HydroNet: An Intelligent Hydroponics Web Service Environment

A. Liopa-Tsakalidis[1], E. Sakkopoulos[2], D. Savvas[3], A.B. Sideridis[4], J. Tzimas[5]

[1] National Agricultural Research Foundation, Institute of Plant Protection, L. Amerikis and National Road, P.O. Box 5149, Patras 26004, Greece
E-mail: aliopa@cti.gr
[2]University of Patras, Computer Engineering & Informatics dpt, Patras 26500, Greece
E-mail: sakkopul@ceid.upatras.gr
[3]Technological Educational Institute of Epirus, Faculty of Agricultural Technology, Department of Floriculture and Landscape Architecture, P.O. Box 110, Arta 47100, Greece
E-mail: savvas@teiep.gr
[4]Agricultural University of Athens, Informatics Laboratory, 75 Iera Odos, Athens 11855, Greece
E-mail: as@aua.gr
[5]University of Patras, Computer Engineering & Informatics dpt, Patras 26500, Greece
E-mail: tzimas@ceid.upatras.gr

Abstract
In this work an intelligent web service environment for managing hydroponics cultivation processes is proposed. The environment is called HydroNet and includes information and personalized support to hydroponics' interested groups. The aim is to give the producer the opportunity to access for the first time hydroponics consulting services that meet his/her particular needs over the web. The environment consists of an underlying web services infrastructure. It supports training, support and recommendation services, adaptive web and user interaction services, remote online access services and GIS support services. The web services are coupled with smart mechanisms such as dynamic information flow, interface adaptation and intelligent web structure reorganization. The exploitation of various state of the art technologies takes place, in order to achieve a user centric approach for the collection, presentation and dissemination of data. Overall the environment aims at encouraging the development of hydroponics in Greece.

Keywords
Intelligent information environment, web services, hydroponics, hydronet.

1. INTRODUCTION

Plant cultivation in greenhouses is internationally based ever increasingly on automated control systems. The existing infrastructure in contemporary greenhouses allows interconnection with information management environments. Consequently careful and intelligent integration using advanced information and communication mechanisms would assist the producer to record, classify, manipulate and receive advise about various data connected to various applied techniques such as yield data, disease control, plant physiology and market conditions. The result is improved yield and increased quality production. In this work we propose an intelligent environment for managing hydroponics cultivation called HydroNet[1] (see information views in Figure 1). It is based on web services (Web Services, W3C, 2004), filtering algorithms (Chakrabarti et al, 1999; Kleinberg, 1998) and it intends to boost production rates, facilitating the use of information technology hydroponics' techniques.

1.1. Previous Work

There is sufficient work in the international literature today that could be used to design an integrated, effective and useful hydroponics' cultivation management environment. Studies which are referred to indicatively are those of Acher et al., (1997); Adams and Massey, (1984); Adams and Ho, (1989); Daum and Schenck, (1998); De Kreij, (1995); De Kreij and Van Os, (1988); De Kreij et al., (1997); De Rejck and Schrevens, (1997a), (1997b), (1998a), (1998b), (1998c), (1999); Graves, (1983); Liopa-Tsakalidis et al., (2000); Ohtani et al., (2000); Mavrogiannopoulos et al., (1999); Raviv et al., (1998); Runia, (1995); Savvas and Passam (2002) Schwartz, (1995); Sonneveld, (1981), (1982); Sonneveld and Straver, (1994); & Sonneveld et al, (1999). A much more complete comparison in the bibliography sources which could be used for this purpose is given by Hannan, (1998) and Savvas, (2001a, 2001b). Systematic research is already taking place in Greece regarding the issue of automated hydroponic cultivation management (Savvas and Manos, 1999; Savvas and Adamidis, 1999; Savvas, 2002a; Savvas, 2002b).

1.2. Hydroponics Overview

Today, hydroponics is defined as every plant cultivation method above ground with or without the use of some solid sub-layer as a means of plant root growth, which is completely based on liquid fertilization (fertigation) via a complete nutrient solution to meet the water and nutritional requirements of plants. Hydroponics' cultivation constitutes an alternate cultivation method for vegetable and ornamental plants in greenhouses, which presents very few disadvantages and many advantages such as:

- Radical root disease management of greenhouse cultivation.
- There is no need to combat weeds, which compete with cultivating plants.
- There is no need to disinfect the soil.
- Reduction in pesticide application and consequently production of healthier vegetables and flowers.
- Management of fertility problems, which appear in many greenhouse soils.
- Control and monitor of desired minimum temperature in the root environment may be more easily achieved and at a lower cost, granted that the plant roots grow within a restricted mass of the substrate or into nutrient solution.
- Plant nutrition is much more precise; it can be controlled and monitored more efficiently and reliably. Moreover it can be readily and quickly readjusted in the case of an error.
- Plant cultivation above ground saves the grower from soil preparation.
- The better physical and chemical properties of the substrate in comparison with the soil, the optimal nutrition and capability of keeping higher temperatures in the root layer during the annual cold season finally result in an increased yield in hydroponics cultivation.

---

[1] In order to find additional information concerning the HydroNET environment please visit http://students.ceid.upatras.gr/~sakkopul/hydronet.htm

- The hydroponics cultivation may include recycling of the run-off solution and consequently the restriction or even the elimination of nitrate pollution problems.

In reality, the basic disadvantage of hydroponics concerns the fact that it is a cultivation method, which is based on the application of modern technology and equipment and consequently requires know how.

1.3. Motivation

In countries where hydroponics is developed, the problem has been resolved by means of developing efficient advisory support systems provided to farmers, by the public service authorities, but also by the private sector too. In all such cases, the advice support to farmers is based on the existence of standardised information systems, through which individualised layouts are designed for each producer and the necessary re-adjustment of nutritient solution is decided during the course of cultivation.

In Greece, until now, there is nothing similar and as a result, various agricultural supplies providers, who are active in this sector, are co-operating with European private agents in order to acquire scientific and technical support. This is not a flexible nor efficient solution, because the consulting services offered do not follow the curve of the farmers needs.

It is obvious from the above that there is a necessity for the development of an integrated information management environment for the support of hydroponics cultivation by taking into account the Greek reality in the fields of greenhouse cultivation.

1.4. Technologies involved

Web application development is a multi-facet activity involving different players with different skills and goals (Ceri et al, 2000). In order to achieve coherence and successful results, several years' now standardized representation is used for both static and dynamic web enabled solutions. Therefore current trends impose both the use of XML schema (XML, 2004) representations of the web applications' structure and a combination of hypermedia design techniques such as the Object-Oriented Hypermedia Design Method (Schwabe and Rossi, 1995). This synthesis of methods allows standardization and separation of concerns that is a key requirement for any Web modeling procedure.

The aim is to give the producer the opportunity to access for the first time hydroponics consulting services that meet his/her particular needs over the web. To achieve this, the proposed environment infrastructure is based on web services mechanisms. Besides the standardization and wide availability to users and businesses of the Internet itself, web services are also increasingly enabled by the use of the XML as a means of standardizing data formats and exchanging data.

A web service environment is built in a step-by-step process supporting an incremental or prototype process model. Each step focuses on a particular design concern, and an object-oriented model is built. Classification, aggregation and generalization/specialization are used throughout the process to enhance abstraction and reuse.

This work is presented in the following sections as follows: In section 2 requirements that have to be fulfilled are presented. In section 3 the functional and operational specifics are described. In the sequel the architectural aspects and the functional details of the HydroNet solution are described within section 4. In the following section 5, implementation issues of the environment are outlined. In section 6 the design of the evaluation and testing procedures is described. In section 7 final conclusion and future steps will be found.

