AN INNOVATIVE LBS DATA SERVICE INFRASTRUCTURE

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ABSTRACT:

Location based services (LBS) is one of the quickest developing technology in the past 20 years. But its QoS (quality of service) is one of critical issues and bottleneck handicapping further development and more application. The current LBS QoS problems include: data especially non-spatial data is out-of-data and/or error, data updating completely by special data provider cannot meet the increasing user demand; what the consumers paid for is not exactly what they wanted most; LBS service and system design are not ego centric but allocentric; and no valid alternative service or measures when network connection is unstable. This paper presents an innovative cell-based multi-level hierarchy data-service infrastructure which is composed of ubiquitous computing technique, GIS and cognition science can partly solve aforementioned problems. In the data-service infrastructure spatial and non-spatial are stored and indexed in cells in various granularity according to various granularity; data provider and individual provide heterogeneous spatial and non-spatial data through web services; data servers provide mobile client-end not allocentric but ego centric service based on context; there is some data replication being stored in mobile client-end, and when the client-end submits query to servers, the servers will check data version of ROI (Region of Interest) in database with the one stored in client-end. The mobile client-end will then decide whether download data package or not; the query result will be packed in one or more package(s) and the package(s) will be transferred sequentially according to their importance grade; the data flow between servers and mobile client-ends is bidirectional; data service consumers are data verifier, data evaluator and data provider too. In the data service infrastructure, lower threshold makes every netizen become data provider and contribute to QoS improving; celled-based data storage makes data transfer and data replication easy to implement; data sequential transferring according to importance grade make users(especially emergence rescue) can get essential data service in the first time in unstable network connection condition, and data evaluation based on spatio-temporal data mining provide an efficient and objective information extraction method. Experiment proves that our data-service infrastructure is efficient and effective in navigation, Wayfinding and emergence rescue.

1. INTRODUCITON

With the rapid development and widespread deployment of information and telecommunication technologies integrated with lightweight mobile devices and terminals, LBS (Location Based Services) has become one of the quickest developing technology in the past two decades. LBS, as being defined as “any service or application that extends spatial information processing, or GIS capabilities, to end users via the Internet and/or wireless network” (Koeppel 2000) or “A wireless-IP service that uses geographic information to serve a mobile user. Any application service that exploits the position of a mobile terminal” (Mabrouk 2005) was constrained to more development and employment by its QoS (Quality of Services). To LBS consumer, the critical QoS problem of current LBS is “what I get is not what I want mostly”. The problems include partially that: data especially none-spatial data is out-of-date and/or error, data updating mainly by special data provider cannot meet increasing user demand; what the consumers get is not exactly what they most wanted; the partially data renew may lead to fully client data updating; LBS service and system design is not ego centric but allocentric(Brown and Laurier 2005; Dransch 2005); and no alternative service or measures is valid when network connection is unstable. These problems are origin from the data service infrastructure. In this paper, we try to propose Mobile SVG based LBS data service frame to solve these problems.

The following part of this paper is arranged as follow: Section 2 describes the data service infrastructure in the aspect of data format, data storage, added value data providing, data updating, data transferring, and data evaluation; Section 3 describes the implementation and key technologies; Section 4 introduces the prototype system and experiment; and the conclusion is discussed in Section 5

2. DATA SERVICE INFRASTRUCTURE

2.1 Vector vs. Raster

There are always discussions about vector format vs. raster one in the development of LBS. Vector format data have the advantage of small data quantity, quick transfer speed, multi times using once downloaded and no need of keeping client-end always online with server when map roaming, and disadvantage of data visualization depending on specific client software. Raster format data needs no specific visualization software, but has the flaw of larger data quantity and frequent data interchange with server even any map operation like panning. In the early stage of LBS development when mobile phones are

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the main stream client-end device, raster format is widely used due to limitation of client-end poor data storage capability, computing power and non-open operation systems. In the recent decades, more and more users use PDA (Personal Digital Aids) as LBS client devices. With increase of data storage capability of PDA and computing power, more and more researchers tend to employ vector to represent spatial data in mobile client. When PDA stores some spatial data in vector format spatial data in mobile client, these data is not necessary to be re-downloaded from server when map roaming. The mainstream PDAs in current market have more than 1G data storage capability, which can store principal spatial data layers of a middle city of China. This method can reduce the network transferring load effectively.

