Data Visualizations on small and very small screens

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Abstract. We can now access to information almost everywhere, at any time, using mobile phone or PDA with connection to the Web. A good way to resume data is visualization but the size of the screen and bad environment generate huge constraints.

We first present some general recommandations for small screens. Then we study the case of time series visualization for more particularly of stock values and describe two solutions fot PDA and two solutions for mobile.
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1 Introduction

Access to information has been improved considerably the last years. Through internet, we can connect to large data bases which are updated continually, most often on the Web.

Moreover, with mobile technology, we can consult this information even if we are not in our office or at home, in front of a standard PC. Indeed we can get information when using a mobile phone or a PDA. But these tools are much more limited in term of memory, power and screen resolution. If we can expect that in the next years, memory, power and screen quality definition will be improved, the size of the screen will not be enlarged because the intrinsic characteristic of a mobile device is to be small, in order to carry it, in the pocket or the handbag.

Whereas human computer interaction was concerned up to now on how present information on screen which enlarged and improved, from year to year, we discover now new (or old) problems due to the size and the bad quality of the screens. The bad quality of the vision is also due to the fact that with mobile devices, we can get information in areas not really well suited for reading: bad lighting, bad posture, using sometimes only one hand.

We have thus to be more innovative and find solutions which are usable, with strong technological constraints.

Visualization of data is a very powerful tool for summarizing information on input data or on results of analysis. It seems thus a good way to communicate information on a small screen but limitation is so high that the solution is not evident. Representations cannot just be adapted from standard PC to mobile devices. We have to find new solutions.

We have also to point out guidelines in order to improve the usability of information representation on mobile. The following paragraph will describe such recommendations.

As a case study for data visualisation, we have developed systems of time series visualization, because the problem is very common, met by many persons in management and finance. Whereas we can assume that results of data analysis like clustering, factorial analysis, regression analysis, can be consulted at work office, time dependant data can be needed in more varied environment. It is why we have oriented our study on this kind of data. As a particular case, stock values are a good example of such series: they interest a lot of people, need to be updated every day and are crucial in our economy. Users will then be very motivated to use good visualization systems.

2 State of the art

Literature about visualization on mobile concerns mostly applications like tourism application [Bornträger *et al.*, 2003][Pospischil *et al.*, 2002], nomadic guide [Schmidt-Belz and Hermann, 2004] [Fithian *et al.*, 2003] [Chinchille *et al.*, 2002], mobile gaming [Sanneblad and Holmquist, 2003], remote control [Tarrini *et al.*, 2002]

Some papers concern also guidelines for tasks on small screens. Many general guidelines for HCI with mobile and PDA performed by mobile industry concern the arrangement of keyboard or the shape and size of the mobile. We will not consider this kind of problems here and will look only at the screen usability.

Some guidelines for small screens have been verified by experimental studies. Most identify good procedures in searching tasks [Giller *et al.*, 2003], [Jones *et al.*, 2002].

Few papers have been published in the field of data visualization on small screen but some systems are available for dedicated data like stock information.

In data visualization field, [Chittaro and Camaggio, 2002] presents solutions for bar charts format representation on WAP phones. For stock information, let us reference specialized sites (www.wap.boursorama.com, www.cprbourse.tm.fr/wap, www.firstinvest.waptoo.com). They give general information, with some visualization like tables and graphics. Those are usually standard time series representing the value of a stock or indices with time

in the X-axis. Time vary in hours, days or years, with of course different level of precision. On mobile phone, these graphics are generally badly readable, due to the lack of definition of the screen.

In what follow, we summarize recommendations for small screens. They are derived and updated from general usability principles [Scapin, 1986] and from some dedicated papers [Jones *et al.*, 2002], [Giller *et al.*, 2003].

2.1 Conciseness, precision and consistency

In order to save space, give precise, concise information: use as few words as possible but enough precise. Precision does not mean necessarily to use technical word. The vocabulary must be understood by the user. This recommendations have been established for usability on standard PC but conciseness has more importance in the context of small screens.

2.2 Navigation

As few information can be displayed on a screen, when information is voluminous, the solution is to split it on several screens. This gives problems of navigation and orientation. Considering searching tasks, [Jones *et al.*, 2002] have shown that screen size has a major impact on user performance. They propose following guidelines which can be interesting in our data visualization context:

- reduce the amount of page-to-page navigation needed to view search. They have observed that additional user effort when vertical scrolling affects performance to a lesser extension that the page-to-page navigation. [Giller *et al.*, 2003] found the same result.
- adapt for vertical scrolling. Users tend to scroll vertically rather than horizontally. [Giller *et al.*, 2003] have shown that in a selection task in a list of items when the users know the target item, 15 items still seems to be OK, whereas for an unknown target, items should lie around 8.

