On Web-based Support Systems

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Abstract. Web-based Support Systems (WSS) is viewed as a multidisciplinary research that focuses on supporting human activities in specific domains or fields based on computer science, information technology, and Web technology. Research on WSS is motivated by the challenges and opportunities of the Web and the recent advancements of computer and Web technologies which make the implementation of WSS feasible. Fundamental issues of WSS are examined, a framework of WSS is presented, and research on WSS is discussed in this article. Some concrete examples such as Web-based research support systems (WRSS) and Web-based information retrieval support systems (WIRSS) are also discussed. It is expected that researchers will pay more attention on the new research area on WSS.

1 Introduction

The advances in computer technologies have affected everyone in the use of computerized support in various activities. Traditional decision support systems (DSS) focuses on computerized support for making decision with respect to managerial problems [15]. With the introduction of Web technology, one has to reconsider the existing methods and re-design or modify the existing systems to meet the challenges, as well as take the advantages of Web technology. The Web is used as a universal interface and the underlying infrastructure for Intelligent Web Information Systems (IWIS) [30]. There is an emerging and fast growing interest in computerized support systems in many other domains such as information retrieval support systems [25, 28], research support systems [28], teaching and learning support systems [5], computerized medical support systems [13], knowledge management support systems[6], and many more. The recent development of the Web generates further momentum to the design and implementation of support systems [22].

Many types of Web-based Support System (WSS) have been considered recently by researchers [23, 24, 26]. An example of such systems is Web-based Decision Support Systems (WDSS) [11]. It is argued that the time to treat Web-based support systems as a new and separate sub-area of Web intelligence is coming based on the observations of existing studies [26]. Recently, two workshops aimed to exchange research on the topics of WSS were held in Halifax, Canada and Beijing China in 2003 and 2004 respectively. Many papers published

in the proceedings cover a variety of Web-based support systems, including decision support [9, 10, 16], research support [8, 14, 20, 21, 29], retrieval support [3, 18, 19], teaching and learning support [2, 4, 5, 17], data mining support [21], agricultural support [7], business support systems [1] and many more.

2 Evolution of Web-based Support Systems

The idea of WSS is not totally new. It is a natural evolution of studies on various support systems.

2.1 Computerized Support Systems: Supporting Human Activities with Computers

It is our dream to build fully automated computer systems that have the same or even a higher level of intelligence as human beings. These system can replace human beings to perform various activities, simple or complex. However, we can only study, design and develop systems that have some abilities to assist, support, and aid us for various activities due to the limited technologies we mastered. We classify this type of systems as computerized support systems. In fact, one of the popular definitions of artificial intelligence (AI) is "*the study of how to make computers do things at which, at the moment, people are better*" [12]. AI is one of the important and popular research topics in computer science. Research proves that it is almost impossible to replace human intelligence with computer systems, at least within the foreseeable future. With this restriction, we have to lower our expectation to our dreams. Decision support systems, computer aided software engineering (CASE), and computer aided design (CAD) systems are some examples of such systems to fulfill our more practical goals.

The study of computerized support systems involves many disciplines of research. The most popular and successful example is DSS. Turban *et al* summarize DSS as *computer-based information systems that combine models and data in an attempt to solve nonstructured problems with extensive user involvement through a friendly user interface*" after discussing various definitions, [15]. DSS can be viewed as a hybrid product of two domains of studies. It is an approach or methodology for supporting decision making. It uses an interactive, flexible, adaptable computer-based information systems especially developed for supporting the solution to a specific nonstructured management problems [15]. DSS are derived from management science and computer science. The same principle applies to other types of support systems. For instance, a medical support system or a medical expert system is the product of the marriage between medical science and computer science. Research support systems are the combination of research methodology and computer science. In general, a specific support system aims to support activities and operations of the specific domain.

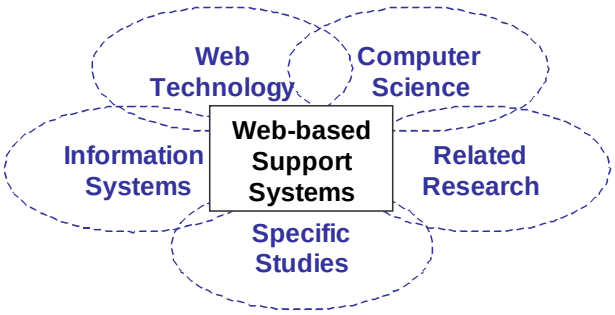

Fig. 1. WSS: A multidisciplinary research

2.2 Web-based Support Systems: Moving to a Standard Web Platform

With the advances in science and technology, we have more data, more information and more tools available. On the other hand, the problems and tasks are more difficult and complex to solve and there are more demands for quality and productivity of these solutions. The World Wide Web provides a new medium for storing, presenting, gathering, sharing, processing and using information. The impacts of the Web can be felt in every aspect of our life. The impacts are in twofold. The advances in Web technology provide with us more opportunities in term of information availability, accessibility, and flexibility. However, there are more challenges in front of us. We need to find the right information and tools from largely available resources. We have to learn to use the existing tools that keep changes all the time.

