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Developing Adaptive and Personalized Mobile Applications: A Framework and Design Issues

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ABSTRACT

The rapid growth of mobile technology has expedited ubiquitous information access via handheld devices. However, the fundamental natures of mobile information systems are different from those of desktop applications in terms of purpose of use, device features, communication networks, and working environments. This poses various challenges to mobile information systems on how to deliver and present multimedia content in an effective and adaptive manner. One of the major challenges is to deliver personalized information to the right person in a preferred format based on the changing environment. This paper proposes an innovative framework for developing mobile applications that deliver personalized, context-aware, and adaptive content to mobile users. The framework consists of four major components: information selection, content analysis, media transcoding, and customized presentation. It can be applied to a variety of mobile applications such as mobile web, news alert services, and mobile commerce.

Keywords

Personalization, adaptive system, context-aware adaptation, mobile application, wireless environment

INTRODUCTION

In the past decade, computing is moving toward pervasive and ubiquitous environments. We have witnessed the explosive growth of small mobile devices such as cell phones, palm pilots, and personal digital assistants (PDAs) that have been used to provide users with ubiquitous access to information. Our society becomes increasingly mobile. Many mobile information systems have been developed for various information-on-demand applications. However, the unique constraints of mobile devices and wireless networks, further confounded by the fact that individual users may have different information needs and preferences, have posed a number of challenges to delivering and presenting multimedia information to mobile users.

Mobile handheld devices have several constraints including small screen size, low resolution, small memory, and limited power. The small screen size can cause web pages to look confusing and cumbersome to read; low resolution restricts the display of multimedia content; and limited memory and power limit computation capability of mobile devices. Low bandwidth of wireless networks can cause serious delay or data loss; and users may experience unexpected network disconnections. In addition, users may have disparate interests and preferences. Everyday, some users may be interested in knowing the latest stock prices, while others may be interested in weather or sports news. Obviously they would like to obtain relevant content that meets their individual needs and can be presented in a preferred format. For example, some users prefer a video clip or an image in addition to a text message, even though it may cause a longer delay. Other users may incline to receive content with images or video already removed in order to shorten the latency.

Therefore, it is desirable to deliver adaptive and personalized information that is customized to best suit a particular device, a dynamic network environment, and a user's preference. Such a process of content personalization and adaptation may include filtering out irrelevant information, converting images to lower scales/resolution, compressing video, and re-authoring the original content (Bickmore and Schilit, 1997; Zhang, 2003).

So far, to our best knowledge, there is no systematic study that has attempted to develop a comprehensive, generic framework for context-aware personalization and adaptation in mobile information systems. This paper tries to bridge the gap by proposing an innovative methodical framework based on the past research and practice. It provides insights into step-by-step development processes and discusses several research issues. Researchers and practitioners can use this framework to design

mobile applications that are adaptive to changing environments and personalized according to interests and preferences of individual users.

In the rest of the paper, we first introduce some related work in this research area. Then a framework for developing adaptive and personalized mobile applications is presented, followed by a detailed description of each component in the framework. The final closing section discusses the research issues we have identified through this research.

RELATED WORK

We classify previous studies on content adaptation for mobile applications into three groups: adaptation based on user profiles, adaptation based on mobile devices and network status, and adaptation based on changing environments.

Adaptation based on user profiles: Several studies have shown that user profiles can shorten time for users to find the right information, thus alleviating the problem of information overload (Samaras and Panayiotou, 2002). For example, NewsDude (Billsus and Pazzani, 1999) utilized users' ratings and information stored in user profiles to personalize news for different users. The system would then select news articles for a user if their content is similar to that of articles that he/she rated 'interesting' in the past. Similar to NewsDude, another personalized news service system developed by Carreira et al. (Carreira, crato, Gonçalves and Jorge, 2004) used Bayesian classifier to select news articles of interest to specific users. However, users' reading behaviors (i.e., average reading time of a text line) were used to determine users' interests in particular news articles instead of users' ratings.

Adaptation based on features of mobile devices and network status: Because of constraints of mobile devices and low bandwidth of wireless network, some studies have investigated using information of device features and network status to generate a new version of document that is suitable to deliver and display on mobile devices. For example, Berche, Brunie and Pierson (Berche, Brunie and Pierson, 2004) proposed an architecture of a content adaptation engine that aimed to customize the original content based on the constraints of mobile devices and wireless networks. In this architecture, an original web page (e.g., CNN) is tailored by reducing sizes of images that are larger than that of mobile screens, removing media (e.g., video) that are not supported by mobile devices, and compressing large-sized media files that may take long delay to transmit through wireless networks (e.g., converting image to png and video to mpeg standards).