2.2 Cell-based spatial data storage and spatial data indexing

The spatial data of desktop GIS is organized and indexed based on spatial object. In this method, a spatial object is abstracted as complete and continuous geometric objects such as point, line, area and volume. The commonly used spatial indexing method includes kd-tree, B-tree, Quad-tree, R-tree and their variety(Guttman A. 1984). These methods are efficient in desktop GIS due to high computing power and storage capability of desktop computers. In mobile GIS, as being limited by only one thirtieth or less computing power of desktop computers and one percent or less of data storage capability of desktop computers, the data storage and indexing method based on spatial objects performs not so good in mobile GIS. In mobile GIS, the server has massive storage and computing power, how to make full use of this power and avoid mobile client computing and storage flaw is a critical issues in infrastructure designing. The main usage of map in mobile GIS is spatial data visualization, and little is involved with complicated spatial computing. It is reasonable to arrange complicated computation and massive data storage in server and only data visualization task and a small number of data storage in mobile client. In this paper we propose cell-based spatial data storage and indexing method.

In this data infrastructure, spatial data is divided into rectangular cells in specific granularity and scale, and each cell is assigned in specific rule (such as Morton code). The vector graphic of each feature are divided to fragments by grids, while the attribute maintain in whole. Each cell has its version information, which includes version number, data updating time, and description information. No matter the feature's shape or its attribute is modified, the cells that the feature covers and only those cells will be updated. When mobile client sends request to the server, only those cells in request region are responded and downloaded. In spatial data storage and spatial indexing based on feature, although only a small part of feature is in the range of AOI (Area of Interest), the server will transfer all nodes of this feature as a whole to mobile client. That may make data transfer load heavier and data storage redundant in mobile client especially when dealing with those spatial objects with long strip shape or covering large area. In spatial data storage and indexing based on cell, as only the cells covered by AOI are responded and transferred, this flaw can be eliminated. In mobile client, as the query area being restrained in the cell of POI (Point of Interest), the efficiency the data retrieval and query is higher. In feature based spatial data storage and indexing, the mobile client need to compute how many and which spatial object that is covered by new AOI when AOI is changed (such as zoom in, zoom out or pan), while in cell-based data storage and indexing, the computing complexity (determined by the cell numbers of new AOI cover) is more low.

2.3 Data providing based on Web services

In traditional LBS data service framework, data provider and updater are from professional organization (in China, it usually refer to Bureau of Surveying and Mapping) with strict data checking and audit mechanism and means. That guarantee spatial data quality (mainly in accuracy and precision of spatial objects position), however in the same time too high data providing technical threshold prevents more organization and individual with richer data resources from entering into LBS data service system. This is the main cause of LBS data impoverishment. In fact, the LBS consumers could tolerant some inaccurate information. (This phenomenon has been verified in internet circumstance, which is filled with abundant inaccurate information) i.e. they want to get more non-spatial data service that need not so high accuracy while they enjoy spatial data service with high precision. LBS consumers need not only spatial data service but also non-spatial data service. Spatial data service provides the basis and common data visualization and integration platform, and non-spatial data service provides added value information. In the recent years, the demand of non-spatial data services is increasing, but service LBS provided quantity and quality hardly meets the LBS consumers' satisfaction. The non-spatial data providers are short of spatial knowledge, and cannot provide their data service based on spatial position. How to integrate spatial and non-spatial data in a low threshold platform is a critical issue. Web services(Lehto and Sarjakoski 2005), which adopts a series specific protocol to describe, transfer and interact with services, is the feasible measure to integrate information from various domain. In Web services based LBS data service providing infrastructure, spatial data is provided and updated by professional organization, and non-spatial data is provided by various data providers distributed around the world. The LBS server only store data services catalogue, and when mobile client moves into the specific region and sends request to the server, the server will send request to service providers according to service catalogue. When the server receives web service from added value data providers, the spatial data and non-spatial data will be integrated and send to LBS mobile client. This data service infrastructure not only assures the accuracy of spatial data, but also lower data providing technical threshold and attracts more service providers enter into data service group with rich data service source and improves QoS of LBS data service by enriching LBS service content.

