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Mobile Guiding System for Parks Based on Highly Precision Electronic Map

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Abstract

Mobile Guiding System for Parks based on highly precision electronic map is of many researchers' concern, but commercial software cannot perform GPS positioning on custom-made maps for parks, and is not accurate enough to satisfy the requirements for drawing high precision electronic maps. This study uses trajectories measured by My Tracks software and a map edited in JOSM software to implement a custom-made electronic map. By processing GPS data gathered by smooth filtering, k-mean algorithm, mean filtering, and weighted-averaging (SKMW), it calibrated a custom-made map for a park mobile guiding system, based on a design from the gvSIG Mini open source project. Using Beijing JiuFeng National Forest Park as a case, this study developed LBS and SNS related service functions. The field test shows that the SKMW method can effectively improve the accuracy of a custom-made electronic map, and the practicality and expandability of a park mobile guiding system.

Keywords: *Park guiding system, electronic map, SKMW method, gvSIG Mini, GPS positioning, Android*

1. Introduction

A park guiding system is a self-help system for outdoor park users. It integrates electronic maps, GPS (Global Position System) and multimedia technology to provide users with scenic area tour guide, real-time positioning, information sharing and LBS (location based services) [1]. Currently, Personal Navigation Assistant (PNA) or Portable Navigation Device (PND) products in the Chinese and foreign markets mainly include the Touch China series of mobile apps (with individual titles like Forbidden City, Summer Palace, and Temple of Heaven), as well as other guiding software. Their GPS positioning function are all based on Google Map technology, but Google Map can neither provide detailed information inside parks nor do GPS positioning on custom-made maps of parks [2]. Obtaining highly precise GPS data is a precondition for making more accurate electronic map and for reducing display errors of user positioning on an electronic map. Outdoor GPS positioning on mobile phones now in the marketplace are accurate from within a few meters to dozens of meters[3], insufficient to satisfy the needs of drawing high precision electronic map. Many researchers therefore processed GPS measurements in real-time or in post-processing[4,5].Among them, KiriWagsta *et al.* [6-9] proved that using k-means algorithm of spatial clustering method can improve positioning accuracy, but the result is far from satisfactory.

To address these deficiencies, we used a GPS data processing method called SKMW (Smoothing, k-means, Mean, Weighted average) [10], which is based on k-means. Taking JiuFeng national forest park in Beijing as a case study, we corrected the accuracy of

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several GPS positioning points in the park, drew a highly precise electronic map of JiuFeng park, designed a park guiding system that can search for and display POI (point of interest) on a custom-made map, and developed information services and positioning related functions based on gvSIGMini [11], an open source Geographic Information System (GIS) client on theAndroid operating system. In field testing, the feasibility and effectiveness of the GPS data processing method were verified, and the system provided new ideas for drawing highly precise electronic maps. Our JiuFeng guiding system, based on high precision GPS positioning, can effectively prevent the visitors from getting lost in the forest park. It can potentially improve the safety of tourists in forest parks, and provides a good research platform in the field of outdoor fire rescue, geographic data collection, and tour guiding services.

2. The Design of a Park Guiding System

2.1. Implementation Platform of a Park Guiding System

Data measurement, as the basis of the park guiding system, determines the precision of GPS positions shown on maps, and that of the maps as well. Among many Android apps now on the market with track recording function, we chose for this study My Tracks for recording GPS track routes, for inserting waypoints into them, and for marking geographic locations. In the complex terrain of JiuFengpark, scenic spots are numerous, and most of the routes are along mountain roads. We switched on the GPS function of our mobile phones in unsheltered places in order to reduce error during the process of data measurement.

