MacauMap: Tourism-Oriented Mobile GIS Application

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Introduction

It is a well-established fact that Macau is a tourist place. 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, paper 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. They 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.
2. It is difficult to locate a street or place of interest being searched for.
3. It is difficult to locate one’s own position in the map.

To overcome these shortcomings of paper maps, and to develop an alternative for tourists visiting the Macau territory, we set out in the Autumn of 2001 to create a tourism-oriented mobile GIS application. The selected target platform was PalmOS, meaning that personal digital assistants (PDAs) made by Palm Inc., Handspring, Sony, and others would be able to run the application. These make up about 50% of the current PDA market, with over 24 million units in use [4]. Later, support for the Pocket PC platform was added, extending support to another 25% of the PDA market.

Following requirements were identified for the application to implement:

1. Display of street layout and street names, coastal lines, green areas (gardens and parks), and lakes.
2. Map navigation: zooming, panning, navigation history (previous/next map view).
3. Ability to display text labels in the map in English or Chinese, and to switch between these languages.
4. Display of the user’s current location using a reading obtained from a connected GPS device.

5. Public bus network and bus guide for calculating an optimal bus route from a starting bus stop to a destination bus stop.

6. Sightseeing guide providing information about museums, churches, temples, and other places of interest, as well as their location on the map.

7. Hotel and restaurant guide providing a choice of restaurants and hotels matching criteria of location, class and style, and displaying the location of selected hotels/restaurants on the map.

Development of the application, designated “MacauMap”, has in the meantime completed, and the application is currently available for free download from the Macau Government Tourist Office’s website [5]. In the first month since its public release alone, some 10,000 copies of the software have been downloaded, and many more thereafter. Out of these, about 90% were for the PalmOS platform and the remaining 10% were for Pocket PC. An example of the interface of MacauMap is shown in Figure 1.

**Technical Challenges**

The MacauMap application is intended to operate on a wide range of hardware devices, on PDAs with processor speeds ranging from 16 MHz to 400 MHz, with memory from as little as 2 MB to 64 MB or more, and with screen resolutions from as little as 160 x 160 pixels to 320 x 320 pixels. Thus the design and implementation of the application had to overcome technical problems in three main areas: performance, memory consumption, and screen size. These are elaborated on below.
Performance

The main challenge in implementing MacauMap was to achieve acceptable map drawing performance. All maps are drawn using vector graphics. A performance target of 1 second drawing speed was set for 90% of all maps, with no more than 2 seconds to be taken for drawing the remaining 10% of maps.

The main problem of map drawing is the large number of graphics elements that need to be drawn on the screen. For instance, a street typically consists of a large number of individual line segments that need to be drawn. For each of these line segments, starting and ending coordinates need to be calculated for the given zoom level and shift of the map relative to the map origin. Thus for a given map, a large number of calculations need to be performed, and these calculations are the most time-consuming part of getting a map on the screen.

Several steps were taken to improve performance and thus to meet the performance goals:

- **Generalization of map data**: Source map data, consisting largely of polylines and polygons, and designed for use on a desktop workstation, are very detailed. Even the road centreline data which is the source data for drawing the road layout in MacauMap, and which is only an approximation of the actual road shape, is too detailed for use on a PDA. Therefore the map data was generalized in order to remove intermediate points in a polyline that do not significantly affect the shape. The result is a set of shapes that contain far fewer coordinates, and thus can be drawn much faster on the map.

- **Filtering**: Macau is a very small, yet densely populated, place: it is only about 25 km$^2$ large, and has some 1200 streets, many of which are tightly packed together in a small area. Therefore, some areas appear cluttered on the screen, particularly at low zoom levels. To overcome this problem, filtering is applied to eliminate small streets from the map view at low zoom levels. To make this possible, a “street level” field is saved along with the data for each street to indicate whether it is a major, intermediate, or minor street. At different zoom levels, only some groups of streets are shown, e.g. only major, or only major and intermediate streets. This has the desirable effect of reducing the number of lines that need to be drawn on the screen, and thus improving map drawing performance.