2.4 Incremental data updating in mobile client end

Since PDA have emerged to the main stream mobile client-end device, mobile client have considerable capability of storage of considerable quantity of spatial data. In order to keep data especially spatial data synchronization with server, the mobile client local data must be updated. Data updating includes entire updating and incremental updating. The former will occupy a lot of mobile client storage resources and heavier network transferring load. In incremental data updating strategy, only renewed data fragment is downloaded from server and updated in mobile client, the network transferring load and erase-write times in mobile client flash disk is relatively smaller. In feature-based data organized infrastructure, the incremental data updating is hardly to implement as it is a time-consumed task to find the specific feature which has the same Object-ID with the one on server, then delete and replace it. In cell-based data organization infrastructure, any feature renewing only involves the cells that the feature covers. The server only updates the cells which is covered by the renewing feature, and modifies the cells version information. And only when the mobile client access to those cells, those cells would be downloaded and update cells stored in mobile clients respectively. Incremental data updating lower data interchanging load between server and mobile client, and ensure the mobile client data keeping in pace with server when those data is requested.

2.5 Sequent data transferring based on importance grade

In LBS application environment, the data may not be downloaded timely due to the unstable network connection. If all the to-be-downloaded data are packed in one package and transferred in whole, the mobile client will not get any service until all the data is downloaded completely. The unstable wireless network connection or any other network accident may lead to service unavailable. In LBS database, the spatial data is organized hierarchically (it usually refers to layer), and so is non-spatial data. To different users, the importance of different layer is different. e.g. To navigation users, the importance sequence of layers may be: road intersection, road, landmark, building etc. while to fire Figure hter, the importance sequence of layers may be: electric network, hydrant, building, road etc. If the data is packed into various package and transferred sequent according to layers' importance level, the mobile client would receive and visualize various data package according to their importance; the most important data will be displayed in the first time, the less important data will be displayed in follow. It is of special significance to some LBS users in emergence (like rescuers and fire Figure hters) or in high-speed circumstance (the moving speed is greater than the data download speed).

Information extraction based on data mining

In traditional LBS systems, the consumers contribute little to improvement of LBS QoS as they receive and consume data service passively and without convenient access to feedback and data service quality evaluation. The collective power of consumers has been ignored. Some LBS systems have their service evaluation system, but it is not so efficient due to the feedback is mainly done by human operation and influenced subjectively. The LBS mobile clients' traces which are collected by GPS or other positioning devices form trajectory, which hide users' subjective purpose and a large amount of circumstance information. Some circumstance information is interesting to LBS users and what the LBS database is lack of. Data mining, which is also called as patterns finding from trajectories has become a hot issue in domain of data mining and geographic science(Nanni, Kuijpers et al. 2008). And it is an effective method to find hidden and interesting spatio-temporal information from massive spatio-temporal dataset. e.g. Mining moving pattern in various time intervals (e.g. rushing hour) can find urban distribution(Lee, Paek et al. 2004). Mining live trajectories can deduce vehicle speed and amount and to find live transport conditions (clear route, hot route or closure route). Some researchers try to mine a large amount of trajectories collected by differential GPS for map refinement(Schroedl, Wagstaff et al. 2004). Some business management condition can be mined from the amount of LBS users assembled in specific time interval. e.g. It can be deducted the business state of some restaurants from the amounts of consumers in dinner time. Not only LBS database map refinement can be done based on the mining results, but also the evaluation of LBS added value interesting point (like restraint, hotel) can be executed on the basis of the mining results. The result of evaluation based on data mining is more objective and efficient than the one based on votes or other human evaluation means.

3. IMPLEMENTATION

In this chapter, we will discuss the implementation of LBS data service. Section 0 introduces data organization based on Mobile SVG, an open graphic standard. Section 0 introduces the data flow of LBS services. And data mining based information extraction is discussed in section 0.

3.1 Data organization based on Mobile SVG

We choose Mobile SVG as the spatial data storage and map visualization standard. Once the format for spatial data content encoding becomes standardised, opportunity will also ensue for the development of a standardised method for defining visualisation characteristics. The SVG specification is an XML technology developed by the W3C to create a standardised vector graphics format for the Web environment. The specification is a W3C recommendation(W3C 2003). The SVG format is widely seen as a probable future standard for all types of vector graphics on the Web and some embedded devices. In texts dealing with SVG technology, maps are frequently mentioned as a typical application area for the SVG format. Currently, SVG images can be visualised on a Web browser, e.g. by using an Adobe-provided SVG Viewer plug-in(Adobe 2003). The SVG standard and its element must be extended and specialized before being applied to spatial data storage and visualization.

