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INFORMATION SUMMARIZATION AND TRANSCODING OF BIOMEDICAL INFORMATION RESOURCES FOR MOBILE HANDHELD DEVICES

BAMBANG PARMANTO, ANDI SAPTONO, LIJING SONG

University of Pittsburgh, Pittsburgh, PA 15260, USA

{parmanto, ans38, lis18@pitt.edu}

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Small screen mobile devices such as PDAs and smart-phones have been popular among healthcare practitioners in the last few years, with a higher penetration rate compared to the general population. The availability of the device allows healthcare practitioners to access online biomedical resources anywhere at anytime. Previous studies have found that the integration of PDAs into clinical practice has lead to the decreased medication error rates and the improvement in physician's adherence to a clinical practice guideline. However, presenting a vast amount of information in the limited space of the PDA display has been the major barrier to the realization of PDA's potential. To overcome the small screen display limitation, we developed a multi-modal transcoder system. The transcoder system adapts information to the limitation of the user's device. Our current project focuses on transcoding full-text biomedical information resources to support mobile devices for healthcare professionals. We developed novel algorithms to understand the structure of biomedical resources through the use of visual template matching and pagelet detection process. The system utilizes simplification and summarization techniques to deliver compact information to the mobile user. A usability study conducted on the system revealed that the simplification and summarization techniques improve the usability of the system.

Key words: healthcare, simplification, summarization, algorithm, PDA, smartphone
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1 Introduction

The delivery of better healthcare depends upon the translation of basic scientific discovery and knowledge from clinical studies into healthcare practice and decision making [6, 25]. Basic and clinical research has resulted in an unprecedented amount of information that poses a great challenge to healthcare professionals practicing evidence-based medicine. Sackett and Straus [26] tested the use of an “evidence cart” during hospital rounds and found that easy access to evidence-based resources leads to incorporation of evidence into patient care decisions.

Personal Digital Assistants (PDA) have been popular among healthcare practitioners in the last few years, with a higher penetration rate compared to the general population. The PDA has evolved from a stand-alone personal device into a mobile networked device with wireless Internet access. The availability of PDA access to the Internet could potentially open the door to various applications that allow healthcare practitioners to access biomedical information resources from anywhere at anytime.

Presenting a vast amount of information in the limited space of the PDA display has been the major barrier to the realization of PDA's potential [5, 18, 21]. This barrier becomes a serious drawback to the PDA usage as most of the information resources available are designed for a full size desktop computer display. All other PDA drawbacks, such as low resolution, limited memory, slow processor, and problematic data input, in time will be solved with better technology. This is the reason why

research on the mobile human-computer interface (HCI) primarily concentrates on finding a better strategy to present information on a small display.

In response to this problem, we developed a transcoding system to retrofit materials that would otherwise have to be developed separately for display on different devices, as is the case with most of the current biomedical PDA applications. Our transcoding system transforms online materials on the fly and adjusts the format to the user's device. This approach increases the compatibility of our system to user's devices without the need for static re-authoring of the pages. The paper elaborates our transcoding system approach, why it was build, and what is novel about the system.

2 Background

PDA penetration among physicians is at 25%, much higher than the 4% penetration for the general population [7, 12]. About 15% of PDAs offered this wireless connection functionality in 2002, and the percentage is expected to grow to 75% by 2007 [17]. The trend toward the convergence of PDAs and cell phones, often called smart phones, will also boost the number of handheld devices accessing the Internet. About 13 million smart phones were expected to ship in 2003, an amount expected to grow about 86 % annually by 2007 [15].

Previous studies have shown that the integration of PDAs into clinical practice has lead to the decreased medication error rates [10] and the improvement in physician's adherence to a clinical practice guideline [30,31]. With a wireless PDA, a physician could search medical databases, read the latest abstracts, access full-text journal articles, and other online resources when the needs arise. This availability and easy access, in turn, will decrease the cost of access. Previous research found that the usefulness of information is related to its relevance, validity, interactivity, and ease of obtaining it. The more relevant, valid, interactive, and easily accessible the information is, the more likely it will be sought [29, 33, 33]. Wireless access to full-text journal articles from PDAs increases the interactivity and ease of obtaining information. In addition to accessing information, the use of PDA for data entry or data capture has been widely used in clinical environment. For example, Serif et al. [28] used PDA for capturing pain data of wheelchair users using visual approach. Young et al [38] evaluated the usefulness of PDA for nurses' data entry.

