Granular interactions with electronic documents :
With a focus on electronic journal articles

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ABSTRACT

This paper addresses issues related to the design of an interface supporting fine grained interaction with documents, focusing on a particular type of scholarly documents, journal articles. In order to make a usable interface we need to understand user behaviors as well as technologies that present new possibilities of enhancing user experience. This paper reviews studies along three dimensions : user information behavior in searching/using documents, new conceptual/technical models for electronic documents, and interaction mechanisms. Putting together the understanding of users and enabling technologies, requirements and considerations in developing systems with granular interactions are discussed in the conclusion.

초 록

디지털 환경에서 물리적인 문헌 단위가 아닌 문헌의 논리적 하위 구성 요소의 접근과 활용이 기술적으로 가능해짐에 따라, 이용자의 전자문헌 활용을 지원할 수 있는 효과적인 인터페이스의 개발이 요청된다. 이 논문은 문헌의 하위 단위로의 접근을 지원하는 이용자 인터페이스 개발을 염두에 두고, 이용자의 정보이용행태, 전자 문헌 모델, 그리고 새로운 상호작용 메커니즘의 세가지 측면에서의 관련 연구를 조사하고 문헌 조사를 바탕으로 새로운 인터페이스 개발을 위한 기본적 요구 사항을 결론으로 도출한다

Keywords : electronic document, information granularity, user behavior, digital library interface
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1. Introduction

One of the challenges in designing digital library interfaces is how to support effective exploration of and interaction with information objects with different granularity. When we talk about 'granularity' in the context of digital libraries, we generally refer to two things : object (component) granularity of materials and scale granularity in metadata descriptions (e.g. time/geography units). Granularity in this paper means the former. This paper will focus on users' interactions with document components, especially of scholarly documents (e.g. journal articles).

In the electronic era, the information seeking and accessing environment has been drastically changed. In the present context of electronic document use, the following three aspects are considered important. First, the distinctions among phases of user involvement with the information are blurred. Before the proliferation of electronic documents, the phase of searching for documents of interest and the phase of reading the actual documents found in the searching phase were clearly separated, at least in terms of interactions with information systems. With the availability of full text online, searching and reading can be interwoven in a single system environment. Second, the concept of document itself is changing. Unlike paper-based documents, electronic documents no longer need to be considered as atomic entities. but as a set of interrelated information objects, which can be aggregated at many different levels of granularity. Given some basic defining features (unique identification, metadata, and content), any piece of information within a document can be a distinct information object. We call such an information object as a 'component' of document in this paper. Third, along with development and deployment of new technologies, novel forms of interaction can be provided.

Taken together, these changes bring a fundamental question to user interface design : How can user interactions with documents be enhanced in response to challenges and opportunities in this changing environment? This paper will approach this problem from one particular angle : issues related to the design of an interface supporting fine-grained interaction with documents.

This paper will first review studies that examine user behaviors associated with the use of documents, especially journal articles. Next, recent developments of technologies that enable different views of documents and effective exploration of them will be discussed. Finally, research addressing user interfaces for supporting document use will be presented. These three sections roughly correspond to the three changes mentioned above. In the conclusion, putting together the understanding of users and enabling technologies, requirements and considerations in developing systems with granular interactions will be discussed.

Further research issues will also be suggested.

2. User interaction with documents

Many studies in information science discuss user behavior in the context of information retrieval and investigate factors affecting users in the process of searching and evaluating documents. In a broader context of document use, in addition to this process of identifying relevant documents, the actual reading and use of the documents should also be taken into account. For the purpose of this discussion, the former will be referred to as the first phase, and the latter as the second phase in the rest of the paper. Among a fairly large number of studies on user behaviors, only those studies that seem to be closely related to the topic of granular interactions with document components will be included here.

