Developing Mobile Spatial Services for the Geosciences*

Martin Breunig[1], Jochen Häußler[2], Wolfgang Reinhardt[3], Joachim Wiesel[4]

[1]Department of Mathematics/Computer Science
Research Centre for Geoinformatics and Remote Sensing
University of Osnabrück
Eichendorffweg 30
D-49377 Vechta, Germany
E-mail: mbreunig@uni-osnabrueck.de

[2]European Media Laboratory GmbH
Villa Bosch, Schloss-Wolfsbrunnenweg 33
D-69118 Heidelberg, Germany
Jochen.Haeussler@eml-d.villa-bosch.de

[3]GIS Study Group
University of the Bundeswehr Munich
Werner-Heisenberg-Weg 39
D-85577 Neubiberg, Germany
E-Mail: Wolfgang.Reinhardt@UniBW-Muenchen.de

[4]Institute of Photogrammetry
and Remote Sensing (IPF)
University of Karlsruhe
Englerstr. 7
D-76128 Karlsruhe, Germany
E-Mail: Wiesel@ipf.uni-karlsruhe.de

Abstract. Mobile information technology offers a new perspective for the geosciences, by providing ubiquitous access to environmental and geoscientific information. With this new instrument the analysis of planning, geoscientific processes, and natural disasters can be supported on-line. In this contribution a geoscientific case study is outlined that shows the potential behind mobile spatial services. First contributions to a system of geoservices usable by on-site clients for geodata management, geodata acquisition, viewing and augmented reality are presented. These clients communicate over network with geodatabase services. Finally, an outlook is given which addresses further research on geospatial services.

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1. Introduction

According to the MICUS market study [FOR03] the utilisation of geospatial information has "a high economic potential and can develop highly innovative products...". In the Unitied States the annual rate of economic growth in the geotechnology segment is foreseen as about 20% which is a volume of 19.3 Mrd. US Dollars for the year 2004. The potential for geoinformation in the European Union has a volume of 35.8 Mrd. EUR. The demand for geoinformation is strongly increasing world-wide. However, its potential has not yet been exploited. Mobile information technology is a new chance for experts, executives, and planners in business and adminsistrative authorities to advance geographic information system (GIS) technology. The number of applications is increasing where GIS have to cooperate with high-performance database management systems [BBB+04] and with powerful mobile applications. This coming paradigm shift from the development of monolithic software systems to flexible and mobile services can be recognized in many other application fields. New spatial services will provide ubiquitous access to geodata needed in applications such as environmental monitoring and disaster management. Therefore the efficient exchange of geodata will be a central and critical task. Furthermore, geodatabases must efficiently manage a huge number of large and complex application-specific objects like 2D, 3D and spatio-temporal models [BCS+03].

In this paper we restrict ourselves to the requirements and first experiments with the development of spatial clients and services usable by mobile applications [BMR+03].

2. Outline of a geoscientific case study

The concrete problem we are refering to is the analysis of slope slides near Balingen in South-West Germany [Ruc02]. Since several years there are active creeping movements of the terrain endangering the traffic on a local road. The geodetic measurements show a gradual sinking of the soil and rocks. A forecast for a slowing down or speeding up of the movements cannot be given. However, mobile data aquisition of the ongoing movements and remote data access to a central station help to watch the situation.

The available primary data of the Balingen examination area are fix points with direction vectors, measurement plots of the extensiometers, digital elevation model, contour lines, path network, measurements, structural edges and slopes in scale 1 : 250. From these primary data the following interpreted data are constructed: 2D profile sections, stratigraphic boundaries, 3D strata bodies.

Typical requirements of the Balingen case study to geoservices are:

- Storage and retrieval of digital elevation model, 2D profile sections, and 3D models.
- Online geodata acquisition and analysis of the terrain.
- Geodata editing of rocks and splits in the terrain.
- Viewing of primary and interpreted data in the terrain. Overlapping of 3D model and reality by augmented reality methods.

The Balingen case study is a typical example for the use of modern geoservices for environmental prediction.