3 Solutions for optimisation of screen use

Even if preceding recommendations are valid for small screen (pocket pc) and very small screen (mobile phone), problems appear differently. They are much more accurate on mobile phone and must be solved appropriately. On PDA, we can try to summarize information on one screen, with opening of windows for more details using at the best colour features and screen definition quality. We have to be innovative in the visualization. We will present some new time series visualization for PDA in paragraph 4.

On the contrary, on mobile phone, we are obliged to simplify the visualization. When the quantity of information is large, we suggest to use analytical method to reduce the amount of information before visualizing the data. In paragraph 5, we present two examples of such reduction using clustering.

4 Examples of visualization on PDA

Most of the solutions for time series representations developped for PDA are a miniaturisation of the common visualizations used for PC. If an overview of a time serie can be viewed by this method, it is not sufficient because the elements displayed are too small and the visualization is not clear. Thus we provide to find solutions to that problems. The two visualizations presented here are very different. They don't use the same scale, one is common and the other uses colour. More, they don't present the information in the same way because the representation of the days is different.

4.1 Brick Wall Chart

The Brick Wall Chart is a very rich visualization, it can display the evolution in one year of 4 different attributes (see fig.1). The Brick Wall Chart uses a scale of colour to represent the data values. The scale goes from the white, yellow, red and black. As recommended by [Spence, 2000] white color represents the minimum value, black represents the maximum value, and between these two colors, we use the interpolation to find the color.

The screen is divided in 12 columns representing months from the left to the right, and each column is vertically divided in rectangles representing days (the number of days depends on the month) from the bottom to the top of the screen. The rectangle is also horizontally divided in 4 small rectangles to represent each attribute. The rectangles are filled with color to represent the data values.

If the user want more precision, he can switch to the same visualization but with only one attribute. The Brick Wall Chart is the same but the days are not divided in small rectangles. Because the days are bigger, the color can be seen with less difficulty, the visualization is then more precise and clear.

The user can obtain the precise values of the attributes for one day, he just has to tap on the sreen over the corresponding day. A box appears on the screen providing the values of the 4 attributes.

4.2 Stacked Bar Chart

The Stacked Bar Chart uses the metaphore of the calendar because it divides the screen in 12 parts representing the months (see fig.2). The scale is classical and use the height of the elements to reprensent their values. Stacked Bar Chart provide showing two different attributes. It is less richer than the previous visualization but is more common and usual. Actually, the visualization is represented by 12 small graphics. Each graphic is a classical one with the time on the X-Axis and the value on the Y-Axis. The first attribute is display in blue, the second in orange. The smaller attribute appears in front of the screen, and the second appears behind the smaller attribute.

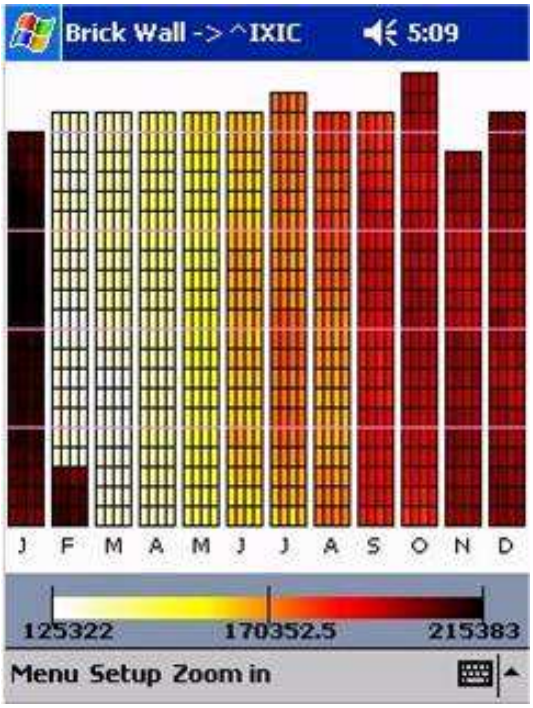

Fig. 1. Brick Wall Chart.

4.3 Evaluation

The evaluation had two goals: compare the efficiency of the visualizations and the preferences of the users.

First, we tested the performance, the time to complete a task, the quality of the representation of the days, the quality of the reprensentation of the values. The results cannot affirm that one visualization is better than another. So we can expect that the users wont prefer any visualization and in this case, the preference would be homogeneous.

But 17 of the 20 users chose the Brick Wall Chart as their favourite visualization and the appreciation for this visualization is better than the one for the Stacked Bar Chart. So, the preferences of the users go mainly to the Brick Wall Chart that use a color scale even if their are both efficient. More information on that evaluation can be found in [Noirhomme-Fraiture *et al.*, 2005].