Several studies have been conducted on physician information-seeking behaviour during patient encounters [11, 24, 27]. These studies found that first-hand information sources, second-hand information appraisal and books play important roles as the physician's main information sources. Similar works from the library resource perspective have also identified that resources such as textbooks, journal articles, drug databases, and prescribing aids are suitable for the PDA at the bedside [21, 22]. Another study found that patients have a good impression of doctors using a PDA during patient encounters, further proving that a PDA usage during the patient encounter does not have a negative effect on the patient's perception [14]. The use of PDA in general environment has been the subject of active research and practice in the last several years. Waluyo, Srinivasan, & Taniar [35] provide an extensive survey on query optimization and processing mechanism for supporting information retrieval via mobile devices.

2.1 Accessing Biomedical Information Resources via PDA

Most biomedical information resources are designed to display optimally in a full-size desktop computer screen. Presenting the same amount of information in the limited space of the PDA display using the same formats, on the other hand, may result in a range of rendering problems. The problem

may be as simple as a dislocated article part or an image spanning outside of the small screen boundary to totally inaccessible content which diminish the usability of the information while being presented on a PDA. Therefore, an adaptation strategy is usually employed in displaying the information on the PDA. The adaptation strategy may vary from a simple web clipping that discards images from the information, such as Palm Web Clipping, to an advanced content summarization as laid out in this paper.

The current approaches to assist PDA users can be classified into three different categories:

1. As services that provide static, replicated, and reformatted information to mobile device users. These services provide users with limited access to already reformatted web pages, sometimes referred to as a "walled garden" approach [37]. This approach is viable since reformatting the entire Web is impossible. For example, popular information-portal services such as AvantGo maintain a set of different web pages for mobile device users. These pages are re-authored to fit into the small display of the PDA. The resources needed to maintain and update the pages are enormous. Ovid@Hand and HealthProLink use similar static reformatting techniques. All of these services work within their own "walled garden" and they are usually accessed not as an online resource, but as a download service through synchronization [3, 36].
2. As a Web intermediary application that provides adapted web pages to mobile device users. This approach, usually called the transcoding approach, transforms online HTML pages into a format appropriate to the users' device. An example of this approach is the Transcoding Publisher server from IBM [16]. IBM uses a simple tag-based approach where the transformation is done at the lowest Web element. Palm also provides a proxy Web clipping service for its paying subscribers [9]. Considering the sheer enormity and fluidity of the Web, as well as the flexibility and scalability of the intermediary, this approach is an attractive solution.
3. As a specialized browser installed into the mobile device. This approach renders web pages using a specialized browser for the PDA at the client side. Internet Explorer for Microsoft Pocket PC and Firefox browsers can fit a web page into the small screen by modifying the font size and the margin of the web page. The transformation capability of the client browser depends on how active the user searches for new updates and plug-ins to enhance their browser.

2.2 Transcoding Biomedical Resources on the Web for PDA Use

Adapting existing biomedical resources on web pages to fit into a particular device proves to be one of the hardest problems for intermediary technologies. The current web does not provide semantic information for end users because HTML is a presentation and formatting language. Different devices have different technical specifications (screen size, memory capacity, etc) thus making it even harder to present the information contained in the web pages optimally.

Our system adapts the third approach in assisting PDA users to access biomedical information resources. The aim of the transcoding system is to make reading full-text documents simple and more usable on PDA. International Standard Organization (ISO) defines usability as “the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments” [4]. The current common belief is that a full-text document is not suitable for a PDA [23].

The IBM Transcoding Publisher is less flexible and more limited than our multimodal transcoding system [20]. The use of genre, visual template recognition and pagelet detection allows higher

flexibility for our transcoding system to summarize the page based on the importance of sections contained in the page. In turn, this approach allows our transcoding system to understand the materials and automatically choose an appropriate transcoding strategy for displaying the information within.

3 Development and Implementation of Novel Mobile Handheld Transcoder

3.1 A New Approach to Transcoding for Mobile Handhelde

The goal of the system is to make the web page more accessible by providing some of the features naturally available to users using full-size desktop monitors. To achieve this goal, our transcoder implements two transcoding techniques: simplification and summarization. Simplification is achieved by retaining those important parts users most concern about on the web page while cutting out the clutter and sections users always ignore. A similar approach using page annotation is page clipping [13]. Instead of annotation, we utilize genre-based template-matching and pagelet-detection algorithms that are potentially more extensible. Summarization is implemented by extracting important points of the page to provide users with a quick glance of the page.

