J. T. Yao, An Introduction to Web-based Support Systems,
Journal of Intelligent Systems, Vol. 17, No. 1-3, pp267-281, 2008.

An Introduction to Web-based Support Systems

JingTao Yao

Department of Computer Science, University of Regina
Regina, Saskatchewan, Canada S4S 0A2

ABSTRACT

We view Web-based Support Systems (WSS) as a multidisciplinary research area 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 Internet and the Web. The recent advancements of computer and Web technologies make the implementation of WSS feasible. This paper presents the fundamental issues of WSS, a framework of WSS, and research on WSS. We also present preliminary studies on two examples of WSS, Web-based research support systems (WRSS) and Web-based information retrieval support systems (WIRSS).

KEYWORDS

Web-based systems, information retrieval, Web technologies

1. INTRODUCTION

The advances in computer technologies have affected everybody's daily life. Computers support and assist almost every single human activity. Traditional decision support systems (DSS) focus on computerized support for making

Correspondence to: e-mail: jtyao@cs.uregina.ca
decisions with respect to managerial problems (Turban 2005). Other good examples are computer aided software engineering (CASE) and computer aided design (CAD). With the introduction of Web technology, one may reconsider the existing methods and re-design or modify existing systems to meet new challenges. The Web is used both as a universal interface and as the underlying infrastructure for Intelligent Web Information Systems (Yao et al. 2001). There is an emerging and fast growing interest in computerized support systems in many other domains such as information retrieval support systems (Yao & Yao 2003, Yao 2002), research support systems (Yao 2003), teaching and learning support systems (Fan 2003), computerized medical support systems (Stalidis et al. 2001), knowledge management support systems (Ginsburg & Kambil 1999), and many more. The recent development of the Web generates further momentum to the design and implementation of support systems (Yao 2005).

Many types of Web-based Support System (WSS) have been studied recently by researchers (Yao & Lingras 2003, Yao et al. 2004, Yao & Yao 2003b). 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 (Yao & Yao 2003b). 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 and other venues cover a variety of Web-based support systems, including decision support (Li & Ruhe 2003, Lu et al. 2003, Power et al. 2002, Wang 2004), research support (Keselj 2004, Tan et al. 2004, Xiang et al. 2003, Xu et al. 2003, Yao 2004), retrieval support (Curra & Higgins 2003, Wegrzyn-Wolska 2004, Wu et al. 2004), teaching and learning support (Cao & Greer 2004, Fan 2003, Fan 2004, Wetprasit 2003), data mining support (Xu et al. 2004), agricultural support (Hu et al. 2004), and business support systems (Bai et al. 2004).

This article is a revised version of research presented at IICAI'05 (Yao 2005b). Its aim is to introduce the new research area of WSS. The organization of this article is as follows. We first discuss the historical view of WSS. A section that presents the framework and some design issues of WSS follows. We present preliminary studies on two examples of WSS,

Web-based research support systems (WRSS) and Web-based information retrieval support systems (WIRSS) in Section 4.

2. HISTORICAL VIEW OF WEB-BASED SUPPORT SYSTEMS

The WSS is a natural evolution of studies on various computerized support systems. An ultimate goal of computer scientists is to build fully automated computer systems that have the same or even a higher level of intelligence as human beings. It is hoped that these systems can replace human beings to perform various activities, either 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 have mastered. Research in artificial intelligence proves that it is almost impossible to replace human intelligence with computer systems, at least within the foreseeable future (Rich & Knight 1991). With this restriction, we have to lower our expectation to implement systems that can fulfill more practical goals. We classify computer systems that support human activities as computerized support systems (Yao & Yao 2003b).

The study of computerized support systems involves many disciplines of research. The most popular and successful example is DSS. Turban et al. (2005) summarize DSS as "*computer-based information systems that combine models and data in an attempt to solve non-structured problems with extensive user involvement through a friendly user interface"* after discussing various definitions. 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 interactive, flexible, adaptable computer-based information systems specifically developed for supporting the solution to a specific non-structured management problem (Turban et al. 2005). 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.

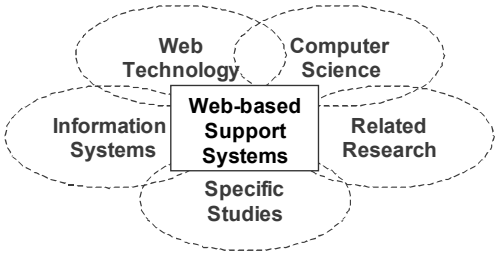

Fig. 1: Web-based Support Systems: A multidisciplinary research

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

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 most aspects of our life. The impacts are twofold: Web technology provides us with more opportunities in terms of information availability, accessibility, and flexibility. However, more challenges are in front of us. We have to find the right information and tools from largely available resources. We have to learn to use the existing tools that keep changing all the time.

