

Internet Searching and Browsing in a Multilingual World: An Experiment on the Chinese Business Intelligence Portal (CBizPort)

Wingyan Chung, Yiwen Zhang, Zan Huang, Gang Wang, Thian-Huat Ong, and Hsinchun Chen

Artificial Intelligence Lab, Department of Management Information Systems, University of Arizona, 1130 East Helen Street, McClelland Hall 430, Tucson, AZ 85721. E-mail: wchung@bpa.arizona.edu

The rapid growth of the non-English-speaking Internet population has created a need for better searching and browsing capabilities in languages other than English. However, existing search engines may not serve the needs of many non-English-speaking Internet users. In this paper, we propose a generic and integrated approach to searching and browsing the Internet in a multilingual world. Based on this approach, we have developed the Chinese Business Intelligence Portal (CBizPort), a meta-search engine that searches for business information of mainland China, Taiwan, and Hong Kong. Additional functions provided by CBizPort include encoding conversion (between Simplified Chinese and Traditional Chinese), summarization, and categorization. Experimental results of our user evaluation study show that the searching and browsing performance of CBizPort was comparable to that of regional Chinese search engines, and CBizPort could significantly augment these search engines. Subjects' verbal comments indicate that CBizPort performed best in terms of analysis functions, cross-regional searching, and user-friendliness, whereas regional search engines were more efficient and more popular. Subjects especially liked CBizPort's summarizer and categorizer, which helped in understanding search results. These encouraging results suggest a promising future of our approach to Internet searching and browsing in a multilingual world.

Introduction

As the Internet grows in popularity worldwide, more users want to access Web content in their native languages. A report published in September 2002 shows that the majority of the total global online population (63.5%) lives in non-English-speaking areas (Global-Reach, 2002). Moreover, that population was estimated to grow from 403.5 million in 2002 to 657 million in 2004 (a growth rate of

62.8%), while the population of English-speaking users only will grow from 230.6 million to 280 million during the same period (a growth rate of 21.4%). The lower growth rate of English-speaking online population suggests that the importance of English on the Internet will decline in the future.

Instead of relying on English, more non-English-speaking users are expected to use their native languages when searching and browsing the Web. However, existing search engines may not serve their needs, because most technologies have been developed for English-speaking users. To facilitate Internet searching and browsing in a multilingual world, an approach that can be generically applied to any language and that integrates existing search-engine technologies should benefit both business and general users.

The Chinese language provides a good example. Chinese is the primary language for people in mainland China, Hong Kong, and Taiwan, where emerging economies are bringing tremendous growth to the Internet population. In mainland China, the number of Internet users has been growing at 65% every 6 months since 1997 (CNNIC, 2002). Taiwan and Hong Kong lead the regions by having the highest Internet penetration rates in the world (ACNelson, 2002). The need for searching and browsing Chinese business information on the Internet is growing just as quickly, and the generic and integrated approach is applicable to address the need.

In this paper, we aim to achieve better understanding of human interaction and analysis with automated systems developed for Internet searching and browsing in a multilingual world. This paper contributes to both the system and human aspects of information seeking. On the system aspect, we believe that our approach has generic applicability and can assist human analysis. On the human aspect, our study contributes to the understanding of the needs of cross-regional information seeking.

Literature Review

In this section, we review various issues related to Internet searching and browsing in a multilingual world. These

Accepted December 3, 2003

© 2004 Wiley Periodicals, Inc. • Published online 20 February 2004 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/asi.20025

include human information-seeking models, approaches to information-seeking research, and Web searching in a multilingual world.

Human Information Seeking

Information seeking in electronic environments (such as the Internet) has been studied in previous research that typically adopts a process model. The process consists of various stages of problem identification, problem definition, problem resolution, and solution presentation (Wilson, 1999). Variations of the process model also can be found in literature (Kuhlthau, 1998; Marchionini, 1995; Sutcliffe & Ennis, 1998). Ellis (1989) studied the patterns of academic information-seeking behavior and found six features of social scientists' individual information-seeking patterns. Sutcliffe and Ennis (1998) succinctly described four stages in their process model of information searching: problem identification, need articulation, query formulation, and results evaluation. By "information searching," they consider a range of behaviors from goal-directed information searching, where the user has a specific target in mind, to more serendipitous or exploratory information browsing when no specific goal is present besides the intention to explore the information repository. Depending on the degree of goal-directedness, searching and browsing can occur differently in each of the four stages. In directed searching, the user first decomposes his goal into smaller problems, then expresses his needs as concepts and higher level semantics, formulates queries using such supports as Boolean query languages and syntax-directed editors, and finally evaluates the results by serial search or systematic sampling. In exploratory browsing, the user first transforms his general information need into a problem, then articulates his needs as search terms or hyperlinks that appear on the system interface, searches using the terms or explores the hyperlinks using such browse supports as concept maps, automatic summarization, and hypertext, and finally evaluates the results by scanning through them.

Marchionini and Shneiderman (1988) defined browsing as "an exploratory, information seeking strategy that depends upon serendipity." Chang and Rice (1993) stated that browsing is a direct application of human perception to information seeking. Spence (1999) defined "browse" as the registration of content into a human mental model. Having compared various definitions, Chung, Chen, & Nunamaker (2003) defined "browsing" as an exploratory information-seeking process characterized by the absence of planning, with a view to forming a mental model of the content being browsed.

As the Internet evolves to be a major information-seeking platform, the human-computer interaction aspect of the process model has been addressed in recent research. Two approaches are found in previous research, namely, a system-centered approach (e.g., Chen, Lally, Zhu, & Chau, 2003; Chung et al., 2003; Furnas & Zacks, 1994; Gloor, 1991; Greene, Marchionini, Plaisant, & Shneiderman, 2000;

Lin, 1997; McDonald & Chen, 2002; Zhu, Leroy, Chen, & Chen, 2002) and a user-centered approach. We only review the user-centered approach here.

The user-centered approach of information seeking concerns the behavioral and cognitive aspects of the information seekers. Under the approach, human information seeking has been described as a behavior that includes questions, dialogue, and social and cognitive situations, associated with a user's interaction with an information retrieval system ((Kuhlthau, 1993; Kuhlthau, Spink, & Cool, 1992; Saracevic, Kantor, Chamis, & Trivison, 1988). The information-seeking process involves user judgments, search tactics or moves, interactive feedback loops, and cycles (Spink, 1992; Spink & Saracevic, 1997). Previous research has dealt with issues relating to user cognitive structure (Ingwersen, 1992) and factors affecting user-intermediary interaction process (Saracevic, 1996). However, relatively little research was done to study the perception of information seekers in the context of Internet information seeking in a multilingual world (an example of such research is Spink, Ozmutlu, Ozmutlu, & Jansen, 2002). Considering the multiple cross-regional information sources that are typically used, two issues deserve more attention: the quality of information sources and regional impacts.

Information quality is considered to be an important aspect of evaluating the quality of a Web site (Loiacono, 1999). It is a multi-faceted concept that has been explored in recent research (Ballou & Pazer, 1985; Huang, Lee, & Wang, 1999; Redman, 1996; Wang & Strong, 1996). A Web site with high information quality is expected to facilitate searching and browsing. To evaluate information quality, a set of 16 dimensions was developed and was tested in Pipino, Lee, and Wang (2002). They were mainly used in evaluating the quality of information of organizations or companies, but not in evaluating the quality of information obtained from search engines. Previous research assumed that equal weightings were applied to these dimensions (Kahn, Strong, & Wang, 2002). However, such an assumption may not be valid for evaluating information of domains that emphasize different dimensions differently.