2. KEY REQUIREMENTS

Successful development and adoption of information technology mechanisms requires careful planning and a clear understanding of potential users and the technology environment in which the solution will be employed.

After a series of thorough discussions with potential users of HydroNet and the distribution of a number of short questionnaires carefully designed by a team of software designers and hydroponics' specialists we obtained that the solution needed to:

- be user-friendly in order to initiate as much as possible cultivators involvement,
- be personalized on the various users computer skills and personal cultivation needs,
- be interactive to cover the personal cultivator's needs,
- advise in form of diagrams, illustrations, tables, graphic figures,
- provide a personalised e-learning module based on the capabilities of the cultivator,
- efficiently handle and interpret the increasing amount of data required to implement hydroponics cultivation,
- be high-speed and lightweight in operation in order to cost as less as possible for internet access,
- support multimedia data in order to present hydroponics techniques,
- ensure the safety of data in different levels (user accessibility depending on their code, e.g. administrator, editor, consultant, user, etc.),
- allow simultaneous access control and synchronisation with local computer,
- share data and information between consultants and growers,
- provide remote management with the use of web browsers,
- handle data transfer between a central database located on a desktop PC and a number of handheld devices,
- ideally include geographical information for the areas of operation,
- be reliable and sufficiently robust to withstand the difficulties of greenhouses data collection and
- provide print options of the recommendations and other hydroponics information.

Web service network infrastructure allows the easy update of the environment. Some additional requirements, which should be satisfied, are:

- The continuous and unobstructed information update and propagation towards the public.
- The integration of the whole set of services under a uniform platform using a friendly and easy to use interface.
- The support of a strategic implementation, which will preview the system's geographic distribution, as well as its users' increase (copying ability – mirroring for the service's use from more than one points, aiming public's faster access).

- The efficient integration (economically and technically) of already existing applications and products (e.g. databases).

Overall the potential users needed an adaptive web service environment with the advice of which they would be able to implement efficiently hydroponics cultivation processes.

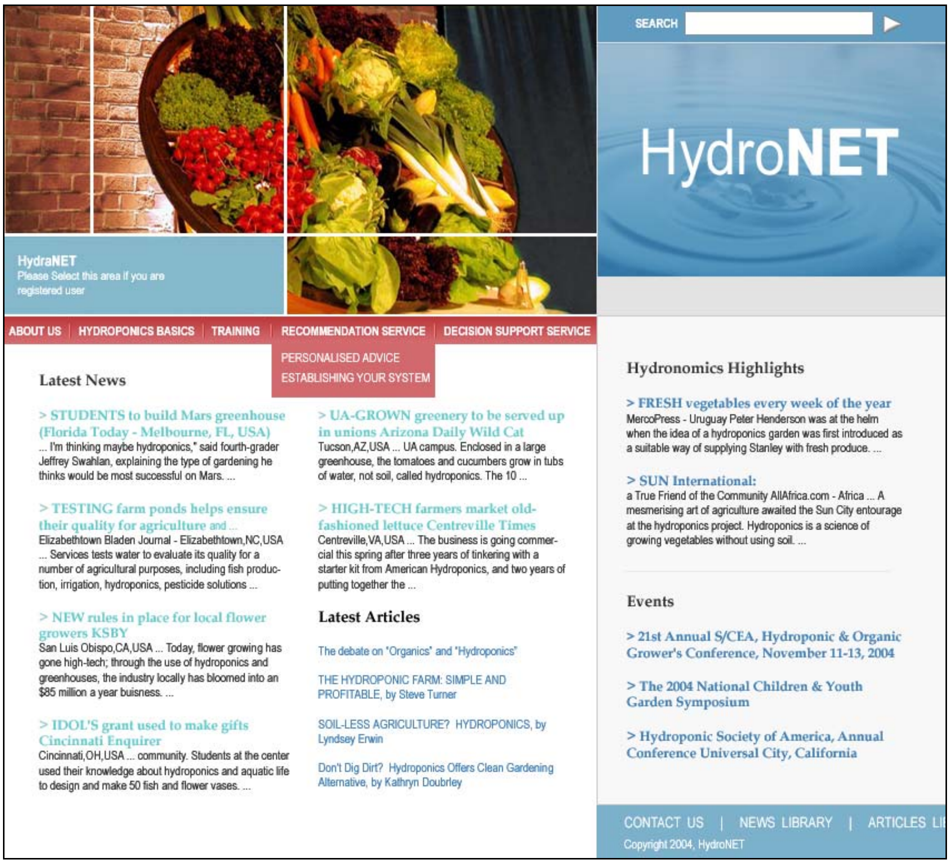

Figure 1: Information view on HydroNET portal service

3. FUNCTIONAL & OPERATIONAL SPECIFICATIONS

The aim of HydroNet environment is to cover a set of fundamental functions and operations according to the specifications explained below.

3.1. HydroNet information and training portal service

The main goal is to inform and further train the cultivator regarding hydroponics. The corresponding application content comprises a relatively large variety of data. Introduction, general information and basic training regarding hydroponics are constructively organised in order to allow ease of comprehension. The acclimatisation of the user with the general function framework of a hydroponics cultivation is the first goal to be achieved.

Another aim of the HydroNet portal constitutes in keeping the interested party informed regarding the transition purpose in hydroponics, its advantages, its disadvantages, and means of dealing with them, its demands, the species of hydroponics' cultivation and the disposable types of substrate cultivation.

The basic training module of HydroNet provides basic courses in hydroponics cultivation for the new cultivators, in order to help them start working with modern cultivation techniques. It supports personalization features to the educational topic and the exchanging information flow in order to customize the educational process to the learning curve of the trainee. This is accomplished by acquiring each user's learning model and activity choices. The educational profile is developed for each trainee based on a questionnaire and continuously evolves according to the trainee's choices and activities.

3.2. HydroNet consulting service

The goal of this service is to provide adaptive support to the personal needs of the cultivator concerning the greenhouse equipment and other establishment to enable hydroponics' cultivation.

The potential hydroponics' cultivator gets the opportunity to introduce to the environment a series of information regarding his/her individual cultivation specifics and production aims, in order to receive corresponding examples and advice (recommendations). The specific information that is usually introduced is:

- the technical and financial data of the area,
- the market the user prefers to address,
- the geographic area where the greenhouse will be established,
- the pre-existing infrastructures in transfers, transport, etc.

This service is a recommendation component allowing the user to provide details and choices in order to get a proposal for an integrated design of a hydroponics system that meets best his/her specific profile.

3.3. HydroNet recommendation service for integrated management of hydroponics cultivation

3.3.1. Design of nutrition layout

Given the data of the related crop, the user will receive a suggested nutrition layout for his hydroponics cultivation. More specifically, after logging into the system the user is prompted to enter information such as the cultivated plant species, the plant growth stage, the hydroponics system utilised (open or closed, sublayer type, etc.) the mineral composition of the water used and the season of the year. Using a set of alternative algorithms, the system makes a recommendation about the final nutrition layout using various visualization forms (tables and diagrams), specifically designed to be completely comprehensible even by non experienced users (required kilos of fertiliser, target values of pH and electrical conductivity of the nutrient solution which will be supplied to the plants, frequency of supply).

3.3.2. Readjustments and corrections in nutrition layout in the course of cultivation

By entering the data of chemical analyses from the root zone (nutrient solution or water extract from the substrate), the growth stage of cultivation, the application or not of recycling devices and possibly some of the cultivator's preferences, the user will receive specific suggestions to re-adjust the nutrition formula that has been followed until then, in an absolutely comprehensible and applicable form.