The study of WSS aims 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 field (as depicted in Figure 1) that focuses on supporting human activities in specific domains based on computer science, information technology, and Web technology. One of the goals is to find out how applications and adaptations of existing methodologies on Web platforms benefit our decision making and other various activities. The following are some potential benefits of Web technology,

- The Web provides a distributed infrastructure for information processing.
- The Web delivers timely, secure information and tools with a user friendly interface.
- The Web has no time or geographic restrictions. Users can access systems at any time and any place.

- Users can control and retrieve results remotely and instantly.

TABLE 1

A Two dimensional view of WSS

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
…	…	…

2.2 A Two Dimensional View of WSS

Web-based Support Systems have two important features that can be understood as extensions of existing research in two dimensions, as shown in Table 1. In the application dimension, A WSS covers support systems in different domains. They can be viewed as natural extensions of decision support systems. In the technology dimension, WSS uses the Web as a new platform for the delivery of support. Along the application dimension, the lessons and experiences from DSS can be applied to other domains. Along the technology dimension, new advances in technology can lead to further innovations in support systems. The two-dimensional view of WSS provides a simple classification. Schematically, suppose *A* is a specific domain, a computerized support system for the domain can be termed as an *A* support

system. The use of the Web results in Web-based *A* support systems.

TABLE 2

Summary of the Google search results on WSS

Search Phrases	*Number of Hits*		
	2003	2004	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

Based on such a scheme, we used one of the most popular search engines, Google (http://www.google.com), to find evidence of various existing support systems. Table 2 shows search results obtained in August of 2003, 2004, and 2005. The first column *Search Phrases* is the phrase we used of links returned by Google with the search phrase. The results suggest that users have conducted numerous research tasks regarding 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 2 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 to by researchers. Therefore, we should investigate more on the technical oriented support systems such as support for data mining, research, and learning.

Although the advantages of applying Web technology to support systems are sufficient, researchers have not paid enough attention to the concept of Web-based support systems. It is clear to see from the search results 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 "Medical support system" and "Medical support systems" are around 1,000. However, there were none when we changed the phrase to "Web-based medical support system" or "Web-based medical support systems" in 2003. 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. Due to the coverage of Google databases, the search results may not always be consistent. However, the general trend is shown as increasing.

3. THE ARCHITECTURE OF WEB-BASED SUPPORT SYSTEMS

Interface, functionality, and databases are some of the components that are needed to be considered when we design a system. The architecture of WSS can be viewed as a (thin) client/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

Internet. The interface that is designed on the server side will be presented on the

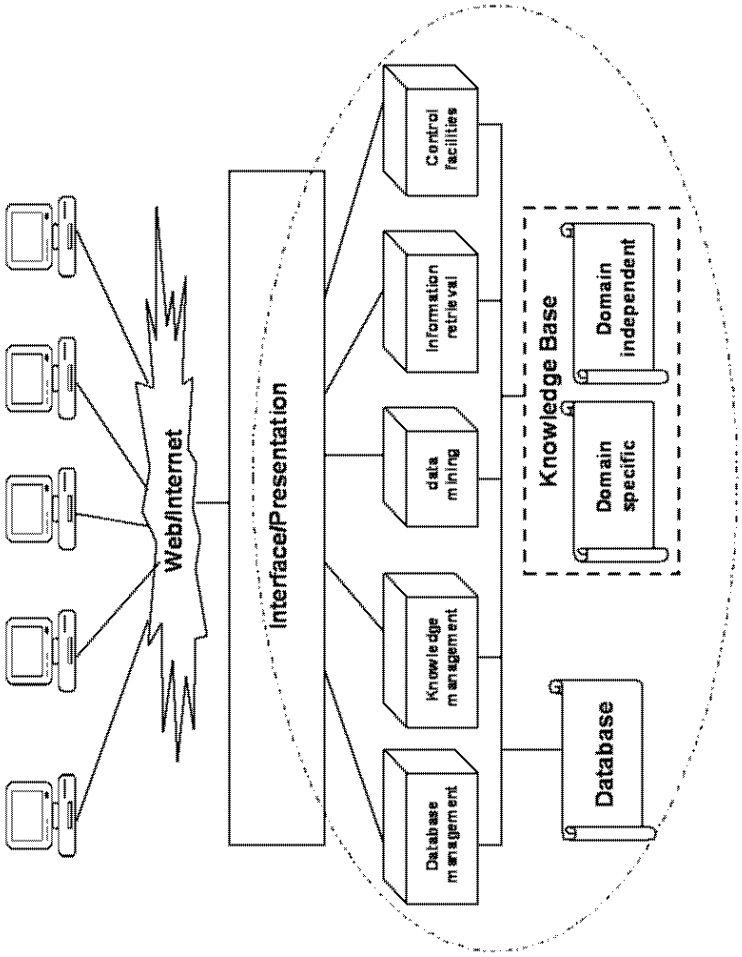

Fig. 2: An architecture of Web-based support systems

client's side by browsers. The lower layers and components encapsulated by the oval dotted line are very similar to conventional computerized support systems. In other words, a Web-based support system can be viewed as a support system with the Web and Internet as the interface.