By utilizing these two transcoding techniques, we are able to provide a preview of the Web page to assist the users. This preview is intended to assist users in navigating through the vast amount of information presented in the Web page. In this work, we created a table of contents (TOC) as a mean for providing the overview of the Web page.

In order to create the preview, we believe that an understanding of the Web page is crucial. Understanding the structure underlying the web-based document and content of the page is the foundation of simplification and summarization. Knowing the structure is a key to identifying the important parts of the webpage, while understanding the content can assist us in extracting page summary. IBM's Transcoding Publisher, for example, relies on annotations manually created by the webmaster to form an understanding of a page and retrofit important information from the page to the device. One work on this subject is displayed in Takagi et al. [34], which uses xPath to annotate various sections of the Web pages in a site. This approach is very efficient for a site-wide transcoding work, since there are usually only minor changes in the structure over the pages within the site.

Our approach, on the other hand, relies on page genre categorization, visual template structure extraction, and pagelet detection to create an understanding of the page automatically. This is done because our goal is to transcode arbitrary sites, which present a different set of problems than transcoding a single site. We found that utilizing xPath to pin-point a Web element creates a scalability issue in transcoding arbitrary sites. Some visual layouts can be built using different HTML codes, thus creating different DOM Tree structures. This means that across different pages, a Web element, while 'visually' being placed at the same location in the display, might have a different xPath to the point. Another problem arises when a page is being generated dynamically. If a 'noise' (such as an advertisement) is placed between Web elements in the page, it might change the xPath slightly. In this case, the xPath might point to a different node, creating a false positive condition. Using pagelet detection, we have a flexible way of detecting page segments (with different DOM Tree structures) while avoiding noise (such as advertisements, which are inserted dynamically).

3.1 Genre-Based Template

3.1.1 Genre

In order to transcode a page into a more accessible and usable version for the PDA user, we proposed a concept of genre categorization. We introduce "genre" for the purpose of describing the type of website in terms of content and utility, such as news, e-commerce, portal, and e-journal. In genre categorization, we classify a page based on its underlying functionality and interaction with the user.

We propose this concept with an assumption that the underlying functionality of a genre is common across the sites in the same genre. Our observation suggests that users do substantially different tasks while browsing sites from different genres. A user browsing a site of the news genre tends to read the first paragraph or the entire news story (which usually is short) while healthcare professionals accessing e-journal sites are more likely to skim through the article and seek for the specific information that they need. This observation implies that the transcoding process should reflect the users' tasks on different genres. Webpages of the news genre is expected to be transcoded in the way to assist users in directly accessing the news stories while sites from the e-journal genre are expected to be transcoded into a summarized version to help users find the specific information in the document.

Our system utilizes two schemas in categorizing pages into genre. The first one is through a table lookup process. Popular websites were listed in the table and appropriate genres were associated to each of the websites. If a particular website does not appear in the list, a second schema is used. The second schema of categorization is done by scanning the content of the page for certain key features that can classify the page into a certain genre.

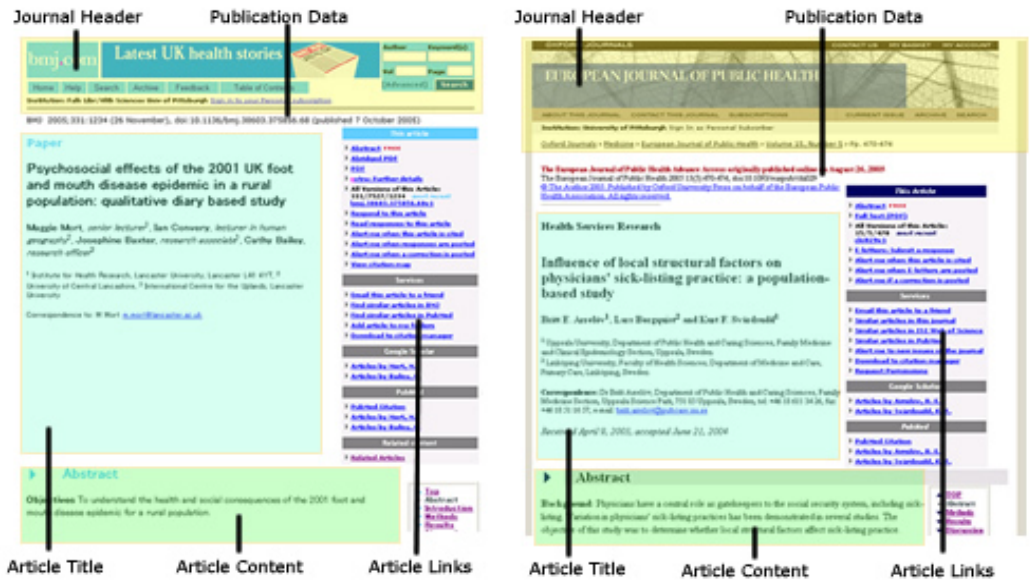

Figure 1 Website examples of eJournal genre: the British Medical Journal and the European Journal of Public Health

