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Fuzzy Logic based Individual Crop Advisory System based on Weather Input Data

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Abstract: *Weather has the most significant influence on agriculture. Various weather phenomenon such as cloudiness, precipitation, temperature, and wind have significant influence on agri-management decisions, management practices and cost of cultivation. Therefore, there is need for development of crop specific advisory to an individiual farmers based on various crop parameters such as type of crop, age of crop, location of crop etc. However, existing advisories are region specific and gives vague advisory and also not available for specific location. This paper is focused on giving overview of development of fuzzy logic based to generate automatic advisory based on type of crop, location of crop and age of the crop. The expert knowledge base available with the agricultural scientists will be utilized for developing automatic crop advisory system using machine learning approach such as Fuzzy Logic. This system is developed with the help of PHP and GUI of weather advisory is made in MATLAB. Testing of realistic weather data and randomly generated weather data is done and Success Rate of both data was calculated.*

Keywords -*Fuzzy Logic, Weather Data, Weather Advisory System, Crop Advisory System.*

I. Introduction

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper. Agriculture in India depends heavily on weather and climate conditions. Weather forecasts are useful for decisions regarding crop choice, crop variety, planting/harvesting dates, and investments in farm inputs such as irrigation, fertilizer, pesticide, herbicide etc. Hence, improved weather forecast based agromet advisory service greatly helps farmers to take advantage of benevolent weather and mitigate the impacts of malevolent weather situation.

The quality and the reliability of long range forecast and extended range forecast are to be improved for preparation and improved weather based agro-advisories. Early drought warnings and their management strategies are to be expended to district level. For monitoring crop growth I any current season, for each crop species, preparation of crop weather diagrams or calendars depicting current events of crop growth is advisable. Development of weather based forewarning systems is the need of the hour in limiting possible excessive usage of insecticides, pesticides and fungicides [1].

Compared to various other sectors of economy, agriculture is unique, whose output is largely dependent on weather conditions. Further to this, it also depends on management aspects of preventing the crops from severe weather conditions. This study begins with highlighting the significance of short and medium range weather forecasts for making adjustments in daily farm operations, followed by detailed description of how weather forecasts are generated and disseminated by the NCMRWF through its AAS units. It is logical to think that dissemination of information in vernacular languages to the farm households would have a higher degree of uptake by the target groups [2].

II. Present Theories and Practices

V. Rao et al [1] provides the overview of the Agrometeorological activities and integration of modern tools in relation to achieve sustainable agriculture in future. Significant achievements include creation of a network of agromet observatories, climatic database and development of models for crop yield forecasting, climatic classification of agricultural, starting of agro advisory units, creating of databank for agrometeorology, integrated agro advisory services, creation of facilities for training and capacity building and national and international cooperation through joint programmes.

Anurag et al [3] proposed Geographical Information System in agrometeorology. The versatile tools or operators available in GIS help in analyzing meteorological data precisely and quickly. GIS methods allow the intensive analysis of spatial and temporal patterns of many atmospheric parameters, providing an in-depth look into the regularities and variability of weather and climate. Timely and accurate Agrometeorological information and forecasts have been recognized as effective tools for crucial decision making in routine farm operations. Surendersingh et al [4] has developed web based Agrometeorological information system for sustainable agricultural development. The efficiency of any Agrometeorological service lies in its ability to disseminate timely and relevant Agrometeorological information to the user community, so that they can act on it suitably to augment productivity.

Agrometeorological information, used for decision making, represents part of a continuum; at the other end is scientific knowledge and understanding. Other components of this continuum are the collection of data and transforming data into useful information. Information has value when it is disseminated in such a way that the end-users get the maximum benefit in applying its content. Weiss A. et al [5] explored the potential of the new information and communications technologies to improve the access to agrometeorological information. Sue walker [6] proposes the dissemination of Agrometeorological information for personal relationship between the parties with continuity being maintained by regular contact and interactions with open communication channels. The content of the message must be relevant to the decisions of the client.

India meteorological department (IMD) is disseminating agromet advisory bulletins to farmers and other stakeholders through about 130 Agro Meteorological Field Units (AMFUs). The AMFUs prepare district-level agromet bulletins which are prepared based on weather forecast and existing crop status information. An effort has started to develop an IT-enabled agro-meteorological advisory system called eAgromet, to improve the efficiency of agromet advisory bulletin preparation and dissemination process by exploiting advances in both agriculture and information technologies. In this paper, Krishna P et al. [7] explain the architecture of eAgromet prototype. Parvinder et al [8] had conducted a pilot study to assess the economic impact of weather forecast-based advisories issued to 15 of the 127 Agrometeorological Advisory Service (AAS) units of the Ministry of Earth Sciences, Government of India. Six seasons comprising three Kharif (summer) and three Rabi (winter) during 2003–2007 were chosen. The main aim was to study the percentage increase/decrease in the yield and net return due to AAS.

