Experience with the Development and Deployment of Expert Systems in Agriculture

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Abstract

This paper describes the experience of the development and deployment of an expert system for cucumber production management under plastic tunnel (CUPTEX). CUPTEX is intended to be used by agricultural extension service within the Egyptian Ministry of Agriculture (MOA), 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, on one hand, and reducing the production cost on the other hand. CUPTEX was developed using a methodology based on KADS. 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 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. CUPTEX could also pay off its cost by charging a nominal price for each copy deployed to private sector farmers. The commitment of MOA to expert systems technology helped and will help in maintaining the knowledge base of CUPTEX. The methodology developed while building CUPTEX have been and will be used for other crops.

Introduction

Expert systems were identified eight years ago, by the Egyptian Ministry for Agriculture(MOA) , as an appropriate technology for transferring knowledge and expertise of agriculture specialists to extension service (Rafea & El-Beltagy 1987). In 1989, the Expert Systems for Improved Crop Management (ESICM) project was initiated with two main objectives: building an expert system laboratory within MOA that has the capacity to identify, develop, and maintain expert systems, and developing two expert systems for the production management of cucumber under plastic tunnel, and citrus in the open field. Since that time, several expert systems for these two crops were developed, (Rafea, Warkentin & Ruth 1991), (Rafea et al. 1992) and (El-Dessouki, Edrees & El-Azhari 1993). In addition, a knowledge engineering methodology has evolved starting by waterfall-like methodology (Rafea et al. 1993a), and ending by a KADS-like methodology (Rafea et al. 1993b), (Rafea et al. 1994). A knowledge representation object language (KROL) on top of Prolog (ESICM 1992) was also developed to implement the production versions of these expert systems.

Expert systems technology has been also applied in the agriculture domain world wide for different crops: wheat (Kamel et al. 1994), cotton (Lemmon 1986), (Plant et al. 1988), tomatoes (Blancard, Bonnet & Coleno 1985), apples (Roach et al. 1987), (Rajotte 1991), soybean (Michalski et al. 1983), and others.

The paper consists of eight sections in addition to the introduction. The first section describes the crop management problem. The second section presents the development methodology. The third section describes CUPTEX. The fourth section describes the design and implementation of CUPTEX. The fifth section discusses the deployment methodology. The sixth section shows how the application can pay off its development cost through a real experiment conducted in the sites in which CUPTEX was deployed. The seventh section introduces the maintenance methodology applied, and finally the eighth section presents the conclusion.

Problem Description

The application described in this paper is the expert system developed for Cucumber Production Management under Plastic Tunnel (CUPTEX). Plastic tunnels are like green houses but made of plastic. Crop production management can be defined as the set of agricultural operations done to produce that crop. Advise about these operations are given by specialists in: soil and water management, plant pathology, entomology, production, breeding, and horticulture. Analysis of these operations has revealed that an expert system for crop management is a family of expert systems that work together to generate a schedule for agricultural operations. The functionality of these operations was analyzed and consequently classified into these categories: fertigation, plant caring, and disorder remediation.

The main objective of this application is to optimize the production of cucumber which is ranked as the first vegetable crop, in production, cultivated under plastic tunnels.

This objective is achieved by transferring the expertise of highly specialized human experts in different agricultural specialties to the extension workers who are agricultural engineers working in protected cultivation sites at the district level. These extension workers advise the farmers regularly when they come to get advises about their cultivation. Some aggressive farmers are also provided by the expert system developed to use it directly.

The objective of increasing production is actually one of the most important objectives of the Egyptian Ministry of Agriculture because of the gap between the food commodities produced locally and the ones imported. Different solutions are followed through training the extension workers, making extension documents, and conducting research to introduce new varieties that produce high yield, using traditional breeding methods, and advanced ones like genetic engineering. The expert system solution lies in the category of enhancing the performance of the extension workers by providing them with an advanced tool. Although we cannot claim that other solutions like training and producing extension documents failed to enhance the performance of extension workers, we see how expert system can efficiently help in this regard because of the integration of the expertise of different specialties provided in one package, and how it over performs the usage of traditional extension documents which give general advise, not specified to a certain situation. The expert system also over performs an individual human expert specialized in one domain.

