A Web-Based Intelligent Decision Support System for Low-Technology Greenhouses

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Abstract. This work describes the architecture of a system developed to introduce computer management into the cultivation process in low-tech greenhouses. The proposed system is implemented as a web-based application using open source technologies and subsystems comprised of modules that provide: (1) static information about the cultivation process and marketing of the supported crops or ornamentals, (2) simulation and forecast models of general interest and (3) expert system capabilities and support. Modular construction of the system allows easy adaptation to new products and expansion into new languages. The centralized management of information and knowledge provides approved and better quality of services.

The system is designed to provide personalized consultation to its users. The consultation process is guided by input data provided separately by each user. After an initial authentication, the user can interact with the system individually in a personalized environment. Each user has his/her own protected storage space where he/she can store his/her data separately from those of others. The system offers a way to supervise the cultivation process, maintain records of user activities and is able to transmit special alerts for necessary actions.

The overall process is monitored by an intelligent decision support system which takes into consideration the data provided by the user, as well as the results of the special models and expert systems, so as to give specialized advice for each individual case. Finally, although the prototype system under development is devoted to tomato, in the future it will be extended to other important greenhouse crops.

Keywords. Greenhouses, expert systems, computer techniques, knowledge dissemination.

Introduction

Plastic-covered greenhouse cultivation is a major economic activity in Greece and the countries of the Mediterranean basin. It is estimated that a number of 4000 ha is devoted to the cultivation of products such as tomatoes, peppers, aubergines, cucumbers, melons and lettuces (Olympios, 1991). Because of the mild climate of these areas as well as other economic reasons, the majority of greenhouses are of low technology, with basic equipment for temperature control.

Although low technology greenhouses constitute a very important horticultural sector they have rarely attracted the attention of computerized management systems. This is because the low capital investment for low-tech greenhouse construction is thought not to justify the extra cost of a special computerized system for cultivation management. However, information technology systems can be introduced to this sector at a low price and with a negligible capital requirement.

Lack of interest from the computer industry and appropriate programs are the one side of the coin. From another point of view, growers usually have low technological skills making the accomplishment of even simple management tasks needed from standalone computer systems a difficult task. There is a need for interesting, useful, and attractive tools to catch the attention of the growers and to realize that it is possible to get useful information and solve practical real problems even at low cost.

The advent of the Internet and its related technologies provides opportunities for new applications and new ways of collaboration between groups of people having common interests. From the early stages of the Internet there were efforts for web-based applications development (Jensen et al., 2000), although systems covering all steps of low-tech greenhouses production is very rare (Passam et al., 2001). Since difficulty to operate standalone sophisticated applications and to distribute new versions with updated and up-to-date content are among the reasons of the low penetration of information technology, web applications seam to eliminate some or all of these obstacles. Furthermore, central administration and distribution of the system remove this weight from the growers and keep the cost fixed, irrelevant of the users participating or joining the effort.

This work describes the architecture of a system developed to provide computer management in low-tech greenhouses. It has been designed as a web based application because of its advantages and benefits

over the traditional standalone systems. It integrates and extends previous efforts (Yialouris et al., 1997; Passam et al., 2001) by extending their accessibility and applicability.

The system implements several modules, covering collaboration, information and management needs of greenhouse growers, using portal technology. All its modules are based on open source technologies and industry standards keeping, thus, the cost low and increasing portability, extensibility and communication with other systems. The proposed system contains modules offering static information about the cultivation process and marketing of the supported crops, simulation and forecast models of general interest and expert systems for irrigation management and pest control. At the present stage of development the system provides support for three crops, tomato, pepper and aubergine.

A unique characteristic of the system is the personalized consultation offered to its users. Each registered grower interacts with the system in a personalized environment. He/she can store his/her data separately from the other users and can get consultation and guidance based on his/her own data.

The following sections describe the design principles, system architecture and the modules constituting the system. The paper ends with a conclusion section discussing benefits and limitations of the system, the current stage of development and its future perspective.

