OASIS System for Organizing, Annotating, and Serving Information to Students without Sight

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ABSTRACT
OASIS (Organizing, Annotating, and Serving Information to Students without Sight) is a novel assistive and rehabilitative system to help students who are blind in accessing digital libraries, with the goal of helping them solve complex problems, using multiple books and other digital information sources simultaneously. Currently, users who are blind can access digital information only with the help of screen reader programs (such as JAWS for Windows). Even though these screen reader software render a given digital text accessible through audio or Braille, it is generally very difficult and time consuming for a user who is blind to search and effectively use relevant content in a digital collection. The problem is compounded when a user needs to drive from multiple books, for example when a student is studying on a particular topic using a digital library environment. OASIS brings the relevant digital content closer to users who are blind and visually impaired, and makes it accessible with minimal interactions, by segmenting, organizing, annotating, and cross-linking digital books to render them easily accessible and navigable by learners without sight.

INTRODUCTION
As part of the iCare project at Arizona State University, in partnership with the Rehabilitation Services Administration and Foundation for Blind Children, we are developing the OASIS (*Organizing, Annotating, and Serving Information to Students without Sight*) digital library system for students who are blind and visually impaired. The ultimate goal of OASIS is to enable these students to effectively use relevant content from multiple books, notes, and web sources when studying on a particular topic. To achieve this goal, OASIS segments, organizes, annotates, and cross-links digital books to render them easily accessible and navigable by learners without sight

Users who are blind cannot simply locate, point, and click on electronic documents; they have to listen searching for the link in the document using only the keyboard and a screen reader program. (Hoz and Asnat, 2001) highlighted that students who are blind use four learning techniques to deal with mostly-linear textual information: summarizing in writing, summarizing mentally or orally, identifying and recognizing ideas, and elaborating on the text with images-pictures from memory. On the coarsest level, sighted users are able to perceive these graphical elements, such as icons, and their relationships without identifying the detailed functionality that

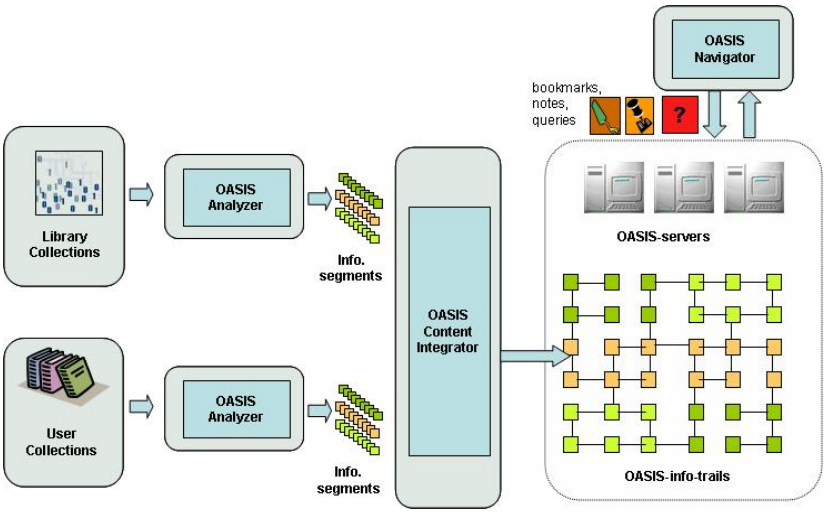

Figure 1. OASIS' segment, enrich, annotate (SEA) approach for the creation of information trails suitable for adaptive navigation within complex information spaces

each of these elements provides. To access more detailed information levels, the human visual system allows us to zoom into individual parts of the user interface.