3.3.3. Regulation of environmental conditions in the greenhouse

By providing the corresponding information, the user can be informed by the system about the best environmental conditions for certain cultivations, as well as their successful cultivation methodologies keeping focus in hydroponics.

3.3.4. Problem solving

A complete diagnostic and problem-solving guide is supported by the system. This service provides a timely and effortless solution for the identification of objective or subjective reasons causing various problems in hydroponics' cultivation. The use a step by step wizard provides a user friendly and thorough problems identification and solving tool, maximising the performance of the farmers cultivation. Such problems may be nutrient deficiencies or toxicities, physiological disorders due to unfavourable environmental conditions, problems due to insufficient or excessive humidity in the root region, unsatisfactory plant growth and low production due to incorrect crop management or other use, etc.

4. DESIGN & ARCHITECTURE

After clarifying the set of specifications, the design and architecture of the environment follow. HydroNet environment includes five (5) main component modules, a) the web service infrastructure which is the core environment, b) the collaboration and learning layer that retains, manages, distributes and delivers hydroponics information, c) the adaptive web interactive module which enables personalization of the users' browsing experience, d) the remote access component that enables the use of handhelds and e) the geographic information layer that enables GIS information flow into the environment. Altogether the modules facilitate the above presented functional business logic in order to assist the potential user in the hydroponics' cultivation procedures. The overall architecture can be found in Figure 2. In the sequel details concerning the architecture are presented.

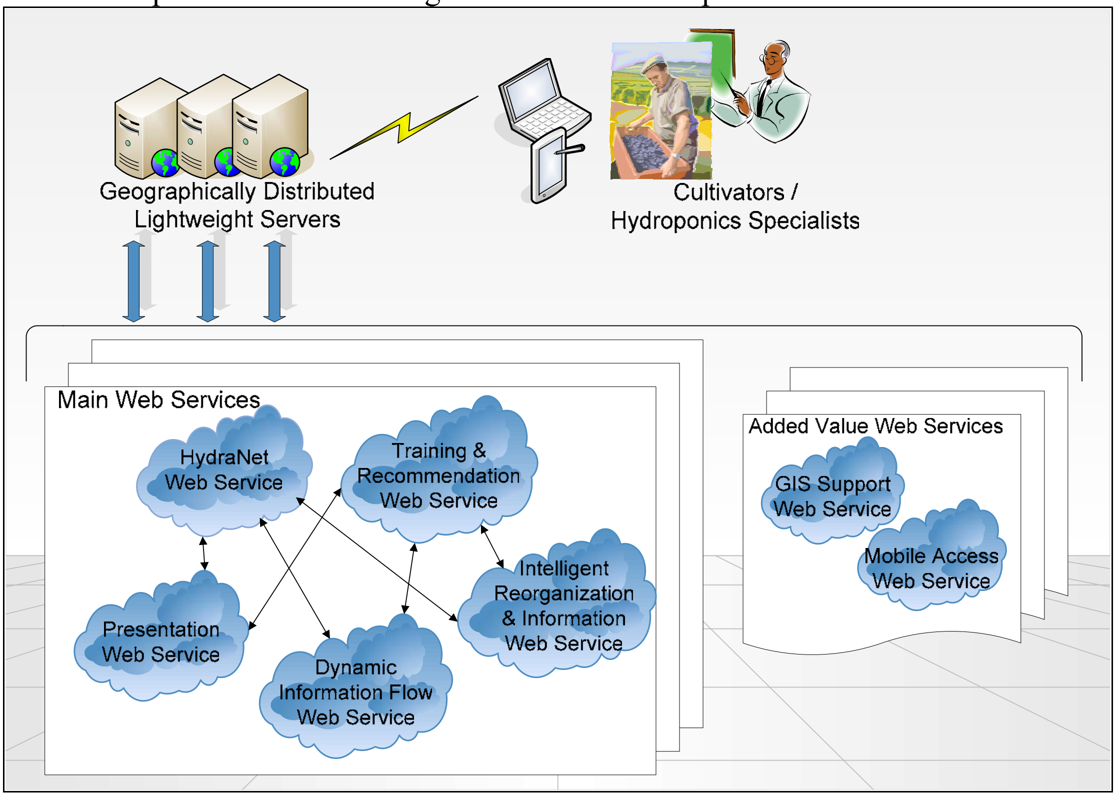

Figure 2. HydroNet Architecture

4.1. HydroNet Web services infrastructure – core

Current approaches in distributed computing are not sufficient to completely meet the needs for cross-platform application-to-application integration. The present trend is moving away from tightly coupled monolithic systems towards systems of loosely coupled components. The web services concept was designed to meet these requirements of business-to-business application interaction. Web Services are based on a set of open, platform independent standards such as XML (XML, 2004), SOAP (SOAP, 2004), WSDL (WSDL, 2004), UDDI (UDDI, 2004) and HTTP (HTTP, 2004) in order to reach a high level of acceptance. They have marked current web engineering methodologies and are ubiquitously supported by IT vendors and users. In short they are interoperable software components that can be used in application integration and component based application development.

Web Services use XML-based messaging to exchange data between the web service and the consumer. One of the core characteristics of a web service is the high degree of abstraction that exists between the implementation and consumption of a service. Web services allow applications and Internet-enabled devices to easily communicate with one another and combine their functionality to provide services to each other, independent of platform or language. Web services are characterized by SOAP messages used to talk to a web service, WSDL files that describe a web service, and the UDDI used to find Web services. Conceptually, web services are very understandable. They eliminate many of the complexities that have been required when there is a need for computer applications to interact with each other.

In this case, potential HydroNet users need an environment ready to deliver their demands in an autonomous and 24x7x365 time frame availability, in order to support hydroponics' processes any time of the day effectively. On the other hand it is resource-expensive to support separate dedicated machines for each necessary service of a hydroponics management environment, because this would complicate the users' data interaction and bring a network management overhead on the environment (synchronization of cultivators' accounts, nutrition & yield data manipulation per geographic position etc)

In order to face the dilemmas posed by the described relationships we have implemented a solution with the use of XML web services (see Figure 2). We believe that we have faced in this way all of the previously named operational discomforts. The proposed web services architecture allows the participation of a numerous simple local systems each one located in a geographic region of the country. These servers can be low cost web servers and they will provide a lightweight access to the main services of the environment with the use of web services. Our solution is cost-effective, because it out-sources the different services, that hydroponics' interested cultivator needs, through a simple web information server to the main web services providers. In this way only the web service provider host will have to be a main-frame machine, while the user will have a quick and efficient interaction with a web information server close to its access position.

The included web services provide informational only functions for the hydroponics' interested group and together complete functionality for hydroponics' activated farmers based in a common standard way (protocol SOAP and XML). There is no need for the local web informational system to get to know and to intervene directly with all the internal hydroponics' core environment. The informational services of such type allow full functionality for the potential user, without having direct access in the central system but through transparent web services.

The use of this emerging technology, XML web services, allows the very rapid incorporation and support of several activities, including interconnection with third party service providers such as chemical laboratories, weather forecast centers or other agricultural partners. It simplifies and accelerates the process of communication.

4.2. Hydronet collaboration and learning service

This is the main service of HydroNet and it comprises a) a collaboration service that allows the communication between hydroponics farmers and specialists as well as several supporting hydroponics information and b) the training, supporting and solution recommendation service.