3.1.2 Template

Visual template recognition is based on the tendency of site builders to use a familiar site environment (template) to capture the interest of their visitors. This tendency is consistent with the fact that humans

interact with a familiar environment better than a non-familiar one. Consequently, humans prefer working in a familiar environment rather than a new, unfamiliar one. Additionally, the use of a template in a website reduces visitors' memory workload by giving them a familiar interaction schema. This concept has been widely adopted by website development tools or document authoring tools by providing templates for several types of websites or documents. It is also no accident that news websites tend to look similar or many e-commerce websites follow the style of Amazon.com. The same tendency can also be seen in online biomedical resources (Figure 1).

In this project, we will exploit the tendency of websites from a similar genre to look alike and to have similar functionalities. Based on the genre concept, we propose to build templates for each website genre. Templates contain important parts of the page that full-size desktop screen users can recognize easily while traversing a Web page. We refer to these easily recognizable areas of a webpage as landmarks. The template of a genre website consists of a set of landmarks that are arranged in a certain composition. Similar to traversing in the real-world environment, landmarks in a website help users navigate that website. For example, a template may have a header landmark, a left-side vertical-navigation bar landmark, and a content landmark.

3.1.3 Genre-based Templates

Based on the genre and the visual template concept, we built a template library for each genre. Genre-based templates are constructed from prototypical websites of each genre. For example, CNN.com is used to construct the template for the news genre; Ovid, Elsevier and BMJ (British Medical Journal) are used to construct templates in e-journal genre; while Amazon.com is used to construct one for the e-commerce genre. If a high variety of features within a genre is encountered, more than one sub-genre can be constructed within that particular genre. Also, within a genre, different templates are constructed for different levels of a website. In the news genre, the template for the main page is different compared to the template for the full story page.

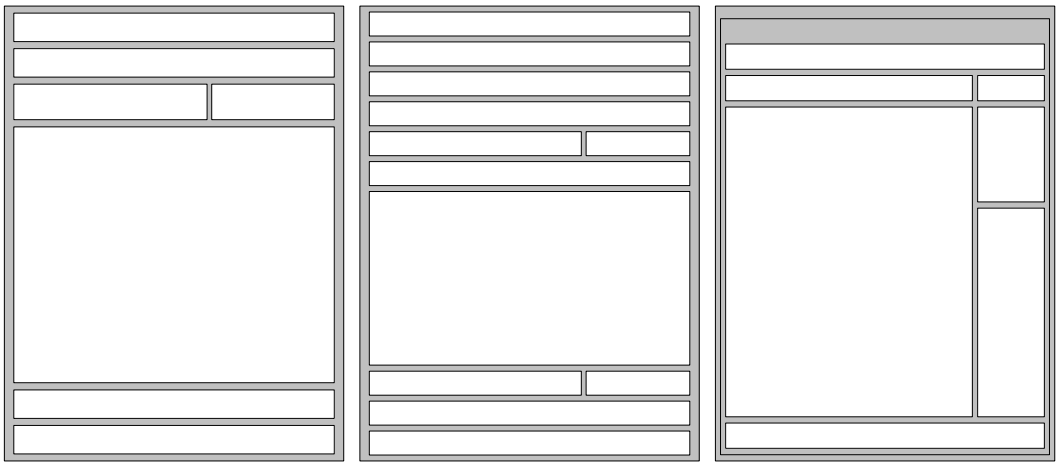

Figure 2 Biomedical Journal templates

Genre-based templates have two functionalities. The first one is assisting the transcoding system to understand the structure of a webpage and determine which sections are important. The second one is determining which transcoding method is most appropriate for that genre.

Templates are implemented as XML documents that contain rules to identify landmarks. A library of templates is constructed to assist the transcoding system in understanding an actual webpage and to help in determining which sections are considered important and what kind of transformation is needed. This template-based approach is especially appealing for structured documents such as full-text medical journals, clinical guidelines, or drug references, which usually tend to follow certain templates. Figure 2 provides an illustration of a library of templates that we have developed.

