Expert System Applications: Agriculture

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Introduction

Expert system can be defined as a tool for information generation from knowledge. Information is either found in various forms or generated from data and/or knowledge. Text, images, video, audio are forms of media on which information can be found, and the role of information technology is to invent, and devise tools to store and retrieve this information. Statistical information is a good example of information generated from data while advises generated by an expert system is a good example of information generated from knowledge.

At the beginning, the concentration was mainly on textual information. Information technology used for textual information ranged from paper archiving tool to the sophisticated electronic computer software tools such as data base management systems, and hypertext tools. Images were very difficult to be included in an information system just few years ago till the scanners technology has been advanced together with the invention of the optical storage devises which have the capacity to store hundreds of mega bytes. This technology has enabled the developers to include images in their systems. Input peripherals to capture video and audio information have been also commercialized and are now available in the market. Storage of audio and video would be impossible unless large storage media were invented.

The advances in data processing have led to generating efficiently information from data. Software tools and methodologies have been developed in the field of statistics and data analysis to process data and to let these data more informative to users who need them. Data base management systems have also contributed to efficient data storage, processing, and retrieval.

The information is sometimes generated from knowledge and experience. When an expert in a specific area gives an advice to a less experienced person, he/she actual uses his/her knowledge and experience to generate this piece of information. This is a very precious piece of information because it is generated after long time of work and experience, and interaction with other experts and practitioners. Sometimes, this piece of information is not included in any form: text, audio, video, or other. Even if it is included, it is not linked with its scientific origin, especially if it is a combination of different domains, and methods. This piece of information gets more precious if it is the result of solving a problem which different specialists participate in its solution. In this case, it is rarely to find this piece of information in any text. Expert systems technology can play a very important role in generating information from knowledge.

This chapter is written to present different aspects related to agricultural expert systems namely: why expert system in agriculture, what applications have been developed, how these application have been developed, and what research issues should be addressed

Need of Expert Systems in Agriculture

The need of expert systems for technical information transfer in agriculture can be identified by recognizing the problems in using the traditional system for technical information transfer, and by proving that expert systems can help to overcome the problems addressed, and are feasible to be developed.

Information Transfer Problems

Static Information: Examining the information stored and available in the agriculture domain revealed that this information is static and may not respond to the growers need. All extension documentations give general recommendations because there are many factors if taken into consideration , so many different recommendations should be included in the document.

Specialties Integration: Most of the extension documents handle problems related to certain specialty : plant pathology, entomology, nutrition, or any other specialty. In real situations the problem may be due to more than one cause, and may need the integration of the knowledge behind the information included in the different extension documents and books.

Combination of more than one information source: Images may need sometimes an expert to combine other factors to reach an accurate diagnosis, and even if a diagnosis is reached, the treatment of the diagnosed disorder should be provided through extension document.

Updating : Changes in chemicals, their doses, and their effect on the environment should be considered. Updating this information in documents and distribute them takes long time. The same arguments can be made for audio tapes that are another form of extension documents but in voice instead of written words. Video tapes are more stable than other media as the information provided through the tape describes usually well established agricultural operations. However, if the tape includes information as what is commonly included in documents and audio tapes, this information should be updated.

Information unavailability : Information may not be available in any form of media. It is only available from human experts, extensionists, and/or experienced growers. In addition, the information transfer from specialists & scientists to extensionist and farmers, represents a bottle neck for the development of agriculture on the national level. The current era is witnessing a vast development in all fields of agriculture. Therefore there is a need to transfer the information of experts in certain domain to the general public of farmers, especially that the number of experts in new technologies is lesser than their demand.

Suitability and Feasibility of Expert Systems

The problems already raised can to large extent be solved using expert systems to generate the information to the growers by using its knowledge base and reasoning mechanism acquired from human experts and other sources.

The expert system generates the advice based on its knowledge base and its reasoning mechanism that are actually behind all developed extension documents, and more. Consequently, when a user enters the data of his/her plantation to the system, the appropriate advice is generated. There are no limitations on the number of generated recommendations. Therefore expert system overcomes the problem of static information provided in extension documents.

