



**City University of Hong Kong
Department of Computer Science**

BSCCS/BSCS Final Year Project Report 2005-2006

(05CS030)

Informative Maps on PDA-phones

(Volume 1 of 1)

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Extended Abstract

It is a trend for people to travel on their own without joining the travel agents in recent years. Travelers would take a map and search for sites to visit. However, reading a paper map is inconvenient and difficult sometimes. With the technology of GIS and GPS, there have already been maps on the Internet. To meet the requirement of mobility of travel guides, maps have to be implemented on handheld devices.

There have been some applications with GIS on PDA or pocket PCs. They mainly provide location based or map based query, however, there is a lack of location detection or tracking functionality. Even though some applications can support GPS and provide routing function, they are useful for drivers only. They are not suitable for ordinary visitors to travel in highly dense areas like Hong Kong.

This project aims to implement informative maps on PDA-phones such that it can provide users' positioning. SIM tracking mechanism provided by SUNDAY LBS is chosen to be used. The auto-detection of current location together with a destination input by the users, an optimal path could be calculated and displayed on a map to teach the users to go to the place. Moreover, audio and photo display functions would also be provided. The deliverable will be of web-based such that dynamic update of data can be available and no software deployment is required for clients.

Throughout the project, technologies in location tracking will be examined. Also, technical problems on path finding, route instruction generation and web UI of PDA-phones will be justified and overcome. The project would be useful for the development of located based applications on handheld devices and could be acted as an extension to provide map information.

Acknowledgements

I would like to give my profound thanks to my supervisor, Professor Horace Ip for guidance and management on my final year project. He gave me professional advices starting from the very beginning when I proposed my project which I can have a good planning and carry out the project smoothly. With his useful suggestions and valuable comments, my application becomes more interesting and my report is more organized. I am pleasure to gain achievements in this project with the support of my supervisor.

I would give my gratitude to CS Lab for offering me with the resources, the desktop PC, the PDA phone and the SUNDAY LBS services for my project development.

Also, I would like to thank Angus Lee for providing me with the information and user documentation of SUNDAY LBS services and my classmates who have given me comments throughout the project.

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1. Introduction

Information has never been so accessible. A decade ago, it would take several days to obtain a single piece of information. Who is Alan Turing? Where did he born? What has he done in computer science? These questions would require several hours of researches in the library in past times. And now, simply with some keywords being typed on some popular search engines, all answers will be popped out within microseconds.

With the emergency of telecommunication technologies and Internet, information is just few clicks away. This is the “Six Degrees” world of information. Every new node being plugged into the network represents the growth of the information super highway.

1.1. *The Challenge*

From library to desktop PC, and now we have Pocket PC. Information retrieval devices are getting more and more portable. Plus with such a high mobile penetration rate in the territory [1], mobile communication services with data capability is reliable and inexpensive.

In recent years, it has been a trend for people to travel on their own without joining travel agents, especially the travel in Hong Kong (Figure 1 [2]). Lots of foreigners like to take a map and search for sites to visit. However, reading a map is quite inconvenient sometimes since they need first locate their current location and then search for a route to go to the desired location.

To facilitate the map reading, there have already been some electronic maps on the Internet [3] [4]. Thanks to the rapid development of mobile technology, electronic maps can now also be implemented on mobile devices.

The existing location based service applications mainly provide point to point query services with users' input. However, how can a foreigner locate his/her location in HK? Foreigners can easily input the district, yet it may be difficult to locate the exact current location. Moreover, the location based applications usually only provide transportation method for users to get to the desired location. There is a lack of information on teaching users to go to the exact location on foot. With only indicating both the current and destination on a map, who can ensure users can find a right path to go to the destination? Once the users get a wrong road, they may then get lost.

In my project, the purpose is to implement an application on PDA-phones that can facilitate people in map reading and location finding. With such application, user can get to the desired place easily.

訪港旅客分析 - 各大主要市場 VISITOR PROFILE - MAJOR MARKET AREAS										所有過夜旅客 ALL OVERNIGHT VISITORS							
所有國家 All Countries		美洲 The Americas		歐洲 Europe		非洲及中東 Africa & ME		澳、新及 南太平洋 Australia, NZ & S Pacific		北亞 North Asia		南亞及 東南亞 South & Southeast Asia		台灣 Taiwan		中國內地 Mainland China	
2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004
旅程安排 % Travel Arrangement %																	
一切全包裹 All Inclusive Package		17	16	6	6	6	6	4	5	27	27	20	22	4	4	20	18
機票及酒店套票 Air + Hotel Package		6	6	8	7	11	10	13	13	10	9	12	14	22	23	2	2
自行安排 Non-Package		77	78	86	87	83	84	83	82	62	64	68	64	73	73	78	80

訪港旅客分析 - 各大主要市場 VISITOR PROFILE - MAJOR MARKET AREAS										度假過夜旅客 VACATION OVERNIGHT VISITORS							
所有國家 All Countries		美洲 The Americas		歐洲 Europe		非洲及中東 Africa & ME		澳、新及 南太平洋 Australia, NZ & S Pacific		北亞 North Asia		南亞及 東南亞 South & Southeast Asia		台灣 Taiwan		中國內地 Mainland China	
2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004
旅程安排 % Travel Arrangement %																	
一切全包裹 All Inclusive Package		34	31	15	15	14	14	8	8	46	47	37	37	7	6	39	33
機票及酒店套票 Air + Hotel Package		7	6	11	8	14	11	16	15	12	10	13	16	33	32	2	2
自行安排 Non-Package		58	63	74	77	72	75	76	77	42	43	50	47	60	62	58	65

訪港旅客分析 - 各大主要市場 VISITOR PROFILE - MAJOR MARKET AREAS										商務過夜旅客 BUSINESS OVERNIGHT VISITORS							
所有國家 All Countries		美洲 The Americas		歐洲及中東 Europe Africa & ME		澳洲、新及 南太平洋 Australia, NZ & S Pacific		北亞 North Asia		南亞及 東南亞 South & Southeast Asia		台灣 Taiwan		中國內地 Mainland China			
2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004
旅程安排 % Travel Arrangement %																	
一切全包裹 All Inclusive Package		2	2	1	1	2	1	2	1	4	4	3	2	1	1	3	3
機票及酒店套票 Air + Hotel Package		7	9	7	7	10	9	12	12	9	9	11	13	13	16	3	6
自行安排 Non-Package		91	89	92	92	89	90	86	87	87	87	86	85	86	83	94	91
訪港旅客分析 - 各大主要市場 VISITOR PROFILE - MAJOR MARKET AREAS										所有入境不過夜旅客 ALL SAME-DAY IN-TOWN VISITORS							
所有國家 All Countries		美洲 The Americas		歐洲及中東 Europe Africa & ME		澳洲、新及 南太平洋 Australia, NZ & S Pacific		北亞 North Asia		南亞及 東南亞 South & Southeast Asia		台灣 Taiwan		中國內地 Mainland China			
2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004	2003 [^]	2004
旅程安排 % Travel Arrangement %																	
一切全包裹 All Inclusive Package		3	2	2	1	2	1	2	1	5	4	5	4	1	1	4	2
機票及酒店套票 Air + Hotel Package		2	1	3	1	6	2	4	2	3	2	3	2	1	1	2	1
自行安排 Non-Package		95	97	95	98	92	97	94	97	92	94	92	94	98	98	94	97

Figure 1 Travel Arrangement of visitors in Hong Kong in 2004

1.2. The Solution

A PDA-phone with GPRS is used with SUNDAY LBS technology to detect user's location. An optimal route is then calculated on the server based on the detected current location and the desired location searched by the user. An informative map would be displayed as a webpage on user's PDA-phone.

The application would be:

1. Ubiquitous

Users are everywhere. With a mobile device on their hands, they expect to gain access to various kinds of information on their tips, at anytime and anywhere they wish. The system would be able to deliver users with the desired information by adopted most cutted-edge mobile transmission technologies.

2. User-Friendly

Users need not to take any other devices or even download any programs. They can just use their own PDAPhone, the most familiar devices that they use everyday for the application. Moreover, there is no new user-interface for users' learning. What they need to do is just browsing the web as they usually do.

3. Availability

Detection of user's location could be available in a majority of areas in HK. Since there are tones of buildings but few rural areas which would be visited by tourists in HK, SUNDAY LBS can cover most of the areas which the detection is good as long as the GSM signal can be reached.

4. Flexible

Since the application is of web-based, the thin-client property enables the application to be updated dynamically. Thus, if there are any changes or updates in the application, the new features could be rolled out at once and users are always guaranteed in using the most updated one.

5. Consistent

All the programs and data are stored on the server side and all clients are using the same set of application. Different users using their devices which can be access to Internet would have the same performance for the application

6. Extensible

The application can be acted as an extension to any location based systems to provide informative maps. By automatic detection of current location and the user's input desired location, an informative map can be provided.

1.3. The Scope

This project will focus on the development of web application on handheld devices to generation of an informative map with all the data processing resided on server side. The detailed scope of my project would include,

- the study of the Geographical Information System
- the study of the different positioning and location tracking technologies include Global Positioning System and SIM tracking
- the study of AI path finding methods
- the investigation of the current location based software on handheld devices
- the use of SUNDAY Location Based Services for location detection
- the implementation of web interfaces on handheld devices
- the implementation of optimal path finding
- the generation of informative maps with zoom levels
- the implementation of the photo display function
- the implementation of audio instruction function

The main functions of the application would provide,

1.3.1. Location detection

Upon request, user's current location can be detected via SUNDAY LBS. The current address information can be viewed.

1.3.2. Optimal route finding

Upon the detection of the user's current location and getting the desired destination location, an optimal route would be calculated from the source location to the destination.

1.3.3. Map display

The map will be displayed with the calculated optimal route to show the user how to get to the desired location.

1.3.4. Zoom in & out

The map with an indication of optimal path can be zoomed in.

1.3.5. Photo display

A photo will be shown to indicate the user with the current appropriate walking direction.

1.3.6. Audio instruction

User can listen to the audio instruction to understand how he can get to the destination.

2. Background Literature

2.1. *Maps*

How to prepare a trip on our own? Traditionally, it was no doubt that travelers would buy guidebooks from bookshops. A travel guidebook could then provide travelers with the information of a particular place and maps teaching them how to get there. The main reason for the popularity of guidebooks is that they are portable and user-friendly.

In this 21st century, information can be achieved everywhere. Many books are migrated into electronic books and it was no exception for travel guidebooks. Nevertheless, while the textual information could be easily migrated into electronic, on the contrary, the geographical maps require much effort.

With important elements portrayed on a piece of paper, traditional maps are abstractions of our real world. To make an electronic informative map possible, techniques are required for representing the spatial elements digitally.

2.1.1. Geographic information system (GIS)

Geographic information system is a powerful set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real word [5]. It is used in an enormous range of applications where there is geographic data to be stored, queried, analyzed and displayed.

The first operational GIS, called CGIS (Canadian GIS) was first developed by Roger Tomlimson in 1960s. It aimed at determining the land capability for rural Canada through the analysis and manipulation of data from CLI (Canada Land Inventory).

In 1990s, it was built to support the federal and provincial resource planning and management. The success in continent-wide analysis of complex data sets stimulated the development of various commercial mapping applications. Due to the rapid growth of Internet in 90s, GIS was combined with Internet to introduce a new technology to handle spatial data on the Internet in 1996. By the end of the 20th century, users began to export the concept of viewing GIS data over the Internet, requiring data format and transfer standards.

GIS represent real world objects in digital data with 2 methods, Raster and Vector. Raster data type uses cells to store data and the value in each cell is either a discrete value or a null value. This kind of model requires lots of storage space to represent data yet allows easy implementation of overlay operations. On the other hand, vector data type uses geometries such as points, lines, or polygons to represent objects. It stores data only where necessary and the vector data can be displayed as vector graphics used on traditional maps. However, it is more difficult for implementation. Raster and vector data models treated the coverage as a gigantic field which can then be subdivided; therefore they can be considered field models although they both referred to as layer models.

Maps have traditionally been used to explore the Earth and to exploit its resources. GIS technology has enhanced the efficiency and analytic power of traditional mapping. Now, GIS technology is becoming an essential tool in the effort to understand the process of global change. Various map and satellite information sources can combine in modes that simulate the interactions of complex natural systems.

2.1.2. Mapping in HK

The Survey and Mapping Office (SMO) of the Lands Department is the central authority for land surveys and all types of mapping in HK. It is committed to the provision of accurate and up-to-date maps in a wide selection of topics and scales to support the rapid and intensive development of HK.

Early days, mapping of urban Hong Kong and Kowloon was at 1:600 scale and New Territories area was mapped at a scale of 1:1200 with neither information of height nor contour. With realization in the early 1960s on the essential needs for accurate large-scale maps with contours for planning and development, a project with aerial survey was carried out for about 10 years. The project provided mapping at 1:60 scale, with 5-foot contours, covering Hong Kong Island, Kowloon and New Kowloon but the hilly areas and outlying islands of the New Territories were covered at 1:1200 scales with 10-foot contours [6].