Spatial data is organized as layers according to spatial clustering. An SVG is a data block determined by extent defined by minX, minY, maxX and maxY. Each layer is partitioned to grids cells according to specific width and height and specific origin point. Each cell is a SVG block removing SVG file head. The attributes of each SVG element are extended to spatial attribute of feature.(Ramos, wright et al. 2006) An SVG file is consolidated to map project, which includes an elementary <svg> element. An elementary <svg> element includes multi <svg> child-element which is consolidated as block. In each block, cell row number <cellRowNum>, cell column number<cellColNum>,cell name<name>, cell version<Version>,cell description<des>, cell width<cellWidth> cell height<cellHeight>, X-coordinate of origin point <originX> and Y-coordinate of origin point <originY> are added. Each cell consists of one or more layers, which is consolidated as <g> element. Each <g> element includes one or more feature, which is denoted as <circle>, <polyline>, <polygon> and <text> corresponding to spatial feature of point, polyline, area and annotation respectively. The following code is an example of SVG file.

```
<svg width="200" height="260" viewBox="0 0 200 260">
    <svg cellRowNum="065013" cellColNum="021325"
    name="Building" version="20060125" des="modify
    building" cellwidth="200" cellHeight="260"
    originX="352450" orginY="2578250">
      <g>
        <polygon fill="#EFE4BE" stroke="blue" stroke-
          width="0.48058" owner="The sixth Kunming
```

```
            middle school" build_Time="1985.10"
            points="56.22807, 28.58499 65.8397, 24.021
            74.97075, 50.44409 76.4125, 73.26404 60.5533,
            74.22488"/>
        </g>
    </svg>
</svg>
```

Non-spatial data service providers provide heterogeneous and heterologous data by web service, which is self-description and in XML standard, which SVG is compatible with. The XML code can be added into SVG document dynamically and can be explained and visualized in mobile client.

The mobile SVG document contains map controlling script element which fulfils some map functions like map visualization, feature inquiry etc. In ego-centric designing based LBS mobile client, each mobile client has its personalized script code to control map visualization and information query. In addition, the same mobile client in various circumstances, the ego-centric designed script code can be added into SVG document when the SVG files are integrated.

3.2 Data flow of LBS data service

The ROI of mobile client covers one or more SVG cells (Figure 1). When the user operates the mobile map, there are four possible cases, which include: 1) the operation is merely zooming (in/out), panning and feature info identity. And the new ROI doesn't exceed the extent of initial SVG doucment used by mobile client (Figure 1-a); 2) the operation is merely zooming (in/out), panning and feature info identity. But the new ROI exceed the extent of initial SVG document (Figure 1-b); 3) the new ROI doesn't exceed the extent of initial SVG document, but the operation is complicated spatial query or spatial reasoning like way-finding (Figure 1-c); and 4) the new ROI exceed the extent of initial SVG document, and the operation is complicated spatial query or spatial reasoning like way-finding (Figure 1-d). In the first case, the mobile client initial SVG document need not be renewed from client svg data set or downloaded from server. The script code embedded in svg document can fulfil these operations. In the second case, the mobile client will send request to server with the current using cells version information (if mobile client has). If the svg cell version is newer than the one in mobile client, or there is no svg cell needed in mobile client, the mobile will send request to server and download corresponding svg cell from server. The downloaded svg cells will be stored in mobile client and renew the older version svg cells if there is any older version svg cell. After the initial svg document replaces corresponding svg blocks with downloaded ones, the current viewBox will redraw. In the third case, the initial svg document will not be renewed, and the mobile client sends spatial query to the server and adds query result to current svg document and viewBox redraws. The fourth case is a joint case of the second case and the third case.

Before mobile client sends request to the server, the mobile client will composite the initial SVG document using the local SVG cell file and view in display. When mobile client receives new svg cell of spatial data or query result, the initial SVG document will be updated. After update function replaces old <svg> file group with downloaded <svg> file group, the viewBox will redraw. This method ensure the mobile client can access the newest data in good network connection condition, and in worse network connection condition there is still map displayed in client and the operation such as navigation, map exploring and feature identity is valid. When the server gets request from mobile client with cell version in mobile client and query statement, the server will check the cell versions with corresponding cells. If there is one or more cell with newer version, the svg cell will be taken out and integrated with XML code from web service and query results. The .svg file will be compressed to .svgz format in order to reduce file size and transfer time.(W3C 2003)