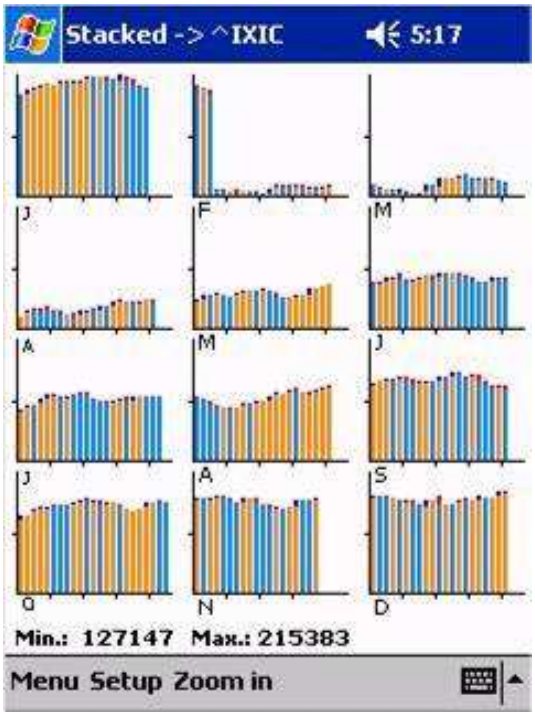

Fig. 2. Stacked Bar Chart.

5 Examples of visualization on mobile phone

On very small screen, superposition of several windows is not advisable. Due to lack of definition, too detailed graphics are not readable. We have to avoid outlines and to privilege pictures with colored or greyed surfaces, because lines are not distinguished. Using Gestalt principles, [Easterby] has shown that a contrast boundary is better than a line boundary for making a shape stand out. We present here two visualization that we have designed to represent stock values. The first one is dedicated to visualization of different values at a given time, the second one is dedicated to visualization of the evolution of such values with time. More visualization and details can be found in [Custinne *et al.*, 2004]. If the values are too numerous, we suggest to summarize them by a clustering. For example, when representing values of stock portfolio, stocks can be very numerous so that it is impossible to represent all the stocks on the same graph. What stock sites do usually is to represent stocks separately. This method is tiresome for the user, does not allow comparing the stocks between them and does not allow having a global view of the portfolio. Many stocks have common behaviour so it is possible to assemble them in classes with homogneous behaviour. As example, we

have operated a K-Means clustering to merge 40 stocks in 7 clusters. The clustering was done on base of the mean value on one month or on variation during one month (max-min).

We could also perform a clustering to reduce the number of days, when we represent the variation of stocks on a long period. In this case, it seems more appropriate to use clustering methods which try to agglomerate days which are contiguous in order to obtain clusters of periods. In what follows, we present the two visualization adapted to clusters (but they can also be used for individual stocks).

5.1 Alternate Bar Chart

This visualization is closed to the kind of representation that workers in stock exchange are used to. The height of the bars are proportional to the value to be represented: maximum variation of stock value during a period. As this variation can be positive or negative, we represent positive value from bottom to top on the bottom line and negative value from top to bottom on the upper line (see fig. 3). Each bar has a different color according to the cluster of stocks. Rectangles are full colored. Details can be obtained when pointing a particuliar bar. This kind of optimise the use of the screen space and allows very quick visualization of the importance of positive/negative variations.

Fig. 3. Alternate Bar Chart.

5.2 Pixel bar Chart

In this representation we visualize the evolution of values during a period for different clusters (or stocks). Each column is dedicated to a cluster, its width is proportional to the number of stocks in the cluster. Each daily value is mapped on a color scale. The different days of the period are represented

from bottom to top. We use the same convention of colour as the one used in the Brick bar Chart on PDA (see fig.4).

Fig. 4. Pixel Bar Chart.

As in the preceding visualization, the representation uses maximum of the available space on the screen. Whereas the alternate bar chart is commonly appreciated and easy to use, people with weak sight have some difficulty with Pixel Bar Char. We hope that improvement in screen quality will reduce this problem.

5.3 Evaluation

We have evaluated the two types of representation with 20 subjects, computer scientists or economists.

Performance were rather good with both visualization but on our test the tasks to be performed were rather simple.

We have thus more analysed preferences and qualitive remarks done by the subjects. Alternate Bar Chart is better perceived, because very close to standard representation. Pixel Bar Chart needs some time for training.

Classification method need also training. Some persons in the sample did not know about K-Means so that preliminary explanations were necessary. Some experts in economy found the method interesting, for use on very small screens.

6 Conclusion

We have presented solutions for time series visualization on PDA and on mobile phone, and considered the particular application of stock market. In our system we have applied the following principles:

- use of the maximum screen space

- do not charge the display
- use contrast boundary instead of line boundary
- give information on demand, interactively.

A substantial improvement will be obtained in linking together the different representations. We are working on such a global system. This system should be tested with real users, in their working environment.

More generally many other applications need to find adapted visualizations on small screens. The research has only started to be explored.

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