As a language can be used in more than one region or country, regional impacts arise because of different cultural, social, and economic environments. For example, Chinese is used differently and has different encodings and vocabularies in Taiwan, Hong Kong, and mainland China. Spink et al. (2002) compared the searching behaviors of FAST search engine users (who are largely European) with those of Excite search engine users (who are largely American) and found that FAST users input queries more frequently while Excite users focused more on e-commerce topics. These results suggest a potential for regional differences in the public Web, arising from possible cultural and social differences. However, their studies focused only on query and topic differences and did not reveal differences in search-engine effectiveness. In the context of Web searching in a multilingual world, the evaluation of regional im-

pacts should improve understanding of optimal design of search engines and portals.

Web Searching in a Multilingual World: Search Tools and Technologies

As more non-English speaking people use the Internet to search and browse information, major search engines have been trying to expand their services to non-English speakers. Also, regional search engines are emerging to provide more localized searching. In addition to English, they typically accept queries in a user's native language and return pages from the regions being served. The following presents a survey of major search engines in Chinese, the most popular non-English language used on the Internet (Global-Reach, 2002). The features, contents, and functions are discussed.

Chinese is the primary language used by people in mainland China, Taiwan, and Hong Kong. Language encoding, vocabularies, economies, and societies of the three regions differ significantly. Regional search engines, therefore, have been developed to provide Internet searching.

In mainland China, the major search engines include Sina and Baidu. Baidu (<http://www.baidu.com>) currently powers over 80% of Internet search services in China, including ChinaRen, 163.net, etc. The database of Baidu stores over 60 million Web pages collected from mainland China, Hong Kong, Taiwan, and Singapore, and grows at a speed of several hundreds of thousands of Web pages per day. Sina (<http://www.sina.com.cn>) is an Internet portal providing comprehensive services such as Web searching, e-mail, news, business directory, entertainment, weather forecast, etc. From our review of search engines in mainland China, we found that Baidu has better search capabilities than the others, as shown by its content coverage. Sina has a wider scope of functions than Baidu.

In Taiwan, the two major Internet search portals are Openfind and Yam. Openfind (<http://www.openfind.com.tw>), established in 1998, is one of the largest portals in Taiwan. In addition to basic searching, Openfind suggests terms that are highly associated with users' queries to help them refine their search. It also allows users to find more related items from each search result and highlights the query terms in the results. Established in 1995, Yam (<http://www.yam.com>) provides comprehensive online services. Its four major focuses are content, communication, community, and commerce (4C). Yam's search engine allows users to search various media: Web sites, Web pages, news, Internet forum messages, and activities (in 18 Taiwan cities or regions). We found that Openfind has better functionality and content coverage, but Yam was better established in the local market (e.g., it powers the search function of the Taiwan government's Web sites).

In Hong Kong, due to its bilingual culture, people rely on both English and Chinese when accessing and searching the Internet. Major search portals include Yahoo Hong Kong and Timway. Of these, Yahoo Hong Kong ([http://hk](http://hk.yahoo.com).

<http://hk.yahoo.com>) is one of the most popular. Yahoo Hong Kong's search engine returns results in different categories, Web sites, Web pages, and news. Headquartered in Hong Kong, Timway (<http://www.timway.com>) provides services such as Web searching, Web directory, e-mail, news, forums, etc. Its database stores over 30,000 Hong Kong Web sites and over 10 million Web pages. Although Timway claims to be the search engine for Hong Kong people, its content coverage is smaller than that of Yahoo Hong Kong. The functions of the two search engines are similar.

Table 1 summarizes the content coverage and functionality of the major search engines in the three Chinese regions. It shows that these search engines have similar types of content but their sizes and functions differ. Most search engines only search for information about their own regions. Some search engines have different versions for different regions, but users need to visit different Web sites to perform searching. Thus, their Web page collections are not comprehensive with respect to the Greater China regions. Furthermore, none of the existing search engines uses meta-searching to collate and integrate different business information sources, or provides post-retrieval analysis for assessment and exploitation of business information.

In general, English search engines are better developed than Chinese search engines in terms of their coverage and functions. The reasons are twofold: English search engines rely on techniques developed in the information retrieval field but Chinese information retrieval techniques are less mature. The word segmentation problem also contributes to the different levels of development of technologies. For English, words are segmented by spaces. For Chinese, words (or characters) are not clearly segmented, making it hard to extract meaningful semantic units from a text. To overcome problems caused by the nature of a specific language, a generic approach is needed to build search engines in any language. From previous research (such as Kwok, 1997; Ong & Chen, 1999), we conclude that a statistical approach is more generic than a linguistic approach because the former is not affected by linguistic differences.

Summary: Research Gaps

From our literature review, three research gaps were identified. First, the rapid growth of non-English Web content aggravates information overload for Internet searching and browsing in a multilingual world. However, technologies for non-English Web searching are not as mature and well developed as those for English Web searching. Second, human perception on the information quality and regional impacts of cross-regional information sources has not been explored in previous research. Third, how human analysis can be assisted by automated information preview and overview has not been widely explored.

Research Questions

The three research questions addressed in our study are:

TABLE 1. Comparing major Chinese search engines.

	Web pages and news on					
	China		Hong Kong		Taiwan	
	Baidu	Sina	Timway	Yahoo HK	Yam	Openfind
Content						
IT	✓	✓	✓	✓	✓	✓
Business	✓	✓	✓	✓	✓	✓
Government	✓	✓	✓	✓	✓	✓
Financial	✓	✓	✓	✓	✓	✓
Medical	✓	✓	✓	✓	✓	✓
General	✓	✓	✓	✓	✓	✓
Size of collection	Very good	Good	Fair	Very good	Good	Very good
Functionality						
Encoding conversion	✓	✓		✓		
Links to related resources	✓	✓	✓	✓	✓	✓
Membership services		✓		✓	✓	✓
Newsgroup search					✓	✓
Web directory	✓	✓	✓	✓	✓	✓
Search for Web sites		✓	✓	✓	✓	✓
Search stock prices		✓				
Search by time period						✓
Search for news	✓	✓	✓	✓	✓	✓
Multimedia search (image, music, software, etc)		✓	✓			✓
Term suggestion	✓	✓				✓
User interface	Good	Fair	Good	Very good	Very good	Very good

1. How can we develop an approach to Internet searching and browsing in a multilingual world such that it can be used to extract meaningful phrases from any human languages, to integrate information from different sources, and to provide automatic summarization and categorization of search results?
2. How can human analysis be made more effective (as measured by accuracy of tasks performed and users' subjective evaluation) by using an automated information-seeking tool developed using the approach?
3. What is the human perception on the improvement in information quality and regional impacts (measured by users' subjective evaluation) brought about by the tool (mentioned in Question 2) in comparison with existing search engines?

A Knowledge Portal Approach: System Design and Architecture

In this section, we answer Research Question 1 by presenting a knowledge portal approach to Internet searching and browsing in a multilingual world. We termed our approach the "knowledge portal approach" because we con-

sider "business intelligence" obtained from our search portal as a form of knowledge that reveals underlying patterns and structures of information. Our approach uses the mutual information algorithm to identify as meaningful phrases significant patterns from a large amount of text in any language (Church & Hanks, 1989; Ong & Chen, 1999). The method is an iterative process of identifying significant lexical patterns by examining the frequencies of word co-occurrences in a large amount of text, thus applicable to any language. In addition, our approach integrates information from different sources and provides analysis capabilities. Meta-searching was used to obtain timely and precise information (Chen, Fan Chau, & Zeng, 2001). Preview (summarization) and overview (categorization) of retrieved Web pages were used to provide added value to searching and browsing (Greene et al., 2000; Zhu et al., 2002).

