Knowledge Engineering for an Expert System on Crop Disease Management

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Abstract

Expert system is the computer system that solves a domain specific real-world problem using human knowledge and reasoning expertise. Knowledge and inference are the two important parts of an ES. In the development of disease diagnostic ES, knowledge engineering and its maintenance is a big challenge as knowledge involved is of dynamic nature. The classification scheme of concepts of disease symptoms is an important issue in the design of entities or objects dealing with disease knowledge. In this work, the complete process of knowledge acquisition and engineering for disease management of crops has been standardized and a new prototype of web-based knowledge management system (KMS) has been developed. The different components of KMS include efficient tools for knowledge acquisition, storing, knowledge engineering, processing of knowledge, management of knowledge, associated reasoning services and a new interface to define, manipulate and query for disease diagnostic knowledge. The current paper discusses the adopted development methodology and the experience acquired during knowledge engineering and the development of web-based KMS for crop diseases.

Keywords : crop disease, expert system, knowledge acquisition, knowledge engineering, knowledge management

1. Introduction

The emergence of Information and Communication Technologies (ICT) with the potentiality of Internet through World Wide Web (WWW), in the last decade has opened new avenues in knowledge management that could play important roles in meeting the prevailing challenges related to sharing, exchanging and disseminating knowledge and technologies. Agriculture knowledge is a special kind of domain knowledge and is a significant basis for knowledge based intelligent information system. Expert systems and information systems have successfully been used in disease diagnosis in crops. An ES is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution [6]. The basic difference of ESs with that of conventional computer programs is that ESs manipulate knowledge while conventional programs manipulate data. It uses domain specific knowledge and inference techniques to simulate the problem solving behavior of a human expert of the same field. One such agriculture domain is plant pathology. ESs for diagnosis in the general agricultural domain are already being explored in several works ([2], [3], [4], [5], [12], [13], [14], [19], [20], [22], [23]). Still, there is a need to improve the current diagnosis

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process of crop diseases by using the potential of Internet. Looking to the necessity of improving the current diagnosis process of crop diseases linked to the potential of the Internet, motivated the development of web-based diagnostic ESs. In this work, for the development of web-based diagnostic ES, the complete process of knowledge acquisition and engineering for disease management of crops has been standardized and a new prototype of web-based knowledge management system (KMS) has been developed. This KMS is one of the modules of the web-based expert system developed for the diagnosis and control of diseases in oilseed crops viz. Soybean, Rapeseed Mustard and Groundnut.

2. Materials and Methods

ESs are distinct from Information Systems in terms of their approach to problem representation. Information system process information, while ES attempt to process knowledge. The reliability of a diagnostic ES depends on the quantity and quality of knowledge that it handles, i.e. the number of diseases it can diagnose and the appropriate representation of the domain expert knowledge. This can be achieved by the knowledge engineer. For this a knowledge acquisition procedure is adopted.

Knowledge in an ES may originate from many sources, such as textbooks, compendiums, reports, bulletins, databases, case studies, empirical data, web resources and personal experience. The human domain experts are the dominant source of knowledge in today's ESs. A knowledge engineer usually obtains knowledge through direct interaction with the domain expert.

A. Knowledge Engineering

The process of constructing knowledge base for a specific domain for use in ES is called knowledge engineering. Knowledge engineering involves the cooperation of the human experts in the domain to codify and make explicit rules or other procedures that a human expert uses to solve real problems [6]. It includes the methodologies for acquiring the knowledge, organizing, analyzing, classifying and structuring the acquired knowledge, representing, verifying and validating the structured knowledge. The process of knowledge engineering is shown in Fig. 1

1) Knowledge acquisition

This is the most critical and problematic phase in the development of an ES as the translation of the knowledge possessed by the expert into a knowledge base is the bottleneck in the process of knowledge acquisition [18]. The domain experts play a vital role in the system's knowledge accumulation and the role of the knowledge engineer is important for the system's efficiency. The acquisition of knowledge can be carried out from domain expert and by gaining the useful knowledge from the standard references.

First of all, the domain knowledge is thoroughly examined for the development of our system. The crop disease experts defined the diseases expected by the system to be able to investigate, different cases for each disease and a proposed way of treating the diseases. Also, relevant information is gathered from literature, pathological experimental field trials, disease compendiums [10], books, scientific papers, disease bulletins [1], [8], [9] photographs concerning the diseases and by interviewing plant pathologists [21]. The knowledge on different disease symptoms alongwith the knowledge on other disease related information viz. causal organisms, geographic distribution, economic impact, favourable climatic conditions, detection methods and effective integrated management of practices were collected and organized.

