

Web Based Device Independent Mobile Map Applications. The m-CHARTIS System

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ABSTRACT

A map is one of the most useful media in disseminating spatial information. As mobile devices are becoming increasingly powerful and ubiquitous, new possibilities to access map information are created. However, mobile devices still face severe constraints that limit the possibilities that a mobile map application may offer. In this paper, we present the m-CHARTIS system, a device independent mobile map application that enables mobile users to access map information from their device. We focus on the main features and we analyse the device independent character of the system. Finally, our implementation is evaluated and directions for future work are proposed.

Categories and Subject Descriptors

H.5.1 [Information interfaces and presentation (e.g., HCI)]: Multimedia Information Systems – Animations; H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces – Graphical user interfaces (GUI), User-centered design.

General Terms

Design, Experimentation, Human Factors.

Keywords

Mobile devices, handheld devices, mobile map application, mobile cartography, map drawing.

1. INTRODUCTION

Modern times are characterized by the rapid evolution of the economy, the accelerated human lifestyle and frequent spatial and temporal changes. People want spatial information to be available anywhere and anytime. The progress in the field of mobile communications and mobile devices, which was achieved during the last years allowed the development of map applications, addressed to the users of handheld devices.

The term mobile devices, refers to devices that have been specially designed to be used while their user is moving. This category includes mobile phones, PDAs (personal digital

assistant), smartphones and Tablet PCs. A laptop is designed to be portable, but its user needs to sit down in order to use it effectively, therefore it is not considered to be a mobile device. Tablet PCs overcome this limitation by replacing the keyboard with a special interface that allows the interaction of a pen with a touch screen; however, they still remain much bigger than the other handheld devices.

In this paper we present a web based device independent mobile map application: the m-CHARTIS system. The main characteristic of this application is that it is designed in a way so that it can be accessed by a wide range of mobile devices, a fact that makes it device independent. The application uses geographic data in digital form to create web maps. It is consisted by two parts. The first part is used by the administrator of the system, providing him/her with the possibility to import information to the maps and requires the use of desktop computer. The second part, which is specially designed for mobile devices, allows the mobile user to access the maps and the information that the administrator has imported in the system.

We organize the paper in the following way. In section 2, we present related work on this field. In section 3, we outline the device independent character of our application. In section 4, we describe the application and its design principles. In section 5 we present bandwidth and time overhead measurements concerning the use of the mobile part of our system. Finally, in section 6, we give our conclusions and the direction for future research.

2. RELATED WORK

Several map applications for mobile devices have been developed following different approaches.

One popular approach is the client side approach. In this case the user is required to download the application to his mobile device in order to use it. Such an application for mobile phones has been developed by the company Kibos [8]. It is a JAVA application and for this reason a JAVA enabled device is needed. The user must also download the maps that want to use. Another client side application which is designed for PDAs and has been developed for tourist purposes is described in [3]. Again, in this implementation the user must download the application and the maps in his mobile device and utilize the resources of the device in order to use it.

We can see another approach in [14]. In this service the user of the phone, after having sent a written message to the service,

receives via WAP the image of the map in his browser. There are four different image sizes to choose according to the size of the display and the zoom capability of the browser.

NTT DoCoMo and other i-mode providers, offer the possibility of providing cartographic services to mobile phones through the connection service i-mode [9]. In order to use these services, the user must have an i-mode phone.

Maporama Company, through the service Maporama Mobile [7], allows the users of mobile phones and PDAs to access maps. Concerning mobile phones, these maps are presented in wml pages. Consequently, they are black and white and low quality maps and as a result they do not exploit the capabilities of modern devices. Concerning PDAs, the same service offers different applications according to the usage mode of the device: wired PDA, wireless PDA, synch PDA

As we can see, all related applications fail in one point. They are not device independent. They are designed either for mobile phones or for PDAs, but not for both. Sometimes they may require a JAVA enabled device or an i-mode device. Moreover, very often the user is required to download special software and install it in his handheld. This weakness led us to develop the application that we present in this paper.