Adaptation based on changing environments: Since users can use mobile applications anywhere and anytime. One of the challenging issues of developing effective mobile applications is the variation of users' environments. Some studies have investigated utilizing environmental information (e.g., location, light intensity, and noise level) (Kjeldskov, 2002; Schmidt, 2000). For example, a mobile application can utilize environmental information (e.g., light intensity and noise level) obtained through sensing devices to adjust font size, voice volume, and screen contrast and brightness level).

Our work aims to integrate these three lines of research together for delivering the personalized and adaptive content based on not only users' preferences, but also the features of individual mobile devices, network status, and users' environments.

A FRAMEWORK FOR DEVELOPING ADAPTIVE AND PERSONALIZED MOBILE APPLICATIONS

We propose a generic framework for developing adaptive and personalized mobile applications, as shown in Figure 1. It takes four factors into consideration: user interests, mobile device features, wireless network conditions, and context of use.

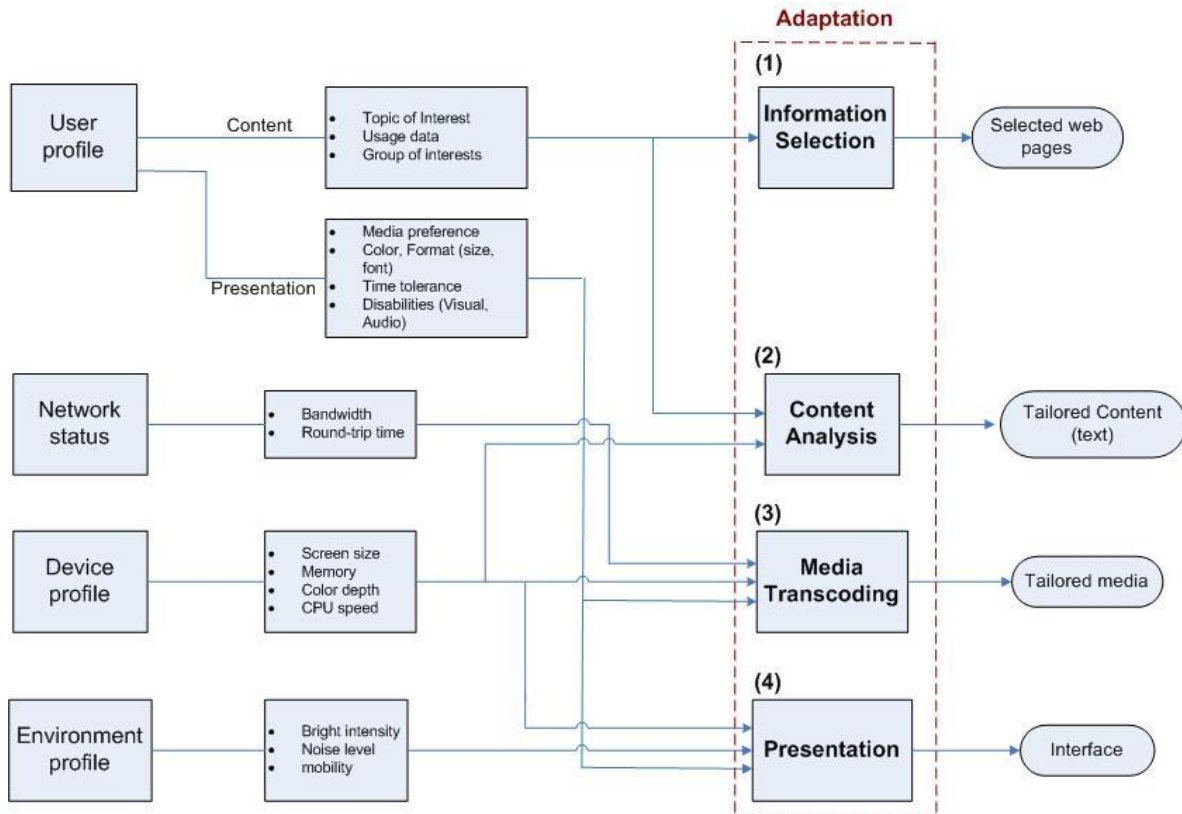


Figure 1. A framework for developing adaptive and personalized mobile applications

User profiles contain information about users, which can be categorized into content and presentation preferences. Content preference represents topics of interests (e.g., sports), usage data (access history), and group memberships (i.e., groups of users with similar interests). Presentation preference includes displaying styles or formats on mobile screens that individual users prefer (e.g., font size, favorite media).