2) Knowledge structuring

The knowledge possessed by human experts is generally unstructured and not explicitly expressed. The knowledge acquired from domain experts needs to be structured properly. For this it is organized, analyzed and classified to form proper knowledge structures. Further, classification and analysis of symptoms is a very important stage in the process of building the knowledge base. In our work, the structure and organization of the knowledge is modeled in the form of object-attribute-value (O-A-V)[17] knowledge triplets. This method was successfully used earlier in an ES for tomato diseases [2], [3].

Most of the disease symptoms appear at a particular growth stage after a certain period of date of sowing and a specific part of the plant is affected. The infected parts of the plant have one or more infection attributes with more than one type of infection value per attribute. So, our knowledge base is divided into knowledge domains based on the 'crop age' as main-domain and 'part affected' as sub-domain. These are stored on knowledge domain server. The knowledge engineers analyzed knowledge domains and discussed their contents with domain experts to get their feed back and to complete the missing knowledge. Finally, the symptoms were classified according to:

the crop age based on date of sowing (30, 60, 90, 120 days after sowing)

the plant growth stages (seed, seedling and well grown plant)

the part of the plant on which the infection was observed (root, leaf, seedling stem, bud, pod, seed etc.)

the type of infection (spots, lesions, pustules, fungal structures, mycelium, mottling etc.)

the type of expression of the infection (brown, water soaked, irregular, sunken, raised etc.)

This classification scheme worked very well for fast retrieval of specific knowledge from the knowledge domain server during the inference drawing process.

3) *Knowledge representation*

It involves translation of domain specific knowledge in the standard symbolic form for representing facts and rules in a computer. Amongst the different methods for representing the knowledge [18], one widely used representation is the ***production rule****, or simply* rule *for diagnostic ESs. A rule consists of an IF part and a THEN part (also called a* ***condition*** *and an* ***action****). The IF part lists a set of conditions in some logical combination. The piece of knowledge represented by the production rule is relevant to the line of reasoning being developed if the IF part of the rule is satisfied; consequently, the THEN part can be concluded, or its problem-solving action taken. In rule-based representation, the representation is made in the format of IF-Then statement.*

In our case, we followed the object-attribute-value (O-A-V) knowledge representation method [17]. This method can easily fit into any rule-based ES development tool. The condition of a rule in this method is represented as a simple sentence which is either true or false, or an OAV triplet. This is clearly depicted in Fig. 2, that shows the diagramatic representation of complete flow of knowledge in knowledge acquisition subsystem. For example, the symptoms for Charcoal Rot and Bacterial Pustule diseases in soybean as observed on well grown plant stage can be represented as in Table 1.

The conditions of each rule is connected with other rule by *And*(conjunction), Or (disjunction), *material implication* and *negation.* The keywords viz rule, IF, THEN, AND, OR etc are defined by the user. With this provision the user can write his own KB in his own language.

The following rules are derived:

R25 : IF plant shows wilting
AND soil temperature is high
AND soil moisture is low
THEN *Ignore* charcoal rot (0.2)

R26 : IF plant shows wilting THEN *slight evidence* of charcoal rot (0.4)

R27 : IF reddish brown discoloration appear on lower stem

THEN *slight evidence* of charcoal rot (0.6)

R30 : IF part affected = "lower stem"

AND light gray or silvery discoloration of epidermal tissue

AND light gray or silvery discoloration of sub-epidermal tissue

AND light gray or silvery discoloration of internal tissue

THEN *probably* disease is charcoal rot (0.8)

R31 : IF part affected = "upper tap root"

AND light gray or silvery discoloration of epidermal tissue

AND light gray or silvery discoloration of sub-epidermal tissue

AND light gray or silvery discoloration of internal tissue

THEN *probably* disease is charcoal rot (0.8)

R33 : IF part affected = "lower stem"

AND minute black sclerotia appear on cortical tissue

AND minute black sclerotia appear on pith region

THEN *definitely* disease is charcoal rot (1)

R275 : IF atmospheric termperature is moderately high

AND relative humidity is high

THEN *Ignore* bacterial pustule (0.2)

R277 : IF minute, pale green, elevated spots appear on leaves

AND minute, pale green, elevated spots appear on interveinal areas on both sides of leaves

THEN *probably* disease is bacterial pustule (0.8)

R281 : IF small, raised, light gray to yellowish pustules surrounded by pale-green halo

AND small, raised, light gray to yellowish pustules appear on center of spots

AND small, raised, light gray to yellowish pustules coalesce to large spots

THEN *probably* disease is bacterial pustule (0.8)

R282 : IF leaves become ragged

THEN *slight evidence* of bacterial pustule (0.4)

Finally, this knowledge base is implemented in the form of relational database tables using SQL SERVER in computer.