In line with the metrication policy in the 1970s, the imperial grid was converted to metric unit of measure in 1975-1977. A re-survey was carried out in 1978-1979 to improve the consistence and accuracy and a new geodetic datum, HK80 Geodetic Datum using International Hayford (1910) as the reference ellipsoid and the same projection origin was adopted (Figure 2 [7]).

Today, digital mapping at various scales from photographs and the terrain data are available for engineering design, earth work calculation and topographic mapping.

Grid System	Hong Kong 1980 Grid System (HK 1980 Grid)
Projection	Transverse Mercator
Geodetic Datum	HK80
Reference Ellipsoid	International Hayford (1910)
Origin of Projection	Old Trig 2 "Patridge Hill" Latitude 22 18' 43.68" N Longitude 114 10'42.80" E
Grid Coordinate of Origin	819069.80 mN 36694.05 mE
Scale Factor	Unity (1.0) along the central meridian at old Trig 2

Figure 2 Projection Parameters for Hong Kong Grid System

2.2. Location Tracking

A variety of ways have been used to track one's location on earth and to navigate from one position to another over decades. From the early mariners relied on angular measurements to celestial bodies to calculate their location to the radio signal was used to locate the direction of shore-based transmitters due to an introduction of radionavigation in 1920s, the methods for navigation was weak. Thanks to the development of artificial satellites, the transmission of more precise, line-of-sight radionavigation signals sparked a new era in navigation technology. And this laid the groundwork for a system that would revolutionize navigation forever - the GPS.

2.2.1. Global Positioning System (GPS)

Global Positioning system is a satellite navigation system operated and maintained by the U.S. Department of Defense. It is used for determining one's precise location and providing a highly accurate time reference almost anywhere on Earth or in Earth orbit [8].

It was developed in the 1970s primarily intended to be of military uses. The first GPS satellite was launched in 1978 and a total of 11 satellites were launched by 1985 on the Atlas-Centaur which were manufactured by Rockwell. It was then planned to detect nuclear weapon explosions, assess nuclear attack, help in evaluating strike damage and monitor compliance with the nuclear test ban treaty. In the 1980s, since GPS became a non-standard weapon system without a clear mission and a history of well-defined operational concepts, this increased the selling of the program to multiple services and the system was used by countless civilians [9].

Commercial GPS equipment aimed at the surveying profession appeared on the market by the mid 1980s. It offered greater productivity and cost savings over traditional survey method. The growth in the GPS survey market then opened the way for a number of GPS niche markets such as aviation. In 1995, Trimble which

was the first company to be awarded the GPS Technical Standard Order certification signed an agreement to cooperate in developing GPS products for the commercial, space and military aviation markets.

With the announcement of GPS as the first approved navigation system aid for all phases of flight in 1994, navigation was proved to be a crucial technique among various uses of GPS.

A fully operational GPS requires at least 24 satellites in 6 orbital planes which each satellite circles the earth twice every day. The satellites carry atomic clocks to provide precise timing information. The receiver requires a clock which should be synchronized with the satellites in order to receive signals from four satellites for the determination of its own latitude, longitude, elevation and the precise time. With the computation for the distance to each of the four satellites, the receiver decodes the satellites' location that it should be located at the intersection of four spheres, one around each satellite (Figure 3 [10]). This yields 3 hyperboloids of revolution of two sheets, whose intersection point will give the precise location of the receiver. If elevation information is known, only the signals from three satellites are required (the point is then defined as the intersection of two hyperboloids and an ellipsoid representing the Earth at this altitude). Thus, GPS can provide an accurate positioning capability. However, since the signals from satellites could be shadowed by the buildings, it cannot be used in urban areas.

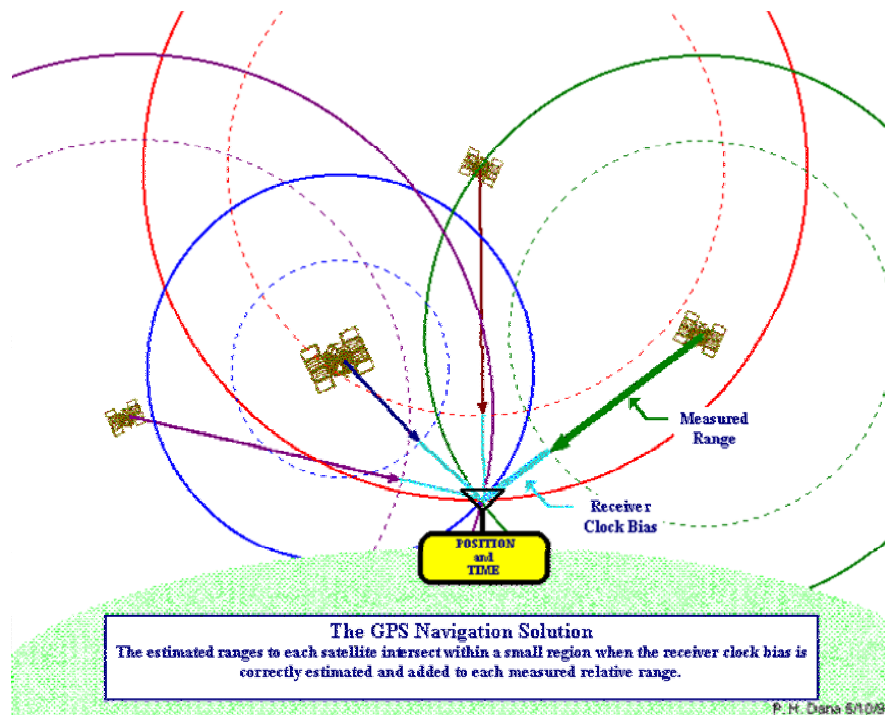


Figure 3 Receiver is at the intersection of 4 range spheres

2.2.2. SIM Tracking

SIM tracking (also called as GSM tracking) is a positioning technology provided by SUNDAY LBS. It is an application burnt into the SIM card with two algorithms, cell based and NMR (Network Measurement Report) based.

Cell based tracking makes use of the cellular concept of GSM network which includes serving cells and neighbor cells. To locate the mobile position, only a single serving cell is used and the location returned is the strongest cell where the user registers to (Figure 4 [11]). The accuracy is of the cell radius, i.e., if the cell is 5 km, the accuracy is of 5 km. NMR based tracking is an algorithm used to better the positioning result. It estimates the location based on NMR which contains serving cells and 6 neighbor cells information (Figure 5 [11]). Since 6 cells are used for tracking, the accuracy can be improved by 25% of the Cell ID based with less than a cell radius.

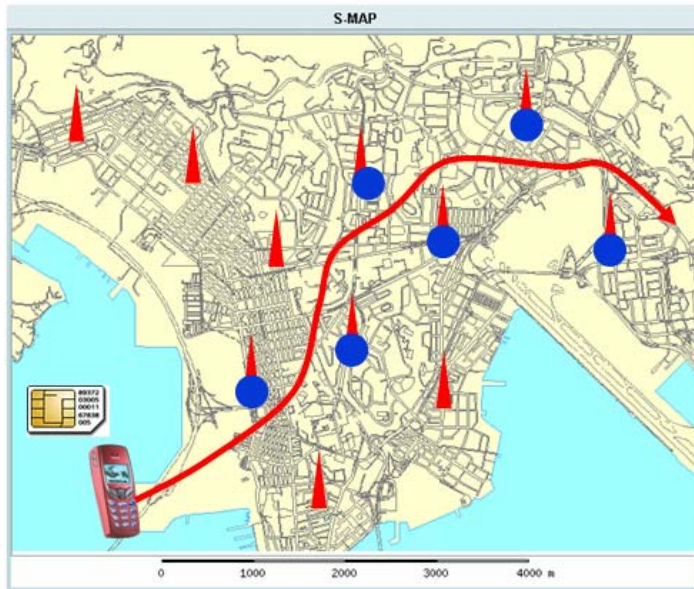


Figure 4 Cell based tracking – Cell ID based (1 Cell based)

Every single base station will report the location of the phone. It is not accurate because the distance between cells can range from 200 m to 500 m in urban areas.

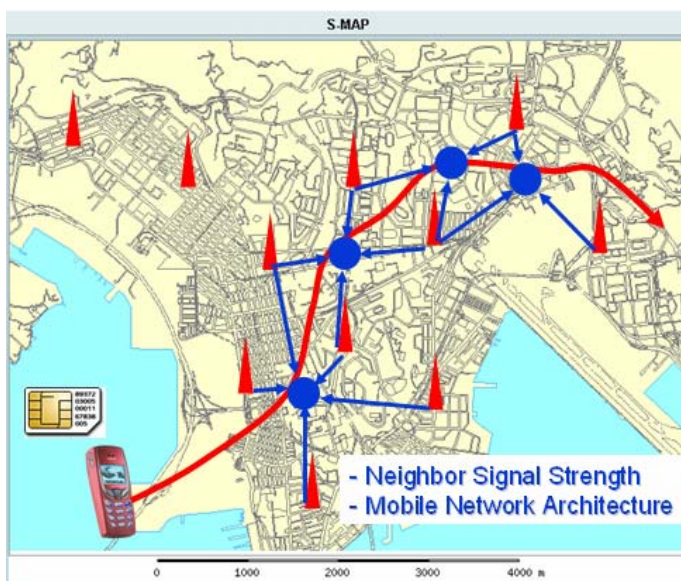


Figure 5 Cell based tracking - NMR based (6 Cells based)

Whenever making a measurement, up to six base stations will be reported. The information achieved will report back to the location server. It then calculates the measurement and estimate the best location. Instead of reporting the user with a single cell location, the route will be estimated with an accuracy of 150 m.

SUNDAY LBS for Corporate Application of Fleet management and Mobile Workforce was launched in 2000. It could be used to track the vehicles fleet both in HK and in Guangdong province so as to enhance the logistics flow and efficiency. In 2003, the first location based Family Care service, Family Watch was launched which the mobile users can location their children or elders anytime and anywhere. Now, SUNDAY LBS with SIM tracking mechanism can be used widely to monitor the locations of staff, vehicle fleet or shipments on a real-time basis.

2.2.3. MLES

MLES, Mobile Location Estimation System is the most accurate mobile phone location estimation technology in the world which is newly developed by HKPC (Hong Kong Productivity Council) in collaboration with industry experts. It was under a \$7.07 million Innovation & Technology Fund Project from 2002 to 2004 with an aim to further improve the average accuracy of the location calculation and commercialize the technology for public use.

Instead of using a single method for positioning, MLES consists of a brunch of location algorithms which each one is designed to solve a specific problem domain. It uses signal strength for the positioning and can provide a stable accuracy with 65 m in selected areas in HK.

MLES was developed using the existing mobile phone infrastructure such that when a mobile user or a client application sends a service request to Application Provider, it will send the location request to MLES. With the cell information obtained from Network Operator, MLES sends the mobile device's location back to Application Provider. At last, Application Provider uses the location to provide the required service to the mobile user or the client application. (Figure 6 [12])

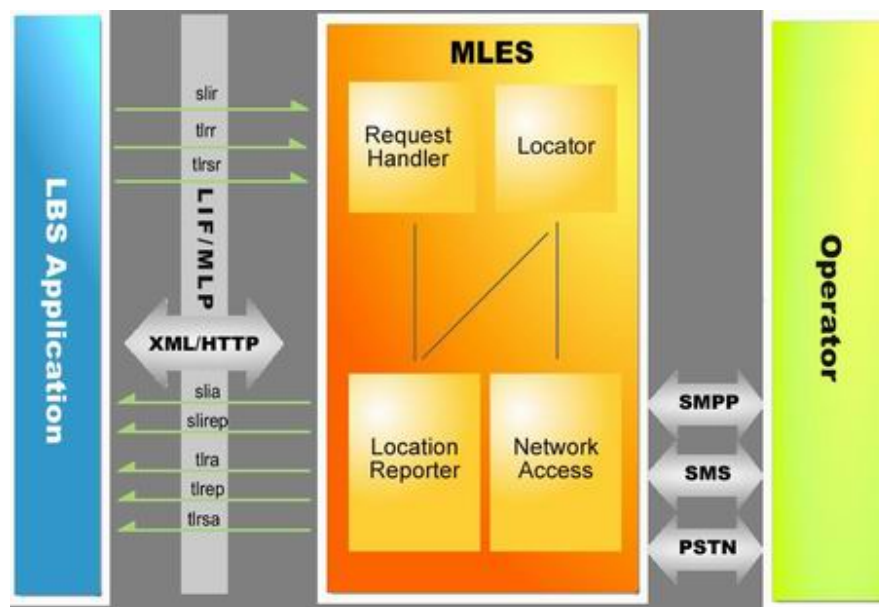


Figure 6 Work flow of the system

Below shows a comparison between different mechanisms for location tracking.
(Figure 7)

	GPS	SIM Tracking	MLES
Setup Cost	Medium - Special installation is required	Low - Mobile phone	Low - Mobile phone
Size	Medium - Receiver	Small - Mobile phone with SIM Card	Small - Mobile phone with SIM Card
Accuracy	Constant accuracy: 5 – 10 m	Dense Urban: 50 - 100 m Urban: 150 – 200 m Sub-urban: 200 m – 1 km Rural: 1.5 km	More stable than SIM Tracking Average accuracy: 50 m
Coverage	Outdoor only	GSM coverage	GSM coverage

Figure 7 Comparison on different mechanisms for location tracking

2.3. Path Finding

Where is ABC restaurant? How to go to the restaurant? To find a route to go to a desired place, the most common way is to read maps. Traditionally, people have to first notice the current location and then the destination on the map for determining the route. It seems to be obvious and trivial; on the other hand, it is not as easy for computers to find an optimal route.