The knowledge acquisition process for building an expert system, facilitates the integration of knowledge and experiences of different specialties. For example, an agricultural diagnostic expert system requires the integration of specialists in nutrition, plant pathology, entomology, breading, and production. Therefore, when a problem occurs, the system can help the user in identifying the cause of the problem in a much more efficient way than consulting a document that handles a specific problem.

Expert systems can be integrated with other information sources such as images bases and/or textual bases to make use of these sources. For example, images can be used for describing symptoms as it is very difficult and very confusing to describe them in words. Images can also be used for confirming the diagnosis of the cause of a certain disorder. Expert systems can also be integrated with textual data bases that may be the extension documents related to the specialty and/or commodity handled by an expert system. This textual data base can be used for explanation purposes of basic terms and operations. It can also be used to confirm the reached conclusion in some situations.

The updating problem is also found in expert systems. However, the knowledge base can be maintained more efficiently than maintaining manual documents. The problem of updating the versions in the field can be eliminated in case that the expert systems are stored on a central computer and accessed through a computer network.
The undocumented experience and knowledge can be acquired and stored in the knowledge base of an expert system for a certain specialty and/or commodity. This experience can be available to all growers using the system. The feedback from the usage of the system can be used as a source of information when analyzed by researchers, the knowledge behind it can be identified, and the knowledge base can be updated continuously. Expert systems can also help in overcoming the problem of the relatively few numbers of experts relative to the demand from the growers. Expert systems technology can help to transfer the information of experts, and experienced growers to farmers through the extension system.

Historical Account

Knowledge-based expert system technology has been applied to a variety of agricultural problems. since the early eighties. The following paragraphs present how expert systems were considered in agriculture in the eighties. The papers have been selected to represent different applications and to be easily obtained by interested readers.

The expert system applied to the problems of diagnosing Soybean diseases (Michalski et al., 1983) is one of the earliest expert systems developed in agriculture. A unique feature of the system is that it uses two types of decision rules: 1) the rules representing experts diagnostic knowledge, and 2) the rules obtained through inductive learning from several hundred cases of disease. Experimental testing of the system has indicated a high level of correctness of the system's advice (in an experiment involving a few hundred cases , approximately 98% of the diagnosis were correct.

POMME (Roach et al,, 1985) is an expert system for apple orchid management. POMME advises growers about when and what to spray on their apples to avoid infestations. The system also provides advice regarding treatment of winter injuries, drought control and multiple insect problems.

COMAX (Lemon, 1986) is a crop management expert system for cotton which can predict crop growth and yield in response to external weather variables, soil physical parameters, soil fertility, and pest damage. The expert system is integrated with a computer model, Gossym, that simulates the growth of the cotton plant. This was the first integration of an expert system with simulation model for daily use in farm management.

In 1987 expert system technology was identified as an appropriate technology to speed up agricultural desert development in Egypt (Rafea and El-Beltagy, 1987). The paper has discussed the importance of applying expert systems in agricultural desert development in Egypt and suggested an integrated structure of an R&D unit to develop and maintain an efficient use of these systems.

CALEX system (Plant, 1989) has been developed for agriculture management. It is domain independent and can be used with any commodity. CALEX consists of three separate modules: an executive, a scheduler, and an expert system shell. The executive serves as the primary interface to the user, to models, and to the disk. The scheduler generates a sequence of management activities by repeatedly activating the expert system. The expert system makes the actual management decisions. Initial development of the system has focused on the development of a package of modules for California cotton and another package for peaches.

In the nineties, several expert systems have also been developed. A sample of these expert systems has also been selected as examples. The selected examples demonstrate trends in the nineties and their accessibility by the reader is also considered.

An agroforestry expert system (UNU-AES) was designed to support land-use officials, research scientists, farmers, and other individuals interested in maximizing benefits gained from applying agroforestry management techniques in developing countries (Warkentin et al. 1990). UNU-AES is a first attempt to apply expert systems technology to agroforestry. This system addresses the option for alley cropping, a promising agroforestry technology which has potential applicability when used under defined conditions in the tropics and subtropics. Alley cropping involves the planting of crops in alleys or interspaces between repeatedly hedgerows of fast-growing, preferably leguminous, woody perennials. With the inclusion of more climatic and socio-economic data and improved advisory recommendations, UNU-AES can be expanded to provide advice on alley cropping in more diverse geographical and ecological conditions and eventually address other agroforestry techniques.