Our aim is to take the opportunities of the Web, to meet the challenges of the Web, and to extend the human physical limitations of information processing. We define WSS as a multidisciplinary research (as depicted in Figure 1) that focuses on supporting human activities in specific domains and fields based on computer science, information technology, and the Web technology. We aim to study issues and challenges brought on by Web technology for various support systems. One of the goals is to find out how applications and adaptations of existing methodologies on Web platform benefit our decision-makings and various activities. Following are some potential benefits of Web technology,

1. The Web provides a distributed infrastructure for information processing.
2. The Web is used as a channel to discuss one of the most popular support systems, DSS on ISWorld DSS research page (http://www.isworld.org/dss/index.htm).
3. The Web can deliver timely, secure information and tools with user friendly interface such as Internet Explorer and Netscape.
4. The Web has no time or geographic restrictions. Users can access the system at any time, any place.
5. Users can control and retrieve results remotely and instantly.

2.3 Two Dimensional View of WSS

There are two important features of WSS. They can be understood as extensions of existing research in two dimensions, as shown in Table 1. In the application dimension, represented by the rows in the table, WSS cover support systems in many different domains. They can be viewed as natural extensions of decision support systems. In the technology dimension, represented by columns in the table, WSS use the Web as a new platform for the delivery of support. Along the application dimension, the lessons and experiences from DSS can be easily applied to other domains. Along the technology dimension, the new advances in technology can lead to further innovations in support systems.

	Technology		
Application domain	Computer technology	Web technology	...
Decision making	DSS	WDSS	...
Business application	BSS	WBSS	...
Information retrieval	IRSS	WIRSS	...
Scientific research	RSS	WRSS	...
Teaching	TSS	WTSS	...
Medical application	MSS	WMSS	...
Knowledge management	KMSS	WKMSS	...
Data mining	DMSS	WDMSS	...
...	...	...	...

$\mathcal{A}$ (a particular domain) + support systems = $\mathcal{A}$ support systems
Web + $\mathcal{A}$ + support systems = Web-based $\mathcal{A}$ support systems

Table 1. Two diemensional view of WSS

The two-dimensional view of WSS provides an easy classification. Schematically, suppose $\mathcal{A}$ is a specific domain, a computerized support system for domain $\mathcal{A}$ can be termed as an $\mathcal{A}$ support system. The use of the Web results in Web-based $\mathcal{A}$ support systems.

Based on such a scheme, we used one of the most popular search engines Google (http://www.google.com) for our background studies. Table 2 shows search results we obtained in August of 2003, 2004 and 2005. The first column 'Search Phrases' is the phrase we used for exact phrase search. The second column 'Number of Hits' is the number of links returned by Google with the search phrase. It can be seen that people have done numerous research on various support systems. Decision support system(s), business support system(s), negotiation support system(s) and medical support system(s) are amongst the highest returned hits. An interesting observation from Table 1 is that the majority of support systems with high hit rates are business and management oriented. Technical oriented support systems had not been paid attention by researchers. Therefore, we should investigate more on technical oriented support systems such support as for data mining, research, and learning.

