

# Integrated Multidimensional Geo-Spatial Data Warehouse and Web-Based Mountainside Management System

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## ABSTRACT

As seventy percent of territory is mountain, mountain management is always a big issue in Taiwan. Soil and Water Conservation Bureau(SWCB) is a government agency who plays crucial rule on mountainside management in Taiwan. It is in charge of multiple management affairs related to Taiwanese slope area, including management of debris flow hazards, management of mountainous wagon tracks, and checking illegal development in mountainside and so on.

The purpose of this study is to integrate and enhance the fruitful result that Soil and Water Conservation Bureau has been working on for years. In recent decade, SWCB has been putting lots of effort on developing computer systems to assist multiple management affairs. Three main geographic Information systems were built to help on geo-spatial related sectors. On the other hand, gigantic geo-database has been generated in this period of time. However, the asynchronous of system's source data and unfriendly, different user interface among systems leads to various confusions. To solve these problems, the idea of developing an integrated platform appears. Several tasks are included in the program, including building a multidimensional geo-spatial data warehouse, developing a web-based integrated system for multiple application of SWCB, and a mobile system to extend the usage of the system.

The multidimensional geo-spatial data warehouse, using ArcSDE and Oracle database server, was built to store all the mountainside geo-spatial data that has been generated in decades. At the same time, a detailed road map with 1:5000 scale dataset was encompassed as the base of web map service. The integrated mountainside management platform was built to integrate SWCB GISystems to improve usability for the officers. ESRI product ArcIMS was used with assistance of multiple technologies to serve multiple applications. Multiple devices are capable to access the platform through internet, from PC-based devices to mobile devices. Besides, a mobile system was developed, to ensure officers are capable to access the system anywhere and anytime, using J2ME technology. This paper provides multiple views on implementation of integrated platform and the building of geo-data warehouse. Several issues of integrating are also revealed.

## 1. Introduction

The burden on the people running the hillside management of Taiwan is certainly one of the most heaviest over the public affairs. As seventy percent of territory is mountain, the government agency that in charge of hillside management duty-Soil and Water Conservation Bureau(SWCB) plays a crucial rule on security of mountainside in Taiwan. It is in charge of multiple management affairs related to Taiwanese slope area,

including management of debris flow hazards, management of mountainous wagon tracks, and checking illegal development in mountainside, recovery constructions and so on.

The purpose of this study is to integrate and enhance the fruitful result that Soil and Water Conservation Bureau has been working on for years. In recent decade, SWCB has been putting lots of effort on developing computer systems to assist multiple management affairs. Three main geographic Information systems were built to help on geo-spatial related sectors. On the other hand, gigantic geo-database has been generated in this period of time. However, the asynchronous of system's source data and unfriendly, different user interface among systems leads to various confusions. To solve these problems, the idea of developing an integrated platform appears. Several tasks are included in the program, including building a multidimensional geo-spatial data warehouse, developing a web-based integrated system for multiple application of SWCB, and a mobile system to extend the usage of the system.

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## **2. Principles and User Interface**

The development of GISystems of SWCB in recent decade has been considered as a model in GIS development work in Taiwan. However, most of the systems are developed by different units for different purposes. At the same time, the different user interface, dataset irregular version and various map layers used by different systems lead to confusion of officers. For solving this problem, we set up several principles before building the enterprise-grade GIS system.

### **2.1 Principles**

#### **A. Compliance of OGC standard**

The data-warehouse was designed as an OGC compliance database, by using Oracle Spatial as the database software.

#### **B. Principle of Importing**

The amount of dataset was huge. Hence, we divided all map layers into several themes, and imported them by theme. This could increase the access performance. In addition, the quite lots of efforts were spent on the correction of data quality, coordinate system and other content issue of dataset.

#### **c. Principle of Data Standardization**

##### **i. Meta-data and naming rule**

To approach quick search functionality, including data source, producer, version and all assistant information, we built a standard meta-data table. The meta-data includes 300 fields, 30 of them are essential to be filled. At the same time, a standard naming rule was also applied as the initial character indicates the data type and second character means data format.

**Table 2.1 Principle of map naming**

Data structure	Vector data			Raster data	
Data type	Point	Polygon	Poly-line	Satellite	Air photo
Naming Initial	VP	VA	L <sup>V</sup>	MS	MP

ii. Format

Different dataset often are produced in different way, for this reason, often are recorded in different format. In this project two file formats were chose as standard format: shape file for vector and world file for raster data.