In general, soft computing methods include Fuzzy Logic, neuro-computing, evolutionary computing, probabilistic computing, belief networks, chaotic systems, and parts of learning theory. FL, ANNs, GAs, BI and DT have been widely applied for research and development in agricultural and biological engineering. Bardossy et al [9] had applied a fuzzy rule-based methodology to the problem of classifying daily atmospheric circulation patterns (CP). Rules are defined corresponding to the geographical location of pressure anomalies. The fuzzy rule-based approach thus has potential to be applicable to the classification of GCM produced daily CPs for the purpose of predicting the effect of climate change on space-time precipitation over areas where only a rudimentary classification exists or where none at all exists.

Agboola et al., [10] has investigated the ability of fuzzy rules/logic in modeling rainfall for South Western Nigeria. The developed Fuzzy Logic model is made up of two functional components; the knowledge base and the fuzzy reasoning or decision-making unit. The model predicted outputs were compared with the actual rainfall data. The developed fuzzy rule-based model shows flexibility and ability in modeling an ill-defined relationship between input and output variables. Somia et al. [11] had interested in rainfall events prediction by applying rule-based reasoning and fuzzy logic. Five parameters: relative humidity, total cloud cover, wind direction, temperature and surface pressure are the input variables for their model, each has three membership functions. Among the overall 243 possibilities they had taken one hundred eighteen fuzzy IF–THEN rules and fuzzy reasoning. The output variable which has four membership functions, takes values from zero to one hundred corresponding to the percentage for rainfall events given for every hourly data.

Savita et al. [12] designed an interface for three subsystems—the knowledge acquisition subsystem with dynamic disease knowledge base, intelligent disease diagnosis subsystem with object-oriented intelligent-inference model and intelligent tutor for crop disease with audio-visual graphical user web interface. The paper describes the design features; functionality and development of intelligent multimedia web interface. Baum et al [13] proposed a fuzzy logic classification (FLC) methodology to achieve the two goals : 1) to discriminate between clear sky and clouds in a 32 3 32 pixel array, or sample, of 1.1-km Advanced Very High Resolution Radiometer data, and 2) if clouds are present, to discriminate between single-layered and multilayered clouds within the sample. To achieve these goals, eight FLC modules are derived that are based broadly on air mass type and surface type (land or water). The training and testing data used by the FLC are collected from more than 150 daytime AVHRR local area coverage scenes recorded between 1991 and 1994 over all seasons. Fuzzy logic is a powerful concept for handling nonlinear, time varying and adaptive systems. It permits the use of linguistic values of variables and imprecise relationships for modeling system behavior. Brian et al [14] presents an overview of fuzzy logic modeling techniques, its applications to biological and agricultural systems and an example showing the steps of constructing a fuzzy logic model. Jadhav et al [15] presents the knowledge based diagnosis of nutrient deficiency observed in sugarcane crop using fuzzy prolog rules. Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. For the adequate growth of sugarcane crop, nutrients are required. It assists or guides the farmers, experts, counselors in agricultural field to find out nutrient deficiency on the basis of symptoms appeared on the leaves of sugarcane crop using fuzzy prolog rules.

III. Formation Of Fuzzy Rules

A database is an organized collection of data. It is the collection of tables, queries, reports, views and other objects. The data is typically organized to model aspects of reality in a way that supports processes requiring information. Database management systems are computer software applications that interact with the user, other applications, and the database itself to capture and analyze data. A general-purpose DBMS is designed to allow the definition, creation, querying, update, and administration of databases. In this study, for the database formation weather data is collected from website of 'National Research Center for Grapes', Pune. The weather data is available from 12th August 2003 to 31st August 2013. And this weather data is collected from weather station no. 1891.