Development Methodology

The methodology is divided into two main parts: knowledge engineering, and software engineering. The two parts of the methodology are interacting through a spiral model. The output of the knowledge engineering process is fed into the input of the software engineering activities. The main interaction is through feeding the results of the knowledge analysis phase into the design activity. The methodology also preserves the design model through introducing a method to transfer the design into an expert system development shell. This methodology (Rafea et al. 1993b), (Rafea et al. 1994) has been based on KADS (Wielinga & Breuper 1991), and (Wielinga, Schreiber & Breuker 1992).

Knowledge Engineering Methodology

The knowledge engineering methodology included : acquiring the knowledge, analysing and modelling the acquired knowledge, and verifying the modelled knowledge.

The knowledge was acquired using structured interview, concept sorting, and protocol analysis techniques. The knowledge engineering team consisted of two knowledge engineers, and five domain experts in the following specialties: production, irrigation, nutrition, plant pathology, and entomology. The developed prototypes were also used as an automated tool for refining the acquired knowledge.

The knowledge analysis and modelling procedure included: domain analysis, inference analysis, and task analysis. Domain analysis: The documented knowledge was analysed aiming at identifying concepts, properties of these concepts, and relations. The relations are either relations between concepts or relation between expressions. Concepts, and relations found to be used by more than one subsystem were identified and grouped in a common knowledge base. Inference analysis: The documents and tapes generated from knowledge acquisition activities were analysed with the purpose of finding the domain knowledge which the expert was using to reach a conclusion from specific components in the domain layer. So, the inference analysis was aiming at modelling the acquired knowledge. This analysis was guided by the inference layer structure described by KADS. The project has succeeded in developing a set of interpretation models for the crop management domain. These models can be used later for developing any crop management expert system . Task analysis: The task analysis was aiming at finding the sequence or the procedure which the expert used to reach a final conclusion.

The knowledge was verified at the knowledge acquisition stage, analysis stage and implementation stage. Reviewing, at the elicitation stage, was conducted by letting the domain experts review the results of the knowledge elicitation sessions. Reviewing, at the analysis and modelling stage, was conducted by letting the domain experts review the filled forms describing the domain layer. It was difficult for the domain experts to review the inference and task layers as described here. Therefore, the task layer was explained in natural language and approved by the expert as a valid way for solving the problem. Reviewing, at the implementation stage, was conducted by letting the domain experts review early any prototype. Multiple experts conflict resolution was considered as some sort of verifying the acquired knowledge. This was because when two experts gave different knowledge for the same thing, then trying to resolve this conflict yielded more reliable knowledge. If no consensus was reached the view of the expert recognized to be more specialized in the area of disagreement was considered.

Software Engineering Methodology

The software engineering team consisted of two software engineers. The approach we proposed for software development was a combination of rapid prototyping, incremental, and traditional methods. The rapid prototyping was used first to complete the requirement specifications. The incremental model started by implementing the Laboratory prototype and ended by implementing the tested version of the field prototype. The tested field prototype was considered the final specification for the production version which was implemented in a shell we have developed on top of the programming language PROLOG. The development of the production version was done in the traditional way as the specifications were completed and tested using the field prototype. The software development, included a set of activities: requirements specifications, design, implementation, and testing.

Requirements Specification: An initial set of requirements specifications was determined as a result of early knowledge elicitation activity. This initial set was the basis for further knowledge acquisition efforts and the basis for the preliminary design of the research prototype. The requirements specifications were revised regularly after each prototype implementation.

Design: A preliminary design was done just after the set of initial requirements specifications were determined, and a preliminary model of knowledge layers was specified. This design was the basis for the research prototype which was used to produce the requirements specifications for the lab. prototype. The design was revised after the implementation of each prototype. Major areas, to be considered in the design, were : the representation of knowledge, interfaces, explanation, data base , control strategy, and tool specification.

Implementation : The first decision taken after the approval of the design was the selection of the implementation tool. This decision was based on: the knowledge representation supported, interfaces to external modules, explanation facilities, the primitives provided to code the control mechanism, and the hardware and software needs for system delivery. Although using a shell speeds up the implementation process, the project experience identified these two major constraints on using shells: Implementing a special explanation module and/or a special control mechanism is unfeasible in less expensive tools, and the delivery of a developed system needs a runtime license for expensive tools that give the user the environment to customize an application, which may cost about $1200. Therefore, the programming language PROLOG was recommended for the production version. For research & laboratory prototypes the NEXPERT/ Object shell was used for implementation.

