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An Empirical Study of Web Interface Design on Small Display Devices

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Abstract

This paper reports an empirical study that explores the problem of finding a highly-efficient, user-friendly interface design method on small display devices. We compared three models using our PDA interface simulator: presentation optimization method, semantic conversion method, and zooming method. A controlled experiment has been carried out to identify the pros and cons of each method. The results show that of the three interface methods, the zooming method is slightly better than the semantic conversion method, while they both outperform the optimizing presentation method.

1. Introduction

With the rapid advance of the Internet technology, an increasing number of people use wireless devices such as Web-enabled cell phones and PDAs (Personal Digital Assistants) to go online. There are significant differences between a desktop computer screen and a small display. First, a small display device has a limited number of input facilities, processor power, memory and bandwidth [1]. The display form also introduces several new constraints for human computer interaction design. Second, there are various kinds of viewing conditions when surfing the Internet, such as varying screen sizes, style preferences, and different device capabilities [2]. For example, consider the case of a user viewing a diagram representing an organizational structure on the Web, the fully expanded diagram is of considerable complexity and may be unsuitable for small displays. Thus, if the diagram is to be viewed on the screen of a mobile device such as PDA, the original layout may not be appropriate. Furthermore, the standard components of traditional graphical user interfaces, such as scrollbars, buttons and menus, which on a desktop only take a small percentage of the available screen estate, take up a considerable percentage of screen estate on a PDA.

In order to adapt to different clients, we need an efficient mechanism to browse the content of the Web. There are increasing demands for the ability of efficient browsing to meet the client side requirements. Present browser technologies for mobile devices can be characterized into three categories [3]: presentation optimization, semantic conversion, and scalable (zooming) methods. We designed a simulator to implement these three methods and compare their pros and cons by a controlled experiment. This paper reports our findings and experience.

Section 2 introduces the aforementioned three interface design models. Section 3 briefly describes the goal and procedure of our experiment. Section 4 reports the results of the experiment, and Section 5 compares these three methods. Section 6 discusses related work, followed by the conclusion and future work in Section 7.

2. Three Interface Design Methods

Chen and Mohapatra proposed the method of scalable browser [3] and argued that this method is a new way to design PDA interfaces. There is however no data or experimental evidence to support this method over other prevailing methods such as presentation optimization and semantic conversion. In order to compare these three methods objectively, we have simulated the methods and implemented a controlled experiment to compare them. Below, we first describe the three design methods that have been simulated.

2.1. Presentation Optimization

Presentation optimization represents a broad range of technologies whose objective is to optimize the rendering process so that the contents to be displayed on the screen are maximized and users' navigation complexity is minimized. For instance, the embedded version of Microsoft Internet Explorer has the functionality of fitting the contents into the screen size. This technology can properly adjust the width of the displayed area such that users are relieved from scrolling horizontally to locate the desired contents [3]. Using this method, we fit the contents of a document to the limited size on a small screen. The disadvantage is that the semantics cannot usually fit the style well and users cannot easily locate their desired content parts within the document.

2.2. Semantic Conversion

Since the presentation capability of mobile devices is limited by their screen sizes, converting the original contents into what will facilitate the reading process is another viable solution. In the semantic conversion approach, the Web contents are parsed, analyzed, and reordered based on certain psychological and statistical rules that determine the rank of importance within the page [3]. We can use text summarization [4] and tree structure to give an overview of contents to users. Users can jump from any page directly to the page containing the desired material.

2.3. Zooming

The zooming approach is based on a progressive rendering process that retains both the structural and semantic information. In the progressive process, the structural data are delivered first and the semantic data are delivered on demand. More specifically, upon requests, the server first replies to the client with the structural data plus a small set of semantic data that assists the client's understanding of the whole information. The client's mobile device can render the structural data within the screen size. When the user at the client side navigates to a certain area and clicks to see the complete semantic information, the browser fetches the corresponding data and renders it using as much screen space as necessary [3].

3. Simulator and Experiment

3.1. The Experimental Content

The purpose of this experiment is to survey the efficiency and effectiveness of the three design methods using our PDA interface simulator.