4.2.1. Hydronet Intranet service - Hydranet

A web service based CSCW (Bouras et al., 2000) environment facilitates the collaboration between hydroponics researchers, as well as provides electronic means of communication and collaboration between farmers and the supporting hydroponics' research community. This service enhances the communication link between cultivators and researchers providing means for:

- Publishing and finding information easily.
- Working productively in teams.
- Connecting effectively with others.
- Providing a consistent user experience.

The CSCW environment, called Hydranet, provides a range of intranet capabilities (Garofalakis et al., 1999a) thus optimizing the collaboration effectiveness between the various groups of users. Some of the system features are:

- Delivery of personally relevant information through audience targeting and through personalization and customization tools.
- Teams are able to publish new content to the portal, helping to preserve knowledge and expertise for the future.
- The users have access to various Document Libraries according to their access privilidges. Documents stored across all document libraries are fully indexed and searchable. The users can create, edit, and upload documents, check documents in and out, and track past versions of documents.
- HydraNet stores lists of information, including announcements, tasks, contacts, and custom lists. Additionally, a search option is supported for searching the contents of lists across the system.
- Provision of collaboration tools and services to users, for either collaboration on documents or for resources relevant to meetings.
- Support of Audiences. An audience is a group of users with similar roles, interests or tasks. The system uses audiences to deliver targeted content to users.
- Support of Topics. To make information easier to find, Hydranet organizes information into topics that contain similar content.
- Alerts messages that inform users when content that they are interested in changes in some way. Alert messages are delivered in an e-mail message or in a Web Part on HydraNet. These alerts help users stay current with the latest version of the content that is important to their work.
- Support of different user profiles.
- Support of advanced full text search for different formats within Hydranet.
- The system supports multiple browser-based management tools, including a browser interface for area managers to manage their areas.

To ensure data integrity of the main storage database, a role based access control model (Sandhu et al., 1996) is applied.

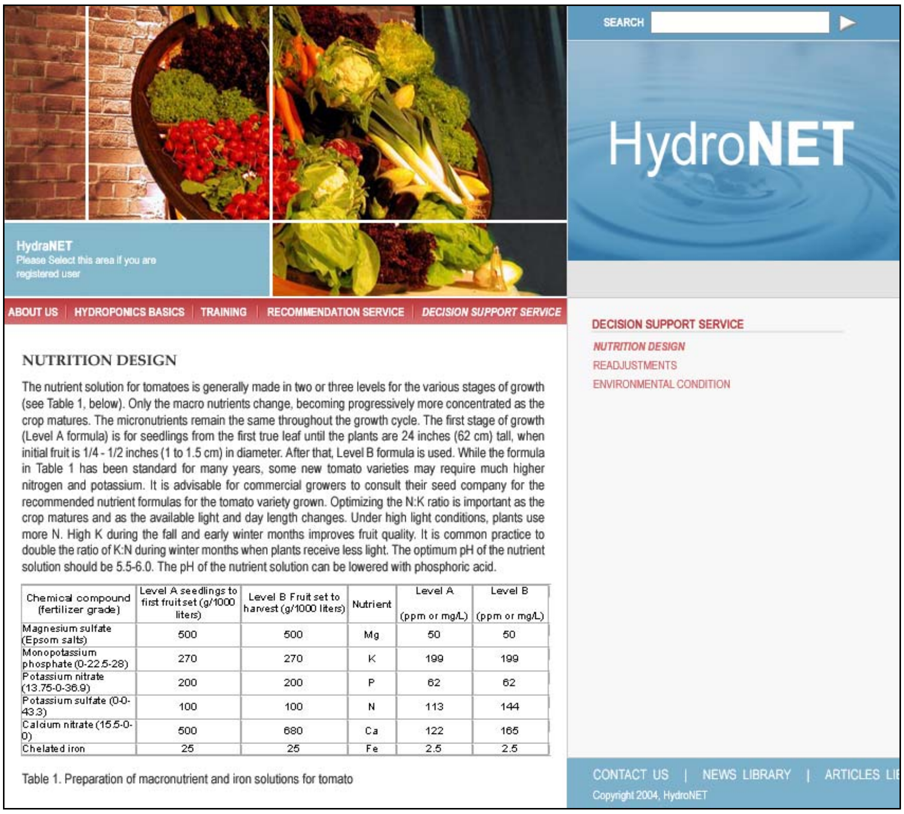

Figure 3: Support and recommendation information

4.2.2. Training, support and recommendation service

The prime objective of this service is the creation, operation and the support of the hydroponics learning and support process. The service should not be merely perceived as a distance learning application in the sense that people can remotely access relative information. The focus is rather placed on setting up an electronic community of learners and hydroponics' specialists that are provided with the necessary IT tools for communicating with each other in order to promote hydroponics efficient cultivation. (Rigou et al., 2004; Garofalakis et al., 1998)

The service assumes three discrete profiles: farmers/ cultivators, hydroponics' specialists and administrators (the first two compile with the available training structure; the last one with the system's operation). Trainees (cultivators) are the main target group, as they are to use the service for learning and getting advice. Specialists recreate and determine the structure of the learning and the recommending modules and incorporate them in the service. They also provide feedback to trainees directly. Administrators are responsible for service configuration and maintenance, as well as for network management.

The social requirement of the learning community concept is two-fold: synchronous and asynchronous, with each mode contributing to various scenarios of communication and collaboration. In order to facilitate asynchronous communication, the system provides the means for message exchange through the "Forums", the "Questions & Answers" or the "Get Personal Advice" facilities (preview in Figure 5). On the other hand synchronous communication was also considered essential for creating a sense of directness, thus the Chat facility was incorporated.

The service underlying architecture (as depicted in Figure 4) is composed of three distinct layers. The core layer provides basic service functionality and in this framework it facilitates the file system, the database system and a web service interface. The learning modules are divided into lessons and topics. The database system is used to store a variety of data. It holds personal data on the user profile. The records for the tutors and the trainees are also located there. It also contains the required information for describing the schema of the learning modules. Finally, it holds data relevant to both the design and the content of the Forum, the Questions & Answers and the Bulletin Board services. The chat server synchronizes the communication among users that takes place via the chat mechanism. It manages the messages exchanged between the users, making sure that all messages are delivered to the appropriate recipients.

The web server accepts user requests returning the corresponding data back to the user. The returned data are not statically stored in web pages, but are constructed on demand by information maintained in both the file and the database system.

The system focuses on hydroponics interested farmers group and for this reason it offers several capabilities related to the learning modules. It also offers diverse support and assistance methods, search facilities and a number of other services. The learning modules are divided into trainings and topics. A trainee can read and download these topics. The system provides a print-friendly version of all the topics comprising training as a separate file, so that the trainee can download or print it. In addition, the trainee can mark topics already studied to his/her personal progress record. Topics marked as read, display an informative message to the trainee suggesting to move on to a topic not completed yet. Trainees can also view their individual progress, in order to have a more general view of the progress of the learning process.

Specialists can manage the learning modules through the web interface. They can structure and upload a module or a part of a module. They can also update the on-line glossary of the system while they are completing all the learning modules. Recorded lectures (in streaming video format for faster client delivery) can be posted to the system. Text announcements can be also posted.