Finding a route on a map is viewed as finding a path on a graph in computer science. Graph is a set of objects called vertices joined by links called edges. Path finding is a problem to find a path between two vertices. Therefore, each location can be interpreted as a vertex and the road or street between locations can be interpreted as an edge.

2.3.1. Breadth-First Search

Breadth-first search is an algorithm aims to expand and examine all nodes of a graph systematically in search of a solution with an uninformed search strategy. The algorithm begins at the root node and explores all the neighboring nodes on of the same level. Then for each of those nearest nodes, it explores their unexplored neighbor nodes until it finds the goal. (Figure 8 [13])

It is complete which guarantees to find a solution if one exists. Moreover, it is optimal technically if the path cost is a non-decreasing function of the depth of the node, e.g. when the costs of all the arcs are the same. On the other hand, it is memory consuming for holding all the generated nodes and the large number of nodes to be examined would cause a large time complexity. (Complexity - $O(b^{L+1})$, where b is the branching factor and L is the level/depth)

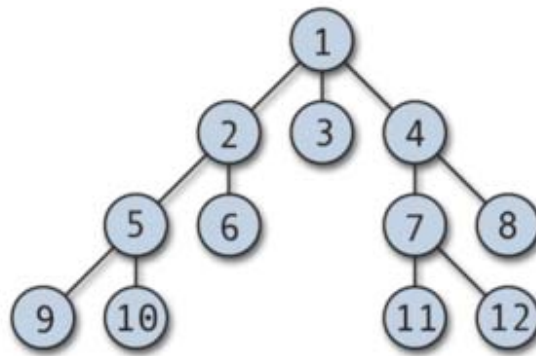


Figure 8 Order of the nodes expansion

2.3.2. Depth-First Search

Depth-first search progresses by expanding the first child node of the search tree that appears and then goes deeper and deeper until a goal state is found, or until it hits the node which has no children. And then, the search backtracks and starts off on the next node. (Figure 9) It is an uninformed search with a guarantee to find a solution if the problem is finite and requires modest memory requirement. (Complexity – $O(bm+1)$, where b is the branching factor and m is the maximum depth of the search tree) However, it may not necessarily provide an optimal solution.

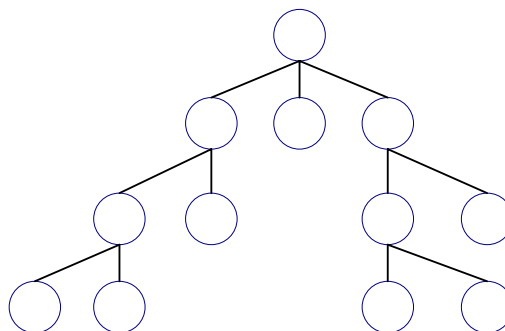


Figure 9 Order of the nodes expansion

The previous 2 searching methods are of uninformed search. That means they do not consider additional information about state beyond that provided in the problem definition. All they do is generate successors and distinguish a goal state

from a non-goal state. While just finding a path is not enough, informed search strategy is introduced.

Informed strategy uses problem-specific knowledge beyond the definition of the problem itself which can find solutions more efficiently. An evaluate function $f(n)$ is usually applied in the searching process to select the node to be explored.

$$f(n) = g(n) + h(n)$$

n represents the current node,

$g(n)$ is the path cost so far from the Start node to the current node n

$h(n)$ is the estimated cost of the shortest path from n to Goal node

2.3.3. Hill-Climbing Search

Hill-climbing search or greedy local search tries to expand the node that is closest to the goal each time. So, it evaluates nodes by only considering the heuristic function: $f(n) = h(n)$ and typically ignore $g(n)$. By doing so, the local best node would always be chosen. Nonetheless, hill-climbing often gets stuck for the following reasons: (Figure 10 [14])

- Local maxima: a local maximum is a peak that is higher than its neighboring states but lower than the global maximum. It will mistake the local maximum as the global one.
- Ridges: ridges result in a sequence of local maxima that is very difficult for greedy algorithms to navigate.
- Plateaux: a plateau is an area of the state space landscape where the evaluation function is flat. It can be a flat local maximum or a shoulder.

Thus, the optimality is not guarantee.

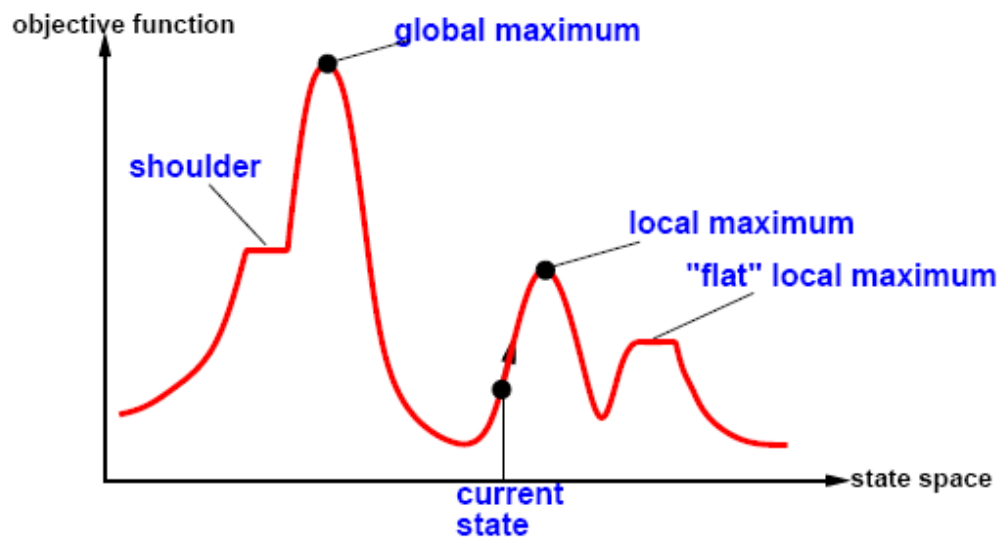


Figure 10 A one-dimensional state space landscape in which elevation corresponds to the value of the heuristic cost function or objective function. Hill-climbing search modifies the current state to try to improve it, as shown by the arrow.

2.3.4. A* Search

A* search evaluates nodes by combining $g(n)$, the cost to reach the current node , and $h(n)$, the estimated cost to get from the current node to the goal:

$$f(n) = g(n) + h(n). [14]$$

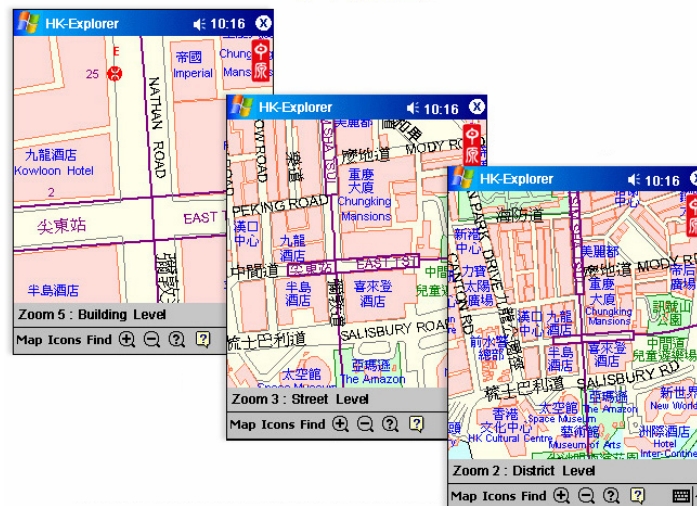
It then visits the node with the smallest evaluated value. In such a way, it can ensure the completeness which it guarantees to find a solution if one exists. Furthermore, A* search can obtain a path which is optimal providing that $h(n)$ is an admissible heuristic, i.e., it never overestimates the cost to reach the goal. It is important since when A* terminates, it by definition has found a path whose actual cost is lower than the estimated cost of any other path through any open node. On the other hand, due to the optimization of those estimates, A* can safely ignore those nodes and ensure that it will not overlook the possibility of a lower-cost path. [15]

2.4. Current Status

There is currently some electronic map guides in the market and below are some of the most popular GIS applications on handheld devices.

2.4.1. HK Explorer

It is an electronic PDA map guide in Hong Kong developed by CentaSolution Limited with technical supports from Mappa Systems Ltd and Unifysoft Ltd. It made use of base map provided by Lands Department and comprehensive geo-coded databases from CentaMap which is a practical tool for PDA users to enrich their city walk and utilize the capability of PDA gadget [16].



Main features and functionalities of HKExplorer are as below.

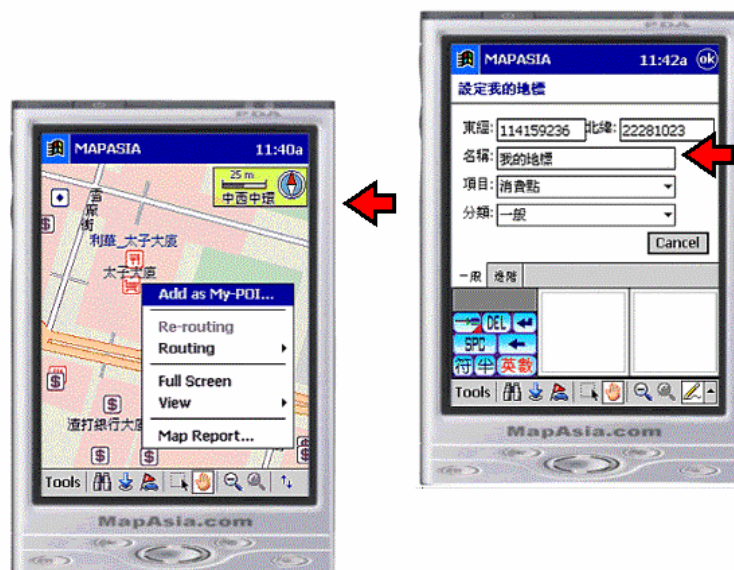
1. Six viewing levels of which close-up building/street locations and general view of the area can be shown
2. Detail transportation information with more than 1200 public bus route is provided
3. Map can be panned in all directions by drag-and-drop
4. Intelligent search is provided to find the location by building name, street, landmark, district, restaurant, entertainment facility or motorist information.
5. Information retrieval is easy by clicking icons on a thematic map
6. Note can be taken on a position of the map

Weaknesses

1. GPS is not support and thus no location information can be given
2. Memory is required for program and data storage
3. Dynamic update of program or information is not possible
4. No transportation methods is provided to show how the user can go to the destination

2.4.2. MapKing

It is the first pan-region multilingual mobile mapping system in Asia managed by MapAsia.com Limited with input from leading Asian partners. It offers maps in English, traditional Chinese and Simplified Chinese covered a majority of countries in Asia. It is a great tool for trip planning and to explore different countries [17].



Main features and functionalities

1. Multiple zooming levels of which close-up building/street locations and general view of the area can be shown
2. Different search methods include the searching by index (by alphanumerical order), keyword, point of interest, distance range, centre location, coordinates and group category.
3. 2D/3D navigation

4. GPS is supported for real-time tracking
5. Route planning function is provided for calculating the driving route from a start location to the destination
6. Point of interest location function is provided such that user can manage his/her own favorite list of place
7. Multiple platforms include PC, Pocket PC and Smartphone are supported

Weaknesses

1. Memory is required for program and data storage
2. Dynamic update of program or information is not possible
3. No transportation methods is provided to show how the user can go to the destination

In general, the mobile mapping systems for handheld devices are user-friendly with basic functionalities in location query and map reading. As location based services becomes popular, location tracking by GPS is tried to be supported. However, it can only be applicable at outdoor and it would be impossible to be used in dense urban areas, like HK for tracking users' location. In addition, there is no guide provided to teach users to go from one point to the destination. Although routing function may be provided, the usefulness is constrained by cars navigation.

Traditional PDA used as an electronic organizer no longer satisfies with the users' needs. With importing different software, it becomes more powerful. However, storing the program requires memory and a more crucial factor is that the update of program or data is difficult. Although the software update can be down through the Internet, un-installation and re-installation is a troublesome to users.