Modules

The contents of the system are organized as separate modules, which can be divided into three major categories. Static information, dynamic models and decision support module. Apart from these three major categories there is also a communication module. The contents and basic characteristics of these modules are described in the following paragraphs.

Static Information

The provided static information concerns crops' cultivation procedures and marketing information. Information concerning cultivation and marketing of tomato, pepper and aubergine is provided using static pages. Information is stored in properly structured XML files, which are converted to ordinary HTML pages by the use of proper XSL files. This kind of information covers greenhouse preparation, nursery and cultivation procedures, and commercial data. Because the crops have certain of this information in common, the XML files used are considered jointly so as to enable their integration and keep redundancy to a minimum.

Dynamic Models

The category of dynamic models contains forecast models providing information about market prices and consumption tendencies in specified time period and weather forecasts for specified geographical areas. Furthermore, two expert systems are provided to help growers with nutrition deficiencies and pest management and to regulate irrigation.

The first expert system is an adaptation of VEGES expert system presented in (Yialouris et al., 1997) to be used as a web based application. It can be used for the identification of pests, diseases, and nutritional disorders. As a result, VEGES identifies the disorder according to the input data provided by the grower and suggests methods of confrontation. The second expert system extends IRNMA, an irrigation and nutrition management system described in (Passam et al., 2001). This defines the daily requirements of the plant for irrigation and fertilizer application relative to the stage of growth, plant population, soil type, and the amount of water evaporating from the soil, as measured by an evaporimeter.

For each expert system, the same knowledge base can be used by all users of the system. Consultation process is guided by input data provided separately by each user. The centralized management of the knowledge base provides better quality of knowledge.

Decision Support Module

This subsystem provides a way to schedule, supervise and analyze the cultivation procedures, keeping records of grower's activities and having the system to remind the grower with special alerts for the needed actions. The grower inserts into the system daily actions and events according to the dates of their occurrence. The system is able to suggest the subsequent actions within a certain future horizon and at the same time to show any problems in the sequence of the previous actions. In case of deviations from the schedule, the system alerts the grower and suggests possible corrective actions. The subsystem uses simulation and statistical techniques, expert system analysis and check lists to accomplish its tasks.

The system handles each greenhouse as distinct unit of reference. Needed data are stored and retrieved according to this unit of identification, the year of cultivation and the cultivation period in the year. For each greenhouse, data concerning the type of the construction are kept, together with its dimensions (length, width, height and area), the geographic location and the cultivated crop. Furthermore, the system keeps track of any treatments during the cultivation period and collects data concerning insecticides, pesticides

and fertilizers. Analysis of data takes into consideration the stage of the cultivation process and the growth level of the crop under investigation.

Communication Module

One of the goals in the design of the system has been to develop a collaborative environment for its users. For this reason the system has been equipped with components such as RSS feeder, email alert subsystem and calendar. Communication module distributes news using RSS feeders and mail alerts in case of something concerning a specific area, such as extreme natural phenomena or disease problem occurred in the neighborhood area.

RSS Feeder: RSS (Really Simple Syndication) feeder is a kind of live bookmarks and is used for automatic feed of news. Server site uses XML to format summaries for important news or announcements incorporating the actual URL of the source. Clients using special RSS readers or aggregators are able to exploit these sources of information. Instead to remember to access the web site and look for changed information, RSS feeder forwards the summary of the changed information to the client's RSS reader and after a review the client can access the full subject through the incorporated URL.

Mail alerts: Mail alerts can be used to forward urgent messages directly to the growers using ordinary mail server. For this service the user needs a valid email address.

Calendar: This is a subsystem allowing each grower to keep his/her own personal calendar of important actions or events on the server and at same time allows events publication of general interest. For the implementation of this feature, CW Calendar has been used which can be integrated easily into the uPortal environment. It is an open source and platform independent calendaring system based on open standards.

System Architecture

The main design goals concerning the described system were to offer a collaborating environment, personalized, highly customizable, providing useful information and knowledge, aiming to help greenhouse growers in their daily activities with a minimum cost. For this purpose, system design followed the subsequent design principles.