In 1991, serious efforts have been started in Egypt to develop crop management expert systems for different crops. A prototype for an expert system for cucumber seedlings productions has been developed. This prototype has six functions: seeds cultivation, media preparation, control environmental growth factors, diagnosis, treatment, and protection. The implementation has used the Hypertext facility included in the EXSYS shell. The overall control was implemented using the language provided by the tool and consequently, the rule base was divided into modules according to the system functions(Rafea et al., 1991). Another expert system for cucumber production management under plastic tunnel (CUPTEX) has been developed to be used by agricultural extension service within the Egyptian Ministry of Agriculture, and by private sector. The main objective of developing such systems is to transfer new technology in agromanagement to farmers through packaging this technology using expert systems. This will lead to increasing the production and hence the national income, from one hand, and reducing the production cost from the other hand.. CUPTEX is composed of three expert systems for fertigation, plant care, and disorder remediation. The validation of CUPTEX has revealed that it over performs a group of experts in different specialties. Although the direct payoff is not the main objective of the development, experimenting CUPTEX in two research sites has revealed that approximately 26% increase in the production, and 15% decrease in direct cost have been attained. These results show that CUPTEX could pay off approximately 60% of the development cost in 4 months if it is used to manage the plastic tunnels cultivating cucumber in the five sites in which it was deployed (Rafea et al., 1995). This system is the first deployed agricultural expert system to be selected in the conference of innovative application for artificial intelligence. It is also the first deployed expert system in developing countries not only in agriculture but in other fields as well.

In Italy, an expert system for integrated pest management of apple orchards (Gerevini et al., 1992), POMI, has been developed. Integrated pest management is definable as the reasoned application of agronomic methods products as well as chemicals to allow optimal productive factors, while respecting the farm worker, the environment and the consumer. POMI addresses the first preliminary phase of the complex process of apple orchard integrated control namely the detection of the insect populations in the field and approximate the populations dimensions. The system consists of two parts: classification of user findings, and explanation of these findings using abductive reasoning.

In India, an intelligent front-end for selecting evapotranspiration estimation methods (Mohan and Arumugam, 1995) has been integrated with the methods that calculates the evapotranspiration factor. Evapotranspiration (ET) is an important parameter needed by water managers for the design, operation and management of irrigation systems. Since there are many methods to compute ET, based on climatic data, an inexperienced engineer or hydrologist is perplexed with the selection of an appropriate method. An intelligent front end expert system (ETES) has been developed to select suitable ET estimation methods under South Indian climatic conditions. Ten meteorological stations located in different climatic regions and thirteen ET estimation methods have been considered in this ES. Along with the recommended method, ETES also suggests suitable correction factors for converting the resulting ET values to those of methods that result in accurate estimation.

A picture-based expert system for weed identification (Schulthess et.al., 1996) has been developed. Most current expert systems for weed identification are rule-based and using text that contains a large number of botanical terms. In this system the hierarchical classification generic task was used and the text descriptions were replaced with pictures to minimize the use of technical terms. Hypotheses are established or ruled out on the basis of the user's choices among options presented as pictures.

Methodologies and Applications

In this section, I am not intending to describe in details different expert systems methodologies as this should be covered in some place else. I will try to analyze the examples given in the previous section from two aspects: the methodological aspect and the domain application aspect. The two main methodologies categories are first generation and second generation expert systems. The first generation expert system methodology is based on using commercial expert system shells after acquiring the knowledge through traditional knowledge acquisition techniques and using rapid prototyping method. The second generation expert systems methodology is mainly based on the principle of knowledge level which means developing a knowledge model at the human level problem solving approach, not at the computational level approach. The domain application aspect will be analyzed taking the agriculture area and the task type to classify the given application. A domain specific methodology will be presented in the last subsection .