Study parameters are Temperature, Humidity and Rainfall. But in our database min, max and average observations are available. Therefore, study parameters are minTemperature, maxTemperature, avgTemperature, minHumidity, maxHumidity, avgHumidity and Rainfall. For the formation of rule we take low, medium and high range to each parameter i.e. seven parameters. Based on the combination rules become more than 2000. After so many trial and errors we reach at conclusion that 27 rules are formed. These are shown in following table as:

Table 3.1: Rules For Temperature Parameter

Rule No.	Rules
Rule 1	minTemperature is Low, maxTemperature is Low and avgTemperature is Low
Rule 2	minTemperature is Low, maxTemperature is Low and avgTemperature is Medium
Rule 3	minTemperature is Low, maxTemperature is Low and avgTemperature is High
Rule 4	minTemperature is Low, maxTemperature is Medium and avgTemperature is Low
Rule 5	minTemperature is Low, maxTemperature is Medium and avgTemperature is Medium
Rule 6	minTemperature is Low, maxTemperature is Medium and avgTemperature is High
Rule 7	minTemperature is Low, maxTemperature is High and avgTemperature is Low
Rule 8	minTemperature is Low, maxTemperature is High and avgTemperature is Medium
Rule 9	minTemperature is Low, maxTemperature is High and avgTemperature is High
Rule 10	minTemperature is Medium, maxTemperature is Low and avgTemperature is Low
Rule 11	minTemperature is Medium, maxTemperature is Low and avgTemperature is Medium
Rule 12	minTemperature is Medium, maxTemperature is Low and avgTemperature is High
Rule 13	minTemperature is Medium, maxTemperature is Medium and avgTemperature is Low
Rule 14	minTemperature is Medium, maxTemperature is Medium and avgTemperature is Medium
Rule 15	minTemperature is Medium, maxTemperature is Medium and avgTemperature is High
Rule 16	minTemperature is Medium, maxTemperature is High and avgTemperature is Low
Rule 17	minTemperature is Medium, maxTemperature is High and avgTemperature is Medium
Rule 18	minTemperature is Medium, maxTemperature is High and avgTemperature is High
Rule 19	minTemperature is High, maxTemperature is Low and avgTemperature is Low
Rule 20	minTemperature is High, maxTemperature is Low and avgTemperature is Medium
Rule 21	minTemperature is High, maxTemperature is Low and avgTemperature is High
Rule 22	minTemperature is High, maxTemperature is Medium and avgTemperature is Low
Rule 23	minTemperature is High, maxTemperature is Medium and avgTemperature is Medium
Rule 24	minTemperature is High, maxTemperature is Medium and avgTemperature is High
Rule 25	minTemperature is High, maxTemperature is High and avgTemperature is Low
Rule 26	minTemperature is High, maxTemperature is High and avgTemperature is Medium
Rule 27	minTemperature is High, maxTemperature is High and avgTemperature is High

Table 3.2: Rules For Humidity Parameter

Rule No.	Rules
Rule 1	minHumidity is Low, maxHumidity is Low and avgHumidity is Low
Rule 2	minHumidity is Low, maxHumidity is Low and avgHumidity is Medium
Rule 3	minHumidity is Low, maxHumidity is Low and avgHumidity is High
Rule 4	minHumidity is Low, maxHumidity is Medium and avgHumidity is Low
Rule 5	minHumidity is Low, maxHumidity is Medium and avgHumidity is Medium
Rule 6	minHumidity is Low, maxHumidity is Medium and avgHumidity is High
Rule 7	minHumidity is Low, maxHumidity is High and avgHumidity is Low
Rule 8	minHumidity is Low, maxHumidity is High and avgHumidity is Medium
Rule 9	minHumidity is Low, maxHumidity is High and avgHumidity is High
Rule 10	minHumidity is Medium, maxHumidity is Low and avgHumidity is Low
Rule 11	minHumidity is Medium, maxHumidity is Low and avgHumidity is Medium
Rule 12	minHumidity is Medium, maxHumidity is Low and avgHumidity is High
Rule 13	minHumidity is Medium, maxHumidity is Medium and avgHumidity is Low
Rule 14	minHumidity is Medium, maxHumidity is Medium and avgHumidity is Medium
Rule 15	minHumidity is Medium, maxHumidity is Medium and avgHumidity is High
Rule 16	minHumidity is Medium, maxHumidity is High and avgHumidity is Low
Rule 17	minHumidity is Medium, maxHumidity is High and avgHumidity is Medium
Rule 18	minHumidity is Medium, maxHumidity is High and avgHumidity is High
Rule 19	minHumidity is High, maxHumidity is Low and avgHumidity is Low

