MacauMap: Handheld Digital Map of Macau

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Abstract

Tourism is one of the main sources of income of the Macau economy. When tourists visit a new destination, a map is one of the indispensable items they take with them. Traditional paper maps have certain disadvantages, such as limited amount of detail, difficulty in searching a street or location, and the inability to keep up-to-date with new development in the territory it represents. MacauMap is a handheld digital map application that was developed to overcome these shortcomings of traditional maps, while at the same time promoting Macau tourism. MacauMap is a software application running on PalmOS-powered Personal Digital Assistants. It allows display of street layout and coastal outlines, and has information on places of interest and the Macau bus network. Maps can be zoomed and panned, and streets can be searched for by name. Information can be displayed in either English or Chinese. An optional GPS unit can provide information on the user’s current location.

1. Introduction

It is a well-established fact that Macau is a city of tourism. Ever since the Macau government’s declaration in 1961 of Macau as a ‘city of tourism’ [1], the tourism industry in the territory has experienced a rapid and continuous growth. Today, tourism is the leading economic sector in Macau [2], having replaced previous economic strongholds of garments and textile. In 2001, around 10 million visitor arrivals to the territory were recorded [3], the majority of whom came to Macau for holiday purposes. Given this background, the continuous development of tourism is an important issue for the local economy.

When tourists visit a new place, they need to orient themselves in that place and for this purpose maps are used. In Macau, tourist maps are made available to visitors free of charge by the Macau Government Tourist Office, showing main areas of interest as well as main streets and thoroughfares. Paper maps such as these are useful for gaining an overview of a place and for finding places that are of interest to tourists. At the same time, such maps also have limitations:

(1) Paper maps are only able to show a limited amount of detail, determined mainly by the size of the map as well as the volume of data that is available for representation in the map. In the case of Macau, a typical tourist map is about the size of an A2 sheet of paper (approx. 60x40cm), while Macau has some 1100 streets and dozens of places of interest. To show all streets in a map of this size is not practical. Thus only main and intermediate size streets are typically included in tourist maps while smaller streets are omitted or are shown but leaving out their name.

(2) Many paper maps make it difficult to locate a street or place of interest. A good paper map may have an index of streets that indicates in which section of the map the street may be found. However, such an index is often lacking in simple maps, so that the map user needs to locate the street by searching over the whole map. Even when an index exists, it can take a certain amount of time to search through the section of the map indicated by the index entry before the street can be found.

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Paper maps are static in that they convey the state of the territory they represent at a certain point in time. They are thus snapshots and cannot reflect any changes that may alter the territory. Thus paper maps may become out of date quickly if the territory changes rapidly, such as is the case in some parts of Macau.

Overcoming these shortcomings, recent years have seen the development of computer-based maps, such as in geographic information systems (GIS). Such computer-based maps, designated as digital maps from here on, are able to overcome each of the shortcomings identified above:

1. A digital map application can be programmed to allow magnification (zooming) of any part of the map to the size where any amount of detail desired can be displayed. Thus if a certain amount of detail may not be shown in a map at a given level of magnification, such as a very short street, the map can simply be zoomed into to magnify the area of interest and thereby provide enough room for display of the street.

2. In a digital map, the search for information can be greatly facilitated by providing search interfaces that allow the selection of the desired information items. Thus when the map user wishes to locate a street, the street could simply be selected from a list of streets and its location on the map shown to the user.

3. Because a digital map is a piece of software, it is possible to change the map contents without having to change the hardware containing the map (unlike in a paper map where the sheet of paper constitutes the “hardware” that needs to be changed to get an updated map).

Thus it can be seen that a digital map presents an attractive alternative to paper maps in all of these three aspects where paper maps suffer from shortcomings. Motivated by the desire to offer such an alternative for use by tourists in Macau, the authors set out create a digital map of the Macau territory. The outcome is a software called MacauMap, a handheld digital map of Macau.

For the development of MacauMap, it was decided that in order to be practical for use by tourists, who can be assumed to travel around Macau either on foot or by public means of transportation, the computer platform needed to be small and easy to use. A personal digital assistant (PDA) was chosen as the platform, and the PalmOS-based family of PDAs specifically was selected as the target platform, given its market domination (over 60% of all PDAs world-wide, or about 24 million, are PalmOS-based [4]).