All in all, technology of GIS and location tracking on handheld devices has been getting started and it is believed that it will be widely applied in the near future. On the other hand, since information technology is under rapid growth in this era,

the traditional thick-client software may not be sufficient to suit users' need since the update is not convenient enough. Thus, to be more dynamic, thin-client software would be more appropriate and suitable to meet the developmental trend for handheld devices.

3. Methodology and Resources

3.1.1. Location Tracking

Though GPS can provide a high accuracy in positioning, it cannot be used in urban areas. According to Figure 7 about the comparison among different mechanisms for location tracking, MLES would then be the best solution. However, this new technology is still under development and requires testing. Hence, SIM tracking mechanism provided by SUNDAY LBS is used in the project (Figure 11 [18]).

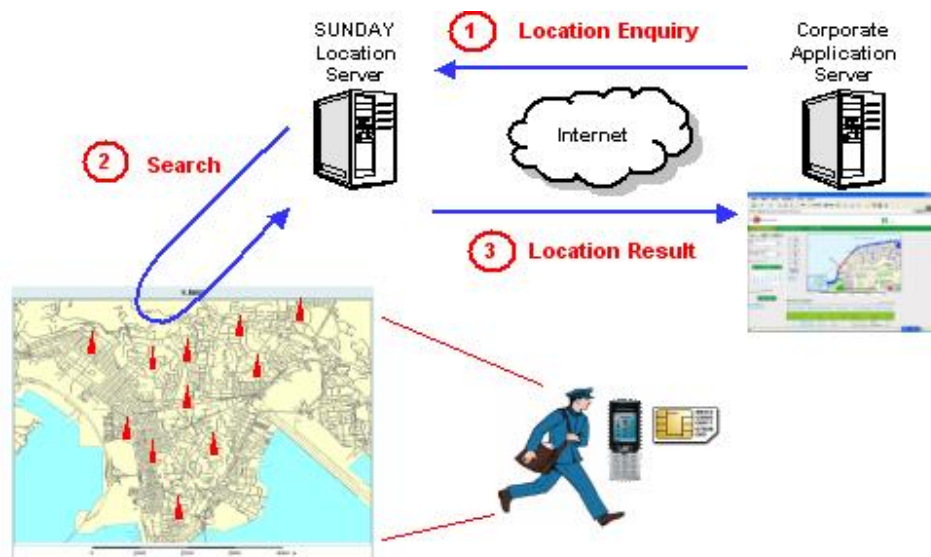


Figure 11 Solution diagram of SUNDAY LBS

The following methods provided by SUNDAY LBS web services [19] will be used.

getLocationXY

Functionality	To retrieve the latitude and longitude of a mobile user using SMPP protocol
Input (Figure 12)	- SMPP System ID - SMPP Password

	- Mobile Phone Number
Output (Figure 13)	XML document (Figure 14) consists of <ul style="list-style-type: none"> - Mobile Phone Number - Latitude - Longitude - Cell Identity Accuracy Index - Network Measurement Result Accuracy Index - Date and time - Timestamp

Parameter	Type	Limitations
SMPP System ID	xsd:string	
SMPP Password	xsd:string	
Mobile Phone Number	xsd:string	No need to add the '852' country code. Must between 8 – 11 characters.

Figure 12 Parameters required for the input of getLocationXY

Node	Description
mobile	The mobile number provided from request with country code '852' added to the front.
latitude	Latitude in HK80 format.
longitude	Latitude in HK80 format.
CAI	Cell Identity Accuracy Index, e.g., if CAI = 120, it means that by using Cell Identity to resolve location, the result may deviated from the actual location by 120m.
NAI	Network Measurement Result Accuracy Index, e.g., if NAI = 50, it means that by using Network Measurement Result to resolve location, the result may deviated from the actual location by 50m.
datetime	HK time, in format YYYYMMDDHHMMSS
timestamp	GMT time, in date/time format defined in RFC 1123, e.g., Sun, 06 Nov 1994 08:49:37 GMT.

Figure 6 obtained from getLocationXY

```

<?xml version="1.0" standalone="yes"?>
<lbs status="0">
  <location>
    <mobile>85262561270</mobile>
    <latitude>835960</latitude>
    <longitude>821852</longitude>
    <CAI>131</CAI>
    <NAI>111</NAI>
    <datetime>20050120112345</datetime>
    <timestamp>Thu, 20 Jan 2005 03:23:45 GMT</timestamp>
  </location>
</lbs>

```

Figure 14 XML sample output from getLocationXY

<lbs> node has an attribute called status. Status = 0 indicates a successful execution through SMPP whilst other values (not equal 0) indicate errors occurrence. The application calling this method would examine the <location> node to get the location information.

getGeoInfo

Functionality	To retrieve the geographical information from SUNDAY LBS using SMPP according to the latitude and longitude provided, which may be retrieved using getLocationXY
Input (Figure 15)	<ul style="list-style-type: none"> - SMPP System ID - SMPP Password - Latitude - Longitude
Output (Figure 16)	XML document (Figure 17) consists of <ul style="list-style-type: none"> - District - Sub-district - Street name - Building name in both English and BIG-5 Chinese version

Parameter	Type	Limitations
SMPP System ID	xsd:string	
SMPP Password	xsd:string	
Latitude	xsd:unsignedLong	HK80 format
Longitude	xsd:unsignedLong	HK80 format

Figure 15 Parameters required for the input of getGeoInfo

Node	Description	Size (English)	Size (Chinese)
district	18 district name.	100	100
subdistrict	170 district name.	100	200
street	Street name.	100	200
building	Building name.	215	430

Figure 16 obtained from getGeoInfo

```
<?xml version="1.0" standalone="yes"?>
<lbs status="0">
  <geoinfo language="E">
    <district>KOWLOON CITY</district>
    <subdistrict>SHEK KIP MEI</subdistrict>
    <street>TO YUEN STREET</street>
    <building>TO YUEN STREET 33,Heung To Middle School</building>
  </geoinfo>
  <geoinfo language="C">
    <district>九龍城</district>
    <subdistrict>石硤尾</subdistrict>
    <street>桃源街</street>
    <building>桃源街 33, 香島中學</building>
  </geoinfo>
</lbs>
```

Figure 17 XML sample output from getLocationXY

The 'status' attribute in the <lbs> node has the same meaning as that in the XML document returned by getLocationXY. <geoinfo> node contains the geographical information returned by the SUNDAY LBS. The 'language' attribute indicates the language of the information: a value 'E' indicates that the geographical information is in English while a value 'C' indicates that it is in BIG-5 Chinese.

getMapFromCentamap

Functionality	To retrieve the map in GIF format from Centamap
Input (Figure 18)	- Latitude - Longitude - Zoom Level
Output	GIF image with dimension of 800 x 600 pixels

Parameter	Type	Limitations
Latitude	Number	
Longitude	Number	
Zoom Level	Number	Must between 1 – 7, while 1 represent the highest zoom level.

Figure 18 Parameters required for the input of getMapFromCentamap

3.1.2. Maps manipulation and Coordinates Collection

There are different ways to manipulate maps. The most common method is to apply the maps from Lands Department and draw the required maps layer by layer. The coordinates in HK Grid 80 format can then be mapped with different areas of the map. On the other hand, such method is not being used in this project.

Since SUNDAYLBS can return a specific map from centamap after the detection of the current location, the returned map can be applied directly. It not only shows the current location at the center point, but also it can be specified with different zoom levels. With the direct use of the centamap, it is much convenient. However, verification of the returned map is required.

To collect the coordinates with the address information, my first attempt is to collect all the coordinates on the required map. However, the collected address information is duplicated for different coordinates. This is because a building is represented as an area on a map and it covers an area of coordinates. It would

cause problems in route finding since there is no unique coordinates to represent a building and the entrance of each building may be required to define manually. Therefore, sampling method is used for collecting the coordinates.

First of all, sample points are taken from a sample map. The samples are then mapped with HK Grid 80 coordinates. With the coordinates, address information is retrieved via SUNDAY LBS [19]. This method is feasible because it is not necessary to consider all the coordinates on the map for route finding purpose and the mapping of coordinates to the map on the PDA-phone need not be very accurate.

The following map (Figure 19) is used as an example in this project. The number shown in each node is the coordinate ID. It is a unique key of coordinates. Each coordinate ID consists of a standard coordinates in HK Grid 80 format as well as its corresponding address. The address information is retrieved from getGeoInfo of SUNDAY LBS web services [19].

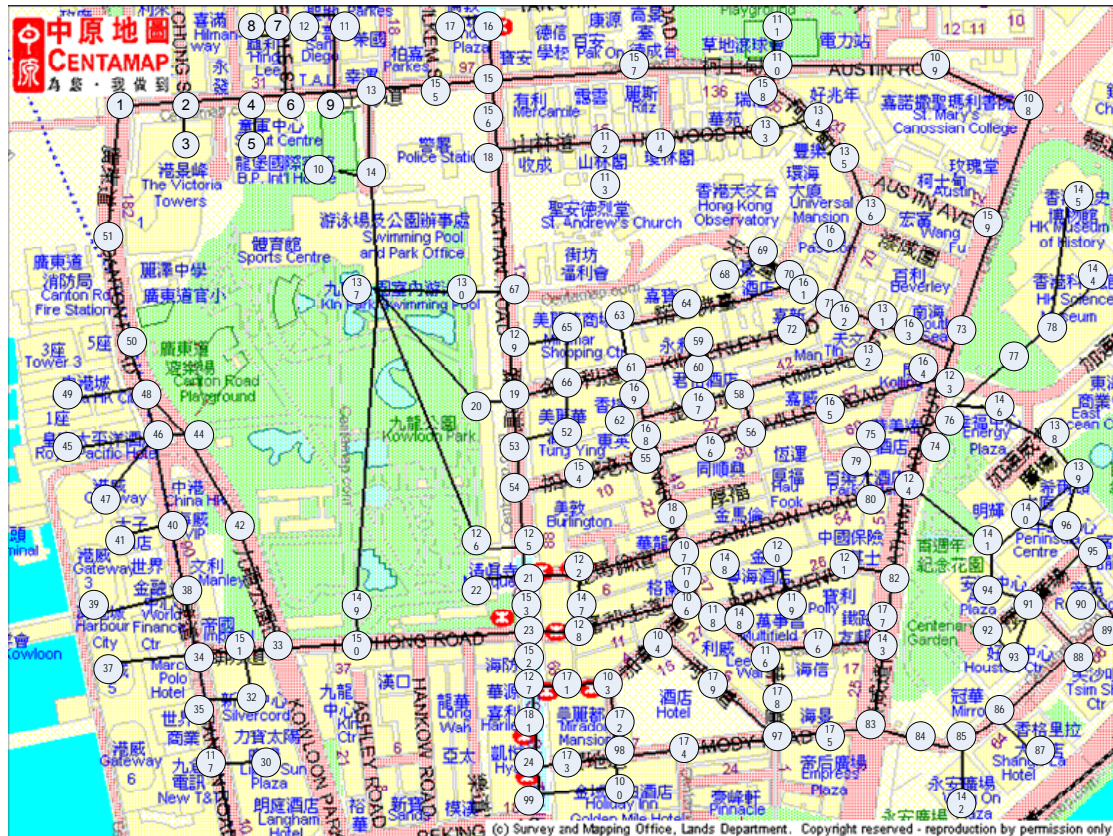


Figure 19 Sample map with coordinates taken and with the linkage information

3.1.3. Coordinates System

Drawing of a point or a line on maps requires the coordinates in pixel format. Thus, the coordinates in the standard HK Grid 80 format have to be converted into pixel format for representation on maps. The returned map from centamap is of size 800X600 pixels and the current coordinate is specified as the centre point, i.e., (400, 300) in the pixel format. With such information, all coordinates given in HK Grid 80 on the map can be converted into its corresponding pixel format.

HK Grid 80 to Pixel Conversion for Zoom level = 4 (Figure 20)

$$\text{FactorX} = 800 / (836380 - 835246)$$

$$\text{FactorY} = 600 / (818334 - 817484)$$

With the centre coordinates of the map with pixel (400,300), any HKGrid 80 coordinates on the map can be converted into pixel form (PtX, PtY)

$$\text{PtX} = 400 + (\text{coordinateX} - \text{centreCoordinateX}) * \text{FactorX}$$

$$\text{PtY} = 300 - (\text{coordinateY} - \text{centreCoordinateY}) * \text{FactorY}$$



Figure 20 Sample map get from centamap with zoom level = 4

HK Grid 80 to Pixel Conversion for Zoom level = 3 (Figure 21)

$$\text{FactorX} = 800 / (836203 - 835423)$$

$$\text{FactorY} = 600 / (818202 - 817616)$$

With the centre coordinates of the map with pixel (400,300), any HKGrid 80 coordinates on the map can be converted into pixel form (PtX, PtY)

$$\text{PtX} = 400 + (\text{coordinateX} - \text{centreCoordinateX}) * \text{FactorX}$$

$$\text{PtY} = 300 - (\text{coordinateY} - \text{centreCoordinateY}) * \text{FactorY}$$



Figure 21 Sample map get from centamap with zoom level = 3

3.1.4. Route Finding

As mentioned before, there are several methods in finding a path. However, uninformed search strategy such as breadth first search or depth first search would not be suitable for this project. Although breadth first search can ensure the optimality, it requires that the edges between nodes of the same weight. Since the weight of the edges (here means the distance to be traveled) between nodes are different, the optimality of breadth first search can only ensure the path with the least number of nodes. Nonetheless, the path with the least number of nodes is neither the shortest nor the optimal path. Therefore, breadth first search is not applicable in this project. Depth first search is also not applicable since it may only find a path reaches the goal state yet it cannot ensure it is the optimal one.

