World Journal of Agricultural Sciences 4 (5): 640-647, 2008
ISSN 1817-3047

Gims: A Web-based Greenhouse Intelligent Management System

[1]M.T. Maliappis, [1]K.P. Ferentinos, [2]H.C. Passam and [1]A.B. Sideridis

[1]Informatics Laboratory, [2]Horticulture Laboratory,
Agricultural University of Athens, Athens, Greece

Abstract: This paper describes 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, (2) simulation and forecast models of general interest, (3) a collaboration environment and (4) 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. Greenhouse Intelligent Management System (GIMS) 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 that specialized advice for each individual case is given. At the present stage of development the system provides support for three crops: tomato, pepper and aubergine.

Key words: Greenhouses % Expert systems % Computer techniques % Knowledge dissemination

INTRODUCTION

The cultivation of out of season vegetables in plastic-covered greenhouses is a major economic activity within the countries of the Mediterranean basin. In Greece, there are over 4000 ha of greenhouses, of which 95% are plastic covered and only 5% glass [1]. The principal greenhouse vegetable crops are tomatoes and cucumbers, but significant quantities of peppers, aubergines, melons and lettuce are also grown. Because of the mild climate, most greenhouse vegetable crops are either unheated or provided with a minimal level of heating and the level of automation (e.g. for ventilation) is low.

Despite the economic importance of this horticultural sector, the low technology greenhouse industry has rarely attracted the attention of computerized management systems. This is because the low capital investment for low-tech greenhouse construction is not thought to justify the extra cost of a special computerized system for cultivation management. However, we believe that information technology systems can be introduced to this sector at a low cost and with a negligible capital demand.

Lack of interest by the computer industry and a consequent unavailability of appropriate programs contribute to the low impact of computerization on low-tech greenhouses. This is compounded by the low technological skills of most growers, which makes the accomplishment of even simple management tasks, such as those required for standalone computer systems, difficult. In consequence, there is a need both for grower education and for the provision of useful and attractive tools to catch their attention and to convince them of the possibility of their being able to acquire useful information and solve practical problems, even at a 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, attempts were made to develop web-based

Corresponding Author: Dr. M.T. Maliappis, Informatics Laboratory, Agricultural University of Athens, Athens, Greece

applications for certain aspects of greenhouse and crop management [2-4], although systems that cover all steps of low-tech greenhouse production are very rare [5]. This is perhaps surprising, since web-based applications can eliminate obstacles such as the operational difficulties and updating problems inherent to standalone applications. Furthermore, central administration and distribution of a web-based system removes this responsibility from the grower and keeps the cost fixed, irrespective of the number of users participating in the effort.

The present paper describes a Greenhouse Intelligent Management System (GIMS) that has been developed to provide computer management in low-tech greenhouses. It has been designed as a web based application because of the advantages and benefits indicated above that it offers in comparison with a standalone system. It integrates and extends previous efforts [5,6] by increasing their accessibility and applicability.

The system implements several modules, which cover the collaboration, information and management needs of greenhouse growers, by using web-based technology. All the modules are based on open source technologies and industry standards, thus achieving low cost and increasing portability, extensibility and communication with other systems. The GIMS 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 important greenhouse 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 consult or obtain guidance based on his/her own data.

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

System description

Objectives and general description: The main design goals of the system described were to offer a collaborative environment that would be personalized and highly customizable, so that useful information and knowledge can be obtained and shared in order to help greenhouse growers in their daily activities at a minimum cost. For this purpose, the system design followed the subsequent principles.

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

The most important issue regarding the acceptance of software by a wider public is its availability. Availability is defined as the possibility of a system to be used in the place and time where it is needed. Software applications are dynamic artifacts which are modified very often. In the case of standalone applications, new versions have to be distributed physically to the users with the essential documentation and installation instructions. This requires a lot of different software installations and upgrades in the course of time, often leading to inappropriate versions and high maintenance costs, or even a lack of essential maintenance.

Web-based applications are available at any time and place with an Internet connection, thus overcoming the problem of availability. Their very nature as server site applications eliminates the difficulties of distribution. New versions of applications are available as soon as they are updated by the server and users are not troubled with application management or maintenance. In addition, their footprint is minimal allowing quick download and operation on client machines without a need for additional hardware.