Search Phrases	Number of Hits		
	Aug 2003	Aug 2004	Aug 2005
Decision support system	212,000	241,000	576,000
Decision support systems	332,000	402,000	662,000
Web-based decision support system	891	745	973
Web-based decision support systems	583	629	663
Web-based decision support	3,460	5490	13,200
Business support system	4,180	5,090	13,700
Business support systems	11,400	12,600	31,200
Web-based business support system	3	4	4
Web-based business support systems	27	30	35
Web-based business support	87	147	155
Negotiation support system	1,270	965	3,940
Negotiation support systems	1,680	1,710	4,590
Web-based negotiation support system	96	273	280
Web-based negotiation support systems	294	100	103
Web-based negotiation support	408	383	390
Information retrieval support system	39	31	36
Information retrieval support systems	98	184	443
Web-based information retrieval support system	0	2	2
Web-based information retrieval support systems	33	80	172
Web-based information retrieval support	33	82	179
Research support system	750	743	718
Research support systems	48	475	512
Web-based research support system	2	15	34
Web-based research support systems	25	44	77
Web-based research support	33	69	127
Teaching support system	231	237	403
Teaching support systems	118	89	92
Web-based teaching support system	1	9	13
Web-based teaching support systems	2	8	7
Web-based teaching support	108	160	222
Medical support system	1,180	914	934
Medical support systems	1,010	809	938
Web-based medical support system	0	2	2
Web-based medical support systems	0	6	4
Web-based medical support	33	49	53
Knowledge management support system	433	286	319
Knowledge management support systems	90	78	100
Web-based knowledge management support system	340	184	160
Web-based knowledge management support systems	1	2	2
Web-based knowledge management support	414	224	208
Data mining support system	7	26	25
Data mining support systems	2	10	12
Web-based data mining support system	0	2	2
Web-based data mining support systems	0	2	2
Web-based data mining support	0	2	2

Table 2. Summary of the Google search results on WSS

Although the advantages of applying Web technology to support systems are obvious, the concept of Web-based support systems has not been paid enough attention by researchers. It is clear to see from the search results obtained in Table 2 that the number of hits for each type of Web-based support systems is dramatically lower than its computerized support system counterpart. For instance, the hits of the search of "Medical support system" and "Medical support systems" are around 1,000. However, there was none when we change the phrase to "Web-based medical support system" or "Web-based medical support systems" in 2003. Web-based decision support systems [11] is one of the pioneer research areas of WSS. The returns of "Web-based decision support system(s)" were also higher than others. By comparing the number of hits from 2003 to 2005, respectively, one can observe that there is a growing interest in Web-based support systems. By examining some of the returned lists from Google, one can also see that WSS workshops have a solid contribution to such a growth. Due the the coverage of Google databases, the search results may not be always consistent. However, the general trend is clear.

3 A Framework of Web-based Support Systems

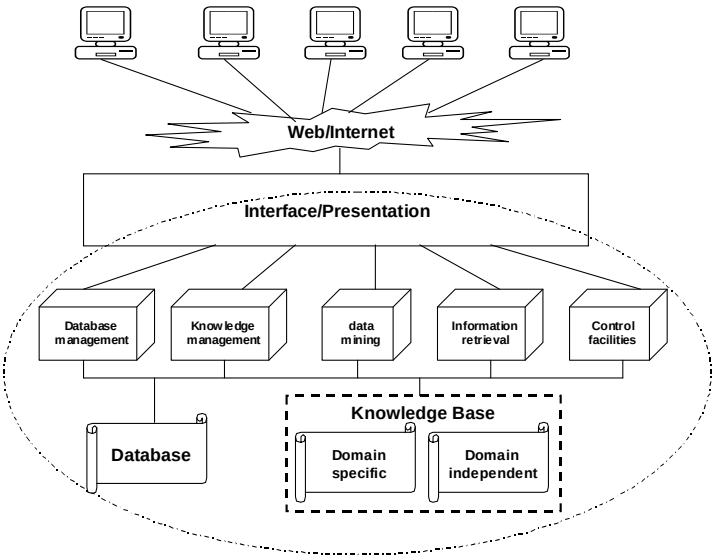

Fig. 2. An Architecture of Web-based Support Systems

Interface, functionality, and databases are some of the components which need to be considered when we design a system. We can view the architecture of

WSS as a (thin) clint/server structure as shown in Figure 2. The users, including decision makers and information seekers, are clients on the top layer. They access the system with browsers via the Web and the Internet. The interface that is designed on the server side will be presented on the client's side by browsers. The lower layers and components encapsulated by the oval dotted line are, in fact, very similar to conventional computerized support systems. In other words, a Web-based support system is a support system with the Web and Internet as the interface.

There are two components on the data layer. Database is a basic component in any modern systems. WSS is not an exception. Another major component is the knowledge base. It stores all rules, principles and guidelines used in supporting activities. We intend to divide the knowledge base into two parts: domain specific knowledge base and domain independent knowledge base. The former is the knowledge specific to the domain. The latter involves general knowledge for all support systems.

Knowledge management, data management, information retrieval, data mining and other control facilities form the management layer. They serve as the middleware of the three-tier client/server architecture. They are the intermediaries between interface and data layers. Reasoning, inference and agent technologies will play important roles on this layer. The split of data and user results in a secure and standardized system. To take advantage of Web technology, these processes are distributed over the Internet to form a virtual server. In fact, databases and knowledge bases on the lower tier are also distributed.