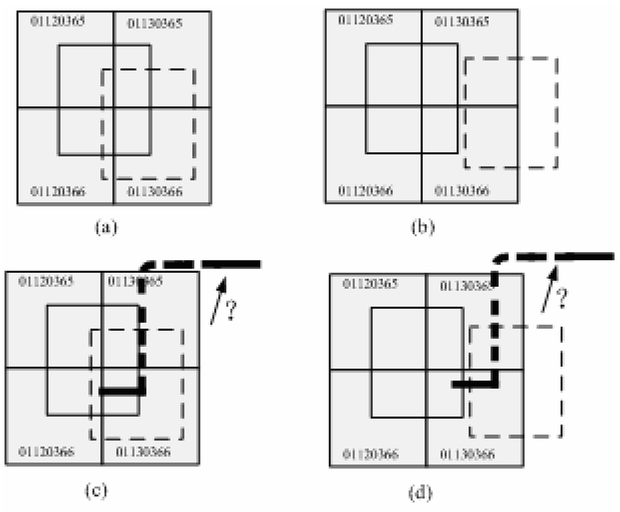

Figure 1 Four Cases of Mobile Client Data Access (The solid rectangles with number are svg cells with their cell number; the transparent rectangle with sold outline is initial ROI of mobile client; the one with dash outline is the new ROI; the bold dash line with an arrow and a question mark is represented as a complicated spatial query.)

When mobile client receives .svgz file, the mobile client will decompress .svgz file and filter the spatial cell svg fragment and replace corresponding local cell file. The view function will integrate local svg fragment, the downloaded svg fragment and query result, and redraw the viewBox. Figure 2 shows the whole data flow.

(1- user operates map and make request through client interface; 2-request doesn't exceed current svg document extent, the script code deal with the request. The mobile client does not send request to local svg data set or server; 3- request exceed current svg document extent, the mobile client retrieve from local svg data set; 4- the retrieval data load in the using document; 5-send request to server through wireless network; 6- the server receive the SVG cell number and their version; 7- send spatial request to spatial database; 8- send request to added value service providers through web service; 9- return retrieved svg cell (in this example, only 3 of 4 cells retrieved); 10-Web Services send back request result or added value service result; 11-SVG and XML are integrated and compressed to .svgz packages according to importance grade; 12- mobile client receives .svgz packages and decompresses them; 13- the current svg document refresh partial or whole data according to response; 14-mobile client save and replace local svg cells; 15- map redraw.)

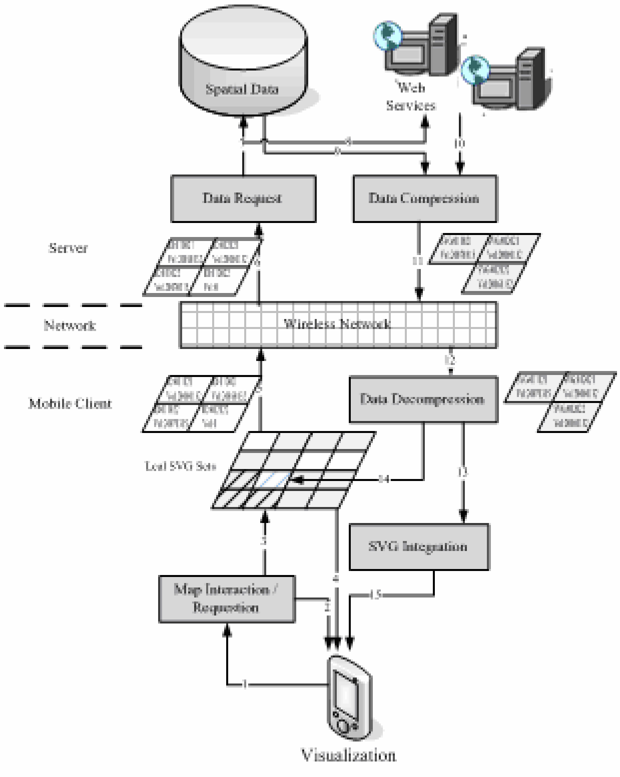

Figure 2 Data flow of LBS

3.3 Information retrieval and Data evaluation based on spatio-temporal data mining

"Data mining", often also referred to as "Knowledge Discovery in Databases" (KDD) and "Pattern recognition", is a young sub-discipline of computer science aiming at the automatic interpretation of large datasets. Knowledge discovery in databases (KDD) is the non-trivial extraction of implicit, previously unknown, and potentially useful information from databases (Fayyad, PiatetskyShapiro et al. 1996) (Kriegel, Borgwardt et al. 2007). Spatio-temporal data mining is a novel train of thought to extract hiding and useful knowledge from moving objects trajectories.