3. DEVICE INDEPENDENCE

Mobile devices, in contrast to personal computers, are constrained by important limitations that impose severe difficulties to the interaction with the user [6][10]. Screen size and resolution are two of the most serious constraints. The number of colors is also limited comparing to desktop monitors. These factors highly affect the quality, the detail and size of graphics, such as the map images that we intend to display as part of our application. In addition, handheld devices have limited computing power and storage space. Moreover, wireless networks are characterized by low data transfer rates, though 3G networks are already introduced to improve this situation. Finally, the interaction between the user and the device is not particularly functional. Although handheld devices are constantly improving technologically, the developers of applications addressed to mobile users should take into account the constraints referred above.

Besides, however, the differences between desktop computers and handheld devices, there are also important differences between mobile devices, according to the type of the device. Not all categories of mobile devices and all devices of the same category have the same capabilities and characteristics. As a result, we do not encounter the above limitations to a similar extent in each mobile device category. In table 1 [17], we see a comparison of the capabilities of different types of handheld devices.

Table 1. Comparison of the capabilities of different types of handheld devices

		Mobile phone	PDA	Tablet PC
Processing power	CPU	Weak	Moderate (400 MHz)	Strong (1800 MHz)

		Memory	32 MB (memory card)	64 MB	256 MB
Display performance	Resolution		140x160	240x320	1024x768
	Colors		Colorful	Colorful	Colorful
Portability	Volume		Small	Moderate	Large
	Weight		Light	Moderate	Heavy
Wireless communication			Convenient	Inconvenient (add-in modem)	Inconvenient (add-in modem)

For our application, we have followed a different approach comparing to the applications that we presented in section 2. Our goal was the creation of an application that would cover the widest possible range of devices and not only one category. Moreover, it would tackle effectively the different constraints that each device category faces and would benefit from its advantages. In other words we wanted our application to be device independent.

We have chosen the web based approach, so that the storage and processing of data takes place at the server's side. In this way we deal with the limitations of low processing power and low storage capability of devices. Furthermore, any mobile device that is equipped with a browser, a feature that nowadays almost all devices offer, can use our application. In addition, using the application does not depend on the connection service to the Internet. The pages are also designed to have the smallest possible size. For example, the page in which the map is presented, when the size of the map image is 176x220 (typical for a smartphone) is around 9 KB. When the size of the map image is 128x160 (typical for a mobile phone) the page is around 6 KB. With this feature we deal with the constraint of low data transfer rates of the network and the pages can be accessed even from devices with limited memory. In addition, we also minimize the cost of accessing the page. Finally, thanks to the possibility of changing the size and the zoom level of the map, the user is able to adapt the application according to his/her device screen capabilities.

In order to confirm that our mobile application is indeed device independent, we have tested it with different devices that cover all categories and have different capabilities. Of course, the usability satisfaction will not be the same in all devices, but this is expected. From the category of mobile phones we have performed our testing in Samsung X460, which has an LCD, 128x160 pixels, 65k colors display, WAP 2.0 access to the Internet and built-in Openwave browser. From the same category we have also used Samsung D500, which has improved features comparing to the previous device: TFT, 176x220 pixels, 256k colors display and again built-in WAP 2.0/xhtml browser. From the category of smartphones we have selected Qtek 8020, with TFT, 176x220 pixels, 65k colors display, 32MB RAM, 200 MHz processor, Windows mobile 2003 SE OS and WAP 2.0/xhtml/HTML browser (PocketIE). Finally, we have also tested the application with HP iPAQ hw6510 PDA, which has a TFT, 240x240 pixels, 65k colors touchscreen, 64 MB RAM, 312 MHz processor, Microsoft Pocket PC 2003 SE OS and PocketIE browser. The application was accessible with no compatibility problems from all the devices that we have mentioned.

4. THE m-CHARTIS SYSTEM

4.1 Overview

The application we present is a web-based application, which has two parts – tools. The aim of this application is the management of information for several cities that would be accessible through maps in mobile devices.

The first part of the application is a tool for the administrator of the system. This tool allows him/her to insert cities in the system, which she/he has the option to delete and modify their details, and to add information about them. The system uses digital geographic data that the administrator has in his disposal in order to draw interactive maps of the cities. Options to create, modify and delete categories for the points of interest exist. There is also the possibility to insert a point of interest. The points that belong to a specific category and their details can be displayed, modified and deleted.