When users have to follow non-linear pathways, however, the navigation is much harder. This creates confusion on the learner who is blind as to how the current page fits into the big picture and how to proceed from that point. Consequently, it is much easier for individuals who are blind to get disoriented in a complex digital environment. Some researches have been studied on easily accessible system for students who are blind. (Kopecek, 1998) presented a blind user oriented hypertext AUDIS system which helps visually impaired students to navigate and locate relevant information by tagging the original textbook with a subset of HTML. BLYNX (Blynx, 1996) is a tool tailored for blind and visually handicapped users to navigate Web pages with Lynx. Different from AUDIS and BLYNX, a particular goal of OASIS is to enable students who are blind to leverage relevant content from multiple books when studying on a particular topic by taking advantage of text segments, summarization, content "relationship mining", and context-aware navigation techniques (Kim et al., 2005; Candan et al., 2006; Kim and Candan, 2006; Qi and Candan, 2006; Sapino et al., 2007). In particular, our goal of reducing the cognitive navigational load on students who are blind involves various technical challenges, some of which are listed below:

- The system establishes, as precisely as possible, what information is needed, based on the current context, access history, user preferences and information, and presents this information to users in a proper way.
- Information sources, such as digital books or studying material, are segmented into semantic information units for proper information presentation to end users. Relationships of these information units within or across books are captured and used in providing context dependent navigation recommendations which enable users to find relevant material (books, book chapters, annotations) more quickly.
- Students who are blind are able to easily locate the desired information providing keywords, using predefined keystrokes, as well as following provided guidance links. Content "summarization" techniques are provided to help individuals who are blind skim through available content more quickly to identify relevant material.

OASIS provides a fully accessible digital library to support students who are blind or visually impaired in successfully accessing books and other educational material. An initial version of the OASIS is being developed and deployed with Foundation for Blind Children (FBC) of Arizona. The cooperation with FBC and continuous feedback from the end users from the initial stages of the OASIS project helped us properly plan and prioritize the development process. The current version supports the following functionalities:

- It supports public and personal information sources to be searched, retrieved and navigated by end users as shown in Figure 1. The students who are blind can access the information not only in public library collection but also in the personal collections where users store their own digital information material including digital books, papers and personal notes.
- It provides semi-automated, interactive content registration tools for helping the content providers in uploading their material to OASIS servers. In particular, the content being registered is analyzed and adapted for effective navigation and search.
- OASIS content access interfaces provide integrated and personalized access to public and personal library collections. In particular, OASIS supports both browsing/reading (linear, less guidance) as well as focused search (learning, context, more guidance) access mechanism.

The context-aware recommendations for better navigational purpose, as well as user profiling and context-sensitive, guided-segmentation mechanism will be incorporated to the system in the near future. Overall system architecture of the OASIS in reference to its initial prototype is presented next in the following Section.

SYSTEM ARCHITECTURE

OASIS adopts a server-based software architecture that is a versatile, message-based and modular infrastructure. Therefore, it provides a good usability, flexibility, interoperability, and scalability. The standard web-browser based interfaces make OASIS quite convenient for end users to access the system at any place and any time, provided that Internet connection is available. The OASIS servers, on the other hand, play an important role to pre- and post-process, analyze, store, reconstruct and manage information resources.

Web-browser Interface

The web-browser interfaces of OASIS consist of two user interaction modules, that is, content registration module and content access module. The interfaces use JavaScripts and AJAX technologies to interact with users and to control the information management, navigation and search.

Content registration module provides semi-automated, interactive functions to help the content providers in uploading their material to OASIS servers. The content being registered is processed, analyzed, stored and adapted in servers for effective navigation and search. Using *content registration interface*, the librarians with the administrator rights can upload books to the public library collection. Registered individuals can also upload their own libraries into the system as personal collections. During search and navigation, information from personal library is accessible along with the public library collections via the *content access module*. Besides uploading books to library collections, another important role of content registration module is to provide content segmentation. With this function, a long digital book is segmented into several

semantic content fragments or information units. The relationships among these information units within and across books are then studied and mined for effective navigation and search.