## 2.2 Customized Layout and User Interface

### A. Reducing user's Cognitive burden

As a integrated system is the aim of this project, a good user interface is essential. To approach this, reduce the cognitive burden was taken into account. We designed a questionnaire to assess the system usage cognition of SWCB officers. Base on this, the system UI was tested to approach a most logical, reasonable and graphical interface. For example, a friendly "Tip Window" was designed to reveal the functionality all the time.

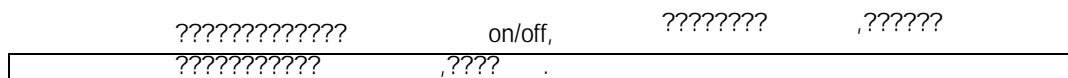


Figure 2.1 Tip window

### B. Consistence

The consistency of User interface and art design was considered as a important factor. Instead of approaching a stylish and diverse interface, we tried to make system fellow one union design logic and artistic rule.

### C. Customizations

Customization is a trendy development of user interface. We tried to meet different needs from different people. Several different version of system was designed, for example the layouts and best browsing resolution.



Figure 2.2 offering best display for different resolution of screen

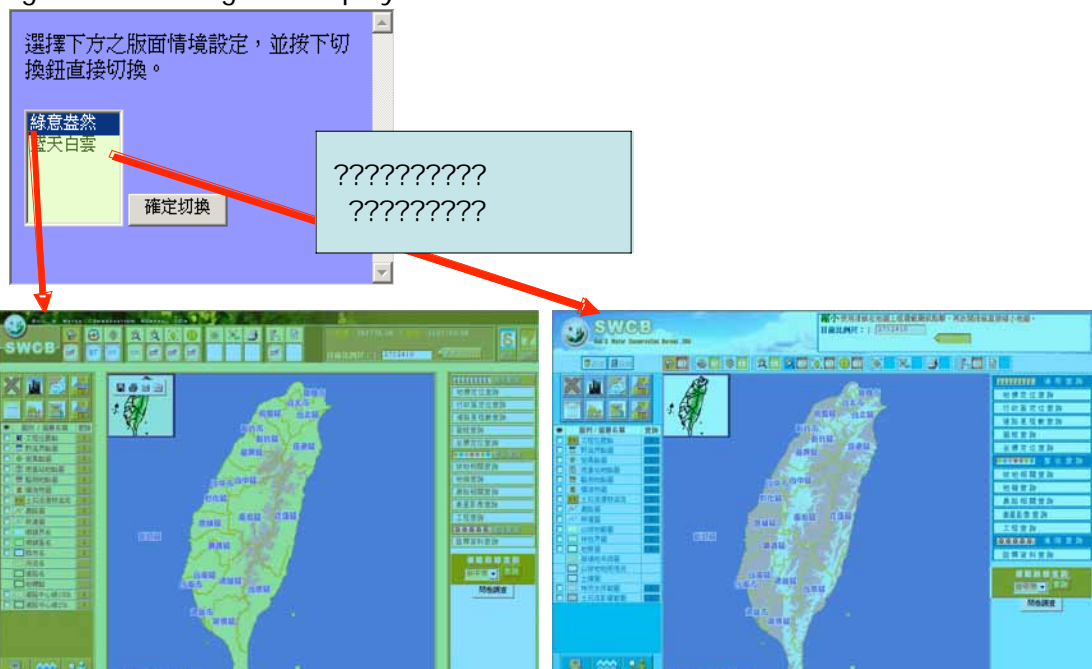


Figure 2.3 Different layouts for user's preference

### 3. Single Sign-On Mechanism

Single sign-on mechanism was used to integrate different system and offer users a better interface. The system used Microsoft Active Directory Server to identify the user identity. Hence, using one id and password, user can easily shuttle within different systems. The operation framework reveals in figure 3.1.