Methodological Aspects

Most of the expert systems developed in agriculture apply the first generation expert system methodology . Examples of this methodology can be found in (Warkentin et al. 1990) , (Rafea et al., 1991) and (Mohan and Arumugam, 1995). The first two applications use EXSYS shell and a documentation of this methodology based on a modified Waterfall method is described in (Rafea et al. 1993). The third example application uses the CLIPS shell while the fourth example uses the VP-Expert shell..

Another approach that can be considered as an intermediate between the first and second generation expert systems is the usage of expert system shells in the implementation of a higher level of reasoning. An example of this approach can be found in (Gerevini et al., 1992). In this application the shell KEE is used but the system is explicitly divided into two parts. The first part is concerned with helping the user in classifying the findings, whereas the second part is an interactive abductive module that suggests explanation of those findings.

Few applications have been developed following the second generation expert system approach. The two methodologies used are the KADS methodology and the generic task methodology. The KADS methodology was used for developing expert systems for cucumber and citrus management (Rafea et al., 1994) and (Rafea et al., 1995), where as the generic task methodology was used for developing expert system for wheat management (Schroeder et al., 1994) and (Schulthess et al., 1996). In the second generation expert systems methodology, there generic models for different types of tasks such as diagnosis, planning, design, and others. In the agriculture domain, we find out that two main generic models are used namely: the diagnosis or more broadly the classification, and the scheduling tasks. In KADS methodology there is a library of expertise model for each one of these two tasks (Rafea et al., 1994), whereas in the generic task methodology, the hierarchical classification model is found suitable for the diagnosis applications and the routine design model is found suitable for the scheduling application (Kamel et al., 1994).

Domain Application Aspects

The agriculture domain can be classified into subdomains namely: plant production, animal production and management of natural resources related to the agricultural operations such as soil and water. I did find that expert systems has been applied in the three subdomains. However, I will concentrate here on the plant production part as most of the expert systems in agriculture have been developed in this subdomain.

Expert systems for field crops are implemented for : diagnosis of Soybean diseases (Michalski et al., 1983), crop management for cotton (Lemon, 1986) and (Plant, 1989) and weed identification for wheat (Schulthess et.al., 1996). Expert systems were also implemented for horticulture crops: apple orchid management (Roach et al,, 1985) and (Gerevini et al., 1992), cucumber production management (Rafea et al., 1995). Agroforestry is another area in plant production where expert systems have been developed (Warkentin et al. 1990). Some other applications cannot be categorized commodity wise such as the expert system developed for selecting evapotranspiration estimation methods (Mohan and Arumugam, 1995).

Another way for classifying agricultural expert systems is the domain specific task that this system performs such as : irrigation, fertilization, pest management, diagnosis of plant diseases, and others. There are mapping between the domain specific tasks and the generic tasks. For example irrigation application is mainly a special case of scheduling whereas diagnosis is a special case of classification.

A Proposed Domain Specific Methodology

The methodology proposed here is based on our experience during the last 7 years in developing expert systems in agriculture. It is not intended to be a comprehensive methodology but it will give some thoughts on domain specific tasks architectures in agriculture. Generally we can classify agricultural operations into precultivation operations and during cultivation operations. Precultivation operations are interested in preparing the field for growing a particular crop. During cultivation operations can be furtherly classified into diagnosis operations which concern finding a reasonable explanation for undesired phenomenon, and scheduling operations that include Irrigation, Fertilization, and Treatment operations. We will concentrate in this section on the scheduling in the agriculture domain as an example.

Our methodology is based on two principles that have emerged during the last decade of AI research:

Knowledge-level Modeling : Knowledge should be modeled on a higher level than that of exploited knowledge representation formalisms, to avoid premature design decisions and to facilitate communication with domain experts.

Reusability of Task and Domain Knowledge: The second principle implies that the complexity of KBS development can be relieved by the construction of reusable components libraries, just as any other engineering activity.