Hill-climbing search and A* search strategies are attempted in the project. Evaluate function $f(n) = h(n)$ is used in hill-climbing search with consideration of the estimated distance from the current location to the target location. A* search would consider the evaluate function $f(n) = h(n) + g(n)$ which take both the estimated distance and the exact traveled distance from the start point to the current location into account. The estimated distance is the displacement from the current location to the destination while the exact traveled distance is the total distance from the start location to the current location with the consideration of all chosen coordinates. The calculation of distance, D between two coordinates, (Coordinate X1, Coordinate Y1) and (CoordinateX2, CoordinateY2) is shown as follows,

$$D = \sqrt{[(\text{CoordinateX1} - \text{CoordinateX2})^2 + (\text{CoordinateY1} - \text{CoordinateY2})^2]}$$

Since an optimal path is not necessarily be the shortest path, the more famous and boarder roads instead of the unknown or narrow one should be chosen for the route. Therefore, a constraint factor is used to indicate the types of the coordinates and is taken into account for the distance estimation in path finding.

By doing so, the optimal route found would include the more comfortable and easier walking roads.

3.1.5. Zoom In/Out

Since the maps are used to be viewed on PDA-phones, the usefulness of the maps to users has to be carefully considered. Although different zoom levels can be specified when getting the map from centamap via SUNDAY LBS web service [19], two zoom levels of maps are provided in this project (Figure 23). First of all, there exist some distortions on the maps beyond the zoom level = 4 such that the building names cannot exactly match with the locations. It would cause misunderstanding to users and thus, maps with zoom level = 4 are chosen to be applied as the most zoomed out version.

It is unwise to take times to load a useless map. Excessive zoomed-in maps are not very useful with showing only large scale of the building while the optimal route calculated cannot be shown. The maps of zoom level = 2 can show only few roads and the viewing of the large scale buildings requires scrolling on the PDA-phones which is neither convenient nor essential. Zoom level = 3 is chosen be the zoomed-in version of the map. In case, users would like to know more details about the current location and how they should walk in order to go to the destination, they can simply switch to the photo display which would be more helpful.

3.1.6. Photo Display

To be more informative, photo display is suggested for users to have more information about the route to go to the destination. Photos are originally designed to be taken for each coordinates sample, i.e., one photo for one coordinates sample. However, it may not be very useful to show the users with the photo sequences of the proposed route. Moreover, loading a sequence of photos on PDA-phones would be time-consuming. Thus, photos are suggested to show users with the direction that they are going to walk from the current location

to the next location. To do this, two photos for every linkage of the coordinates samples are taken which include the forward and backward directions. The quality and the resolution of the photos are kept low due to the limited resources of PDA-phones. Here are some examples



3.1.7. Audio Instruction

After the optimal route has been calculated, the information can be used to formulate a text instruction to teach user how to go to the desired location. SpeechLib in Microsoft Speech SDK 5.1 [20] is then used to convert the text instruction into speech.

As known that midi file should be the best choice to be embedded in the web background for handheld devices. Nevertheless, according to Designing Web Sites for the Internet Explorer for Pocket PC from MSDN [21], only wav files are supported for the web site background sound in PDA-phones and they usually take up lots of space. Therefore, it is important to keep the file size be small with such limitation. To achieve the goal, the instruction in text has to first be kept in short and concise before the conversion into speech.

First of all, all the address information of the optimal route would be gathered for the creation of the text instruction. The creation of the text instruction considers 3 coordinates information at a time and the logic is shown in Figure 22. Since the text instruction has to be kept in short, instructions such as “Turn left/right to ...”, “Walk along...” or “Walk into...” would be used and there is no duplication of any single instruction.

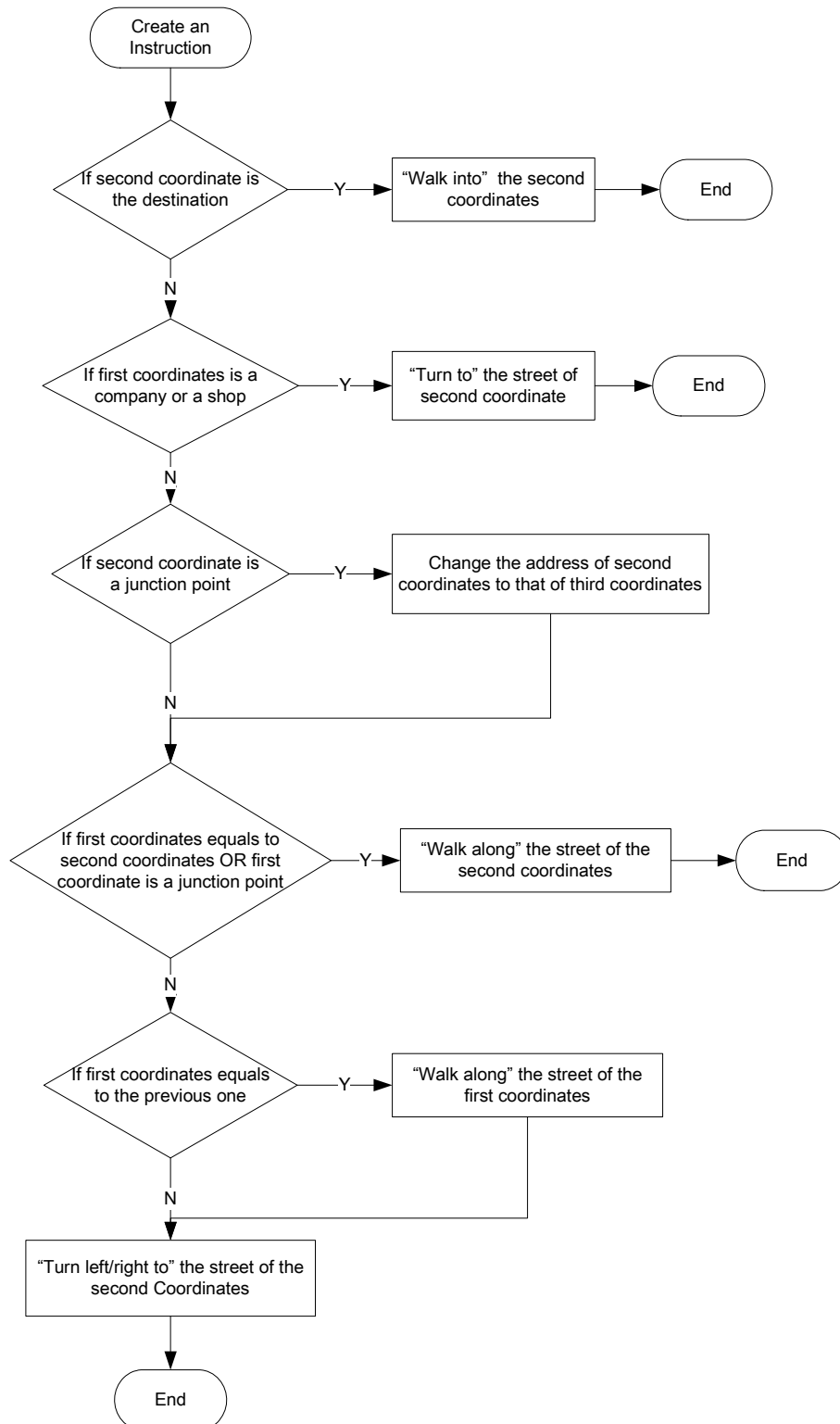
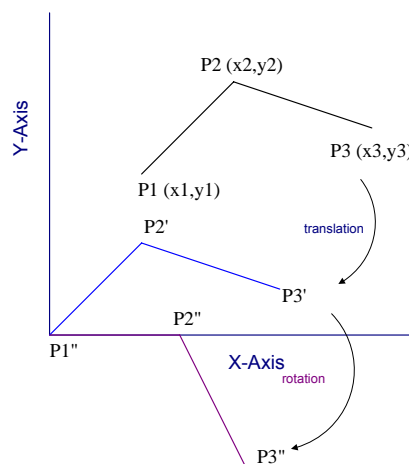


Figure 22 Flow chart of the function for creating single text instruction with considering three coordinates (the first, second and third which is in the same sequence of the route)

There are several methods for determining a point is on the left or right direction of 2 points. The information is useful for noticing users with the direction that they should walk to. Obviously, consideration of different comparison cases for the coordinates is a method, yet there are some mathematical methods which are more accurate can be applied.

Matrix Transformation



Step 1

$P1, P2, P3 \xrightarrow{\text{Translate}} P1', P2', P3'$ with $P1'$ at the origin

Step 2

$P1', P2', P3' \xrightarrow{\text{Rotate}} P1'', P2'', P3''$ with $P2''$ lies on x-axis

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad [22]$$

Step 3

Case1: $(x\text{-coordinate of } P2'') * (y\text{-coordinate of } P3'') < 0$

$\Rightarrow P1, P2, P3$ are collinear

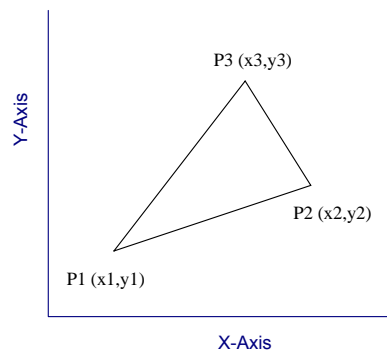
Case2: (x-coordinate of P2'') * (y-coordinate of P3'') < 0

⇒ P3 lies on the left plane of P1P2

Case3: (x-coordinate of P2'') * (y-coordinate of P3'') > 0

⇒ P3 lies on the right plane of P1P2

Triangle Geometry



$$\text{Area of triangle } \Delta P_1P_2P_3 = \frac{1}{2} * \begin{vmatrix} x_1 & y_1 \\ x_2 & y_2 \\ x_3 & y_3 \\ x_1 & y_1 \end{vmatrix} \quad [23]$$

$$= \frac{1}{2} * (x_1*y_2 + x_2*y_3 + x_3*y_1 - x_2*y_1 - x_3*y_2 - x_1*y_3)$$

Case1: Area = 0

⇒ P1, P2, P3 are collinear

Case 2: Area > 0

P1, P2, P3 are arranged in anticlockwise direction

⇒ P3 lies on the left plane of P1P2

Case3: Area < 0

P1, P2, P3 are arranged in clockwise direction

⇒ P3 lies on the right plane of P1P2

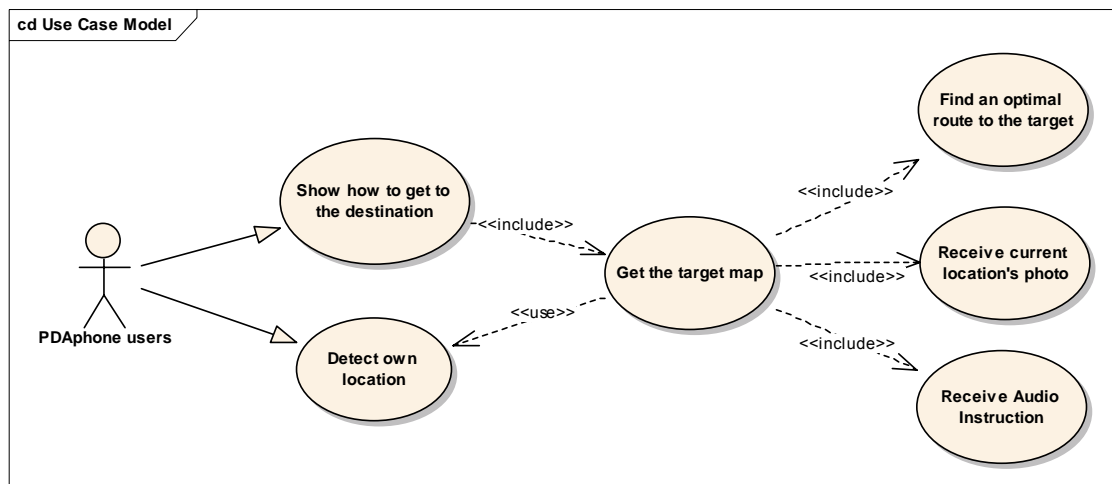
Since it is easier to do the calculation for the triangle geometry method, it is applied in the project. However, coordinates is of HK Grid 80 format which is of a large number, multiplication may cause overflow. To prevent overflow and faster the calculation process, the coordinates are divided by a constant before the calculation.