To further refine the landmarks into smaller chunks of information, we created a semantic analyzer tool. The semantic analyzer scans the landmarks to detect pagelets, a self contained logical region within a page that has a well defined topic or functionality [1]. A Web page consists of multiple pagelets which are grouped into several types based on functionality. One pagelet type may be the heading, which separates one section from another. Another pagelet type may be the navigation menu which takes the user to other parts of the sites.

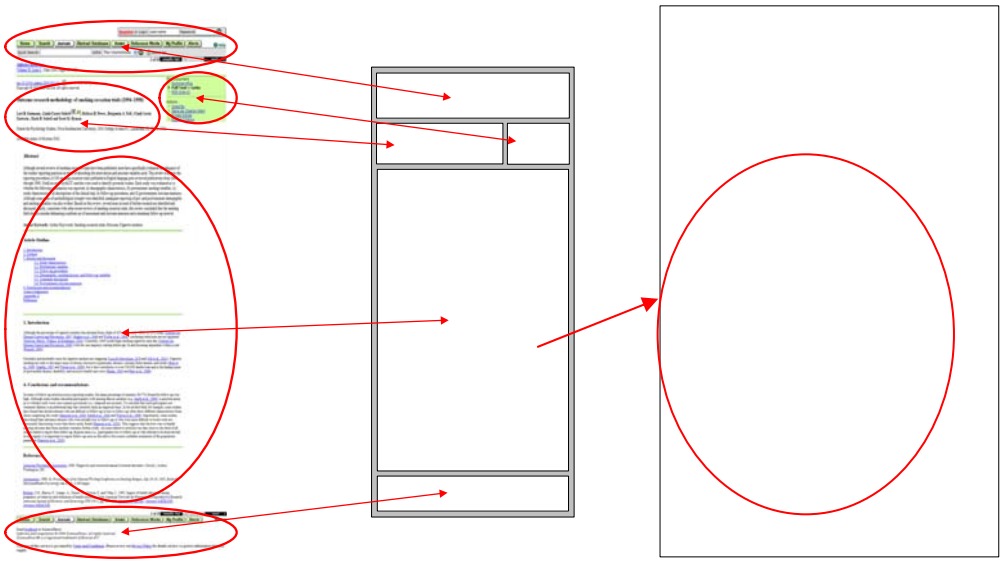

Figure 3 Genre-based Visual Template and Pagelet Detection process

Figure 3 illustrates the implementation of these concepts for an online article from Elsevier. The first step shows the process of obtaining the main structure of the e-journal webpage through the genre-based visual template. The second step subsequently refines the results from the first step by detecting pagelets inside the sections (landmarks) of the article. This figure shows the pagelets detected in the content part of the article.

3.2 Accordion Summarization

We propose a novel page transcoding method for organizing and summarizing general web pages as well as biomedical information sources such as full-text journal articles. For brevity and clarity, the rest of this section will use full-text journal articles for illustration on how the method works. The

method is extensible to any web-based document. The schema of implementation of the system can be seen in figure 4.

The bulk of our work has been in understanding the structure of random journal articles with the goal of transforming the contents into a format that is more accessible to users of mobile devices.