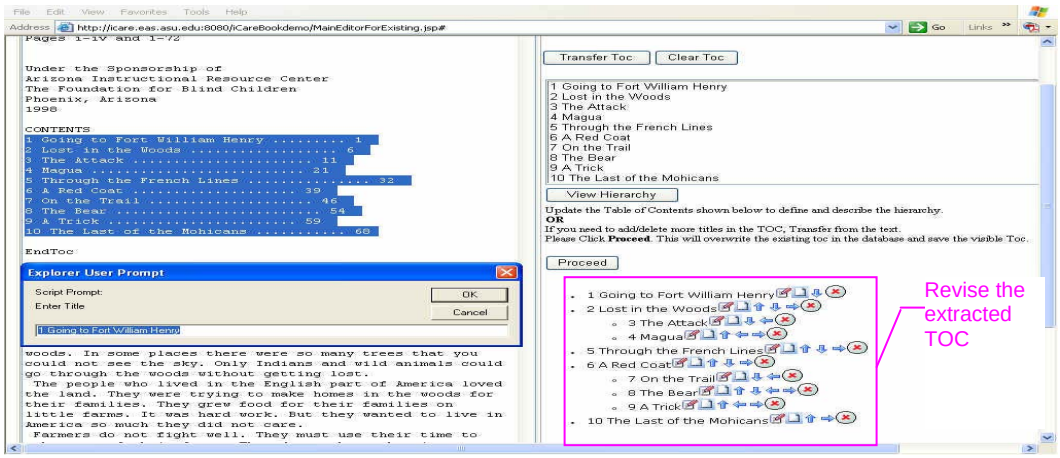

Figure 2. OASIS User Interface for Editing TOC

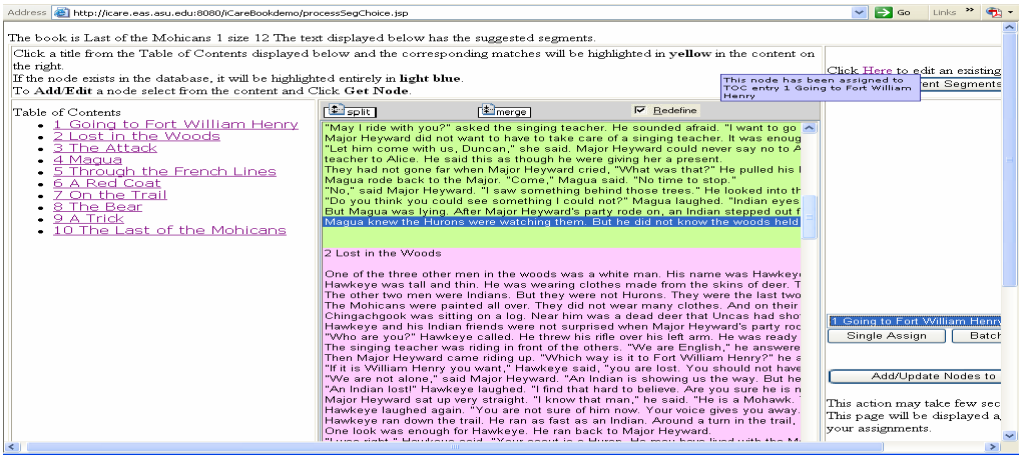

Figure 3. OASIS User Interface for Adjusting Segmentation and Assignment

The information units extracted from a digital text can be Table of Content (ToC) based, if a ToC is available. However, the context-aware segmentation algorithms used in OASIS enable finer granularity information unit extraction from the books and other non-ToC material.

To register a book, a librarian or a volunteer first uploads a book from the local disk to the OASIS server. A user interface for ToC capturing/editing is provided to enable extraction of the table of content from the book. The user interface also enables the user to edit, revise, or reconstruct the hierarchical structure of ToC (Figure 2). With the guidance of ToC, the entire book is segmented into finer granularity information units and these information units are mapped to the corresponding ToC entries. In order to correct any over- or under-segmentation, the user can further adjust the segmentation and ToC assignment results (Figure 3). Note that the visual-interfaces shown in Figure 2 and Figure 3 are designed for the sighted librarians or volunteers to help prepare the book for more effective search and navigation. The students who are blind or visional impaired are provided with a f*ast-registration* option which enables them to register books with fewer interactions: the semi-automated segmentation and ToC assignment

algorithms help accomplish the task without need for extra manual adjustments. The system provides an interface for parents or friends of these students revise and adjust the existing fast-registered books in the personal book collection later.

