Agpest: An Efficient Rule-Based Expert System to Prevent Pest Diseases of Rice & Wheat Crops

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***Abstract*—Agriculture is one of the major sources of income in developing countries like India. Pests are one of the main sources for the degradation of quality and quantity of the major crops such as Rice and Wheat. The lack of knowledge about technical & scientific methods to prevent pest diseases is the main reason for less production of these commodities. This paper presents an architectural framework of an agriculture Expert System and describes the design and development of the rule based expert system for rice and wheat crop pest management. The designed system is intended for the diagnosis of diseases caused by pests in the rice & wheat plants respectively and it also facilitates different components including decision support module with interactive console base user interface for diagnosis on the basis of response(s) of the user made against the queries related to particular disease symp-toms. This paper provides a new approach for knowledge representation in expert systems for agricultural domain. The Explanation block (EB) of the system provides the explanation for a particular decision taken by the system. Explanation block gives the clear view of logic followed by kernel of the expert system.**

***Index Terms*—Expert System, Console base, Explanation block.**

I. Introduction

An expert/knowledge-based system is a computer pro-gram that is designed to mimic the decision-making ability of a decision-maker(s) (i.e., expert(s)) in a particular narrow domain of expertise [1].The primary intent of expert system technology is to realize the integration of human expertise into computer processes. This integration not only helps to preserve the human expertise but also allows humans to be freed from performing the more routine activities that might be associated with inter-actions with a computer-based system.

Structure of Expert Systems

In the early days the phrase [0]Expertsystem[0] was used to denote a system whose knowledge base and

Student Author reasoning mechanisms were based on those of a human expert. A system will be called an expert system based on its form alone and independent of its source of knowledge or reasoning capabilities. The major components which form expert system:

Expert System Kernel :

- Knowledge Base
- Inference Engine
- Explanation Engine
- User Interface

J. *Agriculture Expert system*

This paper is mainly focused on design and development of agriculture expert system. Pest disease control is one of the main area where farmers need expertise from the researchers and specialists of that field. There are various pests which destroy the crops at various stages of their growth. One of the main reasons for this is the lack of knowledge about the advanced fertilizers and pest management information. This paper is mainly focused on design and implementation of the expert system for the diagnosis of pest diseases in Rice and Wheat crops.

The modern farmer often relies on agricultural specialists and advisor to provide information for decision making to achieve good results. Unfortunately, agricultural specialist assistance is not always available when the farmer needs it. In order to alleviate this problem, expert systems were identified as a powerful tool with extensive potential in agriculture [2].

The rest of the paper is organized as follows: In section 2, we briefly discuss the related work. In section 3, we discuss

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the details of our design & knowledge representation. Section 4 gives the implementation details of our expert system using CLIPS 6.0. Section 5 describes the verification and quality check. Section 6 discusses the results. Conclusion and future work are dealt in section 7.

II. RELATED WORK

DENDRAL[1] is the first expert system [3].It holds a significant place in the history of expert/knowledge-based systems because it was the first system to use the expertise of human problem solvers and translate that knowledge into a large numbers of special purpose rules, known as a rule - based system.

In agriculture, applications of expert system are mainly found in the area of disease diagnosis and pest controls. Many domain specific expert systems are being used at different levels. AMRAPALIKA: An expert system for the diagnosis of pests, diseases and disorders in Indian Mango is an application of expert system in the agriculture domain [4]. In this system, the expert system is developed with rule-based expert system, using ESTA. Another expert system Dr. Wheat: A Web-based Expert System for Diagnosis of Diseases and Pests in Pakistani Wheat [5]. The system is for the purpose of pest and disease control of Pakistani wheat. They had developed the system with web-based expert system using e2gLite shell. Expert Systems Applications: Agriculture, is also the application of expert system in the agriculture domain developed by Ahmed Rafea [6]. Decision Support System Crop-9-DSS or Identified Crops, by Ganesan V. is an expert system developed with Macromedia flash MX Professional 2004 6.0 [7] . The system is developed for the purpose of the identification of diseases and pests with control measures, fertilizer recommendation system, water management system and identification of farm implements for leading crops of Kerela. Web based Expert System for Diagnosis of Micro Nutrients Deficiencies in Crops also describes application of expert system in agriculture particularly in the area of nutrient deficiencies in crops [8]. The system is a web based system using the ServCLIPS tool.