We revised the tutorial material of eBay for our experiment text. EBay is a popular Web site on buying and selling commodities on-line and has a large user community. Since it has strict rules on how to buy and sell, we can use the tutorial material in different presentations to test users' understanding and acceptance. Thus, we can compare the efficiency of different Web browser design methods. Also, the tutorial has an intuitive structure and pictures, which are easy to be reorganized and presented in different styles.

We have written a simulation program to model the interface of a small display. Using the http server, the simulator is insensitive to the local environment. We selected two tutorial texts from the eBay web site. These two texts are similar in contents and style so that the experimental results are comparable. The second text is a little longer and more complex than the first text. For each text, we wrote three Web simulation programs to simulate the three Web search methods. For example, the interface simulators for the first text include: OPTv1.html, Seman_v1.html, and Zoom_v1.html, corresponding to the three methods. The ones for the second text are OPTv2.html, Seman_v2.html, and Zoom_v2.html. The http server can record the timing of each page used. We also asked students to record the time they spent on each question.

As shown in Figure 1, the Presentation Optimization method supports navigation page by page. For example, one can only go from page 1 to page 2, then page 3, page 4, and finally page 5.

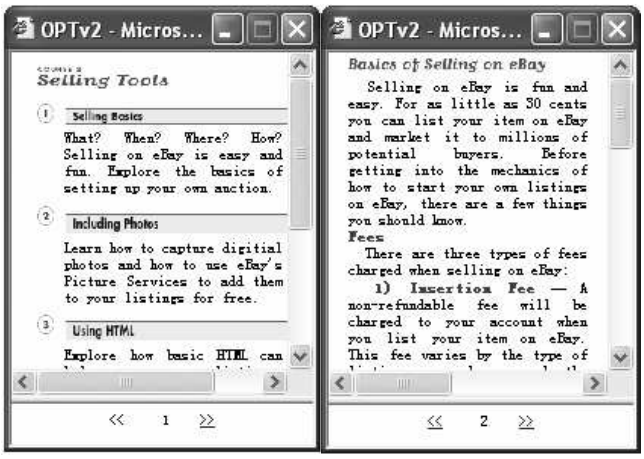


Figure 1 Presentation Optimization method

With the Semantic Conversion method (shown in Figure 2), when clicking on the menu "Form Completion" in page 1, we get page 5 directly. Since the tutorial is organized in a tree structure, we can easily search the directory and find certain subtopics in which we are interested. One needs not to click on the next button page by page to get page 5. There are also UP-level and Home functions.

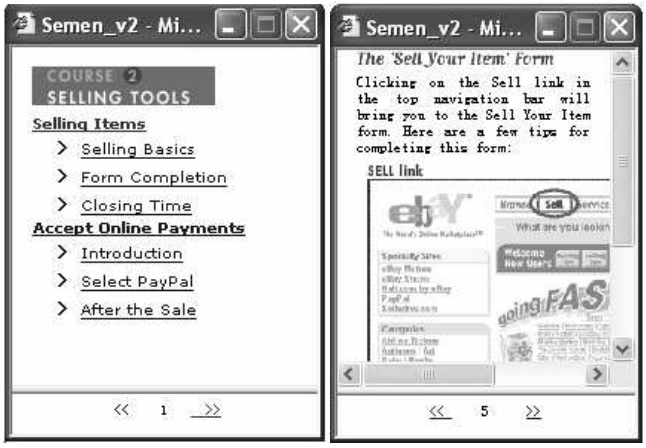


Figure 2 Semantic Conversion method

As shown in Figure 3, the Zooming method is based on the Semantic Conversion method with an additional zooming function. For example, there is a picture in page 4. To see the picture in detail, one can click on it to blow up the full picture as in page 5 (on the right of Figure 3).