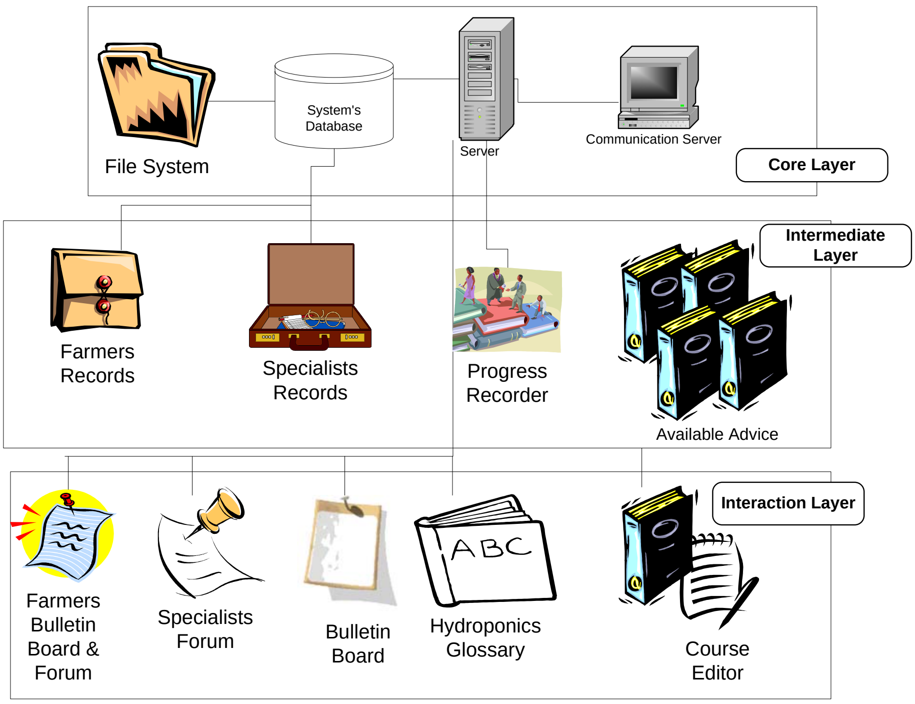

Figure 4. **Training, supporting and recommending service**

4.3. HydroNet adaptive web and user interaction service

HydraNet and the training and support service are end-user services that provide specific solutions in certain farmers' questions and needs. However, in order to have an efficient HydroNet environment several more supporting web services handle intelligently the web browsing behaviour, the presentation of the information portal service and the overall information flow of the environment. Specific intelligent mechanisms and techniques provide added-value services to the main web services of Hydronet. The corresponding details follow.

4.3.1. Dynamic information flow to HydroNet users

All cultivators and hydroponics specialists receive key characterization in the user profile according to interests deriving from their topic accesses. Once a web page is updated with new material concerning a specific topic, the users who had with certain frequency expressed interest on it in the past are informed about the changes. Thus instead of making the users go after recently updated web pages, it is desirable to have information selectively flowed to them. This is called information filtering (Hanani et al, 1999). In this case we address the collaborative filtering method, which is the filtering of information based on the advice of others. The users are not only informed of the recently updated topics that they have visited quite often in the past, but also for those topics that have been accessed with certain frequency by other users belonging in the same group of interest with the first ones. In particular, the profile of the users' information needs is captured through their classification in groups of interest.

The classification of the users into subsets according to their path traversal and page accesses will be achieved by using the spectral filtering method (for the mathematical details of the approach see Chakrabarti et al, 1999; Kleinberg, 1998). The initial motivation for the development of the method was the discovery of high-quality topical resources in hyperlinked corpora. The full power of the approach is visible when being applied on entities other than hyperlinked documents. In our paradigm we have two kinds of entities: web objects and users accessing them. The precise notion of "access" refers to frequency of access.

Following, we will only outline the method of spectral filtering, as it is applied in our environment (further details concerning the mathematical details of the approach see (Bharat & Henzinger, 1998; Chakrabarti. et al, 1998; Chakrabarti et al., 1999; Kleinberg, 1998). Let S_1 denote the set of users and S_2 denote the set of web pages corresponding to a specific section. We associate with each ordered pair (i,j) of entities in S_1 and S_2, a non-negative real-valued affinity A[i,j]. Typically, we set A[i,j] to be a well-chosen function of the accesses user i performs on page j. The A[i,j]s constitute an n x m matrix A, each of whose rows corresponds to users and each of each column to web pages. The entries of the matrices AA^T and A^TA can be viewed as expressing the similarity between different users and web pages respectively (where the notion of similarity is deduced from similar patterns of accesses). The matrices AA^T and A^TA are both real and symmetric and their eigenvectors have only real components. Moreover they have the same set multiset of eigenvalues. Let x_{s1}, x_{s2} be two eigenvectors of AA^T and A^TA respectively corresponding to the same eigenvalue. We can view the components of each eigenvector as assigning to each entity a position on the real line. We deem the entities with large positive values in an eigenvector to be a cluster, and the entities with large negative values to be a different cluster. Alternatively, we can examine the values in the eigenvector (in sorted increasing order). At the largest gap between successive values, we declare a partition into those entities corresponding to values above the gap, and those entities with values below. From the above discussion it follows that the eigenvectors x_{s1}, x_{s2} provides us with two pairs of interrelated clusters (c_1,c'_1), (c_2,c'_2) where ci corresponds to a group of users with similar web-access patterns and c′i corresponds to the web pages that interest the users in the c_i group.

Following the above partitioning process for all the non-principal eigenvectors enables us to group the users into subsets with similar preferences and to map the entities of each subset to the web pages that are of interest to them.

4.3.2. Interface adaptation

Due to the many and diverse requirements and limitations dictated by the potential users, the design of the interface was treated as a primary concern. To avoid developing various independent versions, we decided to take an adaptive approach to the issue; core functionalities and internal data dependencies were implemented at a lower level and then another (architecturally upper) layer was assigned the responsibility of constructing and delivering to the user the adequate view depending on individual preferences and skills (Destounis et al., 2004).

A critical aspect in the attempt to provide more effective and higher quality interaction between humans and artifacts has been the notion of metaphors (e.g., Carroll et al., 1988; Henderson et al., 1986; Moll-Carrillo et al., 1995). Metaphors in human communication are essentially mechanisms for explaining concepts by example. In metaphors, concepts in a source domain are mapped to concepts in a target domain on the basis of some similarity between the two domains (Ueda, 2001).Whereas in the past the use of metaphors was at the discretion of the designer, or in the best of cases, bound to what the underlying development toolkit offers (i.e., trashbins, form filling), today and for certain non-traditional / non-business applications, embedding metaphors to interface design is compelling for the wide adoption and user acceptance of the application (Stephanidis and Akoumianakis, 1998). A metaphor may be used at various levels, ranging from the overall interface design offered by an application, to the task level (i.e., how users engage and perform specific goal-oriented activities), as well as the physical level of interactions (i.e., icons used to convey intended meaning).

In many cases it is important to use even variants of a metaphor in the context of the same application (i.e. for better representing specific tasks) thus leading to the notion of multiple metaphor environments firstly introduced in the context of FRIEND21 (Ueda, 2001), a major collaborative R&D project which proposed a set of guidelines and a conceptual depiction of architectural components for the next generation human interface. One of the key concepts in this effort was the notion of metaware. According to this theory (Stefanidis, 1999), 'the computer can exhibit adaptive behavior in the sense that it can select and present appropriate images to assist the user in executing tasks, based on functions for identifying task intentions and the context of use, as this is provided by the user's personal operation history, preferences and dislikes'.

4.3.3. Intelligent reorganization service

This service focuses on reorganizing methods of web information structures, based on user behaviour. We base the reorganization on the fundamental ideas outlined in (Garofalakis et al., 1999b). According to that method, the number of hits a page receives, as those are calculated from log file processing (see Drott, 1998 for an early analysis on web logs), is not a reliable metric to estimate the page's popularity. Thus a refined metric is proposed, which takes into account structural information. Based on this new notion of popularity, reorganization of certain pages is proposed. After performing some reorganization steps, they also observed an overall improvement to site access.