3. First results

3.1. 3D geodatabase kernel services

To support applications like the Balingen scenario, geodatabase services must provide access to entire 3D-models, as well as to 2D representations (projections and sections) derived therefrom. However, a comprehensive subsurface model may consist of hundreds of geological bodies, each represented by complex objects, e.g. triangulated surfaces, composed of up to more than a hundred thousand elements (e.g. triangles). Considering a portable client instrument, e.g. a robust PDA combined with a GPS client, both the transmission and the graphical representation of such a complex model are not yet realistic, because of insufficient available bandwidth and performance of the graphical display. On the other hand, the geoscientist in the field often needs only a selected part of the information, specified by e.g. a 3D-region, a stratigraphic interval, a set of thematic attributes and some other geometric and thematic criteria. Even such a reduced information may be too large for use in the field, motivating the use of techniques of data reduction and progressive transmission [STC+02]. Graphical representation of a 3D-model can be reduced to a sequence of 2D-sections and projections that are displayed using the limited graphical capabilities of a mobile client. By sliding through successive sections, even a 2D display can provide insight into the form and structure of a complex 3D body.

We are exemplary presenting the 3Dto2D composite application service. Such a service on a mobile device will allow the field geologist to compare the actual observed situation with information provided by the subsurface model, and to take decisions on sampling accordingly. It provides the derivation of 2D profiles from a 3D model and is composed of the following elementary services:

- *RetrieveService* – supports queries for the complex geoscientific objects.
- *PlaneCut* – cuts a planar profile through the 3D model for a given plane.
- *PlaneProjection* – projects objects onto the plane profile.
- *AffineTransform* – transforms the resulting 3D object into a 2D xy plane.

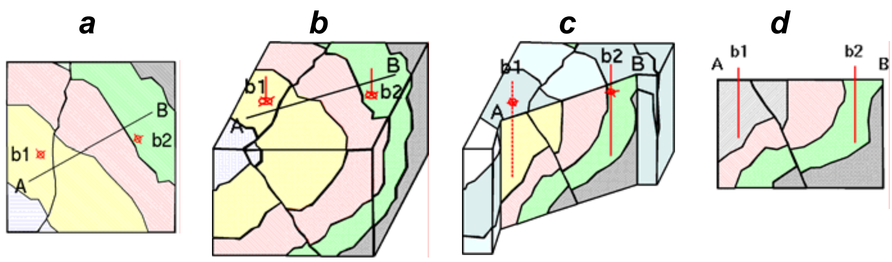

Figure 1: 3Dto2D service

Figure 1 shows the principle steps. The user may specify a planar profile section between endpoints *A* and *B,* with further data such as spatially neighboured boreholes *b1* and *b2.* Figure 1 (a) shows the location in map plane, figure 1 (b) the block view of the 3D model, figure 1 (c) the view of profile section with part of model removed. Finally figure 1(d) shows the resulting 2D profile section with the projected borehole profiles as additional information. The 3Dto2D service has been implemented as remote method invocation in Java.

Each of the elementary services implies geometry operations, and in consequence requires a considerable amount of time. Therefore, in order to reduce the length of transactions, the elementary services of which this 3Dto2D service consists of, are operating each in transactional mode. Single failures of an elementary service can be compensated by restarting the elementary service, and do not require starting the whole process from the beginning.

3.2. Mobile data acquisition of geodata

In our project environment mobile data acquisition of geodata mainly is aiming at the following goals:

Refinement of concepts for mobile data acquisition

This point includes the following important research issues:

- The development of refined worflows for mobile data acquisition which make fully use of the possibilities of the ubiquitous access to various sources of information.
- Quality Management: The already mentioned concept of ubiquitous access allows for various kinds of quality checks directly in the field. Besides a test for completeness of data and also for various aspects of correctness can be treated, for example forbidden overlaps of new collected objects with existing ones, just to give an example. A detailed concept for Quality Management directly in the field will be worked out in the framework of our project.
- Multi sensor treatment: In an user scenario for an application like the Balingen test area, as outlined above, a various number of sensors like GPS receivers, total stations and other geodetic instruments, extensometers and even laser scanning devices have to be considered. There is no continuous concept available to integrate all these data from various sensors logically. The OGC proposal “SensorML” aims at the integration of different sensors but it is not yet clear to what extent the requirements of such a project can be fullfilled.
- Besides also technical issues like the connectivity via wireless techniques have to be investigated. In rural and especially forested areas cellular radio and wireless LAN have to be combined to cover a area of interest.

Development of a prototype system

Within the project a prototype for mobile data acquisition of geodata has been developed and will be extended in the last phase of the project. The most important guidelines for this development are:

- An open architecture based on standards, which means that no propriety vendor dependent modules are included and for example for the access of data, standards like the OGC web map and feature services (WMS and WFS) and the geographic markup language (GML) are used. Also the connection of sensors should be standardised as mentioned before. Section 3.3 (Graphical geodata editor) includes further explanations regarding to this.

