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Rule-promotion: A New Fuzzy-logic Approach for Drawing the Inferences in Rule-based Expert System

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SUMMARY

The paper describes the development of a new fuzzy-logic approach for designing the web based Intelligent Information Systems. The new approach named as rule-promotion approach is suggested for the intelligent systems. The new approach is found to enable the drawing of inferences with enhanced intelligence. It improved the conventional inference process for inferencing. It significantly strengthened the inference drawing power of the rule-based expert system. Rule-promotion approach for web based Intelligent Information Systems is used for diagnosis of diseases in crops. The new approach has been tested and verified for the intelligent diagnosis of diseases of Oilseed-crops. The paper describes evaluation of rule promotion novel approach. It includes the studies on the comparison of the diagnostic results obtained by running the intelligent system without applying rule-promotion approach in conventional way and by applying the rule-promotion approach. The results obtained by applying the rule-promotion approach were found to be more acceptable and lead to more successful diagnosis. The application of Intelligent Information System for Disease Diagnosis in Crops (IISDDC) is made to three Oilseed crops viz. Soybean, Groundnut and Rapeseed Mustard.

Keywords: Disease diagnosis, Fuzzy-logic, Inference-drawing, Intelligent information system, Knowledge base, Rule-promotion.

1. INTRODUCTION

Most of the expert systems developed (Michalski *et al*. 1983, Caristi *et al*. 1987, Latin *et al*. 1987, Donahue *et al*. 1991, Sanchez *et al*. 1993, Zhang *et al*. 1993, Boyd and Sun 1994, Yialouris *et al*. 1996 and 1997, Cirio *et al*. 1998, Airu 1999) so far have a static knowledge base with static reasoning and inference techniques. A conventional rule based expert system characteristic is that the domain expert's confidence in a rule remains unchanged. So, the decision-taking power of these conventional systems remains same throughout the life of the system unless the knowledge engineer changes it explicitly. They lack in effective interactive user interface as they are devoid of multimedia tools.

Moreover, these systems have a conventional GUI. The text-driven GUI provided a less effective interactive interface. This when combined with the text-to-speech (TTS) capability for text-to-talking user interface, can provide a highly effective interactive interface.

A poorly designed interface could in fact affect the overall effectiveness of a program. Keeping this in mind, IISDDC is developed with TTS interface along with multimedia features. It provides access to the disease information at large for oilseed crops, viz. soybean, groundnut and rapeseed-mustard and to provide an intelligent support to improve the decision-making ability of farmers/cultivators, agriculture

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advisors/extension workers, researchers, managers, policy makers etc.

The novel features of IISDDC are as follows (Kolhe *et al*. 2011b):

(i) The introduction of a new fuzzy-logic based rule-promotion approach to strengthen the decision-making power of the expert system.

(ii) The implementation of above new rule-promotion strategy by the development of an intelligent information system for disease diagnosis in crops (IISDDC) with more effective interactive multimedia TTS user-interface integrated on www.

(iii) Object oriented (O-O) inference model, which incorporates a newly experimented rule-promotion and deploys a fuzzy-logic based intelligent inference-technique.

(1iv) Dynamic knowledge-base creation strategy in which the history of rule patterns is stored. The promoted rules are then derived from those diagnosis sessions, which resulted in successful decisions. That enables more efficient decision-making in the future diagnostic sessions.

The basic philosophy of the new rule-promotion approach is that the confidence in a rule should increase as the rule repeatedly leads to a successful decision-making. The rule-pattern is the sequence of the rules that are repeatedly being used in successful decision.

The extent of yield losses due to diseases can be minimized with the real-time application of the system. This is done by making the exact diagnosis and management expertise available on www at right time at right place in the right form in very less cost.

2. RULE-PROMOTION OR RULE-EMPOWERMENT: A NEW FUZZY LOGIC APPROACH FOR INFERENCE DRAWING

The domain expert's confidence in a rule in the conventional rule based expert system, remains unchanged so the inference drawing power of the system also remains the same over the years. The inference technique is made more powerful in the proposed system by the introduction of a new approach called rule-promotion or rule empowerment.

2.1 Promotion to Higher Confidence Level

Suggested rule-promotion approach is based on the natural belief that the confidence in rules increases gradually if the rules repetitively result in right decision. Thus, the difference in conventional inference drawing approach and the new rule-promotion approach is that former attach constant values of Confidence Factor (CF) to rules whereas the new approach is experimenting with variable/dynamic values of CFs based on fuzzy logic; the former one uses the same original CF as initially given by domain experts for all the decisions throughout the life time of the ES while in new approach for each new session, an improved CF is assigned to all the rules based on the results of the earlier diagnosis session. So, if a rule is repetitively used in successful conclusion it is promoted or empowered to higher confidence-level by increasing its CF by the equivalent promotion/empowerment factor (PF). The session is successful if it results in a correct diagnostic conclusion acceptable to the disease expert.

