Accessing Educational Digital Libraries through Adaptive Information Visualization

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ABSTRACT

The focus of the research presented in this paper has been to explore possible approaches for providing dynamic personalized information access to educational digital libraries (EDL) through *adaptive information visualization*. While information visualization is the newest paradigm of information access, it has several unique features that distinguish it from other paradigms, such as information retrieval, filtering, and browsing. This paper provides a brief overview of our recent work by presenting three systems: Knowledge See II, NavEx Advise and QuizVIBE. These systems vary in the underlying visualization approaches, the adaptation mechanisms behind the visualization, and the types of educational resources. Altogether they demonstrate the potential of adaptive information visualization in the context of EDL.

1. INTRODUCTION

Personalization is one of the recognized priority research strands in the field of Digital Libraries (DL). One of the key problems of personalization in DL context is to help the users locate resources that are relevant to their goals, knowledge, and interests through *personalized access* to resources [10]. Personalized access is especially important for educational digital libraries. The results of several research projects have shown that the ability to choose appropriate educational resources requires a relatively high level of background or subject knowledge [4; 18]. We can hardly expect an average student to be able to locate relevant resources without external help, even in a relatively small EDL. In the context of traditional libraries this help is provided by a librarian. In the context of EDL it can be provided by automatic personalization.

The multitude of work on personalized information access in DL context can be classified by the underlying way (paradigm) of information access such as information retrieval (IR), information filtering and recommendation (IFR), hypertext browsing (HB) or information visualization (IV) [9]. Our research team was traditionally focused on personalized HB (also known as adaptive navigation support). More recently, we started to explore the prospects personalized information visualization. While IV is the newest paradigm of information access, it has several unique features that distinguish it from IR, IFR, and HB. Information visualization allows users to see a relatively large set of information resources as a whole, while still being able to discern individual resources. These resources are usually presented in two or three dimensions using various visual cues to show document properties and the relative positioning of documents, in order to express several different relationships between the documents. As a result, a fully two- or three-dimensional IV has a much higher expressive power for organizing information resources than an IR/IFR system, since the latter is limited to a one-dimensional expressive power (a list of links) or hypertext. The higher expressive power of information visualization is usually complemented by a higher level of interactivity (Figure 1): most information visualization systems allow the user to manipulate the presented documents observing the changes in visualization. In the context of information access, such pioneer systems as VIBE [17], Envision [13], and MovieFinder [1] have demonstrated the benefits of interactive two-dimensional visualization.

Both expressive power and interactivity are important for personalized access. Expressive power allows the system to present a variety of personalized details about the documents while interactivity supports better user modeling [12]. Despite that, major research on adaptive information visualization has not yet begun. While dozens of projects were devoted to developing techniques for personalized information access within the three older paradigms [3; 16], at the beginning of our work we have found that only one project – the Lighthouse system [15] – focused on adaptive information visualizations.

The approach to adaptive information visualization explored by our team was motivated by our earlier work on adaptive navigation support in educational hypermedia. Adaptive navigation support, an outgrowth of the field of adaptive hypermedia [3], is a group of technologies created to help users find relevant information resources within hyperspace. Within this group of technologies, we extensively explored *adaptive annotation*, which provides navigation support by attaching personalized visual cues to hyperlinks. These cues express various attributes of the documents behind the links and help users select the most relevant links to follow. By the nature of this technology it can be used in conjunction with many visualization approaches.

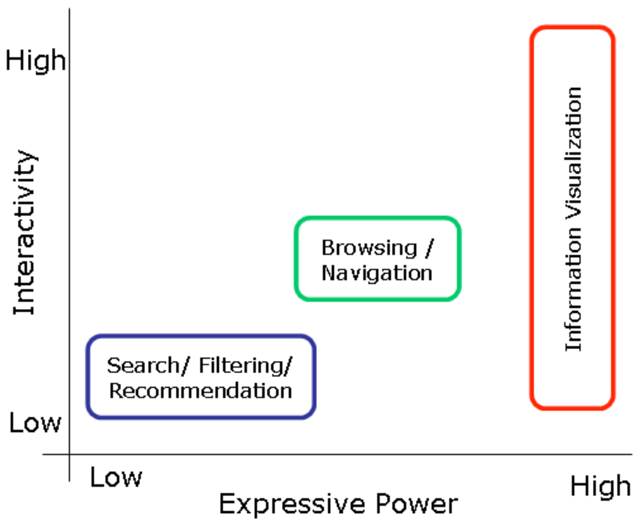

Figure 1 - Interactivity and expressive power of the major information access paradigms

The goal of our work over the last two years was to explore the prospects of annotation-based adaptive visualization in the context of EDL. We attempted to vary the underlying visualization approaches, the adaptation mechanisms behind the visualization, and the types of educational resources. This paper provides a brief overview of our work by presenting three systems: Knowledge See II, NavEx ADVISE and QuizVIBE that vary in almost all of the listed aspects. The presentation of the systems is followed by a brief summary and a discussion of future work.