- A generic approach of data acquisition which allows for a usage of the system in various applications. This is mainly guaranteed by collecting features according to schema information provided by the accessible servers.

Proof of concepts – Application of the system at the "Balingen test area"

The concepts and prototype implemetations have to be proven in the Balingen test area. First investigations are promising [KMP+04] but a lot of tests have to be carried out in the next phase of the project. Figure 2 shows the system configuration for these tests.

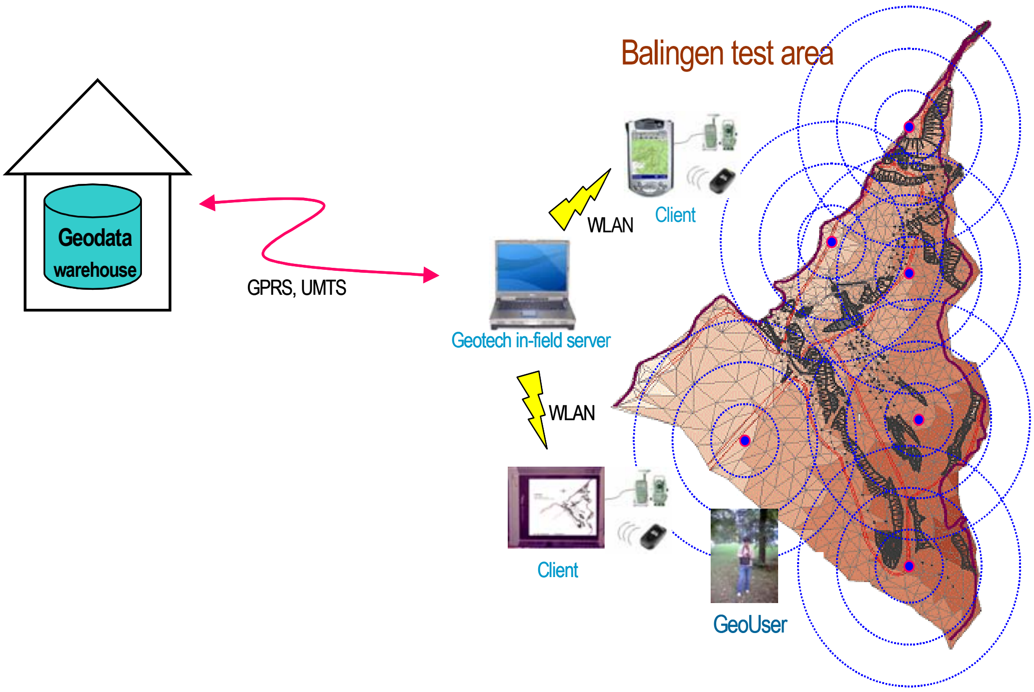

Figure 2: System configuration for Balingen test area

3.3. Graphical geodata editor

A central component of the mobile acquisition system is a graphical editor (see figure 3) for geodata. This is a lightweight Java application running on the mobile device, e.g. a ruggedized Tablet PC. The editor constitutes the user interface of the mobile data acquisition system and provides the core functionality for acquiring and editing geodata in the field. The central element of the editor GUI is a map which displays the geodata received from the server. The usual tools for navigating the map (pan,zoom), getting information about features and editing their attribute data and geometries are being implemented.

