MULTIPLE REPRESENTATION DATABASES TO SUPPORT VISUALISATION ON MOBILE DEVICES

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ABSTRACT:

This paper presents some applications of mobile map technology utilising an MRDB (multi-resolution/-representation database). An MRDB can be described as a spatial database, which can be used to store the same real world phenomenon at different levels of thematic and geometric detail. Additionally the corresponding objects in the different levels are linked. Case studies of utilising an MRDB in combination with WFS (Web Feature Service) have been implemented and will be presented in this paper. To compensate the limitations of the small display of mobile devices multiscale maps are created. The scale will decrease continuously starting in the centre up to the map border, like a magnifying glass effect. Additionally in the centre of the map the built-up areas are exchanged by buildings. Another use of the MRDB is to emphasise special objects like landmarks or points of interest inside the map. These objects of interest are presented in a higher LoD (Level of Detail) than the other objects to direct the attention of the user to the important facts of the map and to design a clear visualisation. The MRDB can be helpful to support these kinds of presentations and applications as it maintains all the necessary data (levels of detail) and also the necessary links between these levels. This study is part of *GiMoDig*, a European project that aims at developing methods for spatial data distribution from national primary geo-databases to mobile users.

KURZFASSUNG:

Eine MRDB ist eine räumliche Datenbank, welche die selben Objekte der Umwelt in unterschiedlichen Auflösungen und Genauigkeiten speichert. Gleichzeit werden die korrespondierenden Objekte in der Datenbank miteinander verlinkt. Es wurden verschiedene Anwendungen entwickelt, welche in Kombination mit einem WFS (Web Feature Service) mobil auf diese MRDB zugreifen. Um beispielsweise die Nachteile kleiner Displays auszugleichen, wurden multiskalige Karten erzeugt. Hierbei nimmt der Maßstab von der Mitte oder der Position des Nutzers ausgehend kontinuierlich ab, gleichzeitig werden die Objekte im Betrachtungszentrum durch Objekte höherer Auflösung ersetzt. Eine zweite Anwendung visualisiert Landmarken und points of interest (PoI's) durch Darstellung der relevanten Objekte mit einer höheren Auflösung als die übrigen Geometrien. Diese und weitere Anwendungen werden erst durch die Struktur und den Inhalt einer multiskaligen Datenbank ermöglicht. In dem EU-Projekt *GiMoDig* werden Methoden entwickelt, um in Echtzeit räumliche Daten, welche in den Datenbanken der europäischen Landesvermessungen vorliegen, an einen mobilen Nutzer zu senden. Innerhalb dieses Projektes werden die Vorteile einer multiskaligen Datenbank zur Unterstützung der Echtzeit-Generalisierung untersucht. Gleichzeitig wird diese MRDB genutzt, um neue Möglichkeiten zur Visualisierung räumlicher Daten auf kleinen Displays zu entwickeln.

1. INTRODUCTION

The latest *Canalys* report (Canalys 2004) points out a still increasing trend related to the number of mobile devices. The EMEA (Europe, Middle-East, Africa) markets register an increase from 1,5 Mill. (Q1/2003) up to 2,5 Mill. (Q1/2004) new mobile devices like PDA's (Personal Digital Assistants) or Smartphones. With the increasing number of these devices the number of applications for these kind of devices is also increasing. Among these a number of application areas, like Location Based Services (LBS) or navigation tools, utilise maps.

The problem at this point is the design of the maps for mobile devices. The deficiency of these mobile maps compared to conventional paper maps or screen maps are the limitations in size and resolution. That means that the criteria of the conventional cartography to visualise spatial data cannot be adopted. New alternative ways have to be found to visualise the spatial information on a mobile device. On the other hand to produce mobile maps on demand offers new possibilities as it can be adapted for a single person and his or her special needs. The spatial data are edited on demand at the moment they are requested within a few seconds. That means these adaptive maps are created individually for each user at the moment they are needed and containing only the actually essential information. During this process certain objects can be emphasised and objects the user is not interested in can be left out.

