MLGL: A Spatial Data Model for Mobile Geoinformatics and Cartography

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Abstract—The paper presents an innovative spatial data model approach named MLGL (Mapsheet-Layer-Grid-Level) to Mobile Geoinformatics and Cartography (MGC) for field land survey. First, the characteristics of MGC environment are analyzed. Then, one county’s spatial data of land use is broken into several town map sheets according as the administrative boundaries. Each map sheet contains multi controllable attribute layers. For the purpose of reducing the data in viewable area, the layers are sliced into uniform grids and only one cell is specified to display each time. The R tree index and Grid index are established for each feature in one map sheet. Moreover, features generalization algorithm based on BLG (Binary Linear Generalization) tree is developed for implementing the Level of Detail (LOD) strategy in the viewable grid. In the research, Filter-Refinement query strategy is ubiquitously utilized in the map operations. Finally, a Mobile Spatial Index Library (MSIL) is deployed for integrating the MLGL model and providing the interfaces of index operation and database access. A land survey mobile application based on the MLGL model applied in 12 provinces proves the feasibility in practice.

Keywords—Spatial Index; data model; cartography; geoinformatics; R tree; Grid; BLG tree; LOD

I. INTRODUCTION

The mobile computing is a revolutionary style of technology that enables us to access information anywhere and anytime. Mobile geoinformatics and cartography as an intersection of mobile computing and some geography capabilities has fostered a great interest in the computer cartography field. Although the mobile computing has been increasingly grown in the past decade; there are still exist some important constrains that complicate work with a mobile information system. The main obstacle of porting the features existed in traditional computing technology to mobile device is the limited resource.

In this paper, we will focus on the land survey area where the MGC (Mobile Geoinformatics and Cartography) system is demanded to provide massive detailed and accurate vector data while surveyor acquiring the changed features with instruments in field mission. To guarantee a high speed for digital map displaying, querying, and computing, an efficient spatial data model for MGC is required for land survey.

This article attempts to provide an innovative spatial data model approach named MLGL (Mapsheet-Layer-Grid-Level) after analyzing the characteristics of MGC environment, the principle of MGC design, and the requirements of land survey. Then, the model architecture and the strategies of index, display, and query based on MLGL are described in paper. Finally, a Mobile Spatial Index Library (MSIL) is deployed for utilizing MLGL model.

II. ENVIRONMENT OF MGC

Mobile device is a portable microcomputer with limited resource. There are remarkable differences in the operation system and hardware configuration between mobile device and desktop PC. Therefore, MGC differs dramatically from Desktop Geoinformatics and Cartography (DGC) system on some aspects (see Table1). Concerning the storage, CPU and display are rare resources in the mobile platform [1], there are four rules to follow for MGC design:
- Use the RAM safely.
- Use the CPU reasonably.
- Use the storage strictly.
- Choose the reasonable display strategy.

### Table 1. The Comparison Between Desktop GIS and MGC

<table>
<thead>
<tr>
<th>Comparative item</th>
<th>DGC</th>
<th>MGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>Hard disk</td>
<td>RAM, ROM or Storage Card</td>
</tr>
<tr>
<td>Fault Tolerance</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Update</td>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>Safety</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Currency</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Reliability</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Code Length</td>
<td>Unlimited</td>
<td>Compact</td>
</tr>
<tr>
<td>Data Capability</td>
<td>Big</td>
<td>Small</td>
</tr>
<tr>
<td>Scalability</td>
<td>Unlimited</td>
<td>High</td>
</tr>
</tbody>
</table>

**Figure 1. The Representation of MLGL Model**

III. MLGL Overview

As the minimum unit of land use data management, county is responsible for updating each town’s the spatial data yearly. The MLGL (see Figure 1) model is designed accordance with the land resource administration manner and avoids the problem of memory shortage on mobile platform.

As shown in Figure 1 (a) (b), firstly, the county spatial data are separated into several town map sheets according to the boundaries of each town. Meanwhile, the town map sheets are stored persistently and dividedly. Secondly, depending on the attributes of geometry feature, the spatial data are detached into different layers. User has the capability to enable or disable the layer visualization as Figure 1(d) and (e) shown. Thirdly, the features in individual layers are sliced into 16 grids in Figure 1(c). Finally, the LOD display strategy is constructed. The spatial objects in the grid are generalized by BLG tree.

### Table 1. Time Consumption of Different Operations under Various Zoom Levels

<table>
<thead>
<tr>
<th>Zoom level</th>
<th>×1</th>
<th>×2</th>
<th>×4</th>
<th>×8</th>
<th>×16</th>
<th>×32</th>
<th>×64</th>
<th>×128</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of features</td>
<td>1192</td>
<td>1009</td>
<td>556</td>
<td>268</td>
<td>124</td>
<td>64</td>
<td>31</td>
<td>17</td>
</tr>
<tr>
<td>Display in sequence (ms)</td>
<td>8506</td>
<td>8352</td>
<td>7231</td>
<td>6906</td>
<td>6589</td>
<td>6534</td>
<td>6387</td>
<td>6352</td>
</tr>
<tr>
<td>Display by R-tree (ms)</td>
<td>8446</td>
<td>6422</td>
<td>4130</td>
<td>2460</td>
<td>1156</td>
<td>947</td>
<td>720</td>
<td>482</td>
</tr>
<tr>
<td>Access in sequence (ms)</td>
<td>6715</td>
<td>6772</td>
<td>6735</td>
<td>6732</td>
<td>6725</td>
<td>6378</td>
<td>6367</td>
<td>6735</td>
</tr>
<tr>
<td>Access by R-tree (ms)</td>
<td>6454</td>
<td>5503</td>
<td>3923</td>
<td>1942</td>
<td>1084</td>
<td>850</td>
<td>705</td>
<td>430</td>
</tr>
</tbody>
</table>
IV. THE STRATEGIES BASED ON MLGL