The domain of Chinese business was selected as the theme of the portal to be developed using our approach because of the growing importance of the Chinese language on the Web and the emerging roles of Chinese economies. "Greater China" is composed of three re-

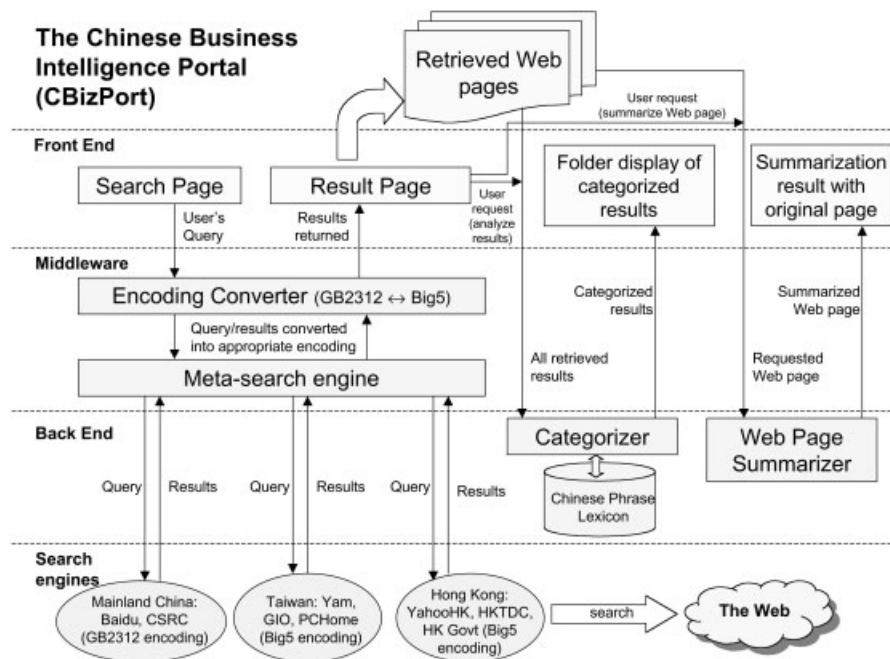


FIG. 1. System architecture of CBizPort.

gions: mainland China, Taiwan, and Hong Kong. With the rapid growth of regional economies and global economic integration, an efficient one-stop portal for searching and browsing cross-regional business information is needed. Because Chinese business information sources are numerous, diverse, and have varying quality, information overload becomes an issue. Users are more concerned with business intelligence than business information. Business intelligence (BI) is obtained through the acquisition, interpretation, collation, assessment, and exploitation of information in the business domain (Chung et al., 2003). Professionals such as business consultants, marketing executives, and financial analysts are heavily involved in the discovery of BI. The quality of their work relies mainly on the capability of the tools they use to obtain business information. Since existing Chinese search engines provide business information rather than business intelligence, there is a need for a better Chinese search portal that integrates results from the three regions.

Figure 1 shows the system architecture of the Chinese Business Intelligence Portal (CBizPort) that has been developed using our approach. (Because of space limitation of this special issue, we only provide a brief description of the system here. Readers are encouraged to visit our Web site at: <http://ai.bpa.arizona.edu/go/dl/cbizport.html>.)

CBizPort has two versions of user interface—Simplified Chinese and Traditional Chinese—that have the same look and feel. Relying on a conversion dictionary with 6,737 Chinese characters in each of the two encodings (Big5 and GB2312), the encoding converter is used to convert all Chinese characters into the encoding of the interface version. The eight information sources selected for CBizPort’s

meta-searching are major Chinese search engines or business-related portals from the three regions. The CBizPort summarizer was modified from an English summarizer called TXTRACTOR that uses sentence-selection heuristics to rank text segments (McDonald & Chen, 2002). Relying on two Chinese phrase lexicons to extract phrases, the CBizPort categorizer organizes the Web pages into various folders labeled by the key phrases appearing in the page summaries or titles. Figure 2 shows screen shots of the system.

Evaluation Methodology

In this section, we describe our methodology used to evaluate CBizPort. We present the objectives, experimental tasks, hypotheses, and design as follows.

Objectives and Experimental Tasks

Our evaluation objectives were threefold: (1) to evaluate the performance of the summarizer as a preview function and categorizer as an overview function to study how effective they can assist human analysis; (2) to compare CBizPort with regional Chinese search engines to study its effectiveness and usability; and (3) to evaluate human perception on information quality and regional impacts of CBizPort, in comparison with existing regional Chinese search engines.

To evaluate how the search engines assist human analysis, scenario-based search tasks and browse tasks consistent with TREC standards were designed (Voorhees & Harman, 1997). An example of a search task is “find two cities in

