Web Page Transformation when Switching Devices

Bonnie MacKay, Carolyn Watters, and Jack Duffy

Faculty of Computer Science, Dalhousie University
Halifax, Nova Scotia B3H 1W5 Canada
{bmackay, waters}@cs.dal.ca, jack.duffy@dal.ca

Abstract. With network and small screen device improvements, such as wireless abilities, increased memory and CPU speeds, users are no longer limited by location when accessing on-line information. We are interested in studying the effect of users switching from a large screen device, such as a desktop or laptop to use the same web page on a small device, in this case a PDA (Personal Digital Assistant). We discuss three common transformation approaches for display of web pages on the small screen: Direct Migration, Linear and Overview. We introduce a new Overview method, called the Gateway, for use on the small screen that exploits a user's familiarity of a web page. The users in an initial study prefer using the Gateway and Direct Migration approach for web pages previously used on the large screen, despite the common Linear approach used by many web sites.

1 Introduction

With network and small screen device improvements, such as wireless abilities, increased memory and CPU speeds, users are no longer limited by location when accessing on-line information. Rather, small screen devices have enabled users to access information, in particular the Internet, from any location with relative ease. In 2002, ComScore Networks Inc. [5] reported that 9.9 million American adults use their PDA (Personal Digital Assistant) or cell phone to access the Internet with news sites being the most commonly accessed web pages. With multiple devices, users can move between these devices while accessing the same information. Users could use a web page on their desktop at the office and use the same information on their PDA while commuting home.

Despite the technical and bandwidth enhancements, PDAs are restricted by the small size of the screen that limits the amount of information that can be displayed at one time. While some research on the effects of different line lengths for reading has found that the limited screen size has little effect on comprehending information, it has been shown to influence reading rates [8],[9]. The small screen can also affect the display of many common web information structures, such as graphs, tables and forms. Using the small screen to effectively access information is further influenced by the very nature of PDA's: their portability. Users using PDAs "on the go" subject themselves to noisy environments with the high probability of interruptions and movement [11]. Similarly, this portability could negatively affect accurate selections on the screen and entering information.

There are two broad approaches for displaying web pages within the small screen constraints of PDAs. The first approach is based on generating static web pages specifically designed for small screen devices. The second approach utilizes some form of automated transformation of the original large web page. The obvious advantage of an automated transformation is the increased pool of accessible web pages for PDA users. However, many current automated transformation options do not consider features such as user task, familiarly with information, web page layout and mobility of the user, and their impact on the usability of the resultant transformed page.

In this paper, we will discuss three approaches to transform web pages to the small screen. We introduce a new method of automatically transforming existing web pages, called the Gateway, for use on the small screen that exploits a user's familiarity with the page to reduce transformation volatility. Transformation volatility results from changes to the look, design, layout and even content when using the same web page on different devices. Finally, we will describe a user study comparing three different display approaches in this context.

2 Web Display Approaches for Small Screens

Many web sites provide a small screen version of their pages for their PDA users. Images may be removed for a text-only version or reduced in size to fit the screen. Font styles and sizes may be changed and reduced. Often the layout, display and sometimes even the content of the original web page are transformed to fit within the constraints of the small screen size. Internet browsers are now available that are better suited to web browsing on the small screens. For example, Windows CE IE has added word wrap and allows users to change the font size to better fit web pages within the screen constraints. Web page transformation, whether at the site or at the browser level, can be divided into three broad transformation categories: Direct Migration, Linear and Overview [14].

2.1 Direct Migration

For Direct Migration, there are no transformations made to the original web page. While this approach does not require human or system intervention, it does require more effort to navigate the page by the users. Users must navigate using both vertical and horizontal scrolling which can cause user frustration and reduce the usefulness of the information on the page as only a small part of the page is visible at one time [1], [9], [12]. Despite the negative points associated with this approach, Direct Migration does provide ready access to most web pages. It can be considered the default transformation for pages without small screen versions. Although browser upgrades have improved web page access on the small devices, these browsers are still limited by the inherent design structure of web pages, such as tables used for formatting and frames.

