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Web Content Adaptation for Mobile Users

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Abstract

Delivering Web content to wireless handheld devices is a challenge. Current popular wireless handheld devices, such as WAP phone, Palm and Pocket PC, have many inherent limitations. In addition, relatively low wireless network bandwidth and user mobility make it necessary to deliver data as succinct as possible to reduce transmission delay and fit into the small screen display. To achieve this goal, Web content has to be tailored to adapt to the mobile Web. This research would examine adaptation challenges and presents a classification scheme for evaluating current adaptation approaches. A model for guiding the development and assessment of adaptive content delivery over the mobile Web is presented. The paper concludes with an agenda for future research.

Statement of Problem

Just like the Web has been the core platform of current Internet business, the mobile Web is the central data exchange channel for extending current Internet business model to wireless services model (Shim et al. 2002). However, due to inherent constraints of wireless handheld devices and the current state of wireless network, proper considerations should be given before delivering Web content to the wireless user. Removal of many unsupported data format and scripting component is necessary to reduce the data transmission over the wireless network. Furthermore, personalization techniques could be applied to the information to meet the user's need (Anderson et al. 2001c; Lankhorst et al. 2002). Thus the adaptation of the content to the wireless platforms and mobile users is the key to extend World Wide Web to the mobile Web.

Wireless handheld devices have many inherent constraints when used as a mobile Web browser to interact with World Wild Web. There are three common constraints in mobile computing: wireless communications, device properties, and mobility (Tsalgatidou et al. 2000). Beyond these inherent constraints, mobile user personalization presents greater challenges because wireless devices are mainly used by individuals. Many established Web personalization techniques such as Web usage mining, content/semantic mining, and structure mining might be well suited for wireless browsing as well. However, it is necessary to devote substantial consideration to the inherent wireless constraints before presenting personalized content to a small wireless browser. Researchers have devoted increasing attention to the need for personalization (Kießling et al. 2001; Anderson et al. 2001c; Lankhorst et al. 2002). While research on Web personalization may offer some solutions, personalization for the mobile Web involves more restrictive considerations. For example, usability guidelines for small display interface design would play a key role in mobile Web content presentation and navigation (Chan et al. 2002).

Research Questions and Objectives

As long as those restriction features (small displays, slow input, etc.) exist, adaptation techniques and methods have to be applied. There are many research questions concerning content delivery over the mobile Web such as:

- What kinds of tasks are special for mobile users?

- What kind of content is suitable for delivery over the mobile Web?

Voice access to the mobile Web content, embedding voice interface into handheld devices, is becoming a promising approach to alleviating small display restrictions. However, the following research questions should be investigated:

- What is the best balance of the voice versus text and
- What kind of content is suitable for voice presentation for wireless handheld devices?

In my study, I would be particularly interested in investigating the following research questions:

- What new and established mobile usability guidelines could be applied to mobile Web content adaptation?
- What adaptation features are to be considered while delivering Web content to wireless small displays?
- What factors determine the complexity of content transformation?
- How could different personalization techniques be applied to mobile Web and how effective they are in the mobile context?

The objectives of this research are to: a) examine content adaptation issues, b) evaluate current adaptation approaches, and c) propose a model for guiding and assessing content adaptation approaches. I present a classification scheme of the current adaptation approaches and propose a model for guiding the development and evaluation of adaptive content delivery over the mobile Web.

Literature Review

Several adaptation approaches are available for wireless content presentation. These approaches have appeared in relevant literature under different classifications, such as mobile-aware versus mobile-transparent approach (Kaasinen et al. 2000); automated conversion versus special language (Gaedke et al. 1998); static adaptation versus dynamic adaptation (Lum and Lau 2002); server-side and proxy-side versus client-side adaptation (Kunz, and Black 1999; Lum, and Lau 2002; Bharadvaj et al. 1998). Trevo et al. (2001) mention four ways of delivering information to small displays: scaling; manual authoring; transcoding; and transformation. In general, the user perspective is often absent in these classification schemes. I propose a new classification scheme in reviewing current adaptation approaches by adding more attention to mobile user features such as usability and personalization issues. This proposed classification scheme groups adaptation approaches into four categories: a) version adaptation, b) template adaptation, c) usability adaptation, and d) personalization adaptation. This classification scheme, together with a proposed adaptation model, could help to clarify research questions pertinent to content delivery over the mobile Web.