Park guiding systems are of used to LSE (Landscape Ecology), a field of study that utilizes many GIS tools. Most of such tools, such as ArcGIS, are commercial software. The only suitable choice for this study was gvSIG, a tool for mobile GIS application developers [12-15] published by OSGeo.org, who organizes yearly FOSS4G (Free and Open Source Software for Geospatial) conferences. gvSIG is open and free, and it supports the viewing of geographic data [16] on OpenStreetMap (OSM), an open source collaborative project for creating maps. gvSIG Mini is a comprehensive mobile GIS client on Android that allows custom editing and accessing, address lookup, and POI search. It is a powerful tool for developing guiding systems [17] and a new visual data mining tool for GIS [18]. To implement a park guiding system, we used gvSIG Mini as its development platform. We chose Java OpenStreetMap Editor (JOSM) as our map editor because JOSM can load standard GPX track data files from the OSM database and because JOSM let us upload our data, edited with nodes and routes as well as labels, to OSM's server for sharing [19].

2.2. Framework Design of a Park Guiding System

The architecture of JiuFeng park guiding system consists of the 4 layers shown in Figure 1: Basic Data includes JiuFeng park's electronic maps, tour guide information, and so on; Software Platform is embedded gvSIG mini, as described above; the system's 9 Function Modules are park information, scenery spots information, electronic maps operations, GPS positioning, route and POI marking, amenities marking, photographing, microblogging, contacting; its Application Interface is graphical and provides users with interactive operations.