The architecture shown in Figure 2 is presented from a usage point of view and is logical but not physical. In practice, data and control components may not necessarily sit physically on the same point of the network, which is one of the major differences between WSS and traditional computerized support systems. System components may be spread all over the network. Users of the systems are located globally. Agent, grid computing, and Web services play important roles in WSS implementation.

The data layer comprises two components. A database is a basic component in any modern system. WSS is not an exception. Another major component is the knowledge base. The knowledge base stores rules, principles, and guidelines used in supporting activities. We intend to divide the knowledge base into two parts: a domain-specific knowledge base and a domain-independent knowledge base. The former is the knowledge specific to the domain that is supported. 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. These serve as middleware for the three-tier client/server architecture and as the intermediaries between the interface and data layers. Reasoning, inference, and agent technologies play important roles on this layer. The separation between the management of data and user profiles 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.

The WSS can be classified into three levels. The first level is support for personal activities. An example of such support is research support for individuals (Yao 2003). Personal research activities such as search, retrieval, reading, and writing are supported. The second level is organizational support, such as research support on an institutional level (Tang et al. 2003). 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. WSS EXAMPLES

4.1 Web-based Research Support Systems

As new technologies evolve and existing technologies expand, scientists must adjust accordingly and make full use of these emerging tools 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; effectively, supporting scientists to meet such challenges is an important issue. Many computerized systems have been implemented to support various research activities. The study of Web-based Research Support Systems (WRSS) is trying to provide a common framework for such systems (Yao 2003). Similar to what we discussed above, WRSS is also interdisciplinary, involving 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 well as a common user interface).

Many computerized systems, although not designed specifically for research support, have been used by scientists in different stages of research. The WRSS 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 actual research process of a scientist. A research process model at the individual level may include the following phases: idea generating, problem definition, procedure design and planning, observation and experimentation, data analysis, results interpretation and explanation, and communication and dissemination (Yao 2003). It is possible to combine several phases into one phase or to divide one phase into more detailed steps. The division between phases is not 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, the WRSS must be flexible and have much functionality (Yao 2003). We summarize some basic functionality in this section.

The first component is profile management, which deals with profiles of users of WRSS, i.e., scientists. Different classes of profiles may exist, such as research interest, personal libraries, address books, Web bookmarks, and many more. The 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. Database, knowledge base, information retrieval, and agent technologies can be used. Web search engines can be used for retrieval. The third component is data/knowledge management. Typically, research involves the collection and processing of a large amount of data. The WRSS must have a module to record the useful data, which gathers information and knowledge during the entire research process. The module must contain some data/knowledge operations and retrieval facilities.

The profile, resource, and data management components 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 functionality: exploring support, retrieval support, reading support, analyzing support, and writing support. As a specific type of WSS, the WRSS assist scientists to improve their research quality and productivity. The feasibility of such systems is based on the assumption that relatively systematic approach exists 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.

4.2 Web-based Information Retrieval Support Systems

Each support sub-system of WRSS has its special feature, as described above. Information retrieval support is the one that has been paid attention by

some researchers (Yao & Yao 2003, Yao 2002). 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. We summarize the 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 have 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 searching and browsing. It is discussed in 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 have been discussed in detail (Yao 2002). The 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 multiple representations of documents. Granular computing plays an important role in the construction of document models. The retrieval model deals with the search functionality. They provide languages and tools to assist a user in performing 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, the WIRSS must support multiple models as well as provide tools for users to manage various models.

A WIRSS focuses on the supporting functionalities of information retrieval. Yet, existing information retrieval systems focus only on the search and browsing functionalities. The WIRSS are more flexible and combine the functionalities of IRS, Web browser, and Web search engines. It is expected that current IRS should 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 functionality. 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

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 existing research. The evolution of the 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 a single machine—a single user computerized support system. 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 that are related to WSS and design, and the development of WSS that can be classified as WSS research.

REFERENCES

Bai, J., Paradis, F. and Nie, J.Y. 2004. Web-supported matching and classification of business, in *WSS'04*, 28-36.