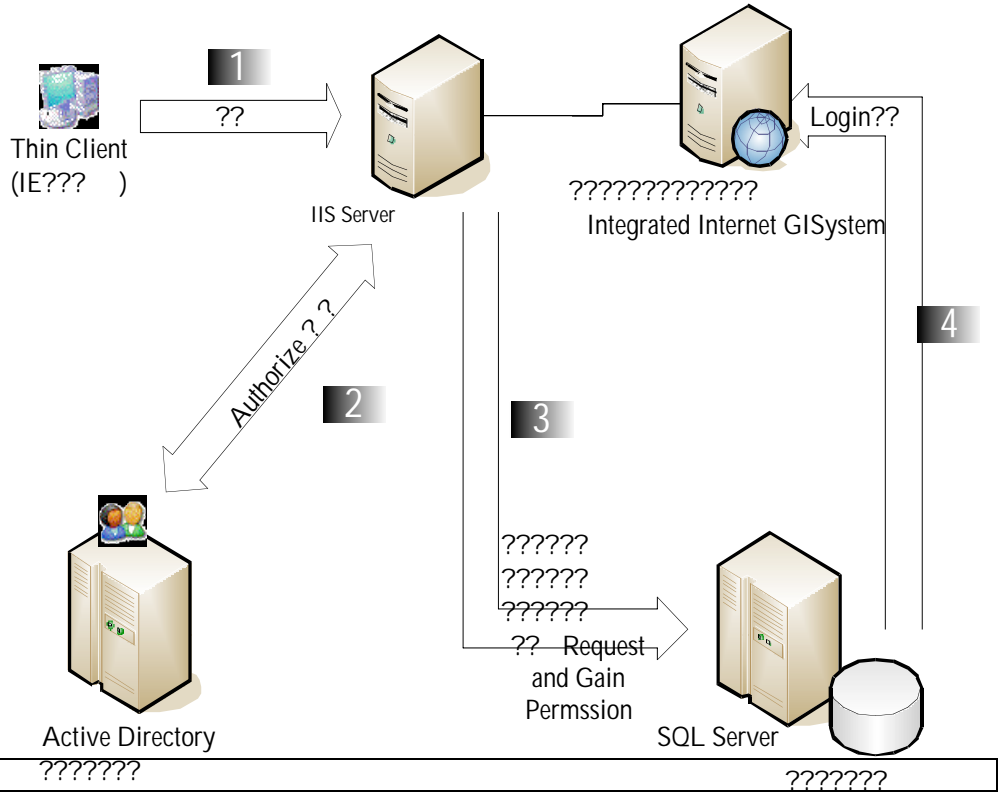


Figure 3.1 Framework of Single Sign-on Mechanism

#### 4. Multi-Dimensional Geo-spatial Data Warehouse and Integrated Web-based Mountainside Management System

The mountainside management system integrates three main GIS systems from SWCB for the first stage, including satellite image hillside use investigation system, hillside information management system and village road management system. We designed two versions, one for officers and the other for public. The framework is showed as figure 4.1.

Figure 4.2 illustrates the system architecture. The Oracle server database is used in the system, which can be accessed by ArcIMS through the spatial data engine, ArcSDE. Several spatial servers are employed to reduce the load on the Web GIS server, thereby improving the system performance.