Verification & Validation: The expert system verification and validation went through four distinct stages: verification of the laboratory prototype through domain experts who participated in the development, validation of the field prototype through external domain experts, validation of the field prototype through the end users, verifying the production version using all the cases used while testing the field prototype.

Development Cost

In effect, when we started this project in the mid of 1989, an initial cost was needed to build the physical infrastructure, and to acquire human resources. At the end of 1991, these efforts have resulted in establishing the Central Lab. for Agricultural Expert System (CLAES) within the Ministry of Agriculture, and a research prototype was produced. The serious efforts for building CUPTEX started at the beginning of 1992. The lab. prototype ended after one year, and the field prototype was completed and fielded by the end of 1993. During 1994, field validation, and lab. validation were conducted. Therefore, the development cost is given at three different stages: lab. prototype, field prototype, and production version, taking into consideration the following items: the domain experts, knowledge engineers, software engineers , and overhead. The cost of the domain experts is calculated from the financial record we keep for each domain expert, as all of them work under what we call "When Actually Employed" contract. The cost of knowledge, and software engineers is calculated based on their salaries and the time they dedicate to CUPTEX development. The overhead is added as 20% of the direct cost. Figure 1 depicts the development cost distributed over the development stages.

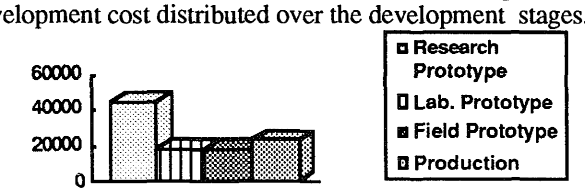

Figure 1 Development Cost(in $)

As can be seen from figure-1 the total cost is approximately $100,000, and the cost of the first two years represents about 40% of the total cost. This amount could be actually considered as a training cost. It is also interesting to note that the cost of developing the production version was mainly for validating the system with domain experts who did not share in the development process.

Application Description

Figure 2 depicts the overall structure of CUPTEX. Knowledge about plantation, water, soil, and climate are shared by the three expert systems. We call such knowledge a common knowledge base. The static data about plantation, water, soil, and climate of a user's farm are stored in data base to be retrieved when needed. CUPTEX was implemented in KROL running under DOS on a 486 based machine. In the following subsections, a brief description is given for each of these expert systems.

Disorder Remediation Expert System

The main function of this expert system is to generate a prescription to protect a certain disorder or a set of disorders. In case that the user suspects the cause of disorder(s), he/she can provide the system with his/her suspicion, and the system confirms or rejects this suspicion. If the user has no suspicion, he/she can provide the system with the symptoms of the disorders, and the system identifies the cause(s) of the disorder(s). A sample of disorder remediation output is shown in figure 3.