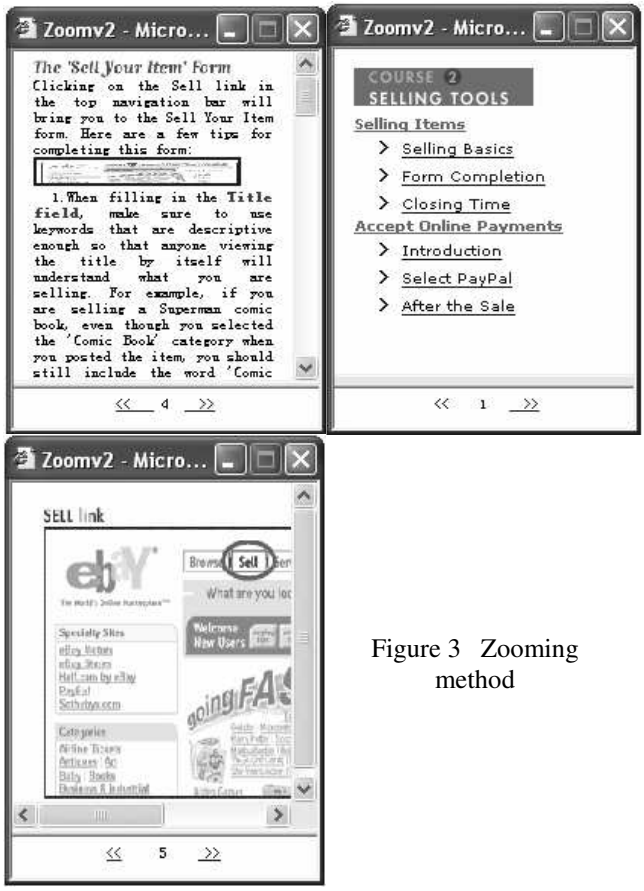


Figure 3 Zooming method

3.2. Experimental Procedure

In this experiment, 27 graduate students majoring in computer science participated as our subjects. 20 of them have not used PDA before. Of the remaining 7 subjects who have used PDAs before, only two have owned PDAs. All the subjects have heard of the eBay Web site, but none of them has read the tutoring material before. We divided the 27 subjects into 4 groups and each group includes 1 or 2 subjects who have used PDAs. We conducted our experiment on the three methods in the following arrangement:

Group 1: OPTv1.html, Seman_v2.html

Group 2: OPTv2.html, Seman_v1.html

Group 3: OPTv1.html, Zoom_v1.html

Group 4: OPTv2.html, Zoom_v2.html

We designed a PDA interface feedback questionnaire to evaluate the effectiveness of each method. This questionnaire contains 10 questions for the first text, 10 for the second text and 7 general questions.

OPTv1.html corresponds to the first text in EBayQuestion.doc using the Presentation Optimization method. Seman_v2.html corresponds to the second text in EBayQuestion.doc using the Semantic Conversion method. Zoom_v1.html corresponds to the first text in EBayQuestion.doc using the Zooming method.

The testing procedure is as follows:

1. Each subject is given access to a server: httpsrv.95zxu, two document files: Readme.doc, EBayQuestion.doc, and two simulator files, for example (OPTv1.html, Semen_v2.html).

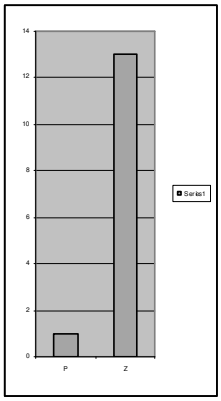
2. The subject clicks on httpsrv.95zxu, and double clicks on startup.bat to run a Java serverlet.

3. Double clicking on the html file, the subject will see a small screen simulating the actual PDA screen. The subject is required to find the answers on this screen. Some questions ask the subject to select as many answers as apply. Also a subject needs to record the time he/she spent on each question and report it in a time sheet.

4. Find the answer on the PDA screen simulator. Upon completion, the subject reports the total time he/she has spent on each text. Under the directory of httpsrv.95zxu, the subject will find a file: cnt.txt. Also, the subject needs to submit this file.