1) Knowledge verification and validation

This is the stage whereby we make quality assurance of the acquired knowledge. The knowledge is verified and validated by running test cases until its quality is acceptable. The verification process ensures that the knowledge in the system is consistent, complete, and correct according to the required specification [16]. This is satisfied by running the KMS using some test cases of a few diseases. The difference between the systems implemented knowledge and knowledge acquired by domain experts were noted in a list of differences. The difference list was used to update the final knowledgebase. After the knowledge base verification and validation, the testing and debugging of knowledge acquisition subsystem was done. The Table 2 shows a part of the brief history of the testing phase of the knowledge acquisition subsystem.

B. KMS for Crop Diseases Management: A user interface design

The KMS for crop diseases is a subsystem of the ES for crop diseases and is designed for efficient handling of the crop disease knowledge during the entire process of knowledge acquisition, classification, representation, processing and final storage with an aim to provide a strong and reliable knowledgebase support for the ES of crop diseases.

1) Software requirements

KMS was developed by using Microsoft .NET. It is a software development platform based on virtual machine based architecture. Dot net is designed from the scratch to support programming language independent application development. The entire .NET programs are independent of any particular operating system and physical hardware machine. They can run on any physical machine, running any operating system that contains the implementation of .NET Framework. The core component of the .NET framework is its Common Language Runtime (CLR), which provides the abstraction of execution environment (physical machine and operating system) and manages the overall execution of any of the .NET-based program.

The .NET framework is a collection of all the tools and utilities required to execute the .NET managed applications on a particular platform. The MS.NET framework includes the standard compilers C#, VB.NET, J#, C++. NET and Jscript.NET. ASP.NET is a web application framework and VB.NET is a windows application framework provided in the Microsoft Visual Studio .NET [11], [15]. We used ASP .NET and C# for development of the system.

2) System functionality and structure

The main web page of the system is shown in Fig. 3. The user can login to either the ES or KAS by using the buttons provided in the home page and by putting the User Name and Password for a specific crop into the textbox provided for this purpose on this page.

The user has three main menu options: master entry, disease rule and disease detail (Fig. 4). When electing the option 'mater entry', the system displays a list of entry tasks by using which the domain expert can enter disease type, objects, attributes, values, confidence factor, keyword, crop age and part affected (Fig. 5) that is to be used for creating and editing disease rules by choosing an appropriate sub-menu option provided in the main menu option, 'disease rule' (Fig. 6). The disease detail option is used to enter disease name, disease information and disease picture (Fig. 7). The disease information includes knowledge on other useful disease related aspects like pathogen, distribution, economic impact, favorable climatic conditions, life-cycle of the pathogen, management practices and laboratory test for the disease/ pathogen confirmation. The disease images assist the user in comparing the case evaluated with the identification result thus leading to the final confirmation of the diagnosed disease.

3. Case study

The aim of this case study is to illustrate how the domain experts use our knowledge management tool for adding, viewing, modifying and deleting both types of knowledge (i.e textual and pictorial) for identification and control of crop diseases. The domain expert with the help of knowledge engineer and using the KMS can create new rules, edit and delete already existing rules whenever required. When the domain expert and knowledge engineer are ready with all the facts required to describe the disease symptoms in the form of OAV triplets, reasoning mechanisms and the complete knowledge base is ready to be implemented on computer. The KMS plays a vital role for the implementation of complete knowledge base with appropriate storage structures. To start the implementation process, first of all using the master entry menu-option (Fig. 5), the expert needs to enter all the basic facts viz. disease type, objects, attributes, values, confidence factor, keywords, crop age and part affected. The 'crop age' is used to create main knowledge domain and this is further classified on the basis of knowledge subdomain i.e 'part affected'. The classification of the knowledge base on the basis of domain and subdomain has greatly reduced the searching process for the easy access of rules to efficiently select the appropriate set of applicable rules to be used during reasoning process. This ultimately helps to take fast judgements.