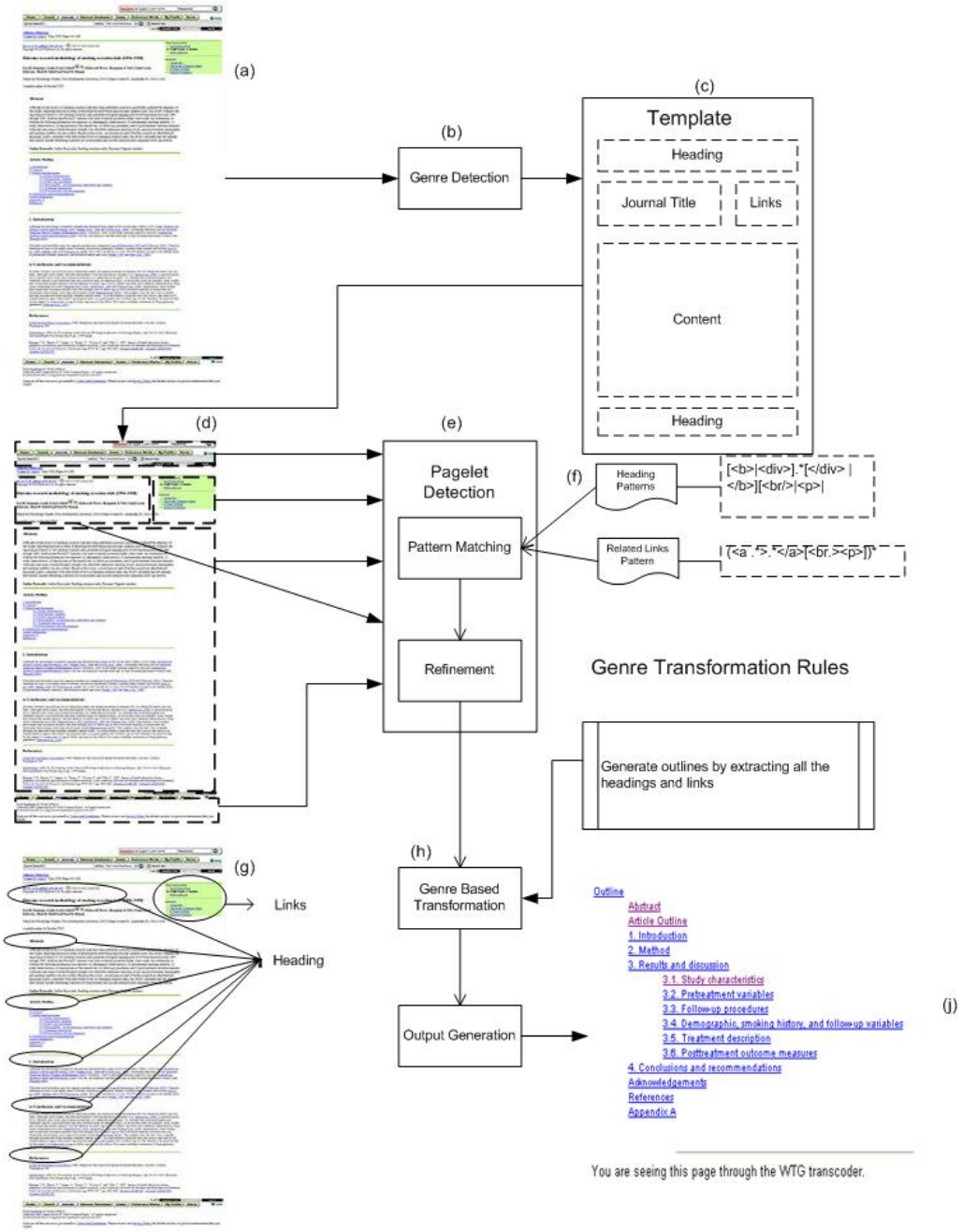

Figure 4 The transcoding process

Understanding the structure of random journal articles can be classified as a complex computational problem. In order to reduce the complexity, we enlist the help of a prototypical template as discussed in the previous section. Since the template library is organized into genres, the first step to understanding a Web page structure is to determine the genre of the page. Again, the purpose of genre detection is not only important in the page understanding process (what type of website the system is dealing with and which template it matches), but also to determine what kind of transformation would be needed.

As mentioned before, the genre detection process is conducted in two phases: table lookup and key features detection through heuristic rules (figure 4b). In table lookup, we list popular Web page URLs in a table and associate them with the appropriate genres. If the URL of the webpage is not listed in the table, the heuristic rules are then used. We analyze the content of the page to gather information that can be used to determine the genre of the page by using heuristic rules. The rules can range from simple text matching rules (such as 'find a sentence with the term "shopping cart" in it'), to more sophisticated rules ('if a certain body of text has a date or time associated with it, it is news text'). These rules were utilized to look for genre-specific characteristics in the content such as the occurrence of specific keywords, length of text, length of menus, etc. For example, 'shopping cart' and links to cart-related pages indicate that the page is part of an 'e-commerce' genre. The latter rule ('if a certain body of text has a date or time associated to it, it is news text') is one of the rules to detect the 'news page' sub-genre.