Rule 20	minHumidity is High, maxHumidity is Low and avgHumidity is Medium
Rule 21	minHumidity is High, maxHumidity is Low and avgHumidity is High
Rule 22	minHumidity is High, maxHumidity is Medium and avgHumidity is Low
Rule 23	minHumidity is High, maxHumidity is Medium and avgHumidity is Medium
Rule 24	minHumidity is High, maxHumidity is Medium and avgHumidity is High
Rule 25	minHumidity is High, maxHumidity is High and avgHumidity is Low
Rule 26	minHumidity is High, maxHumidity is High and avgHumidity is Medium
Rule 27	minHumidity is High, maxHumidity is High and avgHumidity is High

Table 3.3: Rules For Rainfall

Rule No.	Rules
Rule 1	minHumidity is Low, maxHumidity is Low and avgHumidity is Low
Rule 2	minHumidity is Low, maxHumidity is Low and avgHumidity is Medium
Rule 3	minHumidity is Low, maxHumidity is Low and avgHumidity is High

IV. Development of Fuzzy System

A Fuzzy logic presents robust and flexible inference methods in domains subject to imprecision and uncertainty. The linguistic representation of knowledge allows a human to interact with a fuzzy system in an intuitive, seamless manner. A key objective of this section is to design of fuzzy systems for advisory.

Consider that the inputs of the fuzzy systems are represented by ***X*** and outputs are represented by ***Z***. The objective is to find the mapping between ***X*** and ***Z***. In advisory system, the weather data obtained from the database of different parameter X_i can be used as inputs and advisory in terms of Rule will be the output of the fuzzy system. Here,

X= $\{\min Temperature, \max Temperature, avgTemperature\}$ and

Z = $\{Rule1, Rule2, ...Rule27\}$

The weather parameters $\{\min Temperature, \max Temperature, avgTemperature\}$ are treated as input variables. Fuzzy sets with Gaussian membership functions are used to define these input variables. These fuzzy sets can be defined using the following equation

$$\mu(x) = e^{-0.5\left(\frac{x-mean}{std.dev.}\right)^2}$$

Where *mean* and *standard deviation* of the Gaussian membership function are obtained from the mean and standard deviation of each parameter of weather data in this study.

Success rate is calculated using the results obtained after defuzzification. If we test N_T samples of noisy data and out of that if the system correctly classifies N_C times then success rate for rule *p* as a percentage is given as

$$SR = \frac{N_C}{N_T}100$$

Gaussian Membership Function:

In this section, we formulate a fuzzy classifier for weather advisory in twenty seven rules as $\{Rule1, Rule2, ...Rule27\}$ using the 7 features (i.e. 03 of Temperature, 03 of Humidity and 1 of Rainfall). The Gaussian membership function used for the design of this fuzzy system. Based on the observations of weather of twenty seven rules, the mean and standard deviations are obtained to tune the fuzzy classifier.Gaussian membership functions for 7 features are shown in Figures 4.2-4.4 for Temperature, Humidity and Rainfall based features, respectively. Based on the membership function shown in these figures the membership function for weather data will be obtained. The membership value of each feature will contribute to decide the rule for weather advisory.