The second part of the application is addressed to users of mobile devices that are able to connect to the Internet. It can be accessed by any browser, even from one installed in a desktop computer, but it is specifically designed to deal with the constraints that mobile devices face. This tool allows the user to access the information that the administrator has added to the system. There is the option to choose one of the cities that are registered in the system. The user has then the option to read general information about each city or choose between three alternative options. The first one is to navigate through the map. The second one is to search either for all points that belong to a specific category or for a specific point and to see the corresponding part of the map. The third and last option is to perform a search for a specific street.

This is an application that provides the possibility to insert easily important information about a city, and then this piece of information to be accessed in a similarly simple way by a mobile device. It is clear that it can serve at the same time many uses and to function as a tourist guide, professional guide etc.

4.2 Technical details

For the development of this application we have exclusively used open source software. As a network programming language we have chosen PHP (version 5.0.4) with the GD (Graphics Draw) library [5] enabled. GD is a library that offers the possibility to easily and quickly draw graphics and whose functions we have used in order to draw the map images. The information, which the administrator is adding in the system and the user is accessing, must be stored in a database. For this purpose we have used MySQL (version 4.1.10a-nt - extension: mysqli). As an HTTP server we have used Apache, version 1.3.33.

In the part of the application that is designed for the administrator, the content, which is dynamically produced from PHP, is HTML content. Thus, the administrator only needs a browser, for example Mozilla Firefox or Internet Explorer, to access this tool.

In the part of the application for mobile devices PHP produces pages with content that is XHTML Mobile Profile (MP) valid. XHTML MP [16] is a subset of XHTML, specifically designed for mobile devices and it is a standard proposed by Open Mobile Alliance. It is the official markup language in the specification of WAP 2.0. Any XHTML mobile browser can access these pages. Almost all modern devices are equipped with such a browser. The goal of this standard is to bring together the technologies for mobile Internet browsing and that for the World Wide Web.

The geographic data that we had in our disposal were in the form of digital data, stored in shapefiles [4] in the server. Shapefiles are binary files, which are used by the GIS packages of ESRI. In order to develop PHP code that would read these files we should follow the guidelines of the shapefile technical paper published by ESRI.

Since, however, data are in binary form and as a result not directly human readable, the relation between time cost and benefit would be disproportional if we decided to develop code that would parse the shapefiles and draw their data in the map image. Therefore, we had to transform our data files to another file type, human understandable, for example as simple text. For this purpose, we have used MapInfo Universal Translator, a tool which is used to transform geographic data files in different formats.

There are two popular file types that meet our demands: MIF (MapInfo Data Interchange Format) files [2], supported by MapInfo and E00 (Arc Export File Format) files [1], supported by ESRI. After studying the technical reports published for these two file types and opening the same file in these two different formats with a text editor, it is definitely clear that MIF files are more understandable. Therefore, it is more effective to use them for the development of the file parser. For this reason, we have decided MapInfo files to be the input of our application for map drawing, although there is a PHP library for handling E00 files.

We have to remark that we did not find it necessary to store the digital geographic data in a database, but accessing them is possible directly from the files.

Finally, we have decided to use raster images instead of vector graphics, when drawing the map image. As it emerges from Rosenbaum and Tominski's study in [12], raster images offer in general the best trade-off to reduce constraints caused by limitations of current hardware of mobile devices. Another important factor is that at present most mobile browsers do not support SVG images [13], which are the vector format expected to dominate the market in the next few years. Moreover, a special plugin needs to be installed in order to view SVG images in desktop browsers. There are three raster image types that perform data compression, so that the image takes up less space and can be sent more quickly through the network: JPEG, PNG and GIF. We have rejected the first format because of the quality loss that may be caused and because of the large image size in comparison to the other two formats. As there was no noticeable difference in the quality, when comparing the maps in PNG and GIF format, based on tests we had performed with GD library, we have selected the GIF format because of the smaller image size produced in the case of our implementation.

4.3 Functionalities of the m-CHARTIS system

4.3.1 Application for the administrator

As we have already mentioned the part of the application for the administrator is a secondary web based tool, which provides him/her with the possibility to insert in the system maps and information for the projected areas, with the use of a desktop computer.