4. Design and Analysis

4.1. Overview

In general, this project will focus on server-side PC processing and client-side Pocket-PC web-based application. On the server-side, data processing and information retrieval will be done. Only the required information will be sent to client's device via http.

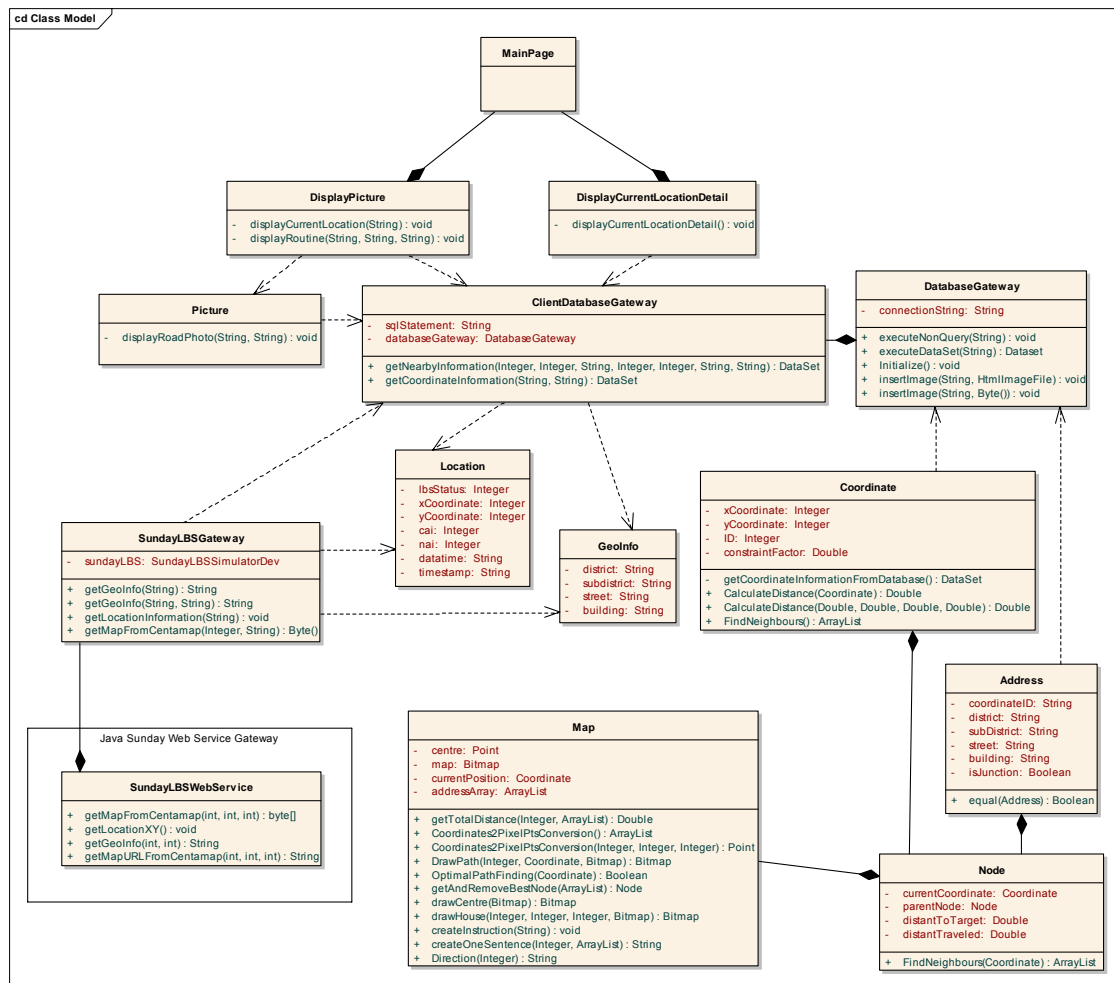
4.2. Use Case Diagram



PDA-phone user has the main functions as follows,

- Detection of user's current location
- Get an informative map to show user how to go from the current location to the destination. (The destination is obtained as Coordinate ID from the location based enquiry system which is done by another student [24])

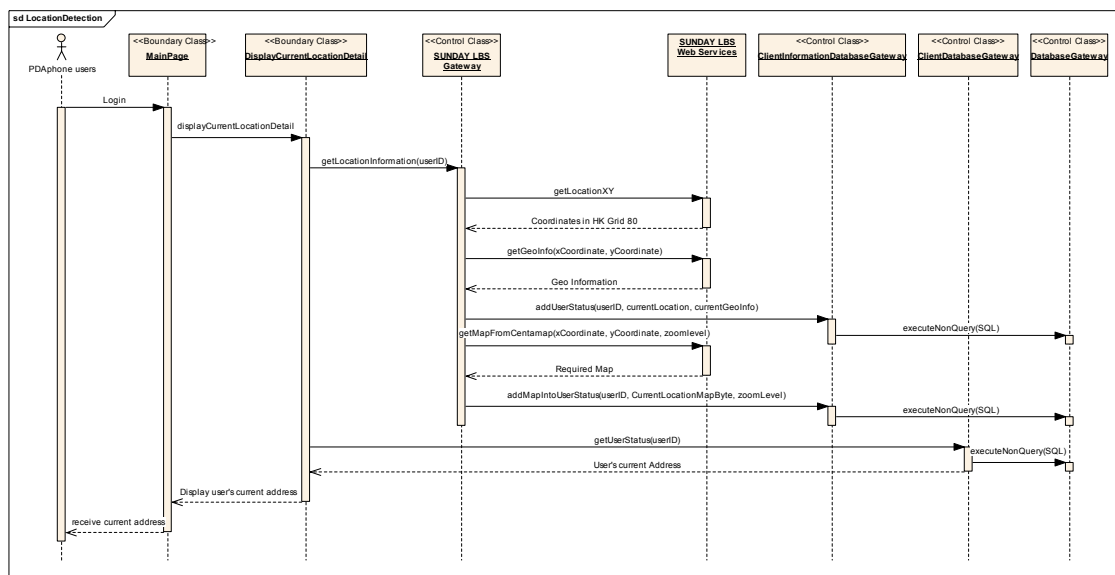
4.3. Class Diagram



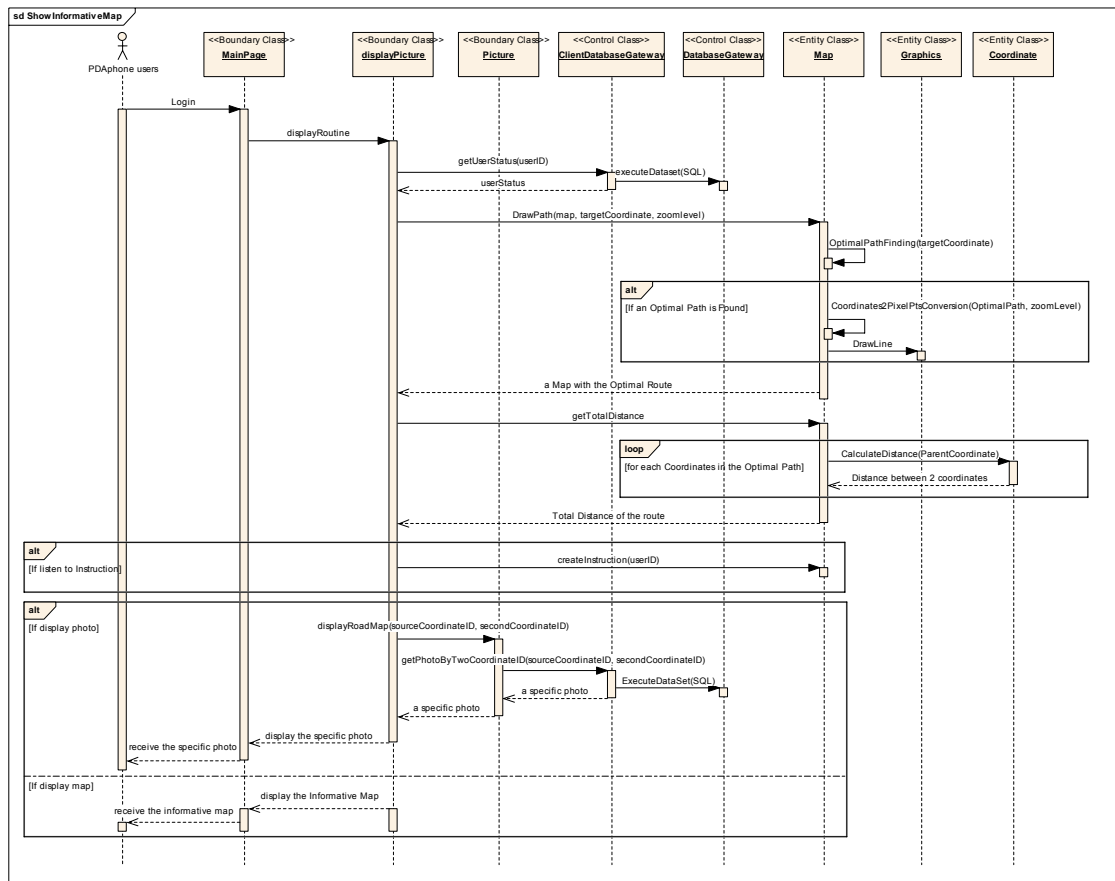
Classes MainPage, DisplayPicture, Picture and DisplayCurrentLocationDetails are the boundary classes correspond to the pages viewed by users on the PDA phones. Classes ClientDatabaseGateway and DatabaseGateway are the control classes for database access. Class SUNDAYLBSGateway is a special class for the connection to the Java SUNDAYLBSWebService. Both the classes Location and GeoInfo are responsible for the interpretation of the XML document received from SUNDAY LBS web services. The remaining classes are the entity classes for data processing.

4.4. Sequence Diagram

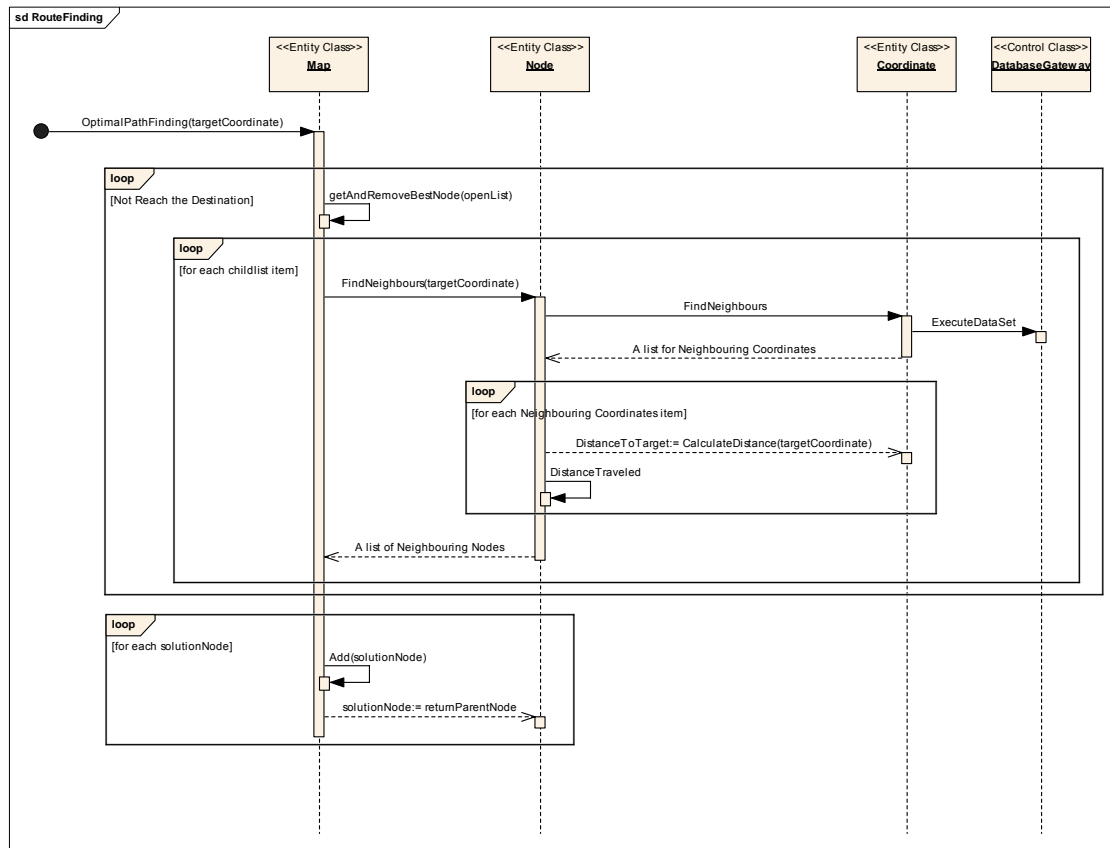
The sequence diagram “Location Detection” shows the classes interactions in the detection of user’s current location. It involves the SUNDAY LBS web services call to access the location information. It is my original design for location detection. However, since my program is integrated with another student [24] for obtaining destination information, the “Location Detection” function is enhanced by him to provide validation checking of the received location information and re-detection of the current location.