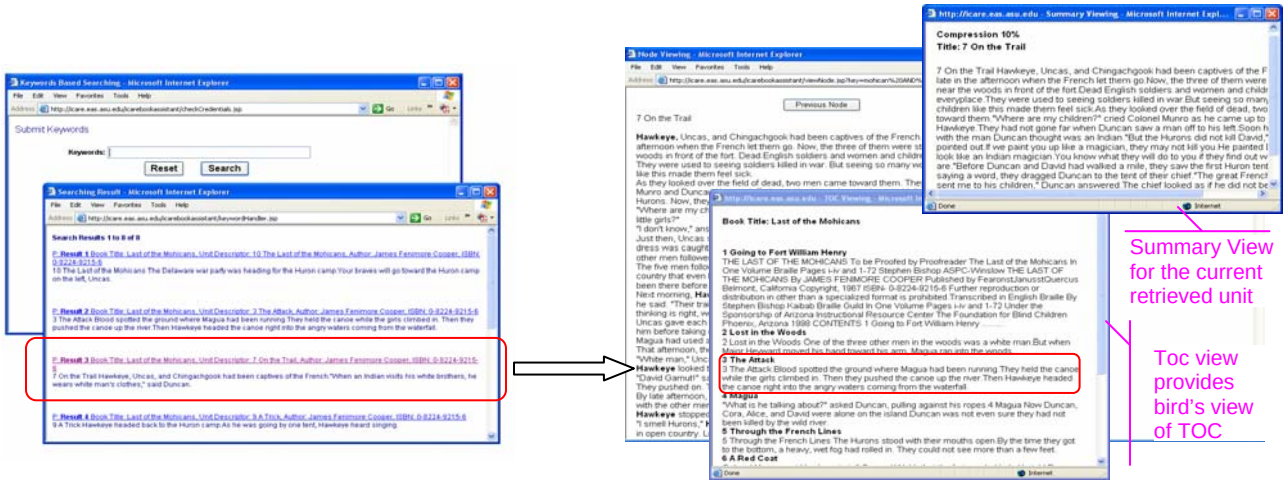

Figure 4. OASIS Search and Navigation Interface

OASIS content access module provides integrated and personalized access to public and personal library collections. It supports both browsing/reading as well as focused search access mechanisms. OASIS listens to user's keystroke events; brings up the most relevant content to the user if a query is provided; describes and presents the content summaries, at multiple-levels of granularity, of the information units to enable skimming, and allows the user to freely browse the entire collection through the Web browser. In particular, OASIS content access module is designed to be fully accessible through keyboard and screen reader software (such as JAWS) for students who are blind.

After logging onto the OASIS–Search web site (http://icare.eas.asu.edu/icarebook assistant/), the user is able to query the entire digital library. A search-result page that contains a list of the relevant information units to user's query is presented to user. Figure 4 gives a snapshot of the search interfaces. The user can add the prefix to the keyword to limit the retrieving scope, more specifically, "I:" denotes only searching the information in individual's personal digital library, "P:" stands for accessing the information in the public collection created by FBC. Otherwise, the retrieved contents come from both public and personal collections. Each returned entry is annotated with an automatically generated summary of the content of the information unit to help the user choose whether to read the unit or not.

While JAWS reads the snippets of returned information units (nodes) to the user, he or she can zoom into the full content of these information units using the predefined hotkeys. When the retrieved content unit is long (which may make it hard for the user who is blind to read the entire unit line by line with the help of JAWS), the user can launch a "summarization view" page, using keystroke ALT + s, to get the main ideas of the information unit quickly. The user can change the degree of "summarization" of the information unit to get higher- or lower-level summaries. With the help of the hotkeys, the user can jump to the previous or the following information units in the book as well. In addition, a "ToC -view" page that provides a bird's eye

view of the book's content can be launched by ALT + t. The ToC-view page enables the user who is blind to navigate within the table of content of the book. Figure 4 gives a snapshot of "summarization view" and "ToC-view" pages with their corresponding information units. With these functionalities, the user who is blind can have a better sense of what the unit is about, where the unit is relative to the content of the entire book, and where to go from the current unit. Note that users do not need to have a significant training to learn how to use the OASIS, except for remembering a few, informative key combinations.

