GEOINFORMATIK 2011

GEOCHANGE

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Preface

The *Geoinformatik 2011* is the third in a series of conferences that calls upon researchers from academia and industry. It provides a forum to come together, exchange ideas and advance the state of the art in GI science. *Geoinformatik 2011* covers a number of exciting topics that include established fields in GI science, current and novel GI applications, as well as new and emerging research directions.

This year's conference theme *"Geochange"* reflects the increasing importance of Geoinformatics methodology and application gained in monitoring, modelling and analysing global change. A substantial number of submissions discuss the role of new GI technologies and approaches in climate, environmental, and energy issues. In addition, the contributions published in these proceedings cover many further well established and emerging topics in Geoinformatics including

- mobile technologies,
- real-time data processing,
- spatial information systems and geographical data infrastructures,
- spatio-temporal modelling,
- geosensor networks,
- volunteered geographic information, and
- open source software development.

For the first time, the *Geoinformatik* conference hosts four workshops and two tutorials that cover a range of relevant topics such as climate/environment, mobile technologies, legal aspects of geographical data, and geoinformatics in education.

The conference offers two different tracks with oral presentations: one scientific track with academic presentations, workshops, and tutorials; and one track with invited presentations that discuss innovative applications. In parallel, companies from the GI sector present their products during an industrial exhibition. In total, 30 full research papers and 19 short papers on innovative applications were submitted to the conference, out of which 34 submissions have been accepted for oral presentation at the conference and a further nine as posters. These conference proceedings contain the accepted, peer reviewed manuscripts, and demonstrate the strongly international character of Geoinformatics research in Germany: 36 submissions were made in English. We received submissions from seven different countries.

Many people have contributed to bringing this conference to life. We particularly would like to thank all submitting authors for contributing their high quality papers to *Geoinformatik 2011*. We also wish to extend our thanks to the program committee who critically evaluated the papers and provided valuable comments that were essential to the quality of the conference proceedings. Finally, we would like to express our gratitude towards the organizing team and the sponsors without whom this conference could not have been realized.

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Geoinformation for the assessment and management of urban water consumption in Mediterranean contexts

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Abstract. Climate change is expected to intensify water supply problems in the Mediterranean. The challenges for managing decreasing water resources more efficiently coincide with the evolvement of disperse settlement patterns. Geoinformation plays an important role in the establishment of indicators for permanent water demands that are the direct consequence of the proliferation of swimming pools and irrigated landscaping in many urbanized seasides, municipalities, and holiday destinations in the Mediterranean. The paper illustrates the application of the methodology for a case study area which exemplifies the nexus of new urban landscapes and permanent water demand on the island of Mallorca, an environment where the water supply situation is already critical.

Keywords. Urban form, residential water budget, indicators, stakeholder-oriented geoinformation

Introduction

At a time when the already critical water supply situation in the Mediterranean is expected to be exacerbated by climate change, urban sprawl and low density residential areas characterize an increasing number of municipalities on Mediterranean coasts [1, 2, 3, 4]. Spain in particular is experiencing a tourist and second-home boom, and residential tourism and leisure structures (golf courses, spas, aquatic parks, swimming pools and irrigated gardens) can have significant impacts on water resources through high levels of consumption. These development pressures coincide with the necessity to manage decreasing water resources more efficiently [5, 6, 7, 8].

The present paper discusses a concept for deriving residential water budgets with the use of geoinformation, and illustrates the extraction of relevant information for a case study area. Other studies in similar climates and contexts have demonstrated the interrelation of urban form and water consumption. The low density urban form produces higher per capita and per area water consumption than the high density urban form. The sensitivity to climate change is positively correlated with irrigated landscaping, a high percentage of single residential houses with private swimming pools, and high income levels [1, 6, 9]. More complete information on this type of water demand is needed by state and local authorities to define priorities for water conservation or demand management programmes. The present methodology is tailored to contexts where extensive meter and/or household survey data is difficult to

access or collect, or where the available per capita water consumption data mask the magnitude of permanent water demand and the variability of consumption levels caused by different land use patterns. The focus is on geoinformation-based indicators to improve statistical coverage of the subject [8].

1. Conceptual issues and the role of geoinformation in water consumption analyses

The present analysis focuses on the relevant variables for residential water consumption models: per capita indoor consumption (dependent on household size, seasonality of inhabitancy and capacity utilization of tourist accommodation), and outdoor consumption for swimming pool and garden maintenance [1, 3, 6, 7, 9]. Water consumption data can be combined with a detailed land use and population geodatabase to allocate water consumption to different types of usage (indoor and outdoor). Relevant input data can be inventoried from cadastral data and remote sensing imagery to circumvent the reliance on water meter data, which are rarely available. The result is a model of urban water demand on the basis of statistics and consumption ratios that is useful as a short-term tool for use in decision-making, defining conservation strategies, and assessing the impact of future urban development [4, 8]. The model requires water consumption data at municipal or sub-municipal level, average estimates for different types of residential units (houses, apartments, hotels), and an inventory of facilities (gardens and pools) that cause permanent outdoor water demand irrespective of occupancy. The land use inventory is pivotal for disaggregating water consumption data in the domestic residential sector to different types of uses, as it has been shown in several studies that gardens and pools are major drivers of water consumption [1, 4, 6, 7, 8, 9]. The model that is proposed here is tailored to water consumption analyses in urbanized seasides that are evolving along Mediterranean coasts, where water demand management is becoming a major challenge [2, 8]. Such municipalities are already typically found in Spain on the Alicante coast, the Costa del Sol or the Balearic and Canary islands, where residential houses, second homes, and tourist hotels and apartment are mixed spatially, and where water demand data do not discriminate between these users [4, 8, 10]. Land use information at sub-parcel scale can be used to calculate and visualize water consumption by outdoor uses in order to identify urban neighborhoods with high potential water demand that should be targeted for water conservation campaigns and that are potentially sensitive to climate change. Visualized in maps, the results are support for and powerful communication means in water conservation campaigns that already address gardens and swimming pools tentatively and encourage the use of more Mediterranean species in gardening, adequate irrigation technology, and pool covers [13].

2. Case study application

2.1. Motivation of the study

The concept of use of geoinformation for the assessment and management of urban water consumption was applied to the domestic residential sector in Nova Santa Ponsa, a sub-municipal census district of the municipality of Calvià in southwest Mallorca,

Balearic islands, Spain. Nova Santa Ponsa is a residential area where more than 80% of all parcels are used by single residential houses. It represents the proliferation of irrigated gardens and private swimming pools as residential resort features, and positional goods that are characteristic for the new urban natures evolving in many Spanish municipalities. Located next to a golf course and marina, Nova Santa Ponsa has experienced a real estate boom, mainly through the active development of second homes with high housing standards. In 2008, there were 18 times more private swimming pools and 3.4 times as many houses as in 1995. Through this type of development, the official residential population grew by 71.5% (1994-2008) in Calvià municipality, and per capita water consumption rose from 300 liters per person per day (lpd) to 700 lpd, exceeding the predicted demand [11, 12]. The Mallorcan water supply situation is already critical and the island government's action program for the Hydrological Plan of the Balearics [13] sets aside over 1 million Euro for stakeholder-oriented communication of water saving measures. Understanding the share of private irrigated gardens with swimming pools in residential water budgets is a first step toward designing water conservation policies focused on reducing outdoor water use and targeting neighborhoods where outdoor use is high. The results presented here could support such water conservation campaigns.

2.2. Assembling the relevant geoinformation

A land use database was built from digital cadastre data and by visual interpretation of high resolution digital color orthophotos (year 2006, geometric resolution 40cm/pixel), and on-screen digitizing [14, 15]. Pool area, garden area, and built-up area (sealed surfaces and buildings) were mapped using the geographic information system ArcGIS™ 9 by subdividing land parcels into these land use types at a scale of 1:600 (Fig. 1). For every parcel with tourist use declared in the online cadastre, the numbers of official tourist beds in hotels and apartments as listed by the Calvià municipal government for the year 2007 (unpublished data) were recorded in the database. For all residential parcels, the number of single houses was recorded and the number of flats in multi-residential houses was queried from [14] and recorded in the database. With this geodatabase structure and content, the relevant outdoor land uses and the relevant data for indoor water consumption (number of inhabitants and tourist beds) can be determined per parcel and for different tourist and residential housing types (Fig. 1).
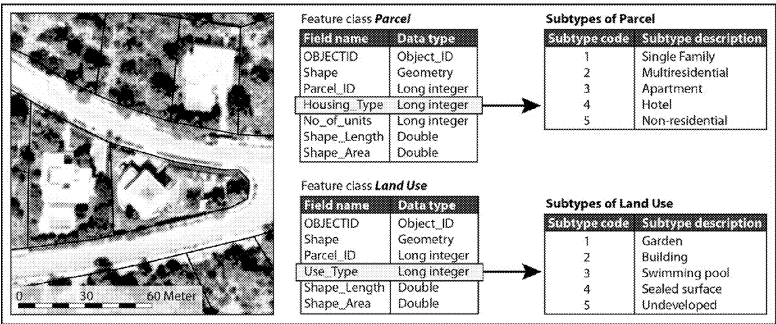
Figure 1. Data model for assembling geoinformation for the water consumption analysis. Orthophoto (year 2002, resolution 40 cm/pixel) reprinted with permission from Sitibsa S.A., Palma de Mallorca.

2.3. Establishing monthly residential water consumption budgets

Monthly water consumption data (2007) for the domestic residential sector was collected from the private water company ATERCA S.A. (Aguas del Término de Calvià, unpublished data). The data exclude the loss in the water supply network, the water consumption of commercial users and golf courses. Monthly indoor water consumption was calculated for the official residents and tourists, taking the monthly percentage of open hotels and tourist apartments, and their capacity utilization into account [16]. The average consumption per bed occupied across different hotel categories is obtained from [4]. Indoor consumption for apartment beds equals the average per capita consumption of single residential houses without garden or swimming pool (142 l/p/d).

The mapped swimming pool surface area is used to calculate water loss from evaporation. The average quantity evaporated over the year for a swimming pool in Mallorca is an estimate of 5 liters of water/m²/day, which amounts to 122% of the average pool water volume [17]. The amount of water available for garden irrigation is derived by deducting the indoor water use and the pool water use from the total water consumed in the respective month. The resulting amount of consumed water is divided by the total garden area, resulting in an estimate of water consumed for garden irrigation per square meter.

3. Results and discussion

The monthly water use profile shows that outdoor water use induces substantial consumption increases in the summer season (Fig. 2). The residential character of the study area and the minor influx of tourists to the couple of hundreds hotel beds in Nova Santa Ponsa are reflected in the low variability of indoor consumption. The estimate of the contribution of pool water loss by evaporation follows climatic patterns and is highest in July, the month of maximum water consumption and evapo-transpiration. On an annual average basis, indoor water consumption accounts for 18.3% of the residential water budget, while 77.1% of water is allocated for garden irrigation, and 4.6% of water consumed in the domestic residential sector is water loss from evaporation from the swimming pools. Currently, there is a lack of reliable, household-level data on water consumption in urban contexts like the one described here, so the results can only be gauged against the findings of other studies in similar climates and contexts. The results on the contribution of garden irrigation and pools to residential water budgets (Fig. 2) are consistent with the findings of studies based on water meter data and interviews where it was observed that water consumed outdoors attains between 50 and 75% of total water consumed in the household [1, 6, 9]. When compared to water consumption in residential areas with lower per capita garden area and lower level of swimming pool ownership in Mallorca and similar urban contexts [4, 10], the per capita water consumption in areas like Nova Santa Ponsa is 2.9 to 3.5 times higher because of substantial outdoor uses of water. These findings support the evidence from other studies that have shown that there is a positive relationship between the presence of irrigated gardens and swimming pools and higher water consumption levels and that the absence of a pool and garden results in a two to three times lower mean consumption per household, per capita and in the month of maximum water consumption [1, 4, 6, 9]. The results presented here are statistical

estimates on the magnitude of the contribution of water-intensive new urban landscapes to urban water demand. These estimates relate directly to a range of indicators suggested by [8] for monitoring the water demand of tourism and its different sub-sectors (second homes, facilities, activities etc.) that elude statistical observation. The proposed geodatabase structure and the water consumption model are operational for calculations of such estimates in order to obtain plausible residential water consumption budgets based on geoinformation, statistics and consumption ratios.
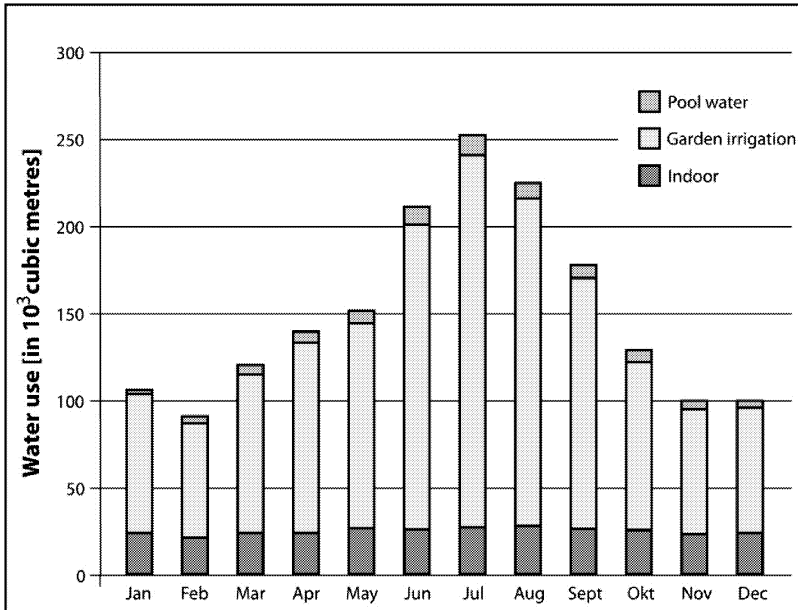
Figure 2. Monthly residential water budget for the case study area (year 2007). Data source: ATERCA S.A.; own calculations.

4. Conclusions and outlook

The results presented here show that gardens and swimming pools are important issues for water management on Mallorca and conservation measures should start to address this more explicitly. For gardens, the use of more Mediterranean species and adequate irrigation technology should be encouraged, and for swimming pools, the use of pool covers and more extensive reuse of water are strongly advisable. The results do not necessarily reflect a close estimate of the actual individual household-level water consumption, but they are the basis for further analysis and could support stakeholder-oriented communication and water-related environmental campaigning. The geodatabase can be queried to select parcels with above average garden size that include a swimming pool to visualize the estimated outdoor water consumption that is a function of pool and garden area. The geodatabase content could equally serve as the basis for a stratified questionnaire household-level survey on domestic water consumption and irrigation practices, or for targeting conservation campaigns at neighborhoods where outdoor use is high. For analyses over larger spatial units, the

methodology could incorporate object-oriented and multispectral analysis of very high-resolution satellite imagery for the mapping of the vegetated garden area and the discrimination of garden types (e.g. trees or turf grass dominated) [18]. The combination of parcel-level land use data and a sample of household consumption data could be used for the refinement of the residential water budget model, and for a comparison of water consumption patterns across different urban forms. Ultimately, the approach is expected to provide a more refined model of water consumption in low density urban areas in the Mediterranean and similar climates and contexts.

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An Event Driven Architecture for Decision Support

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Abstract. This paper presents an Event Driven Architecture for environmental monitoring and live decision support. Multiple OGC web services are integrated into this architecture, including the Web Processing Service and the Sensor Event Service. The system is demonstrated using a pilot from the EC funded GENESIS project. The architecture, the processing steps and the benefits of the system are described in detail.

Keywords. Event Driven Architecture, Spatial Data Infrastructure, OGC Web Services, Decision Support

1. Introduction

Environmental measurements are crucial for decision making and assessing health risks. The variety of measurements is accessed via Spatial Data Infrastructures (SDIs). However, the pure access to the information is not sufficient as the measurements have to be available in real-time. Especially phenomena with a strong effect on health and a fast spread have to be detected and processed as soon as possible.

This paper presents a near real-time system based on an Event Driven Architecture (EDA) and existing web services such as the OGC Web Processing Service (WPS) and OGC´s suite of sensor services. The EDA was developed as part of the FP-7 project GENESIS (GENeric European Sustainable Information Space for environment) [1] which builds collaborative information networks for environment management and health actors. It provides a Service Oriented Architecture (SOA) applying standards from various organizations like ISO, the OGC, the W3C and OASIS.

Section 2 describes basic concepts of OGC web service standards as applied in this paper. In Section 3 the use case applied to the presented system is described. The fourth section presents the system including its architecture and the utilized techniques and processes. Finally the benefits of the system are summarized and an outlook for future developments is given.

2. Related Work

This section provides an overview about the related work on EDAs and the sensor web as applied in this work.

For this paper we follow the event definition as developed in [2]: ”*An event is anything that happens or is contemplated as happening at an instant or over an*

interval of time". Such an event can represent the real world phenomenon or its digital representation. For this paper we understand an event as the latter. An Even Driven Architecture (EDA) is an architectural style in which most of the components execute their actions based on incoming events and communicate via events [3]. To extract specific information from events Event Stream Processing (ESP) is applied. Such processing is performed using so-called data views which provide access to a sub-set of the available events, e.g. all events received during the last hour or the newest 100 events. The processing rules are defined as event patterns [4,5].

The Event Driven Architecture is based on standards for service interfaces and data encodings such as provided by the OGC for geographic applications [6]. The Web Processing Service (WPS) allows clients to perform configurable remote processes over the web [7]. Performing web-based processes on the web is regarded as the next step in SDIs and allows clients to build flexible processing chains [8,9].

The Web Coverage Service (WCS) provides means to query coverage datasets over the web [10]. Coverages are for instance remote imagery or any n-dimensional raster dataset.

Besides the services for raster and processing, the Sensor Web Enablement (SWE) initiative at the OGC develops standards specific for sensors, sensor systems and sensor networks. In the recent years the SWE initiative released several service specifications as well as encodings for sensor metadata and for sensor measurements. Within the SWE initiative also services using a publish/subscribe communication were specified. These are namely the Sensor Alert Service (SAS) [11] and the Sensor Event Service (SES) [12]. The SAS allows clients to subscribe for sensor measurements using filter criteria like a bounding box or a threshold. The SES is a successor of the SAS, also based on the publish/subscribe messaging pattern. It makes use of existing standards such as the Web Services Notification (WS-N) suite from OASIS [13,14,15], Observations & Measurements [16] and the OGC Filter Encoding specification (FES) [17] for the definition of subscription filters. Additionally, it applies Event Stream Processing. The event patterns of the SES e.g. for Event Stream Processing are described through the Event Pattern Markup Language (EML) [18].

3. Use Case

The EDA presented in the following section is based on a use case of the GENESIS project about cyanobacterial bloom in the artificial Villerest reservoir. The reservoir is located in the north-west of Lyon, impounding the Loire River. In the summer months the reservoir is often affected by cyanobacterial blooming. During such a bloom phase the concentration of blue-green algae and natural toxins is largely increased to a degree that it even threatens humans. Consequently, drinking the reservoir's water as well as skin contact has to be avoided. The detection model for cyanobacterial bloom is based on in-situ measurements and remote imagery data [19,20].

4. Event Driven Architecture

Based on the use case the presented EDA needs to perform processing of in-situ measurements (i.e. pH values) as well as of remote imagery. In the following the EDA with its components is described. In particular, the Enterprise Service Bus, the topic

concept, the processing by the SES and the necessary extensions of the components are presented.

The components and data flows of the EDA are shown in Figure 1. The sensors provide pH value measurements. To encapsulate the sensors and to provide a sensor gateway these measurements are sent to a Sensor Alert Service (SAS). The SAS feeds them into the Enterprise Service Bus (ESB), a central communication middleware component, which serves as communication platform. All events (e.g. sensor measurements or other notifications) in the EDA are sent to the ESB and disseminated to the subscribers. The Sensor Event Service (SES), subscribed for pH value measurements, calculates the daily pH value variation based on the sensor measurements. In case of high variations, notifications are produced that trigger the Web Processing Service (WPS).
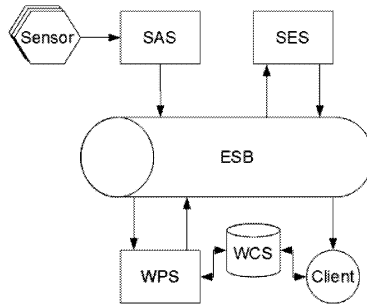
Figure 1. Overview of the components and data flows.

The WPS accesses remote imagery data for the area in which a high variation was detected and scans the image for high concentrations of Chlorophyll A. Details on algorithms for Chlorophyll detection can be found in [21]. The processing results are available through a Web Coverage Service (WCS) for querying. In addition, clients (e.g. a GIS or a web portal) are notified that new results are available. Based on the results, the user decides about restrictions in the affected water body.

4.1. Enterprise Service Bus and Topics

The Enterprise Service Bus handles all event communication. It provides a Web Services-Notification (WS-N) interface for notification as well as for subscriptions of specific notifications, which are grouped by topics. Topics allow users to subscribe for a type of notification without the need of knowing details like "measurements taken by sensor XY". They are abstract filter for types of notifications and are structured as a tree, where a topic may be a node containing further sub-topics or a leaf on which notifications are published. Clients can only subscribe for leaf topics.

Figure 2 shows the topics that were implemented for the use case. The SES for instance is subscribed for notifications on the 'PH' topic to receive every pH value measurement. Critical variations are published to the 'CriticalPHVariation' topic on which the WPS is subscribed. The distinction between 'Measurements' and 'DerivedInformation' allows separating the base data from information that is generated. This helps to identify the topics of interest, especially when taking further phenomena into account (e.g. oxygen saturation measurements and information derived thereof).
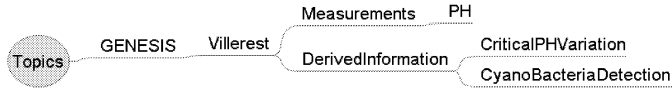
Figure 2. Overview of the topics.

4.2. Sensor Event Service Processing

The SES calculates the daily pH value variation and checks if it exceeds a critical threshold. According to [20], a critical pH value variation is one indicator for a cyanobacterial bloom. Table 1 gives the definition of the algorithm.

Table 1. Definition of the critical pH value variation detection algorithm [20].

Name	Data Type	Unit	Value Range	Threshold for decision process
pH	Float	pH Units	0 to 14	see below
pH variation	Float	pH Units / day	-14 to 14	abs(pH variation) >= 0.5
pH Status	Logical		Normal | Abnormal	if abs(pH variation) >= 0.5 then pH status = Abnormal, else pH Status = Normal

This algorithm is translated into Event Stream Processing (ESP) rules that can be executed on-the-fly in the SES (encoded as EML). For identifying cyanobacterial bloom five event patterns are created (see Figure 3).
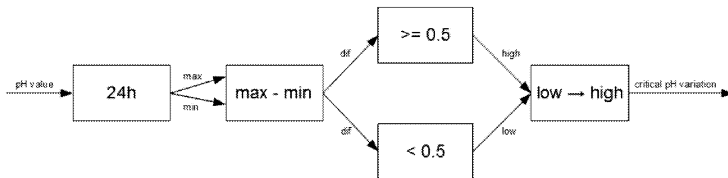
Figure 3. EML patterns for the critical pH value variation detection.

The pH values for a given location are passed onto the first pattern. It uses a data view to provide access to the measurements from the last 24 hours. From this view the maximum and the minimum values are selected and pushed to the next pattern. Here the difference is calculated which is the absolute value of the maximum pH value variation during the last 24 hours (see Table 1, thresholds). Next, this difference is forwarded to a pattern checking if the threshold of 0.5 pH units is exceeded.

In theory one could stop here and generate a notification to trigger the WPS process. But imagine a situation in which the pH value changed by more than 0.5 during the last 20 hours. In that case the three patterns described above generate an output for every new measurement received during the next four hours. This leads to needless triggering of the WPS as the critical situation happened earlier and was already recognized.

To avoid this behavior of the system, two more patterns are needed. A first one looks for pH value changes that are within an uncritical range (< 0.5). The results of the two threshold patterns are then given to the last pattern which checks if an uncritical variation (low) is followed by a critical one (high). If this criterion is matched, the threshold was exceeded for the first time, later critical changes are ignored. In order to generate an output again, the pH value variation has to drop to a normal state again.

4.3. Extensions of Components

Several adaptions to the components were required to execute the workflow described above. First, the Sensor Alert Service had to be connected to the Enterprise Service Bus. There were two options, either to change the SAS to provide WS-Notification compliant notifications or to extend the ESB to accept also notifications sent via XMPP, the messaging protocol used by the SAS. The second option was implemented as it allows an easier integration of external sensors provided via regular SAS instances. For this aim also Sensor Event Service had to be extended to be able to handle SAS notifications.

A larger modification was made at the Web Processing Service as it had to be connected via WS-Notification to the ESB. This connector is able to receive notifications from the SES, extract the location and further necessary information and build the request to execute the Chlorophyll A detection algorithm. Also the notifications after the finishing process are built by this connector and sent to the ESB.

5. Conclusion and Outlook

This article describes an Event Driven Architecture for environmental monitoring and health assessment. The presented architecture is based on standards for web services (e.g. WS-N, SES and WPS). The architecture has been applied to a use case based on the fresh water quality pilot C from the FP-7 project GENESIS.

The presented architecture shows several benefits of an Event Driven Architecture compared to a classic Service Oriented Architecture. At first, the system works on-the-fly, which means that processes are started as soon as possible, namely as the input data (e.g. in case of the SES) or the trigger (e.g. in case of the WPS) is available. This way, the decision maker gets notified when a new decision is needed instead of guessing when new information for the decision has to be requested. Furthermore, there is no need for frequently requesting this inputs which may lead to unnecessary requests (if the frequency is too high) or to missed information (if the frequency is too low). This makes the system very flexible in terms of the application area and deployment context.

This architecture is also very flexible. Due to the loose coupling of the components, data sources can be exchanged easily. New sensors can be added or other remote imagery stores can be used during run time. Also service instances can be added or exchanged without stopping the system. This allows to migrate services to more powerful machines, to add redundant backup machines to avoid down times or to add new services to extend the workflow, e.g. by decision support services that automatically provide recommendations on necessary actions based on the WPS processing results. Furthermore, the processing rules and algorithms of the WPS and SES can be changed during run time by altering the subscribe (SES) or execute (WPS)

requests. This might for instance be necessary due to a change of the remote imagery source. From all this also follows that the system needs to be set up and initialized only once. From that point on it will automatically execute the whole workflow.

Using an Enterprise Service Bus as the communication infrastructure also provides a single point to access data. This might be the final WPS processing results but also the intermediate results of the SES or the SAS notifications.

To make use of these benefits it is envisioned to integrate event based communication mechanisms into existing Spatial Data Infrastructures (SDIs) rather than to replace the current request-response based technologies. This was also used in the EDA presented in this paper: the remote imagery was not sent via the ESB but stored in a Web Coverage Service; only notifications referring to new processing results were distributed this way. This approach is also followed by the newly formed Pub/Sub Standards Working Group (SWG) of the OGC. It develops a standard for publish/subscribe usable by existing OGC web services.

Acknowledgement

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Handling of spatial data for complex geo-scientific modelling and 3D landfill applications with DB4GeO

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Abstract. The handling of geometric and topological data is a central task for many geo-scientific applications. However, the management of complex 3D data is not well supported by current geo-database management systems. Some ideas and results concerning the management of geometric and topological data in the context of a specific geo-scientific scenario and a landfill scenario are presented.

Keywords: 3D database, geometric data, topological data, meta-information, landfill data, DB4GeO.

Introduction

Decision making on competing and sometimes mutually exclusive possible uses of the underground, e.g. for geothermal energy, intermittent storage of excess renewable energy, must be supported by a comprehensive information basis, despite the sparseness and cost of available basic subsurface data. Advanced geoscientific methods are therefore required for the assessment of underground use potential and risk estimation. Thus 3D subsurface models play a central part, integrating a variety of information from different sources with geological expert knowledge. For the management of such models in a distributed multi-user system, spatial 3D database technology is required. In the following we shall present two different scenarios and current work on the development of DB4GeO [1] [2], a 3D database kernel supporting the handling of complex 3D geo-scientific models [3] [4] [5].

1. Complex geo-scientific applications using a 3D database

1.1. Meta-Information, 3D databases and visualization tools as a basis for synoptic interpretation

Data integration in the geosciences may cover diverse fields such as mineralogy, geochemistry, hydrology, geomechanics, geophysics, structural geology, sedimentology etc., each employing a different set of numerical and statistical methods.

A special case is the interactive construction of geological 3D underground models, as it is based on a variety of information sources, and in particular comprehensive expert knowledge.

As shown in figure 1 - instead of a single "monolithic" system - WWW technology is helpful to build a loose structure consisting of a network of individual "sites", and an XML-based data representation and transformation wherever the incurred redundancy is tolerable. The integration is enhanced by a common meta-information database that provides metadata and background information for data and processes. *Semantic Web* technology shall be used to document relationships between different information items, and to represent the flow of information between the different processes leading to a particular result. For this purpose we currently investigate the use of *Topic Map [6]* and *RDF [7]* techniques.
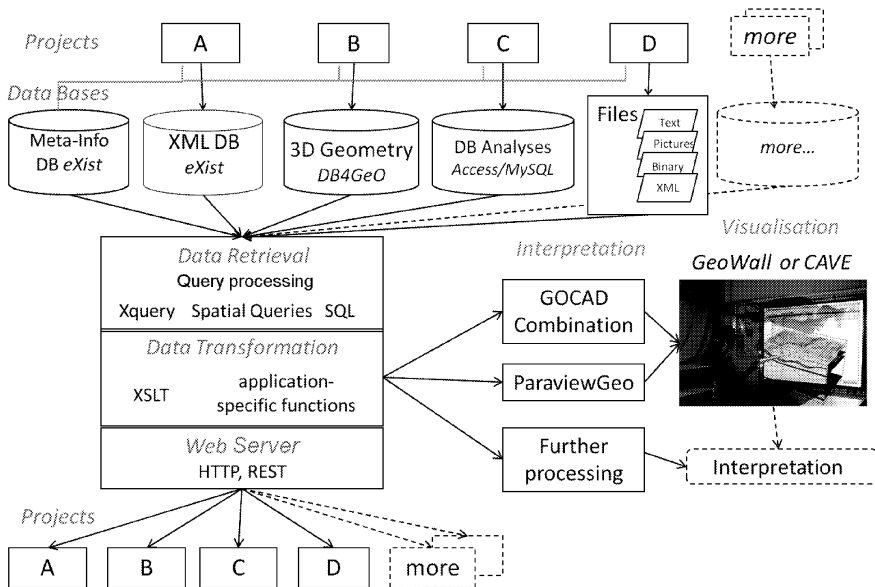
Figure 1: Outline of the heterogeneous software environment of a geoscientific project comprising DB4GeO for spatial data and eXist for meta-information

Sampling, experiment and simulation results provide the information basis for a synoptical representation and interpretation. As a central part of the software architecture, the 3D database management system for geological 3D models handles the spatial basis for information integration and numerical modeling. In combination with 3D stereo-visualization [8], the textual and graphic display of numerical results and meta-information, it provides the basis for a synoptic interpretation.

Our geo-database DB4GeO is integrated into a network of different geo-scientific projects in order to manage the comprehensive geological 3D models using GOCAD[1] [9] at the regional geological service of Schleswig-Holstein[2] [3]. For 3D visualization,

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[1] GOCAD software is distributed by Paradigm.

[2] *Landesamt für Landwirtschaft, Umwelt und ländliche Räume SH, Abt. Geologie, Flintbek, Germany*

software such as GOCAD, IGMAS+ [4], ParaView [10], Geocando [11] and GeoWall hardware [8] can be employed to get a better insight into complex 3D models and their interrelations. Additional background information on the employed methods and documentation of the interaction between the different projects will enhance the synoptic interpretation of the combined models.

1.2. Piesberg landfill application

At the so called Piesberg, near Osnabrück, Germany, the upper carboniferous of the Ibbenbüren coal mining district reaches the surface. Here formerly underground coal mining took place, while at the surface a quarry was situated, part of which later has served as a waste deposit site. Finally, the site has been transformed into a culture and natural park with a mining museum [5]. In the "Piesberg landfill application", spatial data was collected during a period of eighteen years from 1976 – 1993. Today this data is used for a new project examining the 3D data management in the geo-sciences[3].

Figure 2a shows a single time step of these geological data representing a Triangulated Irregular Network (TIN) of a Piesberg stratum surface. The Piesberg data set [5] combines a spatially selected part of the Digital Elevation Model (DEM) at Osnabrück City in North Germany, a SICAD® drawing showing the breaking edges around the dumpsite, and several cross-sections. The 2D drawing has been combined and interpolated with the manually digitized cross-sections to generate several 2.5D TINs of the geomodel. The DEM has been used to expand the geomodel at its boundaries. At a single time step the model consists of about 30K triangles.
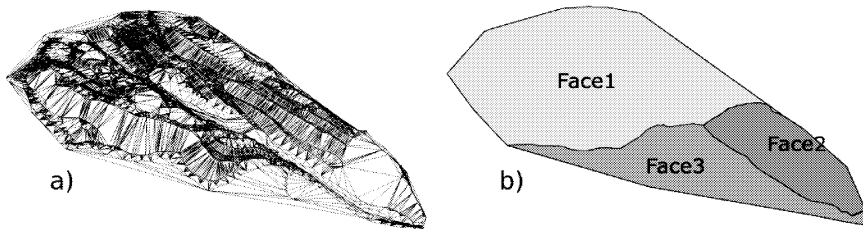
Figure 2. a) Geological application "Piesberg region" showing a single time step of a stratum surface represented as TIN; b) Same region aggregated into three faces according to some thematic criterion

2. Handling of 3D spatial data with DB4GeO

DB4GeO [1], [2] dwells on many years of experience with earlier spatial database developments, in particular the development of GeoToolkit [12] at Bonn University within the Collaborative Research Centre 350 funded from 1992 – 2001 by German Research Foundation. This former geo-database prototype was already used by geological and geophysical research groups [13]. DB4GeO is an object-oriented

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[3] Project "3D data and model management for the geosciences" founded by German Research Foundation (DFG)

database software completely written in Java based on the OODBMS-software db4o [14]. It differs in some aspects from known commercial or open-source Geo-DBMS like ArcGis/ArcSDE (ESRI), ORACLE Spatial, PostGIS (Refraction), cf. e.g. [15]:

- DB4GeO was designed from the outset for fully 3D geoscientific applications.
- Different from the usual object-relational approach, it is object-oriented.
- The use of 0…3-dimensional simplicial complexes as underlying mathematical model provides a sound basis for geometric and topological operations on spatial objects. This feature should be maintained during future extensions of the range of supported spatial structures.
- It was designed with a service-based architecture right from the beginning [2]. Currently the http protocol in REST style [16] is used for internet access.

2.1. Handling of geometry

The present implementation of DB4GeO supports a number of geometric operations, which can be combined into sequences of operations as complex geometric "services" [2]. For example, profile sections may be computed from a geological 3D subsurface model. DB4GeO is accessed exclusively via its geometric and topological services. The kernel of DB4GeO consists of its 3D geo-database which is based on a geometry library and R-tree based spatial access methods. Data are organized in '*projects*' that comprise one or more '*spaces*'. Each space has a Spatial Reference System Identifier (SRID), a '*scale*', and contains all associated spatial and thematic objects. Hitherto DB4GeO only supports simplicial complexes (Point Sets, Polylines, Triangulated surfaces, Tetrahedron meshes) as spatial representations. However, future work will also deal with the extension to other spatial data types such as grids.

2.2. Handling of topology

With data as shown in figure 2a, it can be examined how units comprising many triangles can be topologically defined to represent thematically homogenous parts such as geologically defined surfaces (see figure 2b) and solids with given densities.

3D-simplicial complexes such as polylines, triangulated surfaces, tetrahedron nets, are well suited for the modeling of irregular geological objects. With such spatial structures, topological and geometric operations go hand in hand, and there is not much need for a clear separation of the two. For the modeling of complex solids, however, *boundary representation* (*BREP*) is more frequently used. In addition, for some geoscientific applications, e.g. gravity and geomagnetic modeling with IGMAS+ [4], BREP is better suited for the employed algorithm. Also, for applications such as finite element (*FE*) models [17], a restriction to simplicial complexes would exclude a number of FE classes. Yet another problem is scaling of 3D models [18]: the aggregation of a given subset of 3D simplices according to some thematic criterion generally does not yield a simplex, but rather an irregular shape, however with a well defined topology obtained by the suppression of internal boundaries. Such a shape lends itself to some sort of boundary representation. Basic spatial operations defined for simplices, such as "point in simplex", intersection of (0,1,2,3-) simplices, boundary of a simplex, size (length, area, volume) can be extended to simplicial complexes (e.g. in DB4GeO). The same holds for some basic consistency checks based on these operations. However, the extension of these operations to arbitrary 3D bodies in

boundary representation is not always obvious, and the developer may be left with a great number of "special case" problems to handle.