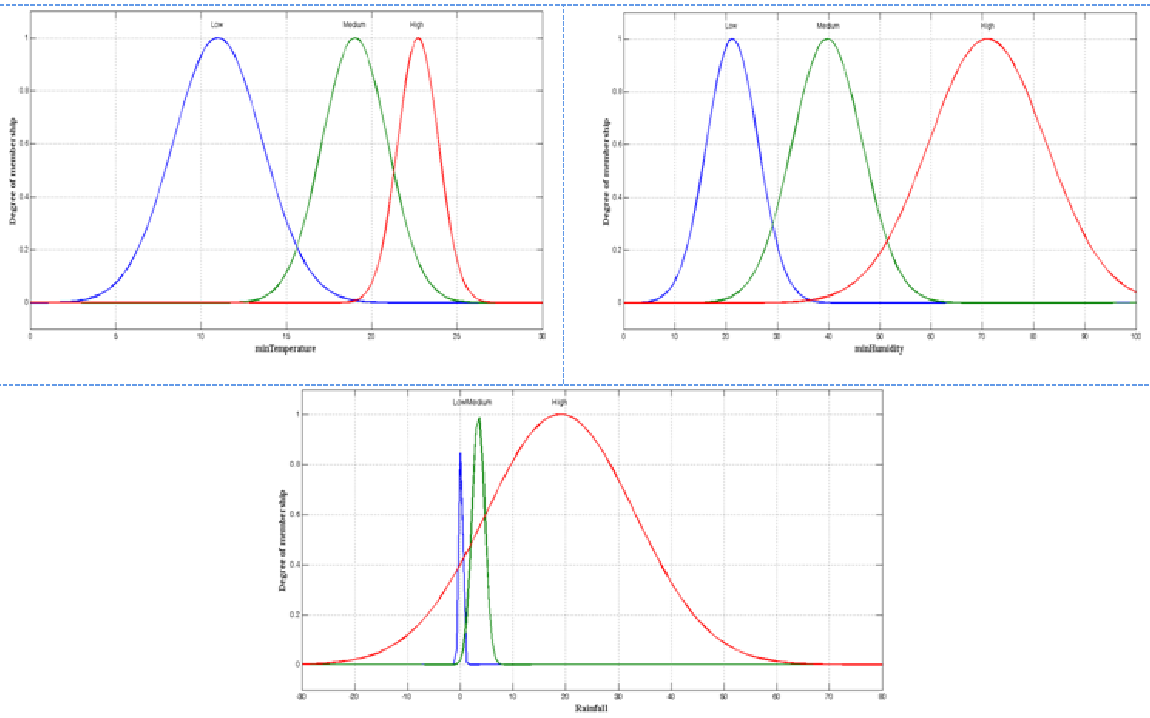


Figure 4.2: Membership function plots of Temperature, Humidity and Rainfall

V. Testing For Real Weather Data

In this section, we are testing the weather data of 10 year (from 12th Aug 2003 to 31st Aug. 2013). For testing we partitioned the data in 50-50% partition (50% for training and 50% for testing), 80-20% and 70-30%. Then calculate the performance of fuzzy classifier for Temperature, Humidity and Rainfall which is shown in table 5.1.

Table 5.1: Fuzzy Classification performance for Temp, Hum & Rain

Sr. No.	Weather Parameter	50-50% partition	80-20% partition	70-30% partition	Total Success Rate
1.	Temperature	99.9824	99.9647	100	100
2.	Humidity	99.8662	99.7541	99.9375	99.8766
3.	Rainfall	99.9383	100	100	100

From the above table 5.1 it is observed that the Temperature parameter gives the minimum success rate of 99.9647% at 80-20% partition, the Humidity gives minimum success rate of 99.7541% at 80-20% partition and Rainfall shows 99.9383% minimum success rate at 50-50% partition. Also it is observed from above table that all the three weather parameter gives maximum success rate at 70-30% partition as for Temperature & Rainfall it is 100% and for Humidity it is 99.9375%.

The fuzzy classification performance for twenty seven rules of Temperature, Humidity and three rules of Rainfall is also calculated. These performances are comparatively summarized in Figure 5.1-5.2. From these tables and Figure, it is observed that 70-30% partition give far better performance as compared to 50-50% and 80-20% partition performance.