Applications in the Server

OASIS servers consist of six main components: 1) a file processor that parses input files to retrieve the book contents; 2) a segmentation processor that partitions the file content into semantically-coherent information units for searching and navigation; 3) a summarization processor that provides multi-level summarization, from the lowest (segmented information units) to the highest (the entire book); 4) a database manager that stores and maintains the metadata of books and user information; 5) an indexing/retrieval engine that indexes and ranks the information units for searching and recommendation; 6) an export engine that exports an original book or a "virtual" book that consists of excerpts from one or multiple books created by a user while navigating and searching. The detailed explanation of each component is presented in the following sections.

File Processor

The current version of OASIS supports two kinds of book files: plain ASCII texts and XML files conforming to the DAISY standard (Daisy). DAISY is an open non-proprietary international standard for accessible Digital Talking Books for the people who are blind or visional impaired. Once a XML file conforming to DAISY standard is uploaded, the file processor constructs a DOM tree (Dom, 2005) and configuration files are read. These configuration files, specific to the DAISY standard, guide the file processor on how to navigate within the DOM tree as well as how to extract information using the DOM tree. A particular challenge arises due to math symbols in text books. The current system represents math formulas in the form of Nemeth representation (Nemeth) encoded in plain ASCII. Thus math formulas are available to students who are blind through screen reader devices.

Segmentation processor

The content of uploaded books is further partitioned into semantically-coherent information units. These units are treated as the atomic units for fine-granularity search and navigation. Instead of presenting an entire book to the user as the result of a query, the appropriate information units are provided to the user. The segment-enrich-annotate (SEA) paradigm of OASIS (Candan et al., 2007) provides the ability to bridge the relevant information units within or across the books and brings the most relevant information to end users. Currently, OASIS segmentation processor provides three kinds of segmentation methods including "Vector Space Scoring" (Hearst and Plaunt, 1993), "JTextile" (Choi, 1999) and "CUTS" (Qi and Candan, 2006). Based on user feedbacks, the CUTS segmentation method proposed by our research group shows a better performance than others in identifying semantically-coherent units. In order to improve the precision of the segmentation process, with the goal of reducing the need for corrections by the user who is blind, we are developing context-aware segmentation methods which partition books into semantically-coherent information units, keeping in mind the context of the book. This context is represented in the form of a concept hierarchy or taxonomy, which

describes the relevancies, importance, and relationships of the various concepts covered in the book.

Summarization processor

Even though it is easy for sighted users to understand a long information unit with a glance, it is a different story for individuals who are blind. They have to resort to a screen reader program, such as JAWS, to read line by line which is time consuming. However, with content summaries, individuals who are blind can skim through available content more quickly to identify relevant material. OASIS summarization processor provides different level of summaries from the atomic information unit to an entire book. Since summarization costs too much, it runs in an individual sever to generate the summaries periodically. OASIS summarizer takes the MEAD (Mead) technologies to get a high quality summarization result. We further improved the quality of summaries by considering the context (type) of the book as well as topic development patterns we learn through the CUTS segmentation.

Database Manager

The database manager is responsible for maintaining the metadata for the books registered in the system, a user-table for the user accounts, a ToC-table for ToC information extracted from the books, and a node-table for the information units. When a book is uploaded to OASIS and the ToC of book is extracted, the metadata of the book and the extracted ToC information are stored in the metadata and ToC tables, respectively. When the segmentation processor segments the book into its information unit, each unit is assigned a unit ID (or node ID) and relevant information including start and end line number is stored in the node table. Meanwhile, memberships of information units and ToC entries are recorded in the ToC-table. Note that these data can be updated, if a user adjusts the segmentation results for better search and navigation via the user interface as shown in Figure 4.