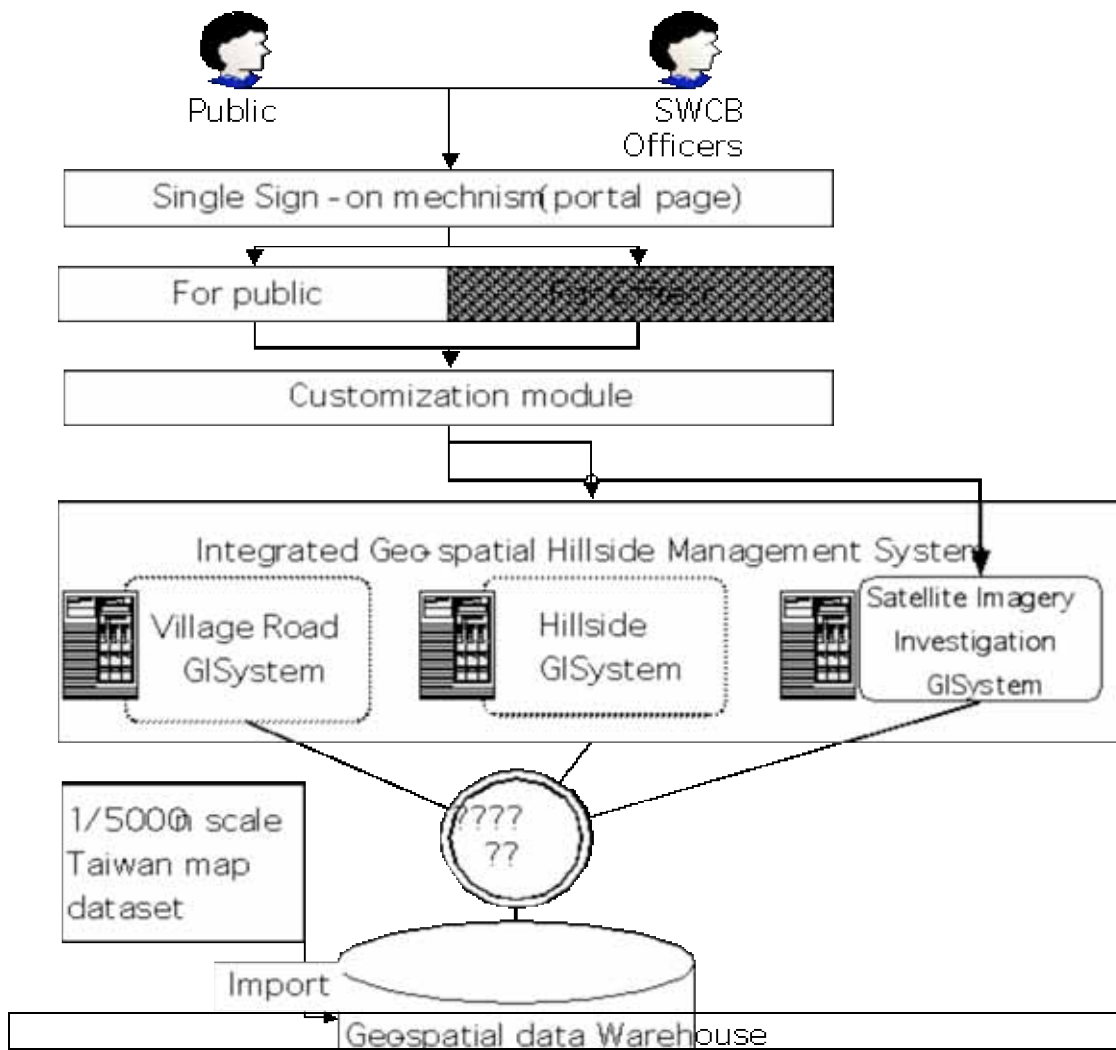


Figure 4.1 operation framework of integrated system

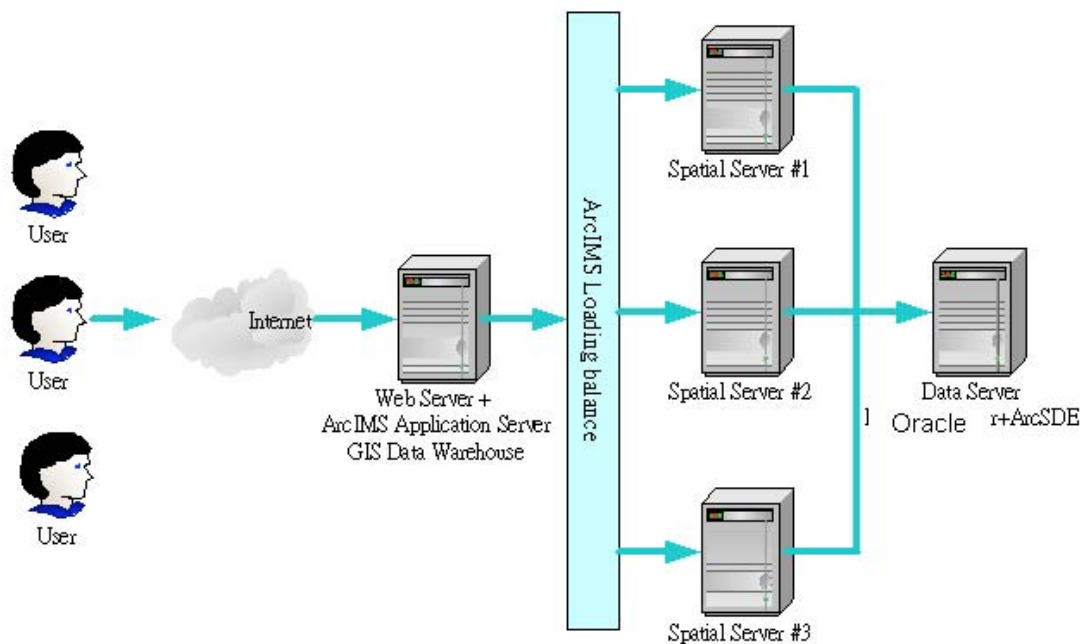


Figure 4.2 Architecture of integrated GIS system

Figure 4.3 illustrates the flow chart depicting data download from the Web GIS

server. In order to ensure data-security, the letter of authorization should be keyed in. In this manner, the statistical analysis for downloading records can be done for decision-making analysis.