New confidence factor of the rule is termed as its Promoted or empowered rule Confidence Factor (PCF).

2.2 Demotion to Lower Confidence Level

Sometimes the rules lead to wrong decision, which doesn't match with the domain experts' decision. This diagnostic session is called non-successful session. The rules in this case are demoted to lower confidence level by decreasing its confidence factor with a lower value of promotion-factor. This is termed as negative rule-promotion or rule-demotion.

The rules are promoted when fired and results in successful sessions. The rules are demoted when fired and results in non-successful sessions. The promotion or demotion of a rule is applied in relation to other rules in the rule-set of a particular disease. A rule is promoted in a rule-set of a disease then other rules are relatively demoted and vice-versa.

2.3 Dynamic PCF

Promotion-frequency (γ) gives number of times a rule is fired and results in successful diagnosis of disease. The dynamic PCF that is generated in the earlier session is used in the final decision making process for each new diagnosis session taken by the user.

2.4 Computations of Different Variables used in Rule-promotion Approach

The computation of different variables-γ, ω, PF and PCF, used in new fuzzy logic approach is mathematically explained (Kolhe *et al.* 2011a). Let the rules R_1, R_2, R_3, R_4 … R_n of a particular disease, are fired and are used in the successful disease diagnosis. Its existing promotion-frequency (γ) increases by one for the next diagnosis session.

Let the values of γ of above rules are say γ_1, γ_2, γ_3, γ_4 … γ_n respectively after the present diagnostic session.

There is a need to calculate weight factor (ω) to calculate the Promotion Factor (PF) as given below.

$$\omega = 1/\sum_{i=1}^{n}\gamma_i \qquad (1)$$

The PF of the rule is calculated as under:

$$\text{PF}(R_i) = \gamma_i \times \omega \text{ for } i = 1 \text{ to } n \qquad (2)$$

[**Note:** PF(R_i) is always < 1]

With this fuzzy logic, $\sum_{i=1}^{n} PF(R_i)$ is nearly equal to 1 always for a particular disease. (3)

PF for this rule is used to increase the existing rule confidence using the following fuzzy logic algebra.

Let the existing rule CF of a rule R_i is say CF(R_i) then its Promoted Confidence Factor (PCF) will be

$$\text{PCF}(R_i) = \text{CF}(R_i) + \text{PF}(R_i) - \text{CF}(R_i) \times \text{PF}(R_i)$$

$$\text{for } i = 1 \text{ to } n \qquad (4)$$

With this logic PCF(R_i) <= 1 always,

Whereas PCF(R_i) = 1 represents FULL (100%) confidence and PCF(R_i) = 0 represents NO confidence in the rule.

2.5 Multi-valued Logical Scale Used in the System

Our system used the certainty factors as shown on the multi-valued scale (Harmon and King 1985) (Fig. 1). The range of certainty factors is from 0 to 1.

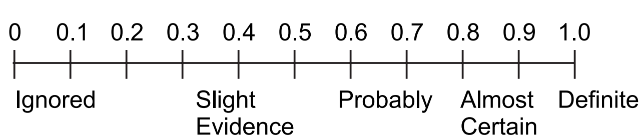

Fig. 1. Multi-valued logical scale of CF used in the system

Zero indicates that there is NO confidence at all in a piece of evidence and 1 indicates that there is FULL confidence in it.

There are five levels in this logical scale as shown below:

First level : 0< final CF<= 0.3 then "Ignored"

Second level : 0.3< final CF<=0.6 then "Slight evidence"

Third level : 0.6< final CF<= 0.8 then "Probably"

Fourth level : 0.8< final CF<1 then "Almost certain"

Fifth level : If final CF=1 then "Definite"

Each level in the scale has upper limit and lower limit of confidence level based on which the final diagnostic decision is given. The final decision statement is shown to the user based on this logical scale.

3. RULE PATTERNS

The IISDDC inference model also maintains a log of the Rule Patterns that are continuously used in every successful decision for a particular disease viz. R_1, R_2, R_3, R_4 … R_n for a disease say D_1. The system uses these rule patterns when the inputs given by the user for making decisions are not adequate to reach the conclusion. The inputs are for the symptoms observed by the user in the infected field. The rule patterns are also used when a very low confidence diagnosis is resulted. The system uses these rule patterns in this case, to prompt the user to give more valid symptoms' input to reach an appropriate conclusion. This helps the system to improve its interactive session with the user by reducing the lengthy same stereotyped non-useful interactions and providing more logical, genuine and useful interactions. The system is deriving in this way what valid questions it should ask next time when a non-fruitful session occurs.