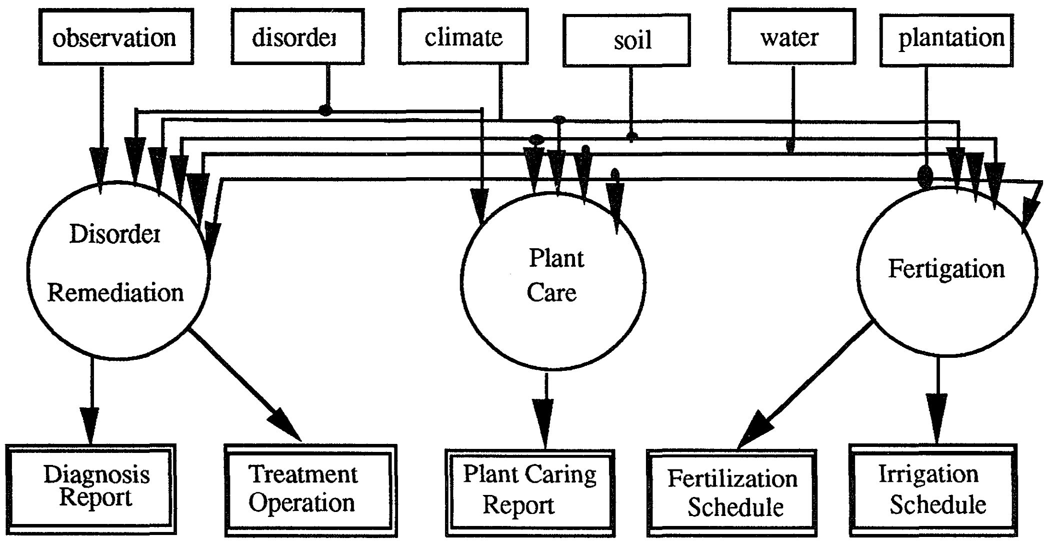

Figure 2 Overall Structure of CUPTEX

Treatment Operation
Detailed Operation Information

Date :	28/6/94
Disorder :	white_fly
Material Name :	actellic 50%
Mode of entry :	contact
Quantity :	300 ml/100 L
Method :	foliar application
Tool :	sprayer
Application Time :	avoid high temperature during spraying
Advice :	install nets before transplanting, spray only when number of insects reaches 2-3 per leaf, make deep harvest before spraying

Figure 3 Typical Output Screen of the Disorder Remediation Expert System

Plant Caring Expert System

The Plant caring expert system mainly predicts from the last previous crop, and plastic tunnel characteristics, the possibility of a pest problem. Based on this information it produces a schedule of operations to be done for protection from any pest. The main function of this expert system is to generate three types of the caring agricultural operations to protect plants from weeds, insects and diseases, and to keep the plantation in an optimal condition. The first type of operations must be done before cultivation, the second type outlines the routine operations that should be done after cultivation, and the third type is the preventive chemical operations, if any. The generated operations, and their method of application done, vary according to the environment, soil, water, and plantation properties. The pre-cultivation operations are scheduled, whereas the post-cultivation routine operations are not ordered as they should be done during the lifetime of the plant. The post-cultivation preventive spraying operations are generated and scheduled by predicting first the disorders that may appear.. The human experts who participated in building this system are on entomologist, a plant pathologist, and, a production specialist. A sample of the plant caring output is shown in figure-4.

Fertigation Expert System

The main function of this expert system is to give the user a recommendation about the quantity of different fertilizers and the optimum irrigation water quantity that fits his /her situation at any cultivation stage. This model takes a number of inputs representing the current situation of the environment. These include, plant age, soil type, water salinity, climate, and some factors related to the plantation itself such as the drainage quality, the soil sterilization, the sequence of grown cucumber in the same tunnel, the type of fertilizers to be applied, and others factors related to the fertilizers to be used and the expected yield. A sample of fertigation output is shown in figure-5.

Date	Disorder	Chemical Method	Operation Schedule Material name	Quantity
8/2/95	root_lesion_nematode, root_knot_nematode	spray	vidate	500 gm/100 lt
15/2/95	root_lesion_nematode, root_knot_nematode	spray	vidate	500 gm/100 lt
16/2/95	fungi, spiders	dusting	agricultural_sulphur, dithane_m45	100 gm + 100 gm
3/3/95	fungi, spiders	dusting	agricultural_sulphur, dithane_m45	100 gm + 100 gm
16/3/95	fungi, spiders	dusting	agricultural_sulphur, dithane_m45	150 gm + 150 gm
1/4/95	fungi, spiders	dusting	agricultural_sulphur, dithane_m45	150 gm + 150 gm
16/4/95	fungi, spiders	dusting	agricultural_sulphur, dithane_m45	200 gm + 200 gm
1/5/95	fungi, spiders	dusting	agricultural_sulphur, dithane_m45	200 gm + 200 gm

[Navigation keys] move around [ESC] exit [ENTER] detailed information

Figure 4 Typical Output Screen of Plant Caring Expert System

Soil Texture : Sand Expected Yield = 3.88 ton							
Pre Cultivation gm/540 m^2			3057 N	7962 K_2O_5		1417 MgO	
Fertilization Schedule gm / 540 m^2							
Week No.	Starting Date	N	P_2O_5	K_2O_5	MgO	Water Qty (lt./540 m^2)	Interval in days
1	1/9/94	----	----	----	----	882	1
2	8/9/94	147	0	82	7	830	1
3	15/9/94	182	0	102	8	1030	1
4	22/9/94	329	58	184	10	1240	1

[ESC] exit [ENTER] detailed information

Figure 5 Typical Output Screen of Fertigation Expert System

Design and Implementation

Domain Layer

The domain layer consists of the domain concepts and their properties, relations between concepts, and relations between expressions. Shared concepts such as climate, soil, and plant, were included in the common knowledge base. Relations between concepts such as the disorder concepts, were also included in the common knowledge base. Relations between expressions were mostly specific to each expert system except for a few relations related for reasoning about soil characteristics; those included into the common knowledge base. The domain concepts were implemented in KROl as objects. Figure-6 shows a sample of an implemented concept. The relations between expressions were implemented as rules. Figure-7 shows a sample of an implemented relation.