2.2 Linear Transformation

This approach is used by many web sites, such as news sites, for their users of small devices. Sites create their own Linear versions or use a service such as Avantgo (www.avantgo.com) or Usable Net (www.usablenet.com) to transform the main site into this format. The layout of information from the main web site is changed to a long linear list that fits within the width constraints of the small device. Images may be reduced or even omitted thereby decreasing bandwidth and download time. Content may be changed or reduced using techniques such as summarization [3] or even removed. The main benefit of this approach is that horizontal scrolling is no longer needed, although vertical scrolling may increase substantially. Users navigate by vertically scrolling and clicking to expand links, such as headlines to retrieve more detail.

2.3 Overview Transformation

This form of transformation provides users with an overview of the original web page. Overviews, such as focus + context [15] and Fisheye views [10] have been used successfully on large screens to display large and complex data sets. This approach has been adapted for use on small devices to display large web pages within the constraints of the small screen [2], [4], [17]. For example, the West Browser uses flip zooming [2] that adapts the fisheye approach for the small screen by dividing a large web page into a hierarchy of individual pages or cards that users can flip through. Each card contains up to seven objects that are a representation of information, such as a thumbnail image or text that users can expand for more detail.

The advantage of an Overview approach is that part or the entire layout and, for the most part, content remains the same as the original web page. As well, scrolling may be reduced or even eliminated. The disadvantage of this approach is that by shrinking the original page, readability becomes an issue requiring creative solutions. For instance, the Thunderhawk browser (www.bitstream.com) uses a landscape view to increase the screen width and a special font that replaces the original web page's font at a considerably smaller size while maintaining the readability of the font. While this helps maintain the layout and consistency of the original web page, users often still need to scroll both vertically and horizontally to view the page on the small screen.

3 Design Motivations and Issues

We first explore the usability issues associated with using web pages on the small screen, including web page layout, familiarity with the web page, user task and mobility, and their impact on both the usability and suitability of web page transformation on small devices. We then introduce a new method of automatically transforming existing web pages, called the Gateway for users who are already familiar with web sites.

3.1 Usability Issues

The first usability issue is *web page layout*. The success of automated transformed pages largely depends on the quality of the original web page. Watters et al [16] generalized the layout of web pages into two broad categories: Broadsheet and Linear. Broadsheet web pages tend to be organized into columns with a combination of images and text, similar to a glossy brochure. Many news sites use this approach. Linear web pages tend to contain more text and require scrolling to read. These pages may be very simple with little navigation features or may contain navigation options using a side or top menu bar. Web pages authors have access to simple usability guidelines to improve the overall quality of web pages. However, many pages still vary on many characteristics such as page length or scrolling, color combinations, and font sizes.

A user's *familiarity* with a web page is the second usability issue. When a user first uses a web page, they establish a mental model of the page based on the structural organization of the information, such as visual cues, layout and semantics [1],[7],[15]. A primary objective when transforming a web page for different devices is to minimize the user effort in re-establishing the existing mental model of the original page. Danielson [7] introduced the concept of transitional volatility and described two ways the web is volatile: web sites can change over time and within sites users can experience different navigation structures. Danielson [7] found that a highly volatile session increased disorientation and decreased user navigation abilities. When users switch between devices to use the same web page, this introduces a new type of volatility: transformation volatility [16]. Transformation volatility is a measure of change to navigation, layout, content and readability from one device to another. When a user accesses a web page on a desktop and uses the same web page on their laptop, the transformation volatility is small. But when the user uses the same web page on their PDA the transformation volatility is substantial. Our goal is to minimize the transformation volatility for users switching between different screen sizes to access the same web pages.