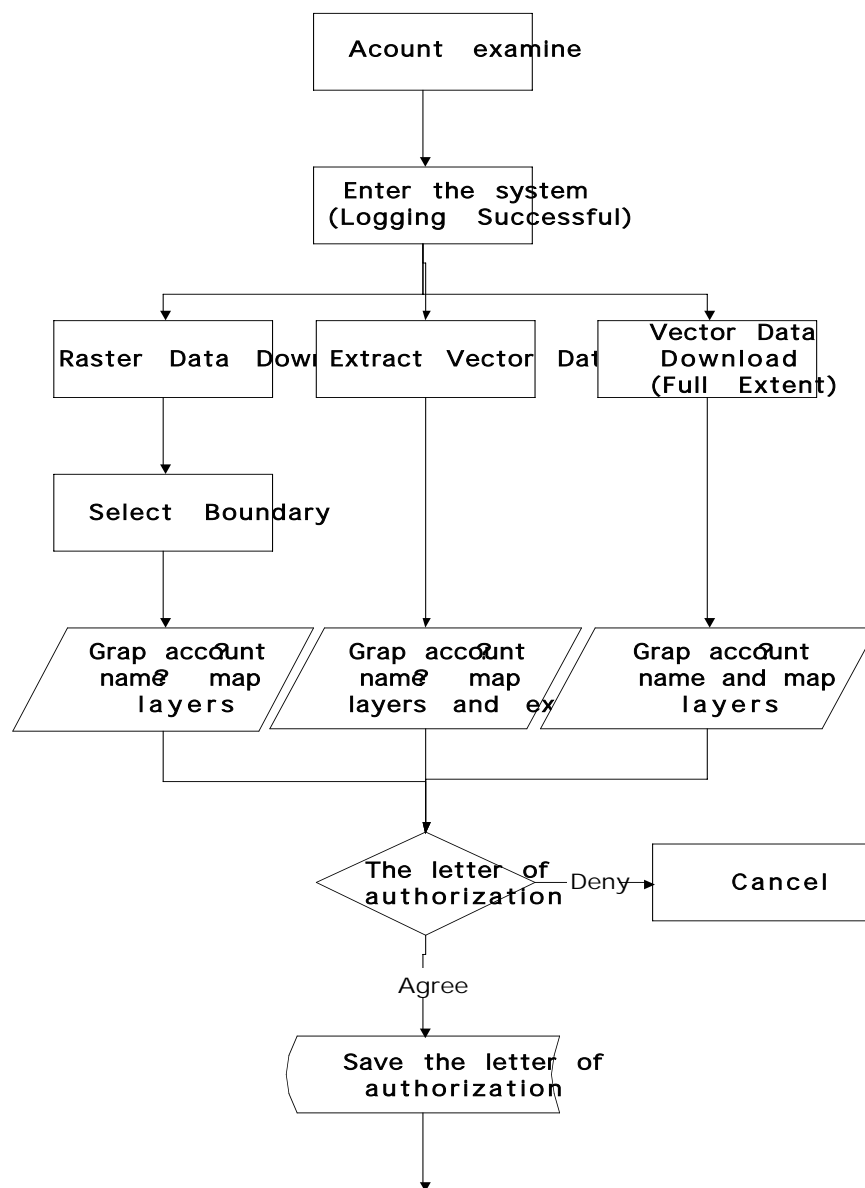


Figure 4.3 flow chart of downloading data from Web GIS server

## 5. CRM Analysis

Customer Relationship Management (CRM) is employed in this data management system to facilitate easier understanding of the system users and faculty. Based on the analysis of a user's habits by CRM, this system can serve as a spatial data warehouse to improve the search mechanism and the system can also offer customized service and a user-friendly interface. For example, when a user searches some layers, the results can be ordered according to the search frequency to save search time. The functionalities of the data management system are shown in Figure 5.1.

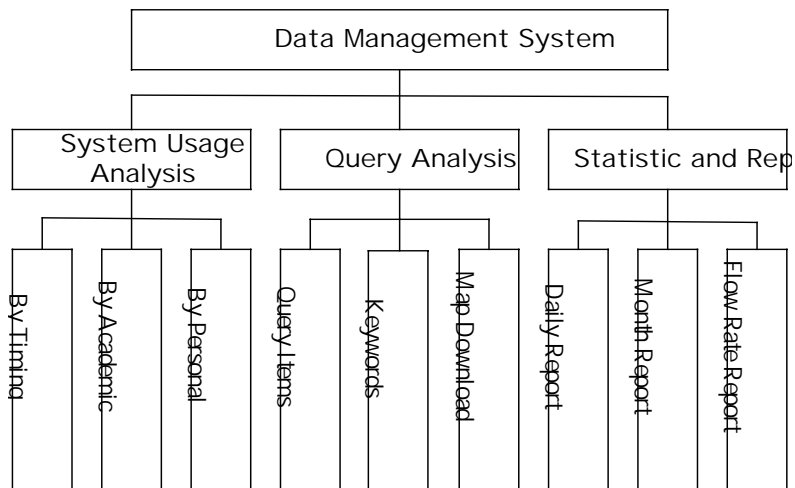


Fig. 5.1 The functionalities of data management system

The operational records containing the user log-in/log-out information can serve as an important reference to follow-up efficiency analysis and report on system enhancement. Figure 5.2 illustrates the current scheme of the CRM database.