The number of rules of the whole system, is about 600, the number of objects is about 250, the number of attributes is about 600, and the number of facets is about 2400.

```
root_observation :: {
super(observation) &
dynamic r_o_color/1 &
dynamic r_o_shape/1 &
source_of_value(r_o_color/1, [user]) &
source_of_value(r_o_shape/1, [user]) &
prompt(r_o_color/1,'what is the root color ? ') &
prompt(r_o_shape/1, 'what is the root shape ? ') &
type(r_o_color/1, nominal) &
type(r_o_shape/1, nominal) &
single(r_o_color/1) &
single(r_o_shape/1) &
legal(r_o_color/1, [brown,normal]) &
legal(r_o_shape/1,[decay,thick,'short with few root
hair', normal])
}
```

Figure 6 An implementation of Root Observation concept using (KROL)

```
d_s_c_verify_d :: {
super(diagnosis) &
 r1([confirmed of verticillium_wilt ='most likely'])
     if confirmed :: verticillium_wilt = likely ,
     water_table_level_cm :: soil < 80,
     cur_avg_tc :: climate < 20 &
 r2([confirmed of fusarium_wilt = 'most likely']) if
     confirmed :: fusarium_wilt = likely ,
     water_table_level_cm :: soil < 80,
     cur_avg_tc :: climate < 20 &
 r3([confirmed of nitrogen_def = 'most likely']) if
     confirmed :: nitrogen_def = likely,
     ec :: soil < 2 ,
     water_table_level_cm :: soil < 80,
     eciw :: water < 1,
     cur_avg_tc :: climate < 16 &
 r4([confirmed of calcium_def = 'most likely']) if
     confirmed :: calcium_def = likely,
     eciw :: water < 1,
     ec :: soil < 2,
     water_table_level_cm :: soil > 80,
     cur_avg_tc :: climate < 16
}.
```

Figure 7 An example of relatio implementation using (KROL)

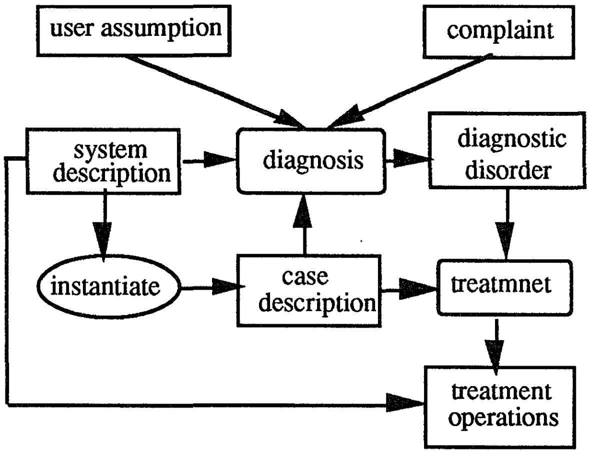

Figure 8 Inference Structure Of Disorder Remediation

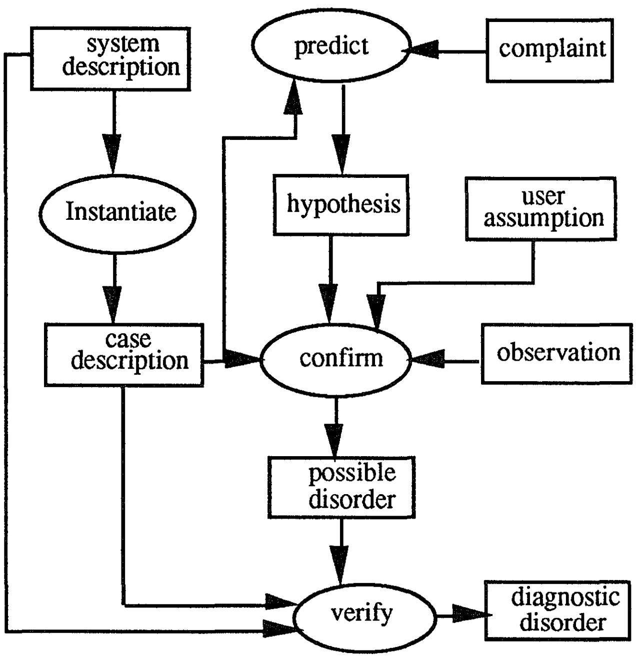

Figure 9 Inference Structure Of Diagnosis Sub Task

Inference Layer

The inference layer consists of meta classes, and knowledge sources. A group of meta classes and knowledge sources were grouped to construct a subtask. For each of the three expert systems, an inference structure was designed.