Web-based support systems can be classified into three levels. The first level is support for personal activities. An example of such support is research support for individuals [28]. Personal research activities such as search, retrieval, reading and writing are supported. The second level is the organizational support, such as research support on an institute level [14]. The top level is the network level. The collaborations between organizations or decision making by a group of people like in group decision support systems fall in this level. The group decision support room may be a virtual room on the Web.

4 Concrete Examples of Web-based Systems

4.1 Web-based Research Support Systems

As new technologies evolve and existing technologies expand, a scientist needs to adjust accordingly and make full use of them when carrying out research. Scientists face many challenges in using Web-based information resources, such as information overload, misinformation, fees, poorly designed navigation, retrieval, and browsing tools. How to support scientists to meet such challenges is an important issue. Many computer systems have been implemented to support various research activities. However, there is a lack of study of such systems in a common framework. The study of Web-based Research Support Systems is trying to provides such a framework. Same as we discussed above, WRSS

is also interdisciplinary. It involves at least three domain of studies: research methodologies (purpose of research, research methods, research activities); computer science (computer systems that support various research activities); and the Web (as an infrastructure and a medium of support delivery, as an common user interface).

Many computerized systems, although not designed specifically for research support, have in fact been used by scientists in different stages of research. Web-based research support systems aim at pooling together all these isolated efforts and un-integrated systems with a common goal of research support. Research activities can be broadly classified into two levels, the institutional level and the individual level. The institutional level deals with the management of research and research projects in an institution. The individual level is the the actual research process of a scientist. A framework proposed by Yao [28] is mainly for the individual level support. A research process model may include the following phases: Ideagenerating; Problemdefinition; Proceduredesign and planning; Observation and experimentation; Dataanalysis; Resultsinterpretation and explanation phase; and Communication and dissemination. It is possible to combine several phases into one, or to divide one phase into more detailed steps. The division between phases is not a clear cut. Moreover, the research process does not follow a rigid sequencing of the phases. Iteration of different phrases may be necessary.

To support a large spectrum of research activities, WRSS must be flexible and have many functionalities [28]. We summarize some basic functionalities in this section.

The first component is profile management. It deals with profiles of user of WRSS, i.e., scientists. There may exist different classes of profiles, such as research interest, personal libraries, address books, Web bookmarks, and many more. Profile management module collects, organizes, and stores all relevant information for a scientist. Resource management is the second functionality of WRSS. Many types of resources exist for supporting research such as human resources, tool resources, and information/knowledge resources. Human resource management maintains an expert reservoir in order to match and retrieve suitable experts. The tool resource and information/knowledge resource management modules maintain different types of objects, but have similar functions. The information resources are combined from many sources, such as libraries, digital libraries, and the Web. Database, knowledge base, information retrieval, and agent technologies can be used. Web search engines can be used for retrieval. The third one is data/knowledge management. Typically, research involves the collection and processing of a large amount of data. WRSS must have a module to record the useful data, information and knowledge during the entire research process. The module must contain some data/knowledge operations and retrieval facilities. Database and information retrieval systems can be used.

The profile, resource, and data managements form a solid basis of WRSS. A research support system consists of many sub-systems to support different

activities. They share common data and knowledge bases. We list some specific supporting functionalities.

- **Exploring support**. In the early stage of research, a scientist may have a vague idea and may not be aware of the works of fellow researchers. Exploration plays an important role. There are many means of exploration, such as browsing databases, libraries, and the Web. A scientist's profile may be useful in focusing the exploration areas. If the Web is used for browsing, the historical data can be tracked. The collected data can be analyzed using machine learning and data mining tools to provide a scientist useful information and hints. The profile can also be updated. Currently, Web browsers are a useful exploration tool. Their functions need to be expanded for providing research support.
- **Retrieval support**. Once a scientist forms relatively solid ideas, it is necessary to search the literature to find relevant information. Retrieval support assists retrieval related activities, such as browsing, searching, organization, and utilization of information [25, 27].
- **Reading support**. Reading critically and extensively is important, especially in the preparation stage. The advances in digital libraries and electronic publications make the reading support possible. A reading support system needs to assist a reader in actively finding relevant materials, as well as constructing cognitive maps based on the materials read. Reading support systems can be combined with exploring and retrieval support systems.
- **Analyzing support**. Successful analyzing support depends on tool management. It is necessary to help a scientist to find the right tool for a particular problem. In addition, the system should also assist a scientist in using a tool. An explanation feature may be needed, which answers the question why a particular tool is used. If the functions of tools are described as plain text, information retrieval systems can be used to find the right tool.
- **Writing support**. There are many writing support software tools, such as word-processor and typesetting software. Many packages come with additional functions, such as spelling-checking, grammar-checking, and various other agents. A writing support system should also contain some functions mentioned in the retrieval support systems. For example, a writing support system can find relevant articles based on the text written by a scientist and suggest possible references.