III. DESIGN ANALYSIS

To build an expert system for diagnosis of the diseases, knowledge representation plays a key role. To prove an expert system is of good quality, it mainly depends on the while decision making. In this paper a new approach is used to represent the domain knowledge that is rice and wheat pest disease information. This AgPest is a rule based expert system. The formulation of rules plays a major role.

AgPest is a rule based expert system it uses forward chaining mechanism. The knowledge base of AgPest must be used in efficient manner to produce accurate decision. To do so we need to formulate rules using pest diseases information i.e., consider symptoms as conditions. If particular condition satisfies then check for successive conditions related to that particular disease.

Let s1,s2.....,sn are symptoms related to the disease d1. The rule base is formulated as follows.

If (s1) Then (s2) Else (No Match)

The same procedure can be followed till sn symptoms are satisfied.'

A. Rules formulation for Rice pest-diseases

The formulation of rules for pest management is done using Agroweb[2] pest database, this database contains information about all crops and their pest diseases and information about pest control. AgPest takes particular decision according to the given environments present condition. AgPest takes users response as an input for the questions related to symptoms of a particular disease. It executes the rules related to the given responses and finally displays the decision about particular disease, in case if any of the user response satisfies the conditions related to a particular disease. Knowledge base of the AgPest contains the rules related to the pest disease diagnosis. The decision taken by the AgPest involves the knowledge base. Knowledge acquisition part of the expert system is crucial.

Proposed Method to formulate rule base for pest disease diagnosis:

Step 1 : The Color division module of the disease model presents some of the diseased plants visuals to the user. These visuals helps user to identify colour of the diseased plant of his own.

Step 2: Divide all pest diseases according to their leaves color. Once the color of the leaf is known, the

[1]It was written in LISP,to benefit organic chemists in identifying unknown organic molecules, by analysing their mass spectra and using knowledge of chemistry correctness, quality and validity of the knowledge base which it uses

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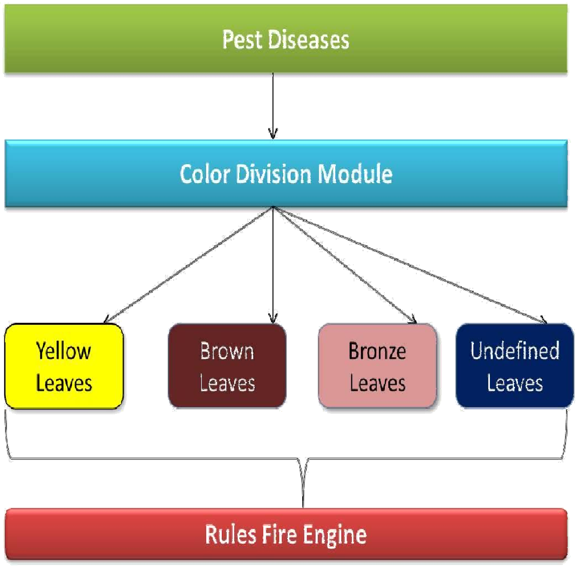

Fig. 1. Rice Pest Diseases knowledgebase classification

TABLE I
RICE PEST MANAGEMENT CLASSIFIED DISEASES

Yellow leaves	Brown leaves	Bronze leaves	Unidentified
Bacterial leaf blight	Blast Pyricularia Oryzae	Grassy stunt	Bunt kernel smut
Foot Rot	Brown spot	-	False smut
Rice Yellow dwarf	Narrow brown spot	-	-

rules related to leaf color will be executed. In this process AgPest fires queries about a particular disease, in this case queries are based on the disease symptoms. Keeping track of user information about the particular disease it executes set of rules and gives disease name and advice.

B. Rules formulation for Wheat pest-diseases

The rules are formulated using same techniques as rice model,but most of the rules are fired sequentially. The symptoms related to the Wheat pest diseases are different from rice pest disease symptoms, so expert system evaluates the rules sequentially till it arrives to conclusion.

C. Knowledge representation in CLIPS 6.0

AgPest is develepd using CLIPS(C Language Integrated Production System) language. CLIPS is a multi-paradigm programming language that provides

TABLE II
WHEAT PEST MANAGEMENT CLASSIFIED DISEASES

Sl.no	Pest Disease
1.	Black Point
2.	Foot Rot
3.	Kamal Bunt
4.	Leaf Blight
5.	Leaf Rust
6.	Stem Rust

support for rule-based, object-oriented, and procedural programming. CLIPS is a forward chaining, rule- based production-system language, which is based on the RETE algorithm for pattern-matching. A command-line interpreter is the default interface for CLIPS 6.0 language.

