An added feature in mobile phones is a whole lot of data and information regarding the city in which the mobile phone user is located. This is of particular interest to the tourists. The mobile phone provides city map, has a tourist guide through which one can locate hotels, restaurants, temples, tourist attractions, street maps, bus routes, can bookmark favorite places, etc. MacauMap is bilingual i.e., Chinese and English.

1. Introduction

MacauMap is a handheld digital map application designed for tourist use. It was originally developed between 2001 and 2003 for use on Personal Digital Assistants (PDAs). Versions of the software for PalmOS and for Pocket PC were released to the public for free download in May 2003. Within the first year of its release, it has been downloaded nearly 100,000 times. The main features of the MacauMap application are the display of the street layout of the Macau Special Administrative Region; the display of information about tourist-related spots, hotels, and restaurants; a bus routing function for calculating an optimal bus route between...
Motivated by the success of the PDA-based MacauMap application, we set out in 2003 to develop a version of MacauMap for mobile phones. The main motivating factors for this were: (1) mobile phones are widely used, and are more widespread than PDAs, thus by deploying MacauMap on this platform a greater number of potential users may be reached; (2) the capabilities of mobile phones are greatly increasing, approaching those of PDAs, thus making it technically feasible to deploy an application as complex as MacauMap on the mobile phone platform.

As with the PDA version of MacauMap, the mobile phone version was also developed entirely from scratch. This means that the map drawing engine, map browser, data storage format, etc. were fully developed by our project team without using any existing GIS applications or programming libraries. Thus many design and implementation challenges were met during development, which had to be overcome in order to achieve a satisfactory map drawing performance.

The remainder of this chapter is organized as follows: the next section introduces the features of the mobile phone-based MacauMap application, followed by a section discussing design and implementation challenges encountered during development of MacauMap, and finally conclusions.

2. MacauMap Features

When running in a mobile phone, MacauMap appears as in Figure 1. The main features of MacauMap are briefly presented below.
2.1 Map Display

MacauMap is a tourist-oriented map application. Thus, the presentation of geographical information in the map should be tailored to the needs of tourists, meaning that the presentation of the map should be simple and should avoid overly complex information. Moreover, as the screen is very small (176 x 208 pixels in our Nokia 6600 phone), the information that can be potentially displayed in a single screen is further limited. Thus the most important feature of MacauMap is display of a map containing only essential features of the territory. In the case of Macau, most of which is a densely built-up urban environment, this consists of:

1. Streets, represented as centrelines and including their street name;
2. Green areas (forested areas, parks);
3. Water areas (lakes, sea);
4. Hotels (including all 3, 4, 5 star hotels in Macau);
5. Restaurants (including all those registered with the Macau Government Tourist Office);
6. Tourist spots (museums, churches, temples, gardens and parks, scenic spots, tourist information offices); and
7. Public bus stops. Typical map displays are shown in Figure 2.

**Figure 2: MacauMap Display of Macau Peninsula (Left), and a Detail Map with Street Name, Bus Stop, and Restaurants (Right)**
2.2 Tourist Guide

Besides basic map information, tourists are usually interested in finding information about tourist places. MacauMap includes a searchable database of such places, including hotels, restaurants, and other tourist spots. These are categorized by several factors to facilitate easy retrieval of the relevant information. For example, hotels are categorized by class (3, 4, 5 star), and district (Macau peninsula, Taipa island, Coloane island). For each tourist place, detailed information such as address, telephone number, description, opening hours and admission fees (where applicable) are included. Where there is a telephone number included, a dial it directly function allows the user to make a phone call to that number by pressing a single button. Tourist spots also include a small photo of the spot. An example of using the tourist guide function for looking up a temple is shown in Figure 3.

Figure 3: Using the Tourist Guide to Look Up a Temple

[Diagram showing tourist guide interaction]

From left to right: (1) listing all temples; (2) showing information (with photo) about temple Lin Kai Miu; (3) scrolling down to show further information about this temple; (4) showing the location of the temple on the map.

