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Applications of Fuzzy Logic in agriculture

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Abstract*—Now-a-days as the technology is moving ahead, so is its use in various fields. Artificial intelligence is the field where machines or systems are made to act similar to humans. They are fed with data which is then analysed by them and then they perform a particular action. This paper contains some of the applications of one of the part of artificial intelligence; known as the Fuzzy System. This paper tells how Fuzzy system is used in the field of agriculture. Also the paper gives the view of how the working of fuzzy components takes place in different parts of agriculture.

***Keywords*—Fuzzy, Fuzzy system, Fuzzifier, Defuzzifier, inference engine, knowledge base, etc.**

I. INTRODUCTION

Artificial Intelligence is the technology which is currently in boom. Companies are moving towards automating their work with the help of artificial intelligence. This is a technology where machines or robots perform task similar to human beings. As a result, human intervention in any kind of work is reduced to a great extent as machines have come up to do jobs that are difficult for humans to do.

Artificial intelligence technologies which are wide spread. Some of them are, neural networks, fuzzy systems, natural language processing etc. Among them is the fuzzy logic system.

Fuzzy means the things which are not clear or vague. This is the technology that is used in decision making for humans. Changing events, processes cannot be defined true or false. Thus fuzzy logic is used to take decisions in such cases. Fuzzy logic is based on boolean values i.e. true/false, 1/0. '1.0' means absolute truth and '0.0' means absolute false values.

Now-a-days fuzzy logic has its application in a wide spread area such as aerospace, automotive, business, defence, electronics, finance, industrial sector, manufacturing, marine, medical, securities, transportation, pattern recognition and classification, psychology, agriculture, biomedical, civil, mechanical and many more.

Following are the components of architecture of fuzzy logic:

A. *Rule base*: Consists of the rules in the form of IF-THEN condition that help in the decision making process. It is associated with the database where the data is stored. This together forms the knowledge base.

B. *Fuzzification*: Part of the system where CRISP data is taken as input and then converted to fuzzy data for further processing.

C. *Inference engine*: This is the part of the system that is responsible for the selection of appropriate rule to be fired based on the input data.

D. *Defuzzification*: This is the part of the system that is responsible for the conversion of fuzzy data into its original form i.e. the CRISP data which is then given as the output.

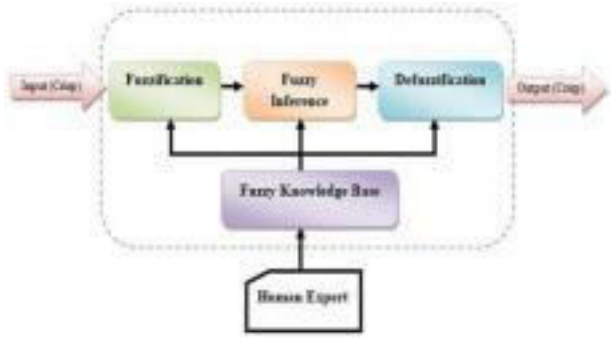

Fig.1. Architecture of fuzzy system [1]

II. EXPERT SYSTEM FOR AGRICULTURAL DEVELOPMENT [1]

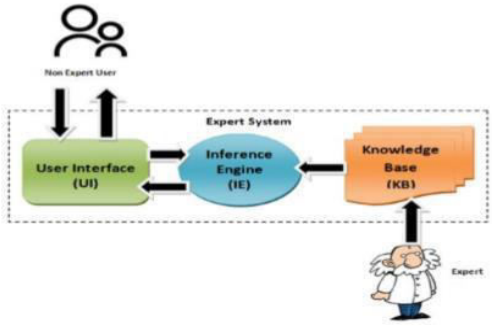

Fig.1.Architecture of expert system[1]

- An expert system is the one that does the work similar to a human being but at a much faster than a human.It is the one that does all the tasks which a human being is not capable of doing.
- The expert system consists of a user interface that is visible to the user.This is the phase where human

interaction with the system takes place. In case of agriculture, the user can interact with the system by placing the leaf which the system then captures as a image.

- The next comes the inference engine. The user interface passes information about the leaf to the inference engine where the inference engine decides which rule to apply and what decision to be taken about the gathered information.
- The knowledge base is the one where all the rules or data is stored. Based on this the inference engine gives the result if the leaf is damaged or not.
- Thus expert system works similsr to fuzzy expert system the only thing is that the fuzzy system gives the decision in the form of Boolean values.