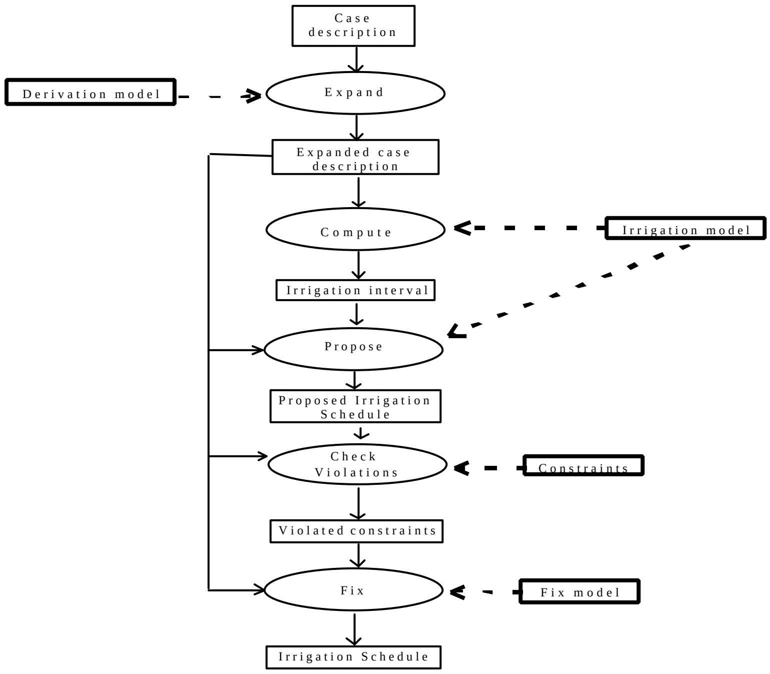

Fig. 1: Irrigation Inference Structure

Following the model driven approach, the KBS development process is composed of two phases. In the first phase, an epistemological model is constructed representing the conceptual model for the application problem. In the second phase, this model is transformed into a computational model, implemented on computer, and preserving the structure of the epistemological model.

An epistemological model in CommonKADS, consists of three main components namely: task knowledge, inference knowledge, and domain knowledge. Generating one generic model for each task :irrigation, fertilization, and treatment, will increase the model reusability among many different crop types, which minimize the effort and the cost of knowledge base systems development. The following subsection describes the inference model of irrigation as an example of this methodology.

The main goal of this task is to design an irrigation schedule for a particular crop in a particular farm. The output schedule is simply a plan of water quantities to be applied and the time of application, according to the requirements of the plant, and the affecting factors like soil type, climate, and source of water, ..etc.

Fig. 1 shows the constructed generic inference structure for the irrigation task. As illustrated in Fig.1, the irrigation task starts with acquiring case description, which includes parameters that affect the irrigation process, such as soil, water and climate data. The expand inference step uses these initial parameters to derive other parameters that are needed in the subsequent inference steps. The knowledge required for this inference step is the derivation model that can be represented as object hierarchies, rules, facts, and mathematical functions, according to the nature of knowledge. The compute inference step, calculates the irrigation interval using the input, and derived parameters. The knowledge required by this step are represented in the form of mathematical functions. The propose step, generates a preliminary irrigation schedule depending on a set of fixed mathematical functions regardless to any additional environmental constraints, which includes all circumstances that are not covered by the irrigation model. The check violation step evaluates the proposed irrigation schedule with regard to some environmental constraints - such as the existence of certain disorders in the farm- , and report these violations to be fixed by the fix inference step, to produce the final, and acceptable irrigation schedule.

Research Issues

The research issues that will be addressed in this section are: the integration of other software components with the agricultural expert systems, agricultural knowledge sharing and reuse, intelligent retrieval of agricultural data and automatic knowledge acquisition.

Integration of Software Components with Agricultural Expert Systems

Some existing expert systems are integrated with other software components such as crop simulation models (Kamel et al., 1994), GIS (Loh et al., 1994), and multimedia (Rafea et al., 1995). Agent based approach can be used to integrate distributed heterogeneous systems and hence can solve the integration problems in addition to other problems related to distributed components on different environments. However, more research is needed as described in the following subsections.

