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ABSTRACT

As businesses increasingly use the Web to share information with stakeholders, the problems arising from information overload and interconnected nature of the Web make it difficult to obtain business intelligence (BI). This research proposes a visual approach to business stakeholder analysis that integrates information visualization and Web mining techniques with human domain knowledge. A proof-of-concept prototype was developed based on the approach to assist in analyzing and visualizing complicated stakeholder networks on the Web. We report results of an empirical evaluation comparing the prototype with a traditional method of BI analysis and discuss the implications on HCI research and BI systems development.

Keywords

Business intelligence, Web searching and browsing, information visualization, system evaluation, user study.

INTRODUCTION

In a turbulent business world, managers rely on business intelligence (BI) to monitor the operating environment, to identify potential risks, and to devise competitive strategies to react to stakeholders' movements (Blenkhorn and Fleisher, 2005). Analyzing stakeholders has been an important practice to obtain BI and it is conventional to put into this practice significant manual efforts, such as personal interview, manually searching for published and unpublished documents, monitoring news media, and observing competitors' movements. In the recent decade, the proliferation of the Internet has offered new opportunities for gathering BI. Voluminous information about business stakeholders can be searched and collected easily on the Web. However, the task of analyzing such information can be difficult and time-consuming. For instance, a business analyst may obtain from a simple Web search thousands of Web pages about his company's stakeholders and is not able to analyze them. Unfortunately, existing BI tools are not capable enough to assist in such analysis (Fuld, Singh, Rothwell and Kim, 2003). The traditional manual approach to stakeholder analysis is not scalable to the rapid growth of the Web.

This paper describes a visual approach to business stakeholder analysis and reports findings from an empirical evaluation that studied the user perception in business analysis using a prototype developed based on the approach and a traditional method of BI analysis. The approach uses information visualization and Web mining techniques to assist human users in understanding a large amount of stakeholder information on the Web. The prototype supports visualization of stakeholder networks of knowledge management companies. Subjects in the empirical evaluation provided ratings and written comments of the two methods they used. This research thus provides empirical findings about human analysis of business stakeholders with the help of a visualization tool. Results of this study will offer insight to BI researchers and practitioners, and HCI researchers in general.

LITERATURE REVIEW

BI is defined as the product of acquisition, collation, analysis, interpretation, and exploitation of business information (Chung, Chen and Nunamaker, 2005). A major BI consultant, Fuld et al. (2003) found that global interest in BI technology has increased significantly in the past five years. However, automated search capability in many BI tools can lead to information overload.

Theoretical and Technical Backgrounds

Traditional stakeholder analysis approaches provide theoretical insights into the analysis of BI (Freeman, 1984), arguing that firms will gain long-term benefits by attending to the interests of all their stakeholders rather than just the shareholders. However, stakeholder theories fall short of supporting scalable system development for monitoring changes in the competitive environment and for representing stakeholder network relationships in e-commerce environment. For instance, Jawahar and McLaughlin (2001) concluded that their descriptive stakeholder theory might be limited to traditional businesses only. New approaches that integrate Internet technologies into stakeholder analysis will be needed. In recent years, information visualization and Web mining emerge as potential solutions (Gregg and Walczak, 2006).

Information visualization holds the promise of alleviating information overload on the Web by summarizing a large amount of data onto a two-dimensional display format, such as map, hierarchy, or network (Shneiderman, 1996). As stakeholders form multilateral relationships in their dealing with a company, portraying such relationships on a network could potentially help business analysts to understand their relationships on the Web. Such relationships are often complicated by the existence of hyperlinks that stakeholders may or may not be aware of. Network visualization models social actors as nodes and their relationships as links (Freeman, 2001) and recent research has applied network

analysis to different domains (e.g., Höpner and Krempel, 2003; Krebs, 2001). However, these network approaches tend to rely on clearly-defined links (such as criminal records and company financial transactions) that cannot be identified easily in complicated business stakeholder relationships on the Web. Moreover, none of these approaches have been applied to business stakeholder analysis, despite much theoretical work done (e.g., Donaldson and Preston, 1995; Jawahar and McLaughlin, 2001).