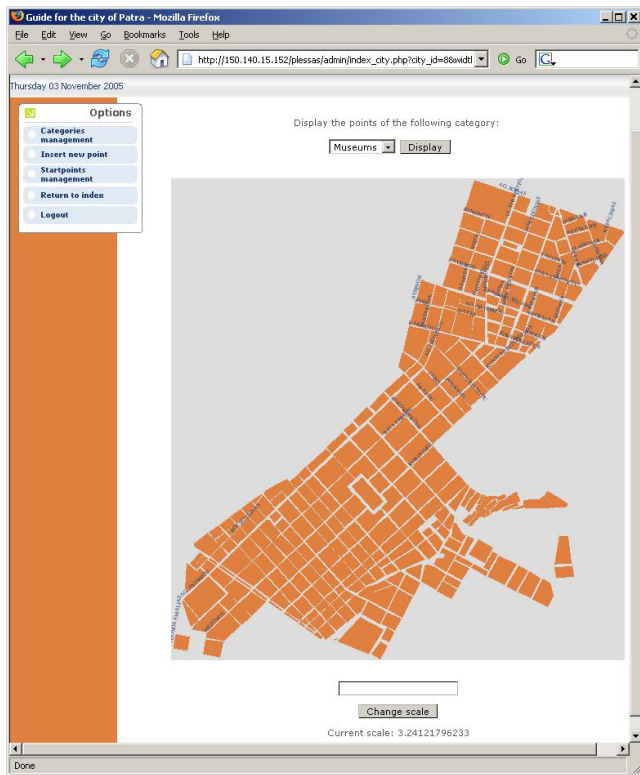


Figure 1. Administrator's tool: the city's index page

In the application's main page, the administrator (as long as she/he is successfully authenticated) has the option to insert a new city, giving a general description and uploading the files with the geographic data for the blocks of buildings and the streets. He/She may also modify and delete the details of a registered city. Another option is to select one of the registered cities and proceed to the index page for this city. Anytime it is possible to logout from the system.

In the index page for each city, as shown in figure 1, the map of the city is displayed. Initially, its scale is computed so that it occupies one fourth of the screen, but the administrator may change it, changing in this way the size of the map.

One of the options for the administrator in city's index page is "category management". This option allows him/her to insert a new category to the system, in which the points of interest (museums, theatres etc.) will be registered and of course to modify and delete existing categories.

Another possibility provided to the administrator is adding a new point of interest and this can be achieved by clicking on the respective point on the map. Then, a form appears where she/he selects the category which the point belongs to and inputs information such as description, address and phone. Furthermore, in city's index page there is the option to show on the map all the points that belong to a specific category. By clicking on one of these points all registered data appear, while it is also possible to modify or delete it.

Finally, in city's index page there is also the option "startpoints management". As startpoint we define a point from which the user of the mobile device may start navigating through the map. Such points are necessary, especially in large cities, in order to help the

user navigate effectively. The administrator is able to insert, modify or delete startpoints.

4.3.2 Application for mobile users

The web-based application, which is addressed to mobile users, allows them to access the maps and the information that the administrator has imported in the system.

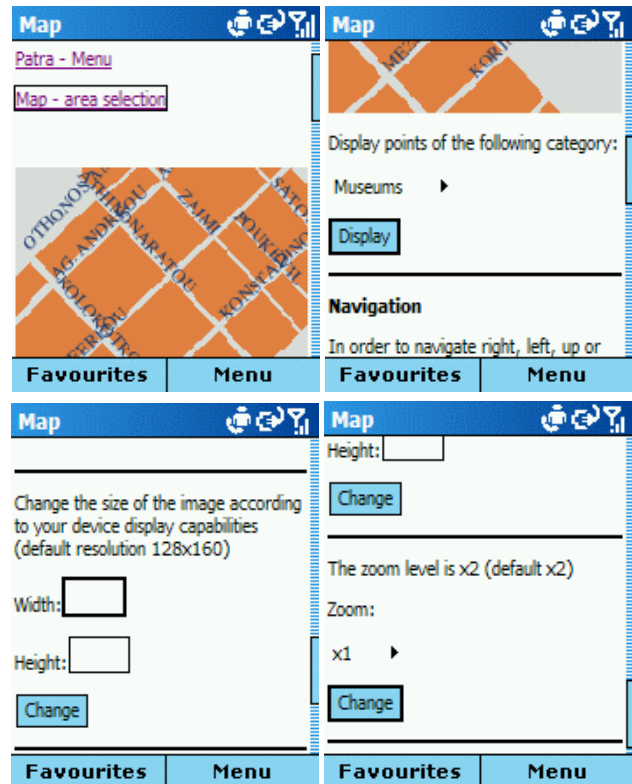


Figure 2. The page for mobile users where the map is presented

In the main page the user selects one of the available cities and next he/she proceeds to the city's index page. From there he/she may see the general description for the city, as given by the administrator.