The aim of our study is to provide individual maps which emphasise the objects of interest and present background objects only in a coarse depiction. This process can, theoretically, be performed only by using real-time

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generalisation. But because the process of generalising data is time consuming and often hard to define analytically we prefer a combination of real-time generalisation and using a Multiple Representation/Resolution Database (MRDB). This database stores different levels of detail of the same real world objects. In this study we study especially how an MRDB can be used in conjunction with the Web Feature Service specification (WFS) from Open GIS consortium (OGC).

The paper starts with an overview of MRDB. The study presented in this paper is part of the EU-project GiMoDig. In section 3.1 a short overview of GiMoDig as well as a description of the GiMoDig system architecture (which is mainly based on OGC standards) is given. Then a short description of the WFS standard follows. Section 5 presents some case studies. These case studies utilise the system-architecture of the GiMoDig-service as well as the MRDB-structure to develop new possibilities to visualise spatial data on small displays as well as to provide new possibilities to obtain spatial information. The paper concludes with discussion and conclusions.

2. MULTIPLE REPRESENTATION DATABASES

2.1 Structure of MRDB

A multi representation database (MRDB) can be described as a spatial database, which can be used to store the same real-world-phenomena at different levels of precision, accuracy and resolution (Devogele et al., 1996; Weibel & Dutton, 1999). It can be understood both as a *multiple representation database* and as a *multiple resolution database*.

There are two main features that characterise an MRDB:

- Different levels of detail (LoD) are stored in one database.
- The objects in the different levels are linked.

The first feature can be compared to the analogue map series of the NMA's: these maps of different scales exist separately, only implicitly linked by the common geometry. In the second case, however, individual objects are explicitly linked with each other and thus each object "knows" its corresponding objects in the other representations.

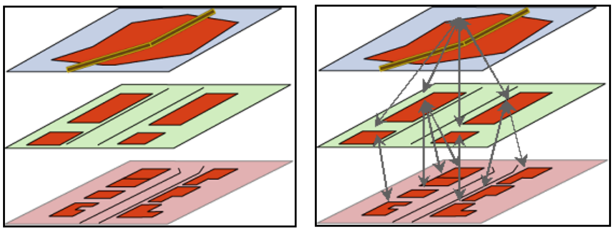

Figure 1. Characteristics of an MRDB: Store multiple representations (left), link corresponding objects (right).

2.2 Applications of MRDBs

There are several applications of MRDB's. Firstly, they can be used for multi-scale analysis of the data: Information in one resolution can be analysed with respect to information given in another resolution. Gabay and Sester (2002) present an example where topographic data is linked with cadastral data. A topographic data set of lower resolution containing only settlement areas is queried concerning the buildings in that area, information that can be derived from a more detailed cadastral data set, whose objects are directly linked.

Another application of an MRDB concerns maintenance of cartographic databases. For example, a major reason for National Mapping Agencies to investigate and implement an MRDB is the possibility of propagating updates between the scales. The appealing idea is that the actual information only has to be updated in the most detailed data set, this new information can then be propagated, utilising the links in MRDB, to all the other scales (Kilpeläinen 1997, Harrie and Hellström 1999).

Vangenot et al. (2002) describe modelling concepts which support not only the multi resolution view but also the different views on the object features like object types, attributes and their values. Kreiter (2002a, 2002b) describes the concept of an MRDB from the NMA's point of view. Cecconi (2003) investigates the use of MRDB for the web mapping.

In this study the motivation to introduce an MRDB was to support and supplement the real-time generalisation. The benefits of the MRDB are exploited by several other use cases like introducing adaptive multiscale maps or to give access to the information of all level of detail stored in the database.

2.3 Combining automated map generalisation and MRDB

To create individual maps for a mobile device real-time generalisation of the data is often required. Considerable progress in this field can be observed in recent years (ICA, 2004), resulting in efficient generalisation methods and algorithms that are applicable to perform scale transitions in given scale ranges. However, the processes involved going from a large scale to a small scale (say 1:10k to 1: 1 Mill.) are very complex. Thus, it is obvious, that (at least today) the generation and visualisation of ad hoc personalised products of spatial data in arbitrary scales on a mobile platform cannot be solved without pre-generalised datasets. Real-time generalisation can only be efficiently performed in limited scale ranges and is restricted to operations of minor complexity that can be solved completely automatically. A way to circumvent the problem of lack of good generalisation routines is to use an MRDB.