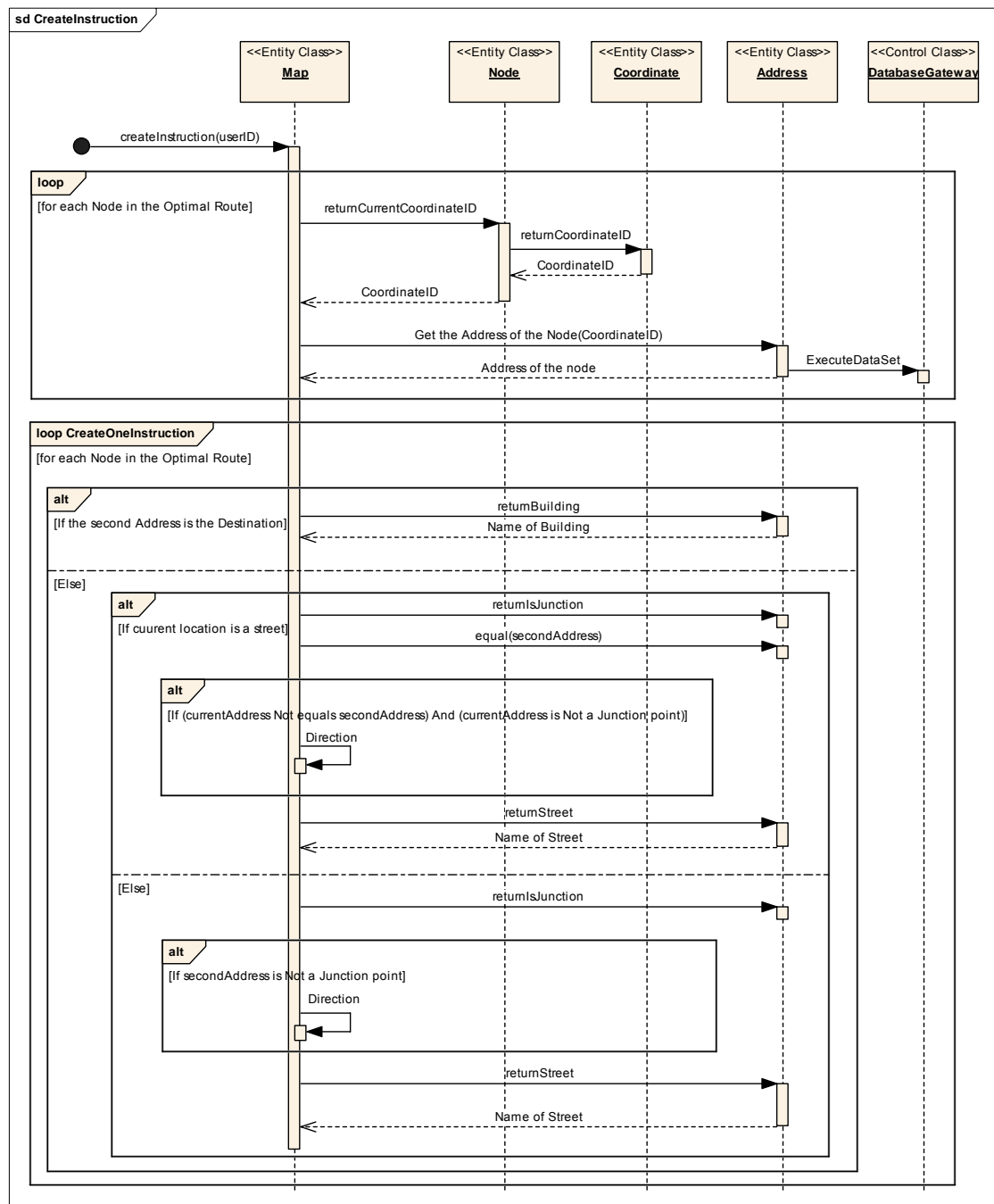
The sequence diagram “Show Informative Map” shows the classes interactions in the display of an informative map. It may include a map with an optimal route together with or without audio instruction or it may just display the requested photo to users.



The sequence diagram “Route Finding” shows the classes interaction in the route finding process. The process is triggered by users through the display of an informative map.



The sequence diagram “Create Instruction” shows the classes interaction when an audio instruction is required by users. “CreateOneInstruction” shown as the name of a loop in the diagram is in fact a function in class Map but it is used as a loop name for simplicity. It is a function considers 3 coordinates at a time to produce one instruction and the detailed logic is shown as flow chart in Figure 22.



4.5. Database Design

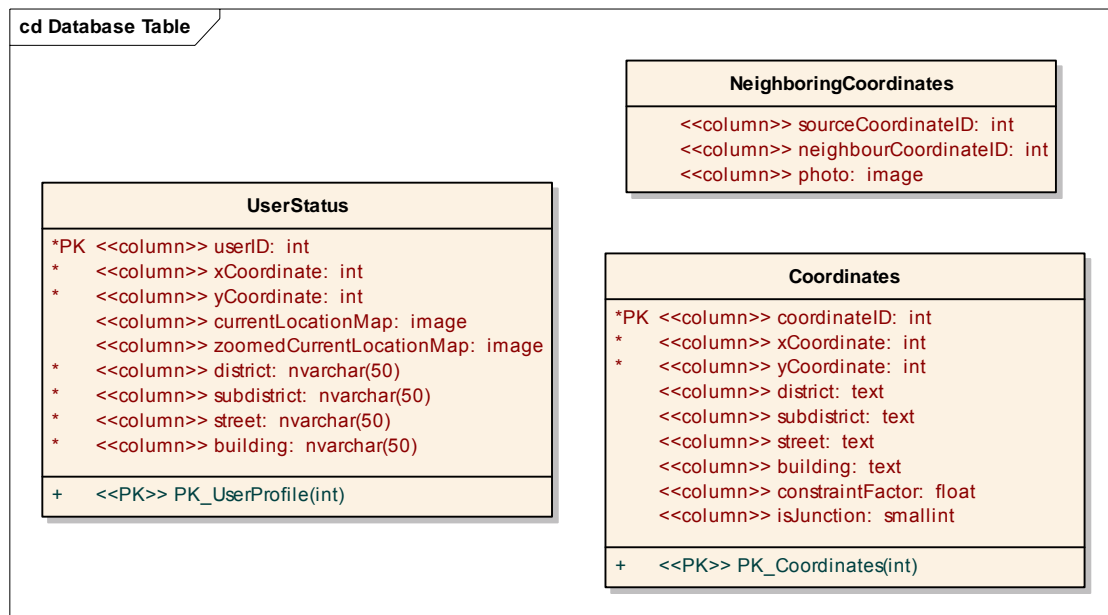


Table User Status

It is used to store the information of PDA-phones users. The X-/Y-coordinates are of standard HK Grid 80 format which is the current location detected via SUNDAY LBS [19]. The currentLocationMap and zoomedCurrentLocationMap are the map retrieved via SUNDAY LBS showing the current location as the centre point. The district, subdistrict, street and building are the address information corresponding to the current location detected.

- userID: a unique key to identify the PDA-phones users
- xCoordinate: x-coordinate of the user's current location
- yCoordinate: y-coordinate of the user's current location
- currentLocationMap: map from centamap with zoom level 4 showing user's current locaiton
- zoomedCurrentLocationMap: map from centamap with zoom level 3 showing user's current locaiton
- district: the district of the user's current coordinates
- subDistrict: the sub-district of the user's current coordinates

- street: the street name of the user's current coordinates
- building: the building name of the user's current coordinates

Table Coordinates

It is used to store all the coordinates' information of locations in HK. The X-/Y-coordinates are of standard HK Grid 80 format. The address information includes district, sub-district, street and building is collected via SUNDAY LBS web services [19].

- coordinateID: a unique key to identify the coordinates
- xCoordinate: x-coordinate in HK Grid 80 format
- yCoordinate: y-coordinate in HK Grid 80 format
- district: the district of the coordinates
- subDistrict: the sub-district of the coordinates
- street: the street name of the coordinates
- building: the building name of the coordinates
- constraintFactor: a factor to indicate the type of the coordinates, e.g. it would be a small value if the road is flat and well-known and it would be large if it is an unpopular
- isJunction: an indicator to specify if the coordinates is a junction point

Table NeighbouringCoordinates

It is used to store the neighboring coordinates which are reachable by one coordinates.

- sourceCoordinateID: identity of coordinates
- neighborCoordinateID: identity of the neighboring coordinates to be reachable
- photo: an image to show the direction from the source location to the neighbor location

5. Evaluation

After the application has been implemented, it is evaluated according to different areas which are discussed below.

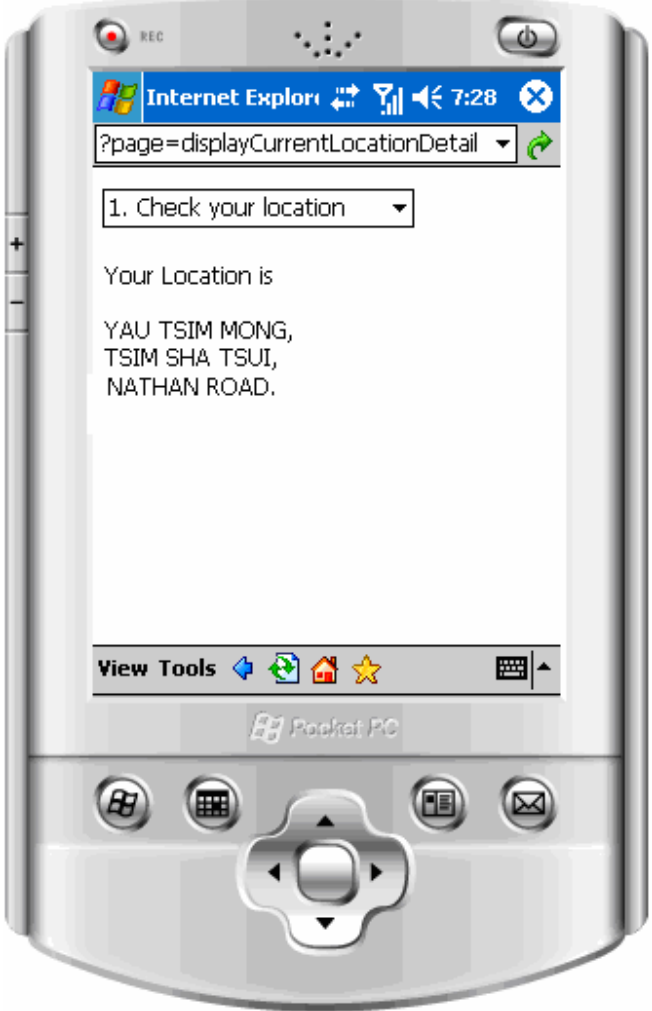
5.1. Interface Design

Since the application requires no users input except the main page for functions selection and all the processes are done on the server side, user interface is only required for displaying the current location information, the informative map and the photo (Figure 23).

Due to the small screen size of the PDA-phones, there are 2 views, default view and desktop view provided for users' viewing webpage on the devices. According to the default view of webpage on the PDA-phones, the oversized elements on the webpage is condensed to suit the screen display such that no horizontal scrolling is required. On the other hand, the desktop view shows the original webpage size as the desktop.

The maps used in the project are of size 800X600 pixels (retrieved from centamap) which are over the size of the screen. However, the condensation of the map into a small one in default view leads to all the details on the map cannot be viewed by users. It should be viewed as desktop view in order to let users understand clearly about the route details. Nonetheless, the display of the photo needs not be that clear or accurate which default view should be used.

Concerning the audio instruction, it is embedded as background sound on webpage. Since the time taken for loading a page with sound is long in PDA phones, it is separated into a page such that the informative map display can be with or without the audio instruction.

Description	Screen Capture
<p>Upon the location checking requested by the user, his/her current address information is displayed.</p>	

The webpage showing an informative map is displayed as desktop view on the PDA phones such that the map is of size 800X600 without condensation.



With scrolling, the user can read the optimal route on the map. (the centre of the map is the user's current location)



Upon the user requests “Zoom In”, a zoomed in version of the map is displayed.

Upon the user request “Listen to the Instruction”, instruction of “Walk along Nathan Road, Turn right to Nathan Road 105, Kowloon Mosque and Islamic Centre” will be spoken out.



If the user requests “Show Photo”, the photo is displayed as default view on the PDA phones such that the photo is condensed to fit the screen size and no horizontal scrolling is required.



Figure 23 User Interface samples on Pocket PC

5.2. Performance

The performance of the location detection and the audio instruction are evaluated. Figure 24 shows that the data obtained from the location detection testing. It reveals that the accuracy in location detection is affected by different location. The denser area would be returned with a more accurate address and some of the buildings may be returned only with its road name. For tourist guiding purpose, the result can be concluded to be acceptable since the detected address is at most nearby their actual location. Moreover, since tourists are used to tour around in some popular areas in HK, the location detection accuracy would not be too worse.