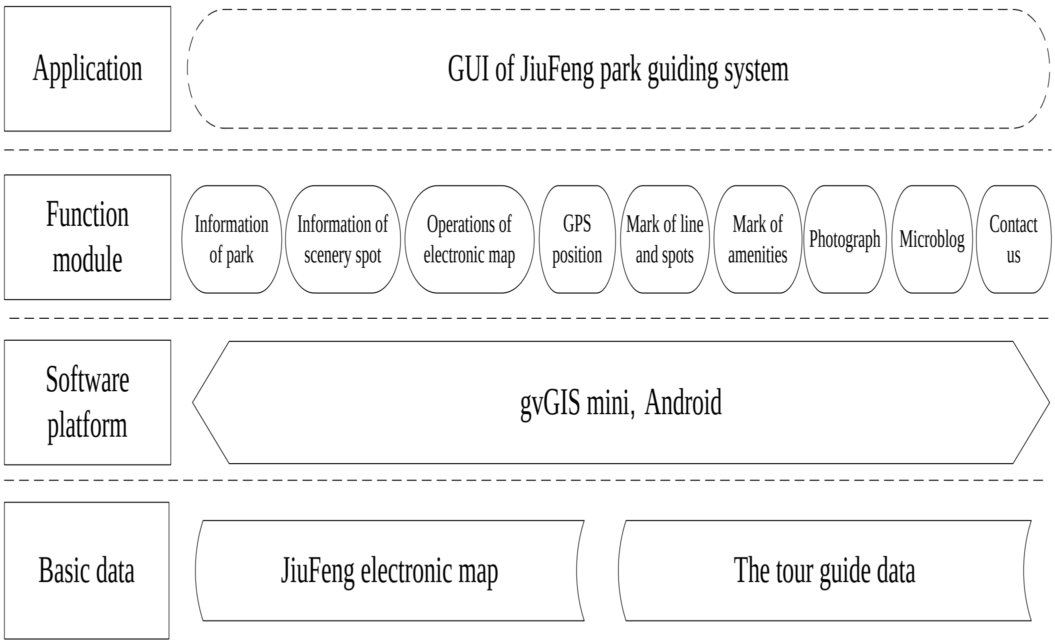


Figure 1. Architecture of JiuFeng Guiding System

2.3. Implementation Flow of a Park Guiding System

The implementation of the system included data measurement, data processing, map plotting, and function development, as shown in Figure 2. For data measurement, we used My Tracks to measure routes and to mark waypoints in JiuFengpark as electronic maps' basic data source; to calibrate the maps, we collected over a period of time GPS coordinates from main scenic spots in the park to be marked as fixed points. During data processing, if GPX files were exported directly from My Tracks, the amount of information would be lost easily; we therefore exported KML files and used GPSBabel to convert them, and processed positioning data points with SKMW method so that map plotting could be calibrated more accurately. In map plotting, we imported basic measured data into JOSM, and used it to edit routes and to indicate attributes of landmarks and waypoints onto a map from OSM with satellite imagery from Bing Sat as an underlay, drawing a pre-calibrated map of JiuFeng park; we then calibrated the map manually by importing fixed points into JOSM, and uploaded the finished result to OSM's server on the net, ensuring that it can be displayed properly. For function development on gvSIG Mini for Android, we imported KML files into gvSIG Mini, embedded custom-made maps into a gvSIG Mini project, and implemented functionality such as GPS positioning, trail display, waypoint display, and scenic spots customization; finally, we compiled and released the final debugged project. With its stronger and wider applicability, the system can be used as a developing platform for general tour guiding systems.

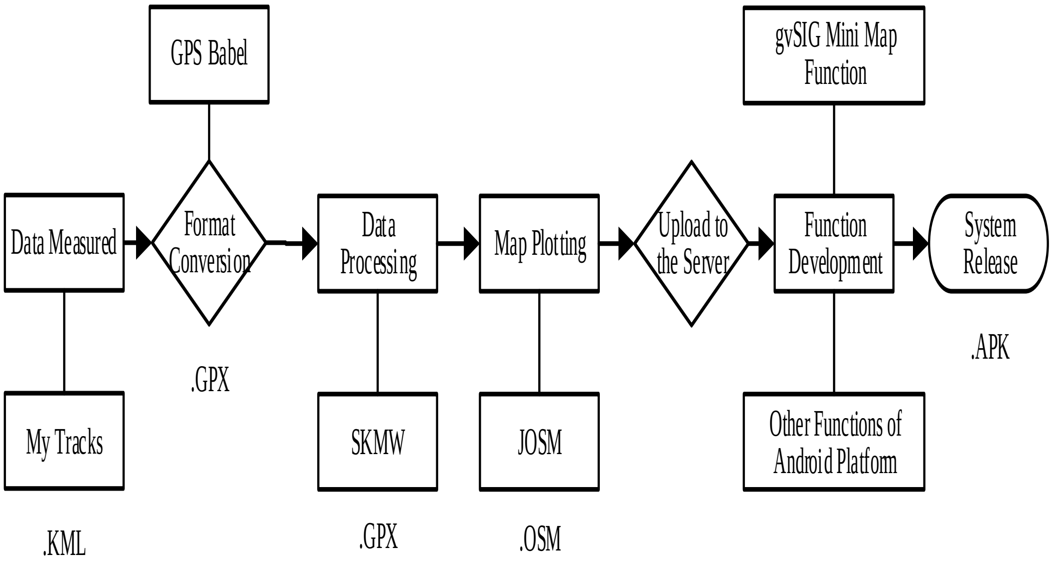


Figure 2. Main Work Flow Chart of JiuFeng Guiding System

3. Drawing the Electronic Map of a Park Guiding System

3.1. SKMW Method

Spatial clustering is an important method of spatial data classification or grouping [20]. Among these clustering methods, k-means is suitable for classifying large amounts of data; it can effectively process dense data in classes, by considering proximities of distances, by initializing centers of masses and by limiting the maximum number of iterations [21]. k-means is also suitable for data sets consisting of mostly similar entries; because a lot of data sets to be processed by GPS applications contain massive amounts of data but with only very few outliers coordinates, it is feasible to use the clustering characteristics of k-means algorithm to classify, according to position, the data in such applications. k-means basically works by picking k points randomly as the centers of clusters in a collection of n pieces of data, and the each of the rest of the data points p is assigned to the cluster whose center is closest to p. The mean of all points in cluster m_i is then calculated as the new center of the cluster, which no longer changes after several iterations, and the clustering algorithm thus converges. The standard measurement function based on mean variance is defined in equation (1) with E as the sum of mean variance of the study objects, p as the data objects representing points in space, and m_i as the mean of cluster C.

$$E = \sum_{i=1}^{k} \sum_{p \in C} \left| p - m_i \right|^2 \quad [9] \qquad (1)$$

The SKMW method (Smoothing, k-means, Mean, Weighted average), based on k-means, constructs its process of filtering GPS positions according to the distributions of data samples. It deals with raw data as spatial samplings by smoothing, and classifies those using k-means. It then collects the average of each class and calculates weighted averages to achieve more accurate positioning. Its usages are not limited to specific regions or areas; it is suitable for both environments in the open receiving stronger GPS signal and environments with a lot of obstructions [22]. Figure 3 below shows the overall process.