Figure 8 shows the inference structure of the disorder remediation expert system which has diagnosis, and treatment sub tasks.

The diagnosis subtask finds out the causes of the user's complaints, or verifies the user's assumption. The treatment subtask finds a suitable recommendation to treat a certain disorder taking into consideration the possible cause of this disorder if any. The outcome of this model is a set of agricultural operation(s) to be performed in order to treat the disorder and remove the cause. Figure 9 shows the inference structure of a diagnosis sub task.

The knowledge sources are implemented in KROL by calling a built-in inference method called conclude-all. This method is a specialized inference engine that works on the relation between expressions. The meta classes are actually a description of the domain layer components which are the inputs and outputs of the knowledge sources. No special handling for meta classes is done in this implementation.

Task Layer

The task layer actually describes the steps of executing the knowledge sources in the inference layer. The tasks and subtasks have been implemented using Prolog code.

Verification and Validation

Verification and validation are conducted as stated in the development methodology. It is interesting to show here the results of the validation process. The validation methodology was applied by generating typical cases and distributing them to three domain experts in a certain specialty. Each subsystem is related to more than one specialty. For example in the remediation subsystem, we have three specialties: plant pathology, entomology, and nutrition. Therefore 9 experts have participated in the validation of this subsystem. For each specialty, an evaluator was selected to blindly asses the responses of the three human experts and the expert system . After the evaluation took place, the domain expert who participated in the development, the evaluator, and the domain experts who participated in the evaluation met together with the knowledge engineer to discuss the evaluation results till they reached to a consensus. The scale used for the evaluation was 3 for excellent, 2 for good, 1 for acceptable, and 0 for unacceptable. The scores shown in figure are the total scores of groups of experts divided by the total number of cases of each subsystem. CUPTEX is not a single expert, it is in effect a group of experts. Experts group-1 score is the score of the best expert in each specialty, experts group-2 score is the second best, etc..

As we can see from figure-10 the maximum score does not reach excellent. That is because the group decision is better than individual decisions. We can also notice that CUPTEX over performs the human expert in two subsystems, and its score in the third one is 0.75 of the best experts-group. CUPTEX can be trained to reach excellency, and this is currently being done. Even with this performance, the field test proved that the system is very useful in reducing cost, and increasing yield as is shown in the application payoff section.

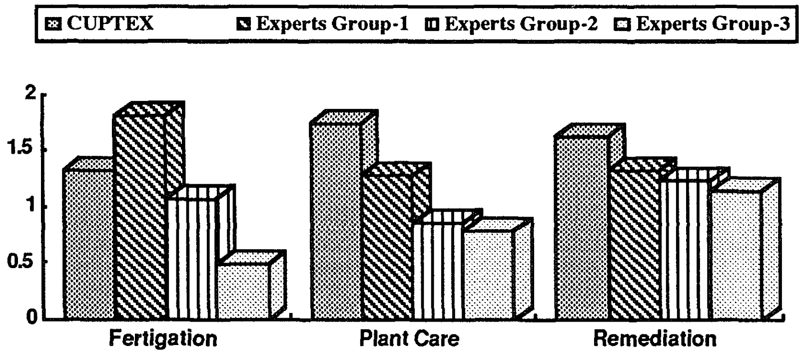

Figure 10 Validation Results

Integration with Other Technologies

The expert system developed is integrated with a data base used to keep the static data of end users as the system was designed to serve the extension workers who receive farmers from different locations.

Multimedia is also integrated with the system. So far, we only use images to explain to the user the symptoms of a certain disorder. In the future, it is intended to include video and sound to explain how agricultural operations are performed.

