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An Object-Oriented Expert System for Diagnosis of Fungal Diseases of Date Palm

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Abstract: In this study, an Object-Oriented (O-O) prototype Expert System (ES) for diagnosis of fungal diseases of date palm is presented. The objectives are to investigate, the potential of a proposed O-O model for expert systems and to provide intelligent computer-based support for farmers or agricultural specialists. The modeling of the system is based on O-O database and O-O rule base. An overview of the system's model and a description of its implementation are presented. The architecture of the ES resulted in a successful and flexible system that enhances soft computing and can also be used to develop expert systems for other domains.

Key words: Expert system, object-oriented modeling, object-oriented database, object-oriented rule base, date palm, fungal disease

INTRODUCTION

In this research, a prototype object-oriented expert system for diagnosis of fungal diseases of date palm is developed. The system is named DatePalm-ES. As the title shows, there are two objectives of this study:

- Investigating a proposed object-oriented structure for building expert systems
- Providing an intelligent computerized support system that helps in the domain of date palm diseases

Study survey reveals that many expert systems were reported in the important field of plant diseases. Reported expert systems domains include: Olive crops (Gonzalez-Andujar, 2009), coffee (Mansingh *et al*., 2007), mango (Prasad *et al*., 2006), date palm (Ministry of Environment and Water, 2008), tomato and cucumber (Clarke *et al*., 1999; Yialouris and Sideridis, 1996), potato (Boyd and Sun, 1994), apple (Huber *et al*., 1990; Roach *et al*., 1987), soybean (Michalski *et al*., 1982), wheat, rice, beans, grapes, barley and orange (The Central Lab for Agricultural Expert Systems, Egypt).

Expert systems: Expert System (ES) can be defined as: A decision-making or problem-solving software package that can reach a level of performance comparable to that of human expert in some specialized and usually narrow problem area (Turban *et al*., 2005). The three major components that appear in virtually every ES are: Knowledge base, inference engine and user interface. For better interaction with users an ES should preferably contain an explanation subsystem component or justifier (Ignizio, 1991; Turban *et al*., 2005).

The knowledge base contains the relevant knowledge necessary for understanding and formulating the ES domain. In rule-based expert systems that are supported with a database, the knowledge base can be considered to include two basic components: rule base of heuristics rules that are used to solve specific problems in a particular domain and database of domain's data and facts. The inference engine is the component that provides a methodology for reasoning and for formulating conclusions. The inference engine provides directions about how to use the system's knowledge by developing the agenda that organizes and controls the steps taken to solve problems whenever consultation takes place. The user interface consists of all screens of interaction between the user and ES. Explanation subsystem help justify ES conclusions by tracing and showing how was a certain conclusion reached or why a specific question is asked by the ES.

Expert systems are practically developed using specialized ES software packages known as ES shells. ES shells support all ES components including an 'empty' knowledge base that can be filled with domain's knowledge and constructed according to the model adopted by the ES developer (Russel and Norvig, 2003; Turban *et al*., 2005).

Date palms and their diseases: With the current uncertainty in the world food production and the increase in demand for food with a population exceeding 6 billion inhabitants, the date palm offers a good food source of high nutritive value. For many date growing countries, date palm tree gives the main food for a considerable number of people (Zaid and Arias, 2002).

According to the official statistics from the Food and Agriculture Organization of the United Nations (FAO), the annual world date production had exceeded the 6 million tons in 2007. Date fruits are considered an ideal food source and contain several main nutrients such as sugar, amino acids, oligo elements and proteins. Calorie wise dates contain three times the energy provided by watermelon, four times of apples and seven times of oranges (Third International Date Palm Exhibition, 2008).

According to FAO, date production is facing serious problems, such as low yields, due to the lack of research and the spread of diseases and pests. This should encourage researchers in all fields to direct their research toward methods of solving or at least reducing this problem and its negative consequences on food security.