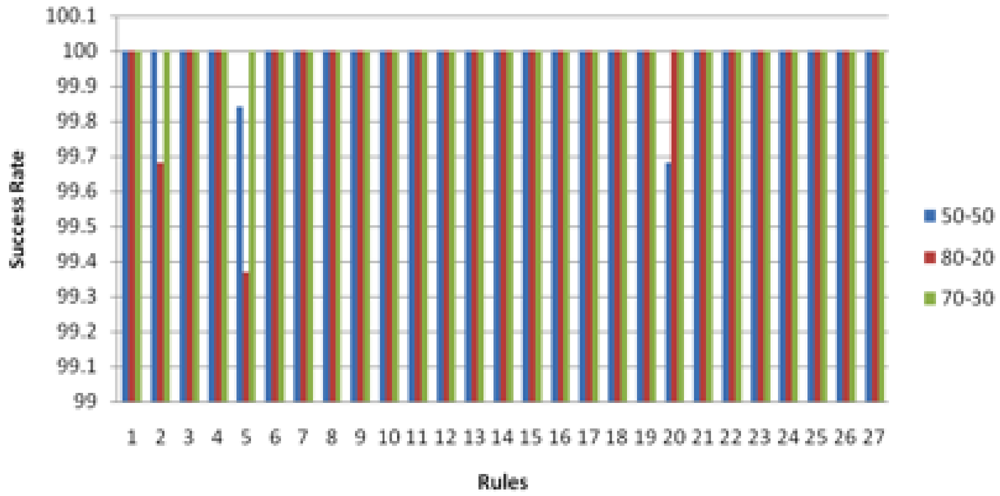


Figure 5.1: Performance of fuzzy logic classifier for Temperature

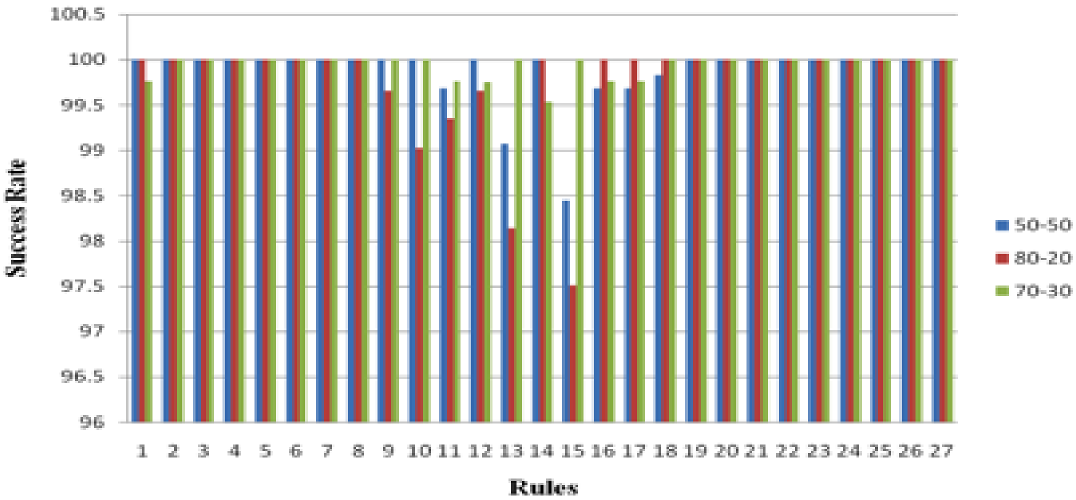


Figure 5.2: Performance of fuzzy logic classifier for Humidity

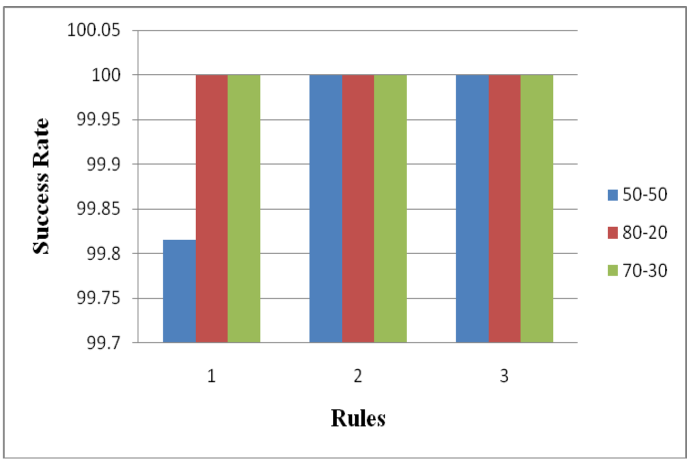


Figure 5.3: Performance of fuzzy logic classifier for Rainfall

VI. PHP based Implementation

In this section, PHP based implementation of weather and crop advisory using fuzzy based approach is described for the easy usage of this methodology whose snapshots are shown in figure 6.1 and 6.2. Figure 6.1 shows the front pages of PHP based advisory system whereas figure 6.2 shows the working steps of Advisory system (weather as well as crop).

Figure 6.1: Front page of PHP for Advisory System

[1]. Working of PHP based Advisory System using the following stepsas:

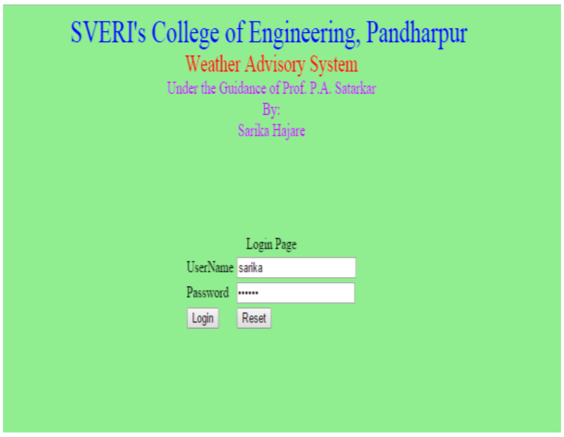
[2]. First go to Login. If farmer is new user then go to Register and make registration with his primary information and get the username for Login as shown in Figure6.2(b).