The following sample code represents the pest disease for rice crop.

CLIPS 6.0 CODE

```
(defrule determine-yellow-leaves

(leaves-color yellow)

=)

(assert (fired rule1))

(printout t ”WHAT IS THE COLOR OF LEISONS”crlf)

(printout t ”OPTIONS:1.YELLOW 2.OTHER”crlf)

(bind ?leison-color (read))

(if(eq ?leison-color 1) then (assert (leison-color
yellow))

else(if(eq ?leison-color 2) then (assert
(check-foot-rot))))
```

Above code is taken from Rice pest management module of AgPest.

Above code represents a typical Rule representation in CLIPS 6.0 Language.In CLIPS rules are declared using defrule construct,facts are declared using assert construct. CLIPS provides a library construct called salience. This constructs sets the priority level for different rules during execution. In CLIPS values assigned to the variables using construct called bind.

IV. IMPLEMENTATION

AgPest is a Console User Interface based application. This expert system interacts with the user in textual mode. It gathers information from the user during runtime and keeps track of user response about environment, accordingly it gives final decision. AgPest domain is agriculture and it is built for diagnosing rice and wheat pest disease management. The development of AgPest involves following processes

Knowledge Acquisition
Knowledge Representation
Implementation in CLIPS 6.0

A. Decision procedure for Rice Pest-Management

As mentioned in earlier Knowledge Acquisition, knowledge Representation plays major role in performance of the overall expert system. These two stages are very important in development of any Expert System. In this paper ,for AgPest the domain knowledge information is gathered from Agroweb.

The rule base for Rice pest management contains various modules that contains different set conditions for testing diseases belongs to that module. These conditions are nothing but symptoms of a particular disease. During the execution/runtime expert system checks these conditions based on user responses to the set of fired questions. This evaluation of conditions is done at runtime, for this purpose AgPest keeps track of user responses.

B. Decision procedure for Wheat Pest-Management

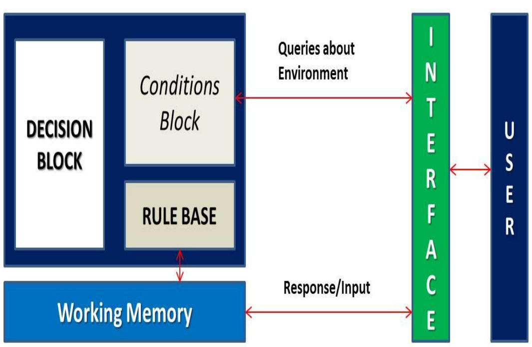

Fig. 2. Sequential flow of Execution Wheat Model

In the above figure first wheat module executes the common rule whose RHS field is empty. This is the starting point for execution in this module. Facts will be assigned during run time and those facts will be stored in working memory,using these facts different rules get fired finally decision will be display through standard output.

C. EXPLANATION BLOCK

AgPest has a added feature called Explanation Engine. The basic mechanism of the explanation engine in any expert system is to provide user with the information about decision making and reasoning behind a particular decision. This explanation engine is quite essential in any expert system. Explanation engine satisfies the user about the decision and user will beassured of correctness of result produced by expert system. In AgPest explanation block is implemented using CLIPS 6.0 File system con-structs. In this paper related to AgPest, the explanation block functionality is as follows:

1*) Explanation Block Mechanism:*

After the completion of execution of Core module of AgPest, result for that particular interaction will be displayed on the standard output. Explanation block files are executed after the main result. The detailed explanation about a particular decision will be displayed after main decision. This result is pro-duced by Explanation block of the expert system.

Explanationblock contains set of Cause [ ] Effect [ ] Decision [ ] type statements.

These statements give user clear picture about the decision procedure followed by AgPest during runtime.

These statements are displayed sequentially i.e.,the order in which questions posed at asked to user, and the actions taken for each user response.

D. Implementation of Explanation Block in CLIPS 6.0

CLIPS 6.0 is an Artificial Intelligence language it provides the inference mechanism and console user interface . Every expert system must have Explanation Block module. Explanation Block module for AgPest using File Constructs in CLIPS. The CLIPS 6.0 is a patteren recognition relanguage. In CLIPS for every execution there will be some set of rules get fired and others will be ignored. So we must keep track of those rules which got fired, so that these rules can be saved in working memory during the shell execution, later when user requests decision mechanism. These rules from temporary run time will be transferred to the working memory to produce explanation about a decision.

in explanation block. These rules which got fired in explanation block contains the detailed explanation about expert system decision. These rules contains a condition statement which evaluates the users response and prints the validation of user response.