The *type of tasks* that the user engages in is another usability issue. Users access the web for different reasons at different times. We have identified five web-based tasks that users frequently engage in: re-finding information, finding new information, comparing information, reading information and general browsing. That is, users may need to re-find information that they have already seen. As well, users may need to find specific information that they have not seen before, e.g. a student looking for references for a paper. Users may want to compare information or details, such as airline prices or dates which could involve looking up information on one page or it could involve going between pages. Users may want to read the web page, such as a news story or journal paper. Finally users may just be browsing the Internet. This browsing may be for general interest, for example planning your next vacation, or it may just be the act of randomly choosing web pages and following links with no particular goal.

The last usability issue that we have identified is *mobility*. Different factors impact the user experience when users are mobile using their PDA to access the web. Some of these factors are external to the experience, such as noise, distractions and movement. While we can not influence these factors, they have an impact on the user.

When users are moving, either physically themselves or while on the move, such as being on a bus, scrolling and clicking using the stylus may become difficult. Distractions, noise and movement can all affect the user's ability to read and concentrate [11], especially if the user is also trying to navigate the web page in the small window using the stylus. A small screen version that reduces the necessary scrolling and clicking would be beneficial in such times, such as an Overview transformation.

3.2 The Gateway

The Gateway is a new Overview transformation prototype designed specifically to minimize the transformation volatility for users who switch between devices to view a familiar web page. The Gateway differs from previous focus + context models in that it provides an exact reduced replica of the large screen web page while maintaining a consistent distortion. Users navigate the Gateway by selecting individual sections, either by clicking or by rollovers, on the web page that are expanded and superimposed over the overview (Fig. 1). Users can then make selections on the section, such as choose a menu item or follow a link, as they would on the large web page. The Gateway is similar to Microsoft's adaptive viewing approach [4], but the Gateway provides a zooming capacity more consistent with the focus + context approach.

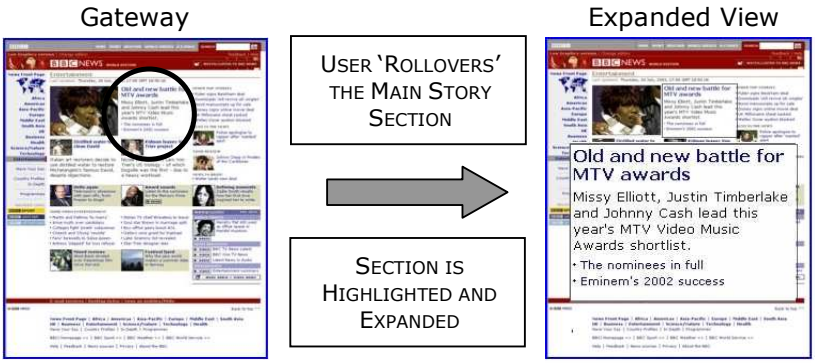

Fig. 1. The Gateway

The Gateway provides a thumbnail style representation of a large web page at a pixel size of 240 by 320. Research on the use of thumbnails for web tasks has found that thumbnail representations of web pages are useful visual memory aids for users that improves user recall [13],[18]. Kaasten et al. [13] found users had a high recognition of web pages when thumbnails had a pixel size as small as 208 by 208. As well, the Gateway maintains the spatial location of the original page that has been shown to help users develop a mental model to make sense of the organization of a page thereby helping users to remember the location of features on the page [6].

3.3 Automatic Transformation of Web Pages

Clearly, there may not be one best automatic transformation for all web pages. The best transformation for mobile devices may depend on the original large web page layout, familiarity of a web page, a feature set of user tasks, and level of user mobility. We conducted a study to examine these features for users familiar with a web page. Users rated each small screen version for five tasks (finding, re-finding, reading, comparison and browsing) based on their experience using each version. The web page chosen for the testing was a news site with a Broadsheet layout. A Linear web page layout was not used in this study but will be included in further testing. Finally, users used two of the small screen versions while moving around to gage the mobility of each approach.