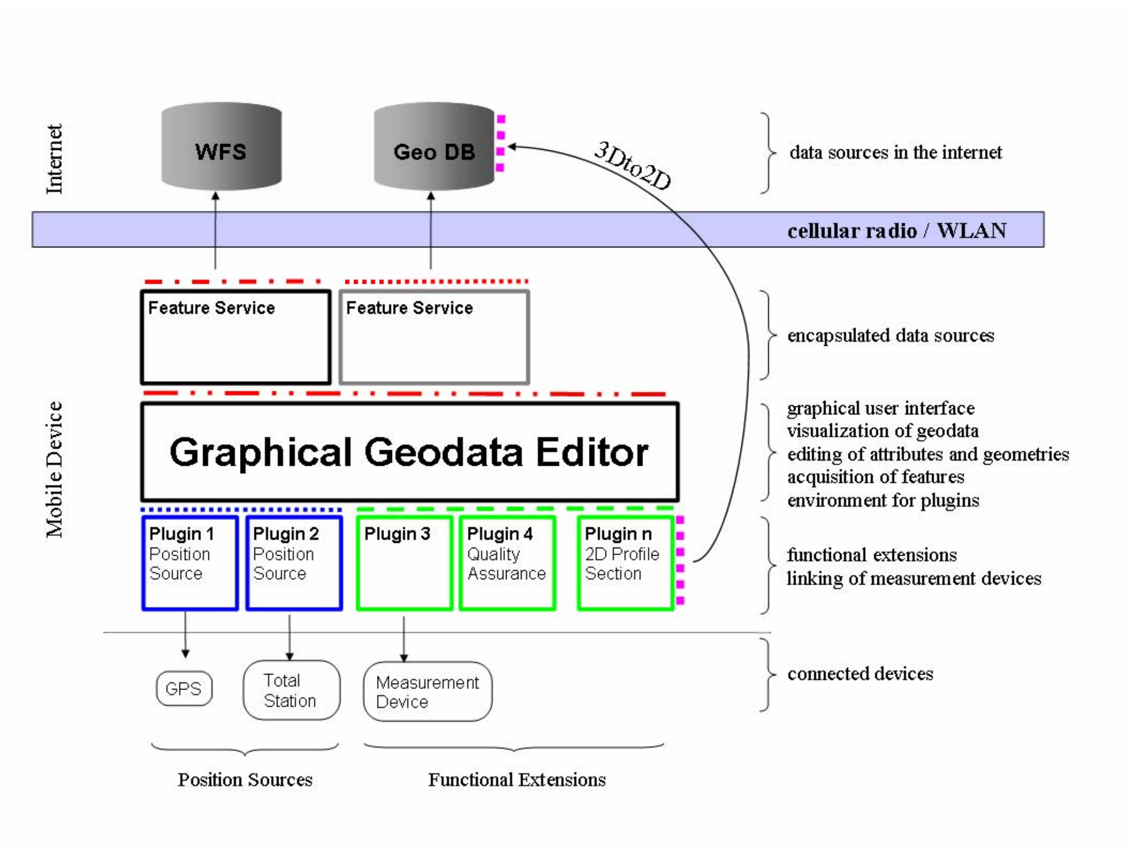

Figure 3: Architecture of the mobile acquisition system

To integrate additional functionality for more specific application scenarios like ours we have developed an architecture and run-time engine for plug-ins. This way parts of the additional functionality can be integrated into the core editor keeping the actual editor component thin. This makes it possible to adopt the system to the application scenario and also fosters the desired reusability of the software application.

One group of plug-ins are 'position sources'. As position sources we denote plugins that provide geo-positions with semantics well known to the user. Examples of position sources are GPS and Total Station. A position source plug-in encapsulates e.g. a single GPS device and provides its measurements to the editor environment, together with additional information like timestamp, precision etc. With such a plug-in the current position can be displayed on the map. Several position sources can be connected simultaneously.

The plug-in infrastructure makes it possible for all plug-ins to connect all registered position sources at any time making the editor a very flexible platform for additional and more advanced functionality.

Other devices which do not function as position sources can connect e.g. other measuring devices which deliver measurements for non-geometric attributes of new or existing features (temperature, soil parameters, precipitation measurements, etc.). Triggering of a single measurement or a series of measurements in certain spatial or temporal intervals and insertion of the respective located measuring point(s) into the database are possible that way.

A third group of plugins are those that do not link hardware devices to the editor but provide other kinds of functionality. Examples of such plugins that are developed in our project include:

- A feature acquisition plugin which generates and adds new features using the position sources as input for the new geometries.
- Sources as input for the new geometries.
- A plugin for quality assurance that controls the correctness of the edited features performing topological tests.
- A 2D Profile Section plugin: The user defines a planar profile section in the map of the editor and gets a 2D profile generated by the 3Dto2D service described in section 3.1.

The described infrastructure provides a flexible and extensible solution for a mobile open standards-based geodata editor.

3.4. Augmented reality client

To support geoscientists doing their field work, an AR System (figure 4) has been designed and built up as a mobile prototype [WSB+04]. We are using a (Stereo) Firewire camera system, a (monoscopic) Head Mount Display (HMD), navigation hardware and the necessary computing equipment mounted on a backpack. The system has been set up to allow a human to walk into the test area and research the geological structures and landslides by

- Inspecting the scene
- Overlaying with time stamped 3D-geo database content (e.g profiles or displacement vectors, geological underground data)
- Gathering new geo data (e.g new clufts or rifts)
- Entering and editing geo data in real time into the geo database
- Entering attribute data into the database