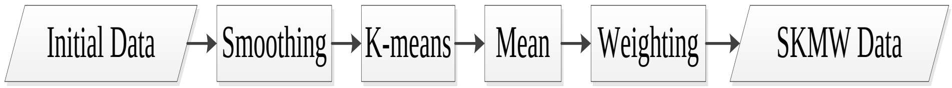


Figure 3. Flow Chart of SKMW Method

GPS receiving devices operate in complex environment influenced by fluctuations in light, temperature and electromagnetism, the acquired data therefore often drifts. To counteract these influences in order to prevent classification error of the k-means algorithm from breaking up similar data and from aggregating divergent ones, we used a smoothing filter called a recursive average filter, also known as a moving average filter, to deal with the degree of aggregation in data. After smoothing, we classified the data was by k-means algorithm, which tends to keep too much unnecessary detail in the data. We use arithmetic mean filter, and replaced the original data points with the average calculated from all data in clusters. This arithmetic mean filter decreased the amount of useless data, reduced the level of details in the data set, and emphasized useful data. Mean filtering can also reduce the complexity of the weighting process by reducing the amount of data. To increase the importance of valid data and reduce that of invalid data, we used an unfixed weight method by calculating weights according to the amount of data obtained by experiments and according to the number of data points in each class found by k-means classification. This can result in improved accuracy and robustness in the use of SKMW [10].

3.2. Electronic Map Drawing based on SKMW

This study measured basic data for all routes in JiuFeng forest park. KML files from My Tracks were converted into GPX files before map drawing. The latter were processed with SKMW method and then imported into JOSM to lay them over corresponding Bing Sat satellite imagery, as shown in Figure 4. Routes are edited in JOSM with its many tools for selection, deletion, zooming, scaling, as well as stretching, and geographic waypoints were marked, as shown in Figure 5. After drawing the map, we upload the result to using JOSM's net service. Figure 6 and Figure7 show the overview and details of JiuFeng park's electronic maps respectively.