Once the genre of the webpage has been determined, the next step is to find the template that matches the page best (figure 4c). Since templates consist of landmarks, the matching process is carried out by comparing the landmarks of the webpage and the template. The templates are implemented in an XML document, with the rules to detect landmarks implemented as the methods. These objects scan the DOM Tree of the webpage to find matching features in the structure and provide a similarity percentage between the structure and the template (for example, a template with title, left menu, right content and footer features will give a 75% similarity percentage when scanning a page which only has title, content and footer parts). The template with the highest similarity with the webpage is selected to represent the webpage. The template represents the macrostructure of the webpage that consists of landmarks such as left menu, main content, etc. The template, however, does not have information about the detailed structure within the landmark. For example, the main content of a news webpage contains several news items. These news items are not identified in the landmark. In order to process the microstructure within a landmark, the concept of pagelet comes into play (figure 4e).

We made a set of HTML element patterns for detecting each pagelet (figure 4f). The patterns are regular expression consisting of tokens representing HTML elements. There may be multiple patterns for each pagelet type. Currently all patterns are created manually based on our observation on the various pagelets found in various Web pages.

The pattern matchers try to match the HTML elements for each section of the page. In our architecture, each pattern matcher executes as a different thread. Each landmark (section) contains different types of pagelets. For example, the info bar landmark looks for the appearance of a navigation menu, while the main content section looks for heading and news pagelets. When the pattern matches a particular HTML element, the corresponding HTML element is marked as the start of a particular pagelet. After all patterns are found, the result of the pattern matching process is refined. If an element is marked as matching two different pagelet patterns, one of the marks is deleted. The choice of the pagelet to delete depends on a priority score of the corresponding pagelet.

A pagelet type is often expressed by visual cues so that users can easily detect and use the various functions for that pagelet. For example, a heading is usually in a different font from the text it precedes. The visual information of a pagelet is encoded in the HTML code. Based on this, we propose the use of HTML element patterns to detect these pagelets.

Selected patterns according to the needs of the transformation process are matched to the HTML document. When the pattern matches a particular HTML element, the corresponding HTML element is marked as the start of a particular pagelet. After all pattern matches are found, the result of the pattern matching process is refined. If an element is marked as matching two different pagelet patterns, one of the marks is deleted. The choice of the pagelet to delete depends on a priority score of the pattern matcher.

For displaying the document on small screens, we implemented the accordion display method [2]. The principle of the "accordion display" is to show the whole document in small fragments that optimally fit the display size (summary of the page). This display technique is in the tradition of fish-eye views [8] where the user sees places nearby in great detail while the larger context is displayed in successively less detail.

To create the display, we implemented a specific summarization strategy for each genre (figure 4h). These strategies consists of rules that determine what kind of sections will appear in the output, which part of the pages would appear inside each section, etc.

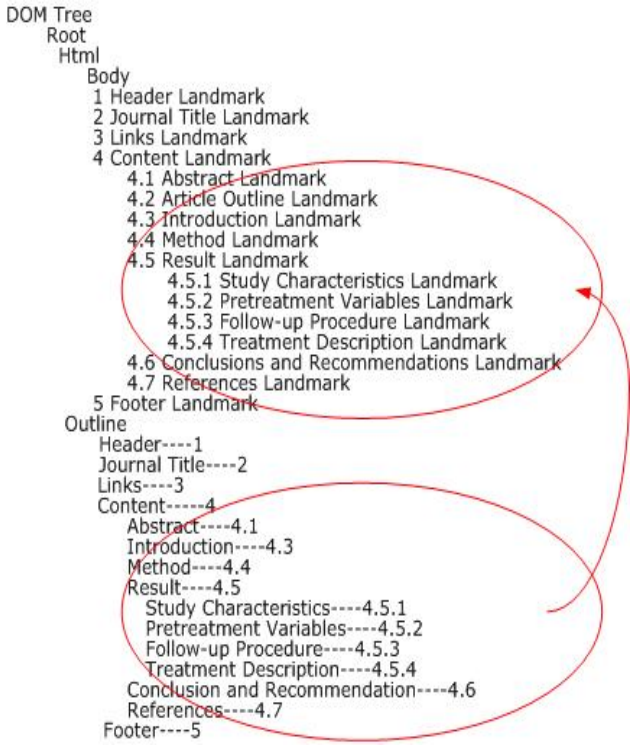

Figure 5 The DOM Tree Structure after summarization

First, we append the original page with section nodes (taken from the appropriate strategy for the genre) to create a skeleton of the new output pages. Selected pagelets, detected through a semantic analyzing phase, are then copied into their appropriate sections. Using full-text journal articles for example, article headings would be used to build a navigation menu, the text area following those headings would be moved into a subsection of the article, and the advertisement pagelets are going to be ignored. The resulting DOM tree can be seen in figure 5.