Bates presents an exemplary study mostly related to the first phase. She proposes a model of information seeking called "berrypicking," which explains user behaviors in terms of interaction with texts. In this model, searching and browsing is depicted as an evolving process in which users change their needs and strategies while interacting with pieces of information (or in other words, components of documents) in several stages (Bates 1986). This model mostly concerns the first phase, the process of identifying relevant documents. On the other hand, Dillon addresses the actual reading of documents, a part of the second phase. After close examination of the reading process and human factors (cognitive and behavioral factors) involved in the process, he proposes a framework of reader?document interaction. The framework has four interrelated elements (a task model, an information model, manipulation skills and facilities, a serial reading processor) and describes reading as "a task-driven activity involving the setting of goals, the evolution and application of an information model, the manipulation of a documents and the visual processing of text images" (Dillon 1994, 164). An interesting aspect of Dillon's study is that it assumes that a user's own model of an information space, which includes his/her understanding of logical/physical structure of components, drives decisions throughout the process of reading.

While Bates and Dillon give general framework/model, some studies specifically deal with how and why scholars use documents or parts of documents. Belkin developed a classification scheme for task, goal, and information seeking behavior, and used the classification scheme in the analysis of how humanities scholars use texts. Data was collected through interviews with the humanities scholars (eleven senior-level faculty members in the Departments of English, History, and Philosophy). In observing user interactions with texts, he paid special attention "to the specific texts that are interacted with,

to the parts of the texts to which the scholars specifically address themselves, to the linguistic and other textual structures which are relevant to seeking and using text, and to the intentions which underlie these interactions with texts" (Belkin 1994, 5). He gives two examples of interaction types with different goals. One is the interaction with the goal of evaluating usefulness. Scholars first look at certain attributes of the text, such as author or title. After identifying potentially relevant documents (mostly in terms of topical relevance) based on these characteristics, users examine additional elements within the text, such as footnotes or acknowledgements, to determine not only the topicality but also the document's usefulness for the given task. Another type of interaction is that with the goal of discovery. This involves scanning the whole text and/or close reading of parts of the text. Further, in this type of interaction, scholars analyze the text moving back and forth between specific parts of texts and the text as a whole. Though Belkin does not explicitly explain the relationship between those two types of interactions, it seems apparent that both kinds of interaction should be combined in fulfilling an information need.

In a journal usage study (Dillon et al. 1989) which was carried out on a sample of regular journal readers interacting with a variety of articles, researchers focused on how users read journal articles and what they see as important in text usage. From the data collected through observation and interviews, consistent patterns in reading of individual articles were found. When readers find an article of interest by scanning the authors and titles, the first phase would be reading or skimming specific parts of the article (abstract, introduction, section headings, conclusions) to get a grasp of the content and determine its relevance. If they decide to proceed with the article after this initial cycle of interaction, they adopt one of two reading strategies depending on the task at hand, time available and the content of the article. The first strategy is serial reading, which involves careful detailed reading from beginning to end. Another is rapid scan reading, which involves reading some sections fully and only skimming or skipping other sections, usually in a non-serial manner. The journal usage analysis also has shown that most readers are aware of the concept of structure as the organizing principle of journal articles and use their knowledge of standard organization frames of scholarly articles when they interact with them. In other words, readers' models of the article structure affect and guide their exploration of articles. In particular, for non-serial access and reading, this model of structure plays an important role.

Bishop introduced the notion of the component to journal articles, analyzing how article components are used by students and faculty members (Bishop 1999). Similar to Dillon's discussion on the structure of a document, this study is based on the premise that a scientific

journal article has a salient structure (both physical and logical), making it possible to be taken apart. She argued that scholars use and 'mobilize' journal article components in many stages of their research including identifying and assessing relevant articles, reading articles, extracting pieces of information from articles (disaggregation), and organizing and integrating them into new documents (reaggregation). Her study focused on observing and analyzing component usage in terms of both underlying needs and actual practices of users. The data was drawn from focus groups, semi?structured interviews, usability tests, transaction logs, and user surveys associated with the University of Illinois Digital Libraries Initiative (DLI) project, in which a prototype system with component search and view features was developed and operated. For the first phase of interaction, the data showed behaviors quite similar to those found in Dillon's study. However, in Bishop's study, for the second phase, not only the reading patterns but also other behaviors associated with further use of acquired information were discussed. In other words, by introducing the concept of disaggregation and reaggregation, the entire cycle of journal usage could be covered. Disaggregation and reaggregation usually involve activities such as marking, note-taking, annotating, and finally, creating new documents.