Open architecture: An open system is a modular construction based on an open architecture and having its components built to open standards. Open architecture and open standards means that their specifications are fully documented and publicly available. Adoption of open system architecture provides system portability, scalability and interoperability with other systems.

Information systems based on open architecture have the benefit of interoperating and integrating easily with any other external system or application. Using open architecture, data interchange is ensured between systems and applications though open, publicly available standards, irrespective of the data types. Using open source software based on open architecture and open standards allows system extensibility and increases its viability. Moreover, it keeps development cost low.

It is not always the case that an open system is constructed using open source software. However, it is often the case that open source components implement open standards and therefore their internal architecture at least is always available to the public. The benefits of open source software are numerous. Their dynamic nature and increased security are noteworthy. An open source component can be modified to suit the specialized needs of a user and provides flexibility, which is lacking in closed products.

The system under consideration has been developed using Java language and J2EE technologies. Web-based applications based on J2EE technology have open architecture and from their very nature are based on open standards. Furthermore, the system is based only on open source software components (see section on System Architecture).

Modularity: Modularity is the property of a system that has been decomposed into a set of cohesive and loosely coupled modules [7] and is perhaps the most widely accepted quality objective for software design [8]. Its adoption reduces system complexity and improves system manageability and maintainability.

This requirement allows incremental development of the system as well as easy extensibility and promotes customization. Web-based technology allows the construction of a system comprised by independent interacting modules. Modules provide a separation between interface and implementation. A module interface expresses the elements that are provided and required by the module. The elements defined in the interface are visible to other modules. Modularity allows the addition of new features, or modification of the old ones, without intering with the functioning of other modules that preserve system stability.

Central management: A system's usefulness is highly dependent on its content. Since one of the main goals of the designed system is to provide useful information, centralized management facilitates adaptation to a constant renewal of information and knowledge. Central management ensures that the provided information and knowledge is always up-to-date. After a thorough check and validation it is provided without any user intervention. Additionally, management actions are concentrated at the most appropriate place. Software maintenance and system backups are handled in one place by qualified people and no longer constitute a user concern.

Personalization: Personalization is the tailoring of a software application to a user based on the personal details or characteristics provided. In the context of the World Wide Web, users are able to customize the page layout or specify what content should be displayed. GIMS provides a personalized environment. After an initial authentication, the user can interact with the system in an individual way. Each user has his/her own storage space where he/she can store his/her data separately from those of others. Each authenticated user is able to insert data about his/her own greenhouses. All individual models take into consideration the user's personal data and work on the specified greenhouse. Additionally, users can initiate a consultation session and invite other users or experts to participate in discussions to solve particular problems or exchange ideas.

Internationalization: A major attraction of the system is its ability to function in several languages. Language selection can be implemented at three points: the presentation level, the application level and the knowledge level. Since the system interface is implemented using Java language and J2EE technology, following J2EE guidelines for software internationalization is enough. The 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 by [9]. This particular knowledge structure allows work with the automatically selected knowledge base in the specified language.

Incorporation of a new language into GIMS 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.