As a specific type of WSS, Web-based research support systems assist scientists to improve their research quality and productivity. The feasibility of such systems is based on the assumption that there exists a relatively systematic approach in scientific research. Furthermore, a general research process can be established, consisting of several steps or phases, such as idea generation, exploration, problem definition, procedure design and planning, observation and experimentation, data analysis, results interpretation, and communication. A number of activities are involved in each of these phases. A WRSS supports each of the activities, such as exploring, retrieving, reading, analyzing, and writing.

4.2 Web-based Information Retrieval Support Systems

Each support sub-system of WRSS has it's special feature as described in previous sub-section. Information retrieval support is the one has been paid attention by some researchers [27, 25]. Web-based Information retrieval support systems (WIRSS) are designed with the objective to provide the necessary utilities, tools, and languages that support a user to perform various tasks in finding useful information and knowledge [27, 25]. We summarize WIRSS in this section.

Information retrieval support systems, Web browsers, and Web search engines extend the basic search functionalities of data retrieval systems exemplified by a database system. They provide basic functionalities to assist a user or scientist in the context of libraries and in the early stage of the Web. A scientist may need to perform many different tasks when finding useful information. The new tasks include understanding, analysis, organization, and discovery, in addition to the conventional tasks of search and browsing. It is discussed in the literature that WIRSS is actually a natural evolution from retrieval systems. The evolution from data retrieval systems to information retrieval systems and from information retrieval systems to information retrieval support systems were discussed in details in the literature [27]. WIRSS attempt to resolve the problems of information retrieval systems by providing more supporting functionalities. A WIRSS provides models, languages, utilities, and tools to assist a user in investigating, analyzing, understanding, and organizing a document collection and search results. These tools allow the user to explore both semantic and structural information of each individual document, as well as the entire collection.

We can classify WIRSS models into three related types. Documents in a document collection serve as the raw data of WIRSS. The document models deal with representations and interpretations of documents and the document collection. They allow multi-representation of documents. Granular computing plays an important role in the construction of document models. The retrieval models deals with the search functionality. They provide languages and tools to assist a user to performs tasks such as searching and browsing. WIRSS should provide multi-strategy retrieval. A user can choose different retrieval models with respect to different document models. The presentation models deal with the representation and interpretations of results from the search. They allow a user to view and arrange search results, as well as various document models. The same results can be viewed in different ways by using distinct presentation models. Moreover, a user can analyze and compare results from different retrieval models. A single document model, a retrieval model, or presentation model may not be suitable for different types of users. Therefore, WIRSS must support multi-model, and provide tools for users to manage various models.

A WIRSS focuses on the supporting functionalities of information retrieval. However existing information retrieval systems only focus on the search and browsing functionalities. WIRSS are more flexible and combine the functionalities of IRS, Web browser and Web search engines. It is expected that current IRS need to be extended to support more user tasks. A WIRSS is based on a different design philosophy that emphasizes the supporting functionality of the

system, instead of the specific search and browsing functionalities. In the process of finding useful information, a user plays an active role in a WIRSS by using the utilities, tools, and languages provided by the system. The components of a WIRSS also include data management, model management, knowledge-based management, and user interface subsystems.

5 Concluding Remarks

Web-based support systems will play more and more important roles in the near future. They provide a potential solution for information and tool overload and the complexity of modern problems. It is necessary and beneficial to study Web-based support systems as a separate sub-field of research.

The emerging interdisciplinary study of Web-based support systems is motivated by the challenges and opportunities of the Web. It focuses on the theories, technologies and tools for the design and implementation of Web-based systems that support various human activities. The research of Web-based support systems is a natural evolution and extension of the existing research. The evolution of application dimension is the extension of decision support systems to computerized support systems. With the emergence of Web technology and Web intelligence, various Web-based support systems are extended from single machine single user computerized support systems. The research on Web-based support systems can be classified into a few categories. There are four types of existing research, namely, WSS for specific domains, Web-based applications, techniques related to WSS and design, and development of WSS, that can be classified as WSS research.

We identify the domain and scope of Web-based support systems, introduce a framework with the viewing angle from a client/server facility, and present two concrete examples of WSS, namely Web-based research support systems and Web-based information retrieval support systems.

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