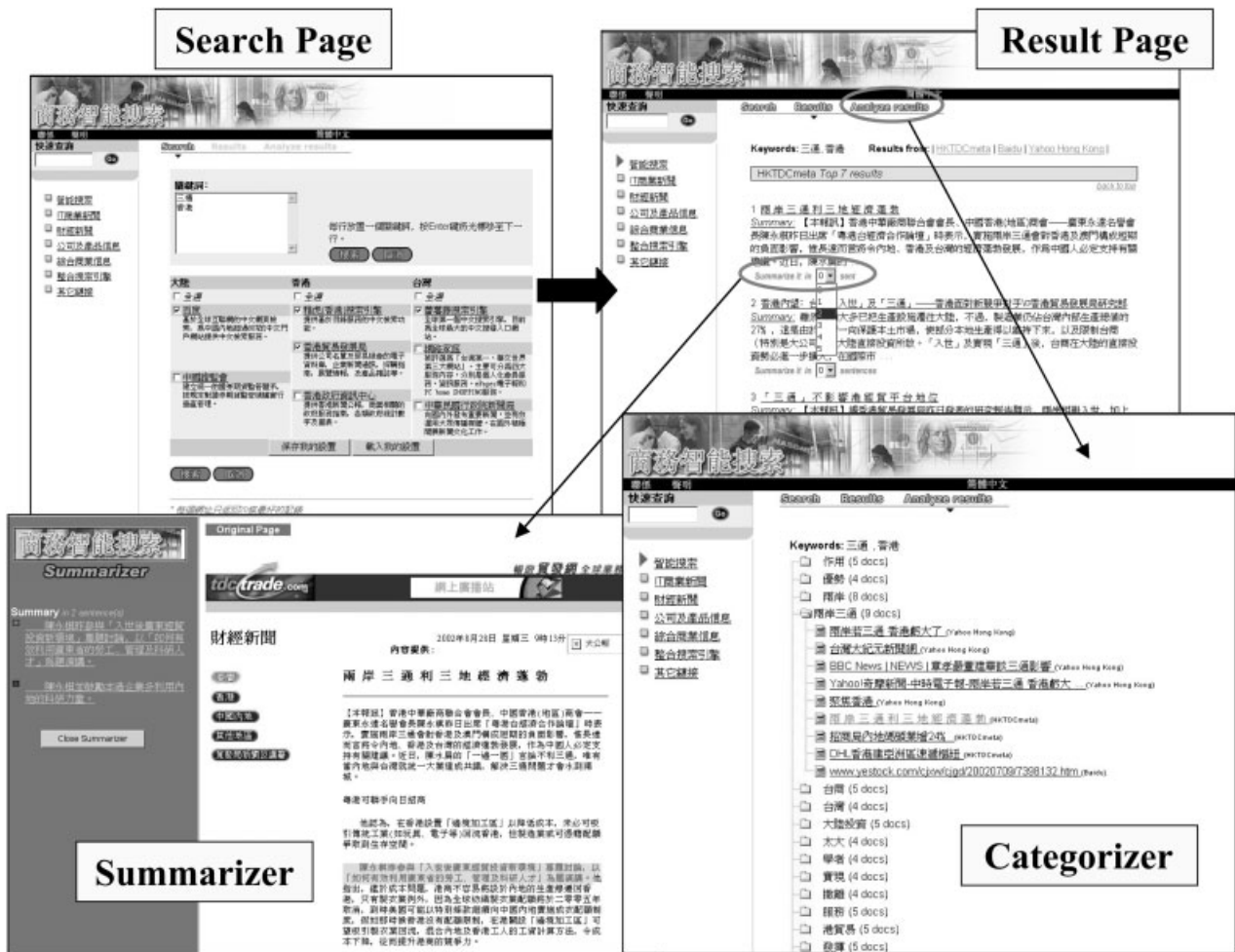


FIG. 2. Screen shots of CBizPort.

mainland China that Motorola has set up its manufacturing operations.” An example of a browse task is “describe, in a number of distinct themes, the economic impacts of removing trade barriers between mainland China and Taiwan towards Hong Kong” (see Fig. 2). The theme identification method was used to evaluate performance in browse tasks (Chen et al., 2001).

To achieve the first objective, we compared the performances of CBizPort’s summarizer and categorizer with not using them. To achieve the second objective, we selected a search engine from each of the three regions as a benchmark against which to compare CBizPort. Based on our literature review, we used Sina, Yahoo Hong Kong, and Openfind as our benchmarks. Although Yahoo Hong Kong has been selected as a meta-search engine in CBizPort, we chose it again as a benchmark search engine because of its familiarity among Hong Kong people and its rich content. To achieve the third objective, we designed tasks that required users to search for information from regions different from their places of origin to compare the performances of CBizPort and benchmark search engines. In addition, qualitative data in the form of subjects’ comments and actions were recorded to provide more details about their behaviors and feedback.

Hypotheses

Four groups of hypotheses were tested (see Table 2). To compare the effectiveness of the systems, we used accuracy for search tasks, and precision and recall for browse tasks. Accuracy refers to how well the system helped users find exact answers to search tasks. Precision measured how well the system helped users find relevant results and avoid irrelevant results in browse tasks. Recall measured how well the system helped users find all the relevant results in browse tasks. A single measure called *F value* was used to combine recall and precision (Shaw, Burgin, & Howell, 1997). The formulae used to calculate the above metrics are stated below.

$$\text{Accuracy} = \frac{\text{Number of correctly answered parts}}{\text{Total number of parts}}$$

Precision

$$= \frac{\text{Number of relevant results identified by the subject}}{\text{Number of all results identified by the subject}}$$

TABLE 2. Hypotheses tested in the experiment.

Code	Hypothesis
1. CBizPort's assistance in human analysis	
H1.1	CBizPort's summarizer significantly improves the effectiveness of searching
H1.2	CBizPort's summarizer significantly improves the effectiveness of browsing
H1.3	CBizPort's categorizer significantly improves the effectiveness of searching
H1.4	CBizPort's categorizer significantly improves the effectiveness of browsing
2. Search engine performance comparison	
H2.1	For general search tasks, CBizPort performs similarly to regional Chinese search engines in terms of effectiveness
H2.2	For general browse tasks, CBizPort performs similarly to regional Chinese search engines in terms of effectiveness
H2.3	For cross-regional search tasks, CBizPort is more effective than regional Chinese search engines
H2.4	For cross-regional browse tasks, CBizPort is more effective than regional Chinese search engines
H2.5	A combination of CBizPort and a regional Chinese search engine is more effective than CBizPort in searching
H2.6	A combination of CBizPort and a regional Chinese search engine is more effective than CBizPort in browsing
H2.7	A combination of CBizPort and a regional Chinese search engine is more effective than CBizPort's summarizer in searching
H2.8	A combination of CBizPort and a regional Chinese search engine is more effective than CBizPort's summarizer in browsing
H2.9	A combination of CBizPort and a regional Chinese search engine is more effective than CBizPort's categorizer in searching
H2.10	A combination of CBizPort and a regional Chinese search engine is more effective than CBizPort's categorizer in browsing
H2.11	For general search tasks, a combination of CBizPort and a regional Chinese search engine is more effective than regional Chinese search engine
H2.12	For general browse tasks, a combination of CBizPort and a regional Chinese search engine is more effective than regional Chinese search engine
H2.13	For cross-regional search tasks, a combination of CBizPort and a regional Chinese search engine is more effective than regional Chinese search engine
H2.14	For cross-regional browse tasks, a combination of CBizPort and a regional Chinese search engine is more effective than regional Chinese search engine
3. Users' subjective evaluations	
H3.1	CBizPort provides a higher information quality than regional Chinese search engines
H3.1a	In terms of presentation quality and clarity, CBizPort provides a higher information quality than regional Chinese search engines
H3.1b	In terms of coverage and reliability, the information quality of CBizPort is similar to that of regional Chinese search engines
H3.1c	In terms of usability and analysis quality, CBizPort provides a higher information quality than regional Chinese search engines
H3.2	CBizPort has a better cross-regional searching capability than regional Chinese search engines
H3.3	CBizPort users achieve a higher overall satisfaction than regional Chinese search engines' users
4. Additional hypotheses	
HA1	Search performance of the three regional Chinese search engines is not significantly different
HA2	Browse performance of the three regional Chinese search engines is not significantly different

Recall

$$= \frac{\text{Number of relevant results identified by the subject}}{\text{Number of relevant results identified by the expert}}$$

$$F \text{ value} = \frac{2 \times \text{Recall} \times \text{Precision}}{\text{Recall} + \text{Precision}}$$

Hypotheses on CBizPort's enhanced analysis capabilities. In H1.1–H1.4, we hypothesized that the use of CBizPort's summarizer and categorizer could significantly improve the searching and browsing performance of CBizPort because the summarizer could extract key sentences from Web pages, thereby saving users' time in browsing and the categorizer could classify Web pages into groups, thereby providing analysis capability that is not widely found in regional Chinese search engines.

Hypotheses on search engine performance comparison. In H2.1 and H2.2, we hypothesized that CBizPort would per-

form similarly to regional Chinese search engines for general search and browse tasks because the two systems have comparable advantages. ("General search and browse tasks" refers to tasks that may or may not ask for information about a particular region that is different from a subject's place of origin.) CBizPort was good at integrating results from different information sources while regional Chinese search engines provided deep coverage of the regions they served. In H2.3 and H2.4, we believed that CBizPort's ability to integrate information sources from the three regions provided more comprehensive coverage of search results. ("Cross-regional search and browse tasks" refers to tasks that require a subject to find information about a particular region that is different from his/her place of origin.)