The project was carried out from October 2001 until June 2002, in the Department of Computer and Information Science, Faculty of Science and Technology, at the University of Macau. By June of 2002 a working prototype system was available. Map data for the application was obtained from the Macau Government’s Cartography and Cadastre Bureau (DSCC). The following sections discuss this prototype digital map application in more detail. Section 2 gives an overview of the application and its functions. This is followed in Section 3 with a discussion of the design of MacauMap. Finally, in Section 4 some conclusions are drawn and future directions are outlined.

2. Overview of MacauMap

MacauMap is designed to provide the same information as traditional paper maps and more. A friendly user interface and fast access to information is one of the main aspects of MacauMap. The application focuses on the most important information that tourists would like to have at their fingertips; information such as street locations, places of interest and bus routes are of most significance to tourists visiting Macau. While running on PalmOS-powered PDAs, the MacauMap application consumes only a small amount of memory and performs at an acceptable speed; it is able to display both English and Chinese map information.

MacauMap’s features are mainly grouped into 4 functional areas: map manipulation, map navigation, information seeking and language switching. These are described in detail in the remainder of this section.

2.1 Functions

The most frequently used functions of the application are presented to the user in the form of an icon toolbar that is located at the bottom of the screen. The toolbar is shown in Figure 1 (note that the labels (a) to (l) are not part of the toolbar), while the meaning of each icon is shown in Figure 2.
Map manipulation

Map manipulation consists of zooming and panning the map. In order to zoom in, icon (f) in the toolbar has to be selected. Zooming in is accomplished by drawing a rectangle over the area that the user wishes to zoom into. To zoom out, icon (g) in the toolbar is selected first. A single tap on the screen will perform a zoom-out with the tapped position at the centre of the new, zoomed-out view of the map. Panning is performed by selecting icon (h) and then performing a drag action with the PDA’s stylus on the screen.

Map navigation

Map navigation allows the user to view previous screens that were results of map manipulations such as zooming and panning. Icons (c), (d) and (e) in the toolbar provide access to the previous view, the view of the whole Macau territory, and the next view, respectively.

A special feature of MacauMap is its support of Global Positioning System (GPS) receivers. If a GPS receiver is attached to the PDA, the application is able to inform the user of their current location by a marking on the screen. The user can then centre the map on the position specified by the GPS receiver by tapping icon (k) in the toolbar.

Information seeking

Information seeking is one of the most important features of MacauMap. The user can easily find the location of streets and places of interest by tapping icon (a) in the toolbar and then entering the name of the location into the search field. It is not necessary to enter the whole name of the location, since matching results will be narrowed for every character that is input. The application will display the selected location at the centre of the map.

By selecting icon (i), the application will enter into the information mode, in this mode, the user can tap on any street or location and its name is shown in a popup box on the screen.

Another important feature of MacauMap is its ability to calculate the bus routes needed to go from one bus stop to another in Macau. When the user enters into bus route mode by tapping icon (b) in the toolbar, all bus stops in the map are displayed with a small icon. Users can then select a starting and destination bus stop, and the application calculates the shortest bus route and the bus number to take.

Languages supported

MacauMap supports both English and Chinese. Switching between these two languages is performed by tapping icon (l) in the toolbar. The information shown on the map, such as street names and places of...
interest changes as the icon is tapped and is displayed in the corresponding language. Moreover, the location searching is also affected by the current language mode. A scenario showing the usage of the MacauMap features is shown in the following section.

2.2 Usage

As an example of the usage of MacauMap, a simple scenario in which a tourist arrives in Macau at the Macau Jetfoil terminal will suffice in showing the main functions of MacauMap while illustrating its ease of use.

Suppose that a tourist arrives at the Macau Jetfoil terminal and wants to take a bus to Hotel Lisboa. From the PalmOS-powered PDA, he launches the MacauMap application and enters into the bus route mode. He selects the bus stop in front of the Macau Jetfoil terminal as the starting bus stop (see Figure 3) and the bus stop at Hotel Lisboa as the ending bus stop (see Figure 4). The application then calculates the shortest bus route, which in this case is to take bus number 28BX (see Figure 5).

![Figure 3 Setting starting bus stop](image1)
![Figure 4 Setting ending bus stop](image2)
![Figure 5 Bus route from Jetfoil terminal to Hotel Lisboa](image3)
![Figure 6 Searching for Largo do Senado](image4)

After arriving at Hotel Lisboa, suppose the tourist wants to tour Macau. The first place to visit is “Largo do Senado”, so he starts the search location function (Figure 6). The screen now shows “Largo do Senado” at the centre. In order to see the location more clearly, the tourist zooms in until a zoom level of 64x (see Figure 7). At this level he turns the “bus mode” on and sees that there is a bus stop near it (see Figure 8). Now the bus routing function can again be used to find the bus route from Hotel Lisboa to Largo do Senado.