These studies consistently show that certain parts or components of journal articles play well-established roles in overall journal article usage, and users often read parts of articles selectively and non-linearly. In the interaction with documents, more specifically journal articles which have relatively stable and well established structure, the structural information plays a vital role in both phases of document use. As for the subjective factors affecting user behaviors, users' goals in a certain situation, their tasks at hand, their knowledge or experience in a specific domain, individual preferences and cognitive styles have been found to be important. Studies reviewed in this section provide a better understanding of how users interact with texts and thus shed light on how electronic texts can be improved.

3. Electronic journal articles and documents

Electronic documents present great potential for searching, reading, and using documents. However, current electronic documents, especially journal articles, have advanced only slightly from paper forms, incorporating a few innovations such as hyperlinks and full text searching. Results of several surveys on electronic journal usage show that the most frequently mentioned advantages of electronic over paper journals are rapid access and convenience of searching (Tomney and Burton 1999 ; Rusch-Feja and Siebeky, 1999). Recently, besides those features, far more radical approaches to improving

electronic journals have been discussed and experimented with to take full advantage of the electronic medium (Moret 1997 ; Ackerman and Simonaitis 1997 ; Holoviak and Seitter 1997 ; Nadasky 1997). Liew et al. argue that many recent electronic journal projects have been centered on "the idea of escaping the static and rigid constraint of paper through digital alternatives" (Liew et al. 2000, 377).

The most important innovation widely discussed in research is different representations of information. In fact, many researchers believe that simply transferring paper documents to the electronic medium is insufficient and that structuring and presenting documents in ways not possible on paper offers great value (Dillon 1994 ; Fox et al. 1993 ; Kircz 1998).

Fox et al. present a spectrum of document representations in the context of a digital library, spanning from 'page image' to 'SGML,' and assume that paper-like page images is the least useful approach because of their limitations on organization and exploration. They suggest that digital libraries should present information in terms of usable objects. Specifically, they propose to model documents "as a collection of ordered hierarchies of content objects" (Fox et al 1993, 481) based on declarative representations (e.g., SGML). Theoretically, this object-oriented approach also allows sophisticated operations upon components of documents, including searching, browsing, extracting, linking, and even further manipulations supporting user tasks.

Zhao and Resh also point out that digital media transforms knowledge representation from the static linear text into dynamic objects with value-added features. Possibilities for presenting alternative and/or multiple structures for an electronic document are also mentioned as a distinct value that electronic documents can offer. They foresee that in future digital libraries, documents can be customized to meet the needs of individuals and small groups by packaging information objects as needed.

A progressive notion of the electronic document adopted from the electronic journal community is presented in the ACM's electronic publishing plan, which states ACM's vision about the future of scientific publishing and describes their own approach to achieve it (Denning and Rous 1995). According to the plan, ACM's database and services will be designed based on the following assumptions about electronic document : "Electronic documents whose contents are logically structured for search and retrieval will be preferred to electronic analogs of the printed page ; Visualization of scientific data through multimedia presentations will supplement and enhance text-only documents. ; Documents will be object-oriented, with some components being other objects already published on the Web. Not all documents will be read-only ; some will be interactive."

In the previous section, we divide user interaction with documents into two phases. Given the capacities of electronic

medium and considerable discussions on advanced electronic documents, we have a sound ground to make granular interactions possible. To implement a system that supports interactions with document components in both phases, we basically need an underlying data structure and a representation mechanism that allow each component to be identified separately and a number of related components to be linked at various levels. A project carried out at the University of Amsterdam, called "Communication in Physics" delves into the conceptual representation of scientific articles. They analyze journal articles in physics and propose a modular structure for electronic articles without presupposing any particular implementation technology. Their approach and the proposed model can be found in Kircz' s paper and Harmsze' s paper.