To minimise the effort of computation work during the real-time generalisation process, the service selects a scale close to the desired scale requested by the mobile user. Based on this neighbouring scale, only limited scale transitions are necessary, that can be handled in real-time. In this way the need for complex algorithms, for example displacement, can be minimised or even excluded.or

3. THE EU-PROJECT GIMODIG

3.1 Overview

The EU-project GiMoDig, an acronym for "Geospatial Info-mobility Service by Real-time Data-Integration and Generalisation", aims at developing the spatial data delivery from national primary geo-databases for mobile use (Sarjakoski et. al, 2002).

The main vision of GiMoDig is a mobile user, travelling within a European country and receiving on-line information of his or her environment on the mobile device. Even when crossing a border, the type of information presented does not change, thus having the situation, that seamless topographic information is available. Furthermore, it is often required that the cartographic data is generalised and/or integrated with other data before it is sent to the user. To support the generalisation process at this point, investigations in using an MRDB for this purpose were undertaken (see section 2.3).

3.2 System Architecture

GiMoDig aims at distributing cartographic data from core databases at national mapping agencies to mobile devices (mainly following the Open GIS standards). Figure 2 shows a simplified overview of the GiMoDig system architecture (see Lehto, 2003 or Sarjakoski & Lehto, 2003 for details). The client makes a request for a map. The request is transformed in the layers below and is finally formulated as a WFS request (see section 4). The response to this request is cartographic data in the form of GML data (GML, 2004). The GML data are sent to a *processing layer*. This layer performs generalisation of the cartographic data as well as creating new queries to utilise the MRDB. The processing layer then sends generalised cartographic and service data to the layer above. Finally, in the latter layer, the GML data is translated into, for example, an SVG (SVG, 2003) or JPEG image for display at the client.

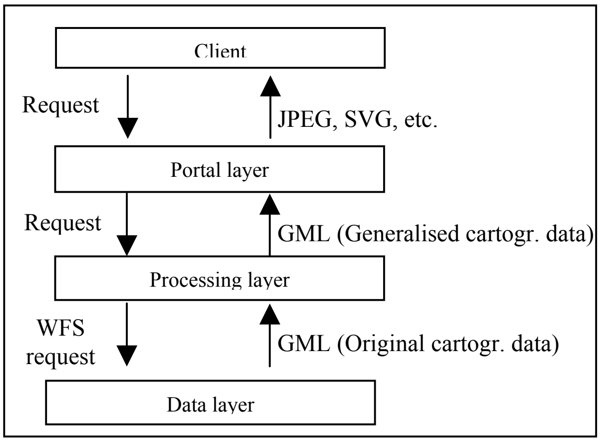

Figure 2. A simplified version of the GiMoDig system architecture.

The main processing platform in the processing layer is a Java-environment called JTS/JUMP (JTS Topolgy Suite, JUMP Unified Mapping Platform) (Vivid Solutions, 2004) which provides certain functionalities to import, handle and manipulate spatial data. The JTS Topology Suite is an API of 2D spatial predicates and functions. It conforms to the Simple Features Specification for SQL (SFS, 1999) published by the Open GIS Consortium and provides a complete, consistent and robust implementation of fundamental 2D spatial algorithms. JUMP provides an API giving full programmatic access to functions, including I/O, feature-based datasets, visualisation, and all spatial operations like buffer or overlay.

During the development phase of the prototype the JUMP environment is also used as an authoring tool to visualise the processed data. Later on the Java-code will work in a servlet environment in the GiMoDig-service.

3.3 Creation of an MRDB

The creation and maintenance of the MRDB is described in detail in Hampe et al. (2003). Here just follows a brief description.

The cartographic data are stored in an object-relational database called *PostgreSQL* (Postgres 2004) with its extension *PostGIS* (Postgis 2004). As our base-data are of a high level of detail, for the scale 1:10k, the other layers were derived from this first dataset by generalising the base data for the scales of 1:25k, 1:50k and 1:100k. Several algorithms to generalise spatial data were developed e.g. for simplification, amalgamation and typification whereas we concentrate on datasets containing buildings or settlement areas and streets.