Another option is "map navigation". The user may start navigating from the startpoints that the administrator has specified. After choosing one of them, the browser loads the page with the map centered at the respective point. This page is shown in figure 2. In this point we should mention that all screenshots of the mobile part of the application were taken with Qtek 8020. Another approach could be to receive from the network cell the position of the user and to transfer her/him to the right part of the map. Unfortunately, we did not have network information in our disposal. The default size of the map image is 128x160 pixels, but the user may change it according to his device's display capabilities. There are also four zoom levels to select the one that suits her/him best. If the user changes once the zoom level or the size of the image the application will "remember" the new settings. In this way he / she does not have to re-enter these settings again. Moreover, keys 2,4,6,8 function as acceskeys and allow moving up, left, right and down on the map respectively. In

case the device does not support accesskeys, navigation on the map is alternatively accomplished with the respective links.

Finally, there is also the possibility to display all the points that belong to a specific category.

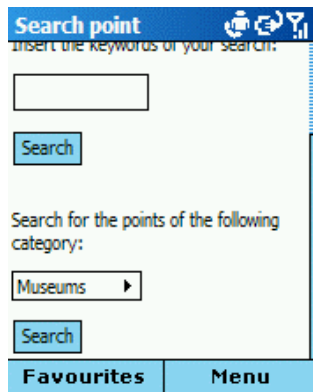


Figure 3. The “search point” page

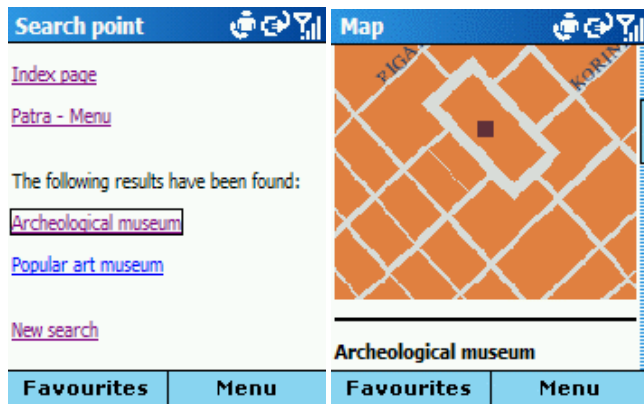


Figure 4. The result of our search for museums

Another option available in each city’s index page is “search point”. The user may search either for all points that belong to a specific category or for a specific point. In the last case the search criterion is the point’s title. If there are any results found, the user, after selecting one of them, is transferred to the page in which a map with the point and the registered information are presented. In this case, there is also the possibility to change the size and the zoom level of the map and to navigate through it. In figure 3, we see the “search point” page. In figure 4, we see the page where the results of our search are presented and a part of the page where the selected one is presented.

The last option available in the city’s index page is “search street”. The system uses for the query the name of the street which the user is searching for. If this street is found in the geographic data files for this city, the system splits it in segments and presents as options those segments that are closer to startpoints, so that the user may see the map with the respective segment of the street. This approach is followed because a street may extent to a long length and we want the user to be able to see the parts of the street that belong to different regions.

We have designed all pages of the application for mobile users according to the design guidelines for mobile web pages described

in [15]. We use the same style for all pages. Each page is divided in discrete parts: at the top of the page there is the part with the navigation links; then, the part with the main informational content; finally, the part with the input forms. In general, all pages are small so that scrolling is avoided. Each page also has a representative title, so that the user knows which part of the application is accessing. Finally, the input forms are compact and the entering text method is automatically changing to the appropriate type. For example, if a form requires numerical input, the input of the device is automatically changing to numerical (when this functionality is supported by the device and the browser). This feature helps the user to save time and makes the application more functional.