III. FUZZY EXPERT SYSTEM FOR AGRICULTURAL DEVELOPMENT[1]

Fuzzy expert system is the one that makes use of the fuzzy logic. A fuzzy logic is the one that gives result in the form of '0' or '1', 'true' or 'false' etc. This system is useful in the field of agriculture to detect the soil type, disease in a plant or leaf, and many more. This system helps in making decisions for humans. This system calculates the risk in agriculture and gives decision.

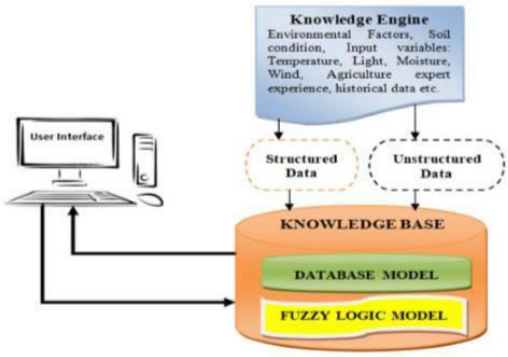

Fig.2.Fuzzy expert system to diagnose and forecast in agriculture[1]

A. *Steps to develop an expert model and indicators to be considered*[3]:

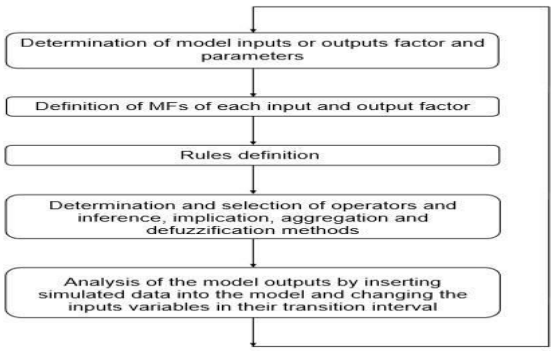

Fig.3.Fuzzy inference model development schema[3]

Following are some of the indicators that are used while making a fuzzy model:

- *Energy indicator*: This indicator is used to check the degree of sustainability and the energy flow. Input energy is given in 'MJ-ha^{-1}'.
- *Pesticide risk indicator*: This indicator is used to avoid the over use of pesticides as overuse of pesticides can harm the crops, the soil, etc and can affect the proper growth of crops.
- *Nitrate risk indicator*: When fertilizer is given to crops, not all fertilizer is used by the crop. The remaining fertilizer gets washed away with water and leads to pollution. Fertilizer containing nitrate in it is more harmful to the environment. Thus this indicator controls the excessiveness of the nitrate.
- *Air pollution indicator*: This is the indicator used to control the air pollution that occurs due to agriculture i.e. due to burning of dried crops to clear land and many others.
- *Economic indicator*: This indicator is used to control the economy in agriculture; meaning that this indicator tries to reduce the cost of equipment and other material necessary in agriculture.

B. *Diagnosis of yield of rice: an example of fuzzy system*[9]:

This is an example demonstration the working of fuzzy logic in rice yield:

1) The data for rice yield such as the input data and the output data is collected first. The input data is the Leaf FolderPestIncidence(LFI),SheathBlight disease(SB),Number of grain pinnacle(GP),Grain weight(GW).The output data is Yield of rice(YD).

2)Once the data is selected then the fuzzy model is designed with the components such as:

- Fuzzification interface
- Fuzzy Verdict mechanism •

Defuzzification interface.

3) The fuzzification interface takes the data that is the CRISP data which is then converted to fuzzy data for further processing.This fuzzy data is then sent as the input to the verdict mechanism.

4) The fuzzy verdict mechanism has four components such as:fuzzy matching,fuzzy inference, combination and defuzzification.Membership degrees are calculated and then matched with the rules then the fuzzy interface is invoked that implies that rules; then the inference results are combined and the combined result is converted to CRISP value and given as output.

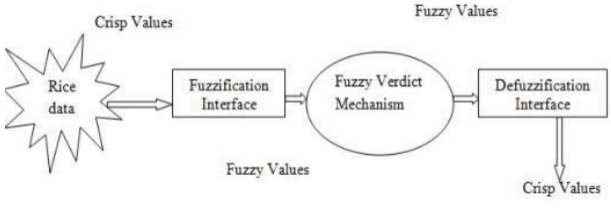

Fig.4.Fuzzy expert system developed for rice yield[9]

IV. APPLICATIONS AND WORKING

A. *Application of Fuzzy logic in disease management*[4,6]:

Like humans even plants are prone to disease. These disease can ruin the growth of plants.To detect the disease in plants, an expert system is used. This expert system makes use of the fuzzy logic to detect the disease. Integrated Disease Management is a technique used to manage the disease in agriculture.