Crop Simulation Models and Expert Systems

The integration of numerical simulation models into the crop management expert system. is receiving wide spread current attention. The reason is largely due to the perceived "naturalness" of an interaction between "experience" to quickly center on a part of a large search space, and numerical methods to select the correct exact solution from the narrowed possibilities. This mode of interaction leverages strengths of both expert systems and simulation models, using the expert system to quickly limit the search space, then using simulation-based methods to find the best candidate within the current focus. For example the simulation model CERES Wheat takes as input boundary conditions, such as planting date and irrigation regime, then predicts (among other items) grain output at harvest. Although quite accurate in its output, one difficulty in the production use of CERES is the level of expertise which must be employed to set the initial input parameters. A scheme has been given in (Kamel et al., 1994), that uses a compiled-level problem solver to determine the initial planting parameters (seed variety, planting date, planting and land preparation methods). These values are used to parameterize the CERES wheat model. The model is then used to predict iteratively the water and nutrient needs of the crop.

The example given has proved to be very useful in integrating numerical and symbolic methods to solve a specific problems. This may encourage to integrate other types of simulation models such as pests infestation and economic models with expert system. There also still research work on the best ways of integration and interfaces between the expert system and the simulation model.

GIS and Expert Systems

An example of integrating GIS and expert systems is given in (Loh et al., 1994). In this example the USDA Forest Service , both expert systems, GIS and relational database management systems (RDBMS) have been introduced for maintaining resource inventories, GIS for organizing and analyzing spatially referenced data, and expert systems for capturing the essence of standards and guidelines of management plans and the accumulated knowledge of experts in the Service. To achieve this objective, some problems have been identified namely: data sharing between the GIS and expert system components, and fitting the two components into a common problem-solving framework. The example application has succeeded in solving these problems using ARC/INFO for GIS, CLIPS for expert system, and ORACLE for RDBMS. However, some other issues have been raised which needs more research such as the enhancement of the expert systems components to reason on spatial rules. This necessitates the inclusion of spatial operator such as “intersect with” or adjacent to” . To accommodate such operators macro would have to be developed on the GIS side to communicate with the expert system shell. The integration of GIS and expert system is fairly new and more problems will be envisaged when more applications using both technologies will be done.

Multimedia and Expert Systems

Integrating multimedia with expert systems is a hot topic that is booming nowadays. The integration with images was frequently done to more efficiently acquire the user inputs, whereas other types of media such as sound, and video are also addressed. An example of integrating multimedia with expert systems is given in (Rafea et al., 1995).

It was found that describing symptoms in words is very difficult and sometimes is very confusing. Therefore, images are identified to be used for two main purposes: describing a disorder symptom, and confirming the diagnosis of the cause of a certain disorder. Detailed images for all symptoms, and unique images that confirm the occurrence of disorders at different stages should be collected.

Although images are very useful in acquiring the user inputs, the uncertainty problem is still there. Therefore, giving the user the option to select an image with a degree of certainty should be provided. Providing more than one picture for the same symptom can reduce the user uncertainty, but this will lead to exerting more efforts in collecting and classifying the images.

As the output of an expert system for crop production management, is a set of agricultural operations, describing how to perform an agricultural operation in words, is very hard and one can never guarantee that the user can understand what has been written. Displaying a video for a professional doing the recommended operation would be very educational.

The sound is essential because sometimes, it is not easy to write terminology used by growers in daily life. In addition, combining the video with sound is also recommended to comment on how the operation is done.

Although the given example proved the possibility of integrating multimedia with expert systems, there are still some problems which needs further research such as the intelligent selection of the appropriate media for presentation taking into consideration the user level., getting input data from images, for example providing the expert system with an infected leaf of a plant for diagnosis, and/or enhancements of all input devices interfaces, which is a general research issue, in order to provide expert system with data in different forms.

Knowledge Sharing And Reuse

Knowledge sharing and reuse is one of the topics that has attracted the attention of the AI researchers in the last few years. The research in knowledge sharing in agriculture can be directed toward identifying common knowledge that can be shared among different expert systems such as identification of agriculture ontology, knowledge related to common resources namely: soil, water and climate, knowledge related to the same taxonomic category of a set of crops, etc... . The research in knowledge reuse can be directed to building a library of domain specific tasks in agriculture such as: irrigation, fertilization, integrated pest management, etc...