In H2.5–H2.14, we believed that a combination of CBizPort and a regional Chinese search engine could augment the insufficiencies in both systems and provide the highest quality of searching and browsing. Since we expected to obtain significantly different results from the two systems, combining the results from them would signifi-

cantly increase recall but create only a small change in precision. Through this arrangement, we tried to mimic a situation in which each subject was allowed to use CBizPort and a benchmark search engine together to solve the same problem.

Hypotheses on users' subjective evaluations. In H3.1–H3.3, we believed that CBizPort has better information quality because, unlike commercial search engines, CBizPort provides a clean, user-friendly interface. Also, we believed that CBizPort performed similarly to regional search engines in the dimensions classified under “Coverage and reliability” (H3.1b) because the former provides comprehensive coverage of the three regions while the latter mainly have regional coverage. In H3.2, we hypothesized that CBizPort had a better cross-regional searching capability because of its ability to integrate results from the three regions. Based on the cited advantages of CBizPort, we therefore believe that CBizPort's users achieved higher overall satisfaction ratings (H3.3).

Additional hypotheses. In this experiment, we assumed that the three chosen benchmark search engines (Sina, Yahoo Hong Kong, and Openfind) belonged to the same category called “regional Chinese search engines” and had similar searching and browsing capabilities. Such an assumption was tested in HA1 and HA2. We expected that the performances of the three benchmarks would not be significantly different from each other, thus allowing us to compare CBizPort with the entire category (but not individual search engines).

Experimental Design

Thirty University of Arizona's Chinese students, ten from each region, were recruited as subjects of the experiment. Each of them received a fixed amount of money as an incentive for their voluntary participation in our experiment. The number of subjects was the same for all regions, as we wanted to maintain equal influence of regional impacts. Each subject's name, age range, gender, education level, and computer literacy were recorded, but were kept confidential in accordance with the Institutional Review Board (IRB) Guidebook.¹

The experiment required each subject to perform 5 search tasks and 5 browse tasks. A time limit of 4 minutes was imposed on each search task and 5 minutes on each browse task. Among the 10 tasks, 3 search tasks and 3 browse tasks were performed using CBizPort (either general search capability, or general search plus summarizer, or general search plus categorizer was used), and 2 search tasks and 2 browse tasks were performed using the bench-

mark search engine from the region of a subject's origin (one task was about information seeking within the region of the subjects' place of origin and the other was about seeking information from a region different from subjects' place of origin). All tasks were randomly assigned to different questions to avoid bias due to task content. A pilot test involving three subjects was conducted to evaluate the appropriateness of the tasks before they were actually used in the experiment. In the pilot test, we found that the subjects used all the time assigned for most search and browse tasks regardless of the system they used. Limited by the duration of the whole experiment (approximately one hour), we decided not to allocate more time to the tasks and focused only on studying the effectiveness and usability (but not efficiency) of the systems.

During the experiment, a subject used each of the two systems to perform the tasks. The order in which the systems were used was randomly assigned to the subjects to avoid bias due to system sequence. As each subject was asked to perform similar tasks using the two systems, a one-factor repeated-measures design was used, because it gives greater precision than designs that employ only between-subjects factors (Myers & Well, 1995). All verbal comments were analyzed using protocol analysis (Ericsson & Simon, 1993).

After finishing the tasks with a system, a subject needed to rate the system on: (1) the information quality provided by the system; (2) the ability to retrieve cross-regional information; and (3) his/her overall satisfaction with the system. To measure information quality, we modified the 16-dimension construct developed in Wang and Strong (1996) by dropping the dimension on “security,” which is not relevant because the information provided by the systems is already public. In addition, because there are different levels of importance in the remaining 15 dimensions, we invited our experts (as described below) to provide ratings on the relative importance of different dimensions. Such ratings were used to weigh the different dimensions of information quality for the Chinese business domain. Their ratings as well as the definitions of the 15 dimensions categorized into three categories are shown in Table 3.

Three experts, one from each region, also were recruited to provide answers for all browse tasks. The expert from mainland China has an MBA degree. The Taiwan expert holds an MS degree in management information systems and is pursuing a PhD degree in MIS. The Hong Kong expert is a PhD candidate in Marketing Management and worked for four years in market research in Hong Kong.

Each expert was assigned three browse tasks that were related to businesses of his/her own place of origin. To increase the quality of the experts' judgment, they were first required to provide a version of answers they had decided on after using both CBizPort and other search engines, and to organize the answers into themes. After the data from all subjects had been collected, the experts read subjects' answers and modified the original answers if needed. The final version of experts' answers was obtained after this two-step

¹The IRB Guidebook can be found at http://ohrp.osophs.dhhs.gov/irb/irb_guidebook.htm.

TABLE 3. Definitions of 15 dimensions of information quality and expert ratings.

Dimension	Definition	Average expert rating ^a
Presentation quality and clarity		
Accessibility	The extent to which information is available, or easily and quickly retrievable	3
Concise representation	The extent to which information is compactly represented	3
Consistent representation	The extent to which information is presented in the same format	2
Ease of manipulation	The extent to which information is easy to manipulate and apply to different tasks	2
Interpretability	The extent to which information is in appropriate languages, symbols, and units, and the definitions are clear	2.67
Coverage and reliability		
Appropriate amount of information	The extent to which the volume of information is appropriate for the task at hand	2.67
Believability	The extent to which information is regarded as true and credible	2
Completeness	The extent to which information is not missing and is of sufficient breadth and depth for the task at hand	2.33
Free-of-error	The extent to which information is correct and reliable	2.67
Objectivity	The extent to which information is unbiased, unprejudiced, and impartial	2.33
Usability and analysis quality		
Relevancy	The extent to which information is applicable and helpful for the task at hand	3
Reputation	The extent to which information is highly regarded in terms of its source or content	2.33
Timeliness	The extent to which information is sufficiently up-to-date for the task at hand	3
Understandability	The extent to which information is easily comprehended	2.33
Value-added	The extent to which information is beneficial and provides advantages from its use	3

^aExpert rating: 3 = extremely important, 2 = very important, 1 = important.

process and was used to evaluate the performance of the systems.

Experimental Results and Discussions

In this section, we describe and analyze the results of our user evaluation study. Table 4 summarizes the system performance in search tasks (measured by accuracy) and browse tasks (measured by precision, recall, and F value). Table 5 shows the mean ratings on various dimensions, Table 6 shows the *p* values and results of testing various hypotheses, and Table 7 summarizes subjects' profiles.

CBizPort's Assistance in Human Analysis

The results of testing hypotheses H1.1–H1.4 show that there was no significant difference between the accuracy, precision, and recall when using or not using CBizPort's summarizer or categorizer. We believe that it could be attributed to the processing speed and time constraint on the tasks. The summarizer processing time included the time to fetch and process Web pages from remote servers, some of which might have slow response times or prevent automatic spidering, thus undermining the performance of summarizer (especially when the Web pages contained the answers of the tasks). In addition, although CBizPort's summarizer and categorizer could provide analysis capabilities, the limited time of the experiment might not be long enough to demonstrate the power of the two functions fully.