4 User Study

4.1 Methodology

We had ten computer science graduate students participate in the study, ranging in age from 25 to 55. There were five female and five male participants. It was a within subject study, where each participant viewed three small screen versions in a different order on the large screen and used the Gateway and Linear version on the PDA in alternating orders. The shortest time to complete the study was about 40 minutes, while the longest session was about 50 minutes. Testing was conducted using both a desktop computer with a 15" monitor and a Toshiba e750 Pocket PC using the BBC news site Entertainment section that was downloaded to a local machine. Users were tested on small screen transformations based on the regular sized web page using three different interfaces (Fig. 2): Direct Migration, Linear and the Gateway.

Fig. 2. Three Small Screen Transformations

The Direct Migration was the actual large web site shown on the small sized screen that required users to scroll both horizontally and vertically to navigate the page. The Linear transformation was BBC's own actual linear textual version that had changes in the layout from the large web page and some stories were omitted. The Gateway used a reduced replica of the actual BBC web page with rollovers to identify the different regions on the page.

4.1.1 Hypotheses.

i) Users who have previously used and are familiar with a web page will prefer using the Gateway to the Linear and Direct Migration transformation approaches.
ii) The Gateway will be preferred for tasks of re-finding information and comparing details on a web page.
iii) Linear transformation will be preferred for finding and browsing information on never seen web pages.
iv) Direct Migration will be the least preferred version for all tasks and general user satisfaction.

4.1.2 The Study. The study consisted of two parts. The first part, a Comparative Task Completion asked users to perform a task using and comparing three small screen versions that were all displayed at the same time on a desktop. First, users became familiar with the large BBC web page on the desktop by opening stories, reading the headlines and using the menu items. Before the actual testing, users performed the same manipulation check (e.g. go to the sports section, find a main story, etc.) to ensure each user had a minimum level of familiarity with the page. Users were asked to choose three stories on the large page that they would recommend to friends. At least one story could not contain a picture or an image. The large version of the web page was then closed and replaced with three small screen versions (Direct Migration, Linear and Gateway) in random order (Fig. 2). Users did the same manipulation check on each of the small screen displays after finding one story on each version. Once finished, the users were interviewed and asked a set of questions relating to their task experience and preference.

The second part, Mobility Feedback, had users actually move around while using the PDA. Users were asked to use both the Linear and Gateway version on the PDA to locate the three stories they found on the large BBC web page. We did not include the Direct Migration approach as we were concentrating on and comparing the Gateway's Overview approach with the commonly used Linear approach. Once users found the stories using both versions, users were asked about their experience of using each interface on the PDA and some general design questions regarding the Gateway.

5. Evaluation and Results

5.1 Part I: Comparative Task Completion

5.1.1 User Preference Results. Users were asked to rank all three versions based on four user preference questions: the fastest to find the story; the easiest to find the story; the most intuitive to use and liked using best to find the story. Users ranked each version by giving the 'best' a score of 1, the 'next best' a score of 2, and the 'least preferred' a score of 3. In Table 1, we added the scores of all users to measure the preference for each question and for an overall user preference score. The best a small screen version could score on an individual question was 10 (10 users times a ranking of 1). The worst score a version could receive on an individual question was 30 (10 users times a ranking of 3). The best overall score a version could receive was 40 (best score of 10 times 4 questions) and the worst overall score was 120 (worst score of 30 times 4 questions).

Table 1. Overall User Preference Scores.