To create the knowledge rules for the Charcoal Rot and Bacterial Pustule, in the 'master entry' menu option (Fig. 5), using the 'object entry' option the objects viz. plant, soil temperature, soil moisture, reddish brown discoloration, light gray or silvery, minute black sclerotia, atmospheric temperature, relative humidity etc. are entered. Using the 'attribute' option the attributes for the rules viz. shows, is, appear on, discoloration of, surrounded by, coalesce to and become, are entered using the small form 'Attribute-entry' as shown in Fig. 4. Similarly values (wilting, high, low, lower stem, epidermal tissue, pale-green halo etc.), Confidence factor CF (0.1, 0.2 ...0.9, 1) as shown below (Fig. 9), Keywords (AND, OR, Nil etc), Crop age (30, 60, 90, 120), part affected (plant, stem, leaves, pod, root etc.) are entered using the options provided for it in the web-form like Fig. 7.

If CF = 1 then "Definite"
0.8 < CF < 1 then "Almost certain"
0.6< CF <= 0.8 then "Probably"
0.3 < CF < =0.6 then "Slight evidence"
0 < CF < = 0.3 then "Ignored"

When the system is ready with the basic facts for the creation of knowledge rules, the expert starts creation of the rules by using the option 'Disease rule' as shown in Fig. 6 that gives the rule entry form as shown in Fig. 8. One by one all the rules conditions are entered by selecting appropriate values for objects, attributes, values etc. for a particular disease using this form (Fig. 9) and the existing rules conditions of the disease are also displayed for the convenience of the expert and to avoid the duplicate entries. Similarly, different online forms are provided for editing of the already existing rules conditions to make any modifications if required. This ultimately helps in creation and edition of rules. The other important disease related information like pathogen, distribution, economic impact, favorable climatic conditions, life-cycle of the pathogen, management practices and laboratory test for the disease/pathogen confirmation is managed by using the menu-option 'Disease Detail' (Fig. 7).

Thus the KMS provides a very user-friendly interface to view, add, edit and delete any kind of disease knowledge for its proper maintenance.

4. Conclusion

The experience acquired during knowledge engineering and the development of KMS for crop diseases revealed that knowledge extraction from experts is a very complicated, tedious and error-prone task in the development of the knowledge base for an expert system. The disease diagnostic knowledge is highly dynamic in nature so the acquired knowledge is never complete at any point of time as the knowledge acquired from one expert may differ from another expert. The development of the KMS has eased the complete process of knowledge management by providing user-friendly interface to the domain expert for entering and storing the domain specific knowledge to solve the disease identification and control problem particularly for oilseeds crops. The following characteristics were found in our system:

- The system facilitates the domain expert by providing an effective tool to enter, view, edit and delete crop disease information stored in the form of a database with the help of knowledge engineer.
- It provides a good platform for easy storage and description of oilseed crop disease symptoms in the form of texts and images by applying a structured approach to the acquisition and management of knowledge.
- It captures the knowledge of an expert's mind through step-by-step interactive sessions, refines the knowledge and automatically generates action tables used in decision-making.

- The errors caused due to indirect communication between developer and experts are eliminated with the direct involvement of the domain expert, this ultimately resulted into the development of accurate end product.
- The system resulted into the development of complete, accurate and consistent knowledge base as described by the expert that lead to more precise diagnostic results by the expert system.
- The classification of the knowledge base on the basis of domain and sub domain has greatly reduced the searching process for the easy access of rules to efficiently select the appropriate set of applicable rules to be used during reasoning process. This ultimately helped in taking fast judgments.

The system gives a procedural approach to get new knowledge, rules and heuristics. Since the system is available on WWW, this gives an opportunity for continuous refinement of the existing knowledge in the system and enables its future maintenance in easy manner.