For topological modeling, the *Generalized Map* (*GMap*) [19] and the closely related *Cell-Tuple Structure* [20] provide a unifying approach: at all levels of detail/aggregation, regardless of the dimension of the model, the same type of formal structure can be used for the representation of topology, and at the cost of some redundancy simplicial complexes can be mapped onto GMaps as well. A set of elementary and complex topological operations and their RDBMS implementation has been presented by [21][22]; these operations are now being integrated into the Db4GeO kernel. GMaps and Cell-Tuple Structures have been employed for large 3D building models and their visualization [18], a current application is the modeling of the development of Piesberg (see above).

3. Outlook

In our future work we will also focus on the handling of spatio-temporal data with DB4GeO, revising our temporal data model implemented in DB4GeO. We intend to provide a more flexible spatio-temporal model allowing the insertion of new version for geo-objects within a scene and secondly to reduce the storage place needed for spatio-temporal 4D models. Furthermore, we will try to develop suitable DB4GeO geometric extensions for regular and for deformable grids, and possibly for other spatial meshes which are not modeled by simplicial complexes. We are also planning to enable complex spatial and thematic queries by DB4GeO using query scripts. Last, but not least, a different topology approach called Relational Chain Complexes is examined in our current research.

Acknowledgements

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Design With Nature 2.0 – A Geodata Infrastructure Approach to Map Overlay

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Abstract. McHarg's "Design With Nature" was a precursor of the layer model in modern geographic information systems. We are reviewing the layer overlay approach from a geospatial data infrastructure (GDI) perspective and experiment with weighted map overlay using Web map services. A case study for natural hazard risk assessment for Southern Quebec illustrates this visual approach to multi-criteria analysis using online mapping. We conclude with a call for more research on thematic mapping and its use for decision support within GDIs.

Keywords. Geospatial data infrastructure, map overlay, multi-criteria analysis

1. Introduction

Ian McHarg is widely credited with inventing the layer model that was adopted in geographic information systems (GIS) (e.g. Goodchild 1992). In his seminal book, "Design With Nature", McHarg (1992) used semi-transparent map overlays for "suitability selection processes", including highway route selection. His printed map transparencies represented social and environmental values around potential routes by degrees of grey shades. The overlay resulted in sensitive areas being "masked" through multiple overlaid maps while more suitable areas remained translucent. Subsequently, the computational overlay of maps has been formalized in map algebra and cartographic modeling (Berry 1987, Tomlin 1990). Map algebra conceptualizes a set of mathematical operators applied to raster data to derive new map layers. It includes various overlay operators and is implemented in commercial GIS software. However, the visual overlay via regular map layer management is the most immediate implementation of McHarg's (1992) approach in today's desktop GIS.

Map overlay is also a key feature of geospatial data infrastructures (GDI). A basic tenet of GDIs is to leave datasets under the custody of an authoritative provider; access them through distributed Web services; and overlay them on the end-user's screen. The OpenGIS Web Map Service (WMS) (de La Beaujardiere 2006) is among the services that support visual overlay à la McHarg, while recent developments aim to support computational overlay, e.g. Holzmeier and Ostländer's (2005) Web Map Algebra Service. While WMS is extensively used, it is usually employed for general reference maps, e.g. road maps. There are few examples of thematic maps within GDIs in general, despite the capability of maps to visualize spatial patterns of natural,

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demographic, and socio-economic phenomena, and support associated planning and decision-making.

In this paper, we replicate McHarg's "Design With Nature" in a GDI environment in order to illustrate decision support capabilities of simple, visual overlay of online thematic maps. Section 2 provides a brief overview of weighted overlay and multi-criteria analysis as they apply to this work. In Section 3, we summarize the pertinent aspects of the WMS specification, the OpenLayers development platform, the alpha blending approach for the rendering of semi-transparent map overlays, and the use of styled layer descriptors. Section 4 illustrates the user interface and functionality of the prototype client. Section 5 describes a case study of using online map overlay for natural hazard assessment in the context of global environmental change. Finally, Section 6 concludes the paper with a summary of results and outlook on future work.

2. Weighted Map Overlay and Multi-Criteria Analysis

Weighted overlay of map layers in GIS is an extension of the general idea of map overlay described above. Eastman et al. (1995) were among the first to systematically describe raster data overlay and provide an implementation in the Idrisi GIS. The authors distinguish between "constraints" and "factors". A constraint limits the set of feasible alternatives in a decision situation by establishing strict boundaries or threshold values to be met. In contrast, a factor "enhances or detracts from the suitability of a specific alternative for the activity under consideration" (Eastman et al. 1995, p.539). In other words, higher or lower measurements on a factor will affect the suitability of locations without setting specific minimum or maximum thresholds.

This terminology links weighted map overlay to the broader field of GIS-based multi-criteria analysis (Malczewski 1999). Each map layer represents a criterion that measures the outcome of a decision. Weights are used to represent different levels of importance attributed to the criteria. Weighted criterion layers can be summed using map algebra tools to create a weighed average of criterion values across a study area.

The weighted average, also known as weighted linear combination, is among the most common multi-criteria methods (Malczewski 2000). This process results in a arithmetic combination of input layers into a single output layer, the cell values of which represent suitability or desirability of each location for the decision to be made. McHarg's (1969) approach can be seen as a purely visual implementation of geospatial multi-criteria analysis, since the grey shades resulting from semi-transparent map overlay represent site suitability in the same way as the GIS-based weighted overlay. We propose to use weighted map overlay as a decision support approach within GDIs.

3. Geospatial Data Infrastructures and Web Mapping Concepts

3.1. Web Map Servers – Use of GeoServer

A GDI is an online platform that provides analysts, decision-makers, and the general public with access to geographic information in the form of maps and geospatial data. Web map servers in a broad sense are a key element of any GDI, and the OpenGIS Web Map Server (WMS) specification provides a widely accepted foundation for mapping services. A WMS must respond to two basic requests: GetCapabilities, which

provides information about available themes and map layers, their geographic extent, and the available graphic output formats; and GetMap, which retrieves an image of a map that has been prepared on the server using parameters set by the client, including data layer, map extent, and output format.

A styled layer descriptor (SLD) is an XML schema that extends the WMS standard and allows user-defined symbolization and colouring of geographic data (Lupp 2007). The SLD implementation specification defines an XML styling language that allows users to define rules to control how data are rendered. A layer-specific symbolization can be included in a WMS request by adding an SLD parameter to the request URL.

In this project, GeoServer was used to provide access to the case study data. GeoServer is an open source Java software package for sharing geospatial data. It implements several OpenGIS service standards, including the WMS with SLD.

3.2. Web Map Client – Use of OpenLayers

The client application in this project was built using OpenLayers, an Open Source Geospatial Foundation (OSGeo) project, which provides a JavaScript library that allows for the integration of maps from distributed sources into the HTML code of a Web page. The map overlay client also uses the jQuery JavaScript library, which helped to define the control elements such as the menu tab used in this application.

3.3. Alpha Blending

Alpha blending is an algorithm used in computer graphics to combine overlapping, partially transparent picture elements. It adds an alpha channel to an image's colour information. The alpha channel contains information about the opacity of pixels, with 0.0 being transparent and 1.0 being opaque. For example, a 50% black colour in an RGB colour model would be represented by the tuple (0.0, 0.0, 0.0, 0.5), where (0.0, 0.0, 0.0) is the RGB encoding for black and the additional alpha value is set to 0.5.
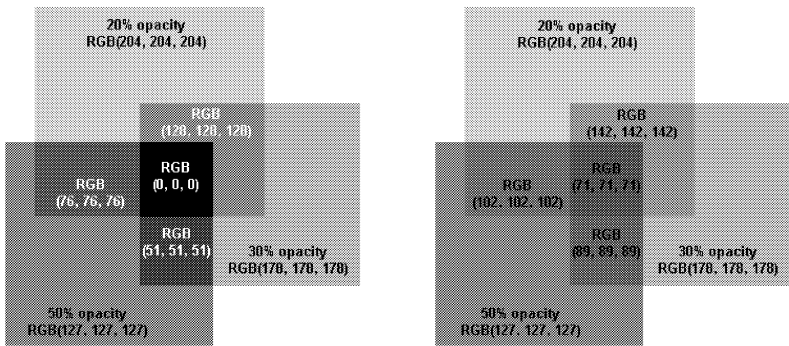
Figure 1. "Logical" overlay of partially transparent (translucent) picture elements with additive combination of opacities (left), compared with graphical overlay with multiplicative alpha blending (right)

The use of alpha blending as the default image overlay method in Web clients creates an inconsistency in visual overlay of weighted map layers. In a greyscale scenario, the three layers shown in Fig.1 have opacities of 50%, 30%, and 20%. If

opacities are considered to represent criterion weights, their weights should add up to 100%, as shown in Fig.1 (left). However, alpha blending does not use additive opacity. For example, the triple overlay in the centre of Fig.1 (right) does not receive full black opacity. Instead, the graphical overlay results in a grey shade with an opacity of 1 - (1-0.5)*(1-0.3)*(1-0.2) = 1 - (0.5*0.7*0.8) = 1 - 0.28 = 0.72. The RGB tuple (71, 71, 71) corresponds to a 72% black.

4. Prototype User Interface and Functionality

A prototype implementation of the map overlay tool includes the following functions:

- Import layers from Web Mapping Services and overlay them in the Web client
- Set up with default collection of WMS URLs suitable for demonstration
- Switch layers on and off, and change the order of layers
- Basic functions of a Web mapping client such as panning and zooming
- Change layer opacity by distributing 100% over selected layers

The user interface (Fig.2) consists of two main elements: map and menu. The map includes controls for panning and zooming as well as control elements for choosing base layers and turning thematic layers on and off. The menu is organized into functional areas. The Add Data area provides text fields for adding layers from OpenGIS-compliant Web services along with sample WMS and WFS layers for direct access. The Change Opacities area contains the sliders for modifying the opacity of each layer. When a layer is added to the map, a new opacity slider is added automatically. Similarly, in the Layer Order area of the menu, buttons for controlling the layer arrangement are added automatically for each layer. The current layer order can also be seen in the control elements within the map.
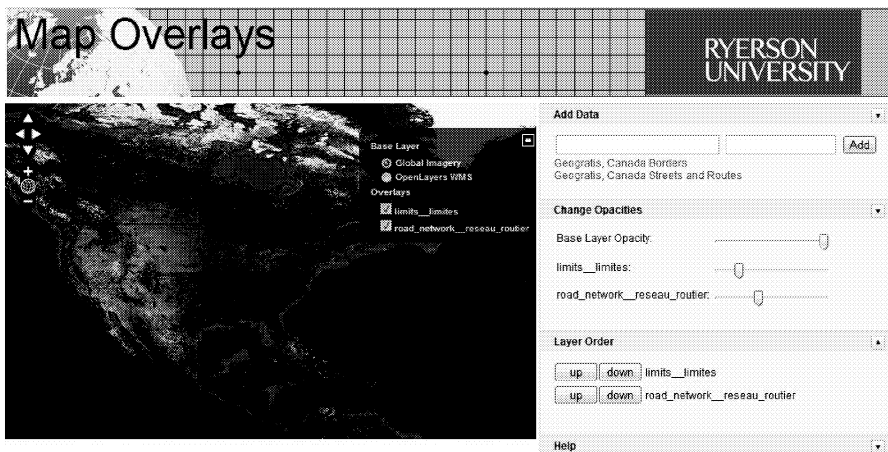
Figure 2. Screenshot of the prototype's user interface

5. Case Study – Natural Disaster Risk Assessment

The global risk data platform (Giuliani and Peduzzi 2011) is an international effort to collect and share information about natural hazards. Access to the data is provided as maps on the site itself (http://preview.grid.unep.ch/), or through Web services. Their WMS offers different maps, including those of risk levels classified between very low and very high, with associated colour coding (e.g. dark red for highest risk). This fixed colour scheme and legend were not suitable for map overlay. Therefore, copies of the data were served from a custom WMS with SLD support. For illustration purposes, the colour black was given to all pixels that were encoded with any risk level above zero.
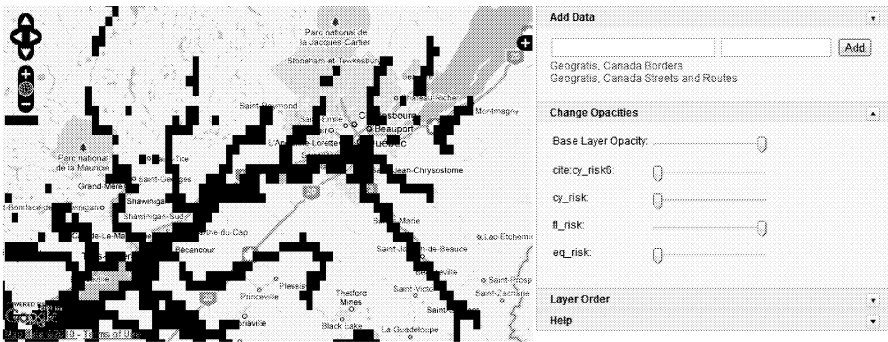
Figure 3. Flood risk areas in Southern Quebec – overlay of UNEP WMS with Google Maps base layer

Three layers representing the risk of cyclones, floods, and earth quakes were included in this case study. The map extent was set to Southern Quebec, Canada. This area borders the Saint Lawrence River, a major shipping route that connects the Great Lakes with the Atlantic Ocean. Quebec City is one of the oldest settlements in North America and its historic district is a UNESCO world heritage site. The City lies at a narrowing of the Saint Lawrence River and can be seen slightly east of the centre of the maps in Fig.3 and Fig.4.

Fig.3 shows black pixels (given full visual weight) that represent areas identified as prone to flood risk by Giuliani and Peduzzi (2011). These areas include the shore of the Saint Lawrence River upstream from Quebec City as well as many of its tributaries.
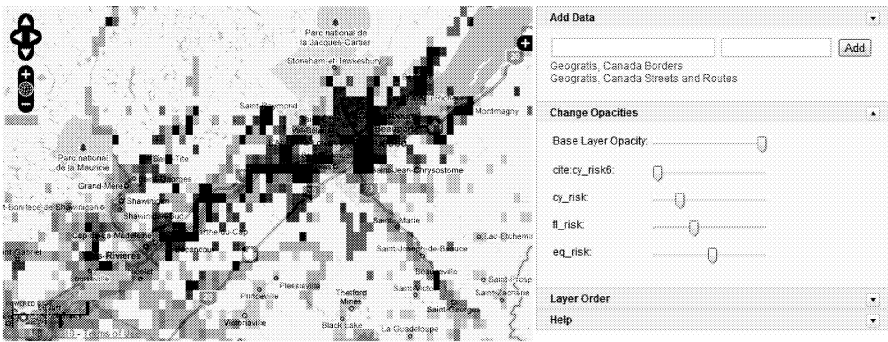
Figure 4. Overlay of three thematic WMS layers using transparency to represent hypothetical importance weighting – cyclone risk (20%), flood risk (30%), and earthquake risk (50%)

In Fig.4, darker grey shades visually indicate the overlap of multiple natural hazard risks. The risk of cyclones, floods, and earthquakes are given hypothetical weights (opacities) of 20%, 30%, and 50%, respectively. The study area shows generally low levels of risk with a concentration of higher risk near Quebec City and along the Saint Lawrence River. An inspection of the three individual layers confirms the similarity in geospatial patterns and considerable spatial coincidence of natural hazard risk in Southern Quebec.

6. Summary and Outlook

The goal of this research was to illustrate the concept of weighted map overlay in a GDI environment, and spark discussion about the use of WMS for spatial decision support. An interesting advantage of the purely visual, non-computational overlay used here is that distributed data sources of different qualities (e.g. spatial resolution) can be jointly explored by the end-user without requirements on compatibility.

The prototypical implementation of a map overlay client was fast and cost-effective, in part due to the use of open source software tools. The current tool needs updates in a few functions, in particular the control of layer weights adding up to 100% in accordance with multi-criteria analysis methods. In addition, we plan to expand the testing of the tool to a regional or local scenario with more decision criteria and involvement of stakeholders who would provide feedback on the weighting approach.

More broadly, we argue that thematic mapping merits more attention from GDI researchers and developers. While specifications and tools are in progress that support the computational combination of data (e.g. Web Processing Service), the basic overlay of thematic map layers in GDIs has not been studied and promoted enough. Geospatial Web services are still a far cry from being able to replace professional GIS mapping.

Acknowledgements

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Track-based OSM Print Maps

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Abstract Mobile devices have become more and more powerful in the last years
and it is possible to use them for locating and navigation. But are they always the
better choice than using a paper map? In many situations – e.g. on a long hike –
a paper map is still useful. This project aims at providing map booklets based on
OpenStreetMap data. In comparison to similar projects creating print maps for an
area of interest this projects creates a map booklet along a given GPS track with
customizable rendering options and overlapping map sections.

Keywords. OpenStreetMap, print map, GPS track, tiling, rendering

1. Introduction

GPS devices or smartphones with specific applications can help you to easily locate
yourself in and navigate through unknown surroundings. But traditional paper maps
still offer advantages over mobile devices. For example on long hiking trips it might be
unforeseeable when it will be possible to recharge your electronic device. In such a
situationa printed map is a valuable alternative. Also, it is much easier to get an
overview of the area on a high resolution A4 paper map than on a 3-inch display.

Searching the web, there are many solutions to export and print map views.
However there is no service that allows to create customized OpenStreetMap paper
maps with integration of tracks or user-defined visualization styles. Creating such a
map with GIS software is much too difficult for a user who is not familiar with this
kind of software.

This paper presents an architecture to create customized OpenStreetMap booklets
on the basis of a GPS track that might be downloaded from hiking websites like
www.gpsies.com. This track can represent the mentioned hiking trail, or any other
intended route, e.g. the navigation instruction from OpenRouteService. The booklet
supports multi-page mode, at which the map sections overlap each other. A step-by-
step interface offers everyone the possibility to create map booklets that fit their
individual needs.

2. RelatedWork

There are some similar projects that offer functionalities to export and print Open-
StreetMap data. The *Walking Papers* project by Michal Migurski encourages users to

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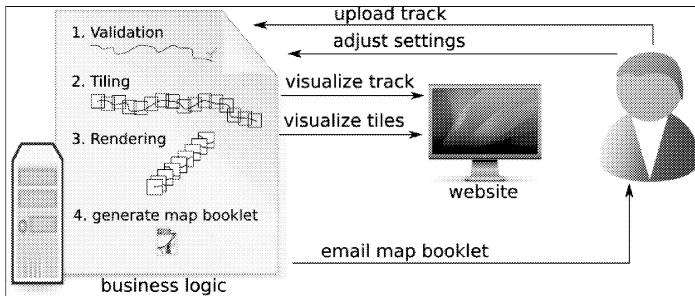
Figure 1. The service architecture. On the left side is the server with the four steps of the business logic. The right side denotes the interaction with the user and via the web interface.

print OpenStreetMaps, annotate and add information, scan the map and then digitize additions and changes. The main advantage of this method is, that no mobile device is necessary for the mapping part. The most famous application was after the earthquake in Haiti [5]. *MapOSMatic* is a free webservice that allows to create printable city plans. It contains the map and a street index, ready to print as PNG, PDF or SVG file [1]. The *TownGuide* is a python program that, like MapOSMatic, renders a map to a PDF file including a street index, but also adds an index of user-selectable POIs. It can run either as a web service or as a stand-alone program if the source code is installed [3]. There are also application-based projects that assist to create a printable map from OpenStreetMap data: The *Osmbook* turns OpenStreetMap data into a printed book. It generates a highlevel gridded overview page and multiple other pages with cross referencing and additional information [2].

All these project have in common that they create paper maps based on Open-StreetMap data for a given area of interest defined by a bounding box. But none of these projects is capable to use a track as an input and render maps along this track.

3. Architecture

The architecture is based on a simple client-server interaction. As depicted in Figure 1 the business logic splits the data processing on server side into four single tasks: validation, tiling, rendering and generating the booklet. The user interaction is realized through a web interface.

The user uploads a GPS track, which is validated against a XML-schema and modified if necessary. An algorithm has been developed to calculate overlapping map tiles along the track. It computes map tiles represented by a rectangle centered around a certain point of the track with a predefined overlap. The tile size is defined by the format of the paper and the scale of the map.

The renderer creates a graphical representation for each tile. This project uses the Kogutowicz renderer [4], which is implemented in Java and offers many setting adjustments.

The renderer fetches the raw OpenStreetMap data for each tile using the OSM API.

Apart from the map in the background the renderer also visualizes the extent of the neighboring, overlapping tiles and the track itself. Figure 2 shows an example of
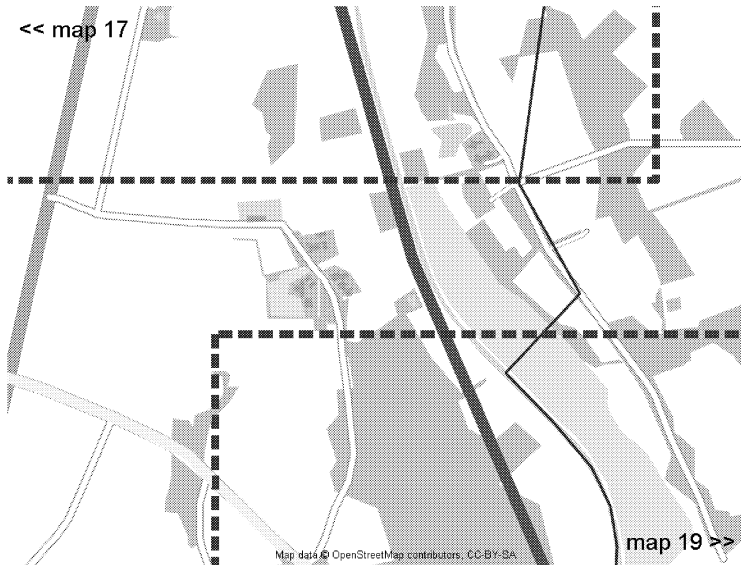
Figure 2. An example of a tile along a track. The track is in blue, the extent of the neighboring tiles is in black.

a rendered map section. In the final step the map sections are linked with additional information, the resulting map booklet is generated and sent to the user via email.

The user gets feedback for each step through the web interface that can be accessed at giv-osm.uni-muenster.de. The validated track is visualized on a map as well as the preview of the tiles. The user can adjust the page settings if necessary and specifythe rendering options.

The whole architecture is implemented in Java. Using OpenStreetMap has several advantages, especially for copyright and licensing. OpenStreetMap data is licensed under the *Creative Commons Attribution-ShareAlike 2.0* License. That means that you are free to copy, distribute, transmit and adapt our maps and data, as long as you credit OpenStreetMap and its contributors.

4. Conclusion

The project demonstrates an architecture to create individual map booklets based on the integration of GPS tracks. Similar projects offering printing functionality of Open-StreetMap data have already been reported. But none of them offers a web-based tool to print maps along a path. This project enables a user to create a map booklet for a specific purpose. The map booklet shows the local environment around a track and provides only the areas the user is interested in.

For this purpose an algorithm has been developed to calculate overlapping map tiles along a track. Existing path splitting algorithms are not capable to perform this tiling. Furthermore this project integrated a renderer to fetch raw OpenStreetMap data, which enables the user to adapt the map individually to the personal needs.

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LOSM - A lightweight approach to integrate OpenStreetMap into the Web of Data

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Abstract. The idea of interlinking spatial data from OpenStreetMap to the large repositories of the Linked Open Data Cloud is already acknowledged as a valid contribution to the semantic web. Since the nature of the OSM data is volatile, this work proposes a dynamic approach to make OpenStreetMap available as linked data. Instead of serializing the whole OpenStreetMap database into RDF and linking upon these triples, we serve resources on the fly and link the original data. Integrating the linkage of the data cloud into the original data prevents redundancies, preserves actuality and creates additional value.

Keywords. OpenStreetMap, Linked Data, RDF, XSLT, Web of Data

1. Introduction

The principal of linked data refers to a set of methods for publishing and interlinking data from different resources in a structured and meaningful way. Following the principles of linked data enables simple integration and fusion of data pieces from different data provider. For example, the spatial representation of the "Statue of Liberty" in OpenStreetMap (OSM) could thus easily be enriched by thematic data available through the Wikipedia project.

Bizer [1] summarized four basic possibilities for publishing as linked data: Static files (like FOAF[2] profiles), conversion tools (for non-XML data formats), mapping from relational databases and wrapping services encapsulating Web APIs (XML- and microformats).

The idea of making OSM data available as linked data is already successfully implemented within the LinkedGeoData (LGD) project [2]. A whole dump of the OSM dataset was first parsed into a relational database and then mapped as triples into a store using Triplify [3]. However, the sheer amount of data and the nature of the transformation process causes multiple side-effects, e.g. redundancy and limited actuality (sometimes several weeks behind the official OSM dataset). Furthermore, LGD provides only a limited number of links exclusively to the DBpedia[3] dataset.

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[2] http://www.foaf-project.org/
[3] http://dbpedia.org/

Another approach, instead of mapping from a relational database, is using a dynamic wrapping service to translate small amounts of data on the fly. Bizer et.al. [4] wrapped several Book Web APIs like Amazon or Google Base into a RDF Book Mashup. They demonstrated how this data could be integrated into theWeb of Data following the linked data principles. While this transformation was more or less "hard-coded", frameworks like Swignition[4] and Krextor [5] provide more generic approaches. Swignition is implemented in PERL, with the ability to call also XSLT processor, whereas Krextor is purely based on XSLT-transformations between XML and RDF. A different attempt trying to overcome the barriers between XML and RDF is XSPARQL. It is a combination of XQuery and SPARQL which can be used to perform queries directly on XML and RDF data [6].

With regard to successively interlinking the OSM database with the Linked Open Data Cloud (LOD), on-the-fly transformations around existing Web APIs can be advantageous: There is no requirement for a local database maintenance, thus also no need for dedicated hardware. It further implies the avoidance of data redundancies and ensures up-to-date data, since it is always requested directly from the original database upon the users needs.

This work describes the conceptual considerations as well as the technical implementation of a lightweight on-the-fly wrapping service for OSM. After reviewing related ideas and work that has already been done, the following sections give an overview of the different parts of the project and its individual implementations before summing up in a conclusive discussion.

2. Towards Linked OpenStreetMap

This section introduces the technical implementation as well as the vocabulary developed to foster such a process and to identify and structure corresponding items.

2.1. Vocabulary

Sharing a common vocabulary contributes to interoperability among people and systems in the general concept of the semantic web. As linked data is part of it, it is affected by the idea of sharing common understanding by means of well accepted vocabularies.

The basic data model of OSM is a topological centric one, consisting of connected nodes and ways (lists of nodes) with an unlimited number of tag elements assigned. Object classes which can be used for mapping and linking OSM entities to concepts, do not exist a priori. Moreover, there is also no well structured and specific vocabulary users have to follow. According to the OpenStreetMap wiki[5], users are free to use any terms that seem appropriate to annotate any features of interest. However, the community tries to agree on a common set of tags that should be used in a certain way. Nevertheless, there are no formal restrictions because this is done rather bottom-up and not by following ontology engineering methods and rules.

Following the linked data principles [7], we tried to reuse terms and properties from existing vocabularies like dc:creator (Dublin Core Vocabulary), rdfs:label (RDF

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[4] http://buzzword.org.uk/swignition/

[5] http://wiki.openstreetmap.org/wiki/Map_Features

Schema), xmlns:dateTime (W3C XML Schema) or geo:lat/long (Basic Geo WGS84 lat/long Vocabulary). While examining existing vocabularies, we tried to map the OSM terms into the PROTON Ontology[6] which was also used in [8]. An advantage of this approach would be a well structured vocabulary from an ontology engineering perspective. However, terms used in OSM are not necessarily used with the same syntax in the PROTON ontology (naming heterogeneity). This led to the question how to state in RDF that they have the same meaning or are similar, since owl:sameAs should only be applied on instance level [9]. Additionally, the PROTON ontology does not seem to be used frequently in the context of linked data.

   Thus, some compromises were made and the final decision was to adopt all terms from the OSM wiki. More specifically, the top level categorization (keys) of the OSM Map features were adopted as they are; keys were translated to classes and the values to subclasses. This categorization was enriched by adding structural layers between the fairly general and detailed terms of the implicitly given set of map feature types. For example, in OSM the term 'amenity' refers to a super class of many heterogeneous small scaled terms like 'bank', 'restaurant', 'bar'. By adding intermediate levels such as 'EatAndDrink', terms of the same genus are grouped together.

   On the one hand we respect the bottom-up way people are used to tag their creations (words, expressions, semantics) while on the other hand more structure is added. This can facilitate basic reasoning tasks like subsumption reasoning and enables more structural browsing and querying.

2.2. Converting OpenStreetMap to RDF

The core of our Osm2Rdf RESTful web-service is built upon the Krextor framework [5], an extensible XSLT-based framework for extracting RDF from XML. Krextor serves as a generic interface for mapping different XML input languages to several RDF output notations. We decided to use Krextor, since it supports the definition of new XSLT input modules independently from the aimed output.

   We extended Krextor by defining a new input module for the OSM XML format (API0.6[7]). Krextor comes along with several templates like 'create-resource', 'addliteral-property' and 'add-uri-property', simplifying the extraction and mapping task.

   For this prototype we restricted the mapping to OSM Node Elements. Defined by a static rule we extract basic attributes like *id, lon, lat, userid* and *timestamp* existing among all OSM entities. We linked them using common terms and properties (section 2.1). Additionally, each *<tag>* element carries an attribute key and value. We consider only nodes having at least more than one *<tag>* child element (usually all other nodes are referred by a way, meaning they do represent more complex geometries). If the key attribute of a tag element matches to 'name', its value is mapped to a literal using the property rdfs:label. Values where the key contains a string 'sameAs' are treated as a resource URIs pointing to resources in other data hubs (section 2.3). We use the owl:sameAsproperty (Web Ontology Language) to link them, since they describe same entity.

   For all the other tag elements it is rather cumbersome to determine appropriate mappings, if one does not want to define several hundred of mappings by hand.

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[6] http://proton.semanticweb.org/

[7] http://wiki.openstreetmap.org/wiki/API_v0.6

However, the OSM community informally agreed on a set of feature types and corresponding tags in order to create, interpret and display the OSM entities in a common way across different applications. This allows us to state some more or less generic mapping rules, by aggregating over common keys taken from the OSM Wiki. In case the key matches to one of the key groups, we extract the corresponding value of the tag element and link it as an instance to our ontology. Of course this generic rule conceals several risks, for example assigning more than one concept to the same resource or linking to not deferrable concepts of the ontology (e.g. someone used a common key like 'k=amenity' but as value 'v=Tiergarten', which does not correspond to a feature on the OSM Wiki thereby also not in our vocabulary). Though, the rules are easily extendable to more constrained ones in the future. The following example shows the RDF serialization of the OSM node representing the new museum ("Neues Museum") in Berlin[8]:

```
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:ns1="http://purl.org/dc/elements/1.1/#"
    xmlns:ns2="http://www.w3.org/2003/01/geo/wgs84_pos#"
    xmlns:ns3="http://www.georss.org/georss#"
    xmlns:ns4="http://www.w3.org/2001/XMLSchema#"
    xmlns:ns5="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:ns6="http://www.w3.org/2002/07/owl#">
    <rdf:Description rdf:about="http://losm.uni-muenster.de/resource/node/1017962501">
        <ns1:creator rdf:resource="http://losm.uni-muenster.de/resource/user/395669" />
        <ns2:lat rdf:datatype="http://www.w3.org/2001/XMLSchema#double">52.5201242</ns2:lat>
        <ns2:lon rdf:datatype="http://www.w3.org/2001/XMLSchema#double">13.3977586</ns2:lon>
        <ns3:point>52.5201242 13.3977586</ns3:point>
        <ns4:dateTime rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">
        2011-03-17T13:18:42Z
        </ns4:dateTime>
        <ns5:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Neues Museum</ns5:label>
        <ns5:type rdf:resource="http://purl.org/ifgi/losm#museum" />
        <ns6:sameAs rdf:resource="http://dbpedia.org/resource/Neues_Museum" />
        <ns6:sameAs rdf:resource="http://rdf.freebase.com/ns/m/0dc57j" />
    </rdf:Description>
</rdf:RDF>
```

As it can be seen, it is already linked to other resources of remote datasets with the owl:sameAs property. The RDF representation is generated on-the-fly and served through our RESTful server interface. At the moment we serve RDF representations of single nodes. The basic URI pattern for this information resources is:

http://losm.uni-muenster.de/resource/node/id

The *id* corresponds to the original OSM node id. Depending on the accept header of the request the response will be returned encoded in RDF or HTML. In addition to single resources, also whole geographically bounding boxes to a limited size can be queried:

http://losm.uni-muenster.de/resource/bbox/left,bottom,right,top

The bounding box *left,bottom,right,top* corresponds to the left-bottom and top-right corner of the BBOX encoded in WGS84 coordinates. Using a HTTP GET Request all OSM nodes of the bounding box are returned encoded in RDF. This is used as a shortcut, since the on-the-fly nature of the service and the amount of the data does not

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[8] http://www.openstreetmap.org/api/0.6/node/1017962501

allow the creation of an ad-hoc queryable graph for the whole dataset. Therefore, the service accepts POST requests with a plain text SPARQL query embedded in the request body limited to a certain BBOX. The results are returned encoded in JSON.

2.3. Semi-Automatic Linking to the Linked Open Data Cloud

The idea of the semi-automatic annotation tool is to recommend links to other entities in the LOD that describe the same feature as the node in the OSM dataset. Therefore we built a set of SPARQL queries to search through the different RDF data dumps. The information used for these queries are taken from the OSM nodes like the name, the coordinates or the type.

Furthermore, a reverse geocoder is used to retrieve information like the country or city of the corresponding node.

The queries are run against the LOD cache SPARQL endpoint[9] which contains the datasets from the LOD. This allows us to address different data dumps within one query, instead of running several queries to various sources. Nevertheless, trying to address several data dumps also has a downside, since these dumps use different vocabularies in different ways. For example, if we want to search the labels of resources, we need to perform the search for triples with predicate rdfs:label, which will deliver results from several datasets, since this property is widely used.

When trying to add a restriction using the coordinates provided by the OSM data this looks different. Inspecting some of the bigger data dumps in the LOD, one will recognize that all of them use different representations for geographical coodinates. For example, DBpedia or GeoNames[10] are using the W3C WGS84 Geo Positioning vocabulary[11], while Freebase[12] deployed a definiton by their own vocabulary.

So for now we decided to optimize the queries for DBpedia entries, for example when making restrictions for coordinates or the category. We chose dbpedia since it has the most consistent and well described dataset connected to several other sources providing us with additional sameAs links.

2.4. Interface

To demonstrate the capabilities and benefits when combining spatial data from OSM with additional sources of the LOD, a small webinterface was developed integrating the different components[13].

The OSM nodes for the current bounding box are requested from our service, displayed on a map and can then be investigated by the user. If the resource is already linked with a sameAs property, this information from the remote data hub is fetched and displayed in a structured way. At the same time, once the user clicks on an existing feature, the link recommendation service queries for new or further possible outgoing links.

To ensure quality and integrity of the data, the suggestions for sameAs links have to be confirmed manually by the user. This should avoid misleading links. If the user

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[9] http://lod.openlinksw.com/sparql/

[10] http://www.geonames.org/

[11] http://www.w3.org/2003/01/geo/wgs84_pos#

[12] http://www.freebase.com/

[13] The prototype and source code is online available at http://losm.uni-muenster.de

has selected one or more suggested annotation links as appropriate, these links will be added to the node in the original OSM database using the tag 'owl:sameAs=[link]'.

An additional command line allows the direct input of SPARQL queries. The queries are posted to our server interface, where the graph is build on-the-fly representing the current bounding box.

3. Conclusion

To conclude, our vocabulary structures the OpenStreetMap data establishing new connections between entities, which were not available before.

The on-the-fly wrapper is able to fetch up-to-date information from the OSM API and convert it according to our vocabulary. Instead of taking a snapshot of the whole OSM dataset and parsing it into a relational database for triplifying it, our prototype serves just as a facade in front of the OpenStreetMap API. Therefore, RDF representations of the OSM data can be offered without any modifications to the OSM infrastructure and with a minimal requirement for software and hardware maintenance. Furthermore, the XSLT nature of Krextor provides a flexible way for defining and changing mapping rules.

Our semi-automatic recommendation service suggests links to already existing datasets in the LOD. In this way the data can be enriched with information not being part of the original OSM dataset. Once approved, the links are stored back into the original OSM database.