Intelligent Retrieval Of Agricultural Data

Meteorological data are very important for agronomists as forecasting weather data helps in giving recommendations to growers. A system that serves as an intelligent assistant for meteorologists to locate and analyze historical situations of interest, has been developed using case based reasoning (Jones and Roydhouse, 1995). This work has been oriented to be used by meteorologists but not agronomists. The basic idea could be investigated to retrieve historical situations that are important for managing different crops.

Automatic Knowledge Acquisition

Automatic knowledge acquisition is a general research issue in expert systems development. In agriculture, research can be directed toward using the knowledge models developed for specific tasks in building tools to acquire the domain knowledge interactively with the domain experts. Another approach is using machine learning to automatically generate and refine knowledge bases. Although this approach was one of the first approaches in building expert systems (Michalski et al., 1983) , no elaboration on this approach was pursued. A recent application that uses machine learning to agriculture data is given in (McQueen et al., 1995). This approach can be very useful when data sets are available in certain area.

Future Trends

In effect, the future trends are highly related to the research issues discussed in the previous section. It is expected that the agent based approach will be extensively used in solving the problems resulting from the integration of expert systems with other software components.

The agent based approach will address other issues related to heterogeneous components that are distributed on different platforms. The agent based approach is a general approach which is suitable for any domain. In agriculture we can see its usage in integrating GIS, multimedia, simulation models with expert systems.

Developing domain specific tasks in agriculture is a very important future trend that will help in knowledge sharing and reuse and in automating the knowledge acquisition process. Successful results in these two directions will expedite the development procedure of expert systems. Machine learning will help also in automating the knowledge acquisition process and more attention will be given to it in the near future.

Sophisticated user interfaces for different media types are expected to be an important issue. Different user interface models will also be investigated as agricultural expert systems have different types of users: researchers, extensionists, and growers. Their requirements and needs are different.

More sophisticated explanations facilities will be provided once domain specific models are well established. The explanation facility should not be as expert systems are providing know , the why and how primitives, but it should be intelligent enough to generate the explanation based on the user level. Intelligent agent based approach may also be used in developing such explanation facility.

Another issue that will play an important role is the usage of Internet to access expert systems developed in different locations. There is a trend now to develop tools to facilitate the dissemination of expert systems through the world wide web. It is expected in the near future that shells and tools will enable developers to put their expert systems on the web.

Summary

This chapter has discussed the needs of expert systems in agriculture and revealed their importance as tools for information transfer through information generation from knowledge and expertise. The advantages that an expert system can offer better than traditional methods, are : providing the growers with dynamic information related to their actual situations, taking into consideration different specialties and different sources of information, shortening the update time of information especially if the expert system is centralized and accessible from different locations, and transferring real experience that is not documented in any form of media by acquiring it from its sources: extensionists, highly experienced growers, and/or researchers.

The expert systems selected to demonstrate applications in the eighties revealed that these systems actually addressed issues that still need research. The usage of machine learning to generate the knowledge base was addressed in the soybeans diagnosis system. The integration of simulation model with expert system was considered and implemented in the Cotton expert system. The concept of task specific package was raised in the CALEX system. The importance of expert system as an appropriate technology to expedite agricultural desert development was emphasized in the late eighties in the paper of Rafea and El-Beltagy.

In the nineties, expert systems have been expanded to include other commodities and disciplines such as agroforestry and meteorology. The second generation expert systems methodologies have been applied. More sophisticated expert system shells were used such as NEXPERT/OBJECT and KEE. Programming languages such as Prolog and Small Talk were also used. The integration of multimedia was firstly addressed due to the advances made in this technology. Expert systems in the field for real use have been deployed.

Research issues in agricultural expert systems are categorized under these topics: integration of software components with agricultural expert systems, knowledge sharing and reuse, intelligent retrieval of agricultural data, and automatic knowledge acquisition. The future trends in research and development of agricultural expert systems are expected to be : using agent based approaches to solve the integration problem of different software components, developing domain specific tasks that will contribute to knowledge sharing and reuse and automatic knowledge acquisition. Sophisticated user interfaces and explanation facilities that depend on the user level are expected to be seriously considered. The dissemination of expert systems through the Internet is also anticipated.

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