4. WEB FEATURE SERVICE STANDARD FROM OGC

4.1 Overview

Open GIS consortium (OGC, 2004) has specified standards for cartographic web services. One of these standards is the Web Feature Service specification (WFS, 2004). WFS specifies a number of requests from a client to a server; two of the most basic requests in WFS are: *GetCapabilities* and *GetFeature*. A *GetCapabilities* request could be sent from a client to a WFS server (using HTTP) and then the client will receive information (in form of an XML-file) about the cartographic data available. Based on this information the client could formulate a *GetFeature* request. When the WFS server gets this request it sends cartographic data in form of a GML file to the client.

The *GetFeature* request contains information about which data should be received (both the layers and a bounding box), specification of the spatial reference system (SRS) and sometimes also additional constraints on the data (e.g., that the data should have specific attribute values).

4.2 WFS-access on MRDB

The applications of the case studies are all implemented in the processing layer in the GiMoDig system architecture (cf. Figure 2). The source data will be requested from an MRDB in the data layer via WFS requests. In the processing layer the data is processed and then distributed to the layer on top in form of GML-data. Finally, this data is converted to SVG for distribution to the client. This combination of SVG-data, derived from an MRDB by WFS-requests allows for new possibilities to adapt the maps depending on the actual situation. The user can point out certain objects in the SVG-image and through new WFS requests certain objects or attributes of interest can be retrieved from the database.

The problem here is that WFS does not support requests specific for MRDB's. That is, it is not possible to utilise the links between the layers in the WFS queries as such. Therefore we have used a technique with repeated WFS requests (Figure 3). For example, the processing layer sends a WFS request of a small-scale layer in the MRDB. When the data is received by the processing layer the data is analysed. If necessary, a new WFS request to a large-scale layer is then performed by utilising the link information from the small-scale layer.

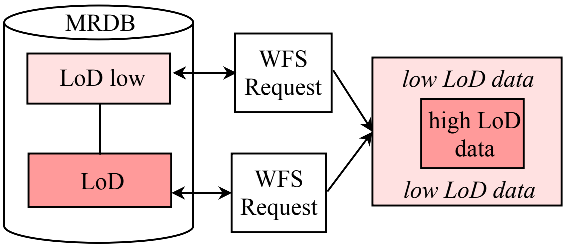

Figure 3. Receive data for multiscale map from MRDB via repeated WFS-request

5. CASE STUDIES

This section describes several applications of utilising an MRDB for creating individual maps in real-time.

5.1 Variable-scale maps

A major problem with mobile maps is their small displays, which puts high demands on the selection of cartographic data to be shown. This becomes problematic when the user requires a considerable amount of cartographic information. In personal navigation, for example, users often need both a detailed map of the area surrounding the current position as well as an overview map. This means, in cartographic terms, that the user requires both large-scale and small-scale cartographic data. To overcome this problem a map can be created where the scale in the middle (close to the user's position) is larger than the scale in the border areas of the display (Figure 4). Details of the type of variable-scale map used in this case study are given in Harrie et al. (2002).

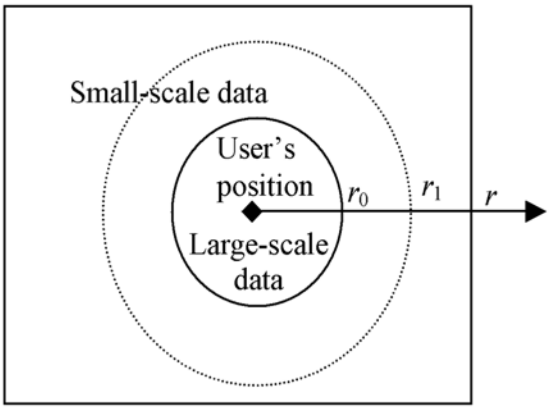

Figure 4. The figure illustrates the circular cap (with radius r_0) where large-scale data is shown and the area outside this cap where small-scale data is shown. (Harrie et al., 2003)

The main problem of creating a good variable-scale map is that the level of detail in the cartographic information should be different in the centre of the map than in the border area of the display. For this an MRDB is very useful.