1) *Plants*[4]

a) *Disease management*[4]:

Disease in a plant can lead to the loss of yield of crops. Thus Integrated Disease Management technique is used to manage the disease in plants. Calculation of the loss the disease may cause to a plant and thus controlling the use of chemicals, pesticides and other measures is the job of the IDM.

b) *Process of IDM*[4]:

Following are some of the steps in which the IDM works:

Step1: Similar to a doctor asking the symptoms to a patient, a fuzzy system checks the symptoms in a plant.

Step2: Once the symptoms are identified, the fuzzy system applies the rules on the symptoms to check what the disease caused is.

Step3:After the application of rules, the level of seriousness of the disease is checked so that the remedies can be applied to make the plant disease free.

c) *Knowledge representation*[4]:

The information that is gathered about the disease in a plant is represented by the defuzzifier that converts fuzzy data into CRISP data that is understood by the humans.

d) *Data collection* [4]:

This can be done by taking a photograph of the crop affected by disease. This photograph can be fed as the input to the expert system to analyse the disease.

e) *Defuzzification of pathometry in IDM*[4]:

This is a field of identifying the plant disease. Disease incidence can be calculated with the formula—

Percent Disease Incidence=(Number of infected plants÷Total number of units assessed)*100 (1)

2) *Leaf*[5]

a) *Image acquisition*[5]:

To identify the disease in a leaf, first step is to capture the image of the leafe affected.This is known as the process of acquiring image. Example is as follows

Fig.5. Image of an affected leaf[5]

b) *Image Pre-processing*[5]:

Before performing the disease identification process, the image needs to be formatted properly.This includes the resizing , filtering, cropping etc. of the input image. This is done in order to remove the noise from the input image for better detection of disease in the leaf. Resizing is done to fit the actual resolution as the system is capable of.

Fig.6. Image resized to fit the resolution determined.[5]

Fig.7. Filtered Image[5]

c) *Color image segmentation*[5]:

This is the process of splitting the image into subparts to change the representation of image in a more meaningful way.

Techniques used for this purpose are clustering, compression-based, histogram-based, region growing, k-means clustering.

Fig.8.Affected part of the leaf[5]

d) *Calculating A_T and A_D*[5]:

A_T Stands for the total area of the leaf and A_D stands for the area affected by disease.

Fig.9. Total area of leaf (A_l),(binary image [5]

Fig.10. Affected area(binary Image)(A_D)[5]

e) *Disease grading by Fuzzy Logic*[5]:
Once the total area and affected area of leaf are calculated, then the percent infection is calculated with the formula(1)—

$$PI=(A_D/A_T)*100$$

Fuzzy logic is used to grade the disease.

B. *Application of Fuzzy logic in pest management*[6,8]:

1) *The Framework for Crop Pest and Disease Management*[2]:

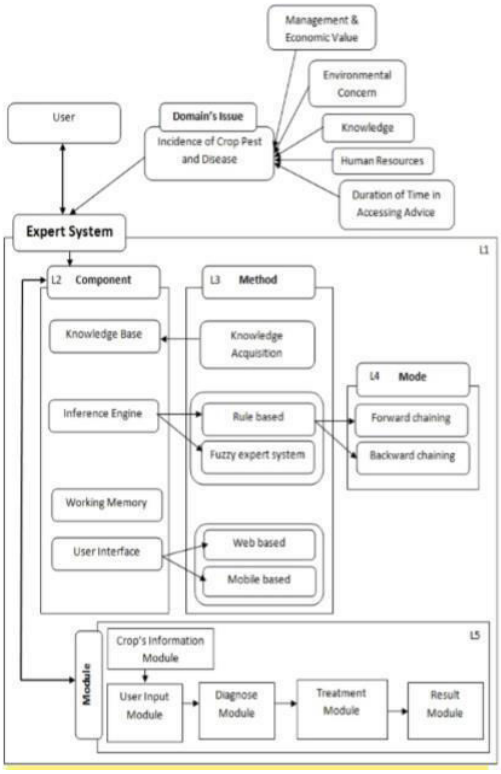

Fig.11.Framework of pest and disease management system[2]

The framework contains an expert system which consists of components such as knowledge base, inference engine, UI where the knowledge base contains the information about the pests, inference engine applies the appropriate selected rule on the fuzzy information, the UI interacts with the user to collect the data as input and give result as output.