4. SYSTEM FEATURES

IISDDC is built using the Microsoft .NET framework, ASP.NET web-application framework provided in Visual Studio.NET. The Microsoft Speech SDK (5.1) is used to develop text to voice multimedia interface. The dynamic knowledge base is implemented using SQL server.

Web-based user interface design of IISDDC is divided into three subsystems – 1) Knowledge acquisition, 2) Intelligent disease diagnosis, 3) Intelligent tutor.

The Knowledge acquisition allows the expert to enter knowledge directly into the knowledge base without any intermediary (Kolhe *et al.* 2011c).

The Intelligent disease diagnosis comprises of Object-oriented Inference Model and TTS Explanation interface for intelligently drawing inferences about disease diagnosis in crops.

The Intelligent Tutor serves as an audio-visual ready-reckoner tool. It retrieves the crop disease information on useful disease related aspects like pathogen, geographic distribution, economic impact, favourable climatic conditions, detection methods and effective integrated management of practices. It is also a very useful and interactive audio-visual training tool for providing pathological trainings with the help of multimedia effects, coloured pictures, videos, texts, and graphics with capability of text-to-voice interface. The concepts of text-to-speech (TTS) translation can be used comfortably with applications built using the Microsoft .NET framework. The Microsoft Speech SDK (version 5.1) is used to develop text to voice software applications (Microsoft 2011).

5. SYSTEM WORKING

The user is linked to the knowledge domain for the specific crop. The domain experts' knowledge can be added and managed as and when needed for the chosen crop. This is done by using the knowledge management interface. The disease diagnosis consultation approach involves the following steps as shown in system flow chart also in Fig. 2.

Step1 : The user gives username and password to get login into the system as a specific crop user.

Step 2 : The user gives initial inputs as date of sowing (main-domain) and part affected (sub-domain) after successful authentication (Fig. 3).

Step 3 : The user provides inputs of all the symptoms observed by him in infected fields on each affected plant part, for the particular crop (Fig. 4).