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Figures

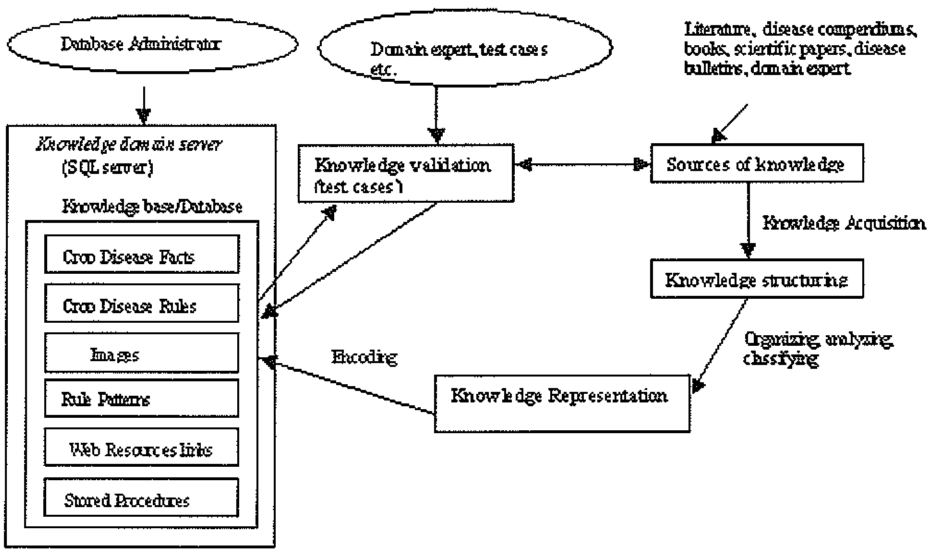
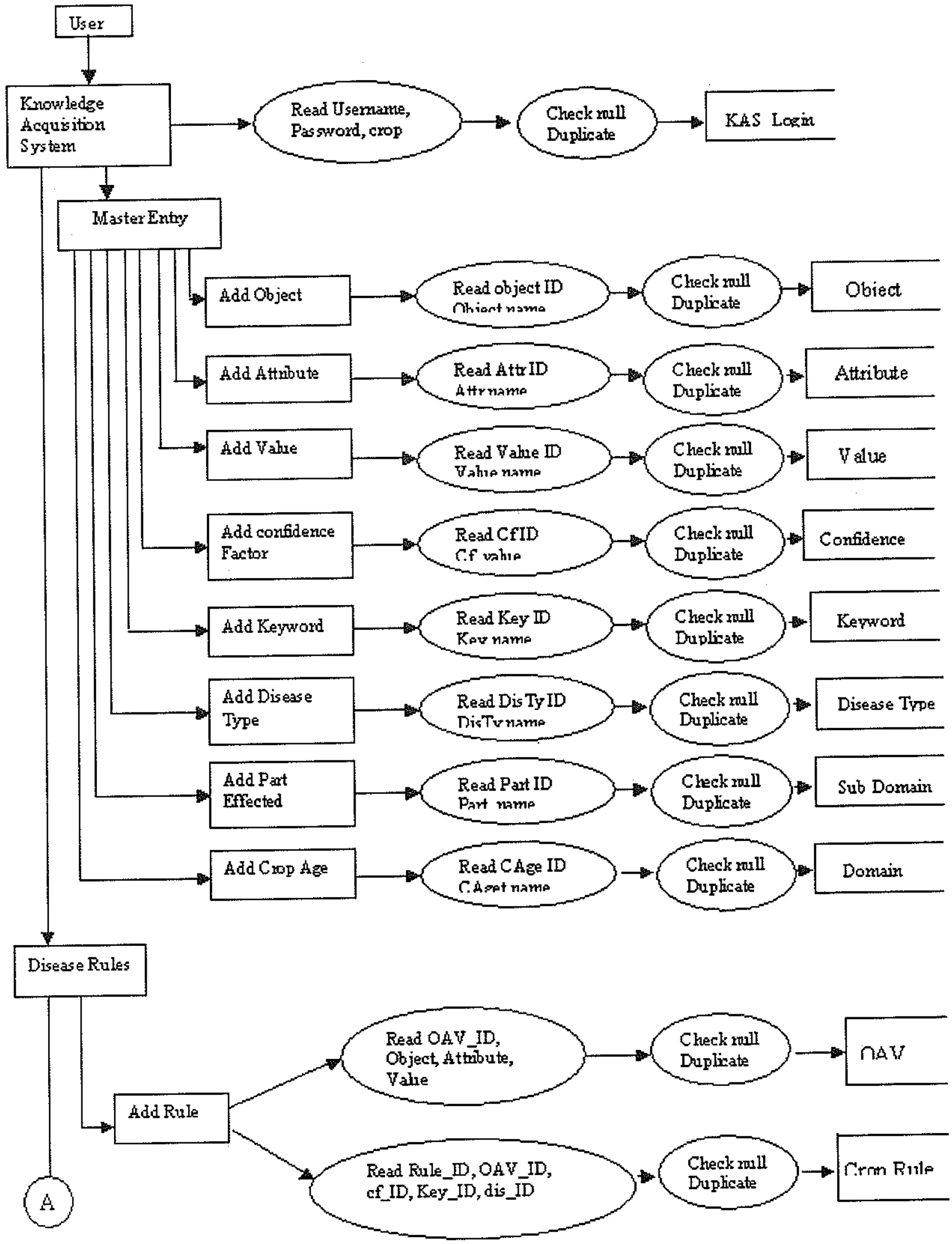