Web mining uses data mining and machine learning techniques to discover and extract information automatically from Web documents and services (Gregg and Walczak, 2006). As businesses increasingly use the Web to share information in the forms of textual Web pages and hyperlinks, mining the textual and structural content of the Web has the potential to assist in analysis of complex business Web site content and structural relationships among sites, leading to more effective and efficient discovery of business intelligence. Unfortunately, research on intelligent Web technologies (e.g., Zhong, Liu and Yao, 2003) seldom addresses the need for BI discovery on the Web (Negash, 2004).

Evaluation of Information Visualization Tools

Evaluation is an important step towards a better understanding of the usability of information visualization tools. A commonly-used evaluation methodology is to compare a tool or technique against a benchmark in a controlled laboratory environment. For example, in evaluating a tool for visualizing patients' medical history, a tabular format was used as a benchmark for comparison on viewing personal history records based on the speed, accuracy and user satisfaction ratings and recall data (Alonso, Rose, Plaisant and Norman, 1998). In a two-phase evaluation of a coordinated visualization tool (called Snap), subjects were asked (in Phase 1) to construct coordinated visualization interface and (in Phase 2) to compare three interfaces – detail only, no coordination, coordination – by performing different browse tasks (North and Shneiderman, 2000). The aforementioned evaluation studies point out the general benefits of visualization tools, but did not address the evaluation of using such tools in analyzing complicated stakeholder relationships.

To study what role visualizations play, a de-featuring approach was proposed and used to evaluate four information retrieval interfaces (Morse and Lewis, 2000). The approach is used to iteratively assess the many features that a visualization tool possesses by mapping the tasks in a visual task taxonomy (Zhou and Feiner, 1998) to the features. The taxonomy contains a large number of tasks commonly performed by visualization tools. Examples of these tasks include Associate, Background, Categorize, Cluster, Compare, Correlate, Distinguish, Generalize, Identify, Locate, Rank, and Reveal. The approach has been used to evaluate a social visualization tool known as CommunicationGarden (Zhu and Chen, 2002) that was found to outperform Netscape Messenger in terms of efficiency in all task types and in terms of effectiveness in "identify" tasks. The study points out the importance of distinguishing different task types using the visualization task taxonomy (Morse and Lewis, 2000; Zhou and Feiner, 1998), especially for analysis purposes. However, it has not been applied to evaluating visualization tools designed for BI analysis.

A VISUAL APPROACH TO BUSINESS STAKEHOLDER ANALYSIS

Although business networks and networked organizations have been used and studied in recent years (Parkhe, Wasserman and Ralston, 2006), network visualization and analysis approaches have not been applied to stakeholder analysis on the Web. Our review shows that information visualization and Web mining technologies hold the promise of supporting complicated stakeholder analysis. However, their application to discovering BI on the Web is scarce and little research on BI systems is available (Negash, 2004). Therefore, we have proposed a visual approach to developing BI systems that can address the needs.

Steps in the Approach

The approach first gathers relevant data through searching and spidering the Web by using proper keywords and hyperlinks as inputs. *Meta-searching/spidering* uses keywords as inputs to search multiple Web search engines to collate a set of results (URL links) ranked among the top-ranked results in each engine. *Domain spidering* uses a set of seed URLs (provided by experts or identified in reputable sources) as starting pages and then automatically fetches the pages linked to the URLs. *Link searching/spidering* uses URL links as inputs to search engines that support searching for Web pages containing these links in their content. Second, the approach extracts such entities as textual content and hyperlinks from the data and indexes these entities automatically to provide more contextual information by showing the relationships among entities. Finally, the approach analyzes the extracted entities to discover BI and to visualize previously hidden patterns through such various techniques as similarity analysis, classification, and network formation.

