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Web-based Research Support Systems

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Abstract

Web-based research support systems (WRSS) are a specific type of Web-based support systems (WSS) that support research activities for scientists. They are motivated by the challenges and opportunities of the Web, as well as the needs of scientists. The recent advancements of computer and Web technologies make the implementation of WSS feasible. A general framework of WSS is presented by considering its basic issues. Within the framework, the principles and issues of WRSS are examined. From the conceptual point of view, WRSS may be considered as a new subfield of study. It focuses on a more systematic and coherent treatment of existing isolated studies of research support. From the implementation point of view, WRSS are based on assembling, integration, and adaptation of existing computer technology and information systems for the purpose of research support. The results of WRSS may lead to new and viable research tools.

1. Introduction

The advance and development of the Web has lead to many innovations in the applications 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 the Web. The Web is used as a universal interface and the underlying infrastructure for Intelligent Web Information Systems (IWIS) [24]. Web Intelligence (WI) emerged naturally as a new field of study to cover such recent research that explores the information, structures, and semantics of the Web for the design and implementation of Web empowered systems [10, 24, 25, 26].

Many types of Web-based Support System (WSS) have been considered recently by many researchers [19, 21]. An example of such systems is Web-based Decision Support Systems (WDSS) [13]. Based on the observations of existing studies, Yao and Yao argue that it is the time to treat Web-based support systems as a new and separate sub-area of Web intelligence [21]. The first workshop of WSS was held successfully in 2003 (http:/www.cs.uregina/∼wss). The papers published in WSS 2003 proceedings cover a variety of Web-based support systems, including decision support [9, 11], research support [14, 17, 18], retrieval support [3], teaching and learning support [4, 16], data mining support [18], and many more.

Web-based Research Support Systems (WRSS) can be viewed as a specific type of Web-based support systems. By examining the basic issues of WRSS, we attempt to demonstrate the usefulness of the concept of WSS. In addition, the study of WRSS can bring more insights into other fields of studies. For example, intelligent agents and data mining can be applied to support research, and research methods in turn can be used to guide studies of data mining [23].

2. Overview of Web-based Support Systems

The motivations and basic issues of WSS, the needs for WSS, the scope of WSS, the characteristics of WSS, and a general framework of WSS have been discussed in detail by Yao and Yao in their WSS 2003 paper [21]. Instead of repeating the same discussion, the original paper is reprinted here for easy reference. In this section, we only briefly address a few additional issues.

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 [15]. 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 tech-

Application domain	Technology		
	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

nology can lead to further innovations in support systems.

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 repeated the same searches reported by Yao and Yao [21]. The results are summarized in Table 2. By comparing the number of hits in 2003 and 2004, 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.

3. Web-based Research Support Systems

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 [14]. 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. We restrict the discussion to the individual level support [23].

3.1 Scientific Research in the Web Age

The impact of computer technology on research can be felt by every scientist. Computer software and information systems have been implemented to support scientists in many activities, such as communication, literature search, data analysis and manuscript preparation. As new technologies evolve and existing technologies expand, a scientist needs to adjust accordingly and make full use of them when carrying out research.

The advantages of the Web are often emphasized without mentioning the related difficulties. Ideally, we need to consider the problems coming with the Web, to be consistent with metaphor that the same coin has two sides. The growth of the Web, as well as information, tools, software, and services on the Web, makes scientific research easier from the point of view of easy access of information and tools. On the other hand, the limited human processing capacity becomes even more pronounced with the explosion of information, tools, and services. The opportunities and challenges offered by the Web for a scientist are summarized as follows:

- **Information on the Web.** With the fast growth of the Web and easy availability of information on the Web, we have arrived at a new information age. The Web provides a new medium for gathering, storing, processing, presenting, sharing, and using information. There is a tremendous amount of online materials, such as articles, journals, newspapers, databases, digital libraries, and so on.

  The easy accessibility and huge amount of information on the Web result in many difficulties for scientists, such as information overload, misinformation, fees, poorly designed navigation, retrieval, and browsing tools [6]. How to make effective use of information on the Web becomes a serious problem. How to digest the materials on the Web and evaluate their quality are related difficult problems.

- **Web-based tools.**

  The advance of science and technology normally leads

Search phrase	# of Hits	
	Aug. 2003	Aug. 2004
Decision support system	212,000	241,000
Decision support systems	332,000	402,000
Web-based decision support system	891	745
Web-based decision support systems	583	629
Web-based decision support	3,460	5490
Business support system	4,180	5,090
Business support systems	11,400	12,600
Web-based business support system	3	4
Web-based business support systems	27	30
Web-based business support	87	147
Negotiation support system	1,270	965
Negotiation support systems	1,680	1,710
Web-based negotiation support system	96	273
Web-based negotiation support systems	294	100
Web-based negotiation support	408	383
Information retrieval support system	39	31
Information retrieval support systems	98	184
Web-based information retrieval support system	0	2
Web-based information retrieval support systems	33	80
Web-based information retrieval support	33	82
Research support system	750	743
Research support systems	48	475
Web-based research support system	2	15
Web-based research support systems	25	44
Web-based research support	33	69
Teaching support system	231	237
Teaching support systems	118	89
Web-based teaching support system	1	9
Web-based teaching support systems	2	8
Web-based teaching support	108	160
Medical support system	1,180	914
Medical support systems	1,010	809
Web-based medical support system	0	2
Web-based medical support systems	0	6
Web-based medical support	33	49
Knowledge management support system	433	286
Knowledge management support systems	90	78
Web-based knowledge management support system	340	184
Web-based knowledge management support systems	1	2
Web-based knowledge management support	414	224
Data mining support system	7	26
Data mining support systems	2	10
Web-based data mining support system	0	2
Web-based data mining support systems	0	2
Web-based data mining support	0	2