Of course this approach also has some limitations. Since all the data has to be loaded from the OSM servers upon request, the response time heavily depends on the extent of the area queried. We tried to overcome this using some server-side caching mechanisms. The performance also depends on the amount of data to be transformed, even though the XSLT transformation process itself is quite fast. Furthermore, the wrapper could be used to stream the transformed triples into a triple store, also incorporating frequently update notifications e.g streaming OSM changes as RSS feeds.

The mapping of tag annotations to our vocabulary is not as straight forward as one might expect. If we look at the "Berlin TV tower"[14] for example, being tagged as attraction and restaurant in the OSM data. After the conversion, we end up with a node of two different types. Describing the data in an unambiguous way was one of the main issues developing the service and still will be in future work. Further investigations are also needed to transform and represent more complex geometries like lines or polygons in an efficient way.

Linking to more and different datasets would further improve the service, as currently most of the links are pointing to DBpedia. Geonames - one of the biggest providers of free geodata - could be a valuable, further option for that. The linkage could also be improved by adding more link types like connecting people via their place of birth or a node to their creator's FOAF page.

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OpenFloorMap Implementation

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Abstract. OpenFloorMap (OFM) is an approach to enhance the level of detail in
open spatial data repositories. OpenStreetMap only provides information up to
buildings being represented as polygons. OFM enables users and developers to
explore building layouts. On account of this, a repository providing data for
buildings and rooms establishes a new kind of platform for open spatial data. Our
prototype includes a mobile application to capture room extent and a web
application to manage floor plans.

Keywords. Volunteered Geographic Information, Android, OpenStreetMap, Floor
plan

Introduction

OpenFloorMap (OFM) is an approach towards an open web repository for floor plans
and 3-D room models inside buildings. Our approach includes a web service, web
application and mobile application to contribute volunteered geographic information to
an repository and to make them available in the web. Three-dimensional room models
are measured within a few seconds using the mobile application. The rearrangement of
measured rooms is implemented in the OFM web application. A RESTful web service
integrates these components and makes the data available on the web.

1. Architecture

The backbones of the OFM prototype are spatial data repositories as Google Maps and
OpenStreetMap, in addition to free software packages for spatial applications as
OpenLayers in connection with Geoserver. OFM is set up as a web service with an
Android mobile application for data capturing and uploading, and a web client for
editing room information.

Furthermore, the web application uses the Web Feature Service provided by
Geoserver in combination with OpenLayers to give users the possibility to locate a
building of interest and obtain the reference from the database.

1.1. Data Model

The data model consists of two Extensible Markup Language (XML) schemas. The
first one (room XML file) represents a single room and is used as an exchange format
between Android application and OFM web server. It consists of the name, floor and

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description of the room and a human readable georeference (Geopath) of the building (country/city/zip code/street/street number). The results of the measurement are stored as nodes: one for each corner including the values for width, length and height which refer to a local spatial reference system.

The second one (building XML file) serves for the representation of a whole building. In this structure a building has a unique identifier, a name and a Geopath. The data set is divided into different floors with a given level. Floor elements contain room elements, whose structure is basically the same as in the room XML.

When room information is sent to the OFM server, the Geopath (e.g Germany/Muenster/48151/Weseler_Strasse/253) is checked by a web service. If it already exists in the database, new room information will be added to the regarding building data file. Otherwise the application creates a new building XML and inserts the committed room data. As the real coordinates of a room sent by the mobile application are unknown, a new room has a local spatial reference system. When it was moved to its correct location by the web application the spatial reference system changes to WGS 84. The current spatial reference system of a room is represented by an additional tag.

1.2. Web Service

The RESTful web service architecture provides web connectivity based on the state-of-the-art web oriented architecture axioms, enabling direct resource accessibly and thus great mashup capabilities. This characteristic underlines our approach of an "open" architecture for floor maps, minimizing the accessibility threshold.

2. Applications

2.1. Android App

The Android application was developed with the intent to create a simple tool for capturing room layout data within a building. The application guides the user by using Google Maps, whose features are already supported by the Android API. For the next version of OFM it is possible to use an equivalent OSM tool instead. With a click on the building the geocoded address will be loaded (Figure 1). Providing the floor level and room name is mandatory as well, while the description is optional.
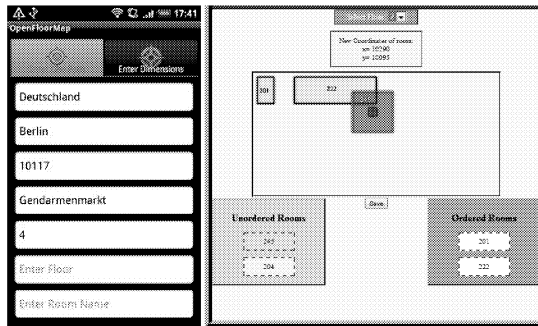
Figure 1. Android application interface (left), Web application interface (right)

The next interface helps capturing the room dimension. This can either be done manually or automatically using the included measuring capabilities. This tool uses the camera functionalities and the orientation to calculate the distance between all corners of the room.

The measurement result generates length, width and height of the room. This information can be corrected manually. The information of the room is sent in an XML-encoded HTTP post request to the OFM web service.

2.2. Web App

Arrangement and rearrangement of room plans is performed via the web application. Figure 1 shows the interface of the prototypical implementation. Additionally, OpenLayers including a Transactional Web Feature Service (WFS-T) helps users to select available room plans at specific locations. At these locations it is possible to view floor plans for each floor of the building. At the top of the web page users can switch between available floors. In the middle the room plan of the selected floor is visualized. At the bottom of the page two different forms of uploaded rooms are listed. The first category consists of unordered rooms representing the rooms that have been captured by the Android application but are not yet arranged within the whole floor plan. The second category, named ordered rooms, includes all rooms that are already placed at the correct location by users who used the web application. The arrangement and rearrangement of rooms is possible by drag and drop of the object from the bottom of the page to the room plan panel above. After this step, users are able to move the room to the correct location and save the changes afterwards. Subsequently, the room plan gets updated and the new arrangement of rooms is visible to all users.

3. **Future Work**

The prototypical OpenFloorMap implementation provides all basic functionalities for a volunteered building layout repository.

Upcoming developments have to address versioning mechanisms as a part of an overall open community infrastructure. Moreover, a 3-D rendering engine is needed to provide comfortable access and integration capabilities for floor map data. These features are the most essential next steps towards an establishment of OpenFloorMap.

Further research should include approaches for indoor positioning based on OpenFloorMap data and smartphone embedded sensors, thus to provide indoor navigation solutions.

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On the Integration of Geospatial Data and Functionality into Business Process Models

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Abstract. Business process modelling is a common instrument to formalise, execute and document complex workflows at an enterprise level. A large part of spatial data and functionality residing in Spatial Data Infrastructures (SDI) and Geospatial Information Systems (GIS) has the potential to be integrated into common business process models. This paper presents an approach to provide geospatial data and functions in business process models. The integration of geospatial tasks into business processes is realised with the common modelling language BPMN. Furthermore the graphical modelling capabilities of BPMN are investigated to foster an integrated methodology for process execution and documentation.

Keywords. Business Process Modelling, Notation, Workflow Management, Spatial Data Infrastructures

Introduction

The portrayal of business processes in a graphical form is a common instrument for representing complex workflows at an enterprise level. Originally it was a means to document business processes of an enterprise to preserve the knowledge of the processes and to be able to pass this knowledge on. The scopes of application have evolved continuously. Today the goal is the integrated execution of graphically modelled business processes by Workflow Management Systems or Business Process Management System (BPMS) in addition to an attractive visualisation. The major scopes of application in business process models according to [1, 2, 3, 6, 10] are:

1) Process documentation and process visualisation
   - Process management, process analysis, process reengineering
   - Requirements development for IT development, software selection
   - Organisational development, staff and task planning, responsibilities, safety constraints, process cost accounting
   - Certification
   - Training

2) Process implementation and process engineering
   - Software development, Model Driven Software Development

- Process control, Enterprise Application Integration Management
- Process validation
- Process definition for BPMS
- Process optimisation with process monitoring

The goal of (1) is to prioritise the formal, abstract description of the processes from the perspective of business users and enterprise management. The goal of (2) is the translation of business processes into software. For both scopes of application different modelling standards, architectures and notations as well as different IT systems to support them have been developed.

At the intersection of Spatial Data Infrastructures (SDI), Geospatial Information Systems (GIS) and Business Process Modelling (BPM) the following research questions can be identified:

- Can methodical and technical approaches of business process modelling be applied in SDI and GIS?
- Is an adoption possible by purely relying on existing standards? What are possible limitations? Are some extensions necessary?

1. Modelling of business processes in SDI and GIS

Spatial Data Infrastructures (SDI) are built up at all levels in state administration. This development is particularly stimulated by the European INSPIRE Directive (Infrastructure for Spatial Information in the European Community) [11], which demands a service-oriented architecture, relying on standardised spatial web services. SDI provide both geodata and geoprocessing capabilities across the boundaries of a specific GIS or database. Thus SDI and GIS provide support processes in EGovernment and E-Business [8].

Existing GIS and spatial ETL (Exchange – Transform – Load) software already offer graphical modelling capabilities to chain specific tools, data sets and compose higher level processing steps (e.g. ArcGIS Model Builder and Workflow Manager, or the Feature Manipulation Engine – FME) to automate recurring processes. The technology is usually proprietary and generic IT standards for process interoperability are not used, thus the specified workflows and models can hardly be used with 3rd party products. Geospatial processes are also increasingly assembled in SDI. Concepts for web service based compositions of individual service are discussed by Kiehle et al. [12] and Friis-Christensen et al. [13]. The service chaining is usually implemented using the Business Process Execution Language (BPEL) or some proprietary hard-wired execution logic. In any of these cases the modelling process is not standardised and rather tool-driven than task-driven. However, geospatial web services with standardised interfaces have the potential to become integrated parts in other service based business processes.

2. Requirements for a process modelling language

To achieve comprehensible modelling of executable business processes in SDI and GIS and the chance for integration with E-Government and E-Business, the following requirements are imposed on the modelling language:

- The modelling language is standardised.

To reach a common understanding and the exchange of the process models among users from different domains or different levels and departments, the modelling language shall be standardised. In order to achieve technical interoperability, it is necessary to standardise the execution logic. The "European Interoperability Framework (EIF) for European public services" [14] recommends using open standards in E-Government.

- The modelling language is neutral to the implementation.

The process description and execution is not bound to any specific platform. Process models may be operated on different Workflow Management Systems, BPMS or executing engines. Established standards like web services should be provided as a default implementation.

- The notation of the modelling language is standardised.

A common understanding and of visualised models between the different people is only possible if there is a fairly simple and uniform graphical notation. The definition of uniform symbols enables fast visual detection and analysis of the business processes meaning.

- The modelling language defines a corresponding encoding.

For the exchange of models between different tools or engines a common encoding shall be used. The encoding shall represent both the graphic representation and the execution semantics. XML languages have been established as a general means for message encoding in a web service environment. The standard should also use an XML-based encoding thus provide an opportunity to be automatically validated (e.g. by X-Schema).

- The process model is executable.

A sole description and documentation of the process is not sufficient. The model must be interpretable and executable by process execution engines.

- The modelling language supports automatic and manual tasks.

Not all process steps can be run fully automatic. Discretionary decisions play an important role in state administration. The invocation of analogous documents, the application of plausibility checks or the necessity to make telephone call are manual tasks and require user interaction.

- The modelling language is extensible.

The modelling language should provide a basic set of symbols that can be further refined and specialised to support new domains. The derived visualisation has to be adapted for a fast perception by users from other domains, e.g. through a generalised visual symbol.

- The modelling language should be able to support organisational aspects.

The description of business processes also serves as a documentation and planning instrument for an organisation's management. Thus the language shall provide means to represent different responsibilities, e.g. by allowing to specify roles.

- The modelling language should offer different forms of visualisation.

Based on that wide application range, process models can be used for different purposes at different levels and in different departments. Recognising those different aspects simplifies the different representations of a business process.

- The modelling language should support quality management, process analysis and process model validation.

To monitor, analyse and optimise the defined processes, it must support the extraction of quality indicators for reporting and monitoring.

- The standard is public and implemented by common software products.

To be able to exchange and run the modelled processes across the boundaries of enterprises or administrations, a wide support of software manufacturers is necessary.

3. Standards for the business process modelling

Standards for business process modelling have evolved over time[1]. The most important modelling languages will be introduced briefly. Languages that are notation-only (e.g. VISIO) or execution-only e.g. BPEL are omitted. The languages are classified according to Gadatsch 2005 [6] who distinguishes script-based, diagram-based, objectoriented, data-flow-based and control-flow-based process description methods. The control-flow-based method EPK represented the base of BPM software ARIS produced by IDS Scheer. EPK was developed in 1992 and became very common in German-speaking countries after it was merged into SAP. Despite this propagation no EPK remained proprietary and was not raised to a standard. EPK evolved to "extended EPK" (eEPK) with further to extensions. In 2008 ARIS announced that it also supports BPMN [4]. The most important differences and similarities between EPK and BPMN in the version 1.2 can be found in [5].

The object-oriented standard UML is frequently used in Model Driven Software Development. In particular, UML defines activity diagrams to describe processes in a detailed technical manner. As UML is focused on modelling of software systems, many modelling elements have a technical motivation, e.g. the processing of objects and attributes. The notation is too technical for process documentation at an enterprise level. Some workflow management systems use or have used UML activity diagrams for notation (e.g. MID Innovator, oxaion open, FlowSys) but the interpretation and execution of those diagrams is not standardised. UML is very common and is supported by many software vendors [4, 9].

BPMN 1.0 was adopted as a standard in 2006. BPMN 2.0 was adopted as an official standard in January 2011 [17]. Unlike the previous BPMN 1.2, version 2.0 is no longer limited to just graphic notation. All attributes necessary for an execution of process

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[1] http://upload.wikimedia.org/wikipedia/commons/d/df/Standards_BPM_2009_11.jpg

models and encoding (XML based) are specified. It offers three kinds diagram representations (Collaboration diagrams, Process diagrams, Choreography diagrams) and different conformance classes (e.g. "Process Modeling Conformance", "Process Execution Conformance"). The binding of the execution is technology independent in which web services and XML languages are partly provided as a default technology. The standard's annex contains some transformations for some modelling pattern to BPEL. The OMG references 73 software tools that support BPMN 2.0[2], ranging from Open Source developments to products distributed by major software companies.

It is also noteworthy that some insufficiencies in the older versions of BPMN (1.0 to 1.2) have been compensated with UML in some software products (e.g. MID Innovator, Oracle 11g).

4. Geo-BPMN as an approach to model business processes with geospatial capabilities

Among the examined standards, BPMN 2.0 performs best according to the requirements specified in section 2 and shall be investigated for a geospatial extension. The following extension-related capabilities are scheduled for BPMN 2.0 [4, 7]:

- Extension of attributes
- Relations to external elements
- Extension of artefacts
- Use of colours (in the notation)

Based on these capabilities modelling elements with specific execution semantics and representations can be defined. BPMN recommends to extent available generic core elements [17].

In SDI geospatial data and functionalities are provided by spatial (data) services. Those services can therefore be represented as the BPMN modelling element "service task". Alternatively, the access to GIS and database systems also can be represented as a "service task". Complex technical tasks or manual process steps can be modelled as a "user task".

To distinguish the variety of spatial data services and components of SDI and GIS appropriate namespaces have to be used. The following suggestion presents a set of namespaces for classifying geo-elements in BPMN:

- OGC:WMS, OGC:WFS, OGC:WCS, OGC:WPS (for OGC web services)
- INSPIRE:ViewService, INSPIRE:DownloadService (for INSPIRE network services)
- AAA:NAS (for specific cadastral interface)
- urn:ogc:wps:1.0.0:buffer, urn:ogc:wps:1.0.0:egenhofer:contains (for OGCWPS process profiles [15])

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[2] http://www.omg.org/bpmn/BPMN_Supporters.htm

The list is just a short overview and can be extended. It shall clarify the methodology of classification. Further implementation details, such as the version of the interface, can be defined as additional attributes of the core elements.

Figure 1 shows the representation of the BPMN core element "service task". All geospecific process steps can be generalised as generic BPMN core elements whose intended execution semantics must be specified at runtime. With the generic graphical representation is applied, geo-specific elements are hardly distinguishable from other elements. Altogether, such a representation is of little practical use. Figure 2 shows a BPMN "service task", which was extended to include a textual description for the task type (invoke a Web Map Service (WMS) [16]). The task is instantiated with a request to an aerial photo. Figure 3 shows an alternative extension of the BPMN core element, that uses the element's "annotation" to identify the task type (invoke a WMS). Both examples already allow a uniform use of WMS, but the visual recording is still limited.

Figure 1. A BPMN 2.0 Service Task

Figure 2. Textual extension

Figure 4 extends the BPMN core element further by defining a custom graphical representation. The basic shape of the core elements is preserved to maintain a certain degree of recognition within the BPMN standard. The symbol is highlighted with a blue background to show that it is input data and another small symbol in the top right corner to illustrate the type of service interaction (a WMS request).
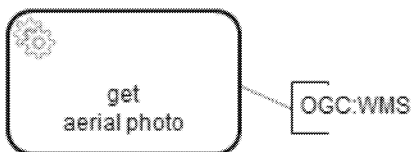
Figure 3. Textual annotation

Figure 4. Graphical extension

Listing 1 shows a possible encoding of an OGC WMS version 1.1.0 as BPMN "service task" element. The task extensions are realised by specialised attributes that describe the execution semantics. The definition has to be register in the Schema of BPMN.

```
<serviceTask       id="wmsRequest110_01"       name="get       aerial       photo"       implementation="##WebService"
operationRef="tns:getMap">
      <ioSpecification>
      <dataInput itemSubjectRef="tns:getMapRequestItem" id="dataInputOfServiceTask" />
      <inputSet>
      <dataInputRefs>dataInputOfServiceTask</dataInputRefs>
      </inputSet>
      <outputSet />
      </ioSpecification>
```

```
        <dataInputAssociation>
        <sourceRef>
        <LAYERS>ortho_rgb06</LAYERS>
        <SRS>EPSG:4326</SRS>
        <BBOX>13.0,51.00,13.5,51.20</BBOX>
        ...
        </sourceRef>
        ...
        </dataInputAssociation>
</serviceTask>
<interface name="OGC WMS 1.1.0" implementationRef="ogc:wms:1.1.0">
<operation id="getMap" name="get Map" implementationRef="ogc:wms:1.1.0:getMap">
...
</operation>
</interface>
```

Listing 1. A WMS query as a BPMN Service Task

A general feature of business process modelling languages is branching to represent conditions in the process flow. In BPMN process flows a branched with so called gateways. Figure 5 shows a WPS invocation for a relationship check between spatial features with the "9 Intersection Model" [18]. An evaluation of the property "contains" is done with a so called "exclusive gateway". The WPS element is highlighted in yellow to distinguish it from data services.
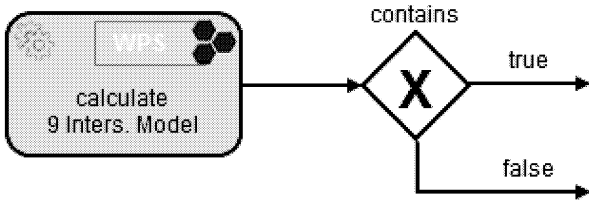
Figure 5. Relationship check of spatial features

Figure 6 shows a simple process in which the images of two WMS are overlaid. The overlay is produced by a web service (Image-Processing-Service IPS) that provides general image processing capabilities. The resulting image is sent as a message to the requestor.
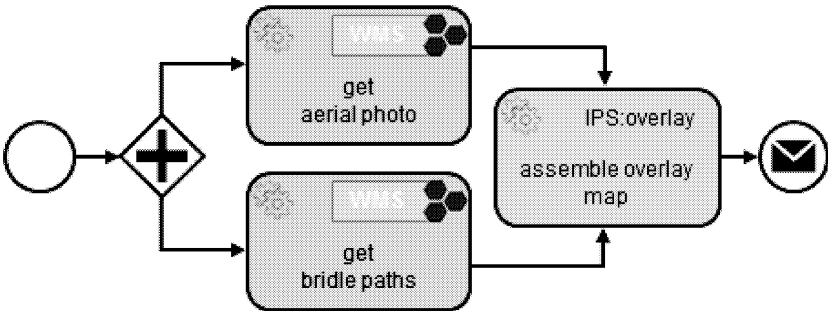
Figure 6. Image overlay example

For some GIS specific tasks a geographic extension of BPMN is not required. This is usually the case for manual or very generic tasks. Figure 7 shows a BPMN user task where a human person has to digitise spatial features. A BPMN script task which determines the surface area of a given input feature is shown in figure 8.
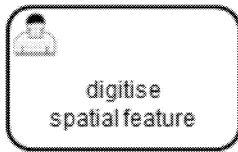
Figure 7. A BPMN 2.0 User Task
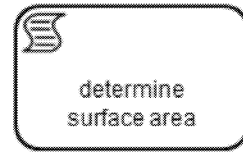
Figure 8. A BPMN 2.0 Script Task

Of course both elements can also be defined as geo-specific elements. An obvious advantage would be the possibility to standardise the underlying procedures and enforce a stronger typing of the input data. But a high degree of automation and complex typing requires a solid foundation, e.g. in terms of a common geoprocessing algebra (e.g. based on [19, 20]). As there is no such algebra for geoprocessing in general, practical reasons suggest the application of custom procedures and code to accomplish certain geoprocessing tasks [21].

To provide interoperable tasks elements, that stem from SDI and GIS, into common business process models it is required to define the described extensions as profiles of BPMN. Such a "Geo-BPMN" might harmonise the invocation of spatial data and geoprocessing functionality. Thus general business processes can draw from the capabilities of spatial services. A first step is the recognition and adoption of standardised service interfaces to enable a late binding to specific services at run time. To avoid the specification of hosts or endpoints of web services instances a lookup procedure in a registry is required. Such a registry would allow inquiries for web services by stating their required features and subsequently invoking a web service that satisfies them.

5. Conclusion

The paper presented an approach to leverage SDI and GIS for business process modelling and execution. The upcoming BPMN 2.0 standard was found to fulfil most the requirements imposed on a modelling language. Some examples for extending the core elements of BPMN were given to illustrate the potential benefits of integrating spatial data and functions into general business processes in E-Government and EBusiness. As a future task the extension of the BPMN core elements to form a Geo-BPMN profile was suggested. Such a profile is expected to be mutually beneficial as it helps to introduce SDI and GIS at an enterprise level in E-Government and E-Business and also justifies the service-oriented provision of spatial data and processing logic. The integrated process modelling approach which focuses on user's and process management's requirements has the potential to lower the thresholds in spatial data handling and thus broaden the community of users of spatial data and functionality.

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Enabling User-friendly Query Interfaces for Environmental Geodata through Semantic Technologies

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Abstract. We sketch the functionality and architecture of the HIPPOLYTOS prototype, which uses ontology-based metadata to allow user-friendly text queries to structured data in the area of environmental information systems.

Keywords. Spatial Reporting, Semantic Search, Ontology, Environmental IS.

1. Introduction

There is a huge amount of environmental geodata available, and with the increasing up-take of INSPIRE, it will dramatically grow in the near future. Up to now, the commercial and societal impact of open governmental spatial data is nevertheless very limited, due to a number of reasons – among others, also the tremendous intransparency of geodata offerings. For a normal citizen, an interested company, even for employees of public authorities in a different domain, the heterogeneity and distributedness of environmental geodata is often overwhelming. Hence, user-friendly and powerful search interfaces are a must-have in this area.

On the other hand, Semantic Web technologies promise advanced functionalities for intelligent search, integration, and processing of Web-accessible data, documents, and services [1]. Based on the annotation of complex machine-readable *metadata* to Web-based information resources, these resources can better be found and interpreted. Semantic metadata instantiate and refer to *ontologies*, powerful conceptual domain-knowledge models, agreed within a certain user community and represented in expressive, logic-based languages, which are standardized by the World Wide Web Consortium (W3C) [2]. The power of semantic technologies relies on several factors – the specific importance of each depending on the specific use case – like standardization of representation languages, metadata or knowledge models, like automation of some reasoning services because of the logic-based semantics, or like empowering user or systems by the domain-specific background knowledge represented in ontologies. Furthermore, ontologies for knowledge organization and

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human search and navigation, often comprise a so-called *lexical layer*, which describes how the concepts are referred to by natural-language expressions, often covering the variability of human language, addressing phenomena like synonymy, or enabling multilingual knowledge access.

Although comprehensive metadata and extensive background knowledge for knowledge organization (in the form of thesauri) are widespread in environmental information systems, there are not yet too many industrial-strength applications of semantic technologies in this area. This paper presents some results and design decisions of the HIPPOLYTOS project which aims at a practicable combination of (i) semantic technologies and (ii) a commercial tool for geodata management and spatial reporting (disy Cadenza). Very generally spoken, the project goals of HIPPOLYTOS were:

- to map an intuitive, text-based search interface at the front-end …
- to complex data structures and relationships in the back-end (environmental information system/ data warehouse) …
- in order to better exploit existing expert knowledge (in domain ontologies and in predefined selectors and selector metadata), …
- but also taking into account real-world constraints and requirements.

The paper is structured as follows: in Section 2, we sketch the look-and-feel of the HIPPOLYTOS prototype. In Section 3, we elaborate on its realization, covering some basic design principles and a rough architectural sketch of the system. In Section 4, we summarize and discuss the current status of the system and some future work.

2. Look-and-Feel of the HIPPOLYTOS Query Interface

In contrast to other semantic search projects, HIPPOLYTOS does not focus primarily on text, documents or multimedia information (as we do in complementary research [3,4]), but on *structured data* in databases, which is continuously collected and provided to the citizen by many public authorities like statistics offices or environmental agencies[2]. HIPPOLYTOS develops a search layer on top of such data repositories realized, e.g., by disy GmbH's Cadenza software.[3]

Fig. 1 illustrates the current prototype of the HIPPOLYTOS system: Assume the user types in "Eisenschrott Ballungsraum Stuttgart" ("iron junk city region Stuttgart") at a Google-like, most easy-to-use query interface. The system now reasons as follows:

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[2] For instance, the „Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW)" offers on its Web portal up-to-date metered values for air quality, ozone, particulate matter, radioactivity, high and low water river stage, several water quality parameters, detailed metereological data, … for all over Baden-Württemberg.

[3] Cadenza (http://www.disy.net/produkte/cadenza.html) is a system for building search, analysis, and visualization solutions for spatial data. At its core stands a repository system, which manages the back-end data sources. An important Cadenza concept are so-called selectors, pre-defined query templates for the back-end systems which are designed by domain experts for specific analysis tasks. Selectors can be described with text metadata in the repository. They stand at the heart of many special applications that disy has built for environmental agencies and other public authorities.

- "Iron junk" is not a technical term in environmental information systems, but "recyclable fraction FE scrap" is – which is represented in the ontology, with "iron junk" as a synonymous wording.
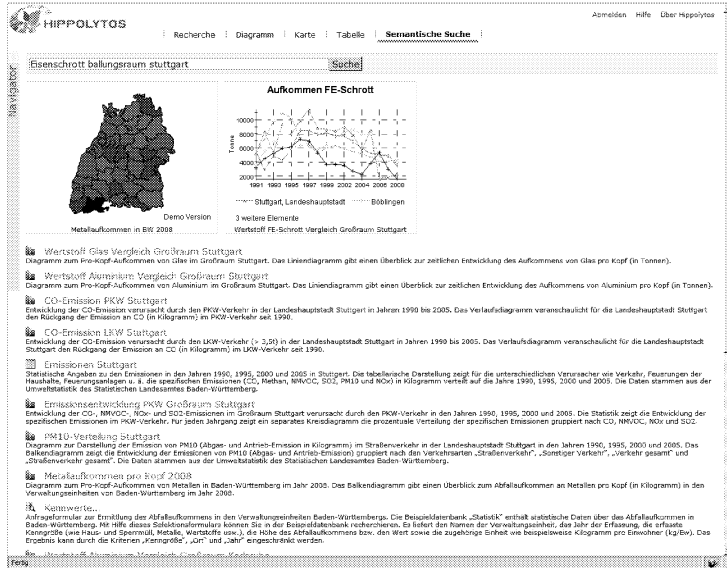
Figure 1. Query for "Eisenschrott Ballungsraum Stuttgart".

- The ontology also contains the taxonomic knowledge that "potential recyclables" is a super-concept of FE scrap and that "metal" is a super-concept of iron/FE whereas "waste" is a super-concept of scrap.
- It also contains in its taxonomy the knowledge that "recyclable fraction Aluminium scrap" and "recyclable fraction glass" may be siblings to "recyclable fraction FE scrap" in the taxonomy.
- Following the relationships in the ontology, we will also find that iron as well as recyclable materials have something to do with cars (passenger cars and trucks, "PKW" and "LKW" in German).
- Furthermore, the lexical part of the ontology knows that "city region" is a synonym for "metropolitan region" or for "urban agglomeration", which is an informal term that can be mapped to several spatial interpretations, such as the city of Stuttgart, the Stuttgart region constituted by 6 neighboring administrative districts, or the geographic area within a certain radius around Stuttgart city center.

Using this lexical and conceptual background knowledge, the system can identify a number of stored and semantically indexed *selectors* – parameterized, pre-defined queries to the structured data sources in the back-end. The match between query concepts and semantic-annotation concepts for stored selectors can be based on:

- The *subject matter* of the selector – e.g., there may be a selector querying for the amount of certain recyclable materials [which is a parameter of this

selector] in sorted waste of a given region [2nd parameter] in a given time-frame [3rd parameter] (here, a proximity match could be made with the "potential recyclables" concept in the set of super-concepts of the query concepts).

- The co-domain of the selector *parameters* – e.g., "FE" could be a parameter value for the 1st parameter of the example selector above, and "Stuttgart" for the 2nd parameter.
- The *visualization* or presentation type for the results – e.g., data value, data series, data table, map-based visualization, specific diagram type. For instance, if the query would contain terms like "comparison", "trend", or "distribution", this could give hints to the expected kind of presentation.[4]

Then – for the given query – the most appropriate selectors and parameter settings can be identified and sent to the back-end system. The result screen in Fig. 1 shows a ranked list of potential result selectors as well as previews of the visualized results of the two top-ranked ones.

3. Technical Realization

Some basic design decisions for the system seem notable to us:

- We settle upon *industrial-strength full-text retrieval* (LUCENE) in order to guarantee performance and scalability. As we search not only within the se-mantic annotations, but also in the free-text annotations already available when defining Cadenza selectors, our results can never become worse (in terms of recall) than those of a pure full-text search in the Cadenza repository.
- In order to guarantee run-time performance, we aim at a reasonable *balance between off-line and on-line processing*. In particular, we do not query the ontology at query-time, but exploit background knowledge for creating exten-sive semantic annotations in the full-text index. In that way, we *materialize* the possibly useful inferences in the pre-processing.
- In order to avoid the well-known knowledge-acquisition bottleneck of seman-tic technologies, we aim *at fully-automatic approaches wherever possible*. In particular, this means ontology-creation from existing sources (import of the SKOS version of GEMET) and fully-automatic semantic annotation of selectors with a heuristic algorithm from [5].
- Further, we *settle upon existing expert knowledge* wherever possible. Concre-tely, this means that – in the current system version – we do not directly search the back-end data sources, but we first retrieve pre-defined selectors with their existing descriptions. Further, we build on the existing GEMET thesaurus for ontology creation.
- Currently, we employ *lightweight semantic technologies* (SKOS ontology to provide background knowledge, no highly-sophisticated logics-based repre-sentations or inferences) as it is sufficient to meet our project goals. The future work has to show whether more complex techniques are necessary or useful for future usage scenarios.

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[4] This kind of „query hints" for the visualization type is not yet implemented.

Fig. 2 below gives an impression of overall system components as well as off-line and on-line processing steps.
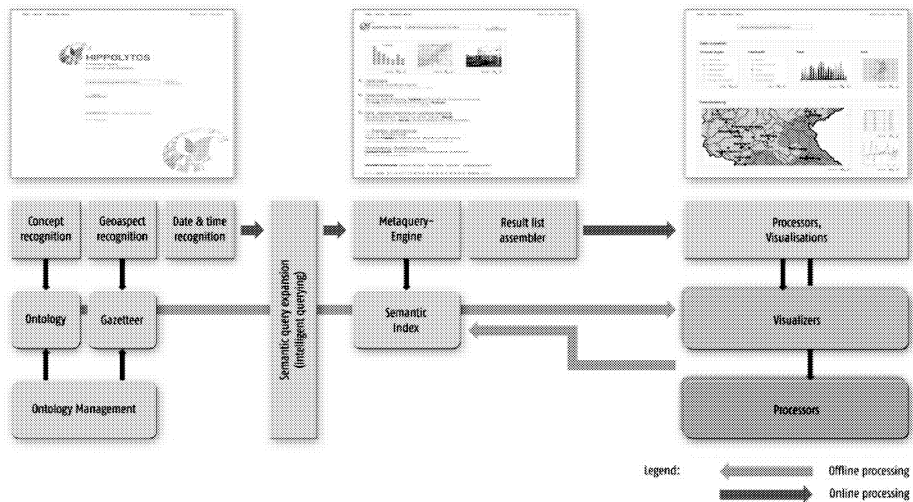
Figure 2. Sketch of Overall Architecture.

4. Summary and Future Work

Summary. We have sketched functionality and realization of the HIPPOLYTOS prototype for semantic search over geo-referenced environmental data. The goal is a "third kind of information access" for disy's Spatial Reporting products, which currently offer map-based and form-based access to geodata. This third kind of access shall be a Google-like, simple text-query interface, which automatically finds and instantiates available selectors and thus automatically configures appropriate structured queries to the back-end data sources.

To this end, repository elements and their textual descriptions are semantically annotated with ontology concepts. The ontological background knowledge about taxonomic and non-taxonomic relationships between concepts and about lexical variations of concept references allows to enrich a conventional full-text index for selectors – such that also vague, too abstract or too specific, or even wrongly expressed queries might be resolved. In order to provide a solution suitable for real-world usage, we aim at largely automated ontology creation and annotation processes.

Status. The current system must be seen as a proof-of-concept that still has some "hardwired" aspects and works on a very small example scenario. It shows already that, also for realistic data volumes and ontology sizes, the approach is able to deliver reasonable results with acceptable performance. Nevertheless, the systematic, large-scale and long-term evaluation of the retrieval *quality* still has to be evaluated in long-term experiments. Obviously, the quality of the retrieval depends on the used ontologies and annotations. Here, the practicability of *fully*-automated ontology creation and semantic annotation still has to be verified in practice – and, probably, user-friendly editors and work-embedded working processes for manual corrections

must be implemented. Approaches for fostering data curation in the linked open data (LOD) community may provide helpful ideas.

     Future work. There are still many areas for future work: (1) In the SUI and SUI II projects [3, 4], more usage and design studies for ontology-based access to environmental information have been performed, including *unstructured* information and the *links* between information sources, as well as *navigational* support for end users through ontological knowledge. A combination with HIPPOLYTOS makes sense.

(2) Besides facilitating *human* search and navigation through background knowledge, another major reason for using semantic technologies is to *facilitate automatic integration* of different information sources and vocabularies. In the SUI II project [4], initial steps in this direction are investigated. In the long-term, such *ontology-mapping* techniques would have to be integrated into HIPPOLYTOS.

(3) The current approach mainly employs background knowledge about the domain of geo-referenced *environmental information*. It does not yet go very deeply into the semantic analysis of the *spatial concepts* themselves in the query. Though the use of ontologies is a longstanding research topic in GIS (see, e.g., [6, 7]), it has not yet found its way very far into OGC or W3C standardization. Pragmatic steps into this direction may be a thrilling long-term goal.

(4) Currently, we only retrieve pre-defined selectors and do not take into account the really existing data values in the back-end data sources when interpreting a user query. This exploits the expert knowledge put into selector definition and annotation, but it is useless if a *completely* new question arises. So, we are also experimenting with so-called *"schema agnostic search"* techniques from semantic search, which exploit DB schemata and distributional semantics of data values in the back-end systems to create SQL queries from scratch, out of text-based user queries.