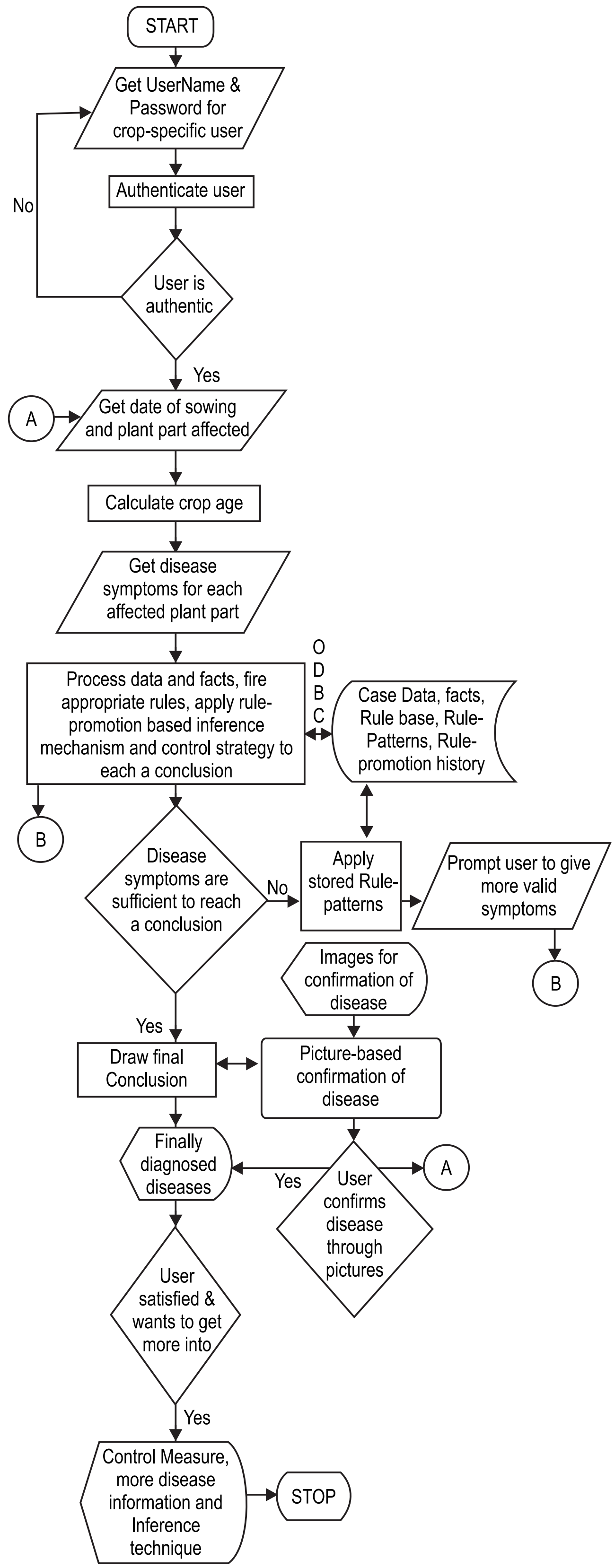

Fig. 2. System flow chart for disease diagnosis

Fig. 3. Web form for collecting initial inputs.

Fig. 4. Web form for collecting all the disease symptoms.

Step 4 : After all the symptoms are entered in the web-form interface one by one by checking the check boxes (Fig. 4), the request goes to the server along with all the symptoms values by client side script through web-browser.

Step 5 : The user request is processed at the server by using server side scripts. The data for processing the users' diagnostic queries are obtained by establishing ODBC with the SQL Server database at back-end.

Step 6 : The inference engine processes all the facts and knowledge. It then applies the rule-promotion based inference model and produces the results as presented in a list of all the diagnosed disease (Fig. 5). If the user symptoms inputs are not sufficient to reach to a conclusion, the system uses the stored rule-patterns. The system with this prompts the user to give more valid symptoms' input to reach an appropriate conclusion.

Step 7 : The user confirms the diagnosed disease through pictures.

Step 8 : The explanation sub-system facilitates the user to see the complete inference technique used by the system to reach the diagnosis conclusion.

Step 9 : The user is provided the knowledge about the most appropriate control measure. The user takes necessary steps to control the diagnosed disease (Fig. 5).

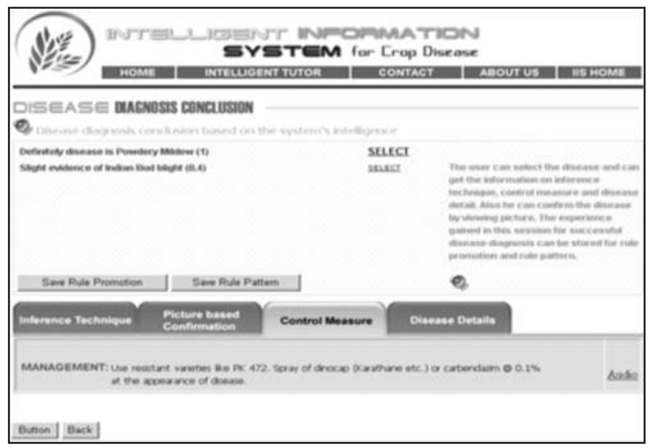

Fig. 5. Screen showing the diagnosed diseases along with the control measure suggested by the system.

Step 10 : The user can gain more information by viewing the other details of the diagnosed diseases. The user can update his knowledge on other useful disease related aspects like pathogen, distribution, economic impact, favorable climatic conditions etc.

Throughout the operation of the system, the user can also hear the information by pressing the icon . The audio feature is provided in the system by using TTS conversion tool provided by the Microsoft Speech SDK.

6. EVALUATION OF RULE-PROMOTION APPROACH

The evaluation of rule-promotion approach includes the studies on the comparison of the diagnostic results obtained (i) by running the intelligent system without applying rule-promotion approach in conventional way and (ii) by applying the rule-promotion approach. The results obtained by applying the rule-promotion approach were found to be more acceptable to the disease experts. The application of new approach has significantly improved the diagnostic decisions.

Total 10 diseases and 25 test cases of each disease were included to test the rule-promotion approach. Following studies were done with the total sample size of 250 test cases.

6.1 Results of Conventional Approach

The domain expert CF for each rule is kept unchanged with its original value in this test case. The system is run without applying the rule-promotion strategy for each sample test case. The same sample size of 250 test cases was used. The successful diagnosis and unsuccessful diagnosis consultation sessions were noted each time. The successful diagnosis is the session that resulted into correct diagnosis and unsuccessful diagnosis is the consultation session that resulted into either incorrect diagnosis or system could not do any diagnosis. The results were verified by domain experts at Directorate of Soybean Research, Indore, India. In this test case, out of 250 cases 141 cases resulted into successful decisions. This gives the success rate = 56.4% as depicted in Fig. 6.