Kircz argued that the linear essay format of a traditional article is tailored to the paper medium, and in an electronic environment, where all articles and parts of them can be interconnected, scientific articles can be presented as a coherent set of linked modules. He pointed out that in order to serve users of academic articles better in finding and using relevant pieces of information, and thus to foster to-the-point scientific communication, new approaches to document representation are required. The first step of this development would be better structuring of existing documents, by proper mark-up of the text with tools like SGML. With information on the overall structure of the document, users can easily jump from section to section. The second step is a much more radical approach in which the linear structure of a document is shattered and rebuilt in a modular manner (Kircz 1998). Harmsze provided a detailed explanation on the model of the modular structure: "We define a module as a uniquely characterized, self-contained representation of a conceptual information unit that is aimed at communicating that information. Not its length, but the coherence and completeness of the information it contains makes it a module. Modules can be located, retrieved and consulted separately as well as in conjunction with related modules" (Harmsze 2002, 32). Another great opportunity offered by this modular representation is that, with the intrinsic connectivity between all parts of all works (within a certain boundary, for example, in a database or a defined set of databases being accessed), it allows users to collect only those modules specifically relevant to their needs from multiple articles and to build up their own 'document'. In order to specify ideas on the modularity in scientific articles, based on the analysis of a sample of physics articles, Kircz presents a heuristic model for a modular presentation of scientific information. The model is comprised of six standard modules: Meta information module, Goal and setting module, Methods module, Results module, Discussion module, and Conclusion module (Kircz 1997).

Phelps and Wilensky proposed a new model of digital documents, named the

'multivalent document' (Phelps and Wilensky 1996). Unlike the above "Communication in Physics" studies which have clear emphasis on conceptual modeling, actual system developments have been done as proofs-of-concept. Their approach to define components is also quite different. In the multivalent model, a single document comprises multiple 'layers' of related data. Each layer presents "homogeneous content," with some distinct characteristics. In addition, layers are associated with dynamically loadable program objects, called 'behavior', which enable various manipulations of the content and relates layers to other objects (layers and/or behaviors). Behaviors also bind together separate but related layers to present a single conceptual document. For example, a table layer includes a table within a document with an associated behavior of sort, and can be related to another layer that has some textual information related to that table. Thus, a multivalent document is defined as interacting layers of content and functional behaviors. It should be noted that in the multivalent scheme, layers are not necessarily defined by the logical coherence or topical relationships of contents. Any small piece of the content (e.g. a table) can be a layer if it has a distinct characteristic and if there is a need to associate a certain behaviors (e.g. table sorting) to it. The strength of this approach lies in its dynamic, active, and flexible characteristics. While a document is conceived as a collection of digital objects like other approaches, components of documents can be assembled and correlated dynamically. Moreover, new layers can be added at any time, thus not only the original author of a document but also others can add additional content or functions later. A very useful example of such an addition is annotations (Phelps and Wilensky 2001). This approach seems to be a way to cover the second phase of granular interaction in an electronic system.

This discussion on new document models brings forth issues related to user interfaces and interactions. For example, how to present fine-grained information objects (sections in structured documents, components, modules, layers) properly, how to show the relationships among objects in an intuitive way, how to aid users in aggregating objects to build up a coherent document, and how to incorporate functions such as extracting and note-taking into the system in a seamless way.

4. User interface and interaction design

In this section, studies on user interfaces adopting novel interaction techniques or implementing new approaches to document use will be reviewed. Among the many digital library interfaces proposed and evaluated, this review will be limited to those designed to present documents at the level of individual documents and parts thereof. A particular challenge for the

interfaces for document component use is how to enable users to focus on the components of the document that make it relevant, without losing the view of the overall structure and relationships between those components and the whole document.