Moving objects trajectories are mixed result of moving objects' 'subjective purpose' and constraints of the circumstance. The 'subjective purpose' is explicit, which can be easily derived from the start point and end point of trajectories or parts of trajectories. Mining 'subjective purpose' can extract many interesting patterns of human behaving (Gidófalvi and Pedersen 2007). The constraints of environment are implicit and mixed by many factors, but are interesting and valuable too. The circumstance constraints include topological constraints and temporal constraints. The topological constraints include restrictions of the road network and obstacles of unmovable objects, etc. The temporal constraints include limitation of temporal rules and accident, etc. A single trajectory is blended with moving object's subjective purpose, synthetic topological constraints and synthetic temporal constraints. It can be noted as:

$$traj = purpose + \sum constr\_topo + \sum constr\_temp \quad (1)$$

The topological constraints can be decomposed to many sub constraint factors such as: speed limitation of specific roads or road parts, turn forbidden of specific intersections etc., while the temporal constraint can be decomposed to many sub constraints factors such as: traffic control in specific time interval, traffic jam, and road-closure in specific instant etc..

$$\sum constr\_topo = constr\_topo_1 + constr\_topo_2 + ... + constr\_topo_m \quad (2)$$

and

$$\sum constr\_temp = constr\_temp_1 + constr\_temp_2 + ... + constr\_temp_n \quad (3)$$

Various trajectories have various topological constraints and variant temporal constraints. But it is possible that two or more variant trajectories have one or more common sub topological constraints factors, if the trajectories pass through the same area and are influenced by the same constraints factors. In like manner, when two trajectories pass through the same area in the same interval, they may be influenced by one or more common sub temporal constraints factors. It was tested by many applications that data mining could find association rules from large amount of phenomena which is not related on appearance.(Lee, Paek et al. 2004) The added value service evaluation could be implemented in similar way.

Mining trajectories speed and amount can extract live traffic conditions like clear route, busy route, and route closure. More accurate analysis can extract lane information like turning forbidden intersection, one-way lane and specific turning lane. The consumers' amount and consumers staying time in specific places and in specific time interval can reflect the management condition and service quality of marking point provided by added value data providers in LBS. These evaluation based on spatio-temporal data mining is more efficient and objective than the ones in other ways.

4. EXERIMENTAL RESULT

We choose Kunming, the capital of Yunnan province of Southwest China, as experimental region. The cell size is 500m ×500m. The average size of each cell svg file is 5kbyte. The spatial data is from fundamental maps in scale of 1:10000, and non-spatial data includes all star-level hotel, restaurant, sightseeing and everyday weather reporting. The LEO Pocket PC2002, Legend XP 218 and Dell Axim X51 are chosen as mobile client end, and GPRS is chosen as transferring network. Each mobile client pre-loaded 50~75% spatial data cell randomly. There are 70 taxis and 26 private cars volunteering in the lasting 30-days experiment. The experiment simulates two LBS application environment: walking and driving. The experimental result shows that the average refresh time is less than 0.5 second, the maximum refresh time is about 1 second (to download several svg cells or execute complicated spatial query.). The weather services, hotel services, and sightseeing are provided by web services in distributed environment. The typical data mining from the trajectories application is finding live traffic conditions, traffic map refinement and hotel management evaluation. Trajectories mining results find 2 new roads and 18 no-left-turn intersection. The service equality evaluation make a conclusion that a hotel management is much better than another, as the Figure ure shows the amount of taxi which destination is the hotel is much bigger than the one to another. Figure 3 is an example of inquiring Five-Star Hotels in the vicinity of 200 meters

Figure 3 An Example of Inquiring Five-Star Hotels in the Vicinity of 200 Meters

5. CONLUSION

This paper presents an innovative cell-based multi-level hierarchy data-service infrastructure, which consists of the cell-based data organization, web service based data provider, incremental client data updating, sequential data transferring based on importance grade, and information extraction and data evaluation based on spatio-temporal data mining. The implementation and experimental result shows that our data-service infrastructure is efficient and effective to improve QoS of LBS and partially solve the current LBS problems that include out-of-date data, poor added value service and un-stable network connection.

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