- **Converting map data to integer**: Originally, the source map data in ArcView shape format stores map coordinates as real numbers. However, calculations involving real numbers are slow, and this is particularly noticeable on a computing device that is already slow, such as a PDA. For this reason, all map coordinates were converted to integer, and all calculations involving these coordinates were carried out as integer calculations. However, because calculations such as integer division involve some loss of accuracy because of the rounding that takes place on the result, the map coordinates of the source data were first converted to large integers, in this case 32-bit integers, so that the loss of accuracy involved in the calculation of these numbers would be insignificant. In this way, a performance improvement of about 100% was achieved.

- **Different map display modes**: To accommodate the large variety of PDAs with different performance characteristics, MacauMap allows the user to control the amount of detail displayed in the map. This is done by offering three different **map display modes**: (1) Simple map display, with streets represented by centre line only; (2) Intermediate-detail map display, with streets represented by centre line, and filling of map background with different colours for land, sea, parks, etc.; (3) Detailed map display, with streets drawn with left and right border, and filling of map background with different colours. Thus different users can choose the amount of detail they desire: those with a slow device may choose a simple map display that produces maps within the performance target time, while those with a faster device may choose the detailed map display to get a better-quality map, also within the performance target time. An example of this is shown in Figure 2 where the same map is displayed in the three different map display modes.
Whereas initial prototypes achieved only about 8 seconds performance for drawing a map, the techniques outlined above led to an improvement in map drawing performance so that eventually the performance goals of 1 and 2 seconds, respectively, were achieved.

Memory consumption

A further challenge was controlling memory consumption. As some PDAs only have a total of 2 MB memory, the application and all its data had to fit into this small space, while also leaving enough memory for other applications. It was decided to require no more than a total of 500 KB of memory for the application and its core data. This presented a challenge, given that source GIS data, provided in ArcView format by the Macau Government’s Cartography and Cadastre Bureau, took up close to 2 MB of storage. Therefore, using the source data in unchanged form on the PDA was not a viable option. Instead, an efficient data storage format was developed which consists of only the essential data elements from the ESRI shapefiles. A custom-written application converts from the ESRI shapefile data to the MacauMap data format. Since many data elements, such as the colour or line style of a shape, are not required and thus are not included in the MacauMap data format, they are simply omitted during conversion. Moreover, the generalization of map data mentioned in the section above also contributes to bringing the size of the data set down. The combined result is a great reduction in the size of the map data to about only 25% of the original size: the MacauMap GIS data now measures only about 250 KB, with another 250 KB being used for the MacauMap application itself. Thus it is possible to run MacauMap even on PDAs having only a small amount of available memory.

For those users whose PDAs have more memory available, however, additional databases are available that may be optionally installed: a tourist guide database containing information about places of interest as well as hotels and restaurants may be installed, requiring about 100KB of storage space; and a photo database containing photos of places of interest, which in its highest-quality version requires just over 1MB of storage space. As the functioning of the MacauMap application is not dependent on the presence of these additional databases, users may choose to omit or install them at will, or even to remove them after installation. Thus users are given some degree of flexibility in the use of the PDA’s limited storage space.

Screen size

The screen size of PDAs is extremely small, when compared with desktop computers. Typical screens measure only about three inches diagonally, compared with 17 inches or more on a typical desktop.
computer. The small PDA screen also has a low resolution, as low as 160 x 160 pixels on older PalmOS devices. Thus a challenge exists in presenting information on the screen in a way that avoids overloading the screen while at the same time providing sufficient information to be useful.