Cao, Y. and Greer, J. 2004. Facilitating Web-based education using intelligent agent technologies, in *WSS'04*, 37-44.

Curra, K. and Higgins, L. 2003. A Web-based intelligent case-based reasoning legal aid retrieval information system, in *WSS'03*, 63-7.

Fan, L. 2004. Adaptation and personalization in Web-based learning support systems, in *WSS'04*, 60-6.

Fan, L. and Yao, Y.Y. 2003. Web-based learning support systems, in *WSS'03*, 43-8.

Ginsburg, M. and Kambil, A. 1999. Annotate: A Web-based knowledge management support system for document collections, in *Proceedings of HICSS-32*.

Hu, Y.G., Zhi Quan, Z. and Yao, Y.Y. 2004. Web-based agricultural support systems, in *WSS'04*, 75-80.

Keselj, V. and Cercone, N. 2004. PPDN—a Framework for Peer-to-Peer Collaborative Research Network, in *WSS'04*, 88-93.

Li, J. and Ruhe, G. 2003. Web-based decision support for software release planning, in *WSS'03*, 13-20.

Lu, J., Zhang, G. and Shi, C. 2003. Framework and implementation of a Web-based multi-objective decision support system: WMODSS, in *WSS'03*, 7-11.

Power, D.J. and Kaparthi, S. 2002. Building Web-based decision support systems, *Studies in Informatics and Control*, **11**, 291-302.

Rich, E. and Knight, K. 1991. *Artificial intelligence*, McGraw-Hill.

Stalidis, G., Prentza, A., Vlachos, I.N., Maglavera, S. and Koutsouris, D. 2001. Medical support system for continuation of care based on XML Web technology, *International Journal of Medical Informatics*, **64**, 385-400.

Tang, H., Wu, Y., Yao, J.T., Wang, G.Y. and Yao, Y.Y. 2003. CUPTRSS: a Web-based research support system, in *WSS'03*, 21-8.

Turban, E., Aronson, J.E., and Liang, T.P. 2005. *Decision support systems and intelligent system*s, New Jersey, USA, Pearson Education.

Wang, M. Design of merchant reputation system: a Web-based purchase decision support system, in *WSS'04*, 149-54, 2004.

Wetprasit, R. 2003. Developing an intelligent Web-based Thai tutor: some issues in the temporal expert, in *WSS'03*, 49-53.

Wegrzyn-Wolska, K. 2004. FIM-metaindexer: a meta-search engine purpose-built for the French civil service and statistical classification of the interrogated search engines, in *WSS'04*, 163-70.

Wu, Z.M., Mundluru, D. and Raghavan, V.V. 2004. Automatically detecting Boolean operations supported by search engines, towards search engine query language discovery, in *WSS'04*, 171-78.

Xiang, X., Huang, Y. and Madey, G. 2003. A Web-based collaboratory for supporting environmental science research, in *WSS'03*, 29-36.

Xu, J., Huang, Y. and Madey, G. 2003. A research support systems framework for Web data mining, in *WSS'03*, 37-41.

Yao, J.T. 2005. Design of Web-based support systems, in *Proceedings of the 8th International Conference on Computer Science and Informatics (CSI),* 349-52.

Yao, J.T. 2005b. On Web-based support systems, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence*, Edited by Prasad, B, IICAI, 2589-600.

Yao, J.T. and Lingras, P. 2003. *Proceedings of 2003 WI/IAT Workshop on Applications, Products and Services of Web-based Support System (WSS'03),* Saint Mary's University, Canada.

Yao, J.T., Raghvan, V.V. and Wang, G.Y. 2004. *Proceedings of the Second International Workshop on Web-based Support System (WSS'04)*, Saint Mary's University, Canada.

Yao, J.T. and Yao, Y.Y. 2003. Web-based information retrieval support systems: building research tools for scientists in the new information age, *Proceedings of the IEEE/WIC International Conference on Web Intelligence*, 570-73.

Yao, J.T. and Yao, Y.Y. 2003b. Web-based support systems, in *WSS'03*, 1-5, 2003.

Yao, Y.Y. 2002. Information retrieval support systems, *Proceedings of FUZZ-IEEE'02*, 773-78.

Yao, Y.Y. 2003. A framework for Web-based research support systems, in *Proceedings of COMPSAC'03*, 601-6.

Yao, Y.Y. 2004. Web-based research support systems, in *WSS'04*, 1-6.

Yao, Y.Y., Zhong, N., Liu, J. and Ohsuga, S. 2001. Web intelligence (WI): research challenges and trends in the new information age, in *Web Intelligence: Research and Development*, LNAI 2198, Berlin, Germany, Springer, 1-17.