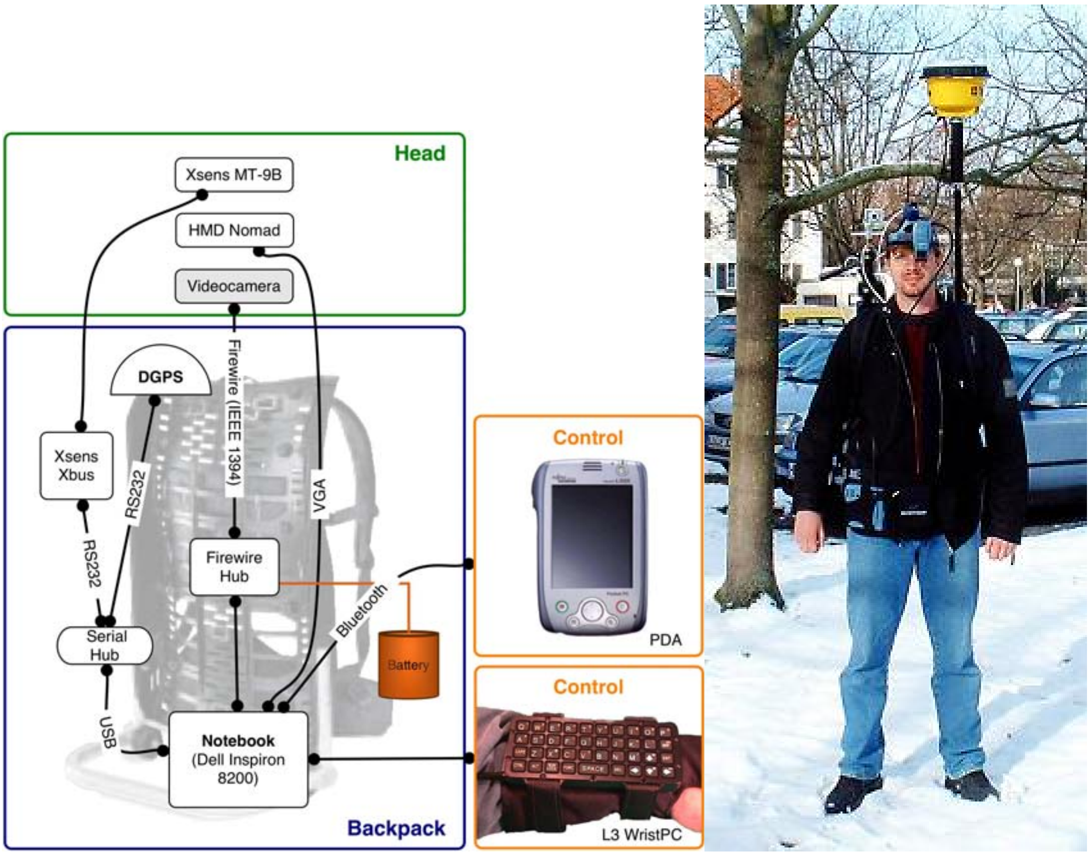

Figure 4: Augmented Reality System Architecture and Hardware Mockup

Navigation and orientation of the sensor system (camera or head mounted display) is crucial for the usability of such AR client. We have combined a GPS-receiver and a low cost Inertial Navigation System (INS) to achieve a positioning precision in the cm range.

By using Real Time Kinematic (RTK) GPS positioning we can achieve a positioning precision down to ±1 cm [SCL04]. Yet in a typical geoscience environment we have to observe GPS dropouts while moving around in the field. To overcome this we are using the Xsens INS system (Figure 4), which can provide velocity, position and attitude of HMD and camera for a short time period .

Studies are going on to calibrate and filter INS data to close the gaps of RTK-GPS measurements.

As the HMD has a very limited field of view and spatial resolution and is only displaying black and white vector data, we have to study the the man-machine interface by free field experiments under different lighting conditions.

4. Conclusions and outlook

In this contribution we have introduced typical geoscientific requirements in a case study presenting first results in the development of spatial clients and services usable by mobile geoscientific applications. The 3Dto2D geodatabase service met the introduced geoscientific requirements by remotely computing 2D profile sections from a 3D subsurface model. Mobile data acquisition and a graphical geo-editor will help geoscientists in their daily work. Furthermore, an AR client is going to support geoscientists in their field work by merging 3D-data base content with the live scene in real time. In our future work we intend to couple single spatial services in a geodata infrastructure and to develop new application services in the geosciences and other application fields.

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