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

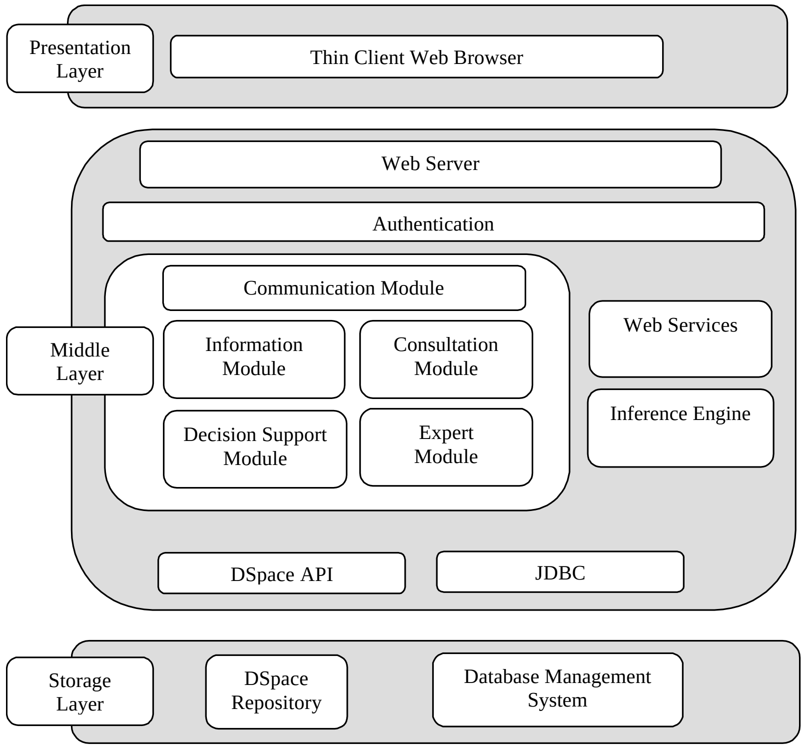

Fig. 1: System architecture

GIMS follows object-oriented design principles and is developed using Java programming language and related technologies. In developing a web-based application the use of a development framework facilitates the process and offers a strict discipline. For this specific purpose Struts[1] framework has been used. Struts is an open source framework, provided by the Apache Foundation, for developing web based applications. It uses and extends the Java Servlet API to encourage developers to adopt a Model View Controller (MVC) architecture. The goal of Struts is to cleanly separate the model (application logic that interacts with a database) from the view (HTML pages presented to the client) and the controller (instance that passes information between view and model). Struts provides the controller (a specialized servlet) and facilitates the writing of templates for the view or presentation layer, typically in Java Server Pages (JSP). The web application programmer is responsible for writing the model code and for creating a central configuration file which binds together model, view and controller.

The system uses a 3-tier architecture comprised of a presentation tier, a middle tier containing web and service components and a storage tier. Business and data logic are usually partitioned into separate components and can be deployed on one or more application servers. This architecture, shown in Fig. 1, can be deployed using one or more application servers. One application server usually encapsulates web and service components, while the storage tier can be deployed on the same or a separate server. 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.

The client tier is a very “thin” tier that contains only presentation logic. Communication with the web server, seated at the middle layer, is accomplished using HTTP protocol through a simple web browser. Each user is able to connect into GIMS using the web browser available on his/her machine. 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.

In the middle layer the most important component is the application server, a web server with intrinsic capabilities to execute Java servlets and support JSP pages, which is able to support the development of integrated web-based applications. The web server handles communication with the external environment and routes external calls to appropriate GIMS components. In this particular case Apache Tomcat[2] has been used as a web and application server. It is an open source application server provided by the Apache Foundation. Tomcat implements the Java Servlet and the JSP specifications, providing an environment for Java code to run in cooperation with a web server. Tomcat includes its own internal HTTP server.

The storage level contains the database of the system. It can be separated into two distinct components. The first is an ordinary database management system (DBMS) used for data, information and knowledge storage, manipulation and retrieval and is implemented by PostgreSQL[3] DBMS, an open source system with professional capabilities in data manipulation. Database is used to store data concerning the cultivation procedures for each greenhouse and the cultivation period, as well as the knowledge needed by the expert systems. The second component is the DSpace repository (see Consultation Module) which is used as a storage medium in the consultation module. The DSpace repository is implemented over the PostgreSQL DBMS.

The web and service tier communicates with the data tier through the JDBC (Java Data Base Connectivity) protocol.

Modules: The contents of the system are organized as separate modules, which can be divided into four major categories providing several facilities: a static and dynamic information module, a consultation module, a decision support module and an expert module. Apart from these four major modules there is also a communication module. The contents and basic characteristics of these modules are described in the following paragraphs.

Information module: The static information provided concerns the crops' cultivation procedures and marketing information. Information concerning the 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, post-harvest and commercial data. Because some crops have certain pieces of information in common with other crops, the XML files used are considered jointly so as to enable their integration and keep redundancy to a minimum.

The GIMS allows registered users to upload their own files and information documents according to the structure of domain ontology. Ontology [10] is a formal explicit description of concepts in a discourse domain that provides a common understanding for a particular domain. Ontologies can be used to describe knowledge domains and to support a search, or to navigate through a body of knowledge to assist knowledge mining. Ontologies are useful for knowledge sharing and re-use and are used to homogenize heterogeneous sources of knowledge and provide a common level of presentation. Ontologies can be used to achieve taxonomy of knowledge. A taxonomy is a hierarchical structure for organizing a body of knowledge; it gives a framework for understanding and classifying that knowledge-how to group it and shows how the various groups relate to each other. In content management, the purpose of taxonomy is to organize information so that users can navigate their way through it more easily.