Hertzum et al. introduced the 'focused retrieval' concept to structured document retrieval and implemented a prototype system, named TeSS. At the point of the user interface, the main feature of the system is that it recommends 'best entry points' to users when it returns a search result (Hertzum et al. 2001). In fact, focused retrieval is intended to identify the most relevant components or parts of a document and to inform users where to start reading in the form of best entry points. It is noted that best entry points can be set at different levels in the hierarchical structure, according to the relative relevance of the information chunks in the document. For example, a whole section would be returned if all or most of its subsections seem to be similarly relevant, but if a specific subsection is deemed more highly relevant than others, a best entry point would be the subsection. By using both the content and the hierarchical structure of documents, the TeSS interface presents useful elements with appropriate granularity to users. More specifically, the interface shows the entire structure of the document in a window with marks of the best entry points, and users can open the text viewer at a suggested entry point or at any other level in the structure. Results of an empirical study on this interface showed that users usually follow the suggested entry points or start at one level above in the hierarchy from the suggested points.

Another approach to presenting components of documents with structural information was discussed recently (Vegas et al. 2002 ; Crestani et al. 2001 ; Crestani et al. 2002). In order to provide a user interface with 'explanatory' and 'selective feedback' capabilities, which the authors believe are essential for effective interaction with structured documents, Crestani et al. introduced a visualization metaphor for a structured document, called 'docball' (Crestani et al. 2001). Docball is a circular iconic representation, which shows a structural element at higher level in the inner circle and presents all sub-elements in the outer circles. The interface has a 'query area' where users enter query text and also set a specificity level (the level upon which the relevance of each document is estimated), a 'query history area' where the results of the query are presented, and a 'document display area' which is comprised of a text area and a docball area. When a user selects a specific element from the query history area, the content is displayed and the corresponding location of the element in the docball is highlighted. The docball depicts the estimated relevance of each element in different colors and thus can express the distribution of relevant elements at various structural levels in the document, as well as their relative degree of relevance. In this way, the interface can 'explain' why

and where relevant information is retrieved. In addition, a selective feedback function is also incorporated. By moving the mouse on any of the elements in the docball users can explore the contents, and then select only those elements highly relevant to their needs for relevance feedback (Vegas et al. 2002). An evaluation of the proposed graphical interface reported that users easily understood the visual representation of the structured document (Crestani et al. 2001).

The 'docball' interface discussed above indicates that a visual representation tightly coupled with a text viewer can be promising for supporting document component use. During the past several years, research on visual interfaces and information visualization has been conducted widely. However, while many studies address problems such as effective exploration in large information spaces or rapid filtering of data subsets (Masui 1998 ; Robertson and Mackinlay 1993; Mackinlay et al. 1991 ; Bederson and Hollan 1994 ; Roth et al. 1996), applications of visualization techniques to navigating within an individual document have not been tried much. Recently, some empirical studies have been conducted to investigate whether information visualization supports reading of electronic documents, and which technique or interface is better than others for this purpose (Hornbæk and Frøkjær 2001 ; Hornbæk et al. 2002).

Finally, Phelps and Wilensky implemented an interface based on their multivalent document model, a multivalent browser (Phelps and Wilensky 1996). Unlike the above other studies, the value of this interface is that users can 'work' with the document, not just 'read' it. The browser includes many advanced features such as annotations (highlight, hyperlink, post-it style note, executable editor marks, etc.), lenses (magnify lens, plain view, ruler, etc.), and data manipulation tools (table sorting, speed reading, etc.). All these features are implemented as third-party extensions called behaviors, and thus desired functionalities can be added or customized. In a sense, this interface can support disaggregation and reaggregation of document components as discussed in Bishop (Bishop 1999).

5. Conclusions

Based on the belief that in order to make a usable interface we need to understand user behaviors as well as technologies that present new possibilities of enhancing user experience, this paper reviewed studies along three dimensions : user information behavior in searching/using documents, new conceptual/technical models for electronic documents, and interaction mechanisms. The problem this paper tried to address in particular is related to document component use.