Prototype Development

Following the aforementioned steps, we have developed a research prototype, called Stakeholder Network Visualizer (SNV), for analyzing and visualizing business stakeholder networks on the Web (see Figure 1). The target users of SNV are business analysts, managers, researchers, and consultants. Their daily work includes analyzing business environment, identifying business stakeholders, studying their relationship with the company, prioritizing efforts in serving these stakeholders, and reporting their findings in textual and graphical formats, such as charts, networks, and figures.

To gather relevant information for creating stakeholder networks, we collected Web pages of business stakeholders of the top 100 knowledge management companies identified by the Knowledge Management World Web site (`http://www.kmworld.com/`), a major Web portal

providing news, publications, online resources, and solutions to more than 51,000 subscribers in the knowledge management systems market. To identify such stakeholders, we used the backlink search function of Google search engine (`http://www.google.com/`) to search for Web pages having hyperlinks pointing to the companies' Web sites. To illustrate the method, we can type "`link:www.siebel.com`" in Google's search box to find the Web pages pointing to Siebel's Web site (the host company). According to Ingwersen (1998), the hyperlinked pages can be seen to mirror social communication phenomena, such as strategic or tactical referral behavior, and pragmatic or common semantic interest in particular sites on the Web. Therefore, a relationship may exist between Siebel and the results because the hyperlinks imply underlying stakeholder relations with the enterprise. It should be noted that Google's link search is just one of many methods to identify stakeholders on the Web and was chosen due to its wide coverage of Web resources. Other possible methods include expert judgment, link search in Yahoo! and Alta Vista, and interview with company managers.

To analyze and visualize the relationships among stakeholder pages, we performed similarity analysis, stakeholder placement using multidimensional scaling, and network formation. The similarity between every pair of stakeholders in a company's stakeholder network was calculated based on appearance of common keywords, mutual referencing through hyperlinks, and citation of both pages via hyperlinks by a third Web page. The relationships among stakeholder pages were then represented by networks in which nodes representing stakeholders were placed on a two-dimensional space using multidimensional scaling visualization, which provided a high-level picture of all the stakeholders and their relationships. We used multidimensional scaling (MDS) to transform a high-dimensional similarity matrix to a set of two-dimensional coordinates (Young, 1987), where proximity between the nodes reflects similarity. MDS was suitable for the current data structure (similarity matrix among stakeholders) and provided a vivid picture summarizing stakeholders' relationships.

Figure 1(a) shows the front-end interface of SNV. A user can click on one of the listed companies to choose the stakeholder network of that company to be displayed. Then the user can click the "Stakeholder Network" tab to view the network, as shown in Figure 1(b). The links of the network represent similarity linkages among stakeholders. These linkages were assigned weights same as the similarity scores calculated above. In the network, the stakeholders of ClearForest appear as nodes and the lines connect pairs of similar nodes. A user can click on a node to display the title, summary, and URL of that stakeholder in the box below the network. By clicking and dragging a highlighted node, the user can move that node to a different location within the network and the links connected to that node will be moved accordingly. This movement allows the user to view some parts with a large number of nodes more clearly. The user also can click a number of buttons and objects to help navigate the network. The "highlight" button allows the user to drag the mouse cursor to zoom in a rectangular portion of the network. When clicked, the "Open Site" button will open the Web page of the selected stakeholder on a new pop-up window. The user can choose to display or hide the names of stakeholders and the weights of links by clicking the "Name" and "Weight" buttons respectively. To prevent the network from being too cluttered, we displayed only the 200 links with the highest similarity weights. The abstraction slider below the buttons can adjust the links and their connected nodes displayed on the networks. A zero abstraction (slider adjusted to the left side) means all links are displayed while a high abstraction (slider adjusted to the right side) will hide links (and its connected nodes) with weights lower than that abstraction.