The selected domain of the developed ES is fungal diseases of date palm. In general, diseases of date palm can be classified into the following main types (ECSSR, 2003; Zaid and Arias, 2002):

- Fungal diseases
- Phytoplasmic diseases
- Other secondary diseases, diseases of unknown cause and physiological disorders

Regarding fungal diseases a review of the literature reveals the following major categories: Khamedj disease (inflorescence rot), Bayoud disease, Fruit rot disease, Brown leaf spot disease, Diplodia disease, Graphiola leaf spot disease, Black scorch disease, Belaat disease and Omphalia root rot disease. Following is a brief description of selected fungal diseases in order to have more insight of the domain of the constructed ES.

Khamedj disease: Khamedj disease causes damage on inflorescences in neglected palm groves in hot and humid regions, or in areas with prolonged periods of heavy rain, 2-3 months before emergence of spathes (Zaid and Arias, 2002). The disease is caused by Mauginiella Scattae Cav, which is always found in a pure state in affected tissues; Fig. 1 (Zaid and Arias, 2002). The first visible symptom of the disease appears on the external surface of unopened spathes and is in the form of a brownish area. It is most apparent on the internal face of the spathe where, the fungus has already begun to infect the inflorescence. When, the infected spathes split, they reveal partial or complete destruction of the flowers and strands. Severely damaged spathes may remain closed and their internal contents may be completely infected. The inflorescences become dry and covered with powdery fructifications of the fungus. Transmission of the disease from one palm to the next occurs through the contamination of male

Fig. 1: An open spathe showing the attack by mauginiella scaettae

inflorescences during the pollination period. The infection of the young inflorescence occurs early and happens when the spathe is still hidden in the leaf bases. The fungus penetrates directly into the spathe and then reaches the inflorescences where, the fungus sporulates abundantly. The frequent appearance of the disease in neglected date plantations indicates that good sanitation and efficient maintenance is the first step in the control of Khamedj disease. The collection and burning of all infected inflorescences and spathes should be followed by treating the diseased palms with the following fungicides after the harvest and one month before the emergence of spathes: A bordeaux mixture or a copper (1/3), sulphate-lime (2/3) mixture or a 3% dichlone spray or a 4% thirame spray at the rate of 8 L palm^{-1} (Zaid and Arias, 2002).

Bayoud disease: Bayoud disease causes the whitening of the fronds of diseased palms. The bayoud disease attacks mature and young palms alike, as well as offshoots at their base. The first symptom of the disease appears on a palm leaf of the middle crown (Zaid and Arias, 2002).

This leaf takes on a leaden hue (ash grey color) and then whitens. A brown stain appears lengthwise on the dorsal side of the rachis and advances from the base to the tip of the frond, corresponding to the passage of the mycelium in the vascular bundles of the rachis. Afterwards, the frond exhibits a characteristic arch, resembling a wet feather and hangs down along the trunk. The same succession of symptoms then begins to appear on adjacent leaves. The disease advances ineluctably and the palm dies when, the terminal bud is affected. The causal organism responsible for bayoud is a microscopic fungus, which belongs to the mycoflora of the soil and is named fusarium oxysporum forma specialis albedinis

(Zaid and Arias, 2002). Contamination occurs regularly from palm to palm and more rapidly as the amount of irrigation increases. The appearance of the disease in locations far from the original infected area is caused primarily by the transport of infected offshoots or palm fragments harboring the fungus. A significant reduction in the amount of irrigation can retard the advance of infection, i.e., stopping irrigation between the months of May and October, during the hot season in the northern hemisphere (Zaid and Arias, 2002). Since, the contamination occurs mainly by root contact, disease-free palms can be isolated by digging a trench of 2 m deep around them. Water should be provided by a trough bridging the rest of the grove to this isolated plot. Under these conditions these palms can be protected for >10 years (Djerbi, 1983; Zaid and Arias, 2002).

MATERIALS AND METHODS

A detailed investigation of the nature of palm diseases shows that each disease has its own identity, which includes characteristics like the causing fungus, disease symptoms, treatment methods, etc. This nature suggests that the Object-Oriented (O-O) model is the most suitable and promising method for computerization in this domain. The O-O model for developing computer software systems is a methodology that finds increasing fields of applications. The fundamental building block of O-O software is the object, which models the real world object in the application domain (e.g., a fungal disease). A software object packages together data and behavior of the real world object it represents.

An important contribution of this research is the O-O modeling used in the construction of both the database and the rule base of the system.