V. EXPERIMENTAL SETUP

The serial code was run on Intel(R) Pentium(R) Dual core 2.20 GHz processor with 4GB RAM on Ubuntu 10.04 LTS and Windows 7. The domain knowledge information is gathered from Agroweb. This is a publicly available repository for Pest management information. The designed expert system domain knowledge is limited to the Agroweb information, it is designed in such that it is scalable.

A. Testing & Verification

There are two different types of testing and verification procedures exists for the expert systems. The first type of verification criteria is focused on the global relationships between the rule clusters (sets of conditions which satisfy common conclusions) such as reachability and dead-end IFs. The second type of verification criteria is concerned with the local properties of a specific rule cluster such as missing rules and inconsistent rules. The significance of this approach is that global criteria are not computationally expensive to test and we can perform exhaustive testing for local criteria on each rule cluster because of the smaller size. If properly

verified, the rule base represents a closed world: local verification criteria are met for the rule base as a whole if they are met for each rule cluster individually.

[15] Local Verification Criteria

Completeness: AgPest knowledgebase is relatively small since it is a tiny experimental expert system. AgPest is throughly checked for missing rules, this verification is done by giving all possible inputs to the expert system for different scenarios. During this testing it is found that five rules belongs to Rice module of AgPest are not declared, but there are some facts which are referring to those rules during runtime. This verification helped in having complete control over all declared rules and runtime facts.

Since CLIPS 6.0 doesnt allow any intercommunication between two rules. An artificial temporary file used for the communication between rules. This file name is [fire(no[3]).dat] in all rules.

All fired rules will have a file called fire with rule number.i.e., for example,fire11.dat - is the file which corresponds to rule number 11.This way all fired rules will be separated from other rule by assigning ”fired” to that particular number file. Explanation Block includes the user response in its result for better understanding so we must keep track of user input for every query. The file named xpl(no[4]).dat is assigned to every rule which stores the user input in that file. Explanation Block, fires a common rule called Explanationrule-explanation.

Explanation block is invoked after every decision taken by expert system. In explanation block module there is a default rule whose LHS field is empty and every time when Explanation block is invoked this rule gets executed. The RHS field of this rule consists File constructs, which will be used to open all the fire(no).dat files and assign the values to variable called var(no[5]), using this var(no) variable, Fact - (rule ?var(no)) gets asserted. This is the initial fact of explanation block. Salience - construct of CLIPS 6.0 is used to set priority of execution for rules. The default rule in explanation block has the highest salience value (1000). Other rules have the salience value in decreasing order i.e., if r1.......rn is set of rules stored in working memory of Explanation Block then

s(r1) = SALIENCE OF RULE 1

s(r2) = SALIENCE OF RULE 2

s(r2) = S(r1) - 1

s(r1)) S(r2) .... S(rn)) S(rn-1) .

Default block, asserts the initial fact into working memory, using this fact CLIPS patteren matches the other rules in knowledge base for further execution. Default rule whose LHS field is empty asserts facts for all the rules which got executed during the disease identification process. These initial facts and Salience priority of rules are the main attributes to fire a rule

[3]This no is relative to rule number
[4]This no is relative to rule number,variable file.
[5]Here rule no - number of the rule Consistency:

Each rule cluster must be internally consistent [9], but it should not happen that no rule should reach different conclusions when given the same input. Special considerations include generalization, incompatibility, and synonymy. The consistency test is done on the rules which gets fired according to their salience[6] and whose LHS field is same, during this test it is found that 2 rules produces different conclusions for same input given by the user.

2) Domain Constraints: All values must be consistent

with the domain. These values must be consistent both locally and globally with respect to legal values, range, and data types. In addition to these general verification criteria, the domain must also meet implementation specific criteria such as host language reserved words and syntax constraints. AgPest System uses integer,char and string data types in rules. Most of the user replies are integer data type based, for consistency of knowledge base and rule execution we have implemented a

condition for each user input. This condition tests the user input for correctness and tests for data type correctness if the input range is out of given range or input data type itself is false then automatically that session ends.