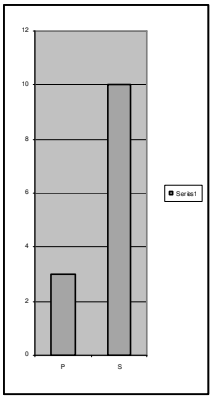
4. Results

4.1. Subject Responses



Presentation	3
Semantic	10

(a)



Presentation	1
Zoom	13

(b)

Figure 4 Subjects' preferences

A total of 27 subjects participated in the experiment. In groups 1 and 2, totally 13 subjects participated the experiment of comparing the Presentation Optimization method (P) and the Semantic Conversion method (S). The result is: 3 voted for the former method and 10 for the latter as the best method. Figure 4 (a) illustrates the subjects' preferences in the Presentation Optimization method verses those in the Semantic Conversion method.

Groups 3 and 4 consist of totally 14 subjects who participated in the experiment of comparing the Presentation Optimization method (P) and the Zooming method (Z). The result is: 1 voted for the former method and an overwhelming 13 for the latter. Figure 4 (b) illustrates the subjects' preferences in the Presentation Optimization method verses those in the Zooming method.

4.2. Pros and Cons

From the feedbacks of subjects and the observation of our experimental results, the pros and cons of three methods are summarized below:

1. Presentation Optimization Method:

Pros: This method is better for a novice user who wishes to learn all information in one page.

Cons: With the Presentation Optimization method, the subjects needed to read through a lot of text just to find the piece of information that they wanted. It was too difficult to search for a specific answer.

Most users do not like the scroll bar. Users are used to seeing outlines of information, simply clicking on the topic of interest, and being taken to the topic details directly.

2. Semantic Conversion Method:

Pros: Easier to navigate, more organized than the Presentation Optimization method. It is easier to see page contents and possibly eliminate the scroll bar.

Cons: Sometimes the information was paged and has to be searched from one page to another.

3. Zooming Method:

Pros: Easy to navigate. When looking for information, a subject only needed to return to the menu and click on the topic that seemed most related to what he or she was looking for. This helped to find the information more quickly than with the other methods.

With the Zooming method, a subject could at least go to the general location to look for the answer. It provides an intuitive and hierarchical structure. It is easy to find and read the desired information.

It is more efficient for a user who wants to capture small pieces and detailed information. A browser implementing the Zooming method is better suited to this type of users.

Cons: The picture showing on a small display cannot be very clear. Also, it lacks the advantage of key word search.

5. Analysis and Discussion

This section further analyses other characteristics of the three design methods. Section 5.1 analyses the time parameters of different methods: the average time spent on one question among all subjects, the average time spent on all questions by one subject and average total time of all 20 questions among all subjects. The time parameter reflects how easy or difficult to understand the material using different presentation methods. Section 5.2 analyses the average correct rates of one question and a total of 20 questions using different methods. The higher the correct rate is, the more efficient and effective the method used. Section 5.3 analyses the page change rates. To find a specific piece of information, a subject may need to access pages backward and forward. The lower the page change rate is, the easier for a subject to find desired contents. Section 5.4 discusses other issues in this experiment.

5.1. Time

1. Average time of one question:

As shown in Figure 5, the average time of a question using each method is obtained by averaging the time that a subject spent on each question. In Figure 5, the time unit is minute. P stands for the Presentation Optimization method, S for the Semantic Conversion method and Z for the Zooming method.

2. Average time of 20 questions

The average time of answering all 20 questions for all subjects using different methods is shown in Figure 6 (time unit: minute). This parameter is an average on all 20 questions for each method. We can see that the Zooming method is the fastest, the Semantic Conversion method is second and the Presentation Optimization method is the slowest.

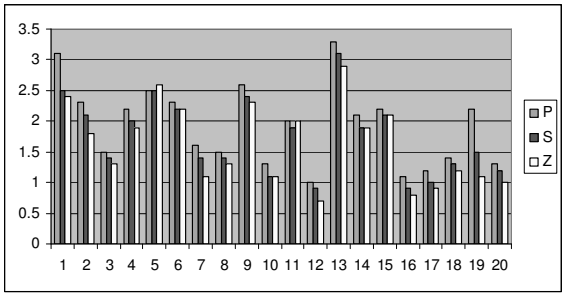


Figure 5 Average time spent on a question using different methods

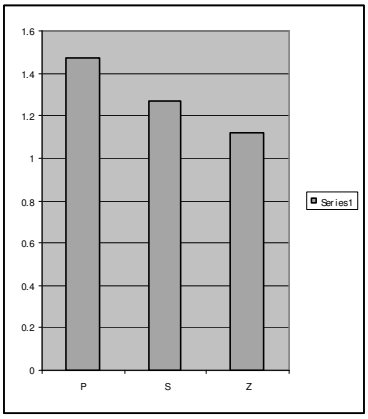


Figure 6 Average time for answering all questions using different methods

3. Total time

The total time needed to finish all 20 questions using different methods is shown in Figure 7.