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Integration of Qualitative Spatial Reasoning into GIS- An Example with SparQ

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1. Introduction

Qualitative reasoning is an approach for dealing with commonsense knowledge without using numerical computation. Instead, one tries to represent knowledge using a limited vocabulary such as qualitative relationships and qualitative categories for representing real values (J. Renz, B. Nebel, 2007). Qualitative approach is use to deal with incomplete knowledge and it is considered to be close to how humans represent and reason about commonsense knowledge. This point, among others, motivates the integration of QSR into Geographic Information Systems (GIS). During the last two decades a multitude of formal calculi for spatial relations has been proposed focusing on different aspects of space like topology, orientation, and distance (Freksa and Röhrig, 1993). However, the application of these calculi in GIS remains sparse. We approach this problem by building an appropriate Application Programming Interface (API) that encapsulates the functionalities of the qualitative spatial reasoner SparQ1 to make them available to GIS applications. Our API which is written in Java provides a set of Extensible Markup Language (XML) data structure for specifying the query to SparQ and returning the results. The API itself resides on the client-side and accepts XML structured queries which it then passes on to SparQ in the latter's own syntax. Results from SparQ are converted back into XML and returned to the user application.

In this paper we will first describe the API we developed for SparQ and how it has been tested with the open source java-based GIS software OpenJUMP2. Then we will note some shortcomings of our work especially with respect to the applicability of the API in a broader context, for example considering restrictions on the types of entities on which qualitative reasoning can be applied. Finally, we will discuss some future directions for our work and the challenges we envisage.

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[1] SparQ was developed and is maintained at the University of Bremen under the project (R3-[Q-Shape], etc.). Go to http://www.sfbtr8.uni-bremen.de/project/r3/sparq/ for more details.

[2] OpenJUMP is an open source GIS application developed and maintained by the Canadian Companies Vivid Solutions and Refractions Research. Go to http://www.openjump.org/ for more details.

2. Connecting GIS to SparQ

2.1. Qualitative Spatial Reasoning Using SparQ

SparQ (**Spa**tial **r**easoning done **Q**ualitatively) is toolbox that makes available a set of binary and ternary calculi and reasoning techniques developed in QSR community (Wallgrün, 2009). As a toolbox, SparQ was designed to be used directly in other application over a TCP/IP connection or as a standalone console application. It is a modular software program with four main modules. The *Compute-relation* module allows computation of operations defined in the specific calculi. It takes as parameters the name of an operation together with a set of variables representing entities from the appropriate domain and constraints between the given set of entities, each labeled by its corresponding relation. The *Qualify* module implements a single operation (qualify) which takes a quantitative scene description (coordinates of entities in the scene) and returns a qualitative description in terms of the possible constraints between the given entities for a particular calculus. *Constraint-reasoning* reads a description of a constraint network and performs operations to identify network consistence. Finally, the *Algebraic-reasoning* module is used for reasoning about real-valued domains using techniques of algebraic geometry.

2.2. QSR API Design

Our API comprises a set of Java classes and XML files. It contains a set of rules and specifications that a software program can follow to access services provided by the API. As previously stated, the purpose of designing an API in this study is to integrate qualitative spatial reasoning engines with GIS applications, particularly to integrate the reasoning engine SparQ with the GIS application openJUMP. The API will serve as an interface between these two applications. Initially, the API establishes a TCP/IP connection with the reasoning engine. Figure 1 shows the global architecture of the GIS-API-SparQ configuration. The API allows a user to send a query in XML format from the client (GIS) application and retrieve results in XML format as well. It parses the given XML file, transforms the query into the syntax and encoding format of the reasoner, forwards the query to the reasoner, and waits for the results. Upon receiving the results, the API transforms them back into defined XML structure and returns them to the GIS application.
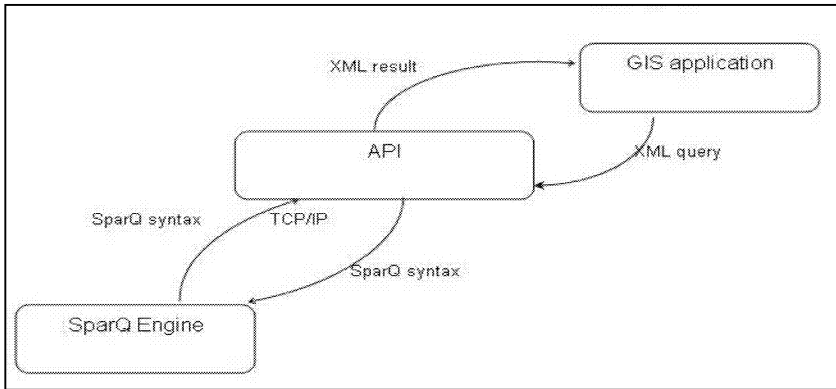
Figure 1: API workflow overview

XML files are defined based on an analysis of SparQ's syntax. Qualitative calculi were analyzed using all modules and their specific operations in SparQ to identify their syntax commonalities. Each module in SparQ takes a command with a sequence of module specific parameters. The general syntax of a SparQ query as it would be given at the command prompt (**$>**) of a terminal is as follows

$> ./sparq <module-name><calculus-name><module specifies parameters>

The module specific parameter must be consistent with the module and calculus specified at the beginning of the command. They include the set of operations, relations, and constraint-networks to be used for the reasoning task. We categorized the possible input queries and designed the XML structure for each module and module specific operation. Every XML query structure is set of tags that include module-name, calculus-name, operation, relations, and other modules specific parameters as shown, for example, in Figure 2 below.

```
<?xml version="1.0" encoding="UTF-8"?>
<module name="qualify">
    <calculus type= "binary" name="dra-24">
            <controlMode>all</controlMode>
                            <entity type="-3 0 8 0">A</entity>
                            <entity type="8 0 4 8">B</entity>
        </calculus>
    </module>
```

Figure 2: XML structure for input queries

The above given XML structure for input query is specific for the Qualify module. The XML query above contains module and calculus names and calculus type (binary or ternary) as attribute values. The *controlMode* tag in the query takes two value (ALL/First2all) used to return all possible constraints between given entities or to

return possible constraints between first-two entities. Each XML structure for input query varies with respect to the module used.

2.2.1. From XML to SparQ Syntax

Queries in XML format are converted into SparQ syntax by reorganizing the data in the query and augmenting it with required non-functional syntactic elements like parentheses, blank-spaces, etc. We use the DOM parser to generate the document tree for a given XML file which is then mapped into a SparQ-syntax formatted query. The resulting query is then forwarded to SparQ as a simple text string. Figure 3 shows an XML query with the Constraint-reasoning module's algebraic-closure operation.

```
<?xml version="1.0" encoding="UTF-8"?>
<module name="constraint-reasoning">
 <calculus type= "binary" name="cardir">
   <operation          type=          "constraint-reasoning">algebraic-
closure</operation>
                        <entity>A</entity>
                        <relation>N</relation>
                        <entity>B</entity>
                        <entity>B</entity>
                        <relation>N</relation>
                        <entity>C</entity>
     </calculus>
```

Figure 3: XML query for constraint-reasoning on given constraint-network

After processing the query above, the resulting string will look as follows.

<constraint-reasoning> " "<CARDIR> " "<algebraic-closure> " "((<A> " " <N> " " <B> " ") (<B> " "<N> " " <C>)) "\n".

2.2.2. SparQ Result Analysis

SparQ results are analyzed to identify the possible output patterns in the results for given input queries. We used all possible modules specific queries to find out commonalities between the results given by the reasoner and the type of errors generated. The purpose of result analysis is to design a suitable mapping into common XML data structures for given results. Based on the analysis, we generalized SparQ outputs into the five categories of simple-text, simple-text and constraint-network, constraint-network, syntax errors and simple-relations. The standard XML structure for requesting a result from constraint reasoning is shown in the example presented in Figure 4.

```
<result type = "constraint-reasoning">
    <operation name= "algebraic-closure" type= "constraint-reasoning">
            <comments> Modified Network</comments>
            <entity>A</entity>
            <relation>rllr</relation>
            <entity>B</entity>
            <entity>A</entity>
            <relation>ells</relation>
            <entity>C</entity>
    </operation>
</result>
```

Figure 4: SparQ result in XML format

The extracted results from SparQ are generalized into five categories. API coverts received result into defined output XML structure. The above mentioned result in XML format contains composition of text and constraint-network. Result-tag that represent used module for reasoning. Operation-tag contains operation-type and name to represent module and module specific operation used for reasoning. Comment-tag is used to pass a received comment to the end-user and the received constraint-network is split into entity-tags and relation-tags that represent possible relationship between given entities.

2.2.3. Converting Results From SparQ Syntax into XML

The developed API extracts results from SparQ and stores them as a string array. During conversion these results are split into sub results based on type of result received from the reasoner. The API contains set of module specific methods and conditions to extract and process the received results from the reasoner. For example, queries using algebraic-reasoning and scenario-consistency generate results as compositions of simple-text and constraint-networks. The results are extracted, stored in a string array, and then split into two string arrays based on predefined numeric values between 0 and 9 and the '.' character. The array that contains simple text is forwarded as comment in the comment tags. The second array that contains the constraint-network is further processed and split based on SparQ syntax (punctuation) rules. During this process the data elements of the substring are mapped back into XML as attribute values or text-data in defined standard tags resulting in a structure similar to the one shown in Figure 4.

2.3. Connecting OpenJUMP with API – A Specific Example

OpenJUMP supports reading and writing shape files and simple GML file format as other GIS applications. It supports different data format including GML, SHP, DXF, JML, MIF, TIFF and postGIS etc (Dalluege, 2006). OpenJUMP provides functionality to extend application by writing own plug-ins, cursor tools, renderers, and other such facilities with the help of the extension class. To test our API we implemented a Java based OpenJUMP plug-in and used it to pass qualitative reasoning tasks to SparQ.

Presently, the extension consists of an input screen for selecting an XML file (using the *Input text field* in Figure 5) containing the query, displaying XML data for the input query as well as its results (the *Output text area* in Figure 5), connecting to and disconnecting from SparQ via the API, and sending the specified query to the reasoner.
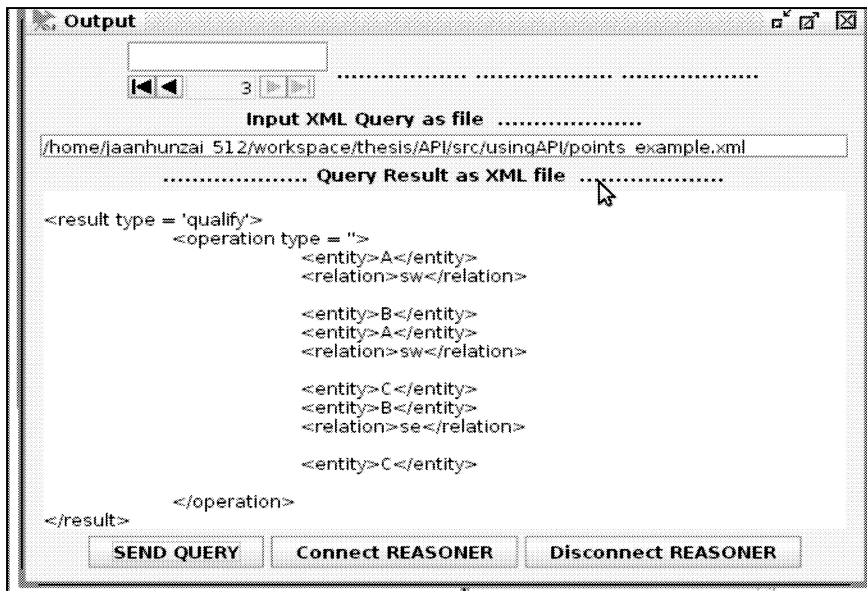
Figure5: OpenJUMP plug-in provides interface for reasoning

The OpenJUMP extensions API provides a broad array of functions that allow developers to not only write code that can access data loaded by the GIS but also to modify and enhance the behavior of standard functionality such as rendering, processing, and editing of the data. The simplicity of the extension model and the above stated advantages are what led us to select OpenJUMP as a testing platform for our study.

3. Concluding Remarks

3.1. Shortcomings and Future Challenges

The developed framework (API) is limited in several respects like selection of qualitative reasoning engines, automating spatial queries, and supporting visual representation of results on the client side. We developed the API based on a particular reasoner, SparQ, in mind. It is possible to improve the developed API to interact with other reasoners but this would involve substantial rewriting of the XML-to-reasoner-syntax translation code. The approach we intend to take here is to improve the current design by making our XML schemas more generic and integrate support for extensible style sheets (XSLT) on which query and result transformations can be based.

Task chaining in which a composite reasoning task is computed in a single query request is an essential feature for GIS applications. One of our targets is to support such chaining tasks by allowing the output of one or more tasks to be used as input for other tasks possibly with additional information supplied by the GIS between subtasks. To achieve this level of functionality we believe it is necessary to understand the sorts of GIS tasks that may require QSR methods. As such, one aspect that needs to be clarified is the utility of QSR in GIS. This leads us to analyze the scenarios in which employing qualitative as opposed to quantitative processing would be most beneficial or at least desirable for GISs and pin point those calculi that are most useful in those situations.

A final shortcoming that is worth noting here is related to the restrictions that formal definitions of qualitative spatial calculi place on the admissible primitive entities that can be reasoned over. For example, SparQ does not directly support reasoning over entities of type polygon (in Euclidean 2-Space) which would be useful for applying RCC reasoning on vector data with geometries of that type. Integrating multiple reasoning engines with different types of reasoning capabilities maybe constitute part of the solution to this problem.

3.2. Summary

The developed a platform independent API allows GIS users to integrate the reasoning engine with spatial applications like ArcGIS and OpenJUMP. The API provides a set of functions for establishing a connection with the reasoner through a GIS application and sending and receiving queries it. The main advantage of the API is that it supports a machine and human understandable format (XML) and can easily integrate with any Java based application or can be accessed over a network or can be converted into a web-based API. Further reasoning tasks can be performed on results from any previous reasoning tasks enabling complex tasks to performed without requiring the reasoning mechanisms to be implemented in the GIS. The qualify facility provided by SparQ will allow developers of GIS extensions that use QSR to focus on the core functionality they intend to provide instead of the details of deriving qualitative descriptions from quantitative data or qualitative reasoning algorithms.

Acknowledgements

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Matching-Based Map Generalization by Transferring Geometric Representations

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Abstract. We present an approach that integrates a generalized dataset of road networks into a digital landscape model to create a smaller-scale map representation. In an automatic matching process corresponding objects from the different datasets are identified and linked. These links are used to transfer the geometric representation from the generalized dataset to the ungeneralized landscape model. All objects not linked, e.g. vegetation areas, are adjusted to the transferred geometries. This is done using a rubber sheeting transformation that propagates the displacements created by the geometry transfer to other objects in the vicinity. Our implementation uses an object-relational database and spatial partitioning such that it becomes capable of handling large datasets. We show exemplary results from processing authoritative data for Germany.

Keywords. map generalization, object matching, spatial data integration, map adjustment, rubber sheeting

1. Introduction

Matching spatial datasets can serve many purposes. Often thematic information about objects of one dataset shall be transferred to matching objects of another dataset. We have investigated a practical scenario where geometric information is transferred between matching objects, and geometries of non-matching objects can be adjusted. On the one hand, a thematically rich large-scale dataset (the German authoritative base digital landscape model) is given, but it needs cartographic generalization for presentation purposes.

On the other hand, another smaller-scale dataset is available that carries the line skeleton structure in an already generalized representation. Actually, the second dataset (a commercial product) shows road networks that have already been generalized for smaller-scale road map production purposes. Thus, it contains only few other objects and much less thematic information.

In order to achieve an efficient generalization of the first dataset, both datasets are first processed by an automatic matching process to identify and link corresponding objects between the datasets. Then these links are used to transfer the geometric representations of road objects from the generalized dataset to the ungeneralized landscape model. Finally, all objects not linked, e.g. vegetation areas, are adjusted to the transferred geometries. This is done using a rubber sheeting transformation that

propagates the displacements created by the geometry transfer to other objects in the vicinity. In order to handle large datasets stored in a spatial database, we utilize a spatial partitioning of the datasets such that the results of processing partitions can be merged without loss of precision.

After surveying related work, sections 3-5 will describe input data, object matching, and geometry adjustment including geometry transfer and partitioning. Section 6 will report on the implementation and typical results.

2. Related Work

Spatial data integration has been investigated by many researchers producing a large amount of solutions to different problems regarding the combined usage of heterogeneous datasets. To keep it short, we only mention some of the approaches containing object matching techniques to link instances from different datasets. [1,2,3] use matching algorithms based on the buffer growing principle to generate candidate matchings that are filtered using some kind of selection algorithm afterwards. In [4,5] methods that match spatially embedded graphs are introduced and applied to geographic data. [6,7] describe techniques for transferring postal data (i.e. points along lines with address information) and routing information between different datasets that are also based on matching and rubber sheeting.

Rubber sheeting originates from the area of image processing. In [8] this technique was used to integrate spatial vector data. [9,10] describe rubber sheeting techniques for vector data, that are not based on displacement vectors but directly on corresponding linear features from different datasets. They also employ sophisticated filtering techniques to restrict the input for the transformation to locally related objects.

3. Input Data Description

For our data integration process spatial data from two sources are used: BDLM and KVD. While the first dataset provides a semantically and geometrically rich landscape model, the latter mainly supplies road networks manually generalized for map production.

The German federal mapping agency (Bundesamt für Kartographie und Geodäsie) collects topographic digital landscape models from all federal states to make up an information system (ATKIS[1]) for the whole country. This includes the *ATKIS Base Digital Landscape Model* (BDLM) which is Germany's large scale topographic landscape model. The *ATKIS Object Catalogue* lists a variety of available object types together with their specific attributes and object modelling rules.

KVD (Kartographische Vektor-Daten) is an object-based vector-formatted dataset, too. As it is primarily used for creating printed road maps, it has been edited in a manual generalization process. Contained objects were shaped by visual aspects and do not follow a strict modelling scheme. There are less and coarser object types than in BDLM.

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[1] Authoritative Topographic Cartographic Information System
   (Amtliches Topographisch-Kartographisches Informationssystem)

In a preprocessing step, a *topological data model* (TDM) is computed for each dataset. The resulting spatially embedded planar graphs represent geographic objects as composed of nodes, edges, and faces.

4. Object Matching

As a central part of the data integration process, an object matching algorithm is used to identify BDLM and KVD objects representing the same real world entity. Object similarity (or equality) is determined by spatial criteria like the object geometry or its topological position and also by thematic attributes like object types.

Most common matching algorithms identify *1:1-matchings* only, i.e. one object from dataset A is matched with exactly one object in dataset B. (*Non-matched objects* can be understood as 0:1- and 1:0-"matchings".) Due to different object modelling rules in the input datasets 1:1-matchings are not always possible to find. This raises a need for more complex *n:m-matchings*, meaning that an *aggregation* of *n* (semantically and geometrically connected) objects from dataset A is matched with an aggregation of *m* objects in dataset B. Figure 1 illustrates a 3:2-matching between line objects.
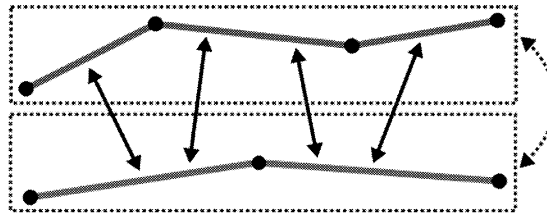
Figure 1. 3:2-matching of single line objects from dataset A (blue) and B (red). An 1:1-matching of the resulting aggregated objects is shown with dashed lines.

As an optimized solution for matching object-based vector data with all constraints mentioned above, we have developed a *graph matching algorithm* [4]. The algorithm operates on topological relations between objects, and uses a product graph construction as well as filtering rules to find a well-fitting "inexact" graph matching. This matching is represented by a set of *links* between aggregated edges as illustrated above.

5. Geometry Adjustment

The links resulting from the matching process are used to adjust the geometries of BDLM-objects to the geometric representation of KVD-objects. For all links, the geometries from the KVD-edges are directly transferred to their matching partners. Also based on the links, displacements are calculated that are used in a rubber-sheeting transformation to adjust the DLM-edges without matching partners. Since all transformations are done on edges from the topology of the BDLM, common geometric parts of different objects are adjusted uniquely. The last step consists in the inverse transformation of the adjusted BDLM-topology to a feature object model.

5.1. Transferring Geometries

Since the matching does not provide correspondences between single edges but rather between groups of edges (*n:m*) we determine the appropriate part of the aggregated KVDgeometry for each BDLM-edge using linear referencing. For start- and endpoints of the BDLM-edges a measure is calculated that corresponds to the relative distance from the start of the aggregated BDLM-geometry.We compute the points that have the same measures on the aggregated KVD-geometry and use them to subdivide it into smaller parts. These are used to replace the geometries of the corresponding BDLM-edge (see Fig. 2).
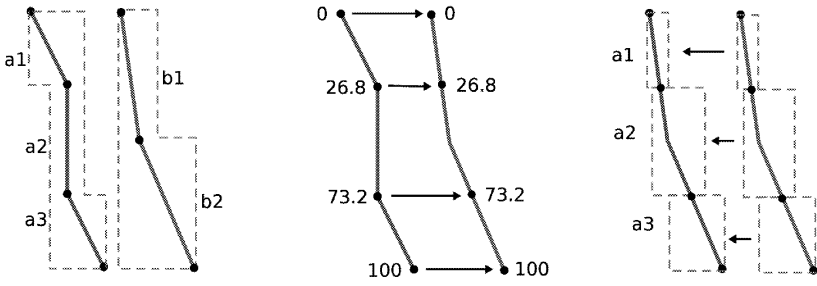
Figure 2. Group of BDLM-edges linked to group of KVD-edges (left). Measures calculated for start- and endpoints of BDLM-edges and corresponding points on the aggregated KVD-geometry (middle). Transfer of subdivided KVD-geometries to BDLM-edges (right).

5.2. Generating Displacement Vectors

We use the links computed in the matching process to calculate vectors that represent the displacements induced by transferring the geometric representations in section 5.1. We want these vectors to closely resemble this displacement, so we first project all shape points of both aggregated geometries on the other geometry using linear referencing again. Each pair of corresponding points on the BDLM- and KVD-geometry represents one displacement vector (see Figure 3). As we also want the vectors uniformly distributed over the length of the linked geometries, we interpolate straight lines between shape points to get additional points for projection and vector generation.
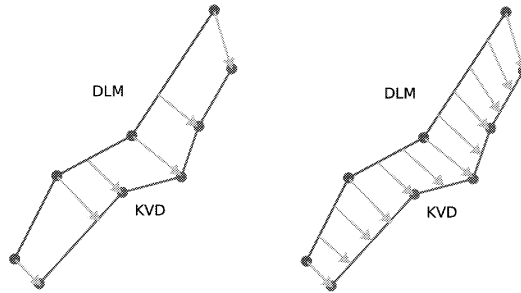
Figure 3. Displacement vectors generated at shape points of aggregated geometries (left). Additional vectors at interpolated points between shape points (right).

5.3. Adjusting Geometries by Rubber Sheeting

The displacement vectors define the rubber sheeting transformation [8] executed on the non-matched BDLM-edges in order to adjust them to the transferred representation of section 5.1. For each shape point p of a BDLM-edge its displacement $\sim v(p)$ is calculated as the weighted average of the vectors $\sim v1; :::; \sim vr$ from section 5.2. The weight $wk(p)$ of the *k-th* vector decreases with increasing distance of its startpoint s_k from p, as displacements in the vicinity of an edge should have a stronger influence than those far away.

$$\vec{v}(p) = \sum_{k=1}^{r} w_k(p) \cdot \vec{v}_k \qquad\qquad w_k(p) = \frac{\left| s_k - p \right|^{-2}}{\sum_{j=1}^{r} \left| s_j - p \right|^{-2}}$$
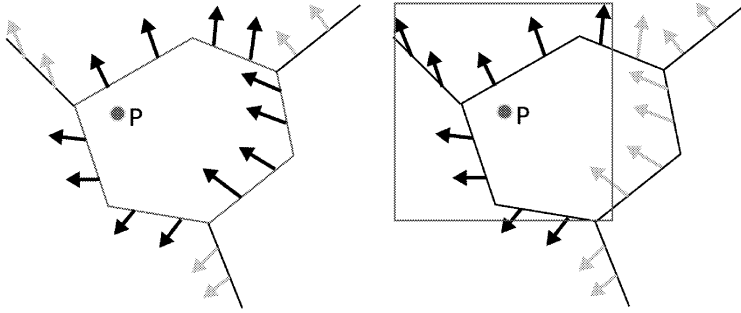
Figure 4. Filtering displacement vectors using a face (left) or a window (right).

Due to the quadratic reciprocity, the influence that displacement vectors far distant from p have on the transformation is very small. Therefore the majority of vectors can be discarded from the transformation of one shape point without significant changes to the (generalization) result, but with a much smaller computation effort [11]. We have developed two filters that are used to reduce the set of vectors for the transformation of p. For the *face-filter* we compute faces constituted from linked BDLM-edges before the rubber sheeting process. To calculate the displacement for p the mesh surrounding it is identified and only vectors with a starting point inside or on border of this mesh are used (see Figure 4). The *window-filter* selects only those vectors with a starting point inside a fixed size window centered around p; it is used when faces are missing or too large.

5.4. Partitioning of Datasets

Since the influence of displacements generated in 5.2 is restricted to the close vicinity in the adjustment step 5.3, it is possible to partition the input data into smaller datasets that are processed independently. Partitions are defined on a *rectangular grid* where each rectangle represents the *interior* of a partition. Before selecting objects from input data that intersect the rectangle, we enlarge it into all directions by a fixed width *border area* that overlaps neighbouring partitions. Objects located in this border area need to be included to compute good matchings and adjustment of objects located at grid lines.

After processing, the partitioned data have to be composed into one result dataset. As partitions are non-disjoint, we eliminate duplicates by discarding objects from the border region of a partition; only objects located in the interior are added to the result. Since these objects are far distant from the outside of the partition, enough spatial context was provided to generate results of equal quality to unpartitioned processing.

6. Implementation and Results

We have implemented our algorithms in Java using an Oracle 11g Database Server for intermediate storage and spatial filtering operations. A graphical user interface for configuring process parameters and viewing results has been developed, too. As none of the known matching algorithms is able to match *all* objects of our datasets correctly, our implementation finally provides a visual interface for manually correcting matching results in exceptional situations. Thereby generalization results can be improved where the computed results are not satisfying.

We have tested our implementation on datasets from different areas of Germany. Since matching is done with roads only, the most notable effects affect objects of this type. In the BDLM dataset the distance between different road objects is proportional to the real distance of the modelled roads. When visualized by rendering line objects with bitmap signatures, often small roads are covered by the signature of a bigger road located next to them. In KVD, extra space is inserted such that the signatures of accompanying roads do not intersect. After this representation is transferred, previously invisible roads are correctly visualized (see Figure 5).
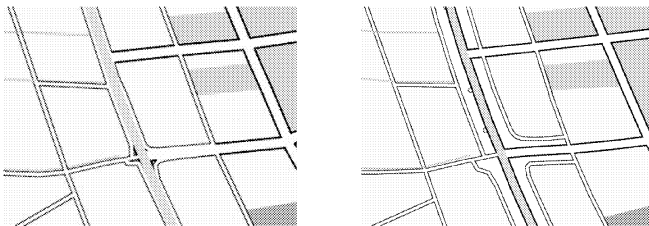
Figure 5. Visualization of a crossing in original BDLM (left) and after adjustment (right).

7. Conclusions

We have presented an approach for generalizing large digital maps applicable whenever an already generalized map is available that can be matched. As manual generalization usually takes high effort and expertise, we believe that the techniques introduced here are a valuable contribution to simplify work and reduce costs in map processing.

As the quality of our generalization results highly depends on correctness of computed matchings, an interesting area of further research is the improvement of existing or the development of new matching algorithms. Also our methodology could be improved to avoid or detect induced topological errors that might rarely occur. Finally we plan to further research scalability issues and hope that the performance of

processing large datasets can be improved by developing sophisticated partitioning strategies.

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Interoperable integration of high precision 3D laser data and large scale geoanalysis in a SDI for Sutra inscriptions in Sichuan (China)

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Abstract. Over the entire province of Sichuan (China) there exist Buddhist stone inscriptions – so called Stone Sutras – dating from 8th to 12th century. So far, the documentation and reproduction of the surface texture of these historic inscriptions took place via simple manual tracing on paper (rubbing). Innovative Terrestrial Laser Scanning (TLS) methods make it possible to capture these artifacts both digitally and in 3D and to derive high-resolution 3D models. This paper presents a concept for the integration of the Buddhist inscriptions into a Spatial Data Infrastructure (SDI) using Open Geospatial Consortium (OGC) Web Service (OWS) standards in archaeological, art-historical and linguistic contexts. The aim is to link existing humanistic data to an interdisciplinary Web-based Geographical Information System (GIS) with appropriate time and space reference. Special emphasis is put on SOA-based geo-processing (OGC WPS) and 3D visualization (OGC W3DS). The whole SDI is enriched with additional historic metadata of the inscription sites and finally joined in a Web Atlas for Stone Sutras in China.

Keywords. *SDI, Geo-processing, 3D Visualization, Stone Sutras, Web Atlas*

Introduction

On the Asian continent the Buddhism was based on both the inscribed words (*Sutra*) and the statues or pictures of the Buddha originally. Chinese Buddhist monks started writing the holy Scriptures into rock faces in the second half of the 6th century [10]. Over the entire province of Sichuan (China) around 80 Sutras dating from 8th to 12th century can be found [8]. In particular in the Chinese area it throws a new light on the history of the Chinese Buddhism and on its adjustment to the Chinese culture. More than 1,500 years the preservation, documentation and reproduction of the surface texture of the Buddhist inscriptions were made via so-called *rubbings* [6]. A copy of the original text was made by simply pressing thin, wet pieces of paper on the inscriptions written in stone and carefully dyeing the paper by manually tracing the surface. By means of these rubbings the teachings of the Buddha could be easily transported and distributed.

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However, due to the progressive weathering of the rock inscriptions and the abrasion with the production of the rubbings this archiving method can be used only conditionally for the protection of this information treasure. Hence, the objective of the research project *"3D-Sutras"* is to investigate and document the stone inscriptions with different scientific approaches and from different viewpoints, including archeological, art historical, linguistically and geographical. New innovative capturing methods are necessary for a permanent preservation of the stone Sutras. A possibility for a contactless archiving of the Sutra text is offered by *Terrestrial Laser Scanning* (TLS) techniques which record the data digitally as 3D point clouds. In the course of several measuring campaigns the stone inscriptions were scanned by precise measuring procedures and processed to 3D models by our project partners at the University of Applied Sciences Mainz (i3mainz, Germany). The point density of the laser scan data depends on the size of the Sutra characters. A typical character covers about 1 cm^2 and a complete Buddhist stone inscription enclosure approximately 3x4 meter. Therefore, the scan has been carried out with a lateral resolution of 0.25 mm, which results in a data set of about 1,500 to 2,500 points per character. The size of the laser data set of an original 3D model of 4m^2 is about 4.32 GB [8].

Sharing all the historic and spatial information as Web services is a fundamental key aspect of our study. In order to make all historic geographical information available in different scales in a sustainable way, all data is integrated into a *Spatial Data Infrastructure* (SDI). The visualization component based on standardized spatial Web services includes an interactive 2D map to geographically browse the available information about the archaeological inscription sites, the historical infrastructure which connected the sites, time dependent information about the development of the area of power of the Tang-Dynasty from to 669 to 820 AD and time dependent information about the itineraries of Buddhist monks involved with the sutras and the province at the specified time [2]. In the research project, conventional SDI was enriched with additional services. Besides the classical SDI for the management and visualization of the spatio-temporal datasets acquired by historical text investigation and interpretation, the proposed Web-Atlas component provides a sophisticated spatial information infrastructure. Important implemented functionality are e.g. the textual description of all inscription sites, an inscription catalog with metadata about the texts, a reading tool to explore the inscriptions and a search module to query the inscription database. Furthermore, a multimedia map combines geographic 2D/3D visualization with 360°-panoramas, annotated photographic pictures and GIS functionality for measuring, searching and analyzing. This study goes even one step further and investigates (3D) geo-processing functionality based on the OGC *Web Processing Service* (WPS) interface specification [9] and 3D visualization component based on the OGC *Portrayal Service* like the *OGC Web 3D Service* (W3DS) [7] in order to give enable realistic 3D exploration of the archaeological sites by means of a virtual 3D model derived by laser scanning and other modeling techniques. This paper focuses on the geo-processing aspects in different scales from region wide spatial analysis to only few millimeter long Sutra inscription character based on TLS data as well as 3D visualization techniques in spatio-temporal and art-historic context.

The objective of the research work is: first to preserve the stone inscriptions with innovative capturing methods based on TLS and improve the readability; second detect spatial relationships associated with historical information of the Buddhist inscriptions between sites; third introduce a new concept for a Web-based SDI covering different scientific approaches from different domains and scales for this purpose.

1. Geospatial Infrastructure for Art History

Within the context of art history, geographical data has been considered only negligibly and not consistently, usually as scanned ancient maps or rubbings, not georeferenced in open formats. In order to make these precious assets accessible in a sustainable and flexible way and usable in a geo-spatial context, we pursued the integration into a SDI. From a technical viewpoint, an SDI is usually based on standardized Web services as specified by the OGC. The Web-Atlas utilizes several standardized OGC Web services for distributing and maintaining vector (*Web Feature Service*, WFS) and raster data (*Web Coverage Service*, WCS), for data analysis (*Web Processing Service*, WPS), and for the portrayal of 2D (*Web Map Service*, WMS) and 3D data (*Web 3D Service*, W3DS).
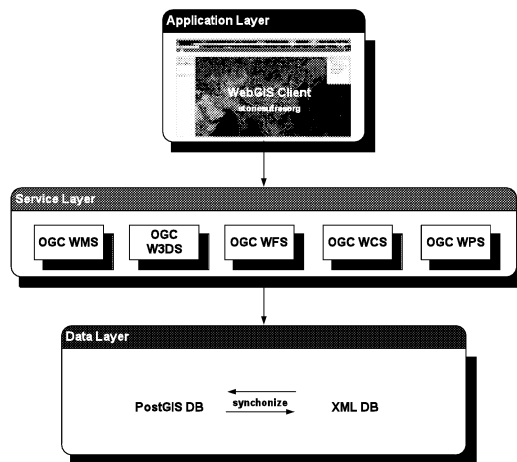
Figure 1. Overview of the 3D Sutra SDI architecture

   A challenge is to develop a sustainable and interoperable concept for the integration of existing digital data of historical Buddhist inscriptions, which are held in a previously set up XML data base, into an SDI. This XML data base originated from a previous research project and is designed for electronic encoding, structuring, and exchange of documents within the domains of social science and art by using metadata standards. The historic data is stored in an open source XML database called eXist (exist-db.org). Industry standards such as XQuery, XPath, and XSLT are used for complex queries and processing of the content. Import of data can be easily accomplished by using a WebDAV compliant editor or an online form [1]. The content of this database comprises textual scientific documents, transcriptions, catalog meta data of inscriptions, context data about inscriptions of sites and caves etc. Each XML document is referenced with a geographic coordinate which enables to utilize geospatial query and analysis methods as well as to directly integrate content in a map application. However, the technological gap must be bridged. Since these documents are not available in a common geo-standard, they cannot be used by OGC services directly. This has been solved by implementing a connector which synchronizes the XML data base with the geo database which is implemented in PostgreSQL/PostGIS. As soon as changes in the XML database occur, events are triggered, which synchronize the geospatial database by creating, deleting or updating Simple Feature geo-objects with respective attributes (Fig. 1). The Web client can then easily access

the combined geospatial data and information on Buddhist inscriptions through a WFS. Alternatively, map overlays can be created using a WMS/WCS based on the same content. This geo-visualization pipeline has been implemented using open source software *Geoserver* and *OpenLayers*.

2. Web-based Geo-processing Toolbox for Historians

The WPS interface standard as specified by the OGC [9] describes an interface in order to provide Web-enabled distributed processing and analysis capabilities for geodata. A WPS process defines the implemented algorithm logic that run the calculation. The rather generic WPS specification provides spatial and non-spatial processes in arbitrary complexity. Thus, it is possible developing services in a wide range of complexity.

In order to analyze both high-resolution laser scanning data as well as large scale spatial relationships between historic sites and monasteries, WPS processes were implemented. Multiple WPS frameworks were used for this task. By utilizing terrestrial laser scanners for capturing Sutras a very high volume of data (point clouds) is produced in a short time. Standalone or classical desktop GIS software can hardly cope with this massive amount of 3D raw data. It is therefore preferred to move the CPU intensive task of processing TLS data to a high performance server accessible through a standardized WPS. The purpose of TLS processing of Buddhist inscriptions is to improve the readability and thus interpretability by applying morphological, geometrical, and image based pattern analysis. As an example for image based processing, phong normals and relief shading maps have been computed from 3D stone inscriptions. They allow a better recognition of the heavily weathered carved characters. The process has been developed using the WPS 1.0.0 interface implementation based on the Java deegree framework [4].