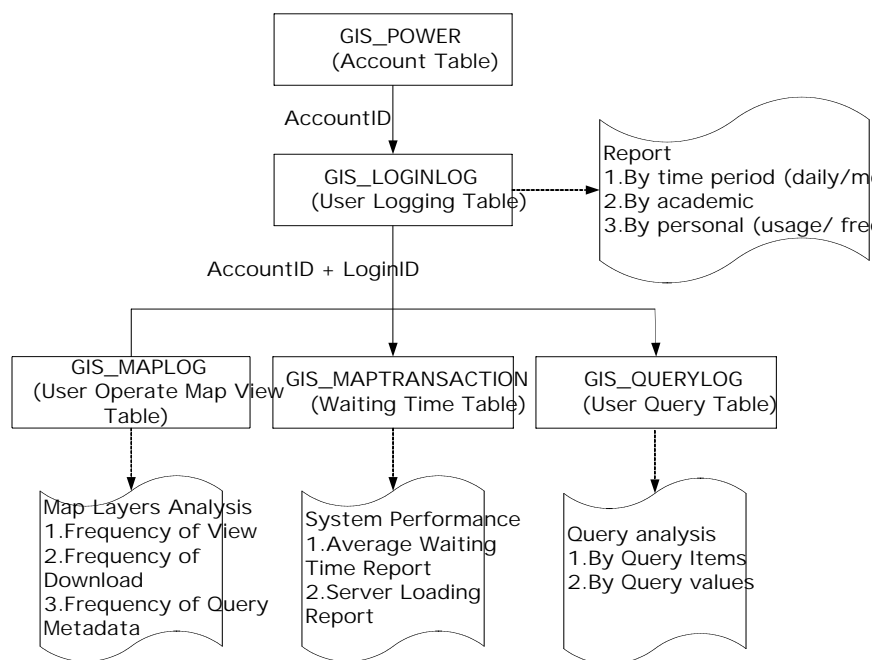


Fig. 5.3 Database structure of data management system

The system records each user's log-in time and the serial number during system log-in; similarly, it also automatically records user's log-out time to facilitate analysis of usage durations and user habits. The users' logging information stored in the logging table can later be analyzed in the form of chronological, individual or academic reports.

The user operational processes, including the idle time and query syntax are also automatically recorded. The recorded information can be analyzed to generate useful reports for the purpose of operational management while using the system.





on the client itself.

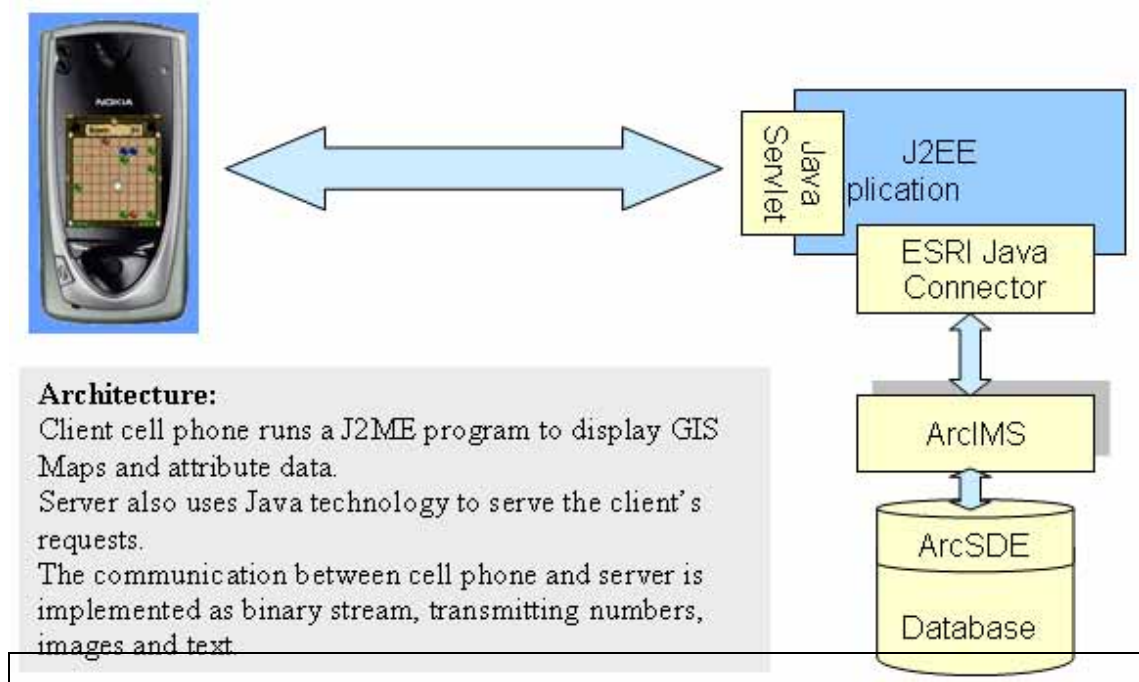


Figure 6-1: System Architecture

## 6.2 Communication

For the communication between client and server, we had the following requirements:

- Has to provide a robust, reliable transport of data from client to server
- Must be able to transport various and complex content. (Text, images, vector gis data, up to the complexity of polylines and polygons with rings).
- The communication protocol has to be easily extensible.
- The parsing and building of the communication datagram's on the client side should be slim if possible, in terms of processing time, storage and runtime memory usage.
- The communication should allow interoperability (using different programming languages on client and server).
- The size of the datagram's should be small.

It is of course nearly impossible to find a solution that fulfills all these requirements. However, we were able to design a solution that meets many of the above mentioned requirements. The chosen communication implementation relies heavily on object oriented programming and the use of the java classes `DataInputStream` and `DataOutputStream`, which are available both on client and server side. Object oriented programming and the usage of Java's stream helper classes leads to a convenient, highly structured and very efficient way of communication between cell phone and server. Efficient because no additional libraries are needed and because the data is transmitted as binary, which leads to smaller datagram sizes. Fundamental to the chosen communication is the concept that every object "knows" how to serialize and de-serialize itself to / from a stream. As the code for serializing and deserializing is contained in the object itself, maintaining and extending the communication is simple.

## 6.3 Map Navigation

### A. Layered map display

An important requirement was to provide information on selected features, similar to the info functionality known from common desktop GIS Applications. But, a cell phone usually does not have a pointing device. Such a device could of course be simulated by an arrow which is moved over the cell phone's screen by using the cursor keys. We found this approach a bit awkward to use and tried to follow a different approach. By loading the currently active layer not as image data, but as vector data to the cell phone, it is possible to jump with each cursor move not from pixel to pixel, but from map feature to map feature. The remaining layers are shown in the background map image generated by ArcIMS.

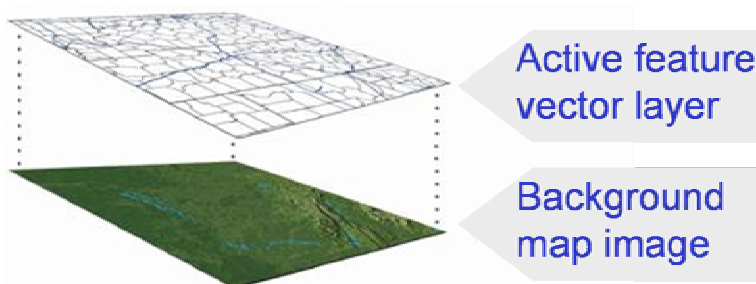


Figure 6.2: Layered client map

### B. Navigation of the active feature vector layer

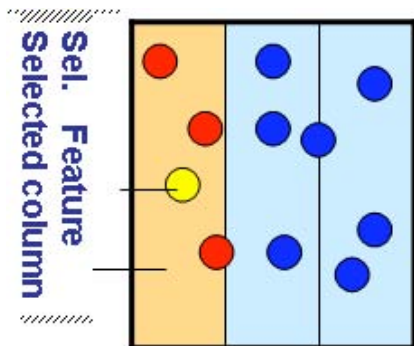


Figure 6.3: Navigation schema

To make sure that all features on the cell phones map can be reached, we divided the screen into 3-5 columns. The server side application assigns each feature to one of those columns due to the location of the features center point. This data structure is served as a whole to the client, where it is used to jump from feature to feature by pushing the cursor keys. As illustrated, by using the left / right cursor keys, the user switches between columns. With the up / down cursor keys, she selects the feature from the features lying within the previously selected column. The point features in illustrate the behavior. Blue feature points can be selected by changing the active column through using the left / right cursor keys. The red point features lie in the currently active column and can therefore be selected through the up and down cursor keys. Using the up key, the nearest neighbor feature in the active column and to the north of the current column is selected. The following screenshots are an example of the feature navigation. The pressed cursors are first down, then left. Note the red shadow which is showing to the user in which column he can select features. The selectable features of a column are drawn in red. The selected feature is drawn in yellow with a yellow-black box showing its envelope. The key attribute of the selected feature is shown in the top right corner of the blue information bar.