Figure 1 : Process of knowledge engineering


User
Knowledge Acquisition System
Read Username, Password, crop
Check null Duplicate
KAS Login
Master Entry
Add Object
Read object ID
Check null Duplicate
Object
Add Attribute
Read Attr ID
Check null Duplicate
Attribute
Add Value
Read Value ID
Check null Duplicate
Value
Add confidence Factor
Read Cf ID
Check null Duplicate
Confidence
Add Keyword
Read Key ID
Check null Duplicate
Keyword
Add Disease Type
Read Dis Ty ID
Check null Duplicate
Disease Type
Add Part Effected
Read Part ID
Check null Duplicate
Sub Domain
Add Crop Age
Read C Age ID
Check null Duplicate
Domain
Disease Rules
Add Rule
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Check null Duplicate
Crop Rule
A

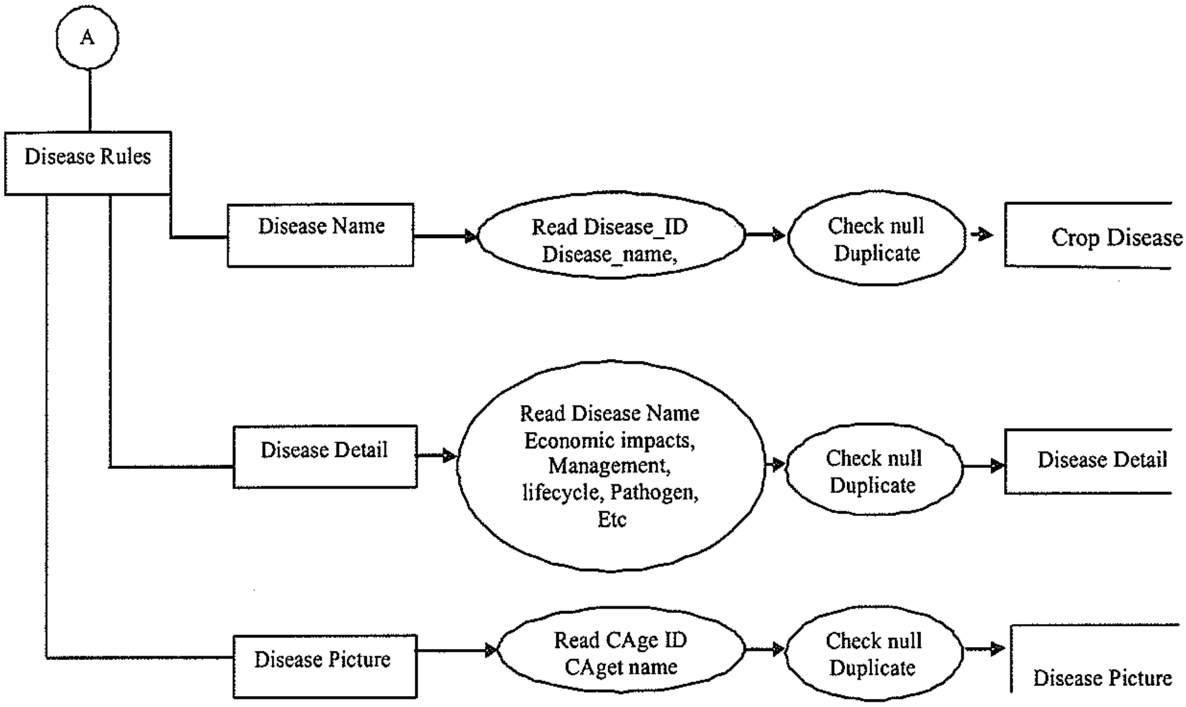

Figure 2 : Diagrammatic representation of flow of knowledge during knowledge acquisition process using KMSCD