Until now, inscriptions are not examined on spatial relationships. In a first step, we evaluate the available spatial data for potential archaeological analyses in historic-geographical context. Classical questions for historians are for example: Which monasteries are visible from a certain point of view? How far did a monk walk by foot within one hour? Which routes have the monks in dependence of the historical route network and the geographical conditions (e.g. slope inclination, river barriers etc) possibly selected? Which path would be a cost-effective path and which were selected? What distance and how many meters of altitude were covered? Which further monasteries lie in a periphery of 300km? From this, typical geographical analysis are identified. An interactive analysis toolbox for historians is implemented based on the historical information of the migration of a monk. Apart from simple measuring functions on the 2D map, regional analyses like the creation of a buffer or a surface profile, the investigation of sight relationship (line-of-sight and viewshed analysis) or accessibility and distance cost analyses are implemented, based on the pyWPS implementation. This WPS implementation offers the possibility to use all GRASS GIS analysis functionalities by a Python implemented WPS interface [3].

3. Interactive Web 3D Service

In contrast to other comparable portals within the domains of art history or archeology, 3D content is not just added as multimedia component for displaying single artifacts

within this project. Instead, terrain and object information within the extent of the site is embedded as independent component (*OGC Web 3D Service*, W3DS) into the SDI. The advantage is on the one hand, that efficient streaming of complex landscapes can be utilized; on the other hand the persistent geo-referencing which allows a straightforward overlay with other geo data. The W3DS is designed as *3D Portrayal Service*, meaning that spatial subsets of 3D data sets for the display in Web GIS or online portals (as in this case) are served. Several information layers can be switched on and off separately. The data exchange with the 3D Web client relies on industry standards (X3D/VRML). Similar to the WMS, the W3DS also provides the capability to retrieve further information on selected objects. Upon a position query (mouse click) and transmitting the coordinates, the server generates a list of available attributes which can then be displayed by the client. Furthermore, the geo-referencing enables superimposing arbitrary 3D models with aerial and satellite imagery. For this project a satellite image has been integrated and is served by a WMS. By spatial tiling as described earlier, the satellite image can be mapped as color texture on the 3D terrain. For each tile served by the W3DS, a WMS GetMap request with matching coordinates is generated and attached as texture URL. A 3D scene viewer is embedded in the atlas system visualizing both the inscriptions in the caves and the 3D surface model.

Figure 2. Parts of the Web-Atlas Interface. Left: Spatial access to meta data and site information, right: detailed 3D view of one site.

4. Conclusion & Outlook

The research collaboration between social science, humanities and geoscience creates new views on technical aspects of SDIs as well as on spatial questions related to archeological and historical research fields. An important aspect of the interdisciplinary research is the integration of existing non-spatial data repositories (e.g. Stone Sutra XML database) into a standardized SDI using Web services. A sustainable and interoperable integration of systems of different domains has been accomplished by locating and geo-referencing Buddhist stone inscriptions. Data on cultural heritage can be collected and maintained using already established user interfaces without the requirement of GIS expert knowledge. At the same time all this data is automatically synchronized and made accessible to map clients through standardized geo services. This study developed a combined 2D and 3D map framework as entry point for all available data. Detailed models of stone Buddha created from TLS data along with multimedia content such as 360°-Panoramas provide realistic impressions of the

historically significant sites. Furthermore, the implemented geoprocessing toolbox can be used, in order to offer different analysis functionalities over the Web client. Altogether the Atlas platform offers an integration of GIS components into classical text-based analysis techniques of the traditional historic art science.

Concluding, this approach has a large potential for future social and historical studies with spatial context. However, there is a need to extend OGC service based SDIs beyond the access and visualization of geo data and to include analytical tasks that support archeological studies. For example, it is possible to develop domain specific OGC WPS Application Profiles taking semantic descriptions and even ontologies into account. Another important research area is processing high volume raw 3D spatial data such as point clouds from laser scans within an SDI [5]. Due to limited processing power and bandwidth, it is preferable to use dedicated powerful servers providing WPS interfaces. Further processing performance could be gained by connecting cloud computing and grid computer clusters to OGC components to achieve (near) real time workflows. It is important to agree on generic concepts that can be applied to a wide range of application domains, and to develop WPS processing profiles, otherwise the flexibility of SDI will get lost.

Acknowledgements

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Integrating Marine Modeling Data into a Spatial Data Infrastructure

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Abstract. Spatial Data Infrastructures (SDIs) have become widespread within the last few years, in Europe largely evoked by the implementation of the INSPIRE directive of the European Union. Search processes for metadata within spatial portals usually result in single data sets spread across several topics without the possibility to get an encompassing overview over a geographic complex. The German Marine Data Infrastructure (MDI-DE) addresses this issue and aims at providing an integrated view on semantically close topics. The Elbe estuary serves as a prototypical example, which is described in detail on several levels. Along with the usual data such as maps, aerial pictures, or gauges, a section of the MDI-DE under the label Elbe will collect results from numerical models of the estuary. This raises additional questions on the technical level, i.e. how to integrate the diverse numerical data into a classic SDI and how to visualize aggregated data. In the following a concept and first prototypical implementation of ways to integrate modeling data into SDIs will be shown.

1. Motivation

The European directive "Infrastructure for Spatial Information in the European Community" (INSPIRE)[1] requires the member states to provide an overview on the present metadata within the countries in a standardized manner. To ensure compatibility on national and international level, implementing rules for metadata, data specifications, network services and others have to be adopted by data providers. The Marine Strategy Framework Directive (MSFD)[2], which should ensure protection, conservation and, if possible, restoration of European sea habitats, demands provision of data from the maritime domain by 2012. Other directives like Habitats Directive[3] already require status reports and data.

In Germany with more than 2000km of coastline including the world natural heritage Wadden Sea and several other nature reserves on different legal levels, the

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[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:EN:PDF

[2] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:HTML

production and maintenance of spatial data for the coastal zone is distributed between different federal state authorities. Additionally, national park administrations conduct monitoring and collect data. Consequently, there are several marine data collectors, providers, and archives, distributed spatially and affiliated with diverse agencies in northern Germany. With the implementation of INSPIRE and the MSFD, data collecting agencies are ultimately required to publish their data according to the directives. Mandatory data encompass, e.g. water networks, protected areas, digital terrain models, and oceanographic parameters.

Numerical modeling is another area handling big amounts of marine data concerning the North Sea. Agencies and companies run models to analyze the impact of dredging in the German estuaries Elbe, Weser, Jade, and Ems. An example, which regularly attracts public interest, is the Elbe deepening [1][2]. As deeper rivers commonly have higher currents, which increase sediment transports and may lead to further bathymetric changes, dredging is pre-assessed in numerical models with regard to risks for the environment and dykes. Federal agencies like the Federal Waterways Engineering and Research Institute (BAW)[4] or the Federal Institute of Hydrology (BfG)[5] regularly develop status reports of the estuaries to back up political decisions.

A central platform for the publication of such reports or related data is currently not available. In the following, we propose a concept for the integration of such data into a Spatial Data Infrastructure (SDI). This concept will be implemented in the course of the Marine Data Infrastructure Germany project (MDI-DE) [3] from 2010 to 2013.

This paper continues with a demonstrative scenario of how model data in SDIs assist in decision making and followed by a section of how the marine data is prepared for the inclusion in the MDI-DE. Subsequently, the structure of MDI-DE is illustrated. Finally, we summarize our findings and outline some ideas for future work.

2. Scenario

For our scenario, an engineer from a coastal authority wants to check the state of the coastal and riverbank protection in the Elbe estuary and to identify potential needs for additional groins after a deepening of the river. Currents are strong in the lower reaches of the Elbe, so groins were built to prevent erosion processes and possible danger for inhabitants during storm surges. Changes to the riverbed can have significant effects on the characteristics of the current, erosion and sedimentation, local water levels and many other parameters of the estuarine system. To get an overview, the engineer chooses to consult a SDI, having in mind specific questions such as "Which parts of the banks along the Elbe could be affected by the deepening of the riverbed?".

Such a query could bring up data sets with groins along the Elbe river. However, a condition of the bank structure can only be approximated within the spatial metadata sets. Without engaging into deeper research of his own, our engineer could with a little luck also find a ready made solution. The Elbe river as one of Germany's largest water ways is an economic factor [4] for the region and is regularly subject of research

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[4] http://www.baw.de
[5] http://www.bafg.de

projects[6] and status reports. Results from these studies provide information based on geographic and model data, and can help users in decision making.

3. Aggregating Marine Model Data

A common thematic map consists of topography and thematic data one wants to show, along with properties for a common reference system and a defined legend [5]. So far, in SDIs one can usually find topographic and thematic data, which enable the user to combine both into one single map. Products in the marine domain are often more complex. For instance, the bathymetry of the Elbe estuary needs regular updates, as conditions are changing continuously. Other than land based topography, the wet zone is under the constant impact of tides and currents. Especially shipping channels, with high freighter traffic volume underlie constant changes and are of both economic and environmental interest. As a daily surveying of an entire estuary is not feasible, numerical models are applied to estimate the bathymetric changes. Consequently, there is not one single bathymetric map, but several, which reflect the different assumptions made in the numerical modeling scenarios.

Model data have the advantage of giving multidimensional overviews in different scales on an area of interest, in our scenario the Elbe river. Several parameters can be calculated within models: currents, sediment transport, and/or changes of bathymetry. Results from numerical models could show the effectiveness of bank fortifications, i.e. does a groin help to stabilize a dike by reducing stress from high tides, are structures redundant or are there places where new obstacles could direct the currents better than in the present state. Additionally, models are not only constructed to show the present state but to forecast the behavior of a system, in this case the Elbe, which can support our engineer with her decisions on possible further constructions. Consequently, model data can provide more information than simple spatial data sets, but connections between geographic data and models must not be underestimated: the more accurate the underlying geographic data, the more exact are the models.

The Marine Data Infrastructure Germany (MDI-DE) is an attempt to aggregate relevant data for marine data products. The collaborative research is carried out with joint project management of the Federal Waterways Engineering and Research Institute and the Federal Maritime and Hydrographic Agency (BSH)[7] of Germany. It is based on the previously conducted NOKIS Project[8] [6] and on the GeoSeaPortal [7] of BSH. NOKIS aimed at establishing a metadata information system for marine data, with a metadata editor as the core element. Several data collecting organizations participated in this research and development project and added several thousand geographical metadata sets, which led for a first time to a publicly available overview over marine data in Germany. Driven by INSPIRE and MSFD to publish spatial data within a tight schedule, public data collectors and providers along the German North Sea and Baltic Sea coast have gathered to fulfill the technical and political conditions to provide not only the metadata but also services to access the data properly. The aim is to set up a portal where available marine data is aggregated, searchable and, unless there are legal restrictions, downloadable.

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[6] http//www.kfki.de

[7] http://www.bsh.de

[8] http://www.nokis.org

The original NOKIS project pinpointed on establishing an initial basic infrastructure for coastal data [8]. MDI-DE will use this basic metadata catalogue and extend the functionality to that of a complete SDI. NOKIS focused on metadata sets from coastal geographic data, so called geo–metadata sets, which are created with the NOKIS metadata editor, or directly imported using a NOKIS XML profile. This NOKIS coastal metadata profile is a profile derived from ISO19115 [9], and includes the INSPIRE profile. Additional metadata profiles regarding research projects and literature have been derived as well and are being used in the Web sites of KFKI[9] and NOKIS[10]. As the ISO standard for spatial data is formulated in an abstract way, it is also possible to describe results from numerical models by specifying an appropriate profile. The editor is being adjusted to represent these model specific metadata elements, i.e. a description of the model grid, model input parameters and possible pre- and postprocessing. The integrated metadata catalogue constitutes therefore a universal platform for different types of data and within the framework of MDI-DE we aim at ensuring interoperability between the existing data types.

4. MDI-DE System

The MDI-DE is a distributed system (figure 1). Several NOKIS Editor instances (so called nodes) are connected via a CS-W Interface to a NOKIS core instance, where the combined metadata is stored. External portals like the German Spatial Data Infrastructure GDI-DE and the German environmental portal PortalU[11], access this core instance via CS-W requests. A new portal "MDI-DE" will be established to serve as main access point for users searching for marine data.
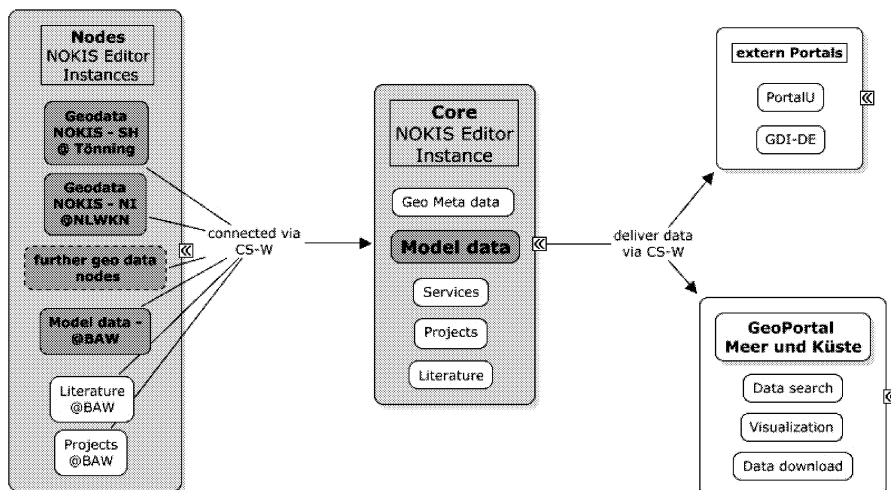
Figure 1. The general structure of MDI-DE. It shows how all information is exposed via CS-W. Relevant elements are marked in dark grey.

[9] http://www.kfki.de/

[10] http://www.kfki.de/nokis/de

[11] http://www.portalu.de

It makes use of the metadata concerning data from numerical modeling, describing projects and referencing literature, which are merged for an integrated information search by NOKIS. All metadata is produced before being searchable within the portal, we discuss further options for handling model data in the future work section.

The new MDI-DE portal will enhance the existing metadata search by visualization and download methods. In case of model data additional methods will be developed in order to cope with three dimensional and time dependent data sets.

In order to make model data available through a SDI, the data first has to find its way into an appropriate service. In a first prototype, this is accomplished by converting the binary export file format of the modeling software into an exchange format, where we chose ESRI shape files, as it is a de facto standard and there are several tools for data transformation and handling available. The shape files are transferred into a database, which can be accessed from different OGC web service implementations [10] to generate diverse services. These steps are wrapped in a shell script for easy batch processing of large model data sets. To guarantee a consistent visualization across platforms according to the conventions of the marine engineering community, the data is classified and visualized via the Styled Layer Descriptor (SLD) technology [11].

5. Conclusions and Future Work

The recently started project German Marine Data Infrastructure aims at pulling all the aforementioned data strings together and to establish an integrated view on complex questions within the coastal community. While spatial data in SDIs only show a small part of the production chain of geographic products, MDI-DE provides a framework for different types of spatial data. Integrating modeling data enhances the capabilities of an SDI, as the results from numerical models enable the user to browse through a complex product based on spatial reference data.

To achieve the desired state, some steps will be considered in the future. The first proof of concept simply displayed 2D maps consisting of model data aggregated into polygons according to the structure of the underlying model grid. A wide range of services can be provided using model data and the variety of OGC Web Service specifications. An obvious choice would be the provision of a Web Feature Service (WFS) [12], but also more elaborate services could be implemented.

Simulations of currents, tides and other marine parameters are usually conducted in three dimensions, thus three dimensional data is produced. To display such data as two dimensional maps means losing a lot of information inherent in the original model data. In order to provide the best information to the user through the SDI, 3D services could be set up, using one of the upcoming OGC services for displaying 3D data like the Web 3D Service [13] or the Web Perspective View Service [14]. These would allow the visualization of 3D structures, objects or point clouds to present depictions closer to the original data than plain maps. The above mentioned SLD technology can be applied to these, too [15].

Using the WFS for data provision is an established and sound method, but it is also be conceivable to utilize a Sensor Observation Service to get the data from the data storage – even though it is not sensor data in the narrow sense [16]. Having set up such a service, the capabilities of the SDI could additionally be improved by adding live sensor data to the SDI and combining them with previously modeled data. On this level, cooperation with the COSYNA project is planed. COSYNA [17] aims at

constructing a long-term observatory for the North Sea including the presentation of near-real-time data on its portal. Metadata is already stored in a NOKIS instance and a connection with proper integration into MDI-DE is being established.

A consequent although difficult step for the future would be to migrate the simulation process itself into the SDI using Web Processing Services (WPS) [18], where some approaches for using model data in WPS have already been made [19][20].

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Leveraging standardized near 'real-time' inSitu sensor measurements in nature conservation areas

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Abstract. This paper presents a standardized workflow from integrating, processing and presenting real-time in-situ sensor measurements in the Nature conservation application domain. Especially the integration of environmental phenomena like weather phenomena like, temperature, humidity, wind speed etc. into automated, SOA based distributed geographic information architecture allows for contextual provision of new domain specific 'spatial knowledge" in understanding ongoing changes in an protected area like the *National Park Berchtesgaden*. Therefore the local climate measurements from weather stations in the national park area have been integrated via geo- enabled sensor networks utilizing OGC Sensor Web Enablement interface standards. New dynamic geographic knowledge can be derived when integrating, combining and presenting this real-time data with existing geographical layers mainly from hydrosphere lithosphere and biosphere domain. To achieve and verify this goal, a framework has been developed which utilizes recent OGC standardization achievements for sensor measurement integration and distributed geographical processing, analysis and visualization methods. Measured data from various sensor sources (text, database) are transformed on-the-fly into OGC Observations- & Measurements XML-structured data, accessible via a custom OGC Sensor Observation (OGC SOS) service. We present a workflow, modules and components which permit the near-real-time integration into GI systems.

Keywords. OGC SWE; Sensor Obervation Service, Geographical analysis; real-time geographical analysis, spatial data infrastructures.

1. Introduction

Environmental data are traditionally maintained, processed, and archived by different national and international organizations. Increasingly, international environmental monitoring initiatives call for the integration of heterogeneous geographic data from local to global levels to assist in decision making and in achieving societal benefits [8]. By nature, in-Situ data are valid for points or very small test areas or, more rarely, for transects. Today, in-Situ data loggers – analogue or digital – are creating terabytes of data resulting in massive archives with enormous information potential. In many – if not most - cases, data access is very often

constrained by organisatorical, technological and/or security barriers. Tools for spatially analyzing, comparing, visualizing and even sharing these data and their extracted information are still in their infancy. Furthermore, policy, legal and remuneration issues in regard to ownership and responsibility of value-added products or products that represent the culmination of different users input are yet to be stipulated but there is significant recent progress in spatial data infrastructure research (e.g., [6], [11], [5], [9]) and research on distributed geographic information processing [8] as well as new legal mandates like the European INSPIRE Directive [3] and their national deducted laws on National Spatial Data Infrastructures within the EU member states.

In this paper we briefly describe recent standardization efforts of OGC and other organizations and exploit them by dovetailing different types of 'real-time data' integration, information/processing services, visualization and knowledge provision. We describe 'Berchtesgaden live', a thematic service bus integrating 'real-time' location aware in-Situ sensor-data, enhance this structured data into thematic information layers, combine and analyze with legacy GI-layers and finally spatially valuate the results to extract new geographical knowledge being used in nature conservation domain.

2. Geo-sensor Network Data Integration approach

Future geo-sensor networks will be based on distributed ad-hoc wireless networks of sensor-enabled miniature platforms that monitor environmental phenomena in geographic space. Individual sensor communication nodes are low cost and low power, potentially allowing dense networks of nodes to be deployed to monitor environmental phenomena. Such geo-sensor networks provide the capability to monitor geographic phenomena in remote, sensitive, or hazardous environments at much higher spatial and temporal granularity than it is possible with well established monitoring systems.

Current research into geo-sensor networks is proceeding rapidly on several fronts. For example, special tasking services may ensure that not all sensors operate all the time. Some being in a sleeping mode may be activated based on threshold values of other sensors and, consequently, power consumption is minimized. However, apart from technical sensor network challenges, the real-time integration and usage of sensor data into expert and decision support systems is a vital part to evaluate and assess current environmental conditions. 'Timely' can differ and vary significantly depending on the specific application context. E.g. the update cycle for land slide monitoring can be around five seconds in some cases, whereas for tracking wild-life, half-our intervals may be sufficient for appropriate research. To guarantee maximum interoperability and wide applicability, the authors aim for a real-time sensor data integration – sensor fusion – into existing GIS systems using well-established geo-data provision standards such as OGC Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS). This allows for an integration of real-time measurements by interfacing live data sources with a broad spectrum of geo-processing service infrastructures. Therefore for ESRI ArcGIS a plug-in data source and a datastore-extension for open source Geoserver 2 software components has been developed to allow the transparent usage of real-time sensor in abroad range of GIS.

3. **Real-time data integration through Geo-Sensor Web standardization**

Current approaches towards real-time data integration usually rely on the traditional request/response model in web service implementations [7]; [10]. Sarjakoski et al [18] establish a real-time spatial data infrastructure (SDI), which performs a few basic operations such as coordinate transformation, spatial data generalization, query processing or map rendering and adaptation. However, the implemented system does not consider the integration of real-time sensor data and event-based push technologies like XMPP which is e.g. widely used in various internet messaging clients (ICQ. Google Talk etc.).

Other approaches try to achieve real-time data integration via the creation of a temporary database. Oracle's system, presented by Rittman [17], is essentially a middleware between (web) services and a continuously updated database layer. The Oracle approach is able to detect database events in order to analyse heterogeneous data sources and to trigger actions accordingly. In Rahm et al. [16], a more dynamic way of data integration and fusion is presented using object matching and metadata repositories to create a flexible data integration environment.

However, all these approaches have their limitations. As data integration and fusion originated in the domain of computer science, very few approaches exist, which are dedicatedly designed for location aware data. Thus, integration of sensor data into GI systems currently mostly happens via the laborious interim step of a temporary physical database. This is not desirable in an automated GIS workflow chain as the database can easily become a bottleneck handling very large data volumes and spatial data sets. Moreover, such an indirect approach unnecessarily adds another component to the overall workflow, which can result in substantially lower performance. Thus, a need arises for an approach towards on-the-fly integration of sensor measurements and flexible adaptation of data containers.

Sensor Web Enablement (SWE) extends the OGC web services and encodings framework by providing additional models to enable the creation of web-accessible sensor assets through common interfaces and encodings. SWE services are designed to support the discovery of sensor assets and capabilities, access to those resources and data retrieval, subscription to alerts, and tasking of sensors to control observations (OGC 2008). SWE shall foster the interoperability between disparate sensors and optionally to simulation models and decision support systems. A number of authors have addressed the issue of service chaining in SDIs, and more particular, the use of distributed processing services that can be combined into value-added service chains to serve as specific GI applications (e.g., [6], [11], [5], [9]).

4. **Leveraging *near-real-time* GI technologies for nature conservation areas and the INSPIRE ‚protected sites' domain**

According to the International Union for the Conservation of Nature (IUCN) a Protected Site is "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means". The European Union Directive 2007/2/EC [3] aims at establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) to support environmental policies. Therefore, harmonized datasets, services and structured information about the geographic

resources are the main requirements for supporting decision-making processes at all levels. Domain experts in *protected areas* worldwide already generated a vast amount of environmental data in accordance with their immediate requirements and priorities. They organize specialized datasets including protected biotopes and habitats, flora and fauna species distribution and supporting datasets like geological data, soil data, forestry, hydrological data, climate data, elevation, administrative units etc.

Within the *nature conservation* domain representations of these various geospatial entities can differ in terms of data model, spatial, temporal and thematic scales, data generalization (the preserved information about real entities and/or phenomena), conceptual models, geographic projections etc. Therefore the integration of heterogeneous geospatial data needs a standardized conceptual model for capturing 'spatial' and temporal characteristics of environmental entities.

The OGC SOS provides an API for describing, accessing and managing deployed sensors and retrieving sensor data in a well structured standardized manner using XML technology. Such approaches for e.g. hydrosphere measurements via standardized interfaces allow for dramatically reducing time and efforts integrating this timely data into nature conservation SDIs.

Additional essential functionalities for embedding real-time sensor data analysis into application-specific workflows are *alerting* and *notification*. As there are a variety of real-time data sources available – with rising tendency – it is increasingly important to organize and filter these data according to pre-defined criteria and rules. For instance, when monitoring protected landscapes, temperature variations may mainly be of specific interest in connection with regard to other phenomena like precipitation and soil conditions in order to better and faster support landslide risk assessment. Only specific combinations of several of these parameters allow for the identification of so-called "events", which can trigger appropriate 'user' actions. 'Actions' could be sending out automated information (e.g. SMS or emails) and/or to trigger further tasks.

OGC SWE therefore defines the Sensor Alert Service (SAS), which specifies interfaces (not a service in the traditional sense) enabling sensors to advertise and publish alerts including associated metadata. Clients may subscribe to sensor data alerts based on defined spatial and property based constraints. Also, sensors can be advertised to the SAS to allow clients to subscribe for the sensor data via the SAS, which is currently in its version 0.9.0, has not jet been released as an official OGC standard. There are still discussions on the common suitability of this standard and the standard document is currently under investigation especially in conjunction with OGC Sensor Event Service (SES).

SAS may use the Extensible Messaging and Presence Protocol (XMPP) a push protocol which has major technological advantages in terms of a very light-weight (low network payload) delivery of sensor notifications in comparison to HTTP. SAS notifications are provided via a Multi User Chatrooms (MUC) for each registered sensor and each predefined sensor alert definitions. To receive notifications, a client has to join the specific MUC. E.g.: There are chatrooms for different gauge-heights on a river-level. Values and alerts may be posted only into those chatrooms which height definitions have been exceeded. With this XMPP technology it's possible for thousands of users to subscribe to OGC SAS and still the network-traffic stays low as the information alerts are casted just once.

5. GI analysis of 'real-time' environmental monitoring information: National Park Berchtesgaden

The geographic information infrastructure in the national Park Berchtesgaden is based on Service Oriented Architectures – SOA - to ensure flexibility, reusability and portability of the components and the overall infrastructure. The Berchtesgaden National Park in southeast Germany is one of the oldest protected areas in the Alps, established in 1978. It comprises 218 square kilometres, with altitudes ranging from 540 meter at lowland Königssee to the towering Watzmann Mountain (2670 m). It comprises one of the oldest GIS installations in Germany. Since 1984 enormous amount of data have been collected, analyzed and archived. The GI system is used as the main instrument for the long term "National Park Plan" which came into force in 2001. The original GIS data structure is currently being reorganized and restructured aiming to integrating also local weather-station measurements directly into the GI-environment for spatio-temporal analysis. The existing climate-station network consists of nine stations which send their measurements via GSM/GPRS to a hosted centralized server providing visual web-access (tables and graphs) for the different entities like temperature, humidity, snow cover etc in a proprietary manner.

    To get spatial information on the actual climatologic situation within the National Park we implemented automated mechanisms (using python scripting language) to structure the proprietary measurements of the weather stations being accessible as OGC O&M on a 10 minutes basis. This enables the accessibility of the structured sensor datasets (temperature, humidity, barometric pressure, rain fall, snow depth etc.) via the well established OGC SOS interface. A special Web map solution (Fig. 1) has been developed (based on Microsoft Silverlight) to support 'real-time' areal snapshot analysis of the recent climatologic situation in the National Park. The measurements are directly integrated into ArcGIS Server (using a SOS custom plugin-datasource) as input for co-kriging and IDW interpolation processes integrating also differences in altitude (via DEM) of the weather stations.
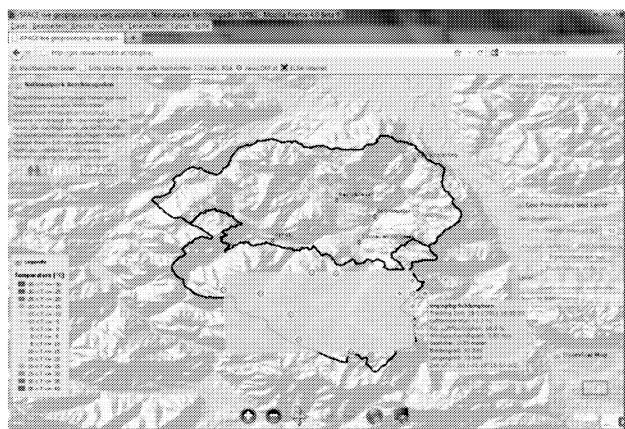
Fig 1: NP Berchtesgaden, Temperature Interpolation Application

This technological approach empowers the on-demand personalized web-based processing of 'near' real-time measurements for providing an interpolated map of the climatologic situation.

6. Conclusion

This new approach directly integrating 'near-real-time' environmental measurements into the nature conservation SDI in the National Park Berchtesgaden enables a faster and better understanding and assessment of environmental dynamics. The proposed and validated system is utilizing upcoming international standards like OGC SOS, interface and processing standards to shift possibilities in extracting new 'spatial knowledge' and enhance the support for National Park administration in their everyday's work.

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GeoURI/GeoURL: A protocol convention to connect mobile Apps and isolated Wifi cells via a distributed indoor-information-infrastructure

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Abstract. The approach of the indoor information infrastructure (iii) uses simple conventions for wifi SSID and file naming to propose a protocol between access points or directly mobile devices without the need to use the Internet and common shared services. Expected payloads are iii-flyers and iii business cards, which correspond to paper based solutions today. The conventions can be realized by configuration and do not need any hardware change.

Keywords. Wifi, p2p between mobile devices, android, nfc

Introduction

After the introduction of the mobile platform in the recent time, many existing and new ideas can now be implemented and start a new "IT rush cycle". Using a very coarse grain view, the current third rush can be compared to two exploited IT rushes with the PC age and Web age. Each age took about ten years and started with a new "gold rush atmosphere" and continued later with refinements (PC: Windows 95 to Windows 7.0, Web: 1.0 to 2.0). Considering regular business information equipments for almost all business, each age converted analogue paper based formats and functions into a digital format and software. Although many other applications exist, most PCs have software installed for the main methods "create, edit, calculate" (MS Office). Former professional printed letter and bill templates were converted into doc and xls. Although many other portals are in operations most Web traffic is caused for search and buy via the main methods publish, transport and integrate. Most catalogues are converted into portals. The paper version of a telephone book is dead. The industrial winning players are well known.
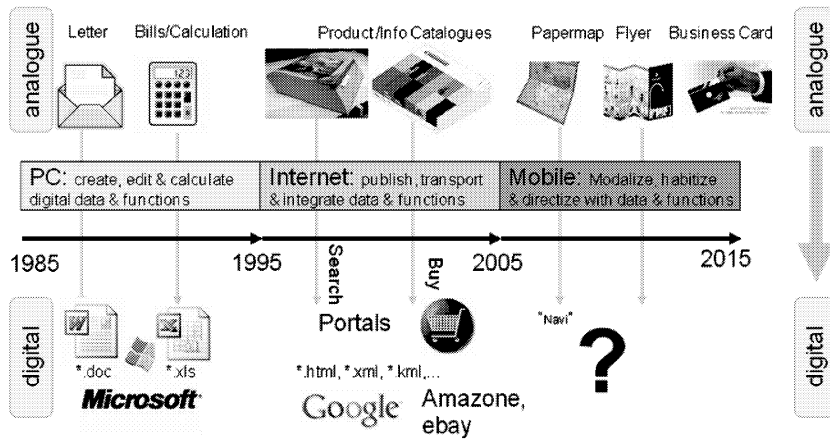
Figure 1. Conversation of business formats from paper to digital by IT ages

1. Hypothesis

Understanding the main fundamental conversion "analogue" to "digital" in the IT Kondratieff cycle on the one hand and orthogonal the demanded classic and still needed major business formats (letter, bills, catalogues, maps, flyer, business cards) on the other hand, what is left for this mobile age? The hypothesis is that flyers and business cards are subjects for conversation in this age.

The earlier ages with their main methods did not offer suitable solutions therefore the primary usage of flyers and mobile cards still remained paper based. Because of the massive usage of the format instances in almost every business worldwide, the potential is very large and the industrial winners of the last two ages show the immense value, which can be realized if the potential is detected.

Hypothesis: Separation of platforms and identification of flyer and business card for conversion from paper to digital formats in the mobile age.

2. Problem statement

In general there are different ways to organize and search information. Basic concepts organize information:

- more or less unstructured (e.g. a text),
- by hierarchy (e.g. file systems), or lists
- by time and
- by location
- (by price)
- other

The PC and WWW platforms use and offer well established functions for hierarchy (hard disc with hierarchic folders and time stamp, URL domains and free text search), but do not support the location dimension in a native way. The location dimension was not that relevant for immobile PCs and virtual networks supporting multiple organizations, which is reasonable. Of course the location issues still remained, but were processed as more or less unstructured information. Many websites offer practical location data like maps or even floor plans, but each web designer needs to re-event the way or need to link externally to other map provider, which took a central data storage approach. An example is an external map link for the coarse grain approach and a little sketch for indoor or on campus orientation. Users need to be human to try to find this information manually. Engines cannot access this data directly, because of missing conventions for automation.

An observation may support this assumption. Although the last queries of Google/OGC KML instance files show that the number is close to 220 Mio. and about 400 Mio people use Google Earth, it seems that the content of most KML instance files is still unstructured and usually not very helpful in search. KML does not correspond currently to the demand of an established format (see hypothesis above).

The mobile platform can help users in orientating in space (and time and organization and unstructured data). Therefore conventions and methods are <u>now</u> needed to handle location in a structured way and to exchange information in short distance without web or PC support in an automated way. Spatial Data Infrastructures (SDI) offer concepts for professional and thematic applications but require already an in-depth understanding and specialized software.

It seems that there is demand also for a simpler concept to handle <u>distributed</u> location information in the web (backwards compatible) and especially for mobile usage starting in semi-maintained areas like railway stations, airports, university campus and shopping centers.

3. Requirements

The success of the PC (market available distributed hardware + text/table processing) or the WWW (HTTP, HTML + Browser) show that these concepts very often do not offer the most technical or scientific performance, but have a good value/cost relationship in a broad sense.

Therefore, the solution should be compatible to the PC and the WWW platforms. It could use WiFi as a component, because it is cheap and already very often up & running. It should support Android/iPhone architecture and sensors. It may support only maintained areas, e.g. via WiFi, but should also support access to remote areas via the WWW, e.g. for planning. NFC can be used for location determination and potentially also for data transport.

From an organizational point of view, a distributed solution is helpful to enhance maintenance. The time dimension should be managed, e.g. to define a meeting point.

It should re-use existing and well known spatial concepts, e.g. address names. Although new sensors like GPS and graphical enhancements like 3D enables additional mechanism to handle location, human builders often created linear structures (1D), like streets. Squares (2D) are used, but are compared to streets relatively seldom. The third dimension (3D) like in buildings or in the underground is usually converted into 2D and even more often into 1D (lift, stairs, escalator, underground line). Postal addresses

correspond to observations and are able to cover most cases. Humans are able to remember postal addresses, but usually they are not able to remember GPS coordinates. An interesting pattern is the usage of IPs for computers and URL for humans, although they correspond to each other (see table below).

Table 1. Pattern for engine and human readability

Engine	Human
IP Address	URL
GPS Coordinate	??? (=> iii geopath)

The concept of addresses also seems to be feasible in most indoor environments, because of the described 1D tendency. Flyers are very compact, and thus can be shared easily. Therefore it should be able to transfer iii flyers as a single file (e.g. zip) containing no necessary, but only optional references. It should be possible to use flyers without any Internet connections, e.g. in foreign countries or for uses without a data plan and to keep all overall costs (also download time) low. No executable logic, e.g. CGI scripts, should be used in the first generation at the web server to enable also simple Access Points to serve as an iii server. Web based iii servers should be harvestable through robots and search engines. A central iii root web site or service, which integrates the distributed iii sources, is thinkable. And at the very end, the solution should be simple, which is possible if it is focused clearly according to an existing demand. The value/cost ratio is more important than the technological achievement.

4. Approach

Humans can better adapt to conventions than engines to human patterns. Therefore good understandable conventions (not necessary standards) are encouraged. The approach for the first generation of the indoor-information infrastructure (/iii/ 1.0) uses conventions only and does not introduce a new technology. It adapts many existing concepts and bundles them with the focus of a digital flyer (iii Flyer) and later business card according to the hypothesis in chapter 1. To enable iii usage via Wifi, access points should be open and not protected. They do not need to offer any internet access and run as an island.