Another issue is the waiting time for user to obtain the requested information. The average time for obtaining the address information is 1 min 15 sec while the time for obtaining an informative map with audio instruction required 2 minutes to 10 minutes depending on the wav file size. It may not be acceptable for users to wait about 10 minutes to obtain an audio instruction but the bottleneck is due to the GPRS Internet connection. With the rapid development in telecommunication, the speed of the Internet connection may be improved in the near future. For instance, if 3G technology could be applied, the performance would greatly be improved.

Address of Testing Location	CoordinateID	Address Detected via SUNDAY LBS services	Time required to obtain the address information
KIMBERLEY ROAD, NATHAN ROAD 132, Miramer Shopping Centre	65	KIMBERLEY ROAD, NATHAN ROAD 132, Miramer Shopping Centre	1:04
NATHAN ROAD , NATHAN ROAD 105,Kowloon Mosque and Islamic Centre	22	NATHAN ROAD , NATHAN ROAD 105,Kowloon Mosque and Islamic Centre	1:12
NATHAN ROAD	67	NATHAN ROAD	0:58
GRANVILLE ROAD	166	GRANVILLE ROAD	1:15
CANTON ROAD , CANTON ROAD 18, Harbour City	39	CANTON ROAD	1:14
KNUTSFORD TERRACE, OBSERVATORY ROAD 11-13,	68	KNUTSFORD TERRACE	1:32

Stanford Hillview Hotel			
MODY ROAD , NATHAN ROAD 50, Holiday Inn Golden Mile Hotel	100	NATHAN ROAD	1:09
CHATHAM ROAD SOUTH, Hong Kong Museum of History	144	GRANVILLE ROAD, Hong Kong Science Museum	1:36
CANTON ROAD, Lippo Sun Plaza	30	KOWLOON PARK DRIVE, CANTON ROAD 30, Silvercord	1:17
GRANVILLE ROAD	146	MODY ROAD	1:22

Figure 24 Data obtained in the testing of Location Detection. The testing was carried out on 10th March 06 from 9:30am to 12:30pm in Tsim Sha Tsui. Some invalid samples including the inability of location detection or the return of NULL address information are not shown in the table.

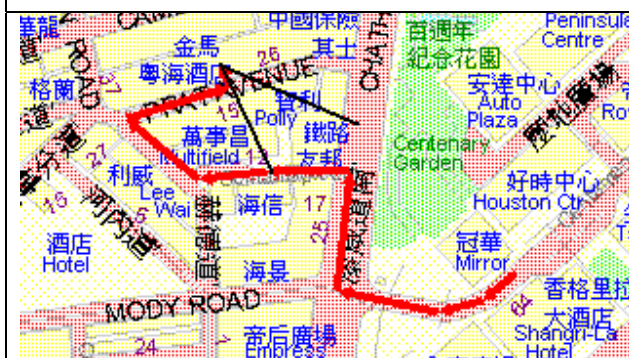
5.3. Optimality

The evaluation of optimality discusses the route found according to the user's current location and the selected destination. Two strategies, hill-climbing search and A* search have been attempted for route finding. Although A* search should take a longer time in computerization than hill-climbing, there is not much different in the testing. It may due to the small size of database for coordinates while the bottleneck of the application is due to the GPRS connection. As A* search strategy give a more satisfying route (Figure 25), it is used in the project.

Hill-climbing search strategy	A* search strategy
 <p>Since the estimated distance from the point at the Kimberley Road is shorter than that from the Observatory Road, it walks along Kimberley road which the resulted path is not optimal.</p>  <p>Since the estimated distance from the point at the Kowloon park is shorter than that from the Nathan Road, it enters the Kowloon Park instead of walking along the Nathan Road.</p>	 



Since the estimated distance from the point in front of the Mosque is shorter than that from the junction of Nathan Road and Haphong Road, it enters the Kowloon Park instead of walking through the Haphong Road.



Since the estimated distance from the point in the Hart Avenue is shorter than that from the Nathan Road, it walks through the Hart Avenue instead of walking through the Nathan Road.



Figure 25 Comparison between the route found by hill-climbing search and A* search strategies. For simplicity, parts of the maps are shown.

6. Challenges

There were some challenges faced and overcome in this project. They are discussed as follows.

6.1. SIM Tracking via SUNDAY LBS

Location detection in the project is relied on the SIM tracking mechanism provided by SUNDAY LBS web services. However, due to the high cost of the SUNDAY SIM Card, the card subscription period was limited. Although a simulator was implemented to return some specific information, most of the data collection could not be done with the simulator. At the beginning, functions were implemented based on my assumption of the behaviors of SUNDAY LBS and without real data testing.

When the SUNDAY SIM Card was ready, difficulties arose in the replacement of the simulator. First of all, my program was written in .Net whilst only Perl and Java are suggested to access the information [19]. Although different methods were attempted to call the web services via .Net, failure obtained. At last, additional Java application is used to access the information and it is published as web service and is being called by another program in .Net.

Furthermore, the information obtained from SUNDAY LBS services is not very accurate. The returned address information may be NULL and the returned map sometimes shows "Server is Busy". Such invalid information is used to be obtained in the evening which may due to the heavy traffic load at that time. It causes inconvenience during testing since the justification is required to determine if the problem is due to my program or if it is due to the abnormal behavior of the SUNDAY LBS services. Thanks to another student's validation checking on the information [24], the application can be more reliable such that location re-detection is triggered if necessary.

6.2. Data Collection

Data includes coordinates information and photos are required to be collected. Originally, it was planned to collect the coordinates information via the location detection of SUNDAY LBS, i.e., retrieve the location details with the use of SUNDAY LBS on a sample location. Nevertheless, it requires one to two minutes for detecting a location and some invalid information is obtained sometimes. It is not possible to collect hundreds of coordinates with such method. Then, collection of all coordinates on a map within a range via program is attempted. However, the problem of address information duplication arose. Thus, the coordinates sampling method is used. Since the sample coordinates are collected manually, it is time-consuming and it may contain human errors.

Since two photos have to be taken for each linkage of the coordinates, about 400 hundreds photos are required. The photos should show users with a clear direction that they should walk to hence they should be taken in day time. However, it used to be crowded in Tsim Sha Tsui and there are some difficulties in taking photos without much people surrounded. Moreover, it is required to mark each photo with the specific location information during photo taking which is quite inconvenient. Although it seems to be an easy task, it is quite time-consuming and it takes me about two weeks to collect the photos.

6.3. Audio Instruction Function Implementation

First of all, the instruction has first required to be created before the conversion into audio. The most difficult part in the instruction creation part is the determination of which direction should be taken at the junction point. At first, I attempt to use different cases consideration to determine the direction. However, there are some missing cases always. Then I tried to use mathematical method. I tried to apply trigonometry, i.e. sine, cosine and tangent properties to determine the direction but it was not successful. At last, I found two mathematical methods for direction determination and the simpler one is applied.

The next step is to convert the text instruction into audio. Although speech SDK5.0 is downloaded and ready to be used, there is lack of examples and documentation showing how to use. Much effort is used on trial and searching information.

With successful creation of the wav file, there is an issue discovered concerning the time waiting in obtaining an audio instruction by users. Midi file with a smaller file size is tried to replace the wav file however, it failed due to the pocket PC web design limitation [21]. So, the text instruction is created to be as short and concise as possible.

6.4. Pocket PC Web design

As mentioned, the client web design is used for displaying the map and the photo which the map should be displayed with desktop view while the photo should be with default view. The two views are defined by the PDA phones, so I tried to find if there is a method to trigger 2 different views behind the web. Nonetheless, it may in relation to the internal setting of Pocket PC and there seems no method to change the views behind the web. At last, I have applied the method which is to enlarge the web page size for informative map display by inserting dummy space characters [24].

7. Conclusion

All in all, my project is a pocket pc web application with all the data processing resided on the server side. It can be extended to provide more functionalities and it is now integrated with a location based enquiry system [24] to provide a useful electronic tourist guide on PDA-phones. With the application, users can choose a desired place to visit through location enquiry easily and get an informative map with an optimal route according to the current users location detected. They can also receive a photo and listen to the audio instruction. It can obviously facilitate people in map reading and location finding. It is a useful and user-friendly application for traveling, especially the tourists in Hong Kong.

The project introduces a creative and innovative idea to include multimedia components to pocket pc web application. Although there is a major long loading speed limitation, especially in the request of audio instruction, the bottleneck of the issue is due to the GPRS connection and it could be overcome with more advanced internet connection techniques. It can be used as a reference for those who are interested in multimedia and mobile computing.

For further development, it can be enhanced to include transportation information such that users can use the application to teach them to go everywhere in Hong Kong. On the other hand, the method of data collection should also be enhanced to be automatic. Apart from this, it can be enhanced to include video clips to show the users with the route.

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9. Appendix

9.1. Information about HK1980 Grid from Lands Dept

Geodetic Datum Transformation and Map Projection Parameter Set for
Computation between ITRF96 Geodetic Coordinates (or Cartesian Coordinates)
and HK1980 Grid Coordinates

Name of Parameter Set : 7P_ITRF96_HK80_V1.0 (Date : 1 March 2002)

Datum Transformation Parameters

	From : ITRF96 (at epoch 1998:121) To : HK80 Geodetic Datum	From : HK80 Geodetic Datum To : ITRF96 (at epoch 1998:121)
Shift along x-axis	162.619 m	-162.619 m
Shift along y-axis	276.961 m	-276.959 m
Shift along z-axis	161.763 m	-161.764 m
Rotation about x-axis	0.067741 "	-0.067753 "
Rotation about y-axis	-2.243649 "	2.243648 "
Rotation about z-axis	-1.158827 "	1.158828 "
Scale factor	1.094239 ppm	-1.094246 ppm

Datum Transformation Equation

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\text{new}} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} (1+S) & \theta_z & -\theta_y \\ -\theta_z & (1+S) & \theta_x \\ \theta_y & -\theta_x & (1+S) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\text{old}}$$

Where

ΔX : Shift along x-axis
 ΔY : Shift along y-axis
 ΔZ : Shift along z-axis
 θ_x : Rotation about x-axis
 θ_y : Rotation about y-axis
 θ_z : Rotation about z-axis
 S : Scale factor

$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\text{new}}$: 3D Cartesian Coordinate in New Geodetic Datum
 $\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\text{old}}$: 3D Cartesian Coordinate in Old Geodetic Datum

Map Projection Parameters of the Hong Kong 1980 Grid Coordinates

Geodetic Datum : Hong Kong 1980 Geodetic Datum	Coordinates of Map Projection Centre
Projection : Transverse Mercator	HK1980 Geodetic Coordinates :
Reference Ellipsoid : International 1910	Latitude : 22°18'43.68" N
Semi-Major axis (a) : 6378388m	Longitude : 114°10'42.80" E
Flattening (f) : 1 / 297	HK1980 Grid Coordinates :
Scale factor along central meridian : 1	Northing : 819 069.80 mN
	Easting : 836 694.05 mE

Numerical Data for Checking the Transformation Computation

Users can use the following data to verify the formulae and parameters used.

ITRF96 Geodetic Coordinates	HK1980 Grid Coordinates
Latitude : 22° 29' 8.777176" N	Northing : 838 477.970 m
Longitude : 114° 00' 1.079932" E	Easting : 818 097.267 m

Enquiry about the map projection and transformation parameters can be made to :

Geodetic Survey Section, Survey and Mapping Office, Lands Department, 24/F, 333 Java Road, North Point, Hong Kong

Tel : (852) 2231 3489
 Fax : (852) 2116 0778
 Email : SLSG@Landsd.gov.hk

9.2. Monthly Log

March 05 - August 05

Propose a final year project topic and gather some information about the topic

Review the background and literature

September 05

Meet with supervisor to discuss the project details

Draft the project plan and class design

Study how to apply SUNDAY LBS and speech SDK in the project

October 05

Refine the class design and database design

Write the project plan

Implement the SUNDAY LBS Simulator

Implement basic class structure and functions

Implement Location Detection function

November 05

Refine the class design and database design

Collect coordinates and address information to build the database

Implement the Route Finding function

Write the interim report

December 05

Replace the Simulator with the real SUNDAY LBS services

Integrate the location based enquiry program [24] to my program such that the destination can be obtained according to user's selection

Test the functions of Location Detection and Route Finding

January 06

Collect photos to build the database
Complete the map display with proposed route
Implement Zoom In/Out function
Implement Audio Instruction function

February 06

Test and refine the Audio Instruction function
Evaluate the optimality of different path finding strategies
Implement the photo display function

March 06

Integrate the location based enquiry program
Test the whole system
Test the route finding with simulating user's walking
Evaluate the performance system
Refine the user interface

April 06

Test the whole system
Write the final report
Prepare project presentation