Despite non-significant results, we found from subjects' verbal comments that the summarizer and categorizer actually helped their searching. Eleven subjects explicitly men-

tioned that the summarizer and categorizer could facilitate their understanding and searching of results. For example, subject 5 said: "CBizPort's summarizer and categorizer are much more helpful than YahooHK's general search." Subject 26 also said that the summarizer and categorizer "can easily extract most useful information." *We believe that CBizPort's summarizer and categorizer provide helpful analysis capabilities for users' search and browse tasks, thus answering Research Question 2.*

Search Engine Performance Comparison

The results of testing hypotheses H2.1–2.14 show that 11 of the 14 hypotheses were confirmed while H2.3, H2.4, and H2.11 were not confirmed. As the *p* values of H2.1–H2.4 are very high (ranging from 0.49–0.78), we found that CBizPort performed similarly to regional Chinese search engines in both general and cross-regional search and browse tasks. The fact that hypotheses H2.3 and H2.4 were not confirmed might result from the additional processing needed for cross-regional search and browse tasks in which subjects tended to issue more queries. As a prototype system, CBizPort did not process the queries as quickly as benchmark search engines that were professionally developed. Moreover, CBizPort searched from different information sources while benchmark search engines searched only from their own databases. The slower speed of CBizPort may, thus, explain why hypotheses H2.3 and H2.4 were not confirmed. Nevertheless, benchmark search engines did not outperform CBizPort. Therefore, *we conclude that CBizPort's searching and browsing performance is comparable*

TABLE 4. Searching and browsing performance of CBizPort and Benchmark search engines.

Portal	Setting	Task	Measure	Mean performance (%)	Std. deviation (%)
CBizPort	Basic searching (with neither summarizer nor categorizer)	Search	Accuracy	36.67	45.36
		Browse	Precision	58.65	42.78
			Recall	22.86	21.85
			F value	31.39	25.46
	Basic searching + with summarizer only	Search	Accuracy	25.00	41.00
		Browse	Precision	51.05	44.19
			Recall	26.06	27.18
			F value	33.10	31.58
	Basic searching + with categorizer only	Search	Accuracy	35.00	47.62
		Browse	Precision	53.33	44.72
			Recall	26.56	28.82
			F value	32.60	30.57
Benchmark search engines	General searching	Search	Accuracy	40.00	49.83
		Browse	Precision	55.67	45.04
			Recall	21.83	23.23
			F value	29.02	27.92
	Cross-regional searching	Search	Accuracy	28.33	42.92
		Browse	Precision	66.37	41.50
			Recall	25.78	22.79
			F value	34.31	24.54
Combination (CBizPort + Benchmark)	(Randomly assigned) ^a	Search	Accuracy	65.00	47.62
		Browse	Precision	76.80	31.88
			Recall	43.08	26.36
			F value	52.32	26.62

^aThe random assignment for the combination is to randomly use one of the three settings in CBizPort plus one of the two settings in the benchmark search engine for the same task.

to that of regional Chinese search engines, thus answering Research Question 2.

In H2.5–H2.14, the *p* values were mostly below 0.05 (except for H2.11 where the *p* value was 0.061, very close to 0.05), indicating that a combination of the two systems performed significantly better than any other settings in most of the search tasks and all browse tasks. The accuracy of search tasks and recall of browse tasks were increased significantly. An unexpected result was that the precision of browse tasks done with the combination also was increased because the increased number of correct themes was slightly higher than the increase in the number of distinct themes obtained by the combina-

tion. Overall, the encouraging results confirmed our belief that CBizPort could significantly improve the performance of regional Chinese search engines. We believe that CBizPort’s summarizer, categorizer, and meta-searching contributed to that significant improvement, as subject number 6 summarized succinctly: “It is difficult to retrieve useful and relevant information from Yahoo Hong Kong, but CBizPort provides more useful tools to enhance the searching ability.” Therefore, we conclude that CBizPort can significantly augment the searching and browsing ability of regional Chinese search engines, thus improving human integration of regional information and analysis. This answers Research Question 2.

TABLE 5. Results of users’ subjective evaluations.

Dimension	CBizPort		Benchmark search engine	
	Mean rating ^a	Std. deviation	Mean rating ^a	Std. deviation
Information quality (overall)	4.47	1.06	4.35	1.23
Presentation quality and clarity	4.55	1.10	4.40	1.31
Coverage and reliability	4.49	1.11	4.28	1.36
Usability and analysis quality	4.39	1.25	4.37	1.23
Cross-regional searching capability	4.45	1.27	4.14	1.55
Overall satisfaction	4.37	1.30	4.03	1.69

^aThe range of rating is from 1 to 7 with 7 being the best.

TABLE 6. Results of hypothesis testing.

Hypotheses for search tasks				Hypotheses for browse tasks (F value)			
		<i>P</i> value	Result			<i>P</i> value	Result
H1: Enhanced analysis capabilities							
H1.1	CBiz + Summ > CBiz	0.326	Not confirmed	H1.2	CBiz + Summ > CBiz	0.81	Not confirmed
H1.3	CBiz + Categ > CBiz	0.883	Not confirmed	H1.4	CBiz + Categ > CBiz	0.853	Not confirmed
H2: Search engine performance comparison							
H2.1	CBiz = Bench (general)	0.782	Confirmed	H2.2	CBiz = Bench (general)	0.759	Confirmed
H2.3	CBiz > Bench (cross)	0.487	Not confirmed	H2.4	CBiz > Bench (cross)	0.668	Not confirmed
H2.5	Combined > CBiz	0.028^a	Confirmed	H2.6	Combined > CBiz	0.007^a	Confirmed
H2.7	Combined > CBiz + Summ	0.000^a	Confirmed	H2.8	Combined > CBiz + Summ	0.002^a	Confirmed
H2.9	Combined > CBiz + Categ	0.019^a	Confirmed	H2.10	Combined > CBiz + Categ	0.025^a	Confirmed
H2.11	Combined > Bench(gen)	0.061	Not confirmed	H2.12	Combined > Bench(gen)	0.001^a	Confirmed
H2.13	Combined > Bench(cross)	0.004^a	Confirmed	H2.14	Combined > Bench(cross)	0.01^a	Confirmed
H3: Users' subjective evaluations							
H3.1	Information quality: CBiz > Bench					0.649	Not confirmed
H3.1a	Information quality (presentation quality and clarity): CBiz > Bench					0.599	Not confirmed
H3.1b	Information quality (coverage and reliability): CBiz = Bench					0.503	Confirmed
H3.1c	Information quality (usability and analysis quality): CBiz > Bench					0.951	Not confirmed
H3.2	Cross-regional searching: CBiz > Bench					0.371	Not confirmed
H3.3	Satisfaction: CBiz > Bench					0.712	Not confirmed
Additional hypotheses							
HA1	Search performance: Sina = Openfind = YahooHK					0.995	Confirmed
HA2	Browse performance: Sina = Openfind = YahooHK					0.718	Confirmed

Note. For details of the hypotheses, please refer to Table 2.
^aalpha error = 5%.

Users' Subjective Evaluations and Verbal Comments

The results of testing hypotheses H3.1–H3.3 show that there was no significant difference between the two systems' ratings. However, among all three subjective evaluation criteria (information quality, cross-regional searching capability, and overall satisfaction), CBizPort obtained the highest average scores (see Table 5).

Subjects' verbal comments, summarized in Table 8, revealed more about the differences in the two systems' performance. Nine subjects agreed that CBizPort generally performed better than the benchmark search engine, four subjects

said that benchmark search engine performed better, and seven subjects did not explicitly say which system performed better, or said that both systems performed similarly.

Many positive comments were made about CBizPort. Seven subjects said that CBizPort was user-friendly and could obtain more precise and relevant results than benchmark search engine. For example, subject number 15 said: "Sina gives many results that are not focused, and is poor at searching for Hong Kong and Taiwan results." Four subjects said that they liked CBizPort's large variety of options in searching for information from different regions and search engines. For example, subject number 2 said: "YahooHK is more limited when searching certain terms in a specific region... while CBizPort can fulfill what YahooHK couldn't do."