Web based application. This type of applications concentrates all development and management efforts on the server side and frees the client from any responsibilities. Furthermore, access to the developed system can be achieved from anywhere with minimum software and hardware requirements.

Open architecture. Using open source software based on open architecture and open standards allows system extensibility and increases its viability. On the other side, it keeps development cost low.

Modularity. This requirement allows incremental development of the system as well as easy extensibility, and promotes customization. It can occur on two levels, on the level of development and the level of presentation. Portal technology standards facilitate modularity on both levels.

Central Management. System usefulness highly depends on its content. Since one of the main goals of the designed system is to provide useful information, centralized management facilitates adaptation to renewal of information and knowledge. Additionally, management actions are concentrated at the most appropriate place.

Personalization. The system provides a personalized environment. After an initial authentication, the user can interact with the system in a separate manner. Each user has its own storage space where he/she can store his/her data separately from the others.

Internationalization. A feature of major concern is the functioning of the system in several languages. Interfere of language selection can be identified in three points, presentation level, application level and knowledge level. Since system interface is implemented using Java language and J2EE technology, following J2EE guidelines for software internationalization is enough. Information material uses XML and XSL to accomplish the goal of internationalization. Texts are stored in XML files following a simple structure. Each set of files is stored in a different catalog corresponding to a separate language. A common set of XSL files is responsible for the proper display of the information context. Expert systems are multilingual by design. Knowledge bases use a special multilingual structure as described in Maliappis & Sideridis (2004).

Incorporation of a new language into the system is a simple task from a technical point of view. The major task is to translate documents in the desired language and create the proper files and database entries.

Technologies

The system has been implemented as a web based application based on open source technologies and subsystems. The system has been implemented using J2EE (Java 2 Enterprise Edition) platform, a standard for implementing and deploying scalable, reliable and secure distributed applications. The J2EE technology is designed to support the rigorous demands of large scale distributed mission-critical application systems

and provides support for multi-tier application architecture.

The system uses a 3-tier architecture comprised of a presentation tier, web and service tier, and data tier. This architecture, shown in Figure 1, can be deployed using a single application server. The application server encapsulates the service tier, which consists of the business and data logic. A single server can support many simultaneous connections. The web and service tier communicates with the data tier through the JDBC (Java Data Base Connectivity) protocol.

The client tier is a very "thin" tier that contains only presentation logic. The business and data logic are usually partitioned into separate components and deployed on one or more application servers. This partitioning of the application into multiple server components allows components to be easily replicated and distributed across the system, ensuring scalability, availability, reliability and performance.