2. KNOWLEDGE SEA II

Knowledge Sea is the platform we use to explore map-based information access. Knowledge Sea uses cell-based maps developed using Self-Organizing Maps [14] to provide access to over 25,000 documents related to teaching C programming, distributed over the Web. The cell-based map is an 8-by-8 table of cells where links to similar resources are places close to each other. Every cell groups links to similar pages of open and closed corpus material, with adjacent cells presenting similar material.

When a student clicks on one of the cells of the map, the cell "opens" and shows the list of available resources inside the cell. Typically, behind each of these links is one section from a web-based C programming tutorial or book. The right side of Figure 2 presents a fragment of one the map cells. The top part of the cell shows a small map that presents the position of this cell in the Knowledge Sea map and the top five keywords of the open cell. The bottom part shows the list of resources. Each resource link has two parts: the identification of the tutorial it belongs to (typically, the author's name, which also serves as a shortcut to the root of the tutorial) and the title of the section. Knowledge Sea II extends the earlier developed Knowledge Sea system [7] with social navigation support that is based on the learner's previous interaction with the system. It provides "traffic-based" and "annotation-based" navigation support on the level of map cells and on the level of individual links.

The idea of traffic-based social navigation support is to visualize the navigational history of each group of learners. The intensity of the background color of each cell on the map represents the intensity of group access to the documents located in the cell [6] . The map starts with a very light shade of blue for each cell and, as the students progress, more frequently visited cells become darker and darker so that students can easily follow the footprints of others. Students can also view the history of their own interaction with the system. The color of the "human" icon shown in each cell reflects the number of cell visits done by the individual student. The more visits, the darker the color of the icon. In this way, students can compare their interaction with the system with those of their total community members by comparing the color of the human icon to the background color (Figure 2). This information helps the students to decide what cell to visit next.

Traffic-based navigation support is also provided inside the cell. Each resource is augmented with a human icon on a blue background. Similar to the map, the background color of the small square represents the intensity of group activity and the color of human icon represents the intensity of user activity. To eliminate unreliable traffic Knowledge Sea II takes into account time spent reading each page.

Annotation-based social navigation support in Knowledge Sea II is based on the annotations provided by the students [11]. Annotation, a natural by-product of reading activity, provides stronger evidence of importance of the viewed page comparing with traffic alone. Resources with students' annotations are augmented with visual cues. On the map, the cell including resources with user annotations are augmented with a small sticky and the cells with group annotation are augmented with a thermometer icon. The temperature grows warmer when more students associate positive annotations with the page. Inside the cell, resources with user annotation are annotated with a sticky note, or a thumbs up depending on the type of the note and resources with group annotations are augmented the same thermometer icon.