DatePalm-ES is developed using Kappa-PC Expert System Shell (IntelliCorp, 1997). Kappa-PC was selected since it fully supports O-O modeling. Other desired Kappa-PC features include: Tools for the development of database supported rule-based systems, explanation component and graphical user interface.

Database: O-O structure allows each disease to be constructed as a different object and the database modeled as a collection of these objects. This model gives more flexibility to each disease to have its identifying attributes while, maintaining the integrity of the whole system. In addition, the O-O model allows representing the behavior of an object as an attribute of it by using methods (more details will be given when considering the O-O rule base of the system).

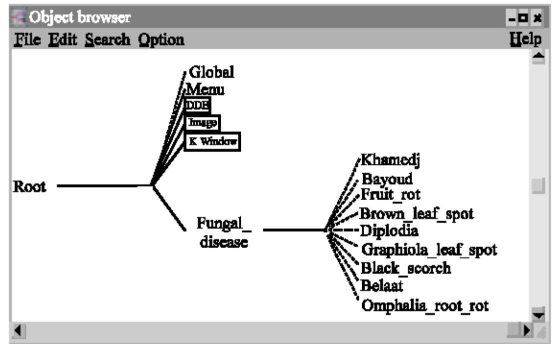

Fig. 2: The object hierarchy of the O-O database

The database of DatePalm-ES consists of the main class: Fungal_Disease. Fungal diseases are descendants (objects) of the main class. Besides, alphanumeric data (texts and numbers), graphics are also available in the database (illustrative photos regarding diseases). Figure 2 shows, a portion of the object hierarchy, which is the Kappa-PC's graphical representation of the developed O-O database structure.

Rule base: In rule-based systems, knowledge is represented as If-Then rules that combine the condition (If) and the conclusion (Then) for handling a specific situation. The advantages of using production rules include: Simple syntax, rules are easy to understand, rule chaining is easy to trace and debug, good explanation facilities and new rules can easily be tested and added into the rule base (Sadik, 2008). The developed rule base contains rules regarding fungal date palm diseases, prevention and treatment guidelines. System's knowledge (data and rules) was compiled from the documentations available in the literature; mainly FAO publications and was discussed with domain experts.

The architecture of the rule base is modeled as following: Knowledge base rules are classified into two categories: General Rules (belong to the general rule set) and Object Rules (belong to object rule sets) Fig. 3.