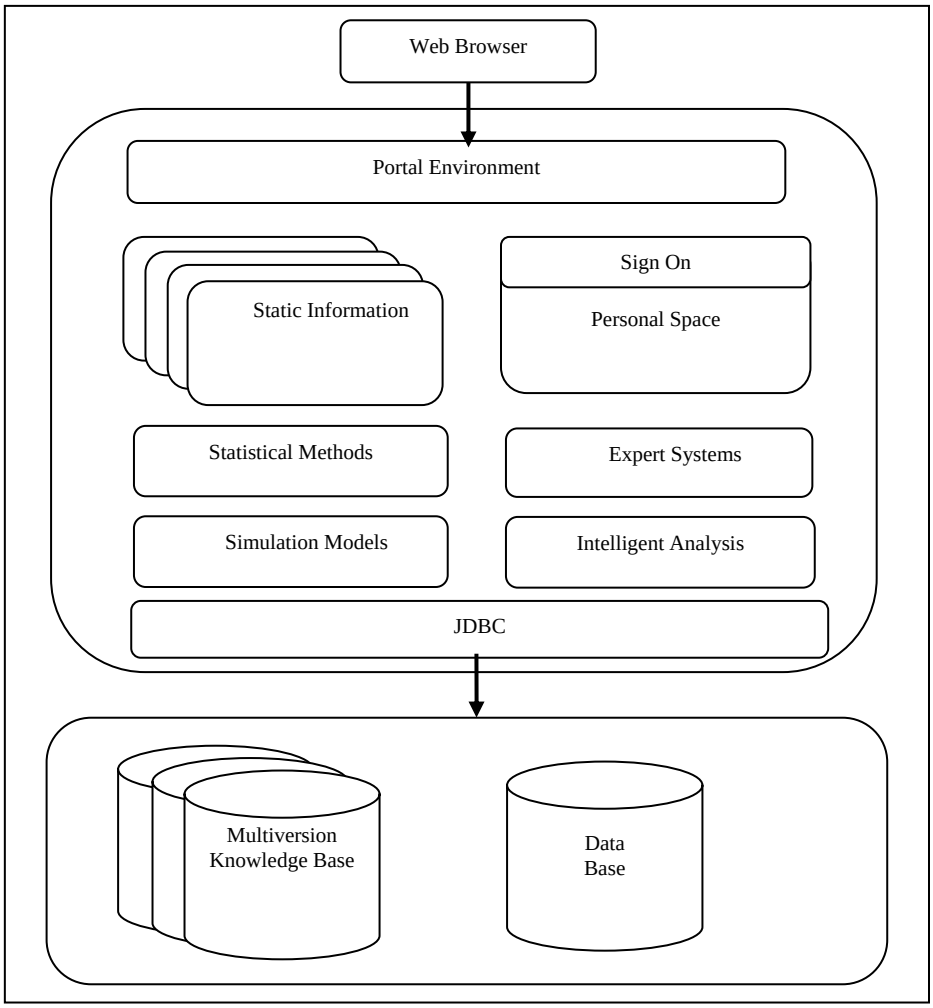

Figure 1: System Architecture

According to this architecture, specialized equipment (hardware and software) is needed only on the server site. In fact, for system implementation only open source software has been used, based on open architecture and standards, keeping thus the cost to the minimum. Particularly, for system integration, portal technology has been used. In fact, the uPortal platform has been chosen, combined with the PostgreSQL

data base management system. uPortal, a system developed using Java language, promotes modularity using portlets, a standard technology to develop contents in portal environments.

Database is used to store data concerning cultivation procedures for each greenhouse and cultivation period. Knowledge needed by the expert systems is stored and been managed on the server following a modular structure described in Maliappis & Sideridis (2004). This kind of management provides the benefit of easily keeping the knowledge up-to-date.

The implementation allows the ordinary user to access the system through a simple web browser. Thus, on the client site a computer is needed with an Internet connection and a web browser such as Firefox, Netscape or Microsoft Internet Explorer. If Firefox is used no other software is needed since it incorporates an RSS reader, otherwise an RSS reader is necessary for RSS feeds to be exploited.

Conclusion

The described system provides a web-based application with centralized knowledge and information management having extended personalization and internationalization characteristics. Its potential accessibility from everywhere and integrated environment with collaboration capabilities provides a way to increase information technology penetration to growers of low-tech greenhouses.

The system, at its present development stage, handles the crops of tomato, pepper and aubergines, which belong to the same family and present similarities in their method of cultivation. System architecture exploits these similarities at the knowledge structure of its intelligent components and the way it stores static information concerning each crop.

Such a tool to be useful, it needs the active involvement of the growers to share their knowledge and communicate their problems asking for solutions. The ideal operator of such a system is a dynamic union of producers in cooperation with specialists of the field to provide useful information and added value services to their members. Emphasis has been imposed on the easy management of the system without the need of special technical skills. Unions are in a position to use the system for communication among their members and to communicate important news using system technical facilities.

The system, since it evolved from a research program in an agricultural university environment, has as a first application field the teaching class. The students can use the system and benefit from the included information and tools. At the same time they will be the front testing line towards the development of a useful system, which can be used to solve real problems.

The adoption of portal technology offers new opportunities and ease of expansion. Features such as forums can be easily established for communication, exchange of ideas, sharing of knowledge and expressing problems. Since the system contains information about certain cultivations, it is possible to be used as a source or a point of negotiation through an eCommerce component. The grower will be able to select whether he/she wants his/her production to be monitored and included in this process.

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