Visualizing Bar Charts on WAP Phones

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Abstract. This paper begins to explore the problem of graphically visualizing numerical data on the very small displays of WAP phones. In particular, we consider visualizations in bar chart format, proposing two possible solutions and testing them with time-series data. A controlled experiment has been carried out to point out possible differences in user performance between the two considered visualizations, and is described in the paper.

1 Introduction

At the midpoint of 2000, approximately 50% of the world's mobile phones shipments were WAP capable, and more than 40 million WAP browser-equipped handsets had been shipped [4]. Since then, the percentage of shipped WAP phones has steadily increased, and today most new models of cellular phones are WAP capable. This is spawning the need for and the development of services specifically tailored to mobile users employing WAP phones. Unfortunately, most WAP phones have a very small, black-and-white screen that makes it hard to design usable and effective services. Moreover, very little has been published on the usability of WAP sites. This situation has prompted a few researchers [1,2,3,5] to focus on the user evaluation of WAP interface design choices.

While the above mentioned evaluations have concentrated on interfaces that mainly displayed textual information (such as menu options, news headlines, movie reservations,…), this paper starts to explore the graphical display of quantitative information on WAP phones. In particular, we consider the problem of graphically displaying a time-series on a WAP phone. Time-series are ubiquitous in several domains ranging from engineering to medicine. The stock market is a particularly suited motivating example, since online stock trading is considered to be one of the most relevant applications for mobile commerce [7]. Figure 1 shows the WAP card returned by a commercial stock market site to a user who is looking for a specific share: the top line shows the name of the share ("Autogrill Spa"), the first displayed number is the

time ("10:21"), the second number ("10,11") is the closing value ("Chiusura:"), and the number for change ("Var.%:") falls outside the WAP phone screen. Figure 1 is representative of how many WAP sites (for this and other services) provide information to users. As one can easily notice, screen estate is used suboptimally: (i) the user is able to see only one change value at a time for the share (making it difficult to assess how that share is actually going over time), and (ii) she has even to scroll the screen to be able to see that single value. Using tables could be a first step to show some more numbers on the same screen, but graphical solutions are typically used in time-series data analysis to make the task easier for humans. Historically, bar charts are a familiar solution to the problem and are known to allow for an easy comparison among the data values of a time-series (this property may not hold in bar charts that include unnecessary graphic elements to look more impressive, see [6] for a discussion).

In the following, we propose and discuss two possible solutions for displaying bar charts on WAP phones, also evaluating them with a controlled experiment.

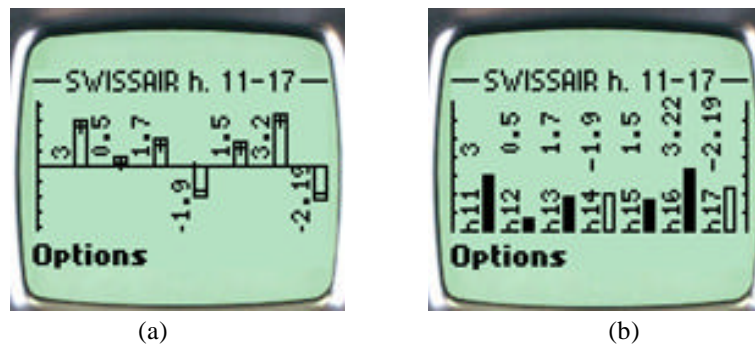**Fig. 1.** Share information visualized as text on a stock market WAP site.

(a)   (b)

Fig. 2. Visualizing information as: (a) bar chart, (b) bar chart with color coded sign.

2 The Considered Solutions

The first problem we had to face in our research was of a technical nature: to display an image, most WAP browsers currently require to use the WBMP file format. We thus had to find a solution for dynamically generating WBMP files encoding the visualizations of the desired data on a WAP site. We faced this problem by resorting to GD 2.0 (a publicly available graphics library that is able to produce files in various formats, WBMP included) and embedding calls to GD in PHP scripts to allow for a dynamic image generation on the WAP site.