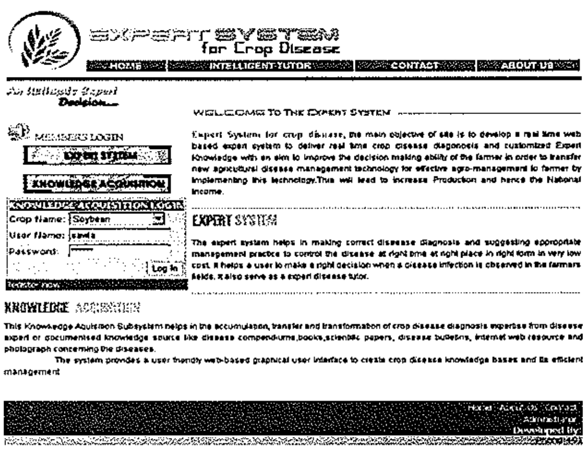

Figure 3 : The home-page of KMSCD

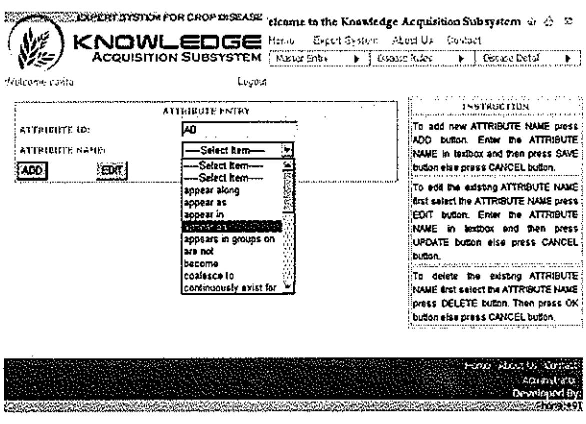

Figure 4 : Different main-menu options with a display of attribute entry.

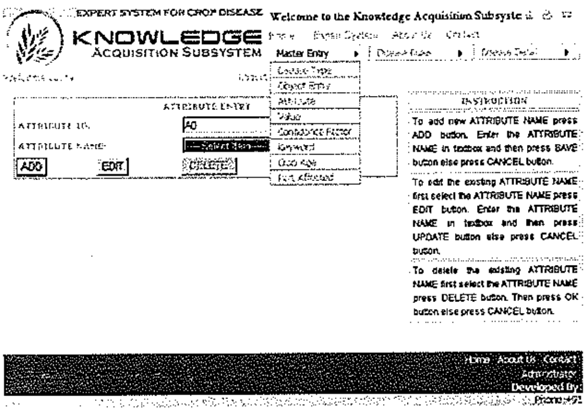

Figure 5 : Sub-menu options of main-menu option of Master-entry

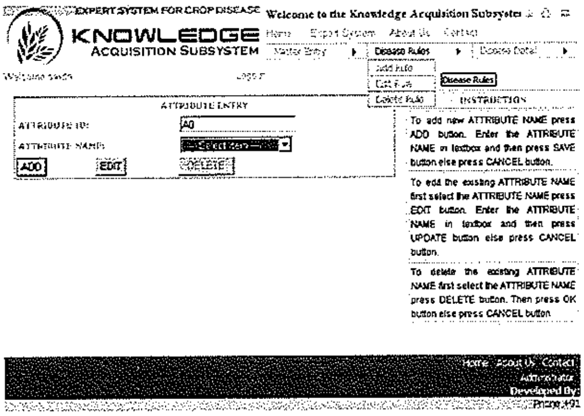

Figure 6 : Sub-menu option of Disease rule main-menu option

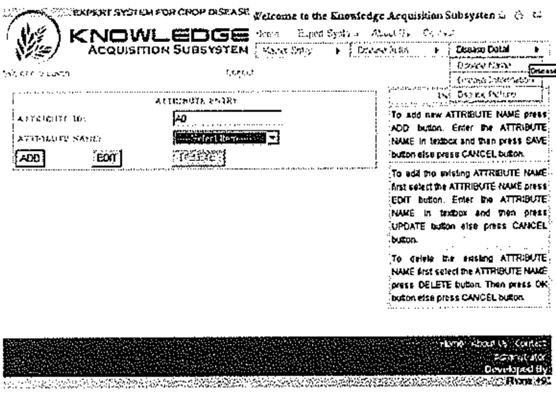

Figure 7: Sub-menu option of Disease detail main-menu option.