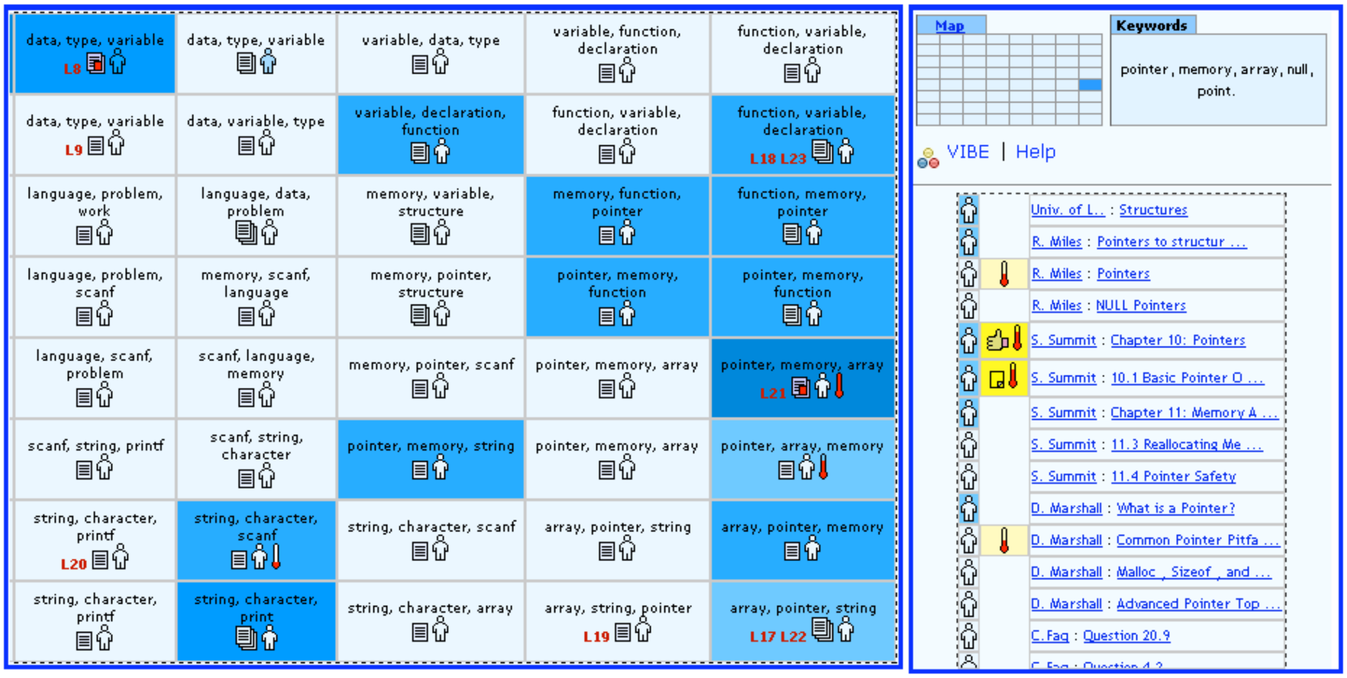

Figure 2 – A fragment of Knowledge Sea map and a map cell with the list of resources

3. NavEx ADVISE

NavEx ADVISE provides an adaptive visualization for C language examples. It uses a spatial similarity map produced by ADVISE 2D using a spring modeling approach. ADVISE 2D is a generic visualization tool build by our team to explore personalized access to Web based documents using spring maps. To develop NavEx ADVISE we integrated ADVISE 2D into NavEx (Brusilovsky, Yudelson, Sosnovsky, 2006), an adaptive hypertext system, which provides personalized access to Web based educational examples. The integrated system uses visualization engine of ADVISE 2D and the personalization engine of NavEx (Figure 3). The job of the spring modeling visualization engine is to allocate examples in a 2 dimensional space so that the examples are closer to each other if they are similar and further if they are dissimilar. The job of the personalization engine is to define the icon to display each example

In order to get the similarity values between examples, knowledge-based index with a set of concepts from the C-programming domain was generated. The concepts are C language constructs such as *decl_var*, *void*, *include*, *main_func*, etc and the indexing process was done automatically by a domain-specific parser. Using the index, we were able to example vectors following a vector space model. Each vector in this model represents an example. The vectors are composed of concepts stored in the examples and each column of the vectors represents single concept. The value of the vector component means the occurrence and importance of the concept in an example using TF-IDF weighting. If a concept appears in an example, the corresponding column has a value greater than 0 (0 when absent). TF means the frequency of the concept in a document and IDF means inverse of the number of examples which contain the concept. Therefore, by deciding weight of each concept as TF multiplied by IDF, we could give more weight to a concept which appears more frequently in a small portion of examples, not dispersed over a whole corpus. Similarity between two of these vectors were achieved by calculating the cosine angle between them and it ranges from 0 to 1, which means complete dissimilarity and similarity respectively. Using this similarity information, the examples are allocated in the 2 dimensional space of the screen following the rule mentioned earlier: the similar, the closer. For example, we can notice the examples like “L11:countdown1.c” and “L11:countdown2.c” are placed closer to each other whereas they are far from the ones like “L21:strcomp.c”, which might be quite different from them in terms of the concepts it contains.

Personalization is achieved by the icons displayed beside of the title of the examples. Each example bears two kinds of annotation: progress-based and prerequisite-based. The progress-based annotation shown as a partially-filled green bullet is calculated as simply the percentage of example code lines already explored by the student, compared to the total number of annotated lines in the example (Figure 4). Computation of prerequisite-based “readiness” for an example is based on a concept-level model of student knowledge. An example is considered ready for exploration if all of its prerequisite concepts are already known to the student to a specified extent. This information is shared and synced with NavEx, so that NavEx ADVISE can provide information according to individual student's progress in the domain. More detailed description on NavEx ADVISE is provided in [5].