This system is used to detect the pest on the crops.Based on the pest and its type, the necessary pesticide is suggested to be used. Forward or backward chaining is used by inference engine while applying the rules. The UI can be Web based or mobile based as shown in the figure.

C. *Application of Fuzzy logic in weed management* [6,8]

Weeds are the unnecessary plants growing in between the required plants. The growth of weeds reduces the growth of necessary crops.Thus these weeds need to be managed in order to maintain the proper growth of the plant .

1) *Materials and methods* [10]:

First the images are captured and then greenness method is used to extract these images to find the weeds in the crops. Meaning that the image is taken as input to analyse affected area.

At times identifying the weeds in the crops becomes difficult because they both look almost the same.Thus weed cannot be manually identified and needs a separate mechanism such using image processing in fuzzy system.

D. *Application of Fuzzy logic to study and analyze soil*[6,8]:

Soil contains Nitrogen(N), Phosphorous(P), Potassium(K). It is necessary to have a proper amount of NPK in the soil to maintain its sustainability.

1) *Methodology*[12]:

Following are some of the ways to use fuzzy logic for studying and analysing the soil:

a) *Data Collection* [12]:

Here samples of soil are take which act as data upon which the analysis has to be done.These soil samples are checked in the labs to see if the sample contains the proper amount of NPK. This is measured in ppm(parts per million).

b) *Linguistic Variables* [12]:

These are the criterias set such as low medium and high.These are used to determine the NPK in the soil and is used as the membership function.

c) *Membership Functions* [12]:

Triangular membership function is used that is in the form of lower-limit, mid-point, upper-limit.

2) *Model of Fuzzy Logic System for soil fertility forecast*[12]:

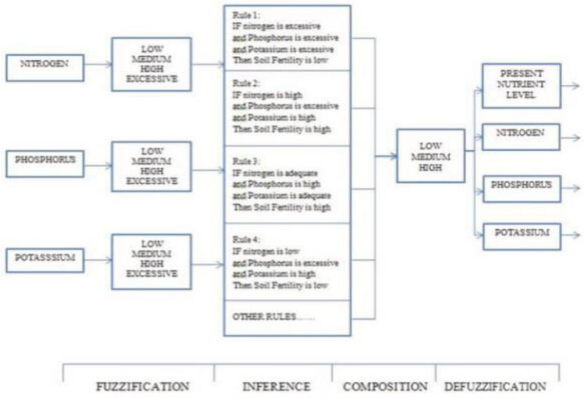

Fig.12.Fuzzy logic model for soil analysis.[12]

3) *Rules* [12]:

The rules used in the systemare interpreted as below:

H:High
M:Medium
L:Low
E:Excessive
NIL:none
N:Nitrogen
P:Phosphorous
K:Potassium
R.N:Required nitrogen
R.P: Required phosphorous
R.K: Required potassium
S.F:Soil fertility

E. *Application offuzzy logic in water irrigation system*[7]:

Fuzzy logic is also used for water irrigation where the amount of water to be supplied to plants is controlled by the system. As and when the need for water arises, the system stats supplying water to the plants.

1) *Input to fuzzy system* [7]:

Following are some of the factors for input to the system:

a) *Soil moisture* [7]:

The amount of moist in the soil needs to be supplied to the systemin order to judge the amount of water to be supplied.

b) *Relative humidity* [7]:

This is the humidity in the air.Many crops grow in the humidity present in the air. This quantity of humidity must also be supplied as input in order to control the supply of water to the crops.The relative humidity is calculated in percentage.

c) *Temperature* [7]:

Temperature around the soil needs to be checked which will affect the moisture in the soil and taking these facts into consideration the crop must be watered as required.

2) *Open loop controller*[11]:

This is the controller where the start time for irrigation, duration of irrigation and the end time of irrigation is set by the user.There is no error feedback by the controller and so it is called as open loop controller.

3) *Closed loop controller*[11]:

This is a controller where there is a feedback provided by the controller in order to control the water amount to be supplied.

V. CONCLUSION

- It can be concluded that fuzzy systemis used in many areas of agriculture such as in disease management, weed management, pest management, soil management, water management etc.
- Use of fuzzy logic has reduced the human intervention of the farmers and has helped them to take decisions appropriately. Also, use of fuzzy logic has helped the farmers to yield a better crop and have a better produce as it provides accurate results.
- Fuzzy logic has its applications in many other fields other than agriculture such as biomedical, engineering, automotive etc.and helped these industries to take proper decisions to increase their produce.
- As a result of the use of fuzzy logic in agriculture, farmers are also benefitting a lot in their produce of the crops.

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