The first visualization we propose attempts to keep the traditional bar chart organization as much as possible, with positive bars growing upwards, and negative bars downwards. Figure 2(a) shows an example of it on a WAP phone (we are using the Nokia 7110 in our work, but many other phones on the market have similar displays). Although this representation is likely to be very familiar to users, it has one serious drawback on small screens when the displayed bar chart includes *both negative and positive values*. In this case, the considered visualization splits the scarce screen space into two smaller areas (one reserved to positive and the other to negative values) and forces one to choose a mix of the two following undesirable limitations: (i) decrease in the resolution available for the discrimination of differences in size among bars, making it more difficult to visually detect such differences, or (ii) decrease in the representation range of the visualization to keep an acceptable resolution.

The second solution we propose – see Figure 2(b) – trades some familiarity for a better usage of screen estate. In particular, the screen is never split into a negative and positive area: zero corresponds to the bottom of the screen and we display all the bars growing upwards regardless of their sign. We highlight with a color coding mechanism (besides displaying the sign character in the textual version of the numbers) which bars correspond to negative and which to positive values. To this purpose, most current WAP phones offer only two (achromatic) colors (black and white): in the proposed visualization, black bars correspond to positive values and white bars to negative values. Unlike the previous visualization, the full screen resolution is now always available both to positive and negative bars.

3 Experiment

A total of 20 subjects was involved in the experiment. Most of the subjects were university students from different programs (Agricultural Sciences, Arts, Computer Science, Engineering). None of the subjects had ever used the WAP capabilities of a cellular phone.

In the experimental task, we showed subjects a dynamically generated bar chart visualization (containing both negative and positive values) on a phone display and asked them to determine: (i) what was the highest value, (ii) what was the lowest value, and (iii) how many times the values displayed in the chart were negative. Before carry-

ing out the task, subjects were briefly instructed about the meaning of the various graphic elements in the two chart types.

One independent variable and two dependent variables were considered in the study. The independent variable is chart type (in the following, we will refer to the more traditional solution as TRADNL and to the solution employing color coding for the sign as CCSIGN). The dependent variables are: (i) time needed to complete the task, (ii) correctness of the provided answer (we employed the strictest requirement for correctness: all three values reported by the subjects had to be correct).

A within-subject design was followed. Every subject performed the task in the two possible conditions. Therefore, two different time-series were needed and we chose them to be of the same complexity. The assignment of subjects to time-series and condition was carried out following a counterbalancing scheme where the order for the assigned time-series and the order for the assigned condition were varied independently.

Table 1 summarizes the obtained results. First, carrying out the task with CCSIGN required about 20% more time on average than TRADNL, and the t-test indicates that the effect is significant ($p<0.05$). Second, most of the 20 subjects provided the correct answer in both conditions. Only a few subjects made errors: in particular, one subject failed in the TRADNL condition, and three in the CCSIGN condition. This result was analyzed using the Wilcoxon test for dependent samples; this difference between the two conditions is not statistically significant (p=0.32).

Table 1. Experimental Results.

	TRADNL	CCSIGN	Significance
Average time to carry out the task	21.1 sec	25.4 sec	p<0.05
Number of subjects who succeeded	19 of 20	17 of 20	not significant

4 Conclusions and Future Work

The experiment has shown that, although the CCSIGN visualization has the advantage of using screen space in a wiser way than TRADNL, it (moderately) increases the time required to examine it. Some considerations must be added. First, since this result might be explained by the fact that CCSIGN was less familiar (in informal discussions with the subjects, it came out that most of them had seen or used bar charts of the TRADNL type, while a number of subjects explicitly commented that they had never seen a bar chart of the CCSIGN type and/or asked for clarifications about it, such as "Why does black stands for positive and white for negative?"), it will be interesting to repeat the experiment with the same subjects over a period of time to contrast the possible differences between novice and expert users of the visualizations. Second, since the drawing algorithm did not make size adaptations of the bars to the available screen space, it will be interesting to test if adding this possibility could favour CCSIGN

thanks to the larger space it can offer.

We are also planning a more thorough experimental activity that will include other alternative visualizations of bar charts and other types of tasks. Another dimension to explore is the addition of more interactive features to the charts: although current WAP browsers severely limit this possibility (a new WBMP file must be generated for any graphic update), there are some useful extensions of our bar chart generator that we are considering (e.g., the possibility of scrolling longer time-series by choosing "left-right" options without having to explicitly formulate another query to the WAP site). Finally, if a number of different visualizations is developed for WAP phones, an interesting research direction will be the inclusion of knowledge-based mechanisms to automatically select the most appropriate visualization for a given set of data.

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