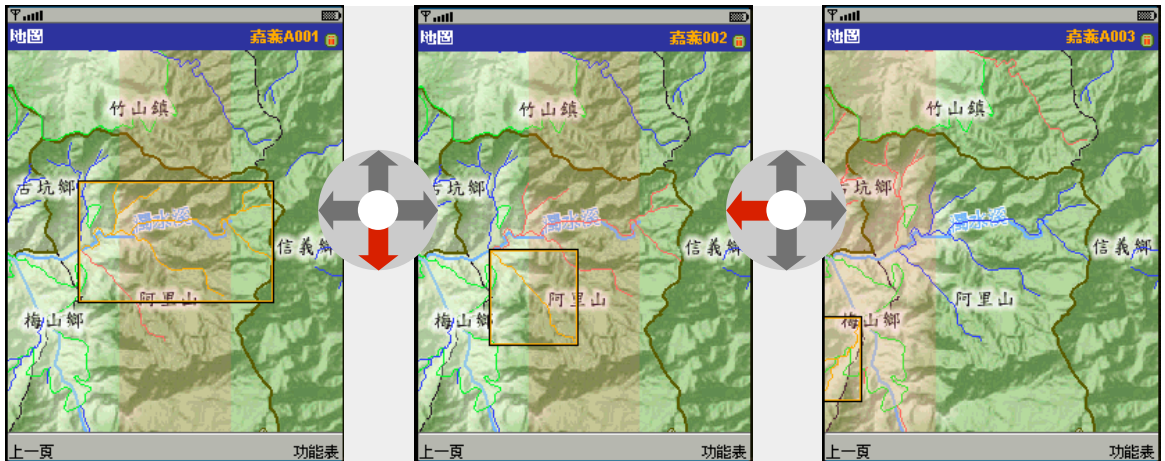


Figure 6.4: Navigation example. Left to middle picture: Key down. Middle to right picture: Key left

### C. Functionality

The functionality consists of the two groups feature location and map navigation\_

#### i. Feature location

The location of map features is done over the features attributes. The application allows the location of the following map features:

- Debris flows
- Landslide
- Landmark
- Road mileage
- Village
- Coordinate

#### ii. Map interaction

After locating the desired feature, the user can interact with the map. The map can be switched between the modes pan, zoom and identify. Identify mode allows the selection of map features as shown in figure 6.4. The selected features attributes can be displayed in a table or the map can be zoomed and centered on the currently selected feature.

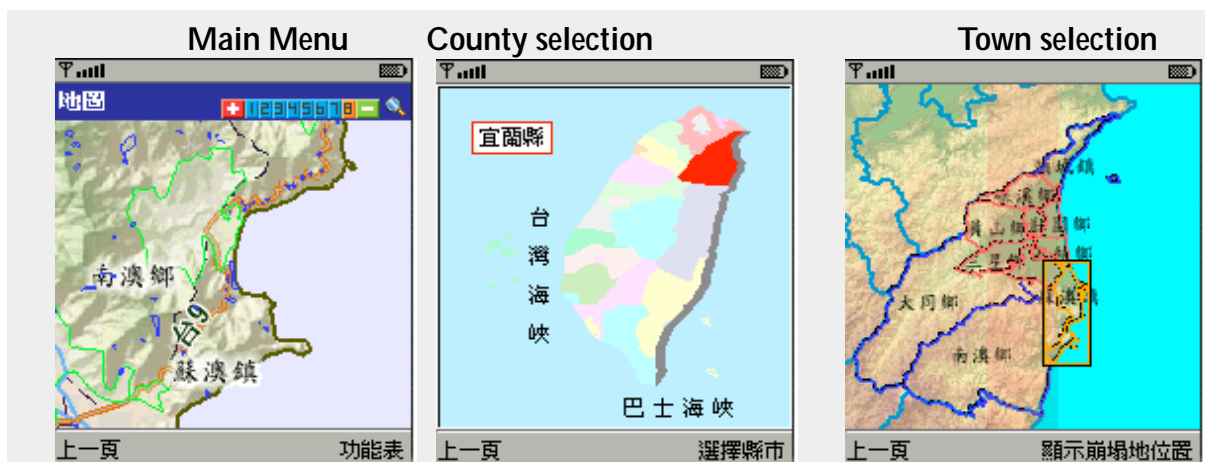


Figure 6.5: Selection of county and town to locate a landslide. The county and

town maps are stored on the client; no server call is needed.

## 7 Conclusion

The aforementioned system provides powerful functionalities for teaching and learning, thus facilitating a thorough integration of multidisciplinary, teaching-related resources. This not only enhances teaching qualitatively and quantitatively, but also fulfils the goal of data sharing and multiple usage via the hillside management platform.