Category	Gateway	Linear	Direct
Thought were fastest on	15	29	16
Easiest to find story	17	28	15
Most intuitive	16	29	15
Liked using	13	30	17
Total	**61**	**116**	**63**

Overall, we found the results quite surprising. We hypothesized that users who were familiar with a web page on a large screen would prefer the Gateway and Linear, and that users would least prefer the Direct Migration approach due the increased effort to navigate the large web page on the small screen. The chi-square test on Table 1 shows that the Gateway is significantly better than the Linear version although not different than the Direct Migration approach. The chi-square equaled 24.2 with 2 degrees of freedom which is significant as a one tailed test at $p < .005$. As well, Direct Migration is significantly better than the Linear version. Linear, a common transformation used by many web sites had the worst score of 116, only four points from being ranked the "worst" version. In fact, users often referred to the Linear version as "hateful", "annoying" and the "worst". One point that influenced the Gateway ranking which was noted by many of the users was that they did not understand at first how to select from the expanded section from the rollovers. When the rollover occurred, users had to click once to then select from the expanded selection. A training session could have alleviated this uncertainty.

We had expected that users would find the lack of readability an issue with the Gateway and had already considered a design for a revised Gateway to improve readability. Particularly interesting was that the users in this study understood readability differently than strictly being able to read the font size. Users found the Gateway readable because it maintained the same layout as the large page and they could expand the sections with the rollovers. Only one user noted that the lack of

readability for the Gateway negatively influenced the ranking preference for it. Despite both the readable font size of the Linear version and that it only requires vertical scrolling, some users chose the Direct Migration as their first preference in some categories. The main issues with the Linear version was that content and layout had changed and while finding the main pictures or top stories was not difficult for some, all seemed to have difficulty finding less obvious stories and menu items.

5.1.2 Task Results and User Comments. Users were asked to rank each version based on five different tasks commonly performed on news web pages: reading a story, find a never before seen story, re-find an already seen story, compare details between stories and general browsing. Once again, users ranked each version by giving the 'best' a score of 1, the 'next best' a score of 2, and the 'least preferred' a score of 3. In Table 2, we added up the scores of all users to measure the preference for each question and for an overall best task-based score. The best a small screen version could score on an individual question was 10 (10 users times a ranking of 1) and the worst score was 30. The best overall score a version could receive was 50 and the worst overall score was 150.

Overall, users ranked the Gateway the highest with a score of 73, which is much more decisive gap over the other two versions. We had hypothesized that users would prefer using the Gateway over the Direct Migration and Linear approaches for familiar web pages. Using chi-square we found that the Gateway is significantly better than both the Linear and Direct Migration approach for performing tasks, where the chi-square is 10.24 with 2 degrees of difference which is significant as a one tailed test at $p < .01$.

Table 2. Task Scores.

Task	Gateway	Linear	Direct
Reading a story	11	12	30
Find a new story	18	19	23
Re-find already seen story	14	29	17
Compare details	14	21	25
General browsing	16	22	22
Total	**73**	**103**	**117**

Unlike the readability of the full web page, *reading a story* refers to the actual reading of a news story expanded from the original web page. The Gateway used the exact same story layout as the Linear version with the menu items deleted from the top and bottom of the page. Since the Linear and Gateway versions had the same story and layout of the story, this was the only category (question) we allowed users to give a tie between versions. Direct Migration had the worst score. Users had to scroll both vertically and horizontally to read the story. Users noted that it was "horrible" and "annoying".

It was interesting that the Gateway ranked so well to *find new stories*. We had first thought the Linear version would be preferred for a task to locate a new, never seen story because users could read the content by navigating in one direction. Still, four users ranked the Linear first and three users ranked the Gateway first. The main

problem that some users noted with the Gateway was that they would be unsure if they had missed something on the page, in that they would not know if they had "expanded all the boxes". Users noted that the Linear version would be fine for main stories or information located at the top of the page but that it would be slower to locate other stories as it lacks important visual cues (such as colours and page layout).

Overall, users felt that the Gateway would be best to *re-find stories* already viewed on the large screen, followed closely by the Direct Migration version. Seven users ranked the Gateway first, with only one user ranking it last. Linear was ranked by all but one user last. Interestingly, we had thought that users would find the Direct Migration version, although exactly the same as the large screen, not very useful as one could only see a small portion of the page at anyone time. Still, these results were as we expected. When users have already viewed and located information on the large screen, they can transfer their existing mental model of that page to the smaller version and re-find the same information easier using the same layout than a different layout.