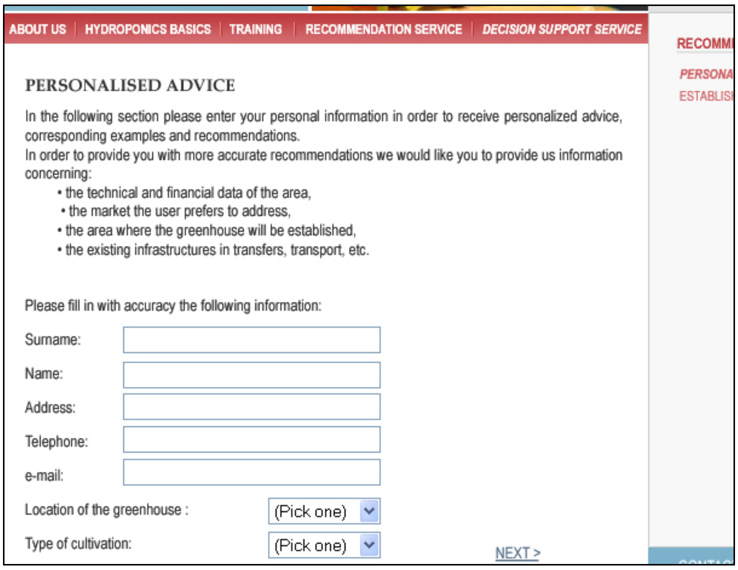

Figure 5: Recommendations and Personal Advice on hydroponics with HydroNET

This service compiles the structural information of the HydroNet portal of the geographically located web servers according to the above web logs processing method. This way each web information portal replica delivers an interface adapted to the needs and interests of its local farmers/ users.

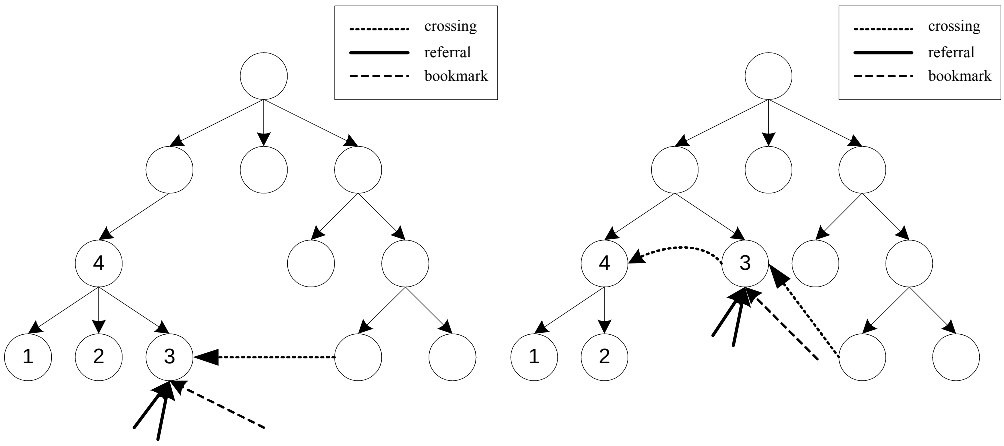

Figure 6: Example of reorganization results according to web logs.

Beside the underlying adaptation services there are also some added-value services that enable interfacing with advanced information management systems such as a) mobile data input and reporting devices as well as b) geographic information data warehouses. These added-value services are also web service based in order to maintain the possibility to be out-sourced.

4.4. HydroNet palm-top remote online access service

For many years, users have requested an electronic device that can be taken into the field to streamline the data entry process, run models of pest development, generate in-field reports of pest status, access historical data for insects and crops, and most of all, save time. To address this, several of the Hydronet management components are suitable for browsing through handheld devices that support mobile browsing facilities.

Previously, users had to write the information they collected in the field on paper, then fax it to a local hydroponics specialist. The mobile environment helps with maintaining data integrity, consistency when there is more than one person collecting information, and time savings in collating information for management decisions. The system specifications, software development, delivery, and the application of the handheld system are described.

In brief, the remote online access system would allow (a) in-field recording and analysis of specific hydroponics data; (b) provide a report of current hydroponics' process status; and (c) have the capacity to download and store data for the future steps of the hydroponics process.

4.5. HydroNet GIS support service

This service is a spatial module interfacing with a geographic information system to generate spatial information regarding agricultural fields (Sirmakessis et al., 1997). Spatial data used in hydroponics' management planning may include fields, streams, ditches, buffers, wetlands, digital raster graphic, soils (soil survey geographic data set), etc.

The workflow involves four sequential processes, namely (1) generate/acquire spatial data; (2) enter attributes for spatial data; (3) create setback (buffer) areas; and (4) analyze and extract information. The starting point for this module is to gather or develop all spatial data required.

It also computes the area percentage of each map unit symbol covering each selected field. The service has interface to connect to geographic database in order to retrieve soil physical, chemical and water feature properties and generates soils reports for selected fields.

5. IMPLEMENTATION ISSUES

The component services that comprise HydroNet follow the service oriented architectural approach. In the following sections details of this implementation approach are given. Additionally discussion of the remote access service and the spatial information service is presented.

5.1. Service oriented approach

HydroNet is a large-scale web service environment, based on Microsoft .NET technology (currently running on .NET framework 1.1) (an overview is offered in DOTNET, 2004). Moreover Web Services Enhancements for Microsoft .NET (WSE) is used. It is an add-on to Microsoft Visual Studio .NET and the Microsoft .NET Framework providing developers the latest advanced Web services capabilities to keep pace with the evolving Web services protocol specifications.

The application designed by SOA is based on services that interact with business components. Each service defines a particular business function. These services interact with each other to accomplish hydroponics' processes.

This service-based design provides the key to flexibility. It allows functions that are designed, implemented, and exposed as services to make use of other services regardless of where they are, on which physical machine they are deployed, and so on. These services aggregated define a system consisting of organizational functions and, when exposed to each other, business relationships.

The web services architecture (also known as Service Oriented Architecture abr. SOA) (SOA, 2004a; SOA, 2004b) is beneficial in the proposed hydroponics environment because:

- Complexity is hidden from the consumer of the service.
- Components can reside on any machine, anywhere in the world and still be accessed the same way.
- Developer roles are focused on a specific development layer.
- Development can be done in parallel.
- The service definition supports multiple client types both typical web browsers and advanced palm-top browsers.
- More re-usability of components across the heterogonous platforms is possible. There are no language and platform integration problems when the functions are defined as services.

5.2. HydroNet palm-top remote online access service

One of the biggest obstacles to writing device applications today is that most devices require learning different APIs than those for desktop applications. .NET Compact Framework uses the same .NET Framework programming model and the same Visual Studio .NET development tools that developers are already using on desktops and servers, as a consequence it greatly increases developer effectiveness. It is also the only mobile development platform with native support for XML Web services (XML, 2004 and Mobile.Net, 2004).

The problem with web-enabled devices is that each one can potentially have its own display issues and capabilities, as well as using a variety of different markup languages. The mobile internet toolkit, an add-on for Visual Studio .NET, provides a solution that can allow developers to greatly streamline their approach to targeting the variety of mobile devices currently on the market, as well as being able to easily handle any new ones that come out in the future.

5.3. HydroNet GIS support service

In order to support GIS interface HydroNet provides collaboration with Autodesk MapGuide 6.5. In this way Hydronet helps to manage, and distribute GIS broadening the access to mission-critical geospatial data.

