Intelligent Systems for Agriculture Domain

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ABSTRACT
In this paper, we describe the different Intelligent Systems developed for Agriculture domain. The development of Intelligent System for disease diagnosis in crops is also explained in detail. Its different components are described one-by-one. The system was evaluated and found useful for Cultivators for effective decision making.

General Terms
Intelligent System, Agriculture.

Keywords
Information System, Intelligent System, Artificial Intelligence, Agriculture.

1. INTRODUCTION
Artificial Intelligence (AI) is a science and technology. It is a collection of concepts and ideas that cannot be commercialized. AI provides scientific foundation for several commercial technologies. The major areas are intelligent systems, natural language processing, speech recognition, robotics and sensory systems.

A few information systems assist in automated decision making with the help of decision support system, which work on models and hypothesis. Information system goes much beyond this, to provide specialized advice to the user, using built-in expert system. Such information system comes under the category of Intelligent Information Systems (IIS) (Gupta, 2000).

The most popular type of intelligent systems is an expert system. An expert system is a computer program, which mimics the behavior of a human expert in a particular field of knowledge (Waterman, 1986). An Intelligent system design may be based on a mathematical model, statistical model, neural network, database, knowledge base or a combination of more than one of these techniques (Buchanan and Shortliffe, 1984). The present work embodies a knowledge-based intelligent system. Intelligent systems have been used successfully in the diversified application areas. For example, there are Intelligent systems that can be used for insect-pest management, schedule routes for delivery vehicles, make the financial forecasts, diagnose crop diseases, diagnosis of plant nutrient deficiency, crop cultivation etc. (Shortliffe, 1976; Latin and Rettinger, 1987; Batchelor et. al., 1989; Plant et. al., 1989; Deer-Ascough et. al., 1992; Tao and Zhang, 1992; Turban, 1992; Boyd and Sun, 1994; Cernohorska et. al., 1995; Yuan-CunXing et. al., 2003; Kolhe et. al., 2007). Intelligent systems for agriculture also combine the experimental and experiential agriculture knowledge, with the intuitive reasoning skills of many specialists to aid the farmers.

Some Intelligent systems are designed to replace the human experts, while others are designed to aid them in the mundane work (Waterman, 1986). Replacement of human expert is not possible in many cases, and in those cases the less experienced persons can receive expert level guidance from intelligent system to perform tasks, which require more specialized expert knowledge.

The enormous advances in Web technology have taken web-based information systems literally to another dimension of intelligent information systems. There is very limited work done in agricultural domain (Plant and Stone, 1991). Therefore it may be the priority area to develop web based intelligent applications useful to agriculturist.

2. LITERATURE REVIEW
The web based intelligent systems are most appropriate in the situations where large numbers of users are spread over geographically far off places or different agro-climatic regions in case of agriculture applications (Jensen et. al., 2000; Bajwa and Kogan, 2010). Users need not approach the physical location of the system. Popular applications are web based learning or education, consultation for diseases, telemedicine, geography and world studies as well as crop management and protection (disease and pest management) (Power, 2002). Enterprises spread over the globe also deploy their intelligent systems over the web for consultation from their different offices. Development of web-based expert system is becoming popular, as their need has been felt world-wide (Jensen, 2001 and Potter et. al., 2000). A few web-based diagnostic expert system has been developed in past and are studied below.

Disease diagnosis expert system for forest tree over the WWW was developed in British Columbia, Canada (Thomson et. al., 1998). It was developed using Hypertext Markup Language (HTML) and Common Gateway Interface (CGI). Pl@nteInfo(www.planteinfo.dk) DSS used WWW to supply farmers and agricultural advisers with just-in-time information and decision support for crop management, is developed (Jensen et. al., 2000). A web-based expert system for gypsy moth risk assessment was developed in USA (Potter et. al., 2000). The Gypsy moth expert system (GyMEs) was developed to estimate the risk that a forest stand faces from the gypsy moth based on the composition, structure, and management objectives of a particular forest. Risk assessment was developed from forest susceptibility to infestation, vulnerability to damage caused by an infestation, and the hazard that management objectives for a forest may be affected if damage occurs. A web-based fuzzy expert system for integrated pest management in soybean was developed by Saini in India (Saini et. al. 1997 and 2002). The entire KB consists of 445 fuzzy and 198 crisp rules.

A web-based system was developed to advise on the relative efficacy of different herbicides for mixes of weed and crop species at different times of the year in forestry (Thomson and Willoughby, 2004). A multi-agent approach for diagnostic expert systems via the Internet was given by Khaled et. al. (2004). The expert systems agents in this work are implemented in Knowledge Representation Object Language

(KROL) and JAVA languages using KADS knowledge engineering methodology on the WWW platform.