To *compare details* users were given the same demonstration using the large web page for a task that required going between two different but related stories from the main page. Users then tried the same task using each of the three small screen versions before ranking each version. Overall, the Gateway was ranked the highest with a score of 14 with a considerable gap between the next highest score for Linear with 21 points, followed by the Direct Migration with 25 points. Seven users ranked Gateway as first for this task, with one ranking it last. Six of the users ranked Direct Migration last for this task. One user noted that the Gateway allowed them to go between the stories very easily. Many users noted that being familiar with the page before conducting the comparison made a difference in their rankings. One user stated that the Gateway "gives a birdview. It is very easy to go where you want especially if you know where to go". Users noted that getting to the stories for a familiar site with Direct Migration "wasn't so bad", but then reading the actual stories to get the details to compare was difficult.

General browsing includes viewing never seen pages, which makes the results on this category very surprising. We had believed that the Gateway would do well for tasks using a familiar web page but believed that Linear would do better for an unfamiliar web page, once again due to the readability factor. Still, users quite decisively ranked the Gateway the highest with a score of 16, although only five users gave the Gateway a ranking of 'best'. One user noted that the "Gateway is good because you can see the relevance of importance of information with the overall structure".

5.2 Part II: Mobility Feedback

Users commented that they liked using the overview of the Gateway to find the stories and found the Gateway to be more navigation based. It should be noted that the Gateway version on the PDA was slightly different then the version on the desktop due to shortcomings of the actual browser on the PDA; it did not use rollovers but required users to click to expand the specific sections on the overview. Only one user said that they preferred not having the rollovers on the mobile Gateway

version, while others noted that they preferred the rollovers. With the Linear version, users stated that they did not like the reformatting of the layout from the original page and found it easy to get lost. A user noted it "was frustrating because I knew where to look if I had been using the other version [the Gateway]." Users also commented on features that they felt as important for web use on the small screen that included completeness and full access to information, consistent layout, readability and no horizontal scrolling.

5.3 Design Feedback

We asked users to provide feedback on a revised version of the Gateway to help with the readability issue associated with the Gateway. We adapted the existing Gateway prototype to enlarge titles and expand keywords from the story headings. So while descriptions under headlines or pictures are still unreadable, users can read the actual sections on each page and in addition to having the visual cues from the original web page, can have word cues. Woodruff et al [18] found that thumbnails enhanced with text performed as well or better then plain thumbnails. Overall, users found this to be a positive improvement. Readable headings could allow users to be more selective with the rollovers and help users quickly scan the page.

6. Conclusion and Future work

Despite the prevalence of Linear versions for small screens, we have shown that users prefer small versions of familiar web sites that are more closely related to the mental model of the larger version and that users preferred the Gateway for web related tasks. Users generally found that the change in navigation structures, layout and content from the large web page to the small Linear version caused confusion and disorientation, especially for re-finding information and comparing information. This was evident when users were both stationary using the desktop version and mobile using the PDA. The Linear versions may be advantageous when users are restricted by bandwidth and processing power or have very small screens, such as mobile phones.

We are ready to perform user studies to compare the efficiency and effectiveness of the Gateway transformation model with the Linear approach using both Broadsheet and Linear web page layouts. We will test users on simple lookup tasks of re-finding and finding new information and on a more complex comparison task. We will compare the results of users who first view a web page on the large screen then switch to the small screen using both the Gateway and Linear model. We will also test users using previously unseen web pages on the small screen device using both the Gateway and Linear model. We speculate that the Gateway will perform better for web sites previously viewed on large screen devices; however, similar to this user study we may have underestimated the impact of the graphical layout on the large screen.