In contrast, benchmark search engines received relatively fewer positive comments. Four subjects mentioned that they were familiar with the user interfaces and functions because of their popularity. For example, subject number 27 said: "I am familiar with the format of Openfind. So that's the reason that I am more satisfied with it than CBizPort." Three subjects complained about CBizPort's slow processing speed. This is understandable because CBizPort is currently an experimental prototype that does not have the professional operations and rich contents of benchmark search engines.

TABLE 7. Subjects' profiles.

Attribute	Subjects' profile
Computer literacy	Average computer literacy = 5 (range: 1–7, with 7 being "excellent")
Gender	17 subjects are male, 13 are female
Education level	10 subjects are undergraduate students, 9 subjects have earned a bachelor's degree, 10 subjects have earned a master's degree, 1 subject did not provide education information
Age	15 subjects, ages 18–25; 12 subjects, ages 26–30; 1 subject, ages 30–35; 2 subjects did not provide age information

TABLE 8. Summary of subjects' verbal comments.

Portal	Strengths	Weaknesses
CBizPort	<ul style="list-style-type: none"> - Provided useful tools to enhance the searching ability - Allowed summarization and categorization that other search engines couldn't provide - More user-friendly because it allowed users to choose from different regions and data sources - Allowed users to type in more than one keywords on the text area 	<ul style="list-style-type: none"> - The processing speed was sometimes slow - Too many results coming from different regions might overwhelm users - Users were not familiar with categorizer - Insufficient time of the experiment made users feel that CBizPort's functions were not as useful as they should have been
Benchmark search engines	<ul style="list-style-type: none"> - Provided higher search speed generally - Users were more familiar with its interface and functions - Provided other functions (e.g., attractive images, news) that were appealing to users 	<ul style="list-style-type: none"> - Search results had less variety, were sometimes less precise and relevant - Analysis functions are limited - Did not provide much information about the regions of the Web pages

Therefore, from the results of testing H3.1–H3.3, we conclude that users' subjective evaluations on information quality, cross-regional searching capability, and overall satisfaction of CBizPort are comparable to those of regional Chinese search engines. From subjects' verbal comments, we conclude that CBizPort is better than regional Chinese search engines in terms of analysis functions, cross-regional searching capabilities and user-friendliness, while regional Chinese search engines have more efficient operations and are more popular. The results answer Research Question 3.

The non-significant results of HA1 and HA2 confirmed our belief that the three benchmark search engines have similar performance and, thus, could be treated as a group in comparisons with CBizPort.

Results of Testing Additional Hypotheses

The non-significant results of HA1 and HA2 confirmed our belief that the three benchmark search engines have similar performance and thus could be treated as a group in comparisons with CBizPort.

Implications of the Results

Three implications can be drawn from our experimental results. First, the encouraging results of testing CBizPort's functions suggest that our knowledge portal approach can benefit Internet searching and browsing in a multilingual world due to its generic applicability. As Fuld et al. (2002) have pointed out, existing business intelligence tools generally lack analysis capabilities; our approach addresses the need by providing summarization, categorization, and meta-searching for obtaining business intelligence.

Second, although it is not our intent to create a new model of human information seeking, the results have pointed out the importance of using preview and overview in assisting human information seeking in the context of Internet searching and browsing. Future research in developing human information seeking model can pay more

attention to such assistance. Relevant research questions include: "How should a model of information seeking be developed that explains the interaction between human and automated assistance to Internet searching?" "How can such a model be applied to information seeking involving individual differences?" "What kinds of information overview and preview work best with human in Internet information seeking?"

Third, cross-regional searching capability is important for building Internet search portals in a multilingual world because a language may be used in regions with different cultural, social, and economic environments. Experimental results show that our approach has addressed this issue; subjects showed a strong preference for CBizPort's cross-regional searching capability. Apart from Chinese, some languages are widely used in regions that have different needs for Internet searching. For example, Spanish is currently the second most popular language in the United States and is the main language in more than 20 regions including Latin and South American countries. Arabic is widely used in Middle East and North African countries. Having capability for effective cross-regional searching is a promising direction for next-generation Internet searching and browsing.

Conclusions and the Future

In this paper, we have reviewed various aspects of Internet searching and browsing in a multilingual world and have proposed a knowledge portal approach to closing the gaps. We have developed the Chinese Business Intelligence Portal based on this approach and conducted a systematic evaluation to test CBizPort's ability to assist human analysis of Chinese business intelligence. Our experimental results show that CBizPort's analysis functions could help users' searching and browsing, as reflected in subjects' many positive comments. While CBizPort's searching and browsing performance was comparable to that of regional Chinese search engines, a combination of the two systems was found to perform significantly better than using either one alone for search and browse tasks.

In addition, users' subjective evaluations on information quality, cross-regional searching capability, and overall satisfaction of CBizPort were comparable to regional Chinese search engines. Subjects' verbal comments indicated that CBizPort performed better than regional Chinese search engines in terms of analysis functions, cross-regional searching capabilities, and user-friendliness, while regional Chinese search engines had more efficient operation and were more popular. Overall, the experimental results are encouraging and indicate a promising future of our approach to Internet searching and browsing in a multilingual world.

This research has several limitations. First, our CBizPort is currently a prototype system that does not have the professional operations and technical supports that benchmark search engines enjoy. Second, the Chinese students we used as subjects may not truly represent the population of Chinese business practitioners, thus reducing the external validity of our results. Third, a limited experimental period restricted optimal testing of CBizPort's functionality.

Many interesting future directions will be explored. First, our knowledge portal approach can be used to develop Internet search portals in other languages. Currently, we are developing such portals in Spanish and Arabic. Regional and language-specific issues will be addressed. Second, more analysis techniques can be used to enhance Internet searching and browsing in a multilingual world. For example, visualization techniques have been used successfully to discover business intelligence in English domains (Chung et al., 2003). They will be used in non-English and cross-regional domains to explore cross-regional business intelligence among businesses in the United States, China, Taiwan, and Hong Kong and to show networks of international partnerships. Third, statistical natural language processing techniques other than mutual information can be used to provide more semantic capabilities.

Acknowledgments

This research is partly supported by NSF Digital Library Initiative-2, "High-Performance Digital Library Systems: From Information Retrieval to Knowledge Management," IIS-9817473, April 1999 to March 2002. We thank Ada Leung, Chienting Lin, Daniel McDonald, Barbara Sears, Byron Marshall, Alan Yip, Mark Chen, Michael Chau, Victoria Zhang, all the subjects who participated in the user study, and other contributing members for their help in this research.