For the e-journal genre, the transcoder extracts an outline from the journal page. The purpose of summarization is to allow the user to gain an overview of the journal page. Using the summary, users will be able to explore successive detailed portions of the page in more depth. Otherwise, the regular journal document would require extensive and cumbersome scrolling. Structured browsing systems have been used widely and been shown to be effective for documents [2]. The result of the summarization process is an outline tree as presented in Figure 6.

Figure 6 Accordion summarization of journal contents.

The final process is the output generation process which outputs one section per request of the user. The output generation process retrieves the section the user chooses to browse and adds additional information such as the title and the URL of the original page being shown. The output generation process also adds links to the other section to enable the user to move from one section to another (figure 4j).

One of the strengths of the transformation method is that it can easily handle variations in the devices. It is versatile in adjusting the contents to fit various versions of the Palm Pilot-based PDAs, Microsoft's PocketPC-based PDAs, as well as WAP-based cell phones. Different rendering techniques can be applied to different types of mobile devices. For example, WAP-based cell phone requires more specific transformation to make the representation fit into the standard of WML. We proposed to generate output using different documents, such as HTML XML, WML to optimize the performance on different mobile devices. Figure 7 shows different renderings for the most commonly used handheld devices.

Figure 7 University of Pittsburgh's Health Sciences Library System website transcoded to different mobile devices

4 Usability Study and Discussion

We performed the think-aloud usability assessments to compare two different methodologies for transcoding the content of an online biomedical resource for PDA display: using summarization and single-page format. Single-page format is a simple transcoding format in which the online journal article is transformed into a single page and modified to fit into the small screen display. Summarization format is the advanced transcoding approach in which the online journal article is summarized and retrofitted according to the user need. We used four popular usability heuristics [19] on which to base our comparison. These included Ease of Learning, Efficiency, Error Rate, and Level of Subjective Satisfaction.

The study was conducted over potential current users and potential future users of the system. Participants were divided randomly into two groups to access journal articles from two journal aggregators: Ovid and Elsevier. Each participant was asked to complete skimming and information-finding tasks on the transcoded online articles using a PDA. Participants were requested to finish 2 tasks in six articles, totalling to 12 tasks per participant. After completing the tasks, each participant was asked to complete a questionnaire about their subjective preferences with respect to the two formats.

Based on the responses from the participants, we concluded that both single-page format and summarized format were easy to learn. Participants understood the concepts underlying both formats and were able to navigate inside both formats after a brief of explanation. In addition, participants expressed that the summarized format was intuitive to learn.

Participants accessed specific part of the article more efficiently using the summarized format compared to the single-page format. Participants often times missed the specific information inside the single-page format due to the sheer amount of scrolling needed to navigate the article. On the other hand, the summarized format made the page simple and gave direct access link to sub-parts of the article, and further helped participants in searching and finding information needed to finish their tasks. Additionally, smaller chunks of information helped participants to focus their attention into the information displayed.

By scrolling back and forth in the single-page format, participants were able to recover from their error of missing specific information on the display. Participants were able to recover from missing a specific piece of information in the summarized format if the summary of the article (the outline) gave enough hints on where to search next.

Participants expressed that they found the summarized format more satisfactory than the single-page format in the survey. Participants agreed that the clear organization of information on the summarized format, the outline of the article and the simple way of finding information from the summarized format were the main reasons behind their preference.

Summarization technique can potentially be combined with other user interface techniques such as coloring and local search to make the reading of full-text documents in mobile PDA more usable. In practical implementation, the transcoding technique can be combined with an enterprise portal for PDA to ease selection of journals.

5 Conclusion

One of the strengths of the transcoding method is that it can handle variations in the devices easily. The transcoding method is versatile in adjusting the full-text contents designed for desktop presentation to fit various versions of the Palm Pilot-based PDAs, Microsoft's PocketPC-based PDAs, as well as WAP-based cell phones. The transcoding approach can potentially unlock the vast resources available on the Web to mobile handheld users. These vast information resources have been designed for desktop presentation and are mostly inaccessible by mobile PDAs. The summarization technique we proposed can further open the accessibility of large documents and make them more readable in mobile handhelds.

Usability studies are necessary to evaluate if the transcoding system makes reading a full-text document more usable (more effective, efficient, and satisfactory) than reading the original document on PDA. The usability study on the summarization and transcoding technique shows that our approach can improve the usability of accessing full-text biomedical resources using mobile handhelds.

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