Figure 5 shows a variable scale map created in real-time using an MRDB. The map was briefly created as follows. First a WFS request was performed to the small-scale layer in the MRDB. In the processing layer then the built-up areas in the centre of the map were identified. By using the MRDB links a new request was performed that requested the buildings (from a large-scale layer in the MRDB) within these built-up areas. These buildings then replaced the built-up areas. Finally, the variable scale map was created by a coordinate transformation.

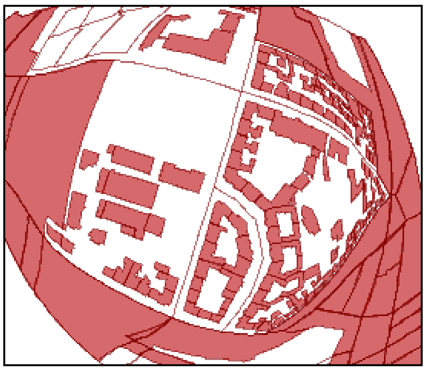

Figure 5. A variable-scale map created using an MRDB.

To create a variable-scale map, such the one in Figure 5, is fairly fast. The process that takes most time in our experiments is the transferring of data from the server to the client. Since the built-up areas objects contain much less data compared to corresponding building objects, the MRDB is an efficient approach for this application. It would take longer time to request all building objects and generalise the outer part of the map (by aggregation) than utilising an MRDB. And most likely, the result is visually more appealing if an MRDB is used.

5.2 Emphasise landmarks and points of interest

For general purposes maps, which serve for a lot more than only one person, the basic principle exists to present similar objects in a similar manner (Hake et al. 2002). The advantage of the non-printed mobile maps is to take the special needs of the user into account while creating the map. The user is interested in certain objects more than in other objects. For instance while navigating the user is interested in landmarks, eye-catching objects or points of interest located within a certain distance from the users position.

To emphasise these objects in the map several possibilities are cogitable. In order to visualise one individual building in the generalised data set a possibility is to use graphic variables like colour, size or the shape of the object (Figure 6 left). At this point the problem occurs that in a certain scale the objects are generalised which e.g. means the buildings are for instance amalgamated which in turn means that we can't localise a single object to point out a landmark or a point of interest (PoI). Alternatively, the position of the PoI's can be marked with a dot or special symbol (Figure 6 right).

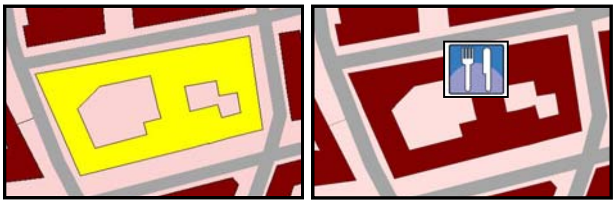

Figure 6. Emphasise PoI using color (left) or symbol (right).

This however hides underlying structures and prevents exact identification of buildings. Thus, a combination of this individual building and the generalised background buildings is desirable, given in Figure 7 (right) with detailed buildings and aggregated builtup areas.

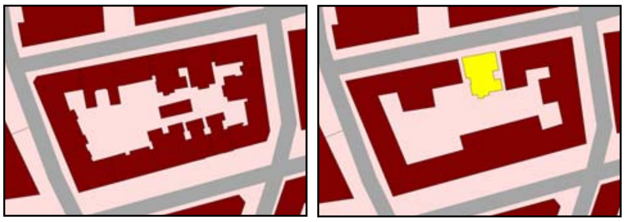

Figure 7. Emphasise PoIs using MRDB: Ungeneralised buildings (left). PoI in full detailed shape, re-generalised remaining buildings (right).

This can be achieved using the following process:
Firstly we identify the building block (Figure 6 left) and then request the individual detailed buildings the block is composed of from the MRDB (Figure 7 left). Afterwards, a new generalisation is triggered where the landmark object stays in original shape and the surrounding objects are aggregated, leading to the final representation (Figure 7 right). A more detailed description can be found in Elias et al. (2004).

On the one hand the user gets detailed information of the objects of interest with a high level of detail and on the other hand he or she gets generalised spatial information of the remaining objects which are adequate for the actual scale and the display size (Figure 7 right).
In this case we preserve a clear map view and at the same time provide all the necessary information covering a larger area.
These kinds of applications can be realised using the structure of the underlying MRDB. Because only a low number of objects has to be transferred and generalised the whole process of adapting the map can be done in real-time.