References

- ACNelsen. (2002). Nelsen/Netratings reports a record half billion people worldwide now have home Internet access. Retrieved February 15, 2003, from <http://asiapacific.acnielsen.com.au/news.asp?newsID=74>
- Ballou, D.P., & Pazer, H.L. (1985). Modeling data and process quality in multi-input, multi-output information systems. *Management Science*, 31(2), 150–162.
- Chang, S.J., & Rice, R.E. (1993). Browsing: A multidimensional framework. *Annual Review of Information Science and Technology*, 28, 231–276.
- Chen, H., Fan, H., Chau, M., & Zeng, D. (2001). MetaSpider: Meta-searching and categorization on the Web. *Journal of the American Society for Information Science and Technology*, 52(13), 1134–1147.
- Chen, H., Lally, A., Zhu, B., & Chau, M. (2003). HelpfulMed: Intelligent searching for medical information over the Internet. *Journal of the American Society for Information Science and Technology*, 54(7), 683–694.
- Chung, W., Chen, H., & Nunamaker, J.F. (2003). Business Intelligence Explorer: A knowledge map framework for discovering business intelligence on the Web. In R.H. Sprague (Ed.), *Proceedings of the 36th Hawaii International Conference on System Sciences*, Island of Hawaii, HI: IEEE Computer Society.
- Church, K., & Hanks, P. (1989). Word association norms, mutual information, and lexicography. *Proceedings of the 27th Annual Meeting of Association for Computational Linguistics* (pp. 76–83). Vancouver, BC, Canada.
- CNNIC. (2002). Analysis report on the growth of the Internet in China, China Internet Network Information Center. Retrieved February 20, 2003, from <http://www.cnnic.net.cn/develop/2002-7e/6.shtml>
- Ellis, D. (1989). A behavioral approach to information retrieval system design. *Journal of Documentation*, 45(3), 171–212.
- Ericsson, K.A., & Simon, H.A. (1993). *Protocol analysis: Verbal reports as data*. Cambridge, MA: MIT Press.
- Fuld, L., Sawka, K., Carmichael, J., Kim, J., & Hynes, K. (2002). *Intelligence software report™ 2002*. Cambridge, MA: Fuld & Company Inc.
- Furnas, G.W., & Zacks, J. (1994). Multitrees: Enriching and reusing hierarchical structure. In C. Plaisant (Ed.), *Proceedings of ACM CHI'94 Conference on Human Factors in Computing Systems* (pp. 330–336). Boston, MA: ACM Press.
- Global-Reach. (2002). Global internet statistics. Retrieved February 10, 2003, from <http://www.greach.com/globstats/>
- Gloor, P. (1991). Cybermap: Yet another way of navigating in hyperspace. *Proceedings of the Third ACM Conference on Hypertext* (pp. 107–121). San Antonio, TX.
- Greene, S., Marchionini, G., Plaisant, C., & Shneiderman, B. (2000). Previews and overviews in digital libraries: Designing surrogates to support visual information seeking. *Journal of the American Society for Information Science*, 51(4), 380–393.
- Huang, K., Lee, Y.W., & Wang, R.Y. (1999). *Quality information and knowledge*. Upper Saddle River, NJ: Prentice Hall.
- Ingwersen, P. (1992). *Information retrieval interaction*. London: Taylor Graham.
- Kahn, B.K., Strong, D.M., & Wang, R.Y. (2002). Information quality benchmarks: Product and service performance. *Communications of the ACM*, 45(4), 184–192.
- Kuhlthau, C. (1993). A principle of uncertainty for information seeking. *Journal of Documentation*, 49(4), 339–355.
- Kuhlthau, C. (1998). Longitudinal case studies of the information search process of users in libraries. *Library and Information Science Research*, 10(3), 257–304.
- Kuhlthau, C., Spink, A., & Cool, C. (1992). Exploration into stages in the information search process in on-line IR: Communication between users and intermediaries. In D. Shaw (Ed.), *Proceedings of the Annual Meeting of the American Society for Information Science*, 29 (pp. 67–71). Pittsburgh, PA: American Society for Information Science.
- Kwok, K. (1997). Comparing representations in Chinese information retrieval. In E. Voorhees (Ed.), *Proceedings of ACM SIGIR*, Philadelphia, PA (pp. 34–41). New York: ACM.
- Lin, X. (1997). Map displays for information retrieval. *Journal of the American Society for Information Science*, 48(1), 40–54.
- Loiacono, E. (1999). WebQual™: A Web site quality instrument. In P. De & J. I. DeGross, (Eds.), *Proceedings of International Conference on Information Systems (ICIS) Doctoral Consortium*. Charlotte, NC.
- Marchionini, G. (1995). *Information seeking in electronic environments*. New York: Cambridge University Press.

- Marchionini, G., & Shneiderman, B. (1988). Finding facts vs. browsing knowledge in hypertext systems. *IEEE Computer*, 21(1), 70–80.
- McDonald, D., & Chen, H. (2002). Using sentence selection heuristics to rank text segments in TXTRACTOR. In W. Hersh (Ed.), *Proceedings of the second ACM/IEEE-CS Joint Conference on Digital Libraries* (pp. 28–35). Portland, OR: ACM/IEEE-CS.
- Myers, J., & Well, A. (1995). *Research design and statistical analysis*. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.
- Ong, T., & Chen, H. (1999). Updateable PAT-Tree approach to Chinese key phrase extraction using mutual information: A linguistic foundation for knowledge management. *Proceedings of the Second Asian Digital Library Conference* (pp. 63–84). Taipei, Taiwan.
- Pipino, L.L., Lee, Y.W., & Wang, R.Y. (2002). Data quality assessment. *Communications of the ACM*, 45(4), 211–218.
- Redman, T.C. (1996). *Quality for the Information Age*. Boston, MA: Artech House.
- Saracevic, T. (1996). Modeling interaction in IR. Review and proposal. *Proceedings of the Annual Meeting of the American Society for Information Science* (pp. 3–9). Denver, CO.
- Saracevic, T., Kantor, P., Chamis, A.Y., & Trivison, D. (1988). A study of information seeking and retrieving. I. Background and methodology. II. Users, questions and effectiveness. III. Searchers, searches and overlap. *Journal of the American Society for Information Science*, 39(3), 161–216.
- Shaw, W.M.J., Burgin, R., & Howell, P. (1997). Performance standards and evaluations in information retrieval test collections: Cluster-based retrieval models. *Information Processing and Management*, 33(1), 1–14.
- Spence, R. (1999). A framework for navigation. *International Journal of Human-Computer Studies*, 51(5), 919–945.
- Spink, A. (1992). Recognition of stages in the user's information-seeking during online searching by novice searchers. *Online Review*, 16(5), 297–301.
- Spink, A., Ozmutlu, S., Ozmutlu, H.C., & Jansen, B.J. (2002). U.S. versus European Web searching trends. *SIGIR Forum*, 36(2).
- Spink, A., & Saracevic, T. (1997). Interaction in IR: Selection and effectiveness of search terms. *Journal of the American Society for Information Science*, 48(8), 741–761.
- Sutcliffe, A.G., & Ennis, M. (1998). Towards a cognitive theory of information retrieval. *Interacting with Computers (Special Edition on HCI & Information Retrieval)*, 10, 321–351.
- Voorhees, E., & Harman, D. (1997). Overview of the Sixth Text Retrieval Conference (TREC-6). In D.K. Harman (Ed.), *NIST Special Publication 500–240: The Sixth Text Retrieval Conference (TREC-6)* (pp. 3–35). Gaithersburg, MD: National Institute of Standards and Technology.
- Wang, R.Y., & Strong, D.M. (1996). Beyond accuracy: What data quality means to data consumers. *Journal of Management Information Systems*, 12(4), 5–34.
- Wilson, T.D. (1999). Models of information behavior research. *Journal of Documentation*, 55(3), 249–270.
- Zhu, B., Leroy, G., Chen, H., & Chen, Y. (2002). MedTextus: An intelligent Web-based medical meta-search system. In W. Hersh (Ed.), *Proceedings of the second ACM/IEEE-CS Joint Conference on Digital Libraries* (p. 386). Portland, OR: ACM/IEEE-CS.