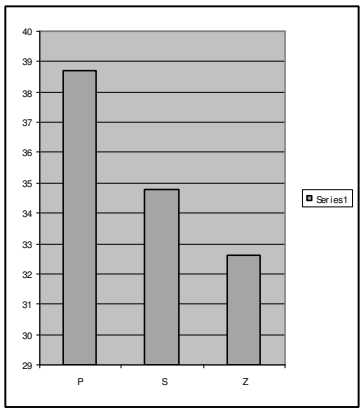


Figure 7 Total time needed to finish all 20 questions using different methods

From the data and figures obtained, we can see that with the Zooming method, users spent the least amount of time to answer a question, which means that the Zooming method is better in browsing the contents of Web pages. The Semantic Conversion method is also better than the Presentation Optimization method, which is the least effective in finding specific information among the three.

5.2. Correct Rate

1. Correct rate: the correct rates of using different methods are listed in Table 1.

	P	S	Z
1	80	80	90
2	90	80	100
3	80	80	100
4	40	50	70
5	70	80	80
6	30	40	60
7	90	90	90
8	70	70	80
9	30	40	40
10	80	80	80
11	40	40	50
12	90	90	90
13	90	90	100
14	100	90	100
15	80	80	80
16	60	70	70
17	70	70	70
18	80	80	80
19	90	90	100
20	30	40	60

Table 1 Correct rate of answering each question using different methods

2. Average correct rates for the 20 questions using different method are shown in Figure 8.

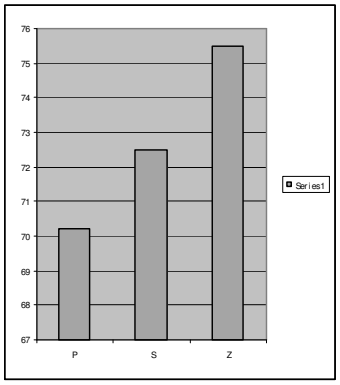


Figure 8 Average correct rates for 20 questions using different method

These results show that using the Zooming method, users can easily locate detailed information and better understand the structure and semantics of the whole text. The Presentation Optimization method is the worst and Semantic Conversion method is in the middle.

5.3. Page Change Rate

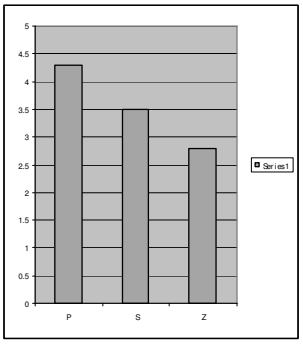


Figure 9 Average page change rates of the three methods

To answer each question, a user may need to change from one page to another. The average page change rates of different method are shown in Figure 9.

Since the questions are not arranged in the same order as the page sequence in the tutorial, a user needs to change from one page to another and jump frequently. The results show that using the Zooming method, a subject can locate specific information faster than using the Semantic Conversion method, which is in turn faster than the Presentation Optimization method.

5.4. Discussion

From the above experiment, we not only obtained data for comparing the efficiency and effectiveness of these three methods, but also gained insights in how to improve Web designs.

1. Adding keyword search may enhance a browsing method. One method is to allow users to click on keywords in the display text to traverse data. This will also strengthen the semantic aspect of the contents.

2. We can further compare the Semantic Conversion and Zooming methods directly. Due to the time constraints and short of available subjects, our experiment only compared the Semantic Conversion and Zooming methods separately with the Presentation Optimization method. The relation between the Semantic method and the Zooming method is obtained indirectly. An experiment comparing these two directly will be conducted in the future.