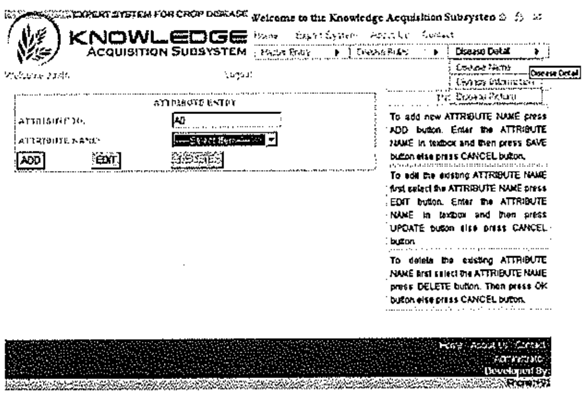

Figure 8 : The form used for creation of new disease rules

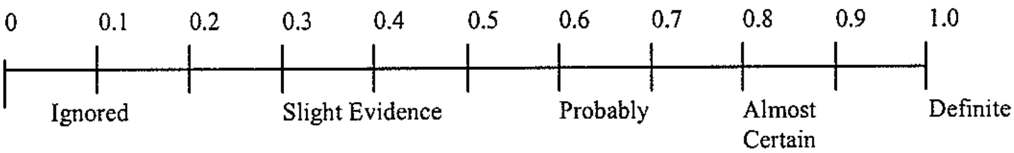

Figure 9 : Multi-valued logical scale of confidence factor used in the system.

Tables

TABLE 1 TABULAR REPRESENTATION OF THE SYMPTOMS OF DIFFERENT DISEASES IN O-A-V FORM

Rule condition	Object	Attribute	Value	CF	Connector Keyword
		Charcoal Rot			
RC25	Plant	Shows	Wilting	0.2	AND
RC25	Soil temperature	Is	High	0.2	AND
RC25	Soil moisture	Is	Low	0.2	NIL
RC26	Plant	Shows	Wilting	0.4	NIL
RC27	Reddish brown discoloration	Appear on	Lower stem	0.6	NIL
RC30	Light gray or silvery	Discoloration of	Epidermal tissue	0.8	AND
RC30	Light gray or silvery	Discoloration of	Sub-epidermal tissue	0.8	AND
RC30	Light brown	Discoloration of	internal tissue	0.8	NIL
RC33	Minute black sclerotia	Appear on	Cortical tissue	1	AND
RC33	Minute black sclerotia	Appear on	Pith region	1	NIL
		Bacterial pustule			
RC275	Atmospheric termperature	Is	Moderately high	0.2	AND
RC275	Relative humidity	Is	High	0.2	NIL
RC277	Minute, pale green, elevated spots	Appear on	Leaves	0.8	AND
RC277	Minute, pale green, elevated spots	Appear on	Interveinal areas on both sides of leaves	0.8	NIL
RC281	Small, raised, light gray to yellowish pustules	Surrounded by	Pale-green halo	0.8	AND
RC281	Small, raised, light gray to yellowish pustules	Appear on	Center of spots	0.8	AND
RC281	Small, raised, light gray to yellowish pustules	Coalesce to	Large spots	0.8	NIL
RC282	Leaves	Become	Ragged	0.4	NIL

TABLE 2. A PART OF THE BRIEF HISTORY OF THE TESTING PHASE.

S.No.	Test Name	Input Data	Output Expected	Actual Result	Remarks
1.	Object Entry	User will provide the object name of the condition	Object name & object ID must be saved in the Database Object	Object name is saved in the database along with the object ID	Passed
2.	Object Edit & Update	User will select the object name And provide the new object name to the system.	The new object name must be update in the database along with the previous object ID	All changes got reflected immediately as user saved the changes.	Passed
3.	Object Delete	User will select the object name To be deleted and press delete & OK	The selected object name must be deleted along with the object ID	Object name is deleted if it is not associated with any other condition.	Passed
4.	Attribute Entry	User will provide the attribute name of the condition	Attribute name & Attribute ID must be saved in the Database Attribute	Attribute name is saved in the database along with the Attribute ID	Passed
5.	Attribute Edit & Update	User will select the Attribute name And provide the new Attribute name to the system.	The new Attribute name must be update in the database along with the previous Attribute ID	All changes got reflected immediately as user saved the changes.	Passed
6.	Attribute Delete	User will select the Attribute name To be deleted and press delete & OK	The selected Attribute name must be deleted along with the Attribute ID	Attribute name is deleted if it is not associated with any other condition.	Passed