Pig-vet: a web-based expert system for pig disease diagnosis has been developed by China Agricultural University (Zetian et. al., 2005). The system has over 300 rules and 202 images and graphics for different types of diseases and symptoms. It can diagnose 54 types of common diseases of pigs.

A web-based expert system was developed to help potato growers in Michigan make important decisions on optimal use and timing of fungicide applications to mitigate the risk of potato late blight (PLB) disease development (Wharton et. al., 2008). The interactive website is accessible over the web at URL: http://www.lateblight.org.

A Web Based Expert System for Milch Cow Disease Diagnosis is developed in China (Rong, 2008). This web-based multi-models expert system called DCDDS, developed for diagnosis of dairy cow diseases through the symptoms submitted by users on web. These Web-based systems had a conventional GUI and they lacked in multimedia tools so the information presented was not effective.

A few diagnostic expert systems were also reported recently using different methodologies viz. Object-oriented technology, web technology, fuzzy-logic inferencing etc.

An expert system for pests, diseases and weeds identification in olive crops was developed to improve decision-making ability of olive oil growers in Spain (Gonzalez-Andujar, 2009). The KB contained information for the identification of 9 weed species, 14 insect species and 14 diseases found in olive crops and 150 digital photos and drawings. The system was then stand-alone and not web-based.

An Object-Oriented (O-O) prototype Expert System for diagnosis of fungal diseases of date palm is developed (Al-Ahmar, 2009). This work has investigated the potential of O-O model for expert systems to provide intelligent computer-based support for farmers or agricultural specialists. The system model was based on O-O database and O-O rule base.

Fuzzy reasoning was successfully used to support a rule-based system for diagnosis of Skin Disease in humans (Akimoto et. al., 2009). A fuzzy reasoning approach for a computer-aided diagnostic scheme using medical imaging was presented in this work. This approach was found to be an effective method for computer-aided diagnosis in disease classification.

An adaptive-network-based fuzzy inference system (ANFIS) was developed to analyze the magneto encephalogram (MEG) background activity in 20 Alzheimer's disease patients (Gomez et. al., 2009).

A multivariate fuzzy logic model was developed for classification and control of lameness and mastitis in cows using the data of the Futterkamp diary research farm of the Schleswig-Holstein Chamber of Agriculture (Kramer et. al., 2009). Rakityanskaya et. al. suggested an approach to the design of the fuzzy diagnostic systems. It gave enabling solution of the fuzzy logic equations together with construction and adjustment of the fuzzy relations on the basis of expert-experiment information (Rakityanskaya and Rotshtein, 2007; Rotshtein and Raktyanska, 2009). A diagnostic problem was formulated as estimating causes from effects. Under expert information represented as fuzzy relations, cause-and-effect relationships were formalized as a system of fuzzy logic equations.

A method for the extensive assessment of uncertainties in compositional fuzzy rule-based models was proposed, evaluated and discussed extensively (Janssen et. al., 2010). Web-StrabNet: a web-based expert system for the differential diagnosis of vertical strabismus (squint) was developed (Fisher et. al., 2010). It was based on parallel instances of multi-layer perceptrons trained on exemplar data generated in consensus by two clinical experts. This machine expert was programmed in MatLab™ and is freely available as an Internet website (www.strabnet.com).

Most of the expert systems developed 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.

Multimedia combines different media such as text, graphics, animation, pictures, audio and video to communicate information to users. The presentation of information in this format has been found more effective in terms of the retention of information (i.e. the recall of facts and steps in a process). Extensive investigation by Mayer (2001). The usability, of these applications and specifically the design of the user interface is beneficial to the users' goal of quick perception. A poorly designed interface could in fact affect the overall effectiveness of a program.

The Intelligent System for Disease Diagnosis in Crops (ISDDC) is developed in the present work. 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, agriculture advisors, extension workers, researchers, managers, policy makers etc.

3. INTELLIGENT SYSTEM FOR DISEASE DIAGNOSIS IN CROPS

3.1 Novel Features

The novel features of ISDDC are as follows:

i) The introduction of a new fuzzy-logic based rule-promotion approach (Kolhe et. al., 2011c) 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 system for disease diagnosis in crops (ISDDC) with more effective interactive multimedia TTS user-interface (Kolhe et. al., 2011b).

The ISDDC incorporates other new features that improve the presently existing expert systems (Kolhe et. al., 2011a).

i) Object Oriented (O-O) inference model, which incorporates a newly experimented rule-promotion and deploys a fuzzy-logic based intelligent inference-technique;

ii) 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;

iii) Audio-visual-graphical user interface using text-to-speech (TTS) conversion tools.

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 creating awareness on pre-disposing climatic factors, making the exact diagnosis and management expertise available on WWW at right time at right place in the right form in very less cost.