Device profiles contain information about characteristics of mobile devices such as screen size/resolution, media support, color depth, etc.

Network status maintains the network traffic data such as bandwidth and transmission latency captured by network monitors in real time.

Environment profile keeps environmental or contextual information such as location and time. This kind of information enables mobile applications to provide services based on the context (Gellersen, Schmidt and Beigl, 2002).

The framework also includes four main processes: information selection, content analysis, media transcoding, and presentation, which are explained in details in the rest of this section.

Information Selection

The information selection process selects content that may be interesting to users while filtering irrelevant part. The process uses information stored in user profiles as input, as shown in Figure 2.

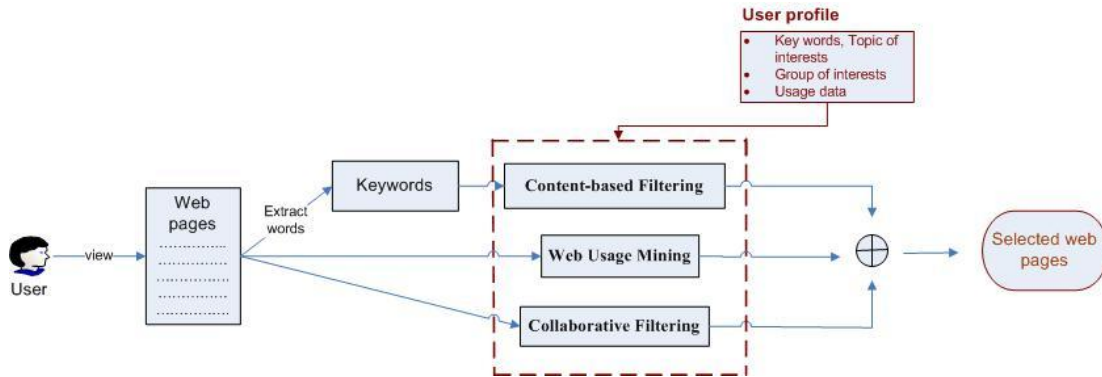


Figure 2: Selecting information based on user profiles

There are three major techniques for selecting information based on users’ interests: content-based filtering (CBF), collaborative filtering (CF), and web usage mining (WUM). CBF analyzes the content of documents that users access and finds new articles that are similar to what users have read (Billsus and Pazzani, 1999). CF uses users’ ratings on individual information items to identify their interests, and clusters users into groups based on their interests. As a result, information in which one user is interested can be automatically recommended to other users within the same interest group. WUM automatically creates user profiles based on information of user access patterns. These access patterns are generated by using data mining methods on Web logs. Users who share similar usage patterns will be clustered into a group, assuming that they have common needs and interests (EiriNaki and Vazirgiannis, 2003).

These three techniques have both of strength and weakness. CBF is straightforward, but it over-relies on text analysis and is difficult to measure the similarity between two documents at a semantic level. CF can be applied to various information domains because the evaluation of information relies on users (i.e., user ratings), but it suffers from data sparsity and scalability problems because users are not likely to give ratings. WUM doesn’t have the problems of CBF and CF because its information selection is independent of content and user ratings. However, WUM requires a huge amount of information (i.e., web log) and intensive computation for pattern analysis. Moreover, WUM cannot capture the change of content. These techniques can be complementary to each other. A better solution may be to integrate them together for content selection.

Content Analysis

The content analysis process analyzes the content embedded in the selected web pages, and tailors it based on user and device profiles. Since a web page normally contains both clutter (e.g., pop-up ads, irrelevant images, and extraneous links) and several topics of content, content analysis aims at tailoring content (text) by filtering advertisements and some news topics that are not interested to users, and customizing the relevant news into a legible and navigable presentation on a mobile screen. Content analysis mainly focuses on text and leaves other media types (i.e., sound, image, and video) to the media transcoding process, which will be described later. Figure 3 shows the activities involved in this process.