General rules: Rules of the general rule set are mainly used to determine the fungal disease based on the dialog between the user and the system. As examples, consider the following simple illustrative rules written in Kappa-PC Application Language (KAL):

```
Rule strange color:
If DatePalm:Symptom1 #= StrangeColor;
Then DatePalm:StrangeColorTest = Observed

Rule StrangeColorType:
If DatePalm:StrangeColorTest #= Observed;
Then AskValue (DatePalm, StrangeColorType)
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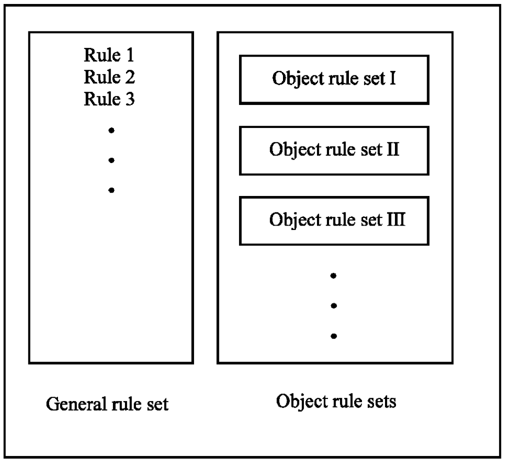

Fig. 3: The structure of the O-O rule base

Rule StrangeColorPosition1:
If DatePalm:StrangeColorType #= Brown;
Then ActivateRule (StrangeBrwonColorPosition)

Rule PossibleDisease1:
If (DatePalm:StrangeColorType #= Brown And AskValue (DatePalm: StrangeColorPosition) #= ExternalSurfaceOfUnopenedSpathes);
Then DatePalm:PossibleDisease1 = Khamedj

The DatePalm in the rules above is a variable that refers to the date palm under consideration in a given ES consultation. DatePalm is described by various attributes and test attributes like: Strange Color Type, Strange Color Position, Symptom1, Symptom2, Possible Disease1, Possible Disease2, Concluded Disease, Strange Color Test, Leaf Test, Trunk Test, etc.

Object rules: Rules of the object rule sets are included inside appropriate objects (fungal diseases) and are utilized consequently in order to perform specialized inference within the identified disease. These object rules are represented as methods thus, forming an O-O rule base (Fig. 3). Kappa-PC allows method body (or code) to be in IF-Then production rule format.

This distribution of selected rules inside appropriate objects further demonstrates the power of the adopted O-O model and makes the system as a whole an O-O system. Methods are procedures that are represented as object attributes. The process of activating a method in a particular object is called sending a message. When, an object receives a message that corresponds to one of its methods, that method is activated and the object carries out whatever, procedure is specified by the method. Different objects can respond to the same message with different methods (IntelliCorp, 1997). Objects that handle the same message can be seen as if they all perform the same procedure, even though they actually perform it in different ways. This is referred to as polymorphism in O-O modeling terminology. As a polymorphism example from DatePalm-ES, sending the message corresponding to the object rule Prevention_Guidelines results in different responses from different diseases. For instance, if the disease is Khamedj and the period is pollination period, then that disease responds to the message by displaying the following sample text: Be careful! Transmission of the Khamedj disease from one palm to the next occurs through the contamination of male inflorescences during the pollination period. Examples of object rules from an object rule set are given below (the rules below are inside the fungal disease Khamedj).

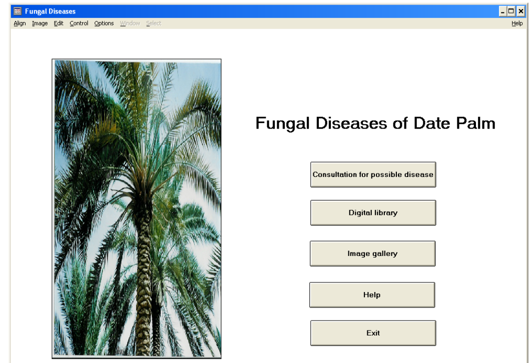

Fig. 4: Main screen of the system

Rule PeriodStatus:
If (Khamedj:Location #= Southern_Hemisphere And (Khamedj:Month #= July Or Khamedj:Month #= August));
Then Khamedj:Period_Status = Pollination

Rule Prevention_Guidelines:
If Khamedj:Period_Status #= Pollination;
Then PostMessage("Be careful! Transmission of Khamedj disease from one palm to the next occurs through the contamination of male inflorescences during the pollination period")

User interface and sample consultation: Interactions between the users and the system are supported through a user friendly graphical user interface running under Windows environment. Figure 4 shows, the main screen of the system where, various options are displayed.