As mentioned in the section on performance above, a number of techniques were developed to improve performance by reducing the number of shapes that need to be drawn on the screen. These techniques also have the side-effect of yielding a more readable display. When drawing a map, MacauMap automatically selects a subset of map data that is determined by the current zoom level and the visible portion of the screen (i.e. an offset from the map origin). This data is filtered in that only those shapes are selected that are defined to be included at the given zoom level. MacauMap has zoom levels between 1x (entire map of the Macau S.A.R. territory) and 256x (finest level of detail). Thus, for instance, only major streets are included at zoom levels under 2x, and only major and intermediate-level streets are included at zoom levels between 2x and 15x. Moreover, when zoom levels are under 8x, all streets are drawn as centrelines only, even when the user selected a detailed map display. Only from a zoom level of 8x and up will streets be drawn with a border, and then also only if they are wide streets. Only starting at 32x zoom level are all streets displayed with borders. This is illustrated in Figure 3: three different maps are shown at zoom levels 1x (a), 8x (b), and 32x (c), each displaying a different level of detail, while the selected map display mode in all cases is the detailed display mode (i.e. with background colours and street borders). The result is a more readable display that avoids clutter.

**Evaluation**

The MacauMap application has now been available to the public since the end of May 2003. Initial feedback from users suggest that it has been successful in meeting its objective of promoting tourism in the Macau territory. Comments posted on web discussion boards by MacauMap users from China and Hong Kong indicate that the availability of the MacauMap application provides a greater incentive for them to make a trip to Macau.

Among the most useful features for tourists are the following three:

1. **Bus Guide**: One of the most useful features to tourists is MacauMap’s ability to suggest a bus route from an origin to a destination bus stop. This is illustrated in Figure 4 where a route from the bus stop “Terminal Maritimo” to the bus stop “Almeida Ribeiro” is being found. Several search options allow the user to control the search method and thereby to find a more optimal bus route.
(a) Setting a starting bus stop

(b) Setting a destination bus stop

(c) Setting search options

(d) Display of the shortest route

Figure 4: Finding the shortest bus route from a given start to a given end bus stop
2. **Tourist Guide:** Another useful feature of MacauMap is its tourist guide which includes information on hotels, restaurants, and places of interest. Users can search for a hotel by class (3, 4, or 5-star), and location (Macau peninsula, or Taipa or Coloane islands). For restaurants, a search by class (deluxe, first class, second class), style (Chinese, Portuguese, Japanese, etc.), and location is possible. After a search is complete, a hotel or restaurant can be chosen from the list and shown on the map, or more information about it can be called up from the database. This is illustrated in Figure 5 where a user is searching for a 5-star hotel in Macau peninsula and has located the “Mandarin Oriental” hotel.

3. **Language Switching:** Another useful feature is the ability of MacauMap to switch the display language between English and Chinese. This allows a user to look up a street or place in their own language and then display its name in the other language. For example, if users know the name of a street or place of interest in, say, English only, they can display it with its English name and then easily look up its Chinese name by switching the display language. This is illustrated in Figure 6 where the same map is shown with English and Chinese text labels. This feature is useful as it helps users who want to ask a local person for directions to that place, and who can show the name of the place in Chinese to the local person.

While mainly intended for tourists, MacauMap is also proving to be useful for local residents, particularly its bus routing and language switching features.

Our current experience confirms to us that there is value in a GIS application oriented toward use by the public in Macau. The decision to make MacauMap available free of charge has contributed to its successful adoption, and early indications are that the Macau tourism sector is benefiting from its availability. More promotional activities are planned so as to make MacauMap known to visitors from outside the region, such as tourists from Europe, North America, Australia, and New Zealand. These could then download and install MacauMap into their PDAs prior to their trip, so as to be able to use it once they arrive in Macau. The ability to download MacauMap from tourist information kiosks in Macau is also planned, and may be available later this year. More work on MacauMap is ongoing: currently both a mobile phone version, as well as a web-based version are being developed. This should soon result in a widening of MacauMap’s potential user base from its current PDA users to mobile phone and home users.
Figure 6: Switching the language of text labels in the map

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References


Biographical Information

Robert P. Biuk-Aghai received his MSc in Information Systems from the London School of Economics in 1990. He is currently completing a PhD in Computing Sciences at the University of Technology, Sydney. Since 1993 he has been a lecturer in computing sciences at the University of Macau. His research interests include geographic information systems, collaboration technology, and distance education, in which he has authored more than 20 papers. Mr Biuk-Aghai is a member of the ACM and of the IEEE Computer Society.