2.3 Bus Route Calculator

In Macau, the public bus is the predominant mode of transportation for tourists. To help tourists find out how to travel from one bus stop to another, MacauMap has a bus route calculator. Users select a start and destination bus stop, and MacauMap calculates the shortest bus route between this pair of bus stops and displays the route in the map. An example of calculating a bus route is shown in Figure 4.
MacauMap Mobile Phone Traveling Assistant

2.4 Bookmarking

MacauMap includes a unique function that allows the user to bookmark their favourite places in Macau which may not already be recorded in the MacauMap database. This function, called My Favourite Macau, thus makes the MacauMap database user-extensible. Users select the location in the map where the spot is located, add a name and short description, and are given the opportunity to take a digital photo of the place using the mobile phone's built-in digital camera (if any). The place then appears as an icon in the map. When selecting the place, the name and description, as well as the photo are displayed.

2.5 Bi-Lingual Data and Interface

All MacauMap data is available in two languages: Chinese (using traditional Chinese characters), and English (or, as in the case of certain proper names such as street names, Portuguese). All parts of the user interface are also available in both Chinese and English. At any time the user may switch the user interface between these two languages, and all data displayed, such as street names, tourist spot descriptions, etc. are also immediately shown in the selected language.

2.6 Walking Tours

The Macau Government Tourist Office has defined seven walking tours through scenic parts of Macau. These walking tours are included in the MacauMap.
application. For each walking tour, the route of the walking tour is shown in the map. In addition, a description of the walking tour is included, as well as an animated slide show of the tourist spots that can be encountered along the tour.

3. Design and Implementation Challenges

The MacauMap application introduced above was developed for the Symbian OS version 7.0s mobile phone operating system, with the Series 60 2.0 user interface. The target device used during development was a Nokia 6600 Chinese edition mobile phone. This device possesses a screen of 176 x 208 pixels size with 65K colour depth, a 104 MHz ARM processor, and 6 MB of internal memory (extensible by adding a memory card). For program implementation the C++ programming language was used, and the standard Symbian OS APIs were utilized [2].

Designing and implementing for this platform is technically challenging, mainly because of the device's small memory, slow processor, small screen, and limited input capabilities. Each of these challenges, and how they were overcome, is briefly described next.

3.1 Small Memory

With only 6 MB of total memory on the target device, memory utilization has to be extremely carefully designed to minimize the use of memory as much as possible, considering that the total memory needs to be shared with all other applications on the device. However, an even greater restriction is the very small stack size available on this platform. Symbian OS 7 applications have only a total of 8 KB of stack available, imposing a severe limitation on the number and size of variables that the program can use.

To overcome the restrictions on total application size, three measures were taken:

1. An efficient storage format for the database of geographic data was designed. The GIS source data is in ESRI Shapefile format, which contains many features not used by our application. Therefore, source data in Shapefile format was converted to Symbian database format, and only required data items were selected in the conversion process.
As coordinates in Shapefiles are floating point numbers, and our application uses integers (for performance reasons, as discussed below), all floating point numbers were converted to integer. To minimize loss of precision through this conversion, the source data's coordinates were multiplied by a factor of 1000 before conversion to integer. As the resulting integer values exceed the range of 2-byte integers, we were forced to use 4-byte integer variables for manipulating coordinate values. However, we discovered that the range of integer coordinate values could be accommodated within three bytes. Therefore, we removed the most significant byte from our 4-byte integer coordinate values before storing into the Symbian database. As the Symbian database does not have a 3-byte data type, all the coordinates are stored successively in a field of the long binary data type. Upon retrieval of a coordinate value from the database, the most significant byte is added back on to the value. This technique allows us to reduce the storage requirement of coordinate values by 25%, resulting in a storage space saving of 100 KB.

2. MacauMap includes more than 100 colour photographs. In order to reduce the storage requirements for these photos, they were first scaled down to a small size (80 x 60 pixels). When a photo is to be displayed on the screen, it is scaled to 4 times the size (double height and double width). The result is a somewhat degraded photo quality, which however is still acceptable, and a smaller storage size. In this manner, the total memory requirement of the photo database can be limited to 800 KB.