Table 2. Summary of the Google search results on WSS

to new and improved tools and equipment for scientists. The development of the Web is no exception. There are also many products, tools and services on the Web, such as news groups, downloadable software, document delivery systems, and so on. A wide spectrum and a huge number of available software systems, such as those used for data analysis, simulation, graphical representation, and document preparation are available. Those tools enable scientists to increase their research quality and productivity.

With the increased number of tools, software, and services, it is a challenge to select the right tools and techniques. It may also take more time to learn to use a new tool or software. Scientists are faced with the problem of keeping in pace with the development of new tools, which may take up their valuable research time.

The quantity of information on the Web does not imply an increased quality and productivity in research. Similarly, the existence of new tools and software does not automatically lead to new scientific discoveries. Scientists can only make new advances by making effective use of information and tools. It is therefore necessary to support scientists to meet such challenges. Web-based research support systems are built for such a purpose. They will support scientists by automatizing many routine activities, effectively managing available information and tools, transforming information into useful knowledge, and so on.

3.2 Research Process and Methods

It is generally agreed that there are some basic principles and techniques that are commonly used in most types of scientific investigations [2]. The study of research methods adopts the view that scientists follow a fairly systematic process in scientific investigations [1, 2, 5, 8, 12]. A model of the research process can be briefly described [5, 7, 12]:

- **Idea-generating phase**. The objective is to identify a topic of interest to study. It may also be referred to as the preparation [2] or the exploration phase. Curiosity, interest, enthusiasm, intuition, imagination, tolerance of uncertainty, diversity, and communication with colleagues are some of the critical ingredients in idea generation [2, 8]. Literature search and reading also play important roles in this phase [2, 8].

- **Problem-definition phase**. The objective is to precisely and clearly define and formulate vague and general ideas generated in the previous phase. Problem definition involves careful conceptualization and abstraction. The success in problem definition increases the probability of a successful research project. With respect to a precisely defined problem, it is relatively easy to find related and solved problems, as well as potential solutions.

- **Procedure-design/planning phase**. The objective is to make a workable research plan by considering all issues involved, such as expected findings and results, available tools and methodologies, experiments, system implementation, time and resource constraints, and so on. This phase deals with planning and organizing research at the strategic level [2].

- **Observation/experimentation phase**. The objective is to observe real world phenomenon, collect data, and carry out experiments. Depending on the nature of the research disciplines, various tools and equipment, as well as different methods, can be used.

- **Data-analysis phase**. The objective is to make sense out of the data collected. One extracts potentially useful information, abstraction, findings, and knowledge from data. Statistical software packages can be used.

- **Results-interpretation phase**. The objective is to build rational models and theories that explain the results from the data-analysis phase. It is necessary to investigate how the results help answer the research question, and how this answer contributes to the knowledge of the field. The connections to other concepts and existing studies may also be established.

- **Communication phase**. The objective is to present the research results to the research community. Communication can be done in either a formal or an informal manner. Books and scientific journals are the traditional communication media. Web publication is a new means of communication. Oral presentation at a conference, or discussion with colleagues, is an interactive means of communication.

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 [5].

3.3 Functionalities of WRSS and Related Computer Technologies

To support a large spectrum of research activities, WRSS must be flexible and have many functionalities. These functionalities and the required computer technologies are summarized in this section, based on a recent paper by Yao [23].

Profile management. The profile management deals with a scientist's profiles. There may exist different classes of profiles, such as research interest, personal libraries, address books, Web bookmarks, and many more. A main

component of profile management is the knowledge base, which serves as the basis of WRSS. Profile management module collects, organizes, and stores all relevant information for a scientist.

Resource management. Many types of resources exist for supporting research. Examples are human resources, tool resources, and information/knowledge resources. The main functions of human resource management are the maintenance of expert reservoir, and the matching and retrieval of a useful group of experts. The reservoir of experts may be a virtual one, which consists of links to other systems, databases, or scientists' home pages. 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.

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. Consider now the following 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 [20, 22, 23].

- **Reading support**. Reading critically and extensively is important, especially in the preparation stage [2, 8]. The advances in digital libraries and electronic publications make the reading support possible. Software packages exist so that a reader can add book marks, make notes, link different parts of an article, and make logical connections of different articles. 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. Machine learning and text mining methods can be used to assist a reader by learning from the reading history. Agent technology can be used to actively look for useful information and periodically inform scientists with new information. On-line dictionaries may also be useful in reading support.

- **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 analyzing data. 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. Computer graphics and visualization may be useful in analyzing support.

- **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.

A research support system consists of many sub-systems to support different activities. They share common data and knowledge bases. As one can not have a clear classification of research activities, it is difficult to have a clear classification of different types of support sub-systems.

4 Conclusion

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.

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.

The study of Web-based support systems, a useful subclass of intelligent Web information systems, will result in many applications of Web intelligence.

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