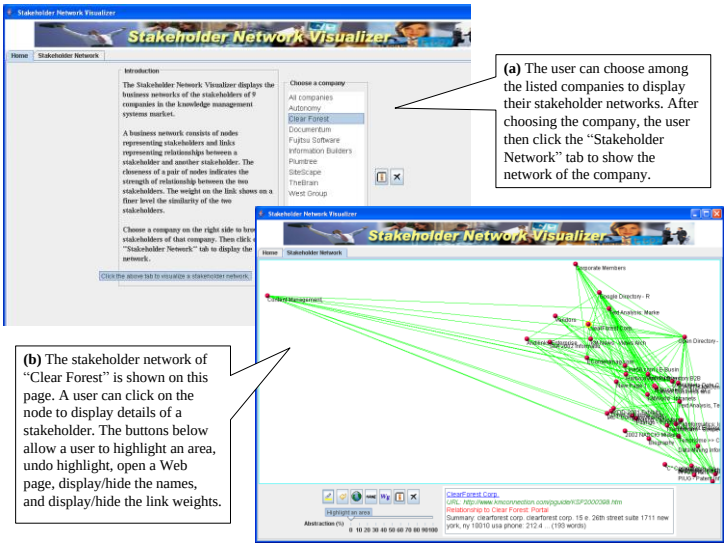

Figure 1. Screen shots of Stakeholder Network Visualizer

EVALUATION METHODOLOGY

To evaluate the usability of the visual approach, we conducted an empirical evaluation of SNV by comparing it with a traditional BI analysis method, in which subjects are provided with a textual list of stakeholders of a company and can search and browse any Web sites or search engines.

Evaluation Design

We employed a de-featuring approach (Morse and Lewis, 2000) in our experimental design because it can be tailored to a specific domain (such as BI analysis) and it has been applied to evaluating systems capable of supporting a variety of visual tasks (Zhou and Feiner, 1998). We designed different types of experimental tasks that focused on the functions of comparing and ranking stakeholders. A "compare" task required a subject to identify two or more objects (e.g., stakeholders) and to compare them based on some specific criteria. An example is "Identify the stakeholders named 'Autonomy (Powered by Genesys Conferencing)' and 'California Computer.' Which one has more connections with other stakeholders?" A "rank" task required a user to arrange objects in a certain order to show

the best or the worst cases. For example, a subject may be asked to rank a number of stakeholders in descending order of the strength of their relationship with another stakeholder. These tasks are commonly performed in BI analysis. Other types of more complicated tasks, though may be performed occasionally, were not selected so as not to lengthen the evaluation undesirably. A BI expert verified that all the tasks used in this experiment were appropriate business analysis tasks. This BI expert is President and CEO of a publicly traded company in North America and had over 26 years' experience in business development, raising capital, negotiations, finance, and strategic planning. He had worked as Vice President of Business Development for the Gallup Organization.

Subjects and Evaluation Procedure

Forty-seven undergraduate (senior-level) students in a business school of a university in the United States participated as volunteer subjects. Each subject used SNV and a traditional method to perform the aforementioned two experimental tasks in each of two sections. In the one-hour experiment, we introduced the two methods (SNV and the traditional method) to each subject and randomly assigned two different sets of tasks to evaluate the methods in the two sections. The two companies appearing in the two sections were Sitescape and Autonomy that were randomly selected from the list of companies shown in Figure 1(a). The order in which the methods were used in the two sections was randomly assigned to avoid bias owing to sequence of use. Each subject provided in a post-section questionnaire ratings on a number of statements categorized into three areas: usefulness, ease of use, and information display and interface design. The construct used to evaluate these three areas was based on the items in the questionnaires developed in Davis (1989) and Lewis (1995). A seven-point Likert scale was used in these ratings. The subject also provided comments on the method right after using it. After finishing the two sections, the subject filled in a post-study questionnaire to provide further comments and demographic information.