3. The available memory on the phone may vary from one device to another. Therefore, MacauMap was designed in a modular fashion to allow only parts of the application to be installed. The core application, which consists of the MacauMap program and all geographical and text data, occupies about 1 MB of storage. Optional parts are the photo database of 800 KB and the animated slide shows of walking tours of 700 KB size. Users have the option to install only the core application, or to also install one or both of the optional components, depending on the amount of memory they wish to allocate to MacauMap.
3.2 Slow Processor

MacauMap uses vector graphics for drawing its maps. The entire map drawing engine was developed from scratch, as to our knowledge there are currently no free map drawing engines available for Symbian OS. Map drawing is computationally expensive, as it involves three kinds of processor-intensive tasks: (1) retrieval of relevant data from the database; (2) calculation of coordinates of all map objects; and (3) drawing of all objects on the screen. Given the slow processor of the mobile phone, each of these three tasks needed to be carefully designed to achieve an acceptable map drawing performance.

As in the predecessor versions of MacauMap, the following two measures were taken to improve map drawing performance:

1. All coordinate values and all calculations use integer data types only. This makes it possible to avoid expensive floating point operations which typically take twice as long as integer operations.

2. The amount of map information displayed progressively increases with the zoom level. For example, no street names are displayed before 24x zoom level (where 1x is the entire map of Macau); no icons of restaurants, hotels, tourist spots and bus stops are shown before 32x zoom level; and some smaller streets are only displayed at higher zoom levels. In this manner, the number of objects that need to be displayed in the map, and that thus require calculation, can be reduced, particularly at lower zoom levels. As a result, all maps can be displayed within about 1–2 seconds on our target device.

3.3 Small Screen

With only 176 x 208 pixels screen size, the display of a very detailed map is not possible. Therefore, the design of map drawing needed to carefully consider the suitable display format of map objects, and the number of objects that can be placed in a given map.

We use road centreline format for display of all roads. Moreover, as mentioned above, not all objects within a given viewport of the map are displayed, depending on the current zoom level. Additionally, some icons exist in different sizes, and
the larger-sized icons are only used at higher zoom levels. This helps avoid clutter in the map and results in a generally good map readability.

3.4 Limited Input Capabilities

Unlike the previous generations of MacauMap, which were implemented on PDAs and thus have pen-based input capabilities, mobile phones using Symbian's Series 60 user interface have only a 12-key numeric keypad, a 5-way navigation button, plus two other programmable buttons available for user input. Thus, user interaction with the MacauMap application is more difficult, and the design of the user interface had to carefully consider how to minimize the required user input while maintaining a high degree of functionality.

In order to make as many functions as possible available through a single key press, shortcuts were defined for all 12 keys of the numeric keypad. Thus, for example, pressing key ‘1’ selects add-favourite, key ‘4’ selects zoom-out, key ‘5’ selects panning, etc.

Another technique implemented was to enable easy map manipulation using the 5-way navigation button. This button is a standard feature of Symbian mobile phones and allows movement in four directions (up, down, left, right), as well as clicking. When users wish to pan the map, or select an area to zoom into, the 5-way navigation button is used to move a panning pointer or zoom rectangle around on the screen. In order to allow both fine-level control of the pointer movement, as well as fast movement, a progressive speed control was implemented: making a short movement with the button results in only a short movement on the screen, whereas holding the button for longer than about half a second results in the movement of a larger distance on the screen.

4. Conclusions

This chapter has outlined the functions and some of the design and implementation challenges of the latest version of MacauMap, a mobile traveling assistant. The release to the public was made in October 2005. As with other versions of MacauMap, this version is available for free download from the website of the Macau Government Tourist Office, and within the first six months the software has been downloaded some 2,000 times. In order to reach the widest
possible user base, the development of other mobile phone versions of MacauMap are currently in progress. A version for Symbian OS Series UIQ is scheduled to be released in the near future, and a version for Java 2 Mobile Edition (J2ME) will follow soon after. Given the success of the previous version of MacauMap on the PalmOS and Pocket PC PDA platforms, it is expected that the new mobile phone-based versions will be equally well received by tourists and locals alike, and thereby promote tourism in the Macau territory.

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