3. Tree is a common structure in interface design. In our experiment, both the Zooming method and the Semantic Conversion method use the tree structure to represent the contents, so that the user can easily locate specific information. This complies with the way in which people learn new knowledge. The number on each page does not really help users in navigating the system.

4. The Zooming (also called scalable) method has good application potential, since it not only distinguishes structural data from semantic data, it is also scalable when delivering the information that the viewer is interested in. Hence, when adopting this concept, we can find a way to adapt to people's learning method and help them find useful information faster.

6. Related Work

Much research has been conducted in the areas of interface design for small displays. Some emphasized on hardware aspect. For example, Mizobuchi *et al.* [5] conducted several experiments to compare target pointing performance with a pen and with a cursor key. Others concentrated on software aspect, such as text summarization, graph compression, hierarchical and dynamical interfaces, adaptation, as summarized below.

In text summarization, Buyukkokten *et al*. [4] presents important ideas of extracting semantics from the Web text yet greatly shortening the length of text. Usually, each text page is broken into a number of text units that can be hidden, partially displayed, fully visible, or summarized. Research has been conducted on dynamic text presentation for mobile devices using Rapid Serial Visual Presentation (RSVP) [6].

Chittaro *et al*. [7] have done experiments to explore the problem of graphically visualizing numerical data on the very small displays of WAP phones, especially the visualization using bar charts. The experiments are, however, not for Web navigation and presentation.

Researchers have proposed useful ideas on Web interface design, but have not performed sufficient experiments to compare different presentation methods in terms of their space efficiency. Hierarchical menu structure has been used in user interface design based on spatial organization of information [8]. For a mobile device, content hierarchy or Hierarchical Atomic Navigation (HANd) has been proposed as a new philosophy to improve Web navigation on small displays [9]. The idea is to divide an original page into zones and make the navigator page as a reduced overview of the original page. Henricksen *et al.* [10] addresses types of adaptation that can be applied to a Web browser in response to diverse context changes, including changes in the user context, input and output device capabilities, etc.

Buchanan *et al.* summarizes that there are three ways of presenting information on a limited screen [11]: **Horizontal Scroll** method: only characters across the display are shown. Users scroll to the right to retrieve remaining sentence. **Vertical Scroll** method: text is wrapped to show full sentences. **Paged** method: a long text is broken into multiple pages. Each page fits on the display screen. User hits "Next" button to get to next page. Performance results have been reported [11] and independently confirmed [13]. The Vertical Scroll method is the fastest among the three methods. It also produced the least number of errors. Paged method was the worst, which is the reason why WAP 1.0 WML failed.

7. Conclusion and Future Work

7.1. Conclusion

This paper has used an empirical method to compare three design methods on small screen displays, such as a PDA screen. A controlled experiment has been carried out to reveal the characteristic of each method. The Zooming and Semantic Conversion methods are better than the Presentation Optimization method. The tree structure is a common method in the interface design for small screens.

Presentation Optimization provides a good method for displaying tutorial materials when it can fit most contents onto the screen, even though one must frequently use the

vertical and horizontal scroll bars. A semantic browser does much of the same with an additional convenient feature: a table of contents, rather than linear browsing as seen in the Presentation Optimization method. A Zooming browser is better organized and allows the user to zoom into pertinent contents as needed. The latter two provide an overall better way for browsing small screens, given their limited resolution. They should be the interface design method used on PDA's, a popular digital tool for personal use.

From this study, we have learned some basic ideas on how to use small displays efficiently. The results of this study will provide a useful reference for future investigation into the performance of browsing on small displays.

7.2. Future Work

We plan to conduct further empirical studies using many more subjects with more diversify profiles. Another future work is to implement the idea of progressive delivery and scalable browsing according to user's requirements. We will research into decoupling of structural and semantic data from Web pages, and use text summarization to obtain the contents of original pages and create space-efficient pages for small display areas.

We will also combine this work with the graph grammar approach [14] to investigate more efficient and effective means for automatically transforming desktop Web pages into pages for small displays. We will focus on the issues and techniques for size adaptation and style adaptation in response to the change of device requirements and users interactions.

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