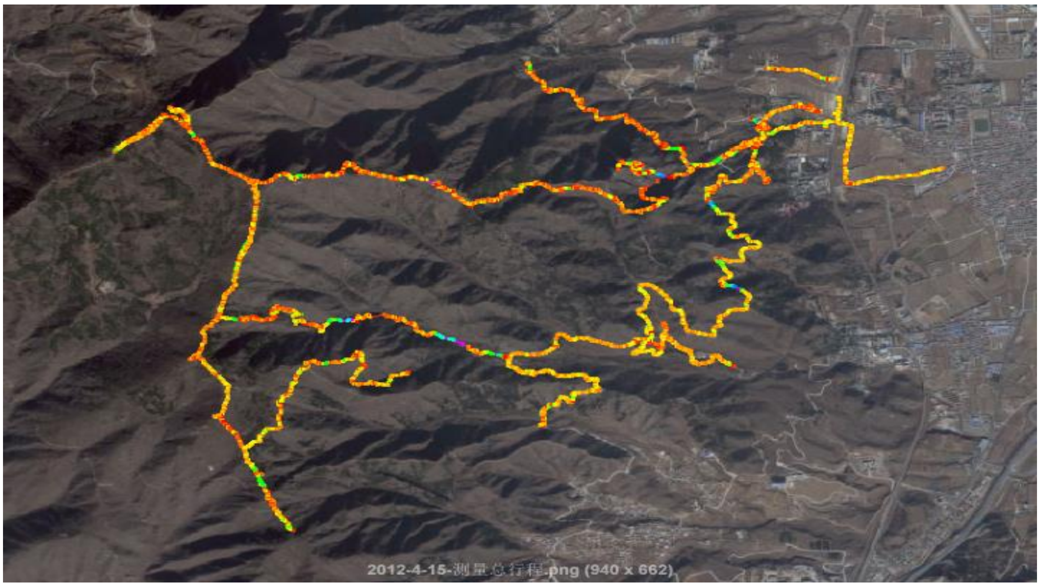


Figure 4. Field Measurements of Routes in the JiuFeng Park

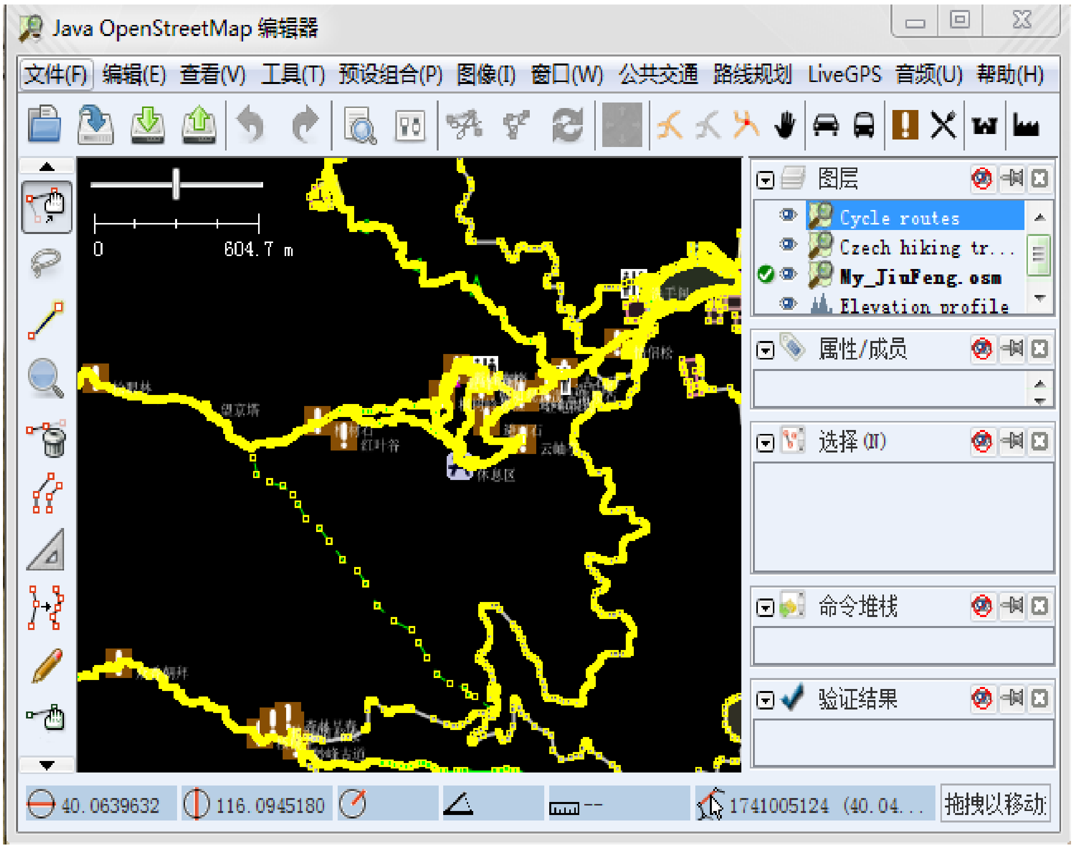
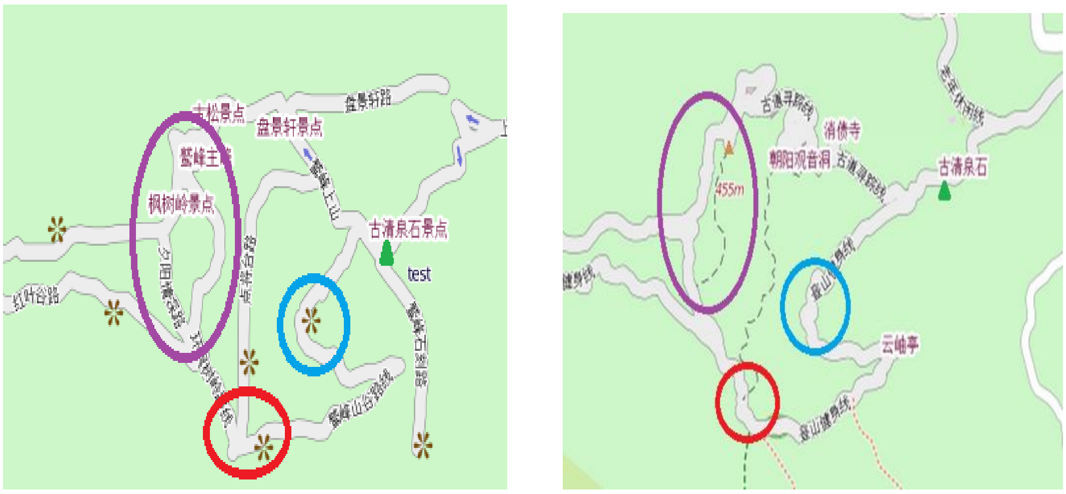