One unique feature of our system is that it is bilingual. We first developed CUPTEX in English in order to be able to communicate with the international communities. Then, we were confronted with the fact that the users prefer Arabic. Therefore, we decided to include the facility of interacting with the system both in Arabic and English. This necessitates the inclusion a system software which arabizes the keyboard, and the display of Arabic characters. It is worth mentioning that the internal knowledge representation is the same for both Arabic and English. We add a presentation layer which handles the language issue.

Deployment Methodology

The deployment process started by training the users and then disseminating the expert system developed.

Training End Users

A training program was developed to train the end users on using the system. This training program included: an introduction to computers, DOS operating system, commonly used ready made packages such as word processors, spread sheets, data base management, and experts system shells, and finally the usage of the developed expert system. The idea was to encourage the extension workers to use the computer in other activities in addition to the expert system. The training was conducted in three cycles. The first cycle covered the subjects mentioned above except for the last subject concerning the expert system which is divided into builds. In each cycle, one of the builds is covered. The training was very useful in testing the developed expert system, and in getting some inputs from the trainees which were used for system enhancement.

Expert System Dissemination

At the end of each training cycle, the trainees from each of the five sites got one of the three builds of CUPTEX. As it was decided that one of the development team should accompany the extension workers to help them in installing the system for the first time, the first training cycle was conducted two times. Each time the trainees from sites near each other, are grouped such that the software engineer accompanying them can visit the sites at the same time. The deployment of the field prototype took six months including the training.

Application Use and Payoff

The CUPTEX expert system was first deployed one year. ago. It is installed in five sites for protected agriculture for testing such that it can be distributed to the private sector later on. Some agricultural institutes, and schools also took the system for experimentation. The target user of CUPTEX is the extension worker. However, researchers and educated farmers can use it very easily as well. In the following subsections, we will describe how CUPTEX paid off its development cost, and what the potential is for more benefits in the future.

Application Payoff

The development of such an expert system aims at giving the farmers good services at the extension offices as part of the mission MOA, and hence increase the national production. This will lead indirectly to paying off the development cost. However, the application payoff can

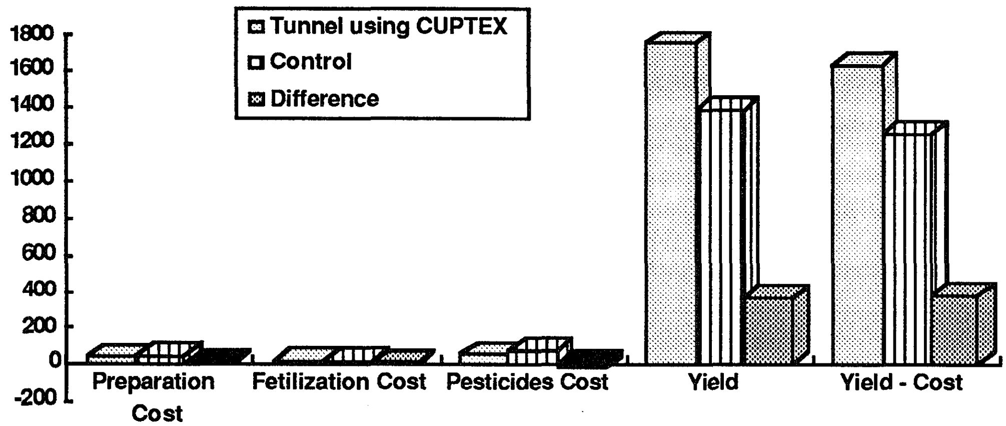

Figure 11 Production Cost and Yield per Tunnel (in $)

also be measured in terms of the increase in cucumber yield and the reduction in production cost in the research locations where cucumber is cultivated for experimentation within MOA as the yield of these locations is sold.

During the last year, experiments were conducted in two sites: El-Bousily, and Mariot, for two purposes: first, to validate the system in the field, and to measure the impact of using the system. The experiment was conducted by selecting two tunnels: one was to be cultivated using CUPTEX without any interference from the agriculture engineer or any specialist, and the other one was to be cultivated as usual (this is a control tunnel). The results of the two sites gave positive results in favor of using the field prototype. The results from Bousily site are shown in figure-11.

So, if CUPTEX is used in the 170 tunnels which are cultivated with cucumber in the five sites for one season (4 months) the benefit gained from the system will be approximately $68,000 ($400x170) which means that about 60% of the development cost including the first two years, can be covered in one season. If the first two years were excluded ,as the technical staff were being trained during that period, the system could pay off the development cost in one season.