4.4 Map Drawing

In order to draw the map, we have developed a parser, which reads the coordinates of the points from the MIF files. Then, the appropriate mathematical transformations are applied, in order to transform the coordinates from the original coordinate system to the reference system that corresponds to the image displayed in the screen.

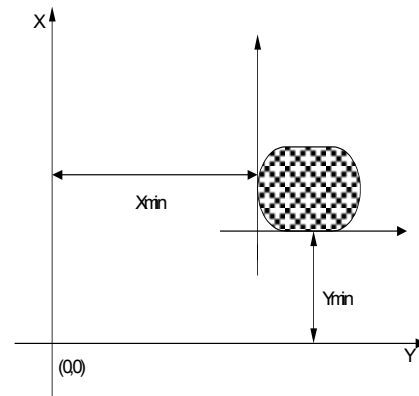


Figure 5. The first transformation of the coordinates

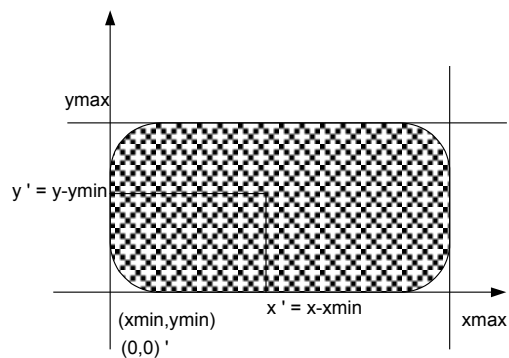


Figure 6. The second transformation of the coordinates

In figure 5, the shadowed part corresponds to the region that the geographic data cover in the original coordinate system. As shown in this figure, the first transformation is a transfer of the axis. If x and y are the coordinates of a point in the shadowed part, x_{min} the

minimum abscissa and y_{\min} the minimum ordinate of the shadowed area, then after the transformation the new coordinates are:

$$x' = x - x_{\min}$$

$$y' = y - y_{\min}$$

Following, a new transformation has to be applied, so that the coordinates of the points are transformed to coordinates in the image, that is to say coordinates-pixels. An important point is that for computer screens and for digital images, as start of the axis is considered the upper left corner and not the down left corner. As shown in figure 6, the maximum abscissa for the area of interest is x_{\max} , the maximum ordinate y_{\max} and the start of the axis is the point (x_{\min}, y_{\min}) in the original coordinate system. The width of the image must be $x_{\max} - x_{\min}$ and its height $y_{\max} - y_{\min}$, in order to include the whole shadowed area, if we consider as measurement unit the pixel. Considering as start of the axis the upper left corner the new coordinates of a point that correspond to the image are:

$$x'' = x' = x - x_{\min}$$

$$y'' = (y_{\max} - y_{\min}) - y' = y_{\max} - y_{\min} - (y - y_{\min}) = y_{\max} - y_{\min} - y + y_{\min} = y_{\max} - y$$

Depending on the scale that the administrator defines, these coordinates are multiplied with a factor that represents the relation between selected scale and the original scale of the geographic dataset.

Finally, using GD library's functions with the transformed coordinates as arguments produces the image of the map. We should note that the names of the streets are retrieved from MID files, which are files with attributes that correspond to the coordinates of MIF files.

Concerning labels presented on the map, such as the names of the streets, we are using a mathematical formula that changes the size of the font according to the scale, width and height of the map image.

5. BANDWIDTH AND TIME OVERHEAD MEASUREMENTS

We have created a simple scenario of navigating in the mobile application with a handheld device. Then, we asked a mobile browsing domain expert to perform the tasks described in the scenario:

1. Select the city of Patras and view general information about the city.
2. Search for a specific point (archaeological museum).
3. Search for a specific street.
4. Navigate from a startpoint to a specific point.

The expert user, who is also developing mobile browsing applications and is very accustomed with mobile devices, had never used the application. We asked him to perform the tasks with 3 different devices (Samsung X460, Qtek 8020 and HP iPAQ hw6510 PDA). Our goal was not to evaluate the interaction with the user but to see the differences in bandwidth and time overhead for these different devices. For this purpose, we have measured the size of each page the user had visited and the time needed to be produced from the PHP script. Of course, this is not the total access time, since it is affected by the available bandwidth of the mobile network and possible lag times. We just wanted to have an idea how fast or slow draw mapping will be.