Version Adaptation

The most straightforward way to achieve adaptability is to re-author Web content in advance for different handheld devices. Version adaptation is accomplished by generalizing the range of form factors to include both physical appearance and software features, such as the types of operating system (OS) and mini-browser. Current handheld devices are diverse in form factors and are in continuous updates. Creating mobile Web site versions for specific form factors means creating a pre-adapted content presentation version for each type of device. A common method is to copy existing HTML Web pages and remove any html tags that are incompatible with that particular type of handheld device.

Template Adaptation

XML language suite, as the de facto standard for information exchange over the Internet, has been well adopted in the content delivery for the mobile Web. Unlike HTML's rigid format tags, XML can have user-defined meaningful tags to store, categorize, and label data at desired granularity. With the help of some other W3C Recommendations, such as XSLT (the Extensible Stylesheet Language Transformations) and XPath (the XML Path Language), data can be extracted by tag names from an XML document and applied to a desired presentation format. Han et al. (2000) have developed a unified XML/XSLT framework, WebSplitter, to facilitate CSCW (computer supported cooperative work) with Web. WebSplitter enables multi-device and multi-user collaborative Web browsing by splitting XML data at the granularity of tags and by grouping tags into independent components and subdocuments, which can then be sent to heterogeneous end users' browsers, including all kinds of PDAs.

Wagner et al. (2001) present an XML-based multimedia middleware for mobile online applications. Based on user profiles associated with client requests, the middle-tier server associates specific style sheets with XML documents to deliver ranked search results to multi-platforms including WAP phones and PDAs. In order to better represent a prototype or template, Gaedke et al. (1998) propose an object-oriented WebComposition model. Its XML-based description language, WCML (WebComposition Markup Language), enables object-oriented specification of Web content to be easily extracted and adapted to different terminal browsers.

Usability Adaptation

Studies on usability of wireless handheld devices are mainly concerned with the use context and tasks of the mobile user and interface design guidelines for small displays. Design guidelines generated from their studies are useful for adaptive content presentation on wireless handheld devices. A usability evaluation study of ten mobile Web sites on three platforms (WAP phone, Palm and Pocket PC) (Chan et al. 2002) has identified usability issues for content presentation pertaining to user tasks, interface design, search facilities, and navigation systems performed on those handheld devices. Among the design guidelines recommended by their study are: a) avoid scrolling, especially horizontal scrolling; b) use a flat hierarchy; c) design navigation system consistent with a regular Web browser; d) provide a history list for traversed hyperlinks. Schmidt et al. (2000) present several guidelines for the input/output designs of WAP interfaces. The bottom line of design guidelines for wireless browsers with small displays is to minimize user interaction during navigation. Mobile Web presentation following these guidelines would give the mobile user more convenient selection and less key entry. Babaria et al. (2001) have conducted experiments on font size, menu design, and scrolling on small handheld devices to examine the effect of those features on a small display as compared to the effect on a regular PC. They concluded that menu depth should be minimized and menu breadth should be maximized for the most efficient location of an item during a search task; search menus on handheld devices should prefer medium font size, etc.

Personalization Adaptation

Personalization adaptation is a content delivery approach based on the user's information needs and preferences. Comparing to previously discussed adaptation approaches Figure 1 illustrates the addition of the mobile user in the adaptation approach.