Currently, the following five options are available. The options Digital library (textual information) and Image gallery (images) form a sort of encyclopedia of fungal date palm diseases. The user can click on help to browse the accompanying help subsystem or click Exit to quit. The help subsystem contains the user manual, which is mainly a general explanation on how to use DatePalm-ES. Consultation for possible disease is the option that guides users in diagnosing a palm tree. Many questions asked to the user during consultations are of type multiple-choice questions. Figure 5 shows, a sample consultation step, in which the system displays the

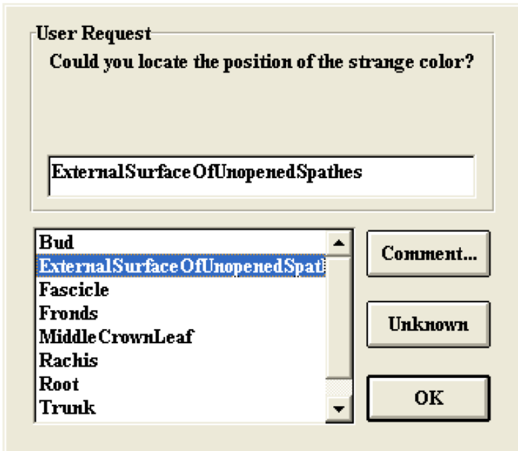

Fig. 5: Sample consultation screen

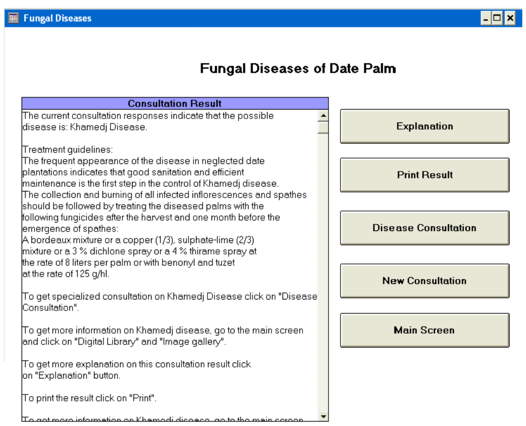

Fig. 6: Example consultation result screen

following question to the user: Could you locate the position of the strange color? As shown in Fig. 5, the user is presented with multiple choices to select the answer from. The button Comment... here is a part of the explanation subsystem since it gives clarification on why this question is being asked. Some questions are supported with photos as guidance for users.

Figure 6 shows, a sample consultation result screen. As shown, this screen gives the name of the disease, displays treatment guidelines and also, offers the following options to the user: Explanation to explain why this result was concluded (explanation subsystem), Print Result' to print the consultation result, Disease Consultation to activate the consultation based on the object rule set of the concluded disease, New Consultation to start a new consultation and Main Screen to return to the main screen. As stated above; clicking on the option Disease Consultation activates a specialized consultation, in which the dialogue between the system and the user is related to the concluded disease only as shown in Fig. 7.

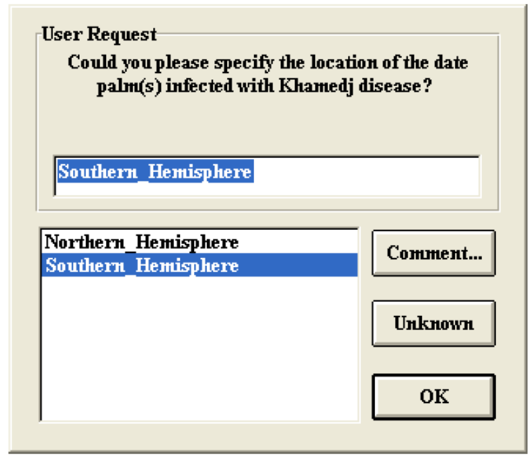

Fig. 7: Specialized consultation dialogue (utilizing an object rule set)

RESULTS AND DISCUSSION

The response of the domain experts who interacted with the system was that the system is successful and promising.

Figure 2 and 3 show that the developed ES is entirely O-O system constructed from O-O database and O-O rule base. Advantages of this proposed approach include:

System's extendibility: Easy to extend the system by adding more diseases, disease categories and production rules.

Code reusability: Reusability is an important software engineering principle. Optimizing code reuse increases productivity and quality, enables efficient co-development and reduces software development and testing time.

Faster processing: The system uses only the appropriate rule set during consultations (general rule set initially and then the proper object rule set in the specialized 'disease-specific' consultation).

Easier maintenance: Maintaining the application becomes easier, since a change needs to be made only once at its appropriate place.

Correct classification of production rules is a difficulty (disadvantage) related to the proposed approach. This difficulty can be solved by more interaction with domain experts.

As stated previously, interactions with the system are performed through multiple-choice questions. This allows the user to select the most appropriate answer from a list of candidate responses. Multiple-choice questions make the interaction easier and also reduce errors that might be caused by user typographical errors.

CONCLUSION

In this study, an object-oriented expert system for diagnosis of fungal diseases of date palm was developed. The present state of the system was discussed and illustrated. The current domain of the system is limited to fungal diseases. Future research that deserves investigation is gradually enlarging the domain of the system to include the other categories of date palm diseases. The design of the system provided evidence that object-orientation principles are more suitable and successful in developing software systems in general and expert systems in particular (for certain domains like plant diseases).

An important contribution of this research is the system's architecture that is composed of O-O database and O-O rule base. The architecture of the ES resulted in a successful and flexible system that is also promising for developing expert systems for other domains.

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