3.2 O-O Inference Model

The inference engine of the intelligent system has been developed as O-O inference model using O-O programming. The C# programming language was used for it that is provided in Microsoft Visual Studio .NET. The Object model of the inference engine of the system has six main elements as shown in the Figure 1.

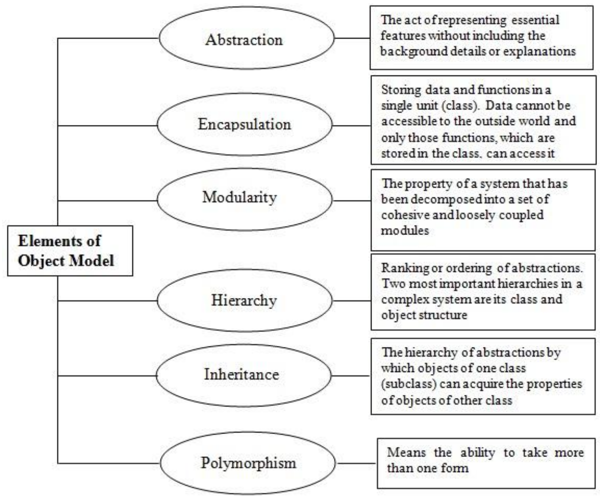

Figure 1 Main six elements of Object Model of ISDDC inference engine and its description

3.3 Software Architecture Model

The intelligent multimedia interface of the software was modeled based on 3-tier architecture design using ASP .NET. Three-Tier architecture of the system contains User Interface (UI) or Presentation Layer, Business Access Layer (BAL) or Business Logic Layer and Data Access Layer (DAL) (Kolhe et. al., 20011b).

3.4 Components of ISDDC

The system comprises of four components (Kolhe et. al., 2009)

Disease knowledge acquisition and management subsystem,

i) Disease diagnosis and management subsystem,

ii) Administration subsystem and

iii) Explanation subsystem.

3.4.1 Disease Knowledge Acquisition and Management Subsystem

It is designed for efficient handling of the crop disease knowledge during the entire process of knowledge acquisition, classification, representation, processing and final storage. The aim of this is to provide a strong and reliable knowledgebase support for the ISDDC. It was developed by using Microsoft .NET.

3.4.2 Disease Diagnosis and Management Subsystem

It is associated with a database, a rule base, O-O inference model and a web-based user-friendly, audio-visual, graphical interface. It provides the user with a friendly and effective web-interface to communicate with the system. It helps a user for correct disease diagnosis and its appropriate timely management for intelligent decision-making.

3.4.3 Administrative Susbsystem

It manages and maintains the authorized users of the intelligent system. This is done by updating or adding new users with different rights for security purposes.

3.4.4 Explanation Susbsystem

It explains about the detailed reasoning process, inferences drawn along with picture-based confirmation of the diagnosis result and other disease related information.

3.5 System Working

The users can login into the system either for knowledge management or for disease diagnosis and management for a specific crop. The user starts a diagnosis consultation session after successful login into intelligent information system. The user feeds the input symptoms and gets the diagnosed disease. The user also gets the appropriate control measures. The measures are then applied to control the disease infection. The disease diagnosis consultation approach involves the following steps (Kolhe et. al., 2013*)*:

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 and part affected after successful authentication.

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.

Step 4: After all the symptoms are entered in the web-form interface one by one by checking the check boxes, 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. 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.

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.

4. SYSTEM EVALUATION

The system was evaluated by performing verification and validation (Harrison, 1991). The verification process ensured that the knowledge in the system is consistent, complete and correct according to required specification. The knowledge base was verified after compilation of all the rules and we made necessary alterations and additions to ensure accuracy. Verification also ensured that there are no dead-end lines of reasoning that would result in unknown conclusions derived through the inference process. All the possible errors and bugs were located in the system. The functional performance was checked. It was ensured iteratively that the system performance was as needed. All the possible logical pathways were also traced to determine their correctness. The system programme was run many times by providing different combinations of all the possible inputs. A different pathologist of that crop throughout the development process crosschecked the conclusion drawn for each diagnostic consultation. The system was validated by using methodology of validation by the end users or live testing (Mosqueira and Monet-Bonillo, 2000; Gonzalez-Andujar et. al., 2006).

5. CONCLUSTION

The development of intelligent systems for agriculture domain are of immense help for cultivators. The development intelligent system has helped agriculturalist in disease diagnosis, in taking appropriate quick decision /judgment in real time field conditions by harnessing the analytical and decision-making capabilities of disease experts. The real-time application of the system has minimized the yield losses due to massive disease attacks to a great extent by providing awareness of pre-disposing climatic factors, making the exact diagnosis and management expertise available on WWW at right time at right place in the right form at minimum cost.

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