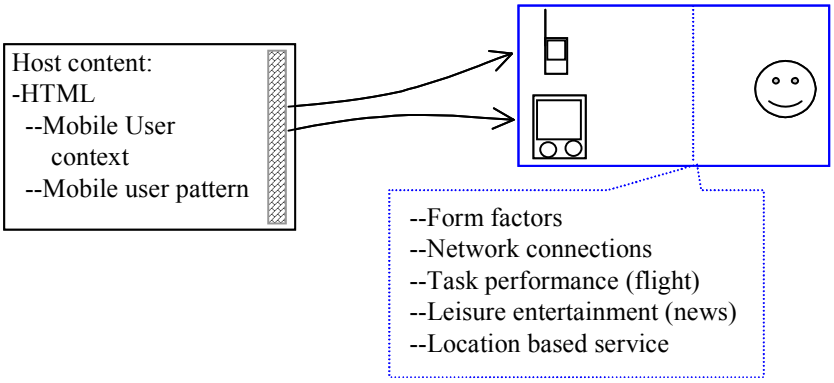

Figure 1. Personalization Adaptation

Technically, using the client-proxy-server model to embed personalization logic in proxy server has been popular in the personalization approach. Proxies mainly deal with the syntactical transcoding, system QoS adjustment, and content transformation. Steinberg and Pasquale (2002) present a WebStream customizer that supports adaptive system-based and content-based customization. Lankhorst et al. (2002) propose a holistic approach to the personalization of mobile data services, emphasizing a personal service environment (PSE) to address profile management, service discovery, and service adaptation. From a methodological perspective, personalized adapted results are mostly reduced data from the source Web content. The reduced content should be more concise and directly related to the user's special interests. Sometimes data aggregation is also necessary. This concept is very similar to database query operations like select, projection, and aggregation. Users are interested in a reduced (adapted) result; they have the ability to control the level of progressive reduction (Heuer and Lubinski 1998). WebViews, in a study by Freire et al. (2001), allows Web users to record their interested destination Web pages and extract

content components in a VCR-style interface from desktops. A user can easily create personalized shortcuts and customized views of Web sites (pages), which could be accessed later via the user's mobile handheld browsers. An obvious advantage of such personalized Web Views is the greatly reduced number of required interactions and the amount of data entry and transmission.

Learning user preference from Web usage data and presenting adapted content automatically by using data mining techniques have advantages over demanding user inputs. Mobasher et al. (2000) introduce and compare three different Web usage-mining techniques for Web personalization based on transaction clustering, usage clustering, and association rule discovery. These techniques could be extended to mobile Web content personalization. The PROTEUS (Anderson et al. 2000b&2001c), MinPath (Anderson et al. 2000b&2001a) and "Web montage" (Anderson and Horvitz 2002) are examples of Web usage mining for mobile users.

Proposed Model of Adaptation

Based on the above review, I propose a three-dimensional adaptation model to guide the evaluation of approaches for adaptive content delivery over the mobile Web and to identify related research issues. In the model, adaptation features are represented as vectors in a three dimensional space. The three main dimensions are conversion, usability, and personalization (see Figure 2).

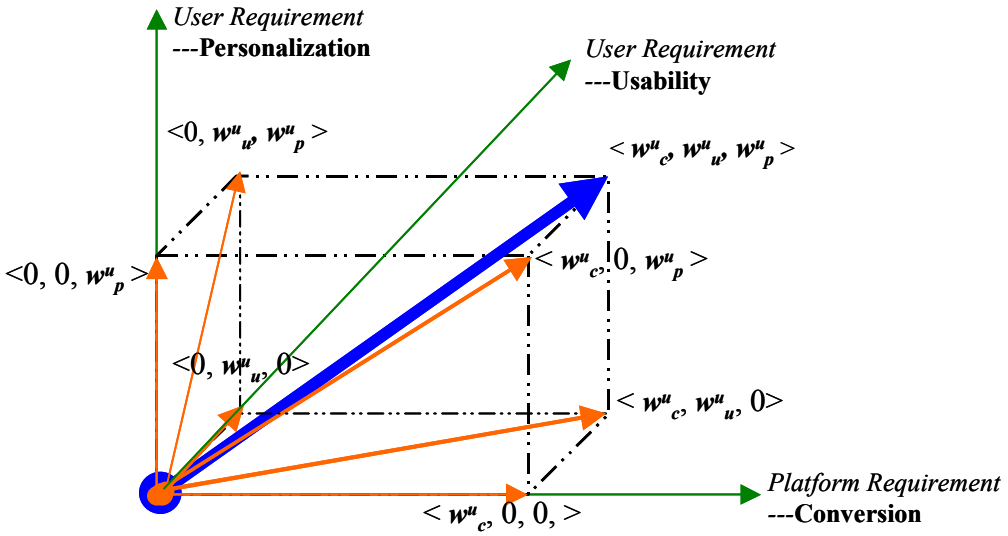

Figure 2. Dimensionality of Adaptation

The four adaptation approaches reviewed above fall into two basic adaptation requirements: wireless form factor oriented adaptation (version adaptation and template adaptation); and mobile user oriented adaptation (usability adaptation and personalization adaptation). The former should be seen as the basic requirement and the first step toward content delivery adaptation to wireless handheld devices. The latter is becoming more important toward pervasive applications, as both usability and personalization are essential considerations. Figure 2 shows a comprehensive view of three-dimensional adaptation model: mobile platforms with different browsers would require conversion flexibility; personalized information delivery meets the user's best interests; and usability guidelines would be applied to the converted, personalized presentation.