It allows streamline data distribution and decision support. Compete better through faster decision making, reduced operational expenses, improved customer service, and streamlined data maintenance. This proves especially valuable for environments with large mobile workforces.

This is the last part of the HydroNet implementation details. Following there is the description of HydroNet testing and evaluation procedures.

6. FIELD TESTING AND EVALUATION

For the evaluation, user testing was considered as the most appropriate method as in our case only members of the target group along with specialized personnel were in position to provide valuable feedback, identify problems and suggest modifications.

Testing and in-field evaluation is designed for a period of 6 months before the formal release of the first version of the environment. The testers' group (already 14 registered participants) varies in terms of cultivation region, the size of the commercial enterprise, and the way they endeavour to use the software.

We plan a series of evaluation sessions using lab observation with at least four groups of test users corresponding to the types of target groups, intending to have more precise results on the systems' performance. We also prepare a series of short questionnaires in order to identify system the systems' usability and performance problems after the in-field testing.

For the lab observation a video camera is set to record the computer screens and a special form is prepared so that the test modulator can write down remarks during observation (moderation will be conducted by CHI specialists that will conduct the evaluation in order to keep users relaxed and in a familiar 'surrounding'). In addition, two sets of questionnaires will collect quantitative and qualitative feedback, along with two types of usage scenarios (novice/expert users), which are executed during the sessions and are designed so as to cover all basic aspects of the primary tasks.

Possible fixes to the software and ideas for additional functionality may be identified. The majority of these will be implemented before the release of the first version. Along with the large-scale field evaluation, smaller trials are to be conducted to assess the benefits of using the various modules.

7. CONCLUSIONS

The study and the HydroNet environment contribute to an integrated and more efficient operation of hydroponics greenhouses with certain financial benefits which will result from:

- Excellent quality and competitive product within the country and abroad.
- Programmed quantity and quality of product during the whole production period.
- Energy saving due to brevity of the whole production process.
- Innovation which aims at upgrading farming products in combination with technological knowledge in a laboratorial and pilot scale.
- Reinforcement of the virtually non-existent co-operative relationship between scientific research and the production sector in our country, which signifies the introduction of new technology in crop production and transmission of high-level knowledge.

Web services provided by the expert environment are a very powerful tool, particularly for inexperienced practitioners and those unfamiliar with the subject of hydroponics. When used in conjunction with known modern cultivating techniques, they can help refine the search for solutions and reduce the amount of time needed when referring to the hydroponics' processes.

Future steps and upgrades of the proposed environment may include:

- integration of the system with various governmental and EU portals providing critical information on farming in the several regions of the country,
- development of sub-portals oriented to the cultivation of specific crop species in order to avoid useless navigation within the Main HydroNet portal,
- development of interactive multimedia training tools that could be provided to the various users for offline training in their houses without the use of Internet,

- provision of a fully personalized Main web page of the system providing personalized news for each user,

8. ACKNOWLEDGEMENTS

We would like to thank all the fellow researchers that supported this work.

9. REFERENCES

Acher, A., B. Heuer, E. Rubinskaya, and E. Fisher, (1997). Use of ultraviolet-disinfected nutrient solutions in greenhouses. J. Hort. Sci., 72: 117-123.

Adams, P., and D.M. Massey, (1984). Nutrient uptake by tomatoes from recirculating solutions. In: Proceedings, 6th International Congress on Soilless Culture. ISOSC, Wageningen, The Netherlands: pp. 71-79.

Adams, P., and L.C. Ho, (1989). Effects of constant and fluctuating salinity on the yield, quality and calcium status of tomatoes. J. Hort. Sci., 64: 725-732.

Bouras, C., Destounis, P., Garofalakis, J., Triantafillou, V., Tzimas, G., Zarafidis, P., (2000). A Cooperative Environment for Local Government: An Internet – Intranet Approach. Telematics and Informatics journal.

Carroll, J., Mack, R., Kellog, W. (1988). Interface Metaphors and User Interface Design. In Handbook of Human-Computer Interaction, M. Helander (Ed.), North-Holland, pp. 67-82.

Ceri, S., Fraternali, P. and Bognio A., (2000). Web Modeling Language (WebML): A modeling language for designing Web sites. WWW9, Amsterdam.

Chakrabarti, S., Dom, B., Gibson, D., Kleinberg, J., Kumar, S.R., Raghavan, P., Rajagopalan, S. & Tomkins, A. (1999). Mining the Web's link structure. IEEE Computer 32 (8) pp.60-68.

Chakrabarti, S., Dom, B., Gibson, D., Kumar, S., R., Raghavan, P., Rajagopalan, S. and Tomkins, A., (1998). Spectral filtering for resource discovery. In Proceedings of ACM SIGIR Workshop on Hypertext Information Retrieval on the Web, Melbourne, Australia.

Bharat, K., & Henzinger, M. (1998). Improved algorithms for topic distillation in a hyperlinked environment. In Proceedings of ACM Conf. Res. and Development in Information Retrieval, pp.104-111.

Daum, D., and M.K. Schenk, (1998). Influence of nutrient solution pH on N_2O and N_2 emissions from a soilless culture system. Plant and Soil, 203: 279-287.

De Kreij, C. (1995). Latest insights into water and nutrient control in soilless cultivation. Acta Hortic., 408: 47-61.

De Kreij, C., and P.C. Van Os, (1988). Production and quality of gerbera in rockwool as affected by electrical conductivity of the nutrient solution. In: Proceedings, 7th International Congress on Soilless Culture. ISOSC, Wageningen, The Netherlands: pp. 255-264.

De Kreij C., W. Voogt, A.L. Van Den Bos, and R. Baas, (1997). Voedingsoplossingen gesloten teeltsystemen (Nutrient solutions for closed cultivation systems). Brochures 1-16. Research Station for Floriculture and Glasshouse Vegetables (PBG), Naaldwijk, The Netherlands.

De Rijck, G., and E. Schrevens, (1997a). Elemental bioavailability in nutrient solutions in relation to dissociation reactions. J. Plant Nutr., 20: 901-910.

De Rijck, G., and E. Schrevens, (1997b). pH influenced by the elemental composition of nutrient solutions. J. Plant Nutr., 20: 911-923.

De Rijck, G., and E. Schrevens, (1998a). Elemental bioavailability in nutrient solutions in relation to complexation reactions. J. Plant Nutr., 21: 849-859.

De Rijck, G., and E. Schrevens, (1998b). Elemental bioavailability in nutrient solutions in relation to precipitation reactions. J. Plant Nutr., 21: 2103-2113.

De Rijck, G., and E. Schrevens, (1998c). Composition of the mineral composition of twelve standard nutrient solutions. J. Plant Nutr., 21: 2115-2125.

De Rijck, G., and E. Schrevens, (1999). Guidelines to optimize the macrocation and macroanion composition of nutrient solutions using mixture theory. J. Agric. Engng Res., 72: 355-362.

Destounis, P., Garofalakis, J., Mavritsakis, G., Rigou, M., Sirmakessis, S., Tzimas, G., (2004). Designing for Ease is Designing for All; Experiences from a Simplified Office Suite. Information Technology & People Journal, Emerald.

DOTNET, Technology Overview of .Net Framework v1.1, Microsoft (2004). http://msdn.microsoft.com/netframework/technologyinfo/overview/default.aspx .

Drott M.C. (1998). Using web server logs to improve site design Proceedings of ACM SIGDOC 98 pp.43-50.