5.3 Information drilling

Another use case which benefits from the MRDB-structure is the "information drilling" scenario. The mobile or non-mobile user may be interested in a certain area or a certain object in the map. For instance the user can request the buildings which are located inside a certain built-up area or a single building which is part of an amalgamated object in the actual map. For example rescue parties might be interested in a large scale map to navigate to the person who needs help as well as in detailed information of some parts of the map, i.e. the environment of a certain building.

From the users point of view it is only necessary to click on the object or position he or she wants to drill for more information. This click activates a request sending the ID (identification) with the number of the built-up area. A servlet passes this request on the WFS by requesting only those objects which are linked to the requested object. The user can determine the deepness of drilling which can go down to a detailed building plan linked with a certain building.

5.4 Getting attributes from linked objects

In some situations it may be useful to get information which are not connected directly to the objects in the actual map. One example may be the name of a city, district or postcode area which is not typically an attribute of the buildings within the map of a certain scale. However if we go down to smaller scales in the MRDB the object built-up area or city owns the attribute "name of the city" and thus the buildings linked with this object can access this information (Figure 8).

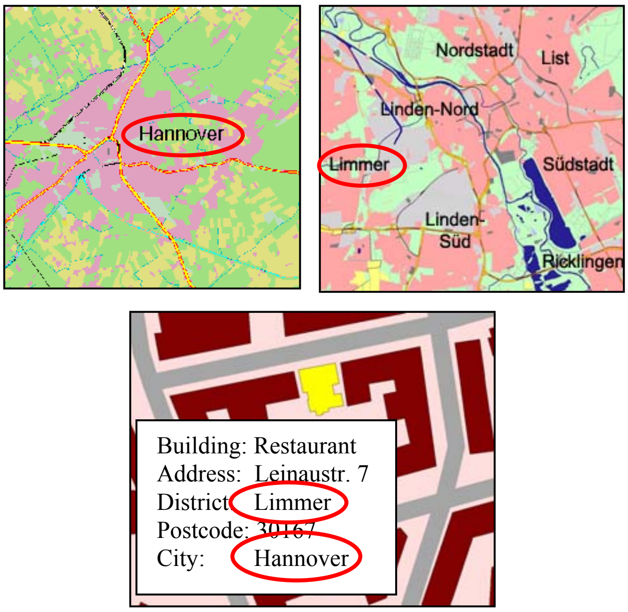

Figure 8. Information from small scale (upper left and right) accessed for large scale presentation using the links in MRDB.

That means the information the user can get is not limited to the attributes stored with a certain feature. Because of the links between the objects in the database the user has indirect access to all the information stored in the database.

6. DISCUSSION & CONCLUSION

The motivation for this paper was to circumvent the disadvantage of small display devices by generating adaptive maps containing only the necessary data visualised in an adequate way. This leads to generalising the data processed in real-time like we aim at in the GiMoDig-project. As the generalisation process can't be handled completely in real-time because of its complexity we need pre-computed data, stored in an MRDB.

As demonstrated by several examples, the benefits of an MRDB can be used for different applications. If we concentrate on mobile applications it serves to customise the map. The objects of interest are visualised in a more detailed way. On the other hand the user gets access to all information related to several scales. The whole architecture combining a WFS and an MRDB allows for fast and mobile access to all spatial information stored in the database. In this study we have shown that an MRDB can be used to enhance the information visualisation on a small display. It is also shown that an approach based on repeated WFS-queries can be used for accessing the MRDB in a real-time environment.
We implemented, tested and presented only some possible use cases based on such a combination. In general the benefit is that there is no need to store all the information on the client device and at the same time the client has access to all the information available in the database.

The future work will concentrate on extending the MRDB to obtain a multiscale database starting at very a high level of detail (1:5k) up to a small scale (1:1Mill.). Additionally the middle layer will be upgraded to contain an intelligent rule based servlet which decides which data have to be requested from the database depending on the users needs. These lead to a more flexible architecture which can serve for several demands.

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