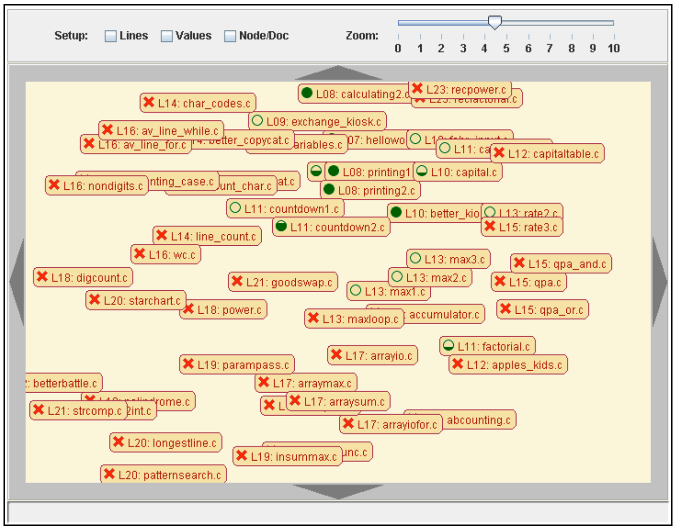

Figure 3 – NavEx ADVISE visualizing educational examples

Figure 4 – Annotation cues in NavEx

4. QuizVIBE

QuizVIBE, a system, which provides personalized access to a repository of self-assessment examples, is based on VIBE approach. VIBE [17] is a relevance-based spatial visualization approach. It is somewhat similar to spatial similarity approaches like ADVISE 2D, but they are different in that ADVISE 2D considers inter-similarity among documents (examples) but VIBE considers similarities between documents and POIs (Points Of Interest). The basic logic of this algorithm is that the documents are allocated according to their relative similarities to the position of POIs. Therefore, if a document has similarity 0.6 and 0.3 to POI A and B, then it is located in a position which is two times closer to A than B. Users are allowed to manipulate and move multiple POIs and therefore, the position of all documents are updated to their relationships to the POIs in a real time.

To explore the potential of VIBE visualization, we re-implemented it in ADVISE VIBE tool, which can work in a Web-based environment and can be re-used with different type of resources. QuizVIBE uses ADVISE VIBE to visualize questions (documents) in their relation to programming concepts (POIs) in a VIBE framework. Figure 5 shows 12 concepts and 8 questions in the C programming language domain. The concepts were automatically extracted from C source codes of the questions and were used for similarity calculation between the questions and the POIs according to the vector space model and the TF-IDF weighting scheme. Users can drag the square shaped POIs and according to their movements the locations of the questions are updated automatically. Therefore, they are able to identify which question is about which concept and access relevant information to their needs. In the figure below, we can notice the questions are located closer to the concepts like *variable_declaration* or *variable_initialization* and are further from the concepts such as *char* or *include*, and therefore we can understand the important concepts of the questions displayed. Users can double click the target icon, open the questions, and then proceed with answering them. QuizVIBE also supports some new visualization helper functions which were not included in the original VIBE: similarity discs and filters, as well as the standard visualization distortion features such as zooming, rotating, and panning.

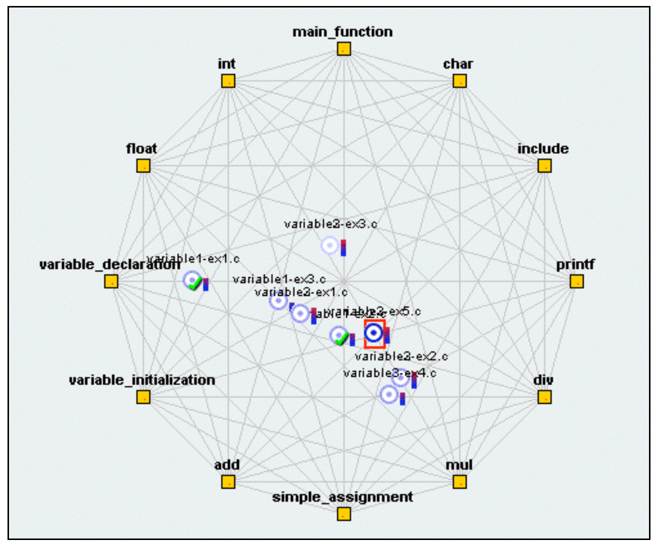

Figure 5 – QuizVIBE visualizing questions (circular target icons) and concepts (squares)

Figure 6 – Annotation cues in QuizVIBE

Along with this basic visualization, adaptive annotations are displayed with visual cues (Figure 6). Here, two types of information are provided: progress and knowledge. Question progress is a binary entry, whether a question has been solved correctly at least once. If it has, each question bears a checkmark icon, which means this question was solved. Students' knowledge about a certain concept is also calculated by the system and the color of the target icons of each question encodes the level of the knowledge. There are five color levels ranging from deep blue to very light bluish grey, which means lower to higher knowledge level, so that users can be attracted more with higher intensity colored icons. This adaptive annotation is shared and synced with QuizGuide [8] which provides HTML based adaptive quiz access. Detailed algorithm and information are provided in [2].

5. CONCLUSIONS and FUTURE WORK

We presented several projects focusing on providing personalized access to educational digital libraries through adaptive visualization. The projects use different visualization approaches and different adaptation engines, yet they are similar in one aspect: personalization is provided through adaptive visual cues on various kinds of information maps. Our next goal is to explore personalized layout algorithms where the positioning of information items is influenced by the user model. This work is supported by NSF grant 0447083 to the first author.

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