Research on user interactions with documents shows that users often consult parts of documents selectively and proceed to read non-linearly. In addition, users' perceptions of the overall structure of the

document often guide the process of reading, especially for partial, non-linear reading. For the purpose of discussion, user interaction with documents was divided into two phases in this paper : the identifying phase (which includes the scanning and skimming of document contents to make relevance judgments), and the reading/using phase (detailed reading of the content either in a linear fashion or not, combined with users' own processing such as underlining, annotating, etc.). In both phases, fine-grained interaction with various parts of documents, if it is provided adequately, can increase the value of electronic documents substantially by supporting and enhancing the component use, which is an important pattern found in users' behavior.

Two most basic requirements for implementing granular interactions into systems can be drawn from prior studies reviewed in this paper : 1) a new structure or representation scheme for documents and parts thereof, and 2) novel interfaces. Specifically, a document should be divided into searchable objects (components) and the overall structure of components should be prepared. When users interact with components, the interface should lead users to the most useful components. With the view of the overall structure and a clear mark of the current position within the whole document, users should be able to move back and forth among components easily. Moving on the second phase, the reading interface should include advanced features such as annotation to support 'active reading' as defined by Adler and Doren (Adler and Doren 1972). In addition, as the second phase of interaction involves activities spanning multiple documents, it is desirable to provide tools to manipulate objects extracted from documents (components themselves and notes/annotations associated with them) in a single interface.

Though these new features and the rationale behind them seem quite appealing, there are also things to be carefully considered. Probably the most important concern is the tension between innovation and established routines. Bishop's studies demonstrate the point (Bishop 1999, Bishop et al. 2000). Even though most users expressed great interests in the basic idea of component features, which was implemented in University of Illinois DLI system, in the interview sessions, the transaction logs of the system showed that those features were seldom used. Besides the fact that some features were somehow hidden because of the poor design, Bishop attributed the discrepancy between users' interests and the actual use to a lack of commitment. Her focus group data suggest that conceivable benefit of component features (not a general notion but the specific implementation in that system) was not sufficiently large to motivate them to break their everyday-routines, or familiar pattern which they had been developed for a long time. How to resolve this kind of problem is certainly an issue in almost every novel system. Another concern is that the use of component

features can be declined if the system-presented model of documents does not accommodate what users have in their mind. In other words, the structure (components and their relationships) the system presents to users should somehow meet users' information model. It requires a careful analysis of document structure (the internal information model) and also a closer look at users' cognitive/behavioral aspects to understand what constitutes users' information model and what kinds of cues lead users identify and use components.

Even though this paper has been deliberately limited to a case of journal articles, most parts of the discussion seem to be applicable to any kind of electronic documents. However, journal articles have a relatively stable and well-established structure in general and users of scholarly journal articles shares similar tasks to some extent in the academic settings. Thus, implications drawn from user studies reviewed in this paper, that users show systematic patterns in the use of certain components and thus designing those behavior into a system is possible and desirable, might not hold in other situations. So, user behavior studies in other domain or for other kinds of materials specifically designed to see patterns of component use can be an interesting study.

In order to cover the whole cycle of document use, this paper defines two phases. Review of literature reveals that way more research has been done with regard to the first phase, especially for electronic documents. However, as electronic documents become prevailing, the importance of supporting the second phases of the use will increase. Though some studies such as projects on reading appliance (Marshall et al. 1999) address the problem of 'reading electronically', we still do not know much about the second phase processing. To make a usable features supporting component use, we will need to solve many problems such as designing a reasonable default granularity level, which need solid understanding of the whole process.

Since the discussion on the interface requirements presented in this paper is solely relied on a literature review and done without any specific implementation in mind, we suggest only high-level, non-specific, generic requirements. We hope this generic discussion could constitute the first step towards the development of the interface we envision, however, we acknowledge that the requirements we suggest are too broad to be incorporated into actual design. Further investigation is required to come up with a full-fledged set of requirements.

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