For this particular situation, OntoCrop ontology [11] is used as a classification and navigation vehicle. Onto Crop covers a portion of the horticultural domain concerning the cultivation of vegetable crops in low-technology greenhouses. It contains knowledge concerning cultivation techniques, pest management and crop physiology. It has also been extended to include knowledge about propagation, post-harvest physiology, consumption and marketing.

Using OntoCrop, users are able to upload their own documents and specify their position in the ontology structure. At the same time they have the opportunity to navigate through the stored documents using the provided ontology. Fig. 2 shows a screenshot of the search process through ontology usage.

Consultation module: The consultation module is a chat-like application enriched with image uploading facilities. Any registered user can initiate an individual private or public session concerning a specific problem or a subject of general interest. Private sessions can be joined by users having an invitation from the owner. Public sessions are open to any authenticated user. During sessions users are able to exchange written messages and upload multimedia files visible by anyone participating in the session.

Fig. 3 shows a snapshot of a consultation process between two users discussing the topic of tomato diseases. During the discussion several images have been uploaded, shown on the left side of the screen as thumbnails. Users are able to download and inspect images in full resolution.

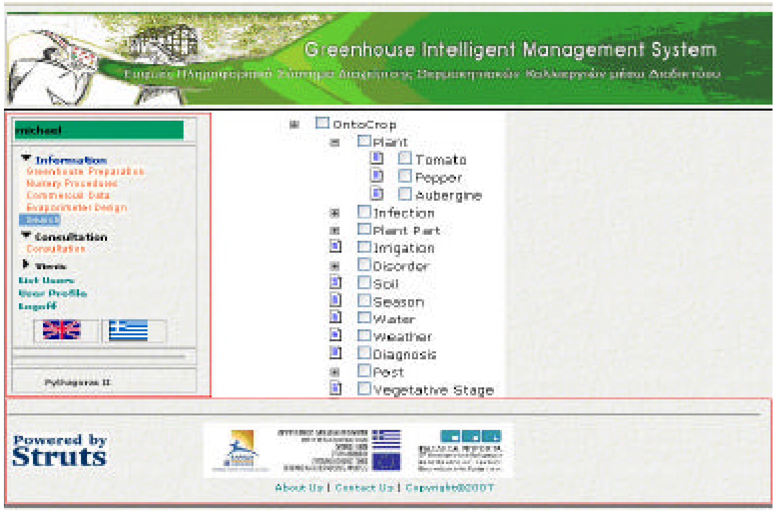

Fig. 2: Searching through ontology

Fig. 3: Consultation module snapshot

The whole conversation process, including uploaded files, can be saved by the session owner in a DSpace[4] repository for future reference. DSpace is an open source software platform that enables organizations to capture, describe and preserve digital assets and provides distributed access to these assets through a search and retrieval subsystem. It is written in Java and JSP and provides its holdings primarily via a web interface.

Session documents and multimedia files can be saved into a Dspace repository as best practice examples and could be useful should similar situations arise in the future. The use of DSpace provides for longer viability and dissemination to a larger audience.

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

The RSS (Really Simple Syndication) feeder is a kind of live bookmark and is used for the automatic feeding of news. The system's 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 of having to remember to access the web site and look for altered information, the RSS feeder forwards the summary of the updated information to the client's RSS reader and after a review the client can access the full subject through the incorporated URL.

Mail alerts can be used to forward urgent messages directly to the growers using an ordinary email server. For this service the user needs a valid email address. In addition, by using the system's capabilities an authenticated user is able to schedule his/her activities by setting specialized alerts.

Decision support module: This subsystem provides a way to schedule, supervise and analyze the cultivation procedures, keeping records of the grower's activities and having the system remind the grower with special alerts about essential actions. The grower inserts his daily activities and events into the system according to their occurrence. The system is able to suggest 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 as well as check lists to accomplish its tasks.

The system handles each greenhouse as a distinct unit of reference. The relevant 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, as well as the geographic location, the crop and variety under cultivation, the prevailing climatic conditions etc. Furthermore, the system keeps track of any treatments during the cultivation period, noting the quantities and time of application of insecticides and pesticides. The irrigation needs of the crop, the fertilizer requirements and the detection of any nutritional imbalances are all achieved through the operation of the expert module, described below. Analysis of data takes into consideration the stage of the cultivation process and the growth level of the crop under investigation.

Expert module: The expert module contains two expert systems which are provided to help growers with nutritional deficiencies and pest management, as well as to regulate irrigation.