The above scenario illustrates some of the main functions provided by MacauMap, which help the tourist perform common tasks of finding a place, and finding a way to get to the place.

3. Design and Implementation Considerations

Since PalmOS-powered PDAs are designed to be very small, easy to carry, and consume very little battery power, most of the hardware components of PDAs are much less powerful than those of
traditional personal computers. Because of this, the design and implementation of MacauMap had to strongly consider the limitations of PDAs. The three major limitations of PDAs that influence the design and implementation of MacauMap are:

![Figure 7 Zooming into an area by dragging a rectangle around it](image1)

![Figure 8 Largo do Senado and bus stop at Almeida Ribeiro](image2)

**Limitation on CPU execution speed**

Most PalmOS-powered PDA have a CPU running at 33Mhz. Compared with modern personal computers running at 2000Mhz+ CPUs, the Palm device is a relatively very slow machine (60 times slower than a modern PC). However, MacauMap needs to perform many graphics and information retrieval functions that are very CPU-heavy. If the execution speed is too slow, the user will not be satisfied with the application. Therefore, one of the main design considerations of MacauMap was to deliver fast enough map navigation and information retrieval functions under the limitation of slow CPU speed.

**Limitation on memory storage**

The memory available to a PalmOS-powered PDA varies from 2MB to 16MB, depending on the model. This includes both working memory and storage memory, equivalent to RAM and hard disk storage of ordinary PCs. Such amount of memory is very little compared to the 256MB RAM and 60+GB hard disks with which personal computers are equipped nowadays. Therefore the sizes of the executable program and the map data of MacauMap have to be carefully designed. A design target of a total size of MacauMap and its data of at most 1 MB was set in order to be able to run on older PDAs with only 2MB of memory. To achieve this, optimization techniques reducing program and map data size were applied.

**Limitation on the screen size**

Most PalmOS-powered PDAs are equipped with a 160x160 monochrome or color LCD screen. Unlike modern personal computers with screen displays of at least 1024x768, there is not much space on this 160x160 screen for displaying detailed graphics. The layout of map content and other related information needs to be carefully designed so as to provide as much information on the small screen as possible while ensuring that the content on the screen is still clear enough for the user to read and understand easily.

The remainder of this section briefly describes the methods used in MacauMap to overcome the above mentioned limitations of the PalmOS-powered devices.

### 3.1 Representation of Map Data

The source map data provided by DSCC are in ESRI Shape file format. This format is a standard GIS format which stores map data as vector graphics. In the shape files, streets, costal lines and bus routes are stored as poly-lines. Streets are shown with no width, as a road centreline consisting of two or more points, and can be displayed by connecting the points together. Scenic spots and bus stops are simply represented as single points with x and y coordinates. MacauMap does not directly use the shape files given by DSCC. The shape files are transformed to a specific format that is designed to allow much faster manipulation of the map data on the PalmOS devices. Several techniques are applied in the transformation process of the map data:
Generalization of road centrelines

Streets, coastal lines and bus routes are represented in the form of road centrelines. A road centreline consists of two or more points. Typically, the higher the number of points constituting a line, the more detailed the shape of the line can be. However, for the 160x160 screen, it is not possible to represent a line in great detail. Hence, an algorithm is used to reduce the number of points for all the streets, coastal lines and bus routes. As a result, the map data become smaller, and the computational effort to display the lines is reduced.

Representation of points

Every map object is represented as a single point or a collection of points. A point consists of two values, its x and y coordinates. In the original shape file, a coordinate is stored using real numbers. Since every map operation involves arithmetic operations on the coordinates, and it is known that arithmetic operations involving real numbers are slower than those on integers, performance can be improved by converting all the coordinate values to integers. However, conversion from real number to integers typically results in a loss of accuracy. After several experiments, it was found that coordinate values stored as 32-bit integers allow fast execution speed with no noticeable loss of accuracy.

Multi-level indexing

With more than one thousand streets in Macau, it can be time-consuming to search for the information of a specific street. Therefore, a multi-level indexing technique was applied. This index was built for all streets, allowing very fast lookup for locating all the data related to a specific street.