References

1. Albers, M. & Kim, L. User Web Characteristics Using Palm Handhelds for Information Retrieval. In *Proc. of IPCC/SIGDOC Technology and Teamwork*. Cambridge, MA (2000), 125-135
2. Björk, S., Holmquist, L.E., Redström, J., Bretan, I., Danielsson, R., Karlgren, J. & Franzén, K. West: A Web Browser for Small Terminals. In *Proc. of ACM Symposium on User Interface Software and Technology*. Asheville, NC (1999), 187-196
3. Buyukkokten, O., Garcia-Molina, H. & Paepcke, A. Seeing the Whole in Parts: Text Summarization for Web Browsing on Handheld Devices. In *Proc. of 10th Internat. WWW Conf*. Hong Kong (2001), 652-662
4. Chen, Y., Ma, W. & Zhang, H. Adapting Content to Mobile Devices: Detecting Web Page Structure for Adaptive Viewing on Small Form Factor Devices, In *Proc. of 12th Internat. WWW Conf.* Budapest (2003), 225-233
5. ComScore Networks. Ten Million Internet Users go Online Via a Cell Phone or PDA (August 2002), from http:// www.comscore.com/press/release.asp?id=87
6. Czerwinski, M., Dumais, S., Robertson, G., Dziadosz, S., Tiernan, S. & van Dantzich, M. Visualizing Implicit Queries for Information Management and Retrieval. In *Proc. of ACM SIGCHI Conf.* Pittsburg, PA (1999), 560-567
7. Danielson, D. Transitional Volatility in Web Navigation, *IT&Society*. (2003), 1(3): 131-158
8. Dillon, A., Richardson, J. & McKnight, C. The Effect of Display Size and Text Splitting on Reading lengthy Text from the Screen, *Behavior and Information Technology*, (1999), 9(3): 215-227
9. Dyson, M. & Haselgrove, M. The Influence of Reading Speed and Line Length on the Effectiveness of Reading from Screen. *International Journal Human-Computer Studies*, (2001), 54 (4): 585-612
10. Furnas, George W. Generalized Fisheye Views. In *Proc. of Conf. on Human Factors in Computing Systems*. Boston, MA (1986), 16-23
11. Jameson, A., Schäfer, R., Weis, T., Berthold A. & Weyrath, T. Making Systems Sensitive to the User's Time and Working Memory Constraints. In *Proc. of 4th Internat. Conf. on Intelligent User Interfaces*. Los Angeles, CA, (1998), 79-86
12. Jones, M., Marsden, G., Mohd-Nasir, N., Boone, K. & Buchanan, G. Improving Web Interaction on Small Displays. *In Proc. of 8th Internat. WWW Conf.* Toronto Canada, (1999)
13. Kaasten, S., Greenberg, S. & Edwards, C. How People Recognize Previously Seen WWW Pages from Titles, URLs and Thumbnails. In X. Faulkner, J. Finlay, F. Detienne (Eds) *People and Computers XVI (Proc. of Human Computer Interaction)* (2002), BCS Conference Series, 247-265, Springer Verlag
14. MacKay, B. & Watters, C. The Impact of Migration of Data to Small Screens on Navigation, *IT&Society*. (2003), 1(3): 90-10
15. Spence, R. *Information Visualization*. (2001) ACM Press: New York
16. Watters, C. & MacKay, B. Transformation Volatility and the Gateway Model for Web Page Migration to Small Screen Devices. In *Proc. of Hawaii Internat. Conf. on System Sciences*. Big Island, Hawaii (2004)
17. Wobbrock, J.O., Forlizzi, J., Hudson, S.E. & Myers, B.A. WebThumb: Interaction Techniques for Small-Screen Browsers. In *Proc. of ACM Symposium on User Interface Software and Technology*. Paris, France, (2002), 205-208
18. Woodruff, A., Faulring, A., Rosenholtz, R., Morrison, J. & Pirolli, P. Using Thumbnails to Search the Web. In *Proc. of ACM SIGCHI Conf.*, Seattle, WA (2001), 198-205