C. Global Verification Criteria

In addition to the tests performed on individual rule clusters, there are several global verification criteria. These criteria focus on the relationships between rule clusters and may be tested through the attribute dictionary and the rules Dictionary. The Rules Dictionary contains the conditions and conclusions used in the rules, information about the state of the AgPest(if it is complete and refined), and the location of the AgPest, while the Attribute Dictionary contains the definitions and sources for each condition and conclusion.

There are only two types of Global Verification Cri-teria: instantiation and domain constraints.

1) Instantiation criteria: The instantiation criteria deals with the creation of output for all possible condi-tions. AgPest System is tested for instantiation criteria, its found that all the conditions and conclusion create an output. That value is used for further execution and final

[6]Salience is the value set for rules. Salience set priority of execution between rules

result is generated based on these values. During the development phase of AgPest this testcase is satisfied by assigning facts for every condition,i.e., if condition is satisfied then positive fact will be assigned and if the condition is not satisfied the alternative procedure fact is assigned . So that, the flow of execution continues till the end.

2) Domain constraints: Domain constraints must also be enforced at a global level. The local verification domain constraints must be enforced between rule clusters as well as within the rule cluster [9]. AgPest uses local variables highly. Therefore the scope of these variables belongs to the rules in which they are declared. AgPest uses File constructs of CLIPS 6.0. File constructs are extensively used to stores the temporary values generated as a result of fired rules, these values can be used any where in the code instead of depending on a particular global variable. Data type is not anissue in CLIPS 6.0 because there is no specific data type declaration for any variable. Its allowed to bind either integer or char value to the variable, there is no type declaration specifically.

IV. RESULTS

AgPest is tested for all the possible test cases. It is found that the decision making capability of the AgPest is correct for all possible valid inputs. The response time for an interactive session is good, These results shown in the Table III for rice module of the AgPest and Table IV represents the wheat module. These two talbes represents complete statistics of AgPest. These tables are mainly focused on the performance interms of speed of execution. These tables contain total timetaken to process a decision, Mean value of the rules fired per session, Number of facts used during an interactive session. These table also shows number of rules fired persecond for each disease during its interation with the user.

VII.CONCLUSIONS AND FUTURE WORK

In this paper, AgPest-Pest disease diagnosis expert system is proposed. The main focus is on design and implementation. This paper discusses novel way of rep-resenting the knowledge base related to pest disease managment. It is observed that after conducting many tests and real time usage simulation environment, Advice or decision given by the AgPest is consistent,accurate and complete. During the period of testing,verification and evaluation, It is observed that the complete statistics

TABLE III

Disease	Runtime	Rules Fired	Rules per second	Mean no of facts	Mean no of Instances
Bacterial Leaf Blight	0.0159	4	250.0	12	1
Foot Rot	0.0160	4	249.9	11	1
Yellow Dwarf	0.0470	5	106.38	15	1
Blast-Pyriculari a oryzae	0.014	4	266.6	12	1
Brown spot	0.047	8	170.21	24	1
Narrow Brown spot	0.046	7	148.93	21	1
Grassy-stut	0.0310	3	96.774	9	1
Bunt/Kerne l smut	0.031	5	161.29	15	1
Falsesmurt	0.030	7	225.80	21	1

RICE PEST MANAGEMENT MODULE COMPUTATIONAL STATISTICS DURING RUNTIME

TABLE IV
WHEAT PEST MANAGEMENT

Disease	Runtime	Rules Fired	Rules per second	Mean no of facts	Mean no of Instances
Black Point	0.016	4	249.0	11	1
Foot Rot	0.0310	7	225.86	20	1
Kamal Bunt	0.0469	7	148.93	20	1
Leaf Blight	0.0469	8	170.21	25	1
Leaf Rust	0.0619	11	177.41	32	1
Stem Rust	0.0469	9	191.48	26	1

VII. COMPUTATIONAL STATISTICS DURING RUNTIME

of AgPest i.e., Run time, Mean value of rules, facts, and rules fired per second for each disease during its interaction with user. These results shows that this expert system is not only gives accurate results but it has a quick response time. In this paper explanation block is implemented for each module independently. It is very useful in real time to get better understanding about a particular decision taken by the AgPest. The logic used to develop Explanation block for AgPest can be used for any other rule-based expert system developed using CLIPS. AgPest can be used as a basic prototype to build expert systems for pest management. Its possible to build a distributed AgPest, where different crops pest managment information can be maintained by isoloted servers located at different locations in the world. During the computation time according to the location of a particular crop those servers located in that area can be queried. AgPest can be parallelized using for quick response time.

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