[3]. After Login he must give the village name and select the option which advisiry he wants to know as mentioned in Figure6.2(c).

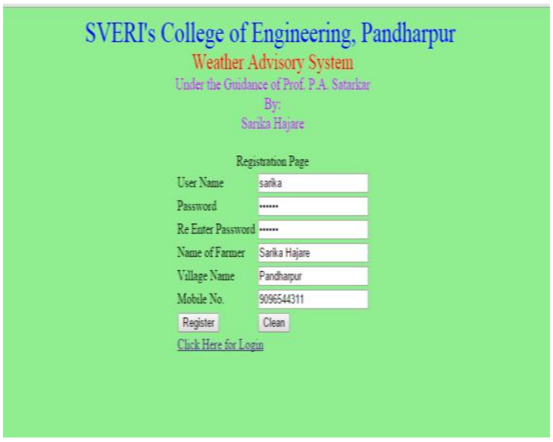
[4]. If farmer/user select weather advisory option, he gets the weather information of village name which he enter as shown in Figure6.2(d). when he enters the village name then it is automatically connected to weather forecasting link which gives the weather of that particular vilage. Weather is the input to the Fuzzy System which gives output in the form of Weather Advisory.

[5]. As shown in Figure6.2(e) and (f) if farmer/user select the Crop Advisory option, then he gets the crop advisory with the age of crop of that particular crop which he mentioned in Name of Crop. Also, this system will be included with planning aspects such as watering pattern, numerical or fertilizer doses with respect to age of the crop. System will automatically calculate the age of individual's crop, based on input date of crop sowing or flowering or cutting or punning etc.

[6]. If farmer/user wants both the advisory then choose the option Weather and Crop Advisory then he will get both the advisory as shown in Figure6.2(g) and (h).