A. Spatial Index strategies

In order to find out the key elements which effect digital map visualization efficient mostly, we did an experiment on PDA (Personal Digital Assistant). A map sheet of one town contains 1192 features is read from flash Rom and display on the PDA screen. From the results shown in Table 2, we can figure out that R tree index [4] makes the significant difference in the display and access operations. Whereas, it still takes more than 6 seconds to read the data and almost 8.5 seconds to draw the map. It is insufferable for common users. The better solution for promoting the display efficiency is to reduce features drawn in the window. As shown in Figure 1 (c), if the map sheet is sliced into 4 x 4 grids and only one cell is allowed to display, it will takes near 2 seconds to completely present all the features under original scale factor.

Moreover, the results indicate that the time consumption of drawing map is even higher than access data operation. Therefore, for the sake of promoting render efficiency in the viewable area, more optimized visualization strategies are demanded.

B. LOD Visualization Strategy

Comparing Figure 2 (a3) and (b3), we will find that mobile device wastes quite many resources to draw the details which are unable to recognized by user in fact. Therefore, it is no sense to represent each detail at a certain zoom level. However, it should not cause the surveyor’s wrong judgment of land change on site.

BLG tree based on the Douglas-Peucker[5] line generalization algorithm is used to solve the variable scale representation problem[2]. Error! Reference source not found. In Figure 2, Level of Detailed (LOD) strategy is implemented based on BLG tree. The drawing operation time consumption decreases significantly at the level of zooming out four times with BLG tree algorithm.

C. Filter-refinement query strategy

Query is a frequent operation in MGC. It is widely hidden behind the user interactions such as views change and features selection. In this paper, we adopt the classic filter-refinement query strategy [8]. Error! Reference source not found. The filter step first returns a list of candidates that is a superset of the objects fulfilling the spatial predicates. This is done by submitting the approximations for instance MBRs (Minimum orthogonal bounding rectangle), which is the smallest axis-parallel rectangle enclosing an object, as parameters for the predicates. The refinement step checks the exact geometry of each candidate returned by the filter step. Such a strategy greatly improves the speed of query processing by limiting the number of candidates which are to be used for complex and expensive geometry calculations.

V. MOBILE SPATIAL INDEX LIBRARY

In order to implement an efficient query strategy, MGC system needs a reasonable spatial index engine to support the user’s related operations. Considering the scalability and portability of the codes, we introduce a Mobile Spatial Index Library (MSIL as shown in Figure 5), an extensible framework that enables easy integration of spatial index structures into existing applications [9][10].

The abstract and concrete classes offered by the TOOLS are shown in Figure 3. These tools address very simple but essential needs for any generic framework. It provides a Variant type for representing a variety of different primitive types (like integers, floats, character arrays, etc.), which is necessary for avoiding hard coding specific primitive types in interface definitions that might need to be modified at a later time. It offers a PropertySet, or a collection of < PropertyName, Value > pairs. Property sets are useful for passing an
indeterminate number of parameters to a method, even after the interfaces have been defined, without the need to extend them.

Figure 3. MSIL Architecture

Spatial access methods are used for indexing complex spatial objects with varying shapes. In order to make our interfaces generic, it is essential to have a basic shape abstraction that can also represent composite shapes and other decorations. In Fig. 5, we define the iGeometry as an interface that all index structures should use to decouple their implementation from actual concrete shapes Error! Reference source not found.. The iVisitor interface is a very powerful feature which provides advanced customization capabilities. The query caller can implement an appropriate visitor that executes user defined operations when index entries are accessed. The core of the spatial index interface is the iSpatialIndex which abstracts the most common index operations such as insertData, deleteData, intersectionQuery, containmentQuery and so on.

R tree and Grid index are wrapped in the Spatial Index module in this research. A critical part of MSIL is the storage manager, which is versatile, very efficient and provide loose coupling between the objects that are persisted and the concrete implementation of the actual storage manager. The iBuffer interface provides basic buffering functionality. It declares the two most important operations of a buffer: adding and removing an entry. An adapter can be embedded on an existing implementation, converting the data to be persisted into appropriate SQL statements that store them in a relational table (e.g., as BLOBs) Error! Reference source not found.

VI. CONCLUSION AND FUTURE WORK

MGC system connected with mapping instruments is an efficient combination for acquiring the field data and updating the original data base in land survey area. A feasible and practical MGC system for land survey has been the main issue argued frequently in recent. In this paper, we focus on mobile spatial data model for land survey and present the MLGL model for MGC. An application based on this model has been using in twelve provinces and the feedbacks indicate that we shall pay more attention to offer topological operations and improve the display efficiency further in the future work.

ACKNOWLEDGEMENTS

The research is carried out as a part of project (No.2008BAJ11B02) named The Development of an Innovative Cadastration Instrument Integrating Inertial Sensors, Total Station, and GPS in National Key Technologies R&D Program. Funding by Ministry of Science and Technology of the People’s Republic of China is gratefully acknowledged.

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