Hypothesis Testing

Because SNV summarizes a large amount of business information and provides visualization of stakeholder networks, we anticipated that SNV would be rated more favorably in terms of usefulness, ease of use, and information display and interface design. Therefore, we established the following hypotheses:

H1. SNV receives a higher rating on the usefulness dimension than a traditional method.

H2. SNV receives a higher rating on the ease-of-use dimension than a traditional method.

H3. SNV receives a higher rating on information display and interface design than a traditional method.

EVALUATION RESULTS AND DISCUSSIONS

In the following, we report and discuss the results of our user evaluation study. Table 1 summarizes the means and standard deviations of various performance measures, and shows the *p*-values and results of testing the hypotheses using pairwise *t*-tests on the sample means.

Measure	SNV		Traditional Method		*p*-value	Testing Result
	Mean	S.D.	Mean	S.D.		
H1. Usefulness	**2.41**	1.05	4.73	1.72	0.00*	Supported
H2. Ease of use	**2.35**	1.02	3.88	1.63	0.00*	Supported
H3. Information display and interface design	**2.53**	0.97	4.23	1.56	0.00*	Supported
Notes: The range of rating is from 1 to 7, with 1 being the best.						

Table 1. Statistical results (alpha error* = 0.05)

Subjects' ratings of SNV on usefulness, ease of use, information display and interface design, and overall satisfaction were all significantly better than those of the traditional method. These encouraging results demonstrate the high usability of SNV in supporting BI analysis. We believe that SNV's visualization and capability to summarize a large amount of information contributed to the favorable results. For instance, a subject said: "The good thing about the system is that it is very complete. It provides an efficient mechanism to correlate the relation between stakeholders." Another subject said that "it is excellent to identify relationships. It is easy to find which node has more connections with other nodes." Subjects liked the fact that SNV helped them save their time and reduce their effort, as a subject said: "I like when you click a node you give some info about it in the bottom box." Another subject commented that it was "easy to understand and manipulate information (and) saves a lot of time." The large differences in ratings between the two methods reflected subjects' strong preference toward a user-friendly and visually-pleasing method such as SNV.

In contrast, the subjects were dissatisfied with the traditional method of BI analysis (Web searching and browsing) because of the difficulty in finding stakeholder information and the inconvenience of identifying stakeholder relationships. Many subjects complained about the lack of organization of information. For instance, a subject said that the "information is hard to compare, (and) there is no sense of organization." In particular, they had much difficulty finding relationships among the stakeholders. One subject said that it was "very hard to find links between shareholders" and another subject even considered this method "absolutely worthless" when frustrated with the difficulty. Nevertheless, some subjects liked the fact that they were familiar with Web searching and browsing and they could get as much information as they wanted. Based on the hypothesis testing results, we conclude that *H1, H2, and H3 were supported*.

CONCLUSIONS

The encouraging results from our evaluation study demonstrate the high usability of SNV as well as the visual approach used to develop the system. We believe that the system's comprehensiveness in information collection and

useful functionality for BI analysis and visualization contributed to the results. Given the importance of Internet in today's global economy, this research has shed light on research and practice about collecting and analyzing BI on the Web. This research thus contributes to (1) developing a new approach to BI system development, (2) providing a proof-of-concept prototype of the approach, and (3) offering insights into the way information visualization can assist human analysis work.

There are several limitations in this research. While Google provides a wide range of Web resources to help identify stakeholders, it may still be unable to cover certain Web resources that lack hyperlinks to other Web sites and it cannot identify stakeholders having no presence on the Web. The use of students in the user study might have limited the external validity of the results. A lack of prior work in BI research also has limited our literature review and the choice of a benchmark method in the user study.

We are pursuing several interesting research directions. As information of different types of stakeholders (e.g., customers, partners, media, etc.) can be modeled and integrated into system design, traditional stakeholder theory can be studied and possibly revised to incorporate new information and relationships identified by new technologies. Furthermore, newly designed BI systems may require evaluation approaches specifically developed for studying the new system features. Research in these evaluation methods will offer new insights into HCI research and the MIS discipline in general.

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