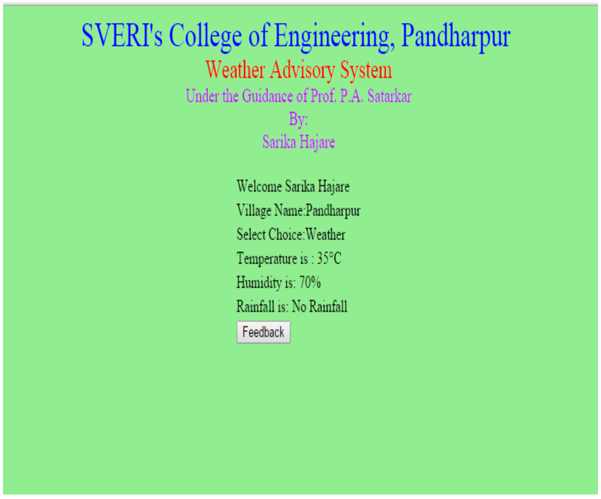


a) Login page for farmer

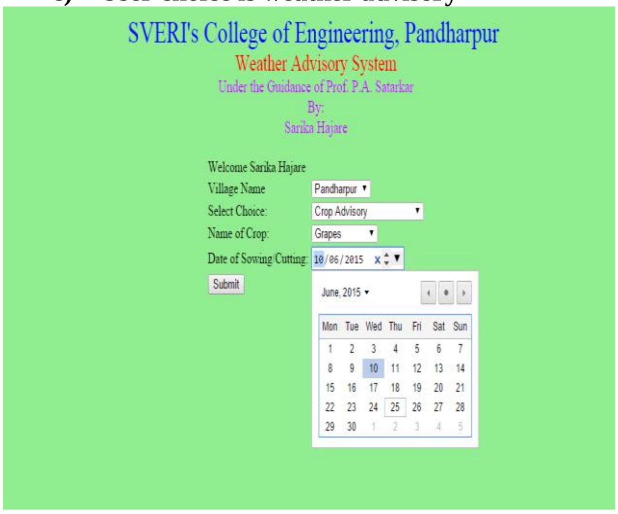


b) Registration page for new farmer

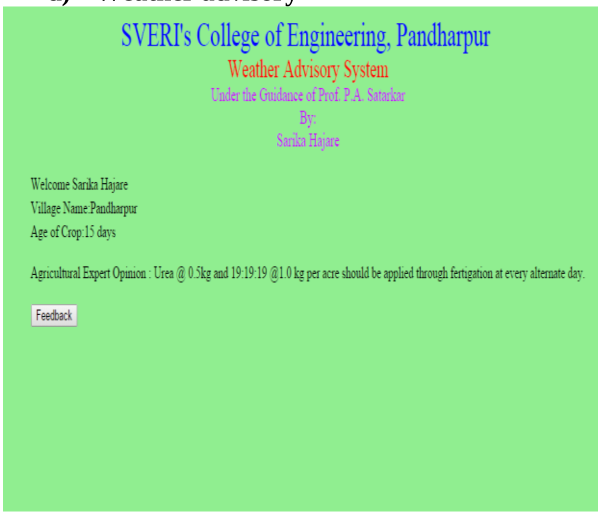
c) User choice is weather advisory



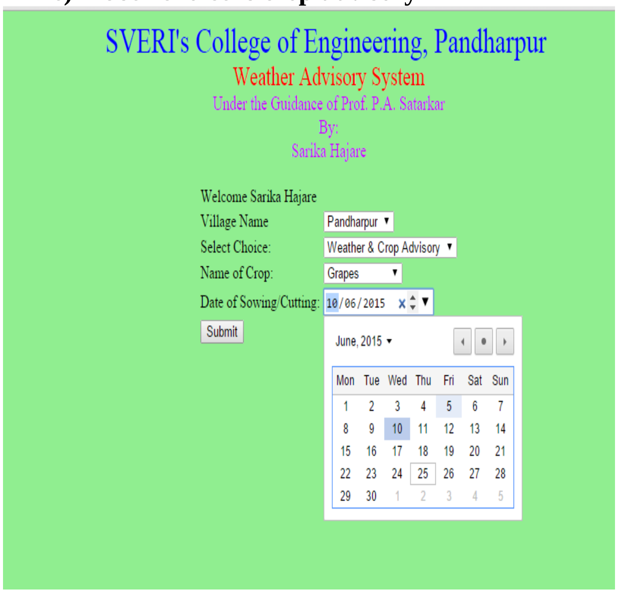
d) Weather advisory



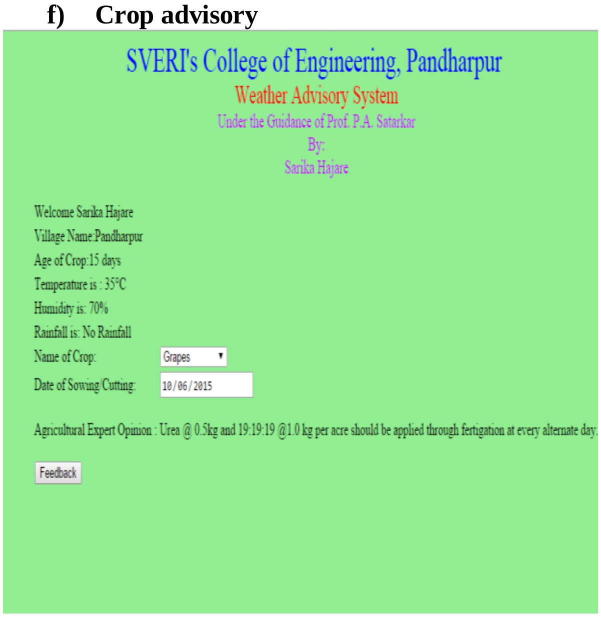
e) User choice is crop advisory



f) Crop advisory



g) Both choices weather & crop advisory



h) Weather & crop advisory system

Figure 6.2: Working steps of PHP based Advisory System

VII. Conclusion

Advisory system developed using fuzzy classifier is studied in this thesis. Conclusions of this study are given below:

1. In data analysis and cluster formation, from weather parameter plots and the combination of parameter plots it is observed that in some combination of fuzzy rule there is no weather data is available. Those combinations are deleted and twenty seven fuzzy rules are formed for the development of advisory system.
2. Fuzzy logic classifier is developed for advisory system. This classifier is developed for rules by using weather data as input. These classifiers are tested for various sets of weather data inputs. The classifier gives superior classification performance for all the three parameter such as Temperature, Humidity and Rainfall. While testing for various sets of weather data inputs, it is observed that 70-30% partition give far better performance as compared to 50-50% and 80-20% partition performance.
3. Demonstration of fuzzy classifier is done in PHP. PHP tests the three parameters Temperature, Humidity and Rainfall using fuzzy logic and generates the message, which tells rule generated from fuzzy logic.

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