With the introduction of Near Field Communication (NFC) to Android 2.3 in December 2010 and March 2011 with write functionality for version 2.3.3, a new promising exchange channel was added [6]. Although the technology was developed and used already some years ago, it seems that Android has the potential to expand this technology to mass market usage. Flyers and business cards can be exchanged by NFC to trusted people or because it is convenient. A known (position of a) NFC hotspot is also very important for indoor orientation and augmented reality. Bluetooth (BT) may get a revival due to simple coupling by NFC also. Figure 2 shows some relationships. BT was neglected.
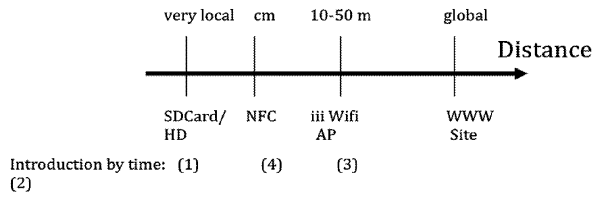
Figure 2. Distances with different communication & storage technologies

5. Adaption

The *geopath* adapts the requirements postal address pattern, ability to memorize for humans, PC and WWW backwards capability and simple usage, e.g. on a regular hard disc. A postal address is encoded URL/URI compatible with the largest spatial unit as a root. To mark-up and manage (war file) the linear reference string, a convention "/iii/" is added as iii root. As URL/URIs, the string is not case sensitive. Space characters are allowed and will be escaped. Other URL/URI conventions apply. Similar to external objects like street, parcels, floors and office rooms are named and added. Local postal address systems do apply. A global referenced geopath adds a domain name with the convention "iii" instead of "www". A deep geopath has all parts of the external and internal address items. A relative solution is also possible. Similar to the WWW convention "index.html", an entry file should be named to "index.iii".

Global and deep example:

```
http://iii.beuth-hochschule.de/iii/d/berlin/13353/
Luxemburger Straße/10/Beuth Hochschule für Technik
Berlin/Bauwesen/425/index.iii
```

Wifi local and relative example with global iii SSID:

```
SSID:iii.beuth-hochschule.de
http://iii/iii/index.iii
```

Wifi local and relative example with relative iii SSID:

```
SSID:iii
http://iii/iii/index.iii
```

A relative initial request should be re-directed to a deep geopath. The geopath can be used to mark-up documents in the metadata tag, videos, images, html files and other files, but also calendar entries in the location input field. A geopath should be used also in email signatures.

Similar to an URL, a geopath offers methods to mark-up, compare, separated, store, transport and integrated distributed sources.

The iii component with its geopath can and should co-exist with existing homepages. Similar to a photo album generator, an iii generator can create a geopath in

the file system and add an "iii" subdirectory to the www root. It should be easy to copy & paste well-known (iii), known (e.g. jpg) and unknown files.

An application example for a known file might be a beamer instruction file in pdf format:

```
http://iii.beuth-hochschule.de/iii/d/berlin/13353/
luxemburger straße/10/Beuth Hochschule für Technik
Berlin/Bauwesen/429/beamerInstruction.pdf
```

Because the time dimension is often used together with location, this paper suggests a simple convention taken from own observations. Many users name photo, business protocol and other directories or folders with a datetime entry, although the operation system already supports date and time natively.

An example is

```
2010-09-13_abcMeeting.doc
```

This observation should be defined as a convention for iii file names (not for directories, which remain reserved for spatial and organizational content). It is derived from ISO 8601 [5], but uses another separator as a forward slash "/", because that separator is already used for directories. The separator "T" can be re-used. An underscore or a dot may be used in a free form. The preference is a middle dot.

Datetime-stamps should be encoded like

```
20101115T1930.index.iii
```

with 4 digits for year, 2 for month and 2 for day (YYYYMMDD). A "T" separator is used for a time entry with 2 (hours), 4 (and minutes) or 6 (and seconds) digits. The ISO 8601 Wikipedia paragraph suggests the usage of a double "--" hyphen for an interval.
A time interval is therefore expressed by two datetime stamps, separated by two hyphens, e.g. like

```
20100903T0000--20100905T2359.index.iii
```

An example for a named iii file is

```
20101014T0945--1115_lectureB.iii
```

The directory listings of any iii (www) server should be enabled. Therefore clients can look for time or non-time tagged files.
In opposite of the comparison of two GPS coordinates (which requires some mathematical logic and often other geo data), the comparison between two geopath instances is easy as subparts or via directory browsing. An application example for a sub geopath comparison is given here:
Two persons are in contact via email. The email includes the iii geopath. Later a physical meeting is scheduled in the office of person A. Person B arrives at the office

from A. The location app of Person B detects an iii wifi access point, because of the SSID name "iii.companyA.de". The app connects to this wifi AP. The successful request returns a geopath tree. The app compares the detected geopath tree with the pervious received geopath in the email. Therefore the app can suggest something, e.g. high light the office room of person A, automatically without any needed user interaction.

6. Outlook

Many observations show that the hypothesis of a missing digital format for flyers and business cards exists and that other solutions cover it only indirectly. Therefore the solutions are not optimized for the virtualization and interaction of flyers. The approach and adaption are tested with students in Münster and Berlin. Therefore a project was defined. The MAGUN project started in October 2010 and aims to test and redefine, but also apply the concepts in application scenarios (railway station, university and environmental flooding show case with solar powered iii access point).

NFC seems to be very interesting, but must be evaluated in detail especially for practical data volume.

7. Invitation

Conventions are valuable, if many actors are using them. Therefore we invite everybody in using the iii conventions. The first version starts with just basic adaption. Contributions are welcomed for the next version any time.

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A reference schema for interoperability between geo data and 3d models[1]

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Abstract. To support the automatic reconstruction of urban object models from conventional 3d models smooth interoperability between geo data and 3d model formats is needed. The fact that 3d data are handled differently in various communities hinders the mutual stimulation and synergy between them. This paper reports on an interoperability environment for CityGML and different 3d model formats based on a comprehensive graph-based reference schema. The automatic reconstruction of a 3d urban object model of a university campus from two conventional 3d models is presented as a case study.

Keywords. Geo data, urban object models, 3d models, interoperability, reference schema, CityGML, Collada, OGRE.

Introduction

A goal of the *geoinformatics* (GI) community is the automatic reconstruction of urban object models from conventional 3d models [6], which assumes interoperability between geo data and 3d model formats. Other disciplines like *computational visualistics* (CV), which subsumes computer graphics (CG) and image processing (IP), use 3d models with their own formats and tools. In this article, we describe an approach to bridge these worlds by defining a reference model that supports interoperability for various formats and corresponding tools from both areas to support comprehensive infrastructures including all kinds of 3d data.

3d model processing consists of creation, adaptation, transformation, and rendering. With regard to contents 3d model creation covers the specification of a terrain and the definition of objects populating this terrain. Technically it comprises the production of 3d objects and usually their composition via scene graphs. A 3d object usually consists of geometry/topology, appearance and animation information. Overall activities comprising 3d models are import, export, exchange and storage.

Challenges in CG are the combination of existing 3d data including different kinds of geometry, topology and appearance information and the integration of different 3d model formats [5] with a focus on fast rendering and physically correct appearance and animation of complex 3d models. Challenges in GI are the combination of existing geo data including textual data as well as their integration with 3d models [7]. Here, the focus is on simpler 3d models, where objects are usually buildings and city furniture. The goal is providing good overviews instead of perfect visual and physical illusions.

This paper reports on an *interoperability environment* for different 3d model formats and a subset of CityGML based on a comprehensive graph-based *reference schema*

(Section 2). 3d models and urban object models are imported and transformed into graph-based models conforming to this schema. The models can be processed automatically by algorithmic components comprising different kinds of correction, supplementation, and integration activities. They can be stored and/or exported into any of the supported formats. As a proof of concept, we present a 3d urban object model of the university campus, which was reconstructed automatically from two CG 3d models containing different kinds of urban object information (Section 3) and exported to CityGML. Further information and results can be found on the STOR website[2].

1. Related work

The simplest approach to interoperability between different tools is the exchange of data through files. The CV and the GI community both use various tools for model processing and a lot of formats for model representation, exchange and storage.

Computational Visualistics (CV). Exchange formats should be open, schema-based, and readable by humans. Collada (.dae)[3] and X3D (.x3d)[4] are such up-to-date XML-based formats for 3d models. They both comprise all aspects of 3d models and are defined by an XML Schema Definition (XSD) accompanied by comprehensive specification documents. Collada is open, and well-established 3d model software supports it; some tools like Google Earth even adopted Collada as their internal format. X3D which is similar to its predecessor VRML is not so popular, although both are defined by ISO standards. FBX (.fbx)[5] and 3ds (.3ds) are binary formats for 3d models also comprising all 3d model aspects. FBX is the current Autodesk format for exchanging digital assets, and it is widely used in commercial software. 3ds was formerly the internal format of 3D Studio Max and emerged to a de facto standard in 3d modeling, although it was only unofficially published[6]. While it is out-dated, most well-known 3d model tools still provide import and/or export to 3ds. OBJ (.obj & .mtl) is an open, ASCII-based format for 3d model geometries and corresponding textures which also emerged to an unofficially published de facto standard[5].

3d model software should be free, support common operating systems (Linux, Mac OS X, and Windows, each with 32/64 bits) and provide exchange with established 3d model formats. Well-known tools covering the whole 3d model life cycle are Blender[7] as well as 3ds Max[8] and Maya[9]. Established tools specialising in one particular 3d model aspect are SketchUp (Pro)[10] for 3d model creation as well as the OGRE[11] API for 3d model rendering. Blender and OGRE are free, SketchUp is distributed as a free and as a commercial variant, Maya is a commercial product, and 3ds Max is distributed in two commercial variants. Blender, OGRE and Maya support all desired operating systems, SketchUp supports Mac OS X and Windows while 3ds Max supports only Windows. All of them comprise tool sets for various 3d model

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2 http://er.uni-koblenz.de/
3 http://www.collada.org/
4 http://www.web3d.org/x3d/
5 http://www.autodesk.com/fbx
6 http://www.martinreddy.net/gfx/3d
7 http://www.blender.org/
8 http://www.autodesk.com/3dsmax
9 http://www.autodesk.com/maya
10 http://sketchup.google.com
11 http://www.ogre3d.org

processing activities and offer scripting facilities. All of them have an up-to-date internal format for 3d model processing, covering all aspects of 3d models.

Geoinformatics (GI). In recent years 3d data have become more and more important in the area of GI. An important step for the unification of 3d geo data was the development of the *City Geography Markup Language (CityGML)*[12], a specialisation of *GML*[13], an XML-based language for representation and exchange of 3d urban object models. CityGML explicitly distinguishes between geometry/topology, appearance and semantics (in terms of thematics) of urban objects. It defines a good basis for the storage of 3d urban object models and their exchange between different GIS applications.

There are different kinds of free CityGML tools[14]. The FZK Viewer, the Autodesk (LandXplorer) CityGML Viewer and Aristoteles are free CityGML editors. citygml4j is a Java API for import, processing and export of CityGML models. It is based on some DOM tree, loading complete CityGML models in the (main) memory. 3D City Database is a free relational database for (slightly simplified) storage and management of 3d urban models based on CityGML. There are some commercial systems enabling creation and processing of CityGML models, but there is *no free established tool* for CityGML model processing. CityGML models may be created in established 3d model software and exported to CityGML, but these tools are usually not able to process CityGML's semantics aspect. An exception is a set of third-party plugins for SketchUp from GeoRes for the export of CityGML models including its building theme[15].

Interoperability. Berthelot et al. [1] introduced an exemplary implementation of a generic architecture for interoperability between 3d model formats and rendering applications for using provided APIs for 3d models.

Based on the TGraph technology [3], the approach of this paper combines the capabilities of three different interoperability methods [2]. The interoperability environment can be used as a *direct data converter* between two standard formats. Moreover data can be processed by a schema-conforming *API* and they can be *stored persistently* as a schema-conforming graph.

2. Reference schema and Interoperability

To enable interoperability between 3d model processing software and GI applications, a bridge must be built between the different formats which respects their commonalities and differences. A powerful bridging approach is the definition of a common *reference schema* that is rich enough to keep the information of the respective formats and small enough to avoid redundancies. With such a schema and import and export components for models, it is possible to convert data between formats with minimal loss using an intermediate *reference model* conforming to the schema. This model can be subject to algorithms that adapt, enhance, and/or transform the data [4].

STOR Reference Schema. The STOR reference schema is a schema intended to describe the information used in CV and GI applications. It is structured into six basic packages (Figure 1) that represent different concerns. The *image package* comprises images and typical image parts as used in CG and IP, like pixels, edges, and regions.

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12 http://www.opengeospatial.org/standards/citygml
13 http://www.opengeospatial.org/standards/gml
14 http://www.citygmlwiki.org
15 http://www.geores.de

The *geometry/topology package* comprises typical geometry and topology elements from CG, i.e., object structure and the positions of its parts in a specific coordinate system. Geometric entities are points, line segments, different kinds of faces and specific collections (e.g. triangle lists). Topological elements are relations between geometric entities to describe higher order substructures. The *appearance package* comprises properties like colours and/or textures of objects. Appearance entities usually correspond to geometric entities. An object can have more than one appearance for different circumstances.
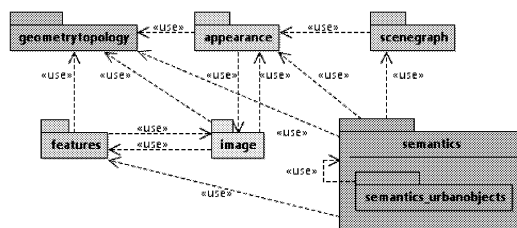
Figure 1: STOR reference schema

The *scenegraph package* comprises typical scene graph entities used in CG. A scene graph forms some kind of tree that describes global object positions in a specific terrain via transformations from different local coordinate systems. Scenegraph entities are branch nodes and leaf nodes possessing local geometries, usually in terms of triangle or polygonal face sets. Leaf nodes and branch nodes can carry transformation information that defines how an object is scaled, rotated and/or translated into a parent node's coordinate system. The scene graph part is strongly interwoven with appearance information. The *feature package* comprises typical elements from IP, e.g., blobs, corners, key points, and corresponding descriptors from various feature detection and extraction algorithms. The *semantics package* contains only one abstract element, named "Semantic Object" that is connected with a lot of elements from other packages. For concrete application areas semantic subpackages may be plugged in to the schema. All semantic elements in any semantic subpackage have to be derived from the semantic object.

A subpackage of the semantics package for urban applications is the urban objects package. It is influenced by CityGML, but enhanced with some intermediate/temporary objects and relations, since CityGML has some restrictions concerning urban object relations that are adequate for final models but not during (automatic) model processing. As an example a window can be related to a boundary surface of a building but not directly to the building itself, though during urban object derivation (Section 3) it may happen that the building is known but not yet the concrete boundary surface. In this case it is useful to create a temporary relation that is enhanced later.

STOR Interoperability Environment. The STOR reference schema can be used for all kinds of tools that work on 3d and urban data. The JGraLab Java API[16] allows creation and manipulation of corresponding models as Java data structures. These models are represented as graphs which can be subject to all kinds of algorithms [3].

The STOR interoperability environment is a set of *schemas* and corresponding *components* that enable the conversion of models between different 3d data and geo data

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16 http://jgralab.uni-koblenz.de

formats, using the STOR reference schema as a mediator. It thereby offers interoperability between different 3d and geo data formats.

For every format to be handled by the environment one schema and four components have to be supplied: (1) a *format schema* close to the original format definition (usually a DTD or XSD file) representing all entities of the format with their attributes and relations in an explicit manner, (2) an *import component*, which imports a model from a file in the original format into a graph conforming to the format schema and a corresponding *export component*, and (3) two *transformation components* that transform a graph conforming to a format schema to a graph conforming to the STOR reference schema and vice versa.

The STOR interoperability environment is independent of concrete tasks to be performed with the given 3d and/or geo data. Note, that the graph representation gives rise to easy algorithmic enhancements of the models [4], which is not easily supported by XML.

3. Case Study

As a case study, we developed a set of processing components enabling the automatic derivation of explicit 3d urban object models from conventional 3d models, based on the STOR interoperability environment (Figure 2). We applied it on a set of 3d models of the university's campus created by students lead by Priese et al. We built on a *detailed model* created in SketchUp Pro and exchanged to OGRE for quick renderings of single images and on a *semi-detailed model* created in Blender and exported to WebGL for publication on an interactive web site[17]. Both models have the same world coordinates. The detailed model contains some *urban object information* in terms of the type (e.g. window, door), the dedicated building, and the ordinal direction of objects, which are implicitly encoded in their names and/or their appearance information. The semi-detailed model contains some information about *room locations and geometries.*

OGRE. Automatic processing of the detailed model in the OGRE XML format is handled by the following components: (1.a) *OGREModelImport* (imports the OGRE model into an OGRE graph) and (2.a) *OGREModel2STORModel* (transforms the graph to a STOR graph according to the STOR reference schema). The resulting STOR model consists only of elements of the *scene graph part* and the *appearance part* of the STOR reference schema, where the scene graph part comprises local geometries. The other reference schema parts are derived from this information by (3) *Global-Geometry-Enhancement* (examines the transformations and the local geometries of the scene graph, reconstructs global geometries, and assigns them to the nodes of the scene graph), (4) *BoundingBoxEnhancement* (computes bounding boxes for all scene graph nodes based on the global geometries), and (5.a) *UrbanObject-Reconstruction* (transforms the implicit urban object information to explicit urban objects). The resulting CityGML format is achieved by (7) *STORModel2CityGMLModel* (transforms the STOR graph to a CityGML Graph) and (8) *CityGMLModelExport* (exports the CityGML graph to a CityGML file).

Collada. The Collada part consists of (1.b) *ColladaModelImport* (imports the Collada model into a Collada graph), (2.b) *ColladaModel2STORModel* (transforms this graph to a STOR graph), and (5.b) *UrbanObjectReconstruction* (transforms the implicit building and room information into explicit urban objects). The components 3 and 4 were enhanced to be used for both formats.

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17 http://erkunden.uni-koblenz.de/icw/

Data. The detailed *OGRE* model consists of 1 .scene file (6220 KB) and 4469 mesh files (177.731 KB) with 2.946.392 XML-elements. The OGRE graph consists of 1.690.637 vertices and 4.014.165 edge. The semi-detailed *Collada* model consists of 1 .dae file (26.762 KB) containing 33.809 XML-elements. The Collada graph consists of 22.189 vertices and 26.310 edges. The whole process takes 106 seconds[18].
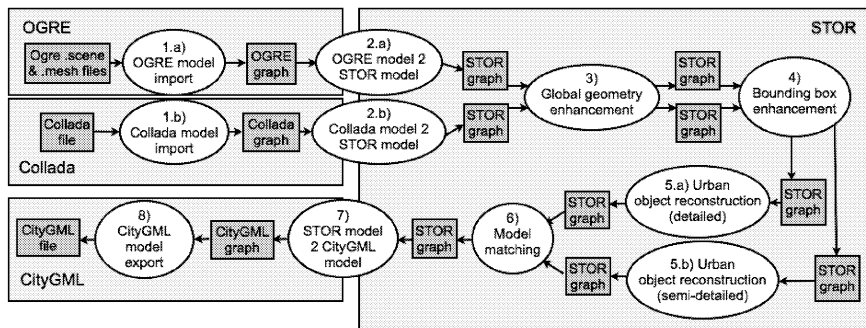
Figure 2: Case study processing components.

The two models are joined by (6) *ModelMatching* (takes the room objects of the semi-detailed model and integrates them into the detailed model).The component chain delivers a *comprehensive 3d urban object model* of the campus, containing the urban object information from the detailed model as well as the room information from the semi-detailed model, both in terms of explicit urban objects with relations to each other. All application dependent cleaning, inferring and merging actions are encapsulated in components working on the reference graph.

4. Conclusion

This paper reports on a reference schema intended to allow maximal interoperability between several formats from the geoinformatics and the computer visualistics community, thus supporting urban model creation using free software for 3d model processing. Supplying one schema and four transformation components for every format, allows the easy transformation of data between tools. Using graph technology for storing the intermediate models several enhancements can be added, too, and the models can be accessed using a schema-conforming API.

The STOR interoperability environment is still under development. While the reference schema seems to be almost stable, transformation components exist only for the OGRE XML format, Collada and CityGML when submitting this paper.

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Disambiguating Resilience

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Abstract. While the salience of resilience has been acknowledged across domains, there still exists the need to translate the abstract concept into an operational entity. In this paper, the first step towards making resilience operational is presented. Heading for an ontology as a reference frame in the long term, we analyze notions of social and ecological resilience across different domains, from which a a general definition of resilience is derived.

Keywords. Resilience, Reference Frame, Climate Change

Introduction

The environment is the natural fabric, which holds society together. It affords the existence of various systems at work within the environment. More specifically, it offers direct benefits and life supporting processes commonly referred to as ecosystem services for the progression of society [25]. De Groot [6] highlighted that the environment has four main ecological functions: it posses a natural affinity to regulate atmospheric gases, supply human accommodation, provide goods and services as well as furnish the cognitive development of society. Embedded within this natural framework is the ability to cope with environmental changes, an ability known as resilience. The resilience of an environment is central to building its adaptive capacity and adaptation, especially in light of climate change.

Coastal zones are dynamic environments that play an important role for Small Island Developing States (SIDS). In essence, SIDS can be considered as coastal environments because of their small physical extent coupled with the heavy reliance placed on these zones. Coastal areas support social and economic activities such as human settlement, subsistence agriculture, fisheries and tourism[2]. For the islands of the Caribbean, most development occurs along these zones with over 50% of the population living within 2km [22] and approximately 80% of the economic resources located within 5km of the coastline [10]. Thus, the careful and sustainable management of coastal areas is a necessity for such communities as they are faced with resource demand pressures coupled with the external threat of climate variability and induced sea level rise.

Although coastal vulnerability assessments are conducted, such assessments without knowledge of the systems' ability to cope and persist in face of climate variability do not give a holistic account of the state of the systems and its interactions with climate and sea level rise models. For resilience to be integrated with

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[2] http://islands.unep.ch/d96-20a7.htm (last accessed 21.03.2011)

vulnerability, it has to be made operational, which means making resilience a measurable property. Thus, we propose a reference frame for resilience as a means of operationalization. To our knowledge no such framework exists, and operationalization of the concept is hindered by a plethora of different definitions in various domains.

In this paper, the first step towards making resilience operational is presented. This was done through the disambiguation of prominent notions of resilience in social and ecological science, which are evaluated in Section 1. Heading for an ontology as a reference frame [14,15] in the long term, a general definition of resilience was extracted from the concepts investigated. Subsequently, it is shown how two definitions put forward by major stakeholders active in the domain of climate change fit into it in Section 2. Section 3 concludes the preliminary work and discusses future steps towards the ontology.

1. The Concept of Resilience

Resilience was first introduced by Holling [9] in Ecological research. The pertinence of the concept was unmasked, quickly becoming a fundamental notion in ecology and a highly debated concept across disciplines. Holling noted the dichotomy that existed between resilience and stability in ecosystems.

Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variable, driving variables, and parameters and still persist. [9, p. 17]

On the other hand, Holling defined stability as the ability of a system to return to a state of equilibrium after a temporary disturbance. In other words, a very stable system would not fluctuate greatly and would return to normal quickly whereby a highly resilient system may be greatly unstable in that it may undergo significant fluctuations [7].

Likewise, Pimm's [20] notion of resilience was birthed from his work on complexity and stability of eco-systems. In attempts to sort the complexity-stability paradigm within ecological research at that time, Pimm [20] noted resilience as a variable of stability. According to the author, resilience of an ecosystem is a measure of the speed of which the variables return towards their equilibrium following a perturbation adding that stable systems will not always be resilient the more complex they become. Adger [1] expressed the same view in which resilience of an ecological system relates to the functioning of the system rather than the stability of its component populations or even the ability to maintain a steady ecological state. These fundamental ideologies have led to the present day paradigm of Engineering Resilience after Pimm [20] and Ecological Resilience after Holling [9].

From its origins in ecology, the resilience notion has transcended across domains. It has been deemed an essential concept not only in ecology but also sustainable development, disaster management and climate change [7,1,12,13]. Whether or not diversity of the ecosystem enhances resilience is not known for certain. There are separate views regarding this matter. Pimm [20], Naemm [17] and Tilman[23] share the sentiments that there is no defined relationship between diversity of ecosystems and resilience whereas Schulze and Mooney [21], Peterson et al [19] and Chapin et al [4] are in support of the view that diversity enhances resilience. One certainty is that

ecoloegical resilience is a characteristic of ecosystems to maintain themselves in face of disturbance [1].

In [7] a typology of resilience was devised based on the institutions that govern the interaction of systems. The paper aimed to disambiguate the hindrances to sustainable development within societies. Resilience as it pertains to sustainability relates to how a system copes with major perturbations to its operating environment [7]. Similarly, resilience in risk management relates to the preservation of daily activities of communities within the human species [7]. The aforementioned notion is reflective of resilience in the domain of Psychology. Waller [29] also acknowledges that resilience study emerged from the area of risk. Here, resilience is viewed as the positive adaptation to adversity by humans, irrespective of pervasive risk factors and uncertainty that undermines society.

In dealing with pervasive risks and uncertainty that occur between systems, Handmer and Dovers [7] specified two forms of resilience that a system can portray: i) reactive resilience and ii) proactive resilience. A system that develops a reactive approach to resilience does this by strengthening its status quo and making the current system resistant to change whereas a system that establish a proactive method to resilience accepts the inevitability of change and attempts to create a system that is capable of adapting to new conditions and imperatives. This definition created a new dimension in the resilience research where resilience is place on a continuum with proactive and reactive resilience being placed at extreme ends.

As cited by Kendra and Wachtendorf [11], in the domain of Disaster Management, resilience is contrasted with anticipation. Wildavsky [30] states that:

Anticipation is a mode of control by a central mind; efforts are made to predict and prevent potential damages before damage is done whereby Resilience is the capacity to cope with unanticipated dangers after they have manifest learning to bounce back. [30]

Handmer and Dovers [7] noted Wildavsky's contrast of anticipation and adding to Wildavsky's contribution, Handmer and Dovers stated that the resilience is to enhance the ability of the system to perpetuate itself unchanged with minimum disruption in everyday activities drawing a link to institutional stability. From a geographical perspective, Adger [1] took the resilience dilemma one step further as he aimed to explore whether or not a relation existed between ecological and social resilience. The author defined social resilience as the ability of communities to cope with external stresses and disturbances resulting from social, political and environmental change whereas he describes ecological resilience as a characteristic of an ecosystem to maintain itself in face of disturbance. The link between both concepts lies in the dependency of society to the ecosystem. This dependency is governed via institutions such as norms and values of societies, stakeholders and government organizations that provide legal systems and distribute property rights to regulate resources [1]. The symbiotic relationship of society and ecosystem brings into focus two other key concepts amidst the resilience discussion: vulnerability and criticality where social vulnerability is described as the exposure of groups of people or individuals to stress as a result of environmental change and criticality refers to the extent of environmental degradation that precludes the continuation of current use systems and levels of human well being given feasible adaptations and societal capabilities to respond [1]. The identification of stress within an environment illustrates the resilience of a system. In

other words, resilience is not the absence of vulnerability [29]. Adger [1] states that stress is pervasive and related to the social and economic structures that underpin society. Similarly,Waller [29], identifies risk factors as stresses that influences the resilience of an individual and by extension a community. From a psychological standpoint, Waller [29] noted the non-static nature of resilience, adding that resilience is not an innate ability of the human system and at different periods an individual may respond differently to the same stress i.e. being resilient to one event but vulnerable to another.

It was noted by Costanza et al. [5] that coastal ecosystems have a high resilience due to the regulatory functions they perform thus resilience of the coastal communities is enhanced by the re-generating and absorptive capacity of the coastal ecosystem. However, in determining whether coastal communities in Vietnam were resilient Adger [1] had inconclusive results. Nonetheless, the author highlighted indicators of social resilience throughout the paper such as: economic situation of society, environmental variability, stability and migration and mobility of population. These indicators have to be considered collectively since observation of one indicator will not give the full picture of resilience. With regards to climate change, resilience has been linked to the concept of vulnerability. Timmerman [24] has defined resilience as the measure of a system or part of a system's capacity to absorb and recover from the occurrence of a hazardous event. Since Timmerman [24], other researchers have also tied resilience to vulnerability. Pelling [18] considers resilience as one of three components (the others being exposure and resistance) of vulnerability to natural hazards wherein resilience is described as the ability of an actor to cope with or adapt to hazard stress. In the same light, Turner et al [26] taken from Miller et al. [16] also considers resilience as one dimension of vulnerability assessment with the other two components being exposure and sensitivity. One of the salient milestones in the resilience academic debate is the acknowledgement of the interrelation of human and ecological systems, which has led to the adoption of the concept, socio-ecological system (SES) from Berkes and Folke [2]. The importance of resilience was further sealed with the formation of the Resilience Alliance, a group of scientists aimed at executing resilience research to inform sustainable development policies. The Resilience Alliance defines resilience of a SES as having three dimensions:

The amount of disturbance a system can absorb and still remain within the same state or domain of attraction; The degree to which the system is capable of selforganisation; The degree to which the system can build and increase the capacity for learning and adaptation. [3]

In addition, the United Nations International Strategy for Disaster Reduction (UN/ISDR) has also acknowledged the pertinence of resilience in dealing with natural hazards and defines resilience as:

The capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level in functioning and structure. This is determined by the degree to which the social system is capable of organizing itself and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster. [27, Annex1 p. 6]

In Klein et al. [13], the usefulness of resilience concept was investigated. It was their view that definitions, which incorporated a system returning to an equilibrium state are outdated as it applies to megacities and disasters. The reason being that it is difficult to identify the equilibrium position of cities under constant flux. Furthermore, the original state prior to disaster implies a vulnerable position held by the city, thus reverting to the original state after disaster implies returning to its vulnerable position. This view can be extended to resilience and climate change as societies aim to achieve longevity amid environmental variability with the aim of reducing its vulnerability to the exposure. Furthermore, concepts that include the self-organizing aspects of systems are desirable as it contributes to the idea of recovery by the system, however it does not help prevent disasters or reduce immediate impacts unto the system[13]. Adding to this point, concepts that integrate the idea of building learning capacity of a system and adaptation are also considered desirable, which is appropriate for policy and management. Conversely, Miller et al. [16] highlight the tension in resilience definition that discusses the persistence of a system in its current state versus the transformation of the system to a new state. It was cited by the authors that research into resilience of rural communities to climate variability in Africa have revealed that maintaining a current state effectively allows society to cope with a particular stress but stifles development through lack of innovation and technology by society.

2. Discussion

After four decades of discourse, the notion of resilience still remains on the abstraction level. The current dilemma entails translating the abstraction into an operational entity. To make a concept operational means taking the idea from an abstract state into a form that is measureable. To make a concept measureable implies creating a reference frame for the notion for example, the concept of weight only becomes operational when the reference frame of units (kilogram or gram) is applied. By building an ontology of resilience a reference frame can be established [14,15] as a step towards operationalization.

To begin the disambiguation process, a generic definition of resilience was derived as a result of reviewing several literatures [9,20,7,1,29,13,11,16] that aimed at conceptualizing resilience (c.f. Section 1). Concepts across domains were correlated against each other to evaluate the degree of overlap or divergence from each other. In so doing, five key components of resilience were identified: ability, system, cope, external factor and bounce back. Resilience was thus defined as: "the ability of a system to cope with an external factor that undermines it, with the system bouncing back."

First, the existing concepts refer to a system. Based on general systems theory, a system can be defined as a complex of interacting elements with the interactions of the elements specifying a particular relation [28]. This can be applied to the inter-relation of the components discussed in the previous section that constitute the social and ecological systems coined socio-ecological system. Furthermore, the system has been described in literatures as having a particular ability or a capacity to do something as it pertains to resilience. This something relates the ability to manage or deal via some mechanism with stress or disturbance unto the system, which we termed as "cope". The external factor is a generalization of the stress or disturbance that threatens the system. However, its qualification as undermining the system makes it a synonym to stress or

threat. The latter definitions of resilience included the function of recovery by the system from a disturbance that is denoted by "bouncing back" in the generic definition. Thus, the generic definition represents the most general form of resilience that can be deduced.

From our observations, we deemed the idea of coping as the central component of resilience. According to the Oxford dictionary [8], to cope means to effectively deal with something. From the concepts examined, the idea of dealing or handling of stress by a system have been conveyed in the use of the words such as "absorb" [13,24,9], "resist" [27,1,7], "withstand" [1], "adapt" [18,3,27,29,7], "self-organise" [13,3,27], "maintain" [1], "return" [20], "remain" [3]. These words describe actions taken by the system to deal with stress or disturbance and can be seen as strategies of coping.

To see how well the specialized definitions fit into the general one, two familiar definitions are aligned it i.e. The Resilience Alliance and UN/ISDR definitions. The Resilience Alliance considers three dimensions of resilience. At a glance, this definition fits well with our general take on resilience since the key elements are identifiable within its structure wherein each dimension indicates one strategy of coping. Re-arranging the first dimension such that it is expressed as: the capacity of a system to absorb an external factor and remain within the same state or domain of attraction. Repositioning the second dimension such that it states: the ability of a system to self-organise in face of an external factor that undermines the system. Altering the third dimension in the similar manner: the degree of adaptation by a system to an external factor that undermines the system.

The UN/ISDR definition consists of two dimensions. The first dimension fits easily into the general definition. Coping with respect to an external factor can be implied. Likewise, the second dimension does not require altering to meet the general definition. In the second dimension, the authors specified a particular system i.e. the social system. If "the degree to which a system is capable of organizing itself" is one way of describing resilience then this part of the UN/ISDR definition implies that social resilience determines the overall resilience of a system. This reiterates the link that the social and ecological systems share via institutions and the management of resources (see [1]).

A disparity exists between the first dimensions of both definitions. The Resilience Alliance emphasizes the perpetuation of a system in its current state whereas the UN/ISDR implies a transformative perspective wherein the system assumes a new acceptable state. Miller et al. [16] has identified this conflict among resilience concepts. The authors acknowledged that in light of climate change the persistence of a current state by systems would curtail the positive adaptation that encourages sustainability and social equity. Thus, this form of coping undermines social resilience in the long-run. Examining the idea of "cope", some specializations are more related to each other than others. Withstand and resist are synonymous with each other. To withstand or resist a disturbance implies keeping out the disturbance from the system as much as possible, before the disturbance occurs. In the U.S., forms of resistance are evident. Local governments have began taking precautionary measures against sea level rise by adding sand to the beach to offset beach erosion; in other coastal communities residents are encouraged to raise their structures via the incentive of lower flood insurance premiums as well as areas of coast has been reserved to allow for the retreat of wetlands[3].

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[3] http://www.epa.gov/climatechange/effects/coastal/index.html (last accessed: 04.02.2011)

Absorb implies an amount of disturbance a system can take in before a change in its structure occurs. Absorb can be tied to Adger's [1] concept of criticality that exist between social and ecological systems. Criticality states that feasible adaptation measures are in place, however a system can absorb a disturbance without choosing to resist first. In Tuvalu, some farmers continue crop cultivation despite coastal inundation and decrease in the amount and quality of produce thereby absorbing the disturbance[4]. Maintain, return and remain have been linked to preserving a particular state of the system i.e. the system does not transform to a new state. With regards to sea level rise, returning to an original state prior to coastal inundation is not possible. As stated previously, maintaining and remaining in a particular state stunts adaptation and sustainability in face of climate change and sea level rise and are not desirable attributes.

To adapt to a disturbance implies continuous change by the system. It is based on the system's experience, which enables it to adjust accordingly. Self-organisation is one form of adaptation wherein the system alters its structure in face of a particular stress. In Tuvalu where there is evidence of sea level rise and coastal inundation, residents have opted to raise their houses and buildings to restrict flooding and new houses are required to be constructed on 10-foot tall stilts[4]. Therefore, we can suggest a process of coping wherein a system first resists then absorbs followed by adaptation to a disturbance (climate change and sea level rise) after which the system absorbs once more.

3. Conclusion and Future Work

Global warming is expected to have disastrous effects on societies, such as the induced rise in sea level. The threat of sea level rise to SIDS would unmask its socio-ecological systems to the effects of coastal flooding, salinisation, erosion, etc.. It is established that resilience is a pertinent concept that can be effective in dealing with the uncertainty surrounding climate change. Resilience has been linked to vulnerability as both concepts aim to understand socio-ecological system dynamics in face of disturbance. As such, there is a need for convergence of theoretical and methodological approaches of both concepts [16,25]. Thus, integration of concepts can lead to holistic adaptation strategies in face of sea level rise. Noting the complementary nature of both concepts, this paper aimed to focus solely on resilience since it underscores systemic characteristics that facilitate recovery. However, resilience still remains on the conceptual level as several domains focus their academic debates on the definition of resilience, in lieu of methods of extraction, formalization and application across domains to resolve developmental and sustainability issues of society. The notion of resilience as a property (of a socioecological system) taken with reference to an external entity (the external threat) makes semantic reference systems [14,15] a promising approach to operationalize resilience. In creating this reference frame, other aspects of resilience still need to be considered such as socio-ecological system feedbacks, limits to adaptation and the dichotomy of system based or actor based approaches of resilience [16].