Table 2. Page size measurements

Page	Size (KB)	Size (KB)	Size (KB)
	Samsung X460 (128x160)	Qtek 8020 (176x220)	HP hw6510 (240x240)
Index page	0.65	0.65	0.65
City menu	0.75	0.75	0.75
City info	2.56	2.56	2.56
City menu	0.75	0.75	0.75
Search point	1.97	1.97	1.97
Search results	1.15	1.15	1.15
Result selection	7.36	7.36	7.36
Change zoom level	7.90	Not needed for the task	Not needed for the task
Change image size	Not needed for the task	11.1	14.3
City menu	0.75	0.75	0.75
Search street	1.18	1.18	1.18
Search results	1.53	1.53	1.53
Result selection	7.20	13.4	19.3
Navigation downwards	6.91	Not needed for the task	Not needed for the task
Select startpoint page	1.4	1.4	1.4
Selection	7.46	12.1	18.1
Navigation diagonally	5.98	7.12	8.42
Navigation diagonally	5.93	Not needed for the task	Not needed for the task

Table 3. Page script execution time measurements

Page	Time (sec)	Time (sec)	Time (sec)
	Samsung X460 (128x160)	Qtek 8020 (176x220)	HP hw6510 (240x240)
Index page	0.0065	0.0065	0.0065
City menu	0.0064	0.0064	0.0064
City info	0.0064	0.0064	0.0064
City menu	0.0064	0.0064	0.0064
Search point	0.0067	0.0067	0.0067
Search results	0.0071	0.0071	0.0071
Result selection	0.04	0.04	0.04

Change zoom level	0.048	Not needed for the task	Not needed for the task
Change image size	Not needed for the task	0.038	0.034
City menu	0.0064	0.0064	0.0064
Search street	0.0065	0.0065	0.0065
Search results	0.031	0.031	0.031
Result selection	0.017	0.019	0.02
Navigation downwards	0.041	Not needed for the task	Not needed for the task
Select startpoint page	0.0084	0.0084	0.0084
Selection	0.028	0.023	0.024
Navigation diagonally	0.018	0.06	0.06
Navigation diagonally	0.038	Not needed for the task	Not needed for the task

The results of our measurements are shown in tables 2 and 3. In static pages, like menus, the size and execution time is the same for all devices. The difference, there is in pages where map images are presented. The largest the resolution of the device is, the biggest the image size is. However, in all cases each page size is small. As we can see, in the worst case (PDA) the size is 19.3 KBs, but only if we want to exploit the full display capabilities of the device. When screen resolution is 128x160 (best case), page size does not exceed 7.90 KBs. Although the image resolution differs from device to device, the execution time is almost the same. It seems that since there is not an impressive difference in the image size, it takes the same time to draw the map.

Thus, the results of our measurements show that our application is fast (concerning script execution time, not overall time since it depends on the network) and since pages' size is small, it does not require a big amount of memory. Small page size reduces also network transfer time and cost (since in mobile networks charging is not flat rate).

6. CONCLUSIONS AND FUTURE WORK

In this paper we outlined the m-CHARTIS system, a web based device independent mobile map application. We presented the assistant tool for the administrator, which was designed for desktop pc and is used to insert geospatial information in the database.

Following, we presented the part of the application that is addressed to mobile users. During the design phase we had taken account of the constraints that handheld devices face. We wanted this tool to be accessed by a wide range of devices, to deal with the limitations and also to benefit from each device type advantages. We aimed, through this application, to provide the user with the possibility to navigate through maps and to access the information that the administrator has inserted in the system. We emphasized on device independence, as current applications for mobile devices do not take into consideration this important, in our opinion, point. Finally, we presented our measurements concerning page size and script execution time.

In the future we intend to add more features in our application. We are planning to implement the feature of finding the shortest path from one location of the map, specified by the user, to another. For this purpose a graph of the map area needs to be created and shortest path algorithms need to be applied. We are also planning to transform the application to be context-aware and adaptive. The user and his context affect the quantity and the detail of the required information, as well as the way the data are presented [11].

We would also like to perform an evaluation and user assessment of our application in order to determine its weaknesses and try to improve them.

7. ACKNOWLEDGMENTS

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