3.2 Map Display Considerations

Zoom level

Within MacauMap, the map of Macau can be displayed with different zoom levels. When the zoom level is 1x, the whole of the Macau territory is displayed. As the zoom level increases, only a specific region of Macau is displayed with magnification. Since there are so many map objects including streets, scenic spots, coastal lines, bus stops and bus routes, the screen will be hard to read if everything is displayed at the same time. For the line objects including streets, coastal lines and bus routes, lines are displayed selectively on different zoom levels. For example, when the zoom level is 1x, only very long lines will be drawn. With high zoom levels, shorter lines will be displayed too. For point objects including scenic spots and bus stops, icons with different sizes are used to represent them under different zoom levels. When the zoom level is low, small icons are used, while when the zoom level is high, large icons are used. By applying the above approaches, the map readability can be increased.

Screen boundary

When the zoom level of the map is larger than 1x, only part of Macau is displayed. The map objects outside the current screen boundary will not be visible to the user, and those objects can be ignored completely. A method was developed to filter out unneeded map objects, saving valuable CPU resource.

Line Clipping

Given a certain zoom level, a line object may lie across the screen boundary, i.e. part of it is inside the visible region, and part of it is outside the visible region. The Liang-Barsky Line Clipping algorithm[5] was applied to clip the line so as to further reduce the CPU load.

4. Conclusions

This paper has presented MacauMap, a handheld digital map application. MacauMap allows the display of information about streets, places of interest, coastal lines, and bus routes in the entire Macau territory, including Macau peninsula and Taipa and Coloane islands. Searching information is made easy through user-friendly search interfaces. Maps can be zoomed into and out of, as well as panned. Information in the map can be shown in either English or Chinese. Information on bus routes includes the location of bus stops and the function of searching for the shortest bus route between two bus stops. With an optional GPS unit, the current location can be displayed in the map.
MacauMap is successful in overcoming the shortcomings of paper maps mentioned in the Introduction. Maps can be zoomed into up to a maximum magnification level of 256 times that of the overview map, making it possible to display even the shortest streets. A convenient search function facilitates the finding of streets and places of interest, which is facilitated further with the fuzzy search option with which locations can be searched for by any part of their name. Finally, an auxiliary map database creation program developed for MacauMap makes it possible to update the map database when new map data becomes available.

While the MacauMap application is able to overcome these shortcomings of traditional paper maps, it should also be understood that a digital map such as this one is not without its own weaknesses. Particularly, the limited screen size of PDAs can make it somewhat difficult to obtain an overview of the territory as a whole at an intermediate level of detail, such as a typical tourist map provides. Using MacauMap, either an overview of the entire territory at a low level of detail can be obtained, or an intermediate level of detail can be displayed, but only for a portion of the map, so that the user needs to pan the map around to gain an overview. Here a paper map has a definite advantage over a PDA-based digital map. Thus it is not claimed here that digital maps can replace paper maps. Instead, a more realistic view would be to see the two as complementary: the paper map can be used for getting a quick overview, while the digital map can be used for searching and displaying map data in greater detail. Each has its own strengths, and both can be used together.

The first version of MacauMap is a working application that can already be useful to tourists. In the near future, MacauMap will be available for tourists from around the world to download from the Macau Government Tourist Office’s web site. Thus tourists who own a PalmOS-based PDA can prepare for their trip to Macau by installing MacauMap into their PDAs and having it ready for use once they arrive in the territory.

The future plan for MacauMap is to developed it further by adding more features in two areas: firstly, adding more information that will be useful to tourists, and secondly to improve the map display to make the map more easy to read. In the first area, the inclusion of history and related information about places of interest will be added, including photos, opening hours, entrance prices etc. Furthermore, a hotel and restaurant guide will be added that will be categorized by a number of factors (class, location, type). Hereby a user will be able to search the database, for example, for a high-class Portuguese restaurant in Taipa, or a medium-class hotel in Macau, and have their location shown on the map. In the area of improving map display, it is planned to show streets with their left and right border, instead of just by a single line. Moreover, the background of different areas in the map will be shaded in different colours, such as by using a separate colour for parks, built-up area, streets, sea, etc.

It is hoped that when all the proposed improvements will have been implemented in the next version of the MacauMap application, it will gain further in usefulness as an information tool for tourists. Thereby MacauMap has the potential to make a contribution, however small, to the sustained development and promotion of tourism in the Macau territory.

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**References**