Garofalakis, J., Sirmakessis, S., Tsakalidis, A., Tziavas, P., Tzimas, J., Vassiliadis, V., (1998). An Interactive Web-based Approach for Environmental Science Courses in Secondary Education, in the Proceedings of the World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications (ED-MEDIA & ED-TELECOM 98).

Garofalakis, J., Kappos, P., Kondilis, T., Tsakalidis, A., Tsaknakis, J., Tzimas, J., Vassiliadis, B., (1999a). Communication and Collaborative Work via Intranet Technologies. World Conference on the WWW and Internet, WebNet 99.

Garofalakis, J., Kappos, P. & Mourloukos, D., (1999b). Web Site Optimization Using Page Popularity. IEEE Internet Computing 3(4): 22-29.

Graves, C.J., (1983). The nutrient film technique. Hortic. Rev., 5: 1-44.

Hanan, J.J., (1998). Greenhouses: Advanced technology for protected cultivation. CRC Press, Boca Raton, Florida, U.S.A.

Hanani, U., Shapira, B. & Shoval, P. (1999). Information Filtering: Overview of Issues, Research and Systems. User Modeling and User-Adapted Interaction, Kluwer Academic Publishers, Netherlands.

Henderson, JR., A., Card, S., (1986). Rooms: the use of multiple virtual workspaces to reduce space contention in a window-based graphical user interface. ACM Transactions on Graphics, vol. 5(3), pp. 211-243.

HTTP, HyperText Transport Protocol (2004). http://www.w3.org/Protocols/ .

Kleinberg, J. (1998). Authoritative sources in a hyperlinked environment. Proc. ACM-SIAM Symposium on Discrete Algorithms.

Liopa-Tsakalidou A, Bonatsos D., Tzempelikou K, Konstantinidou-Doltsninis S., (2000). Qualitative characteristics of lettuce (Lactuca sativa L) variety Butter head Rex RZ cultivated in hydroponic system. 8th Hellenic Conference on Botatany, Patra 5-8 October 2000.

Mavrogianopoulos, G.N., J. Spanakis, and P. Tsikalas, (1999). Effect of carbon dioxide enrichment and salinity on photosynthesis and yield in melon. Scientia Hort., 79: 51-63.

Mobile.Net (2004). Developing Applications for Windows Mobile, Microsoft.http://msdn.microsoft.com/mobility/default.aspx?pull=/library/en-us/dnppcgen/html/devmobfaq.asp

Moll-Carrillo, Salomon, G., March, M., Fulton Suri, J., Spreenber, P., (1995). Articulating a Metaphor Through User-Centred Design. In the Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'95), Denver, Colorado, New York: ACM Press, 7-11 May, pp. 566-572.

Ohtani, T., A. Kaneko, N. Fukuda, S. Hagiwara, and S. Sase, (2000). Development of a membrane disinfection system for closed hydroponics in a greenhouse. J. Agric. Engin. Res., 77: 227-232.

Raviv, M., A. Krasnovsky, S. Medina, and R. Reuveni, (1998). Assessment of various control strategies for recirculation of greenhouse effluents under semi-arid conditions. J. Hort. Sci., 73: 485-491.

Rigou, M., Sirmakessis, S., Tzimas, G., (2004). An Architecture for an Adaptive Web-Based Learning Environment. in the proceedings of the IASTED International Conference on Web-based Education (WBE 2004), pp. 637-641.

Runia, W.T., (1995). A review of possibilities for disinfection of recirculation water from soilless cultures. Acta Hortic., 382: 221-229.

Savvas, D. and G. Manos, (1999). Automated composition control of nutrient solution in closed soilless culture systems. J. Agric. Engin. Res., 73: 29-33.

Savvas, D., and K. Adamidis, (1999). Automated management of nutrient solutions based on target electrical conductivity, pH, and nutrient concentration ratios. J. Plant Nutr., 22: 1415-1432.

Savvas, D., (2001a). Nutritional management of gerbera (*Gerbera jamesonii*) grown in a closed soilless culture system. Acta Hortic., 554: 175-182.

Savvas, D., (2001b). Nutritional management of vegetables and ornamental plants in Hydroponics. In: Crop Management and Postharvest Handling of Horticultural Products. In: Dris, R., R. Niskanen and S.M. Jain (eds). Science Publishers, Inc., Enfield (NH), USA. pp. 37-87.

Savvas, D., and H.C. Passam (Eds). Hydroponic Production of Vegetables and Ornamentals. Embryo Publications, Athens, Greece: pp. 299-343.

Savvas, D., (2002a). Automated replenishment of recycled greenhouse effluents with individual nutrients in hydroponics by means of two alternative models. Biosystems Engineering, 83: 225-236.

Savvas, D., (2002b). Nutrient solution recycling. In: Savvas, D., and H.C. Passam (Eds). Hydroponic Production of Vegetables and Ornamentals. Embryo Publications, Athens, Greece: pp. 299-343.

Schwabe, D. and Rossi, G., (1995). The Object Oriented Hypermedia Design Model, Communication of the ACM, Vol. 38, #8.

Schwarz, M., (1995). Soilless Culture Management. Advanced Series in Agricultural Sciences, Vol. 24. Springer-Verlag, Berlin, Heidelberg.

Sirmakessis, S., Tsakalidis, A., Tzimas, G., (1997). A Distributed Object Oriented System for Map Design and Production. in the Proceedings of the 3rd Joint European Conference and Exhibition on Geographical Information, EGIS-AM/FM-UDMs (JEC-GI'97).

SOA, Web Services Architecture, W3C. (2004a).http://www.w3.org/TR/ws-arch/ .

SOA, Service Oriented Architecture, Microsoft Corporation. (2004b). http://msdn.microsoft.com/architecture/soa/default.aspx .

SOAP, Simple Object Access Protocol Reference Site (2004). http://www.w3.org/TR/SOAP

Sonneveld, C. (1981). Items for application of macro-elements in soilless culture. Acta Hortic., 126: 187-195.

Sonneveld, (1982). A method for calculating the composition of nutrient solutions for soilless cultures. Translated edition. Informatiereeks, No 57. Glasshouse Crops Research Station Naaldwijk, The Netherlands.

Sonneveld, C., and N. Straver, (1994). Nutrient solutions for vegetables and flowers grown in water or substrates. 10th Edition. Serie: Voedingsoplossingen Glastuinbouw, No 8, 45 pp. P.B.G. Naaldwijk – P.B.G. Aalsmeer, The Netherlands.

Sonneveld, C., W. Voogt, and L. Spaans, (1999). A universal algorithm for calculation of nutrient solutions. Acta Hortic., 481: 331-339.

Stephanidis, C., (1999). The GRAFIS Word Processor for People with Disabilities ERCIM News No.38. Available at http://www.ercim.org/publication/Ercim_News/enw38/stephanidis.html.

Stephanidis, C., & Akoumianakis, D., (1998). Multiple Metaphor Environments: Issues for effective interaction design. In Proceedings of the 8th ERCIM - DELOS Workshop on "User Interfaces for Digital Libraries", Stockholm, Sweden, 21-23 October.

UDDI, Universal, Description, Discovery and Integration Specifications (2004). http://www.uddi.org .

Ueda, H, (2001). The FRIEND21 Framework for Human Interface Architectures. Chapter 13 in User Interfaces for All, Concepts, Methods and Tools, Stephanidis, C. (Ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Web Services, Web Services Activity Statement, WWW Consortium (2004). http://www.w3.org/2002/ws/Activity .

WSDL, Web Services Description Language Reference Site. (2004). http://www.w3.org/TR/wsdl .

XML, Extensible Markup Language (2004). http://www.w3.org/XML/ .