Figure 5. Editing Electronic Maps of JiuFeng Park

Figure 6. Electronic Map of JiuFeng Park, Overview

Figure 7. Electronic Map of JiuFeng Park, Details

In order to verify the validity of the SKMW method, we used it to deal with the several attractions in JiuFeng Park as marked points. We marked them in pre-calibrated electronic maps so that we could make more accurate electronic maps by manual editing and by SKMW correction. Figure 8 shows in comparison JiuFeng Park's electronic map (a) before and (b) after correction. In both are the same routes in the park, but the difference in precision is obvious. In the purple area, the two corrected routes are closer together, with curvature different from the uncorrected ones. Near the red area, the corrected focal point of three lines is more rounded. In the blue area, the uncorrected road is more jagged. The green triangle marking the scenic spot named Gu Qing Quan Shi is located away from the intersection of three roads in the correctly version instead of at the intersection. There are many other differences in details but we will not list them exhaustively here.



(a) Electronic Map Before Correction (b) Electronic Map After Correction

Figure 8. Comparing Electronic Map Before and After Correction

4. Implementation and Analysis of a Park Guiding System

4.1. Implementation of System Function

In order to implement the map function of this system based on a gvSIG Mini project, we establish the JiuFengWithMap project as the main framework of our park guiding system, and then reconstruct the entire project by combine it with the gvSIG Mini project.

Firstly, we implemented the display function of the map page by receiving GPS coordinates and by setting the zoom level of the map for displaying the particular area to be shown after initialization. For that, the code is:

```
//set the Latitude and longitude
getMapView().getMapViewController().setMapCenterFromLonLat(116.091959,40.061492
);
//set the zoom level of map
getMapView().getMapViewController().setZoomLevel(15);
```

Secondly, we implemented the function of automatic positioning, which is to display more accurate maps on the screen to center the map on the processed GPS coordinates. The code is:

```
//display the map
getMapView().adjustViewToAccuracyIfNavigationMode(this.getMapView().getLocation
Overlay().mLocation.acc);
//set the center of map
getMapView().getMapViewController().setMapCenterFromLonLat(this.getMapView().ge
tLocationOverlay().mLocation.getLongitudeE6()/1E6,this.getMapView().getLocation
Overlay().mLocation.getLatitudeE6()/1E6);
```