Expected Additional Benefits

In an economic study conducted by MOA(Zayed 1992), the total number of plastic tunnels is estimated to be 15018 nation-wide. These tunnels are owned by 905 different owners. The percentage of tunnels in which cucumber is cultivated is estimated as 47.5% . This means that the estimated number of plastic tunnels in which cucumber is cultivated is approximately 7134. The average number of tunnels per owner is approximately 17 tunnels. Therefore, an estimated benefit of $6800, which an owner can make in one season, will cover the price of purchasing a computer (486 based) and more. Therefore, another source of funding for CLAES can be created by charging a nominal price for each copy of CUPTEX. If this nominal price is $300, the income from CUPTEX could be $126,000 (The number of owners cultivating cucumber is estimated to be equal to 420 owner).

Maintenance

Maintenance was one of the most important activities to be considered in the methodology. The knowledge base is to be maintained by CLAES. As the knowledge to be updated is mainly concerning the appearance of new materials such as fertilizers, and/or pesticides, and since this does not happen very frequently , the updating of the knowledge base was decided to be done every six months. The update will also include any changes the user may require after being cleared from a committee formed for this purpose.

Forms were designed and distributed with the packaged expert system to assist the users in documenting their remarks and feed them back to the expert system lab. Continuous review of the expert system was done by experts to include any new piece of knowledge. Meetings are arranged between the users and the domain experts to discuss the problems and ideas of the users in order to reach consensus on what to be added.

In effect, using the KADS methodology facilitated the manual maintenance so far. This is because each expert system is separated from the others. Interaction between the systems is defined through the common knowledge base. The division of the knowledge base into concepts, relation between concepts, and relations between expressions, and determining how the control mechanism uses this knowledge through the knowledge sources, helps a lot in determining problems when any changes are performed . In effect an internal procedure was established such that only the leader of the development group is to be responsible of any changes. He should sign a form prepared to indicate what the type of change is, and why the change should be done, and its source, etc.. A Data base is now being prepared to facilitate the job of the team leader to follow up these changes.

In order to properly manage the maintenance of the system, a group was formed within the lab. to take care of user problems , and to follow up the delivery of the updated versions in collaboration with the development group.

Conclusion

The work presented here shows how expert system technology can be harnessed to serve developing countries like Egypt in which there is a scientific infrastructure capable of receiving this technology. The success of CUPTEX can be described from two aspects: the development aspect, and the deployment aspect.

From the development point of view, the team within CLAES has succeeded in building an expert system which contains approximately 4000 pieces of knowledge using one of the second generation expert systems methodologies, KADS, which has become the defacto standard for building knowledge bases in Europe. The development of such a system lad to training 8 persons on knowledge base systems development. Some of the team members have traveled abroad for studying and were replaced with others. In Egypt we have a relative advantage in the availability of human resources. Therefore we developed an on-the-job training program to be able to convert a computer science graduate to a software engineer or to a knowledge engineer under the supervision of the team leader. This means, that we were able to overcome the problem of loosing trained personnel either to abroad or to the private sector.

From the deployment point of view, the system was used in the field. Although direct pay off is not the policy of MOA as it provides services to farmers, and consequently these services will contribute to the national income, experimenting with CUPTEX showed that it could pay off approximately 60% of its development cost in one season which is four months as explained in the paper. The potential benefit of CUPTEX is very high when it is used by farmers having plastic tunnels nationwide.

Updating CUPTEX and including other facilities by integrating multimedia technology will dramatically enhance its usage. We are working now on providing very detailed explanation facilities, and using Machine Translation techniques to support its bilinguality. The issue of multilinguality will also be addressed such that it can be easily modified and used at the regional level.

Acknowledgment

The work presented here is funded by United Nation Development Program(UNDP), and Egyptian Ministry of Agriculture(MOA), and executed by Food and Agriculture Organization (FAO) through the Expert Systems for Improved Crop Management project (ESICM). The authors would like to acknowledge domain experts who participated in developing and validating the knowledge base of CUPTEX , especially Drs. Ahmed Abdel-Fatah, and Fahmi Fadle, the team who developed KROL, especially Dr. Mahmoud Rafeh, and the management staff who supported the administration issues in ESICM project.

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