Indexing/Retrieval Engine

The indexing/retrieval engine provides the indexing and searching capabilities to the OASIS. It builds the index based on the information units obtained from segmentation task. We adopt multifile index structure to support the incremental indexing function since information units can be adjusted and redefined via user interfaces. A big index file is divided into several sub-index files. The adding and deleting operations occur only in the newly created sub-index file, which is periodically merged with other, existing sub-index files. In particular, the retrieval engine does internal buffering by holding newly added documents in memory prior to writing them to the disk. This is done automatically and transparently. For search task, the retrieval engine computes the importance (similarity) scores for information units, given a user query expressed as a list of keywords. The relevant information units are returned to the end user, as shown in Figure 4, in descending order of importance.

Export Engine

The export engine provides the functionalities to let users download the entire or parts of books in plain text or DAISY format for reading on other devices. OASIS provides a unique mechanism to let users construct a single “virtual” book by combining relevant contents from one or multiple books. While a user is searching and navigating through the books in the OASIS library, he or she can create a new topic, mark relevant information units, and export the content in a DAISY format as a new book.

CONCLUSIONS AND FUTURE WORK

OASIS provides a semi-automated, interactive content registration tools for helping the content providers in uploading their digital books, notes, and other digital material to OASIS storage server. In particular, content being registered is analyzed and adapted for effective search and navigation support to individuals who are blind. To achieve this goal, OASIS relies on a segment-enrich-annotate (SEA) paradigm to adapt the existing digital materials for helping students without sight (Candan et al., 2007). OASIS content access interfaces provide integrated, personalized, and contextualized access to library collections, personal collections, and user notes as shown in Figure 4.

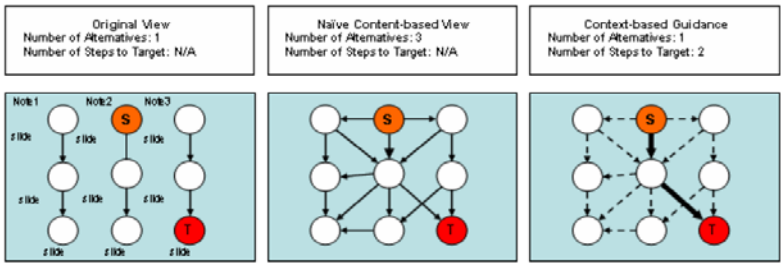

Figure 5 . OASIS guidance from a source S to learning target T through content based relationship mining and context-aware annotations

Note that, while segmenting a book into its information units, annotating and indexing them for effective search, and enabling the user to create virtual books out of relevant segments, enable more effective access to digital book, OASIS aims to provide further navigational support to its users. In particular, since the goal of OASIS is to help a student who needs to leverage multiple books to accomplish a task (for example a student who is studying for an exam on a particular topic or preparing a survey using a digital library environment), OASIS aims providing context–aware, inter-book navigational guidance within the digital library. As shown in Figure 5, without any guidance, a student who is blind is left alone to locate the relevant materials. A simple content-based integration mechanism would enable discovery of access-paths. However, without the use of context, the number of alternatives that the user who is blind has to filter through will be too large. The use of context and user profiles, on the other hand, enables access to the data with smaller number of interactions. Thus, OASIS aims providing context-aware navigation suggestions based on the current context, access history, user preferences, and content relationship. We have already explored text and data mining (Kim and Candan, 2006) and segmentation (Qi and Candan, 2006), user experience modeling , context-aware summarization, and dynamic guidance (Candan et al., 2006; Sapino et al., 2007) to enable users to find relevant material (books, book chapters, annotations) more quickly. We are currently building on our existing work for developing content "relationship mining", query-relevant summarization, and context-aware navigation techniques to provide context- and task-aware navigational guidance within a digital library.

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