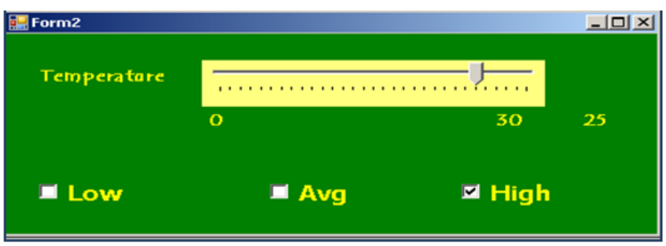

Figure 12.Range of Temperature

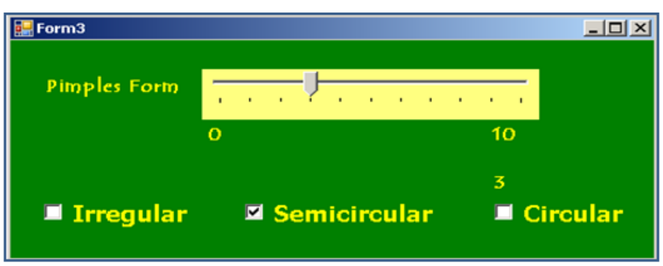

Figure 13.Classification Of Pimples Form

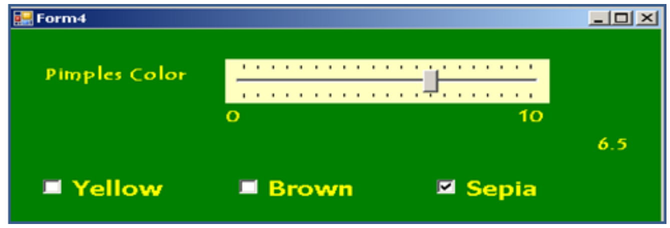

Figure 14.Classification of Pimples Color

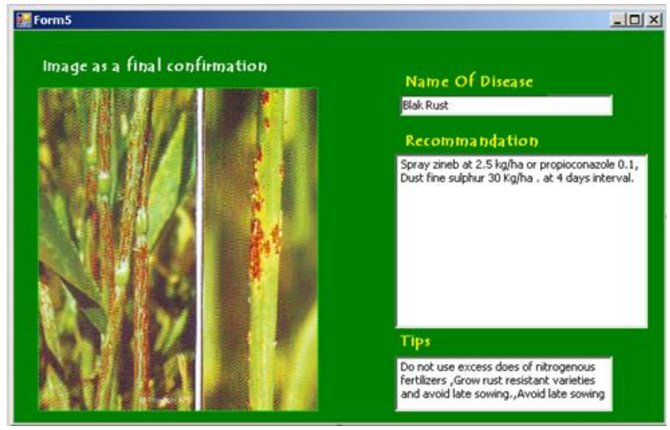

Figure 15. Final Result with disease name and the recommendation

10-Conclusion

In this research, a hybrid expert system has been designed and developed using fuzzy logic and ANN for diagnosis of diseases in the wheat plant. Expert systems have the capability to give the advice to the farmers efficiently and effectively. So researchers have to try to develop such an expert system which will guide to growers to take decision into different aspects of crop management like soil preparation, seed selection, pest management, fertilizer management, weed control, irrigation management, nutrition management etc. Expert systems are a better option over traditional systems .It is proven that expert systems in agriculture helps a lot in increasing the crop production .Expert system is offered as the second choice after expert on consultation. The future work can be extending this work for diagnosis other plants' diseases also can design and implementing an online web based expert.

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