Thirdly, we implemented the loading and display of tracks and waypoints. We modify the format of KML track files as adjusted by SKMW method, and imported them into the root directory in the simulator's SD card. Then we set the showing and hiding of tracks, waypoints and their information. The show function and the hide function of waypoints let users mark toilet, store and other public facilities. We modified the mode for setting provided by gvSIG Mini from manual to automatic by adding into the related class some display control code:

```
ActivityBundlesManager.getInstance().getMapView().getOverlay("201301127JiuFeng.
kml").setVisible(true);
this.getMapView().getOverlay("201301127JiuFeng.kml").setVisible(true);
```

Lastly, we implemented the custom display function of scenic spots information, which returns custom scenic spots information, including pictures and text, upon request by users' clicks on waypoints information. The code for deciding the waypoint corresponding to the bubble clicked on display is:

```
((es.prodevelop.gvsig.mini.geom.impl.base.Feature)this.lastSelectedFeatures.get
(1)).getText();
```

The code for associating names of scenic spots with information activities using the <name> tag is:

```
for (i = 0; i<spots_list.length; i++) {
if(spotName.contains(spots_list[i])){…
intent.setClassName(this.getContext(), activiities_list[i]);
this.getContext().startActivity(intent);
…}
}
```

Figure 9 shows map functionalities implemented in JiuFeng park guiding system. Besides these, the system features other information service functions such as photo, microblog, and so on.

Figure 9. Map Functionalities Implemented in JiuFeng Park Guiding System

4.2. Test and Analysis of System

Our system's map display function is based on gvSIG Mini. To install the system onto a mainstream smartphone (with Android 2.2 or above and GPS function), use common apps installation procedures, and copy KML files containing custom-made electronic maps and trail data for route recommendations onto the root directory of the phone's SD card. To enter the system, click the Logo icon. To display high precision custom electronic maps, select either of online map downloading or offline map adding modes. Switch on GPS to show current location. To browser details of scenic spots, click waypoints buttons on routes.

Table 1 compares JiuFeng guiding system and other well-known guiding systems on Android, showing JiuFeng guiding system to be based on more precise custom-made electronic maps, with more and better functions. Field usage and testing in JiuFeng National Forest Park showed that the system can conveniently and quickly serve information for location, landscape and route using highly precise maps without deviation that effectively

Table 1. The Comparison between JiuFeng Guiding System and Other Famous Android Guiding Systems

Software Name	The Interface of Map	Development Team	Electronic Map	Map Operation	Public Facilities Indicated and Settings	GPS Position with Map	Positioning Effects	Size
Guiding system of the Imperial Palace		TouchChina	Google Map	Exist	Marked on the map, can be set	Positioning on Google Map		6.89M
Guiding system of the Palace Museum		Beijing Future Developer Co. Ltd	Google Map	Exist	No mark on the map	Positioned by compass, invisible on the map		10.96M
Guiding system of the Summer Palace		School of Information, Beijing Forestry University	Picture	Exist, but only the zoom operation	Marked on the map, cannot be set	GPS coordinates only, without map		8.13M
JiuFengguiding system		School of Information, Beijing Forestry University	Custom-madeelectronic Map	Exist	Marked on the map, can be set	GPS positioning, marked on the Map		12.63M

reduces display error of positioning. We tested it on Android phones with fifth generation chips by U-Blox, and the proposed SKMW reduced error from within ten meters to less than one in our experiments.

5. Conclusion

This study focuses on integrating highly precise custom-made electronic maps with the display of GPS positioning. Using My Tracks' track data measurement function and JOSM's map editing feature as well as gvSIG Mini's loading and display functions of custom-made maps with self-measured tracks and waypoints data, we designed and developed a relatively advanced, general and expandable park guiding system that works closely with SNS (Social Network Service) and LBS, providing the experience and basis for future research on the development of park guiding applications.

The system is not perfect: SKMW's performance depends on the amount of and accuracy of raw data, and SKMW's algorithmic efficiency and effectiveness warrant further studies. A highly complex project of gvSIG Mini can easily lead to problems such as system incompatibility and excessive memory usage, to be improved upon through optimization of algorithm and improvement in hardware performance.

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