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Mobile In-Situ Sensor Platforms in Environmental Research and Monitoring

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Abstract. The use of Unmanned Aerial Vehicles and Autonomous Underwater Vehicles as mobile sensor platforms in environmental science is growing. While the vehicles and sensor technology have reached maturity for practical operation, we observe that the potential of artificial intelligence allowing these devices to perform their tasks autonomously is not utilized. We give an overview of current applications of such mobile sensor platforms in the domains oceanography, meteorology and atmospheric dispersion and discuss the approaches for intelligent adaptive sensor movement proposed in research and applied in practice.

Keywords. mobile sensors, sensor movement planning, Unmanned Aerial Vehicles (UAV), Autonomous Underwater Vehicles (AUV)

Introduction

Technological advances of Unmanned Aerial Vehicles (UAV) and Autonomous Underwater Vehicles (AUV) generate new opportunities in environmental research and applications. UAVs and AUVs are increasingly being deployed as sensor platforms in environmental exploration and monitoring, or emergency response. There are growing efforts and investment in unmanned aircraft technology for earth science by European and US national research institutions [13,12]. Unmanned vehicles have the ability to operate in remote areas with limited accessibility by humans, or in hostile and hazardous environments, avoiding direct human intervention and risk to humans. An obvious example is the assessment of pollution from chemicals that are poisonous, odourless and opaque gases, where vision sensors (i.e. remote sensing) are not applicable. This paper will provide an overview of the current use and concepts for use of mobile in-situ sensor platforms in environmental exploration and monitoring. We will discuss examples from the domains oceanography, meteorology and atmospheric dispersion. Our special interest is in concepts and algorithms for intelligent movement strategies for in-situ sensor platforms. This brings us to the fundamental problems of integrating mobile in-situ sensor data into environmental models and using environmental models for efficient use of mobile in-situ sensors, which both constitute research challenges of multi-disciplinary interest to Geographic Information Science.

1. Environmental applications of mobile in-situ sensor platforms

Mobile in-situ sensors are employed in environmental research and monitoring for various tasks. This section will review their current use in the three major application areas oceanography, meteorology and atmospheric dispersion.

1.1. Oceanography

Scientific mapping and survey missions of the deep sea have traditionally been performed by inhabited submersibles, towed vehicles, and tethered remotely operated vehicles (ROVs). These are now being replaced by AUVs due to superior mapping capabilities and improved logistics [30]. These AUVs carry sensors like cameras, sonars, but also in-situ sensors for conductivity, temperature, or chemicals, mass spectrometers or magnetometers. Yoerger et al. deployed an AUV for the exploration of hydrothermal plumes and the discovery of hydrothermal vents [29]. Other applications are estimating the heat flux from vent fields, the exploration of cold seeps or bathymetric and magnetic mapping [30]. AUVs are used in research expeditions under the Arctic ice, where the operation of inhabited submersibles is considered too risky and the ice permits the use of towed or remotely operated vehicles. NASA's Astrobiology Science and Technology for the Exploration of Planets program funded an expedition for the exploration of hydrothermal vent fields in the Arctic in 2007 with the explicit goal of investigating robotic technology to explore Europe's ice-covered ocean [16]. Ramos and Abreu describe AUV surveys of wastewater plumes from coastal sewage discharges [20]. These surveys aim at a better understanding of the dilution processes and predicting environmental impacts. AUVs equipped with mass spectrometers have been used for analysing naturally occurring oil seeps and also for tracking subsurface oil leaks from damaged blow-out preventers. When the blow-out of the Deepwater Horizon offshore oil drilling rig in April 2010 caused the largest oil spill in history, researchers deployed AUVs equipped with mass spectrometers and found a continuous subsurface oil plume of more than 35 kilometers in length [3].

1.2. Meteorology

Unmanned aircraft technology is increasingly employed in meteorological research to complement observations of meteorological towers and radiosondes. The robotic aircraft Aerosonde was first used for meteorological observations in the Arctic in Alaska in 1999 [4]. The Aerosonde is equipped with sensors for relative humidity and air temperature and is continuously improved for operation in Arctic weather conditions. One future goal is to use the Aerosonde in targeted or adaptive observational strategies to provide input to operational numerical weather prediction models. Van den Kroonenberg et al. describe an unmanned aircraft called M²AV, which is collecting horizontal wind vector data for boundary layer research [25]. The M²AV is equipped with a five-hole probe for wind measurements and a combined temperature and relative humidity sensor and performed flights in the Weddell Sea of the Antarctic in 2007. Reuder et al. used an unmanned aircraft system equipped with sensors for temperature, humidity and pressure to obtain profiles for atmospheric boundary layer research in 2007 and 2008 in Iceland and Spitsbergen [21].
    They also describe a study using a UAV to monitor the horizontal variability of
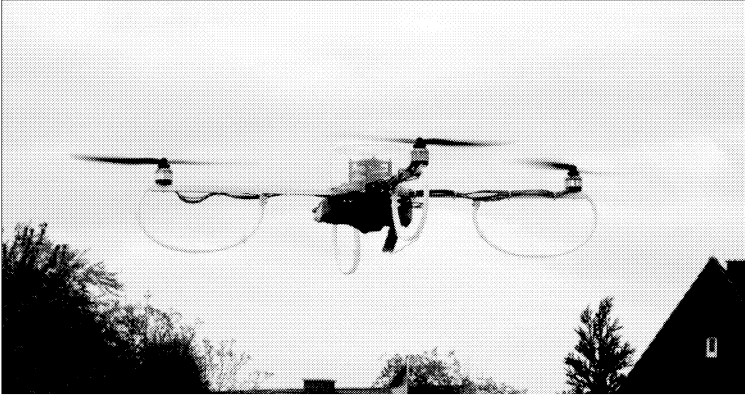
Figure 1. The Ifgicopter equipped with humidity and temperature sensors.

temperature and humidity fields above different types of agricultural land use. Frew and Argrow propose an unmanned aircraft system to study the process of tornado formation in severe convective storms, which requires in-situ measurements of the thermodynamic and microphysical properties in the rear-flank region of supercell storms [9]. The Ifgicopter project at the Institute for Geoinformatics in Münster uses microcopters for identifying boundary layers near the ground [27]. Figure 1 shows the Ifgicopter equipped with humidity and temperature sensors. The microcopter is also used for research on vertical distributions of methane gases and for locating emitters of methane.

1.3. Atmospheric Dispersion

The deployment of UAVs for surveillance tasks of atmospheric dispersion of gas or particles, i.e. toxic emissions, is well-motivated but compared to applications in meteorology and oceanography it did not mature beyond an experimental stage to this day. UAVs and swarms of UAVs equipped with in-situ sensors are proposed in a number of application scenarios including environmental monitoring and emergency response [2]. Daniel et al. propose a system architecture for a swarm of micro unmanned aerial vehicles for the assessment of contaminants in the air in emergency response called AirShield [5]. The AirShield project is funded by the German Federal Ministry of Education and Research as part of a program for protection systems for security and emergency services. One practical example for a kind of UAV deployed in atmospheric dispersion monitoring is the work of Harrison et al., who equipped a balloon (radiosonde) with charge and aerosol particle sensors to investigate the volcanic ash plume generated by the Eyjafjallajökull in Iceland in April 2010, which prohibited aviation for several days over large parts of Europe [10]. Volcanic ash constitutes a serious threat to aviation and thus is continuously monitored by the nine Volcanic Ash Advisory Centers1, which have to run their models on the basis of satellite imagery with limited availability due to temporal delay and cloud coverage. This is one example for an application where quick availability of in-situ data collected by unmanned aircraft systems would be beneficial.

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[1] http://www.meteo.fr/vaac/eindex.html

2. Approaches for intelligent sensor movement

An intelligent movement strategy for a mobile sensor is crucial to effectively perform time-critical observation tasks or to account for the dynamics of a phenomenon to be observed, e.g. to track a pollutant plume. Research in statistics and artificial intelligence has brought about various concepts for movement strategies for mobile in-situ sensors. These address different observation goals such as mapping a phenomenon, locating the source of an emission, or delineating an area where measurements exceed some threshold. We will give an overview of approaches for intelligent sensor movement proposed in research, which we divide into biomimetic and model-based approaches, and approaches being applied in practice.

2.1. Biomimetic approaches proposed in research

Different sensor movement strategies for locating sources of gas or odours, which have been developed in robotics, are inspired by nature, e.g. insect orientation. For example Ishida et al. and Li et al. suggest to mimic insect orientation strategies to pheromone with robot platforms [14,17]. Marques et al. discuss odour source localization strategies inspired by male silkworm tracking of female moth pheromone [18]. The main shortcomings of these methods are that they can only deal with odour sources that are not moving and that they require wind information.

2.2. Model-based approaches proposed in research

Several methods utilize a model of the observed phenomenon. This model can be for example a numerical model based on partial differential equations describing a dispersion process. Patan et al. and Song et al. propose methods of optimal sensor motion planning for parameter estimation of distributed systems [19,23]. Walkowski describes a geostatistical approach for sensor network optimization that uses the kriging variance as a measure of the information deficit at a location, i.e. the need for additional measurements [26]. A similar idea can be found in Elston et al., who use the geostatistical concept of the variogram to identify regions of high variability, which they associate with high scientific interest [7]. Heuvelink et al. propose a geostatistical methodology for optimizing the allocation of mobile measurement devices complementing a static radioactivity monitoring network [11]. Spatial simulated annealing is used to optimize the sampling design according to the criterion of minimizing the costs of false classifications into above or below intervention level concentrations. The reference concentration map is based on the outcome of a physical atmospheric dispersion model. These geostatistical approaches address the problem of positioning a mobile sensor within an existing network of mobile sensors and thus are not easily applicable to a scenario with one or only few mobile sensors. Moreover, these methods identify some sensor location within the study area rather than one step of a continuous sensor movement.

Other approaches use qualitative models of the observed phenomenon. Subchan et al. present a method for cooperative path planning of two UAVs to detect and model the shape of a contaminant cloud, which is modelled as a discrete Gaussian shaped plume [24]. The boundary is approximated by connecting the entry and exit points detected by the UAVs with line segments of constant curvature to form splinegons. This method however uses a static model and does not address the temporal dynamics

of the contaminant cloud. Brink proposes a concept for spatio-temporal reasoning about a gas plume based on a Gaussian model as a basis for adaptive sensor movement [1]. This approach infers qualitative information about the plume movement and size from the sensor data that is relevant for tracking a moving plume. The main drawback of these qualitative methods is that they yield only imprecise results. However, compared to the methods that use quantitative models, they also require less or less precise information as input.

2.3. Approaches applied in practice

Very few UAV or AUV explorations in environmental science are automated in terms of an intelligent adaptive movement strategy. Yoerger et al. employ a movement strategy for hydrothermal vent discovery and exploration with an AUV that begins with a conventional grid survey and then revisits the locations of clusters of anomalous sensor readings, which are ranked according to their relative value of being revisited [29]. For assessing the extent of the hydrocarbon plume resulting from the Deepwater Horizon oil spill Camilli et al. navigated the AUV in a zig-zag pattern starting from the leak [3].

3. Conclusion

Developing intelligent autonomous mobile sensor platforms poses a couple of open interdisciplinary research questions, among which we identify two important aspects. The first aspect is the integration of geospatial information relevant for the exploration or monitoring task. In the context of monitoring contaminant dispersion using UAVs Daniel et al. point to the need for integration of dynamic and static data, such as safety relevant geodata, e.g. locations of kindergartens, schools, hospitals and retirement homes, and terrain and weather data [5]. This information can be used to increase efficiency of the observation by concentrating the measurements where the data is most urgently needed.

    The second aspect is the development of intelligent sensor movement strategies that are able to efficiently collect the data relevant for a specific observation task [8]. This requires the integration of environmental models describing the behaviour of the observed phenomenon, e.g. atmospheric dispersion models, or models describing underlying and related phenomena such as weather nowcasts and forecasts. Daniel et al. suggest realtime dispersion modelling of aerosols and gases as a basis for flight routes of UAVs and using the collected sensor data to enhance the model [5]. This type of high-fidelity models can be too computationally intensive to be included in a real-time path planning loop or there can be too little data to characterize the phenomenon with sufficient accuracy [7]. Frew and Argrow propose the combination of real-time science driven control of unmanned aircraft systems with online modeling and data assimilation using domainspecific reduced order phenomenological models [9]. They envision vehicles that have simple models of atmospheric phenomena onboard that only retain features of the environment necessary for their guidance. Research in Geosensor Networks elaborates on object-based models of dynamic environmental phenomena [6,28,15,22]. Object-based modelling of the observed phenomenon (as for example in [24,1] mentioned in Section 2.2) might be a reasonable approach to meet

the requirements of 1) sensor movement planning in real-time and 2) applicability in situation where there is little phenomenological information.

This paper illustrates the state of the art in autonomous mobile in-situ sensor platforms for environmental exploration and monitoring. The presented examples from practice reveal a gap between the advances in vehicle and sensor technology, which is mature to operate in practice, and the development of artificial intelligence, and sensor data integration and modelling, which seems to lag behind. This review suggests, that there is currently no generic method for navigating mobile sensors, which would make use of all potentially available phenomenological and other relevant data and allow to automate an exploration or monitoring task. We think that future research in this area would be of high benefit to various geo-disciplines and is essential to fully exploit the large potential of UAV and AUV technology for environmental sciences.

Acknowledgements

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Building Tracking Applications with Sensor Web Technology

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Abstract. This article introduces a new kind of Sensor Web application for near real time ship tracking. Typically, most existing Sensor Web systems concentrate on the monitoring of certain thematic attributes (e.g. water level, meteorological parameters or air quality) that are visualised as diagrams. The system presented in this paper has a different focus: it shows how Sensor Web components can be used for handling observations that concern the dynamically changing position geometries of objects (ships). Furthermore, an approach is presented how a Sensor Web based tracking system can be coupled with other conventional spatial data infrastructure components (i.e. Web Map Services) for providing user friendly visualisations.

Keywords. Sensor Web, Ship Tracking, Automatic Identification System

Introduction

In recent years more and more applications based on the Sensor Web technology have been deployed. Most of these applications were built to handle observations of all kinds of environmental phenomena like environmental pollution [1], hydrological measurements [2] or oceanographic data [3]. Usually, these implementations concern time-dependent thematic parameters for certain fixed locations that are visualised as time-series plots.

This article introduces a new type of application which demonstrates that the Sensor Web technology can also be used for tracking moving objects like ships. The next sections offer a more detailed view of the developed system which is the result of a project of the Open Source Initiative 52°North [2] and the Service Centre Information Technology of the Federal Ministry of Transport, Building and Urban Development (DLZ-IT BMVBS) [3].

The developed system has to be seen in the context of existing (web based) GIS applications that are currently available. Usually there are specific applications which provide functionality for displaying tracking data (e.g. Flightradar24.com and MarineTracking.com). However, for integrating tracking functionality into (internal) spatial data infrastructures, the presented system was developed as a complementary standards based approach.

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1. Technological Background and System Architecture

The ship tracking data used in the project is gathered by the Automatic Information System (AIS)[4]. This is a system which is mandatory for most ships that are active in commercial shipping. Usually a ship has to be equipped with an AIS device which comprises a GPS receiver for determining the ship position and a radio transmitter that broadcasts the ship position as well as further data about the ship (e.g. destination, information about dangerous goods, dimensions of the ship, etc.). A base station (e.g. operated by the Waterways and Shipping Administration of the Federal Government[5]) is then able to collect the transmitted ship data for further processing and use. In the context of the presented project the access to the collected ship tracking data is provided through a SOAP Web Service that is based on a non-standardised interface.

In order to achieve the seamless integration of the ship tracking data into spatial data infrastructures the Sensor Web Enablement (SWE) framework of the OGC was chosen [4]. More specifically a Sensor Observation Service (SOS) was set up that encapsulates the proprietary interface of the SOAP Web Service so that the AIS ship tracking data becomes accessible in a standardized manner. Thus, every client capable of understanding spatial observations provided by a SOS is able to retrieve the ship tracking data and to make them available to users.

Finally, for creating user friendly visualisations of the ship tracking data, an OGC Web Map Service (WMS) was set up. This WMS instance, which is based on the 52°North OX-Framework [5], is able to consume the latest ship tracking data for a certain area from a SOS and to render according maps. These maps can be displayed by any WMS compliant client application. Within the project an Open Layers based client was developed that features an automatic update mechanism so that every five seconds a new map is displayed. This makes it possible to watch the ship movements directly within the WMS client.
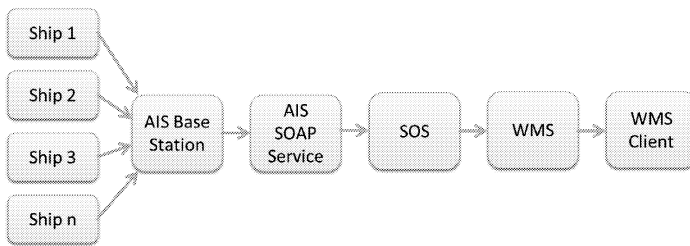
Figure 1. Overview of the system.

An overview of the system is shown in Figure 1. Figure 2 depicts an example of a map which shows the ship locations as well as additional labels containing information about the speed and course of the individual ships.

In summary our work comprised the development of an approach how tracking data can be mapped to the SWE information model, the design of a service chain that allows adapting a proprietary data source through a proxy to the SWE interfaces and the implementation of a WMS façade for integrating the tracking data also into legacy web mapping clients.

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[4] http://en.wikipedia.org/wiki/Automatic_identification_system
[5] http://www.wsv.de/

2. Conclusion

The experiences gained in the project showed that the Sensor Web technology is capable of handling near real-time ship tracking data. Within the area covered by the project (the Weser River between Bremen and Minden) it was possible to achieve update rates of less than five seconds with a latency of a few seconds. The number of ships travelling in the area covered by the system was usually in the range of 50 to 60. By optimising the service architecture a significantly larger number of objects can be handled as well.

Figure 2. WMS layer showing ship tracking data.

The system developed within the project had the character of a feasibility study. Thus, for the future the speed of the data delivery can be further enhanced. The main factor that was limiting the performance was the relatively long chain of services that was used for delivering the AIS data. In the future this can be optimized by relying on efficient caching mechanisms. Furthermore it might be interesting to deploy event based approaches that ensure the delivery of new tracking information as soon as it becomes available.

In summary it can be concluded, that the Sensor Web framework is not only capable of delivering conventional time series data but also of handling near real time tracking data. By relying on the interoperable SWE interfaces it is possible to apply the presented approach to any other kind of tracking application besides ship tracking.

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Web-Based Near Real-Time Geo-Analyses
of Environmental Sensor Measurements

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Abstract. This paper demonstrates two web-based applications for near real-time
geo-analysis. Environmental sensor measurements are directly integrated in a fully
service oriented workflow. Emphasis is put on rapid web-based dissemination of
in-situ data (points) and their interpolation results (lines, polygons, or surface) for
web clients such as Google Earth or common web-browsers. One aim of such
applications is to enhance time-critical spatial decision support in crisis
management.

Keywords. web-based geo-processing, standardised environmental monitoring

Introduction

Nowadays, near real-time analyses of a vast amount of sensor information is crucial
for decision-support systems utilized for crisis management. Geographically oriented
perspectives on such sensor data might enhance spatial temporal awareness of decision
makers.

Today's technology is already capable of generating measurements of environmental
phenomena that can be (pre-)filtered and quality assured. Additionally, standardized
web-services are able to deliver this information in real-time by means of smart in-situ
sensors [1, 2]. Distributed geo-sensor networks in combination with Geographic
Information Systems (GIS) can be deployed "intelligently" to automatically generate
multidimensional information beyond point measurements through web-based geo-
processing routines [3, 4]. Such information could e.g. inform the general public with
"live weather data" or enhance crisis management with near real-time localisation of
harmful substances such as toxic gases or radioactive radiation.

In order to demonstrate how such technology can be used to assist time-critical
decision support, we developed two web applications for near real-time geo-analyses of
environmental sensor measurements. In contrast to previous research, we integrate
these measurements directly into GIS. We show "live" interpolation results of
temperature and gamma radiation dose rate measurements. The utilization of
standardized services enables the seamless integration of these measurements and their
analysis results into a variety of other systems including widely accepted visualization
clients such as Google Earth.

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1. Methodology

Environmental measurements are usually available in a variety of well-established but mostly heterogeneous, and thus incompatible, systems. Recent standardization efforts tackle this problem and enhance data accessibility and integration. We, therefore, follow the 'live geography' approach [1] which fulfils the needs for environmental monitoring almost perfectly in terms of interoperability. Up-to-date environmental in-situ sensor measurements are requested from accurately calibrated weather stations and highly mobile intelligent sensor pods (see [5] for a detailed description) using Open Geospatial Consortium (OGC) Sensor Observation Service (SOS). In order to integrate these measurements in real-time into GIS, we developed a SOS plug-in for ESRI ArcGIS which we utilize as a geo-processing engine. As a result, spatio-temporal data (e.g. temperature) provided via SOS are directly integrated into the (geo-)processing workflow. In-situ sensor measurements and their geo-processed results, i.e. interpolation, are then published as standardized web-services. Client-side usability includes easily interpretable visualization of interpolation results. Thus, emphasis has been put on simple user interface design and the use of widely accepted visualization clients (e.g. Google Earth).

2. Results

Figure 1 illustrates 'live' Kriging interpolation results – elevation corrected – of temperature measurements from fixed weather stations within a mountainous region. Two selected clients are shown herein, ArcGIS Explorer (left) and Google Earth (right).
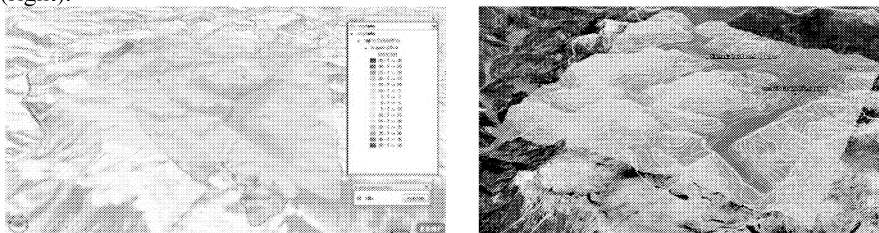
Figure 1: web-based 'live' Kriging interpolation of temperature measurements (elevation corrected)

Figure 2 shows Inverse Distance Weighting (left) and Kriging (right) interpolation results of gamma radiation dose rate measurements obtained from 'intelligent' sensor pods mentioned above. During a radiation safety exercise, two scenarios have been conducted: placement of one (Figure 2 left), and two radiation sources (Figure 2 right).
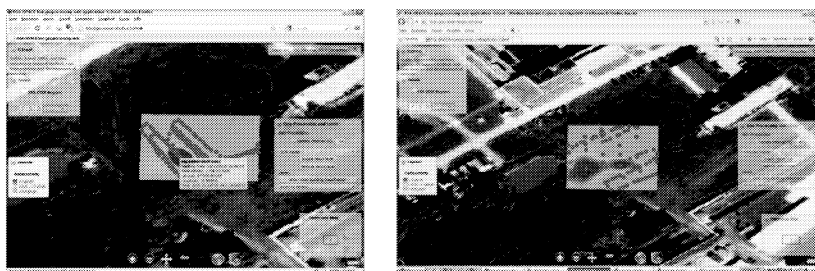
Figure 2: tailored web-application: 'live' spatial interpolation of radiation dose rate measurements (points)

3. Discussion and Conclusion

This paper illustrates web-based geo-analysis of sensor measurements in near real-time. Two selected applications served as examples to highlight the added value of using web-based geo-processing routines, in particular spatial interpolation methods.

Temperature measurements and their interpolation results shown in Figure underline the flexibility of visualisation on different clients. It also demonstrates the use of rather complex underlying models which integrate also legacy geodata, for example Digital Elevation Models for elevation correction of temperature measurements.

Geo-analyses results shown in Figure 2 have been captured in the course of the G2real project[2] exercise 'shining garden', which is described in detail in [6]. In the first case, as shown in Figure 2 left, the radiation source is clearly identifiable based on the spatial interpolation result. In the second case, two radiation sources were placed and subsequently precisely localised as shown in Figure 2 right. The results have been evaluated by domain experts and show that this near real-time approach can enhance time-critical decision making.

We conclude that standardized services enable an easy and direct integration of sensor measurements and their interpolation results into a variety of internet-based clients, in particular for visualisation purposes. The rapid web-based dissemination of geo-processing and geo-analyses results improve, depending of the application specific context, spatial awareness for the environmental phenomenon of interest. Monitoring the current state of the environment is an important component for various applications and domains, for example public information platforms and time-critical spatial decision support.

Acknowledgement

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Towards Highly Parallel Geostatistics with R

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Abstract. Tools for geostatistical analysis are standard functionality in geographic information systems. The underlying algorithms are well studied and usually optimized for today's state-of-the-art hardware. However, real-time provision of large spatio-temporal datasets, the availability of highly parallel hardware such as programmable graphics processing units (GPUs) and the resulting specification of programming models such as OpenCL or CUDA call for re-thinking established sequential programming paradigms. This paper presents the prototype of the gpugeo R package that aims at taking advantage of highly parallel computing resources for geostatistical analysis.

Keywords. Parallel Geostatistics, OpenCL, Spatial Interpolation, R

1. Introduction

The R Project for Statistical Computing [9] provides a wide range of well developed tools for geostatistical analysis. Since open web enabled geosensor networks envision real-time availability of large spatio-temporal datasets that report information on environmental change, it would be convenient to improve the available tools using accelerated hardware, in particular for such fundamental predictive modeling tasks like spatiotemporal interpolation. In fact, graphics processing units (GPUs) offer the opportunity for highly parallel processing on virtually each notebook or desktop computer. Yet, their computational power seems to be underemployed due to a lack of integration into common data analysis and GIS software. To bridge this gap, it is necessary to re-think established sequential programming paradigms and to identify parallelizable computing tasks. There are several commercial and open source software projects that aim at integrating the computational power of GPUs into existing software. We limit our discussion to current open source initiatives relevant to the research field of geostatistics. The GPUML package [12] accelerates machine learning [8] algorithms building upon CUDA, NVIDIA's proprietary parallel computing architecture for GPUs [6]. The R gputools package [1] provides a set of common data mining algorithms also implemented in CUDA [6]. The R magma package enables parallel basic linear algebra operations (BLAS) in hybrid CPU and GPU architectures [13]. However, geostatistics involves but is not restricted to data mining algorithms and accelerating geostatistical functions at the BLAS level is often not optimal since

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matrices in geostatistics often have a functional representation such as distance or covariance matrices.

This paper discusses the prototype of the R gpugeo package that aims at improving the performance of geostatistical algorithms using the non-proprietary Open Computing Language (OpenCL) [5]. The remainder is organized as follows. Section 2 describes the architecture of the R gpugeo package. Section 3 evaluates accelerated functions for inverse distance weighted (IDW) and kriging interpolation, i.e. spatio-temporal prediction, and discusses some possible extensions for conditional simulation of spatial random fields. Section 4 concludes with relevant findings.

2. R and OpenCL for highly parallel geostatistics

2.1. GPU basics

Highly parallel geostatistics as addressed in this paper aims at taking advantage of massively multithreaded computing capabilities as provided by today's programmable GPUs. A GPU's architecture is designed for single-instruction-multiple-data (SIMD) tasks with high arithmetic intensity, i.e. high number of numeric operations per memory access. Due to its specific properties the GPU is a co-processor. It can support the CPU in certain computations rather than replace it.

The architecture of a modern GPU can be seen as a grid consisting of blocks. Each block houses a number of work items (or threads) that perform the computations. Each work item can read from and write to a private register. All work items within a block share a local memory and all blocks have access to the global memory. Among the different kinds of memories on the GPU, global memory has the largest capacity but also the slowest access time. Regular access patterns that make each work item within a block read and write to consecutive global memory locations reduce the effort (memory coalescing). Thus, optimization of algorithms for the GPU has two main targets: first, define regular access patterns to control global memory accesses, and second, maximize usage of private registers and local shared memory.

2.2. Architecture of the gpugeo R package

The open source R statistical environment does not provide support for GPUs by default. It is necessary to add specific interfaces. We build upon the R gstat package [7] and use OpenCL to accelerate the spatial interpolation functions. In contrast to NVIDIA's CUDA programming standard, OpenCL is an open standard not only for GPUs but for parallel computing on heterogeneous platforms with CPUs, GPUs and other processors. It is specified by the Khronos Group, a non-profit consortium. OpenCL consists of a programming language (OpenCL C) for writing functions that are executed on a computing device (also called kernels) and an API that interfaces between host applications and the task executions of the computing devices. Kernels are executed in a massively parallel manner and are compiled at runtime for the dedicated devices.

Figure 1 illustrates how the gpugeo package interfaces between R and OpenCL, i.e. between the host (CPU) and the highly parallel device (GPU). The gpugeo package comprises a set of R function definitions (.R) and C source files (.cpp) that wrap the OpenCL specific kernels. The CPU invokes the R functions and the host C source

code. The host C source code is the heart of the R/OpenCL interface: it is responsible for device memory allocation, device initialization and kernel execution. Because of the different types and architectures of devices, different kernels can be implemented for one function, optimized to a specific device type. The gpugeo package is optimized for GPUs. When loading the gpugeo package into an R session it checks the properties of the available computing devices automatically and compiles the respective kernels.
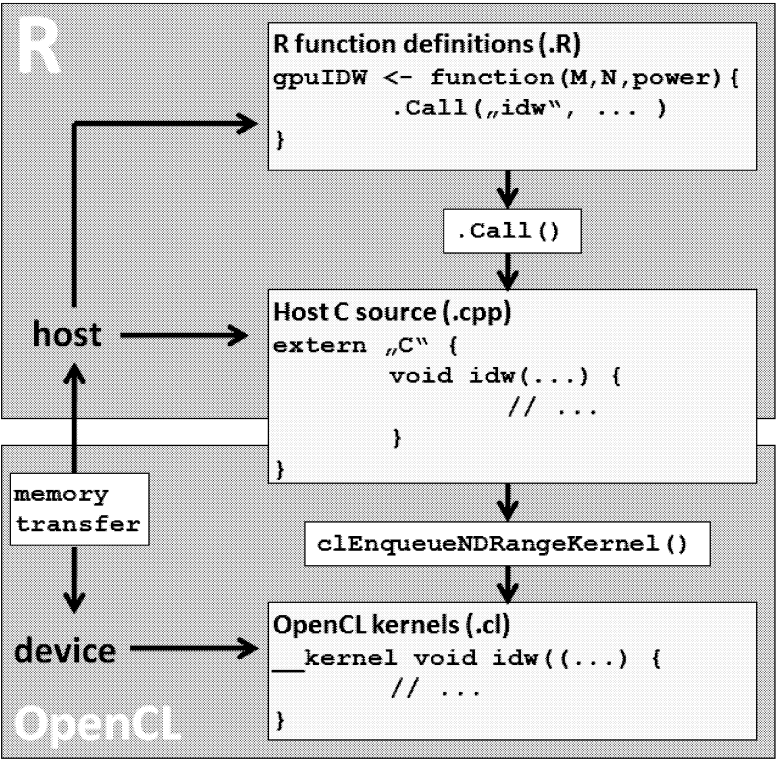
Figure 1. Architecture of the gpugeo R package: here "host" represents the CPU, "device" a highly parallel co-processor, i.e. GPU.

3. Interpolation and simulation with the gpugeo R package

3.1. Spatio-temporal prediction

Spatial and spatio-temporal interpolation algorithms such as IDWand kriging [2] predict quantities at unobserved locations based on a limited number of data points. Usually, the interpolated values are computed as a linear combination of data values. This part of interpolation, to which we will refer as spatio-temporal prediction, can then be expressed as a simple matrix-vector product

$$Wz_{data} = \hat{z}$$ (1)

where W represents the $m \times n$ spatial weights matrix, z_{data} the $n \times 1$ vector of data points and and ▢ the $m \times 1$ vector of interpolated values. An item w_{ji} denotes the weight of the i-th data point to predict the j-th location. In case of IDW, the w_{ji} are given as a function of distance between the data point and the prediction location. A condition for valid IDW predictions is that the w_{ji} sum up to one. For kriging, the w_{ji} are determined by the covariance function (or variogram model) of the spatial random process [2]. The IDWimplementation for the GPU is straightforward and has a computational complexity of $O(nm)$. Kriging requires the solution of an $n \times n$ linear equation system prior to spatio-temporal prediction:

$$Cq = z_k \Rightarrow C^{-1} z_k = q \qquad\qquad (2)$$

where C is the variance-covariance matrix of the data z_k and q the $n \times 1$ solution vector of the linear system that replaces the vector z_{data} in equation 1. The overall complexity of kriging is $O(nm+n^3)$ where n^3 is the effort for solving the linear equation system. For a comprehensive explanation of how the classic kriging algorithm can be re-formulated to exploit highly parallel computing architectures the reader is referred to Srinivasan et al. [11]. In our implementation, the linear kriging system is solved on the CPU.

The main steps of the GPU optimized OpenCL algorithm for spatio-temporal prediction can be summarized as follows (according to [12]):

1. Each work item within a GPU block is assigned to compute the weighted linear combination, i.e. interpolated value, for one prediction location.
2. To reduce accesses to global memory, the data points are loaded into local shared memory. Each work item reads the information of one data point thus taking advantage of coalesced memory access.
3. If the number of data points exceeds the capacity of local memory, which is likely to occur, the data points are divided into subsets and processed sequentially.
4. Each work items computes the weights for the data points currently present in local shared memory on-the-fly and updates the weighted sum.
5. Once all subsets of data points are processed, the resulting weighted sum is written to global memory.

Exploiting the highly parallel GPU architecture for spatio-temporal prediction results in significant acceleration. Table 1 compares the computation time of OpenCL accelerated gpugeo IDW to gstat IDW. In most cases we obtained speedup factors between ≈ 8 and 15. Note that these depend on the technical set-up of the test setting, i.e. not all GPUs would compute our implementation faster than any CPU. All our experiments were performed on a Quadro FX 4800 NVIDIA GPU with 1.5 GB global memory and an Intel Xeon Quad-Core 2.67 GHz machine with 6 GB RAM and an Ubuntu linux operating system version 10.04. The size of speedup in table 1 also illustrates the potential of acceleration for the spatio-temporal prediction step in kriging. The possible overall acceleration of kriging is subject to further investigation and depends on different factors including computation time needed for (i) parameter estimation of the covariance model, (ii) solution of the $n \times n$ linear equation system, and (iii) spatio-temporal prediction.

Table 1. Comparison of computation times in seconds (sec) between gpugeo IDWand gstat IDWfor different numbers of data and prediction locations. The speedup factor is specific for the test setting (see text for technical details).

Data points	Prediction points	gstat *sec*	gpugeo *sec*	speedup
10^2	10^4	0.03595	0.00295	12.2
10^2	10^5	0.36285	0.0143	25.4
10^2	10^6	1.9288	0.1275	15.1
10^2	10^7	19.18675	1.49675	12.8
10^3	10^4	0.1051	0.0112	9.4
10^3	10^5	1.1237	0.0875	12.8
10^3	10^6	9.0918	0.8281	11.0
10^3	10^7	92.7756	8.3546	11.1
10^4	10^4	0.8662	0.099	8.7
10^4	10^5	8.4246	0.826	10.2
10^4	10^6	84.0154	7.8916	10.6

3.2. Routines for conditional simulation of random fields

The ideas presented in the previous section can be re-used and expanded for simulation of spatial random fields. The gpugeo package offers some basic routines for conditional simulation [2] based on covariance matrix decomposition. These routines may complement existing procedures in gstat and other R packages. Due to the limited scope of this paper, we focus our discussion on the main concepts:

1. The conditional simulation procedure starts with drawing a vector of independent random numbers from the standard Gaussian distribution with mean $\mu = 0$ and variance $\sigma^2 = 1$. This step is entirely computed on the GPU [3].
2. By multiplying the vector of independent normally distributed random numbers with a lower triangular Cholesky root of a specified variance-covariance matrix, we obtain a vector of correlated random numbers. The variance-covariance matrix describes the spatial dependence among the simulation locations which in case of 10000 simulation locations has dimension 10000×10000. We compute the lower triangular "offline" on the CPU and employ the GPU for the matrix multiplication part.
3. The vector of now correlated random numbers is equivalent to an unconditional simulation of a random field and is conditioned to data values using ordinary kriging [2]. Here, we re-use the procedures for spatio-temporal prediction as described in section 3.1

The above approach exploits a GPU's strength for random number generation and matrix multiplication. Step 1 and 2 have been discussed in [10] to accelerate financial Monte Carlo. Critical for the computational performance is the number of simulation locations which determines the size of the covariance matrix. To obtain several conditionally simulated realizations however seems less critical. Roughly speaking, our implementation allows generating "stacks" of correlated random numbers, i.e. unconditional simulations in matrix form. These are conditioned to a set of data values

within one GPU call which is equivalent to the interpolation of several datasets at the same time.