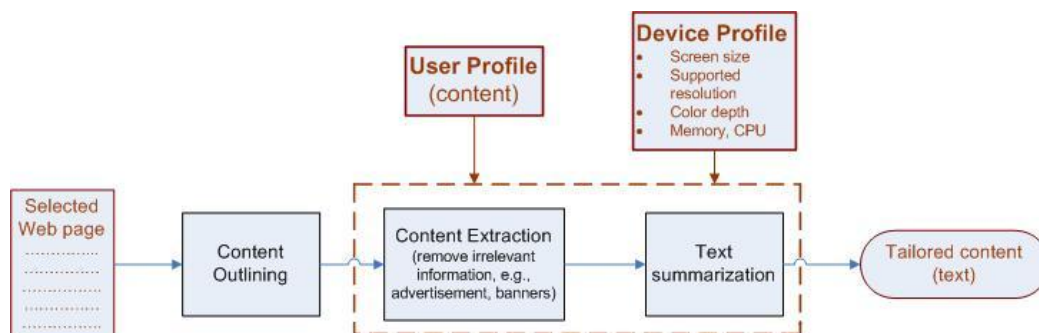


Figure 3. Content analysis

Content Outlining

The content outlining component aims at drawing a layout of a web page. A web page often contains several content parts that are called “content blocks” (Lin and Ho, 2002). The content within a content block may include a variety of media objects (e.g., text information, images, and movie clips). The main task of the content outlining component is to examine how many content blocks are in a web page, how they are related, and how many media objects reside in each content block.

W3C has developed Document Object Model (DOM), a standard interface that creates a tree structure for HTML and XML documents (W3C, 2005). Based on DOM, a web page can be represented a hierarchical structure of content blocks, as shown in Figure 4. The structure of these content blocks can be used to generate a layout of presentation on mobile screens. For example, content can be presented in a order of content blocks starting from top to bottom and left to right direction of the tree structure. For example, the order of presenting content blocks are C1, C2, C3, C5, C7, C4, and C6.

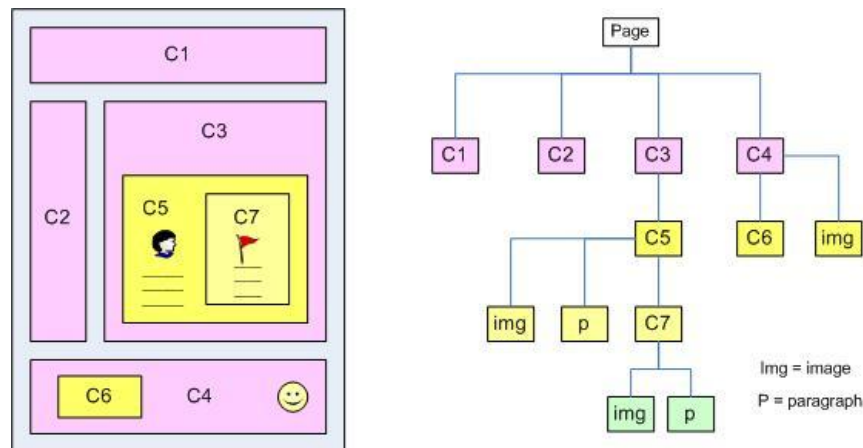


Figure 4. Using a DOM tree to present a layout of a web page

Content Extraction

Extracting content blocks that are interesting to users and removing irrelevant ones are the main tasks of content-extraction component. Using the information stored in user profiles, we can measure the similarity (e.g., using cosine similarity function) between the user profile and content in individual content blocks. Content blocks with high similarity values can be considered relevant to users' interests.

However, when a user accesses a new web page that is not recommended by a mobile application (e.g., typing a new URL), the challenge lies in how to define what content block(s) the user is interested in. Some studies focus on eliminating noisy content blocks (e.g., advertisements, navigation panel), and presenting informative content blocks (e.g., news) to users (Lin and Ho, 2002).

Text Summarization

If the original content within content blocks is displayed as it-is, users may have a difficult time to find information of their interests. Some studies have shown that summarization can help mobile users to quickly identify whether information is of interest to them (Buyukkokten, Kaljuvee, Garcia-Molina, Paepcke and Winograd, 2002; Yang and Wang, 2003). Therefore, it may be beneficial if summarizations are applied in mobile applications (Zhang, 2003).

So far, summarization is applied to condense content without considering what information users want. However, mobile users usually already know what information they want. Therefore, mobile summarization should provide selective information required by users for their specific tasks. Moreover, since different mobile devices have different screen sizes, a summary that fits the display of one device may not fit another. Therefore, it may be beneficial for users if summaries are generated and adapted to fit in different mobile devices.