The first expert system is an adaptation of the VEGES expert system [6] 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 [5]. 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 daily by a simple, manually operated evaporimeter.

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

The inference engine [12] is accessible through web services. The user provides the symptoms to the system using special forms. The system converts the data provided into XML format and submits them to the inference engine using the appropriate web service. The results follow the reverse procedure and are displayed to the user using HTML. Every inference trial is stored in a database for future reference.

CONCLUSION

The system described provides a web-based application with centralized knowledge and information management having extended personalization and internationalization characteristics. Its potential accessibility from anywhere 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 stage of development, handles three important greenhouse crops (tomato, pepper and aubergines), which belong to the same family (*Solanaceae*) and present similarities in their cultivation methods. The system architecture exploits these similarities at the knowledge structure of its intelligent components and in the way it stores static information concerning each crop.

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

Because it evolved from a research program in an agricultural university environment, the system has an immediate application within the field of horticultural education. The students can use the system within the classroom so as to acquire information and solve practical problems (e.g. disease assessment under virtual reality). However, as well as being helped in their own education, the students will also act as front line testers of the system so as to improve its capabilities.

Modular construction of the system allows ease of expansion. Features such as forums can be easily established for communication, the exchange of ideas, sharing of knowledge and for expressing problems. Since the system contains information about certain crops, 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.

ACKNOWLEDGEMENTS

This work is supported by the "PYTHAGORAS-II" research project, which is co-funded by the European Social Fund and Greek national resources (EPEAEK II).

REFERENCES

1. Mavrogiannopoulos, G.N., 2001. Greenhouses. 3rd Edition. Stamoulis Publications, Athens, (in Greek).
2. Jensen, Allan Leck, Peter S. Boll, Thysen Iver and B.K. Pathak, 2000. Pl@NteInfo-A Web-Based System for Personalised Decision Support in Crop Management. Computers and Electronics in Agriculture, 25 (3): 271-293.
3. Xin, Jiannong, M.T. Momol, R.K. Sprenkel, Howard W. Beck, F.S. Zazueta, P. Vergot and G.C. Wisler, 2003. Using Web-Based Distance Diagnostic and Identification System a Tool for Biosecurity. 2003 ASAE Annual International Meeting, Las Vegas, Nevada, USA.
4. Koumpouros, Y., B.D. Mahaman, M.T. Maliappis, H.C. Passam, A.B. Sideridis and V. Zorkadis, 2004. Image Processing for Distance Diagnosis in Pest Management. Computers and Electronics in Agriculture, 44: 121-131.
5. Passam, H.C., A.B. Sideridis, C.P. Yialouris and M.T. Maliappis, 2001. Improvement of Vegetable Quality and Water and Fertilizer Utilization in Low-Tech Greenhouses through a Decision Support Management System. Journal of Vegetable Crop Production, 7 (1): 69-82.
6. Yialouris, C.P., H.C. Passam, A.B. Sideridis and C. Metin, 1997. VEGES: A Multilingual Expert System for Diagnosis of Pests, Diseases and Nutritional Disorders of Six Greenhouse Vegetables. Computers and Electronics in Agriculture, 19: 55-67.
7. Booch, G., R.A. Maksimchuk, M.W. Engel, B.J. Young, J. Conallen and K.A. Houston, 2007. Object-Oriented Analysis and Design With Applications. 3rd Edn. Addison-Wesley.
8. Card, D.N. and R.L. Glass, 1990. Measuring Software Design Quality. Prentice-Hall, Inc.
9. Maliappis, M.T. and A.B. Sideridis, 2004. A Framework of Knowledge Versioning Management. Expert Systems, 21 (3): 149-156.
10. Beck, W. Howard and Helena Sofia Pinto, 2002. Overview of Approach, Methodologies, Standards and Tools for Ontologies, Agricultural Ontology Service, UN FAO.
11. Maliappis, M.T., 2007. Investigating Ontology Development and Usage in Horticultural Production. In the Proceedings of the EFITA/WCCA 2007 Conference, Glasgow, Scotland.
12. Maliappis, M.T., 2006. Design and Implementation of a Knowledge Base Versioning Management Framework. Agricultural University of Athens, Greece.

[1]http://struts.apache.org
[2]http://tomcat.apache.org
[3]http://www.postgresql.org
[4]http://www.dspace.org