4. Discussion and Conclusion

In this paper, we presented the prototype of the gpugeo R package that integrates highly parallel computing power into the R gstat package, a widely used open source tool for geostatistical analysis. In contrast to the majority of other software initiatives that target the integration of highly parallel computing power into existing software, the gpugeo R package builds upon the non-proprietary OpenCL programming model.

Classic geostatistics usually comprises four core components: (i) model selection, (ii) parameter estimation, (iii) prediction and (iv) simulation. The current gpugeo implementation particularly adresses spatio-temporal prediction and provides accelerated functions for IDW and kriging interpolation. Nevertheless, the underlying ideas can be expanded for geostatistical simulation, employing e.g. efficient random number generation and matrix multiplication. Thus, the gpugeo package also offers some highly parallel routines for unconditional and conditional simulation of (spatial) random fields which may complement existing procedures in gstat and other R packages.

At the stage of this paper, the architecture of the gpugeo R package follows a hybrid approach, taking advantage of CPU and GPU capabilities in a personal computing environment. Whereas IDW is an example for an algorithm that completely can be executed on the GPU kriging and the routines for conditional simulation are examples for hybrid implementations. Performance tests indicate significant acceleration for both, promising considerable benefit for GIS applications such as but not restricted to (real-time) mapping from sensor networks. We conclude that even if only a part of the overall task complies with the highly parallel paradigm re-thinking wider classes of geostatistical algorithms is worth the effort. Moreover, advances in multi-GPU computing (e.g. [4]) offer numerous perspectives not only for geostatistics but further GIS related modeling and image processing tasks.

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Agricultural land use dynamics in Tenerife (Canary Islands): The development of fallow land as resettlement area for adjacent natural ecosystems

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Abstract. Since the middle of the 1960s, the island Tenerife is subject to an economic change from an agrarian to a service based society, mainly focused on tourism. This development lead not only to an increasing expansion of infrastructure near to the coasts but also to increasing fallow land in higher and backward areas. The presented study aims at the modelling of agricultural land use changes for detecting fallow lands as potential regeneration areas for natural ecosystems on Tenerife. This formerly cultivated land can be seen as a major factor influencing natural reforestation and renaturation of sensitive ecosystems (e.g. laurel forest or pinewood). It provides potential space where adjacent ecosystems can spread and hence a natural resettlement of formerly cleared and agriculturally used land can come into effect. For this purpose an object-based classification of satellite images over the last thirty years is done followed by a change detection analysis on the basis of a post classification comparison. Taking into account the different local and global driving forces for these changes the spatial development of fallow land will then be simulated and visualised. Based on these results a prospection of the possible resettlement trend in fallow lands through different sensitive ecosystems can be done.

Keywords. Tenerife, Object-based LULC classification, Change detection analysis, Multi-Agent-System modelling

1. Introduction and objectives

On Tenerife, political and economic developments lead to a transformation process over the last decades (especially inducted by an expansive tourism), which caused concentration- and intensification-tendencies of agricultural land use in specific areas as well as agricultural set-aside and rural exodus.

Since the 1960s, the mass tourism on the island increased from 1.3 million in 1978 to about 6 million tourists a year nowadays [8]. So today more than 75% of the employees on Tenerife are working in the service-based tourist sector, whereas in 1978 it constituted only 56%. At about the same time the cultivated area decreased from about 26.000 ha in 1982 to 16.500 ha in 2008. The number of small scale farms with a parcels size under 5 ha also decreased from 23.000 to 12.000 ha (from 1989-1999) [2].

Due to these modifications in the economic sectors significant changes in land use and land cover (LULC) can be observed. The touristic induced development of the service sector in the last few decades lead to migrations from the economically disadvantaged rural areas to the urban tourist centres, resulting in a spatial concentration of the population and settlements near to the coasts and increasing fallow land in higher and backward areas [6].

However, these LULC changes will also have an impact on the future development of natural ecosystems on Tenerife. The fallow land in peripheral regions can generally be seen as potential area for natural reforestation and renaturation. It provides space where adjacent ecosystems can spread and hence a natural regeneration of the formerly cleared and agriculturally used land can come into effect.

The central hypothesis of the project is that there will be a further increase of agricultural fallow land on Tenerife in the next decades, driven by the change from an agrarian to a service based society. These areas will have a high environmental value according to the preservation of sensitive ecosystems like the laurel forest and its numerous endemic species. To address and valuate the spatial increase of ecologically valuable areas, it is firstly proposed to analyse and model the future trend of agricultural land use changes on Tenerife (with special respect to fallow land) under regard of different economic scenarios by GIS and remote sensing based methods. After detecting those possible hot spots of natural regeneration, a prospection of the possible resettlement trend through different sensitive ecosystems can be done.

2. The study area Tenerife Island

The study area is located about 350 km far from the western coast of Morocco (see fig. 1). Tenerife is the largest and highest (2052 km^2, 3718 m at Pico del Teide) island in the Canary Archipelago (27° - 29° N, 13° - 18° W) with a very mountainous landscape of volcanic origin, dating back to 6.5 - 11.6 Ma [3].

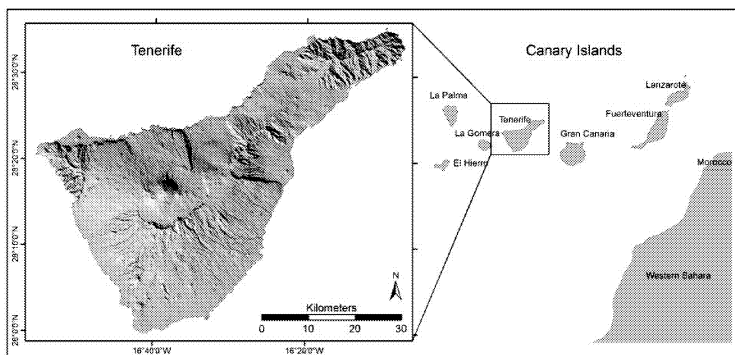**Fig. 1:** Location of the Canary islands and the research area Tenerife [2]

Due to the different mountain ranges in conjunction with the exposure to the humid northeast trade-winds, the research area furthermore shows an enormous spatial variation in precipitation with a subtropical-arid climate in the south (mean annual precipitation of approximately 100 mm) and a more humid northern part with a mean

annual precipitation of 300 - 600 mm (to over 900 mm in the highest northern and northeastern parts of the Anaga massif) [1, 3].

Both parts of the island (especially the South) present developed agricultural areas, which can be divided into two types: A dynamic and more developed type with the aim of exportation (plantations) and a more traditional second type for local consumption and the domestic market. In general, the agriculture drastically transformed the landscape of Tenerife, mainly by building of large terraces to get flat agricultural surfaces. The use of greenhouses is also a frequent practice today. The main crops grown for export are bananas and tomatoes. Agriculture for domestic market consists mainly potatoes, wine grapes and fruit orchards. These crops are primarily localised in a region between 300 -800 m above sea level [12].

3. **Research methodology**

The study is based on three main working steps: (1) Remote sensing techniques to get information about agricultural land use changes, (2) Spatial modelling techniques to analyse the future spatial development of fallow land and (3) GIS-based prospection of resettlement trends. These will be explained in detail below.

3.1. LULC classification and multiresolutional change detection analysis

In order to get information about the agricultural development of the last 30 years, medium resolution satellite images from 1978 (Landsat3), 1988 (Landsat5), 1998 (Spot4) and 2010 (RapidEye) are classified by an object-based classification method. Therefore a multi-scale, knowledge-based segmentation procedure will be developed with a main focus on the exact differentiation of the main ecosystems and their subsystems as well as settlements, different forms of agriculture and fallow land (fig.1). To achieve this aim, additional geodata like a Digital Elevation Model (DEM), digital soil and geological maps etc. and in addition extracted information from the satellite images (NDVI, Principal Component Analysis etc.) will be integrated into the segmentation algorithm.

The generated LULC-classifications are then analysed by a change detection analysis on the basis of a post classification comparison. In this approach, two independently classified and registered satellite images will be compared pixel wise by generating a change matrix [4]. Main advantage of this method is the possibility to merge land use classes which present very different spectral signatures (e.g. due to different seasonal recording dates) into the same land use. Thus the procedure based on the comparison of independent classifications is less sensitive to radiometric variations between the scenes and is more appropriate, when dealing with data recorded at different dates [6].

The aim of this method is to detect two main change types: (1) The change from "agricultural areas" to "fallow" to get information about the spatial development and the main regions of recently abandoned land, and (2) the resettlement of fallow land through adjacent ecosystems. By analysing this second change type, potential resettlement trends on formerly abandoned agricultural land though the ecosystem, as well as different influencing factors for renaturation shall be identified.
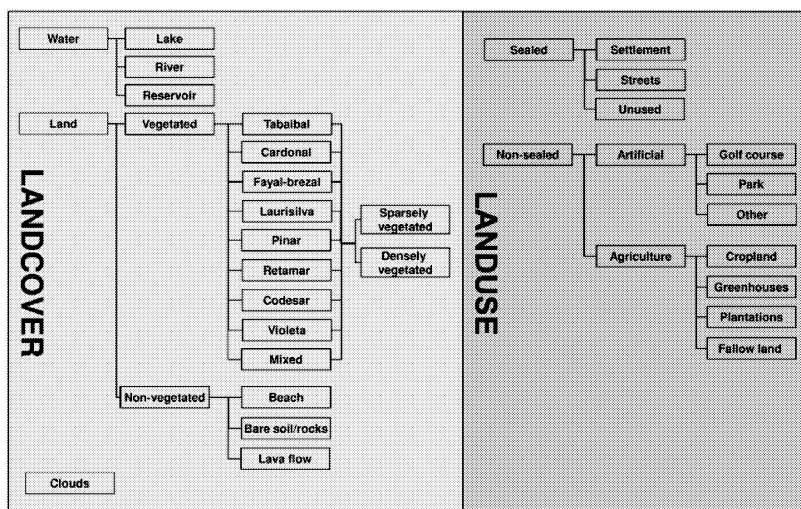
Fig. 2: Target class structure of the object-based LULC classification

3.2. Modelling the future spatial development of agricultural fallow land

Once the change detection analysis is realised, it is necessary to identify the different influencing factors, which are responsible for agricultural land use changes. In general, these so called driving forces can be subdivided into different groups: (1) socioeconomic drivers, for example different price trends (of e.g. water, crops, level of wages), development of employees in agriculture and the tourist sector (as an alternative income for farmers) etc.; (2) proximate drivers, which can be seen as land management variables, for example regional planning or the establishing of nature protection areas [14] and (3) location-specific drivers which do not 'drive' land use changes directly, but can influence land use abandonment decisions, for example the closeness of the agricultural areas to settlements or the location of fields in very mountainous areas.

The statistical connections between agricultural land use changes and driving forces will be identified by the use of correlation and regression analyses, followed by a causal proof to avoid statistical but not causal interactions of the correlations. Since these connections are detected, it is also possible to construct different future scenarios of the socioeconomic development on Tenerife. These various scenarios are then used as a basis for the subsequent land use modelling.

With the use of the detected driving forces and land use changes, an adequate modelling technique for the simulation of the future spatial development of agricultural land use will be developed. Multi-Agent-System models of land use and land cover changes (MAS/LUCC models), a combination of two approved modelling techniques, seem to be well suited for this step. They combine a cellular model that represents the landscape of interest with an agent-based model that simulates decision making by individual agents explicitly addressing interactions among individuals. The cellular model as the spatial modelling framework further includes biogeophysical and ecological submodels whereas the agent based model represents human decision

making. So the first model is part of the agents' environment, in which agents act according to given rules [9, 10, 11].

3.3. GIS-based prospection of possible resettlement by different ecosystems

With the use of the land use scenarios and former analysis of resettlement trends in the past, it is possible to give a prospection for different ecosystems and their potential expansion on formerly cultivated areas. However, it must be noted that a positive renaturation of fallow land depends on many factors, on the one hand on soil characteristics, or the type and intensity of the former land-use and on the other hand on characteristics of the respective ecosystem, e.g. the kind of seed dispersal, growth rates etc. These factors will be considered in the GIS-based resettlement analyses.

4. First results and outlook

First results of the object-based segmentation procedure are shown in fig. 3. The example comprises the region around Puerto de Santiago in the south western part of Tenerife. The algorithm, generated with the object-based image analysis software eCognition 8.0 Developer, has been developed and tested with RapidEye imagery from april 2010.
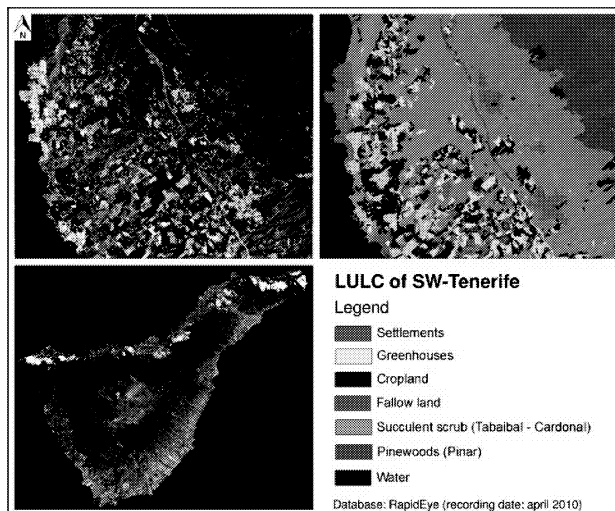
Fig. 3: LULC classification of SW-Tenerife

To get closer information about the formerly agriculturally used areas in Tenerife, an adequate detection method needs additionally to be developed, which allows a more exact identification of older agricultural fallow land with a higher level of natural succession. Previous field trips on Tenerife showed that especially in mountainous areas, crops are solely planted in terraces. This leads to the assumption that long-term fallow areas can mainly be detected together with old agricultural terraces and its specific linear texture. One solution for the acquisition of such areas could be the texture-based

detection and area-wide extraction of linear terraces structures in current orthophoto images of Tenerife and its subsequent integration in the existing LULC-classification. A first object-based algorithm in this respect has been developed and needs now to be validated.

After a further modifying of the classification technique with regard to the applicability on satellite imagery from other sensors and the later change detection on the basis of a post classification comparison, it is necessary to find the controlling factors (driving forces) for agricultural land use changes. These will have a considerable influence on how the MAS/LUCC model can finally be implemented, especially with regard to the agent architecture (agents' behavior) and the interaction with the agents' environment.

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Towards Standards-Based, Interoperable Geo Image Processing Services

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Abstract. The OGC Web Processing Service (WPS) Standard has received high attention among the geo community due to its generality – on principle, any algorithm can be offered via an open WPS-based interface. However, this generality comes at a price: Normally, WPS instances are not interoperable as only the function signature, but not the semantics is described in a machine-readable fashion.
To achieve WPS interoperability we propose to establish specializations (application profiles in OGC nomenclature) based on well-defined service components and present such an application profile for raster data. It is based on the OGC Web Coverage Processing Service (WCPS) which defines a raster processing language.

Keywords. OGC, open standards, WPS, WCPS, raster services

1. Introduction

Server-side processing capabilities are of steadily growing importance for geo services. Quality of service can be distinctly improved when shifting from a paradigm of *data stewardship* to *service stewardship*. This in particular as the sheer amount of data increasingly prohibits a "data shipping" from the server for client-side processing.

The alternative is a "code shipping" approach where the server, possibly in some scripting language, can be tasked by the clients. However, this raises the issue of the server-side programming interface. Recently, the OGC Web Processing Service (WPS) Standard [5] has received high attention among the geo service community due to its generality – on principle, any algorithm can be offered via a WPS interface. However, this generality comes at a price: Normally, WPS instances are not interoperable as only the function signature, but not the application semantics is described in a machine-readable fashion. Concretely, WPS only describes syntax in a formalized XML structure; semantics is only captured in the *Title* and *Abstract* tag containing free text (Figure 1). Hence, there is no way for a client to *automatically* verify that the server code really performs what is advertised.

Figure 1. Sample WPS 1.0 process description.

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Database-style query languages show a way forward: their high level style allows phrasing requests independently from storage structures; they usually are "safe in evaluation" so that no single query can block the server forever; and the declarative language design enables extensive server-side optimizations. This role model, which SQL has introduced on alphanumeric data, has been adopted by the Web Coverage Processing Service (WCPS) Standard issued by OGC in 2008 [2]. WCPS can be summarized as "XQuery for multi-dimensional raster data". Due to its formal semantics there is a stable fundament for interoperability: all servers will interpret a given query identically.

In the VAROS project [7] funded by the European Space Agency (ESA) we have developed a specification draft, backed by an implementation pilot, where WCPS acts as an Application Profile of WPS. An Application Profile, in OGC nomenclature, is a strict subset of a standard (in terms of this standard's functionality) with the possibility to add extra, application specific definitions. In the case of WCPS, only a specific process type, *ProcessCoverages*, is introduced which receives a WCPS query as input and delivers a result list. Actually, the WPS specification [5] expressly recommends such a procedure for interoperability: "This document does not specify the specific processes that could be implemented by a WPS. Instead, it specifies a generic mechanism that can be used to describe and web-enable any sort of geospatial process. To achieve interoperability, each process must be specified in a separate document, which might be called an Application Profile of this specification."

The remainder of this contribution is organized as follows. In the next section, we give a brief overview of WCPS so as to enable understanding of the semantic level. Section 3 explains the approach of using the WPS protocol for WCPS query shipping. The interoperability experiment conducted is described in Section 4, followed by a discussion of use case scenarios in Section 5. Section 6 concludes the paper.

2. WCPS in Brief

The WCPS language resembles a high-level, declarative query language on spatio-temporal geo raster data of unlimited volume [2]. As such, it defines syntax and semantics of expressions for specifying ad-hoc search, extraction, aggregation, and analysis of coverages containing multi-dimensional sensor, image, or statistics data.

The following example shows the flavour of the WCPS language, see [4] for an extensive discussion of concepts, expressive power, and also design decisions. From a list of 3-D MODIS time series data cubes, it picks those ones which contain at least one pixel where, over land, the near-infrared component (*nir*) exceeds 250; of these matches, a particular time slice is delivered as HDF-EOS file:

```
for $c in ( ModisTS1, ModisTS2, ModisTS3  ),
    $m in ( LandSurfaceMask )
where count( $c.nir > 250 and $m ) > 0
return
    encode( ( ($c.nir - $c.red) / ($c.nir + $c.red) )
            [ t:"http://www.opengis.net/def/trs/
                ISO-8601/0/Gregorian+UTC"
              ( "Sun Mar 22 13:33:29 CET 2009" )
            ], "HDF-EOS"
    )
```

WCPS only defines the abstract service language and is protocol agnostic. The syntax comes in two semantically equivalent flavors, XML and a so-called Abstract Syntax – used in the above example – which lends itself towards XQuery to facilitate a future integration.

3. WCPS over WPS

The WPS Application Profile for Coverage Processing is a draft specification for a WPS supporting the server-side evaluation of WCPS queries on multi-dimensional coverages [1]. To this end, the WPS process type *ProcessCoverages* is defined. This process has one input parameter, the query string, and a – possibly empty – list of output parameters, either coverages or scalars (in case of an aggregation query). The XML code below shows a sample WPS *Execute* request invoking *ProcessCoverages*, with the input query provided in WCPS Abstract Syntax (but could be in WCPS XML encoding as well):

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<wps:Execute service="WPS" version="1.0.0" …>
  <ows:Identifier>ProcessCoverages</ows:Identifier>
  <wps:DataInputs>
    <wps:Input>
      <ows:Identifier>Query</ows:Identifier>
      <ows:Title>Query in Abstract Syntax</ows:Title>
      <wps:Data>
        <wps:LiteralData>
          for $c in ( MODIS200908310815 )
          return
            encode( $c.red + $c.nir, "tiff" )
        </wps:LiteralData>
      </wps:Data>
    </wps:Input>
  </wps:DataInputs>
</wps:Execute>
```

Notably, no change to WPS as such had to be made. This orthogonality keeps available all WPS functionality, such as asynchronous processing. Another advantage is the stability against WPS changes. At the time of the specification drafting, only WPS 1.0 has been available, although the WPS Standards Working Group is working heavily on WPS 2.0. It is expected that few or no changes will have to be made to the Application Profile once WPS 2.0 is stable and rolled out.

4. The Interoperability Experiment

In the VAROS project, a proprietary geo client, ChartLink, has been coupled with an open-source raster database, rasdaman [8]. Figure 2 shows the overall architecture. The interactive client accepts user input, transforms it to a WCPS request which is shipped to the server using WPS. The rasdaman server receives this request through its petascope component, a Java servlet which performs decoding of WCPS queries, resolves the geo semantics with the aid of its internal metadata, and facilitates translation into a

pure array query of the rasdaman raster query language, rasql. This rasql query is evaluated by the rasdaman engine. The multi-dimensional array data themselves are maintained in a partitioned manner in so-called tiles; each such tile is kept in a Post-greSQL BLOB. The query result is constructed by the rasdaman engine by fetching all relevant tiles into main memory, composing the result by performing all necessary processing steps, encoding the result into the data format requested, and delivering back this result to petascope which finally forwards it to the client.

5. Use Case Scenarios

The two stakeholder and end user partners in the project, the UK Royal Navy and the German Governmental Spatial Data Infrastructure Initiative (GDI-DE), have made

Figure 2. ChartLink / rasdaman architecture.

available suitable sample data sets encompassing bathymetry, elevation, orthoimage, and several thematic layers; additionally, AVHRR SST images have been downloaded from USGS. On these data sets, the following seven use case scenarios for WPS-based coverage processing have been addressed:

*   Ortho image retrieval. This consists of simple zoom and pan access to otherwise unmodified data; in other words, it emulates a WMS.
*   Terrain/bathymetry integration, demonstrating dynamic multi-source fusion by generating a seamless altitude map from a Digital Elevation Model and a Bathymetry Model.
*   Terrain slope calculation, as a representative for focal operations and general convolutions.
*   Topographic classification/coloring.
*   Copyright protection. In this case, a constant image (such as the data provider's logo) is overlaid on all requests. In a practical scenario, a corresponding query sub-expression would be added server-side to enforce stamping.
*   Decision support. A weighted composition of an elevation layer and several thematic layers is established and colored so as to highlight areas fulfilling particular criteria. Weights can be adjusted in the client by the user.
*   Flood analysis; as a representative for "what-if" analysis types, the combined bathymetry/elevation terrain map is shaded according assumed high or low tidal or flood situations.

Most of these use cases focus on interactive clients for map visualization tasks (Figure 4). Fully automated (batch) clients probably convey further characteristics to be captured by additional use cases. This is subject to future research.

Figure 3. ChartLink query editing dialog.
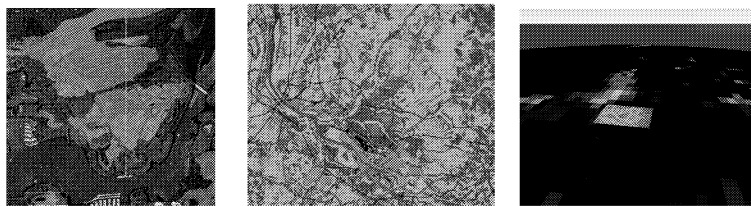
Figure 4. ChartLink visualization of map overlay (left), weighted classification (center), and projected view of classification (right).

We want to draw particular attention to the way queries are generated in the client. As the WCPS interface defines query strings (or XML documents, resp.) as the only interface, the client is tasked with transforming user input into such queries. We have found three scenarios particularly characteristic:

- Completely prefabricated queries maintained in the client and invoked by the user through a mouse click.
- Queries parametrized with geometry. Users navigate to a particular location and activate a virtual layer, whereupon the client patches the corresponding coordinates into the query generating this virtual layer. This we found the most frequent use case by far.
- Queries parametrized with sub-expressions. Depending on the user's knowledge about the WCPS language, the spectrum ranges from simple expressions to complete queries. For example, a normalized difference index formula, such as the NDVI, could be entered by the user; the client would embed this into an overall query and add appropriate bounding box and resolution parameters. This request type has not been used in VAROS, but in an earlier coupling of rasdaman to an astrophysical simulation tool.

The Chartlink client is powerful enough to allow defining and editing of any such definitions, including interactive parameter instantiation (Figure 3). The language inter-

face has proven outstandingly useful for distributed development and debugging in the project: code snippets could be exchanged easily for discussion, and both syntactic and semantic errors could be spotted easily in the server log by looking at the queries sent.

6. Conclusion

Geo processing has a high potential, but currently suffers from a lack of machine-understandable semantics the more powerful operations get. However, a concise agreement between client and server is indispensable for Semantic Web services where there is no human supervision any longer. Envitia Ltd, engaged in the OGC WPS group and vendor of WPS solutions, has stated that "Previous research led to the conclusion that WPS offered no significant benefit over a bespoke web service because unlike other OGC services there is no common domain semantics between differing WPSs. WCPS would offer a particular benefit therefore in the areas of environmental data comparison, exploitation and validation which are key interests of many of our customers." One might ask, then, why to go the WPS way in the first place and not straight the Web Service way? The answer is twofold. First, geo processing standards obviously are beneficial to the community if interoperability can be achieved – and WPS sees an eager take-up in geo communities and by geo tool vendors. Second, the roadmap to WPS interoperability is described already in WPS 1.0 [5] – what we did is exactly following this roadmap.

With our work, we aim at lifting raster services to the semantic level. Coupling WPS and WCPS is one step towards this goal (a connector into WCS exists already). Actually, the WPS Coverage Processing specification is part – and the first – of a major initiative within OGC to establish altogether five Application Profiles. In VAROS, two independently developed tools – the rasdaman server and the ChartLink client – have been coupled successfully, giving a first indication for interoperability.

In future, service providers can choose whether to use WCPS raster processing through the WCS or the WPS transport protocol. Services which are mainly data oriented or embedded in standard Web GIS environments, such as combinations of a Web Map Service (WMS) with virtual coverages obtained through dynamic WCPS requests might prefer WCS. In a more processing oriented environment which might want to exploit the advanced process handling foreseen for WPS 2.0, this might be the choice.

On a larger perspective, this activity is part of the overall harmonization and integration of coverage-related activities in OGC. Harmonization between GML, SWE Common, and WCS has been achieved already, WPS, O&M, and data exchange formats like GeoTIFF, JPEG2000, and NetCDF are under way. The ultimate vision is that coverages can be exchanged freely - and independently from their particular encoding - between all OGC-based services, thereby getting closer to the Holy Grail of coverage service interoperability.

Acknowledgement

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Extracting the Evolution of Land Cover Objects from Remote Sensing Image Series

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Abstract. We live in a changing world and this acceleration of change provides a strong motivation for research in GeoInformatics. Our tools and methods for representing and handling land cover data should be capable of dealing with change. In this work we developed a land cover model to handle the evolution of land cover objects. This consists of an abstract data type ('land cover object') and uses a limited number of spatial operations such as 'create' and 'split' to elicit the changes it suffers in time. We present an application of the model to the data provided by the Brazilian Amazon Deforestation Monitoring Program.

Keywords. Evolving objects, geosemantic algebra, object history, spatiotemporal objects evolution.

Introduction

We live in a changing world and this acceleration of change provides a strong motivation for research in GeoInformatics. Our tools and methods for representing and handling land cover data should be capable of dealing with change, that is defined by Singh [1] as the different states that objects adopt in distinct observed timestamps. Indeed, there is much work in the literature about modelling and representing change in land cover objects [2] [3] [4] [5].

One of the challenges for modelling geographical change is dealing with the massive spatial data sets generated by remote sensing. Understanding land change using remote sensing data requires more than having access to multitemporal data sets. The researcher needs to build a conceptual model of the processes that cause change. Then, he needs to relate these processes to objects identifiable in the images. The next step is describing how these objects change from one image to the next. After the information is organized in a coherent spatio-temporal view, the researcher can relate the evolution of the objects found on the images to his conception of the land cover dynamics. An important question that we should be able to answer is: "*How can we reconstruct the changes in the areas, given a set of snapshots of the area*"?

To help answer this question, this work is based on the notion of 'image objects' and 'land cover object' that were previously described in [6]. Image objects are static entities whose existence is tied to the image they were extracted. An image object is geometrically represented by one or more polygons which enclose homogenous areas. They are usually obtained by a segmentation followed by a classification [7]. A 'land

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cover object' is a spatio-temporal object whose boundaries and properties change, but whose identity remains during its existence. Given a sequence of images from the same area, a land cover object will be associated to one or more image objects extracted from each image. Matching land cover objects to image objects is usually subject to topological restrictions. When a land cover object is matched to two image objects extracted from successive images, most applications require that the image objects have part of their boundaries or interiors in common. Thus, one land cover object might be mapped to many image objects detected in different images taken at different times.

We propose to exploit this multitemporal dataset of land information systems by detecting and storing the history of land cover objects that emerge from processes related to change. We do this by applying a limited number of spatial operations *create*, *update*, *merge*, and *split* on the land cover and image objects, accordingly to a set of rules that gives semantic to the land cover objects. We call the model a *land cover evolution model* and is described in the next section.

1. The Land Cover Evolution Model

There is a common situation in land information systems, where data comes from multitemporal remote sensing images. The input is the state of the world at discrete times t_0, t_1, ..., t_n. In a time t_i we have a set of image objects detected from an image taken at t_i that represents the change detected from t_{i-1} to t_i. These are image objects and there is no linking from them to the land cover objects detected times t_0,..., t_{i-1}. In our model, the application needs to define a suitable set of rules for controlling how an image object (that represents change) object relates to land cover objects detected at the same time or previously.

We start with a 'merge rule" that defines when an image object should be spatially joined to an existing land cover object, for example: '*if two objects are topologically adjacent (they touch), they are joined'.* Meaning that the image object detected at this time is the result of a change suffered from an existing land cover object in a previous time. Conversely, we have 'split rule' that determines when an image object represents the changes suffered from two previously existing land cover objects. For example: '*if an object is detected and it overlaps a previously existing object, it should be split'.* The sequence of operations suffered by each land cover object in the data set represents its history and allows us to infer patterns of evolution or identify agents responsible for the evolution.

1.1. The Evolution Data Set

In order to apply our model we consider an input data set, called *OD - Objects Dataset* that contains the image objects, representing change, detected a given time. From this dataset we create a second data set to store the corresponding land cover objects, including the history of image objects that contributed to its current configuration. This data set is called *EOD - Evolving Objects Dataset*. At the initial time t_0, we retrieve the set of objects from the original *OD* and insert it into the *EOD*. For each timestamp from t_1 to t_n, the land cover evolution model combines the image objects from the *OD* in time t_i with the land cover objects from the *EOD* in t_{i-1} resulting in the objects in *EOD* in time t_i. This sequence of steps is illustrated in Figure 1.
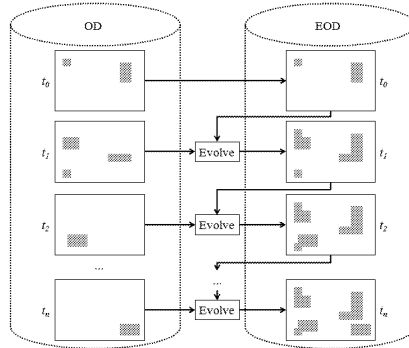
Figure 1. The Land Cover Evolution Model.

We use a genealogy tree to describe the history of each object. At the lowermost level of the tree, we have the ancestor objects. As these 'merge' and 'split' with others, the tree grows upwards.

We implemented the concepts described here as an algebraic model for handling land cover objects. The algebra is described in details in [8] and [9]. In this algebraic model, we can associate types to the land cover objects and define the evolution rules according to these types. As a practical consideration, evolution rules that depend on topological considerations (such as objects touching each other) may be affected by the geometric matching between two snapshots. In general, the user needs to perform suitable pre-processing operations to ensure that there is good correspondence between data from subsequent time steps. This pre-processing avoids incorrect rules resulting in an analysis generated by distinct computational distances of tolerance values.

2. Evolution of deforestation in the Brazilian Amazon: a case study

This section presents an example of applying the Land Cover Evolution Model to study the evolution deforestation in the Brazilian Amazon rainforest. We use data from the surveying work done by the Brazilian National Institute for Space Research (INPE). Using remote sensing images, the INPE provides data on deforestation and degradation of the Brazilian Amazon tropical forest: it indicates that more than 37,000,000 ha were cut from 1988 to 2008 [10].

To study the evolution of deforestation our input data are a set of image objects associated to patches of change detected in subsequent remote sensing image. We are interested in detect and monitoring the land cover deforestation evolving objects during the evolution process. We analyzed deforestation process in the Vale do Anari municipality, Rondônia State (2). This is a 400,000 ha region where occupation started with government-planned rural settlement.
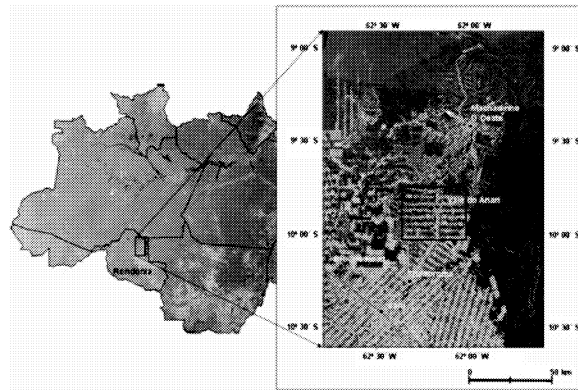
Figure 2. Location of Vale do Anari study area. Source: [11].

Figure 3 shows the sequence of images detected by LANDSAT on four different timestamps and that shows the changes occurred in Vale do Anari municipality, from 1985 to 1994, with a three-year interval between each set. Clear areas represent the deforested areas on these images.

(a) 1985

(b) 1988

(c) 1991

(d) 1994
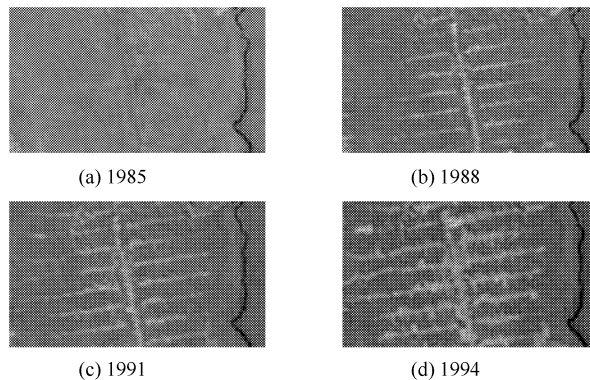
Figure 3. Location of Vale do Anari study area.

Silva et al. (2008) [11] and Mota et al. (2009) [12] proposed a classification for the land this dataset according to the land change agents acting in this region based on expert knowledge about the area. They recognize three different land cover objects: *AlongRoad*, *Concentration* and *SmallLot*. In one time stamp, each image object can be classified with one of these three types. Mota et al. (2009) [12] went a step further and developed the following rules for the evolution of these land cover objects according to their types:

R1.Two adjacent *Concentrations* merge and the new object is a *Concentration*.

R2.Two adjacent *SmallLots* with areas smaller than 50 ha merge and the new object is a *SmallLot*.

R3.A *SmallLot* with an area smaller than 50 ha adjacent to a *Concentration* merge and the new object generated is a Concentration.

Our model allows us to discover when objects of one type become another type, which we call evolution. In this case, this represents discovering when and where the deforestation processes change. The correspondent *OD* and *EOD* can be seen in Figure 4 that gives a general view of the model application.

Time	Objects Dataset (OD)	Evolving Objects Dataset (EOD)
1985		
1985 to 1988		
1988 to 1991		
1991 to 1994		

- AlongRoad
- Concentration
- SmallLot

Figure 4. The OD and EOD datasets for Vale do Anari.

By looking the resulting *EOD* we verified when some *SmallLot* objects evolved to *Concentrations*, allowing us to identify the land concentration process on this study area, and that if reflects on the observed deforestation patch patterns. Field data [12]

support this conclusion, thus the application of the land cover evolution model can improve the accuracy of deforestation detection.

3. Conclusions

The main contribution of this paper is to propose a land cover evolution model to track the evolution history of a set of evolving objects as well as the individual history of each object in the set. Our model combines distinct types of land cover objects, describes and recovers the evolution of objects in a flexible way and considers constraints derived from knowledge about the application domain.

We applied the land cover algebra in the domain of environmental change monitoring using remote sensing images to analyze a time series of deforestation land cover objects in the Brazilian Ama