Media Transcoding

Because of the limited network bandwidth that can potentially cause very long transmission latency while delivering multimedia content such as video or images. In addition, small local memory and small size of a mobile screen sometimes are also a barrier. Therefore, some large-sized media items (e.g., video clips and images with high resolution) that may take long downloading time and consume excessive memory to display should be tailored in media transcoding.

Media transcoding is a process that customizes media objects based on the features of a mobile device, the status of network environment, and a user's preference. We include user's preference here because different users have diverse preferences of media content (e.g., some users prefer only text, while others prefer images). A challenging issue lies in creating an adaptation model that can integrate user preference, features of device, and network status to define appropriate transcoding techniques to tailor the media content.

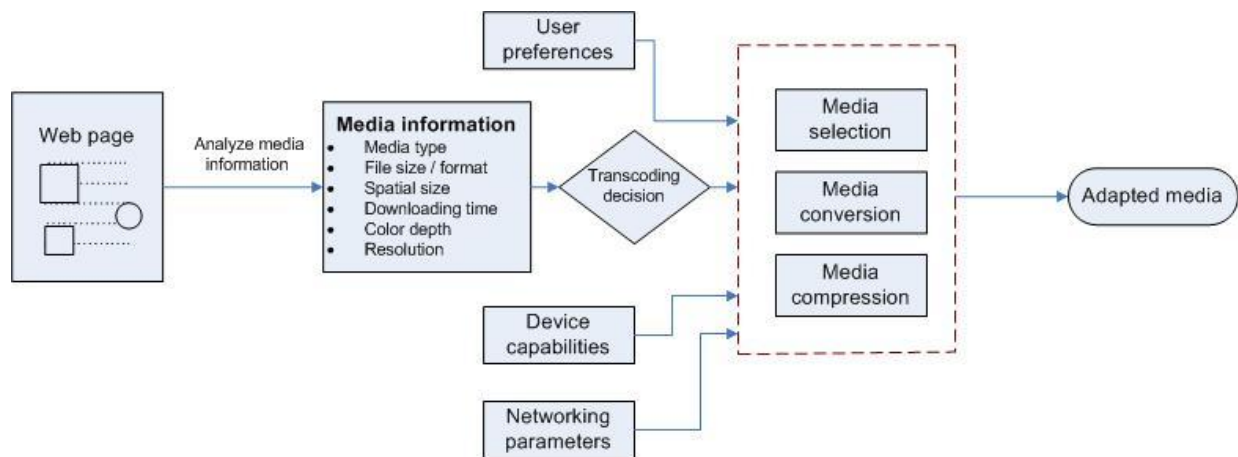


Figure 5. Media transcoding and its components

Multimedia content can be transcoded via three common techniques in order to reduce file size and bandwidth consumption: 1) media selection – removing media types that are not supported by mobile devices; 2) media conversion – converting media types (e.g., converting video to image, audio to text); and 3) media compression – reducing media size in term of scale, color depth/resolution, and file formats.

Presentation

Several techniques have been explored for presenting a large amount of information on mobile handheld devices, such as presentation optimization – fitting the original content on a screen and using vertical scrolling; semantic conversion – presenting content in the form of a tree structure and allowing users to drill down for further details; and focus & context techniques – users can view local information they are interested in (i.e., the focus) in details on a segment of the screen, while other peripheral information (i.e., the context) is also showed in the surrounding area with the reduced granularity of detail (Furnas, 1986; Qiu, Zhang and Huang, 2004).

There are trade-offs of the above approaches. Presentation optimization enables users to view the original content immediately but the frequent use of scrolling bar can reduce reading speed. The tree structure presentation of the semantic conversion approach enables users to see an overview of the entire content at the beginning and find the interesting content quickly. However, users need to take additional steps to retrieve and then view the original content. Focus & context can enable users to enlarge information of interest (focus) without losing sight of other peripheral information (context) but it needs intensive computation process. Therefore, it is important to determine which presentation scheme is more appropriate under certain circumstances.

In addition, mobile applications can utilize environmental information (e.g., location and light intensity) to adapt presentation corresponding to environments users are in, for example, adjusting interface configurations such as font size, color, and brightness level of the screen if users use mobile devices at night.

CONCLUSION

This paper proposed a framework for developing adaptive and personalized mobile applications. The framework consists of four main components: information selection, content analysis, media transcoding, and presentation. These components utilize information from four profiles (i.e., user, device, network, and environment) to produce the customized content that is relevant to interests of users, and adapted to device features, network status, and the contextual environment. We have briefly discussed each component and some challenging issues. The framework can be applied to a variety of mobile applications such as mobile commerce and context-aware mobile services.

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