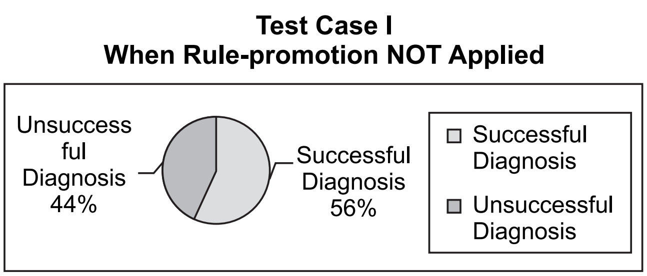

Fig. 6. Results of Test Case I - when rule-promotion is not applied

6.2 Results of Rule-promotion Approach

Rule-promotion strategy is applied in this test case for the same sample and different successive trials were run on the system. Total thirteen successive trials were done, because after 10 trials no significant changes were observed. Every time rule-promotion strategy is applied in all the trials. First trial shows that out of 250 cases 156 cases resulted into successful diagnostic decisions leading to success rate = 62.4% (Fig. 7). Out of total cases in Second trial 177 cases resulted into successful conclusions. The success rate is increased to 70.8%. The third and fourth trial resulted with success rates as 76.4% and 80.8% respectively. The successful diagnosis in each of the thirteen successive trials are shown in Fig. 8. The last trial improved the success rate up to 92.4%. This shows that the new rule-promotion strategy could be successfully applied to the expert systems with successful diagnostic results every time.

This showed more confidence level in the final decision when rule-promotion is applied as compared to the conventional methods when rule-promotion is not applied.

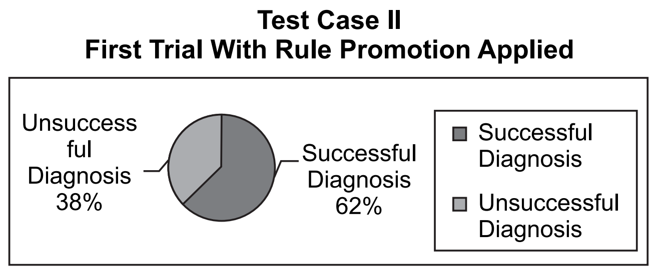

Fig. 7. Results of First Trial of Test Case II when rule-promotion is applied

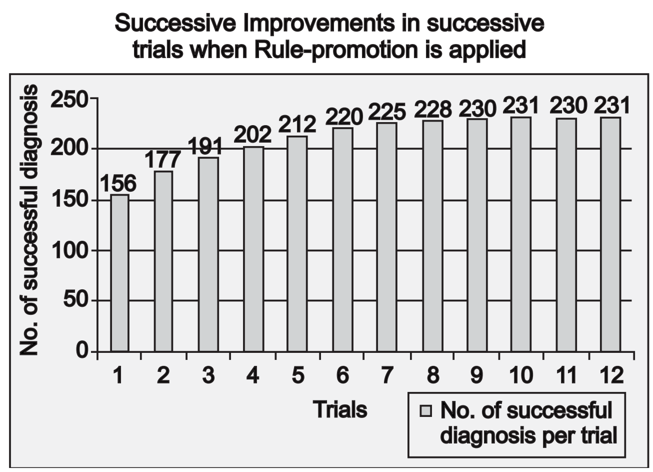

Fig. 8. Results of successive trials when rule-promotion is applied

7. CONCLUSION AND FUTURE DIRECTIONS

The new rule-promotion fuzzy-logic approach has opened a way to increase dynamically the confidence level of useful rules. This was not possible in conventional approach, wherein the confidence level remained always constant. The results indicated that the new methods have improved the inference procedures of the expert systems, and the new architecture has some advantage over the conventional architectures of expert systems on both efficiency and accuracy. The IISDDC as a whole can be a powerful means for transfer of technology of agriculture pathological technologies to practices over the web. The system is presently working on local server at DSR, Indore and soon it will be made available to the users on institute website http://www.dsrindore.org.

The system can be used for other diagnostic applications in future. Suggested applications are human disease ES, fault diagnosis in machines, pest diagnosis and weed diagnosis. The same system can be used for these with minor modifications in it. The inference model template developed in this work can be reused as such in all the Rule-based ES to promote the rules. The rule promotion gradually strengthens the inference drawing power of the Inference Engine. The system presently contains disease knowledge about soybean, groundnut and rapeseed-mustard crops. The same application can be used for expert disease diagnosis of other crops by storing its knowledge in the same system.

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