This model could provide insights for application development and adaptability evaluation. For example, given a particular mobile user

$$u \in U,\ U=\{u \mid \text{users with mobile browsers}\};\quad U: \leftarrow \text{user profiles}$$

and a certain type of mobile browsers

$b \in B$, $B=\{b|$ *WAP phone, palm, pocket PC*$\}$; $B: \leftarrow$ *standard device profiles*

If mobile web adaptation features are viewed as a three dimensional vector:

$ADT = <$***C****onversion,* ***U****sability,* ***P****ersonalization*$>$

Then the following vector *adt* will represent the combinatory adaptation of different features for a particular mobile user *u* with a certain wireless browser *b*

$$adt = < w_C^{ub} , w_U^{ub} , w_P^{ub} > \quad u \in U, b \in B, w=W;$$

where $W \in [0, max]$ is defined as the significance scale of each dimension. The determination of this scale value is subject to detailed experiments and evaluation methods. The adaptability value can be computed by taking the norm $\|\boldsymbol{adt}\|$. The difference in effectiveness between different combinatory adaptability can be measured by their distance. Taking a similarity measure *cosine coefficient* commonly used in information retrieval as example:

$$sim(adt^A, adt^B) = \frac{adt^A \cdot adt^B}{\| adt^A \| \cdot \| adt^B \|} = \frac{\sum w_i^A \cdot w_i^B}{\sqrt{\sum (w_i^A)^2 \cdot \sum (w_i^B)^2}}$$

or distance measure

$$dis(adt^A, adt^B) = 1 - sim(adt^A, adt^B) = 1 - \frac{adt^A \cdot adt^B}{\| adt^A \| \cdot \| adt^B \|}$$

In particular, the three-dimensional adaptation model could be extended to *n* dimensional vector space if sub-features are added to each feature dimension. Increased complexity of content conversion, ranging from scaling, syntactic transcoding, to semantic transformation (Trevo et al. 2001), and more usability and personalization could achieve greater adaptability gain.

The exact adaptability value gained could be computed as distance measure between two vectors. From the perspective of conversion complexity, in order to improve adaptability, linkage or structure rearrangement of content is necessary. Merely scaling down to squeeze the Web content to a mobile browser without usability and personalization considerations has the least adaptability. Scaling down a full size Web site to fit into small screen is currently seen in Pocket PCs. a recent research (Chan et al. 2002) indicates such method often leads to awkward rendering effects and poor usability, such as excessive scrolling and malfunctioned scripts. It is clear that content rearrangement is required for small displays. Transformation involves significant modification and restructuring on both content and structure in addition to basic syntactical transcoding. The M-Link navigation model (Trevo et al. 2001) and the Digestor system (Bickmore and Schilit 1997) have followed this approach. Usability guidelines and personalization techniques could be applied while content and structure are transformed. The combination of dynamic transformation and personalization results in greater adaptability for wireless small screen browsers and mobile users.

Methodology and Research Schedule

As long as those restriction features (small displays, slow input, etc.) exist, adaptation techniques and methods have to be applied. Technically, many constraints related to mobile computing infrastructure would be overcome by the advance of new technologies. Nevertheless, the small display versus the portability convenience is always a trade-off. In this paper, I have discussed adaptation challenges and approaches to wireless data delivery mainly from the perspective of Web content presentation. The proposed classification scheme and the adaptation model represent my initial research in studying content adaptation over the mobile Web. A WAP prototype design has been implemented.

The proposed adaptation model would serve as the basis of my future research. My ongoing research schedule and methodologies are as follow:

(a) Clarify the variables and refine the adaptation model. Particularly, I would examine the weighting scheme of the dimension features. Personalization methods for mobile users are the focus of this stage.

(b) Improve the prototype design and implementation on the basis of the dimensionality study. Current implementation is merely based on the designer's perspective. By incorporating these dimensional features, I expect the improved design would be more suitable for mobile users. Usability guidelines for wireless handheld devices and transformation techniques would be incorporated in the implementation.
(c) Experimentation and evaluation. In this stage, the variables and weighting scheme defined in the first state would be used as the factors for designing experiments and measurement metrics.
(d) Data analysis. Appropriate statistical methods and tools are to be applied in this stage to test the significance of the result.

The following research questions would be investigated in depth in later study:

- How to coordinate and measure three dimensions (conversion complexity, usability, and personalization) featured in our proposed model?
- What new and established mobile usability guidelines could be applied to wireless content adaptation?
- What factors determine the complexity of content transformation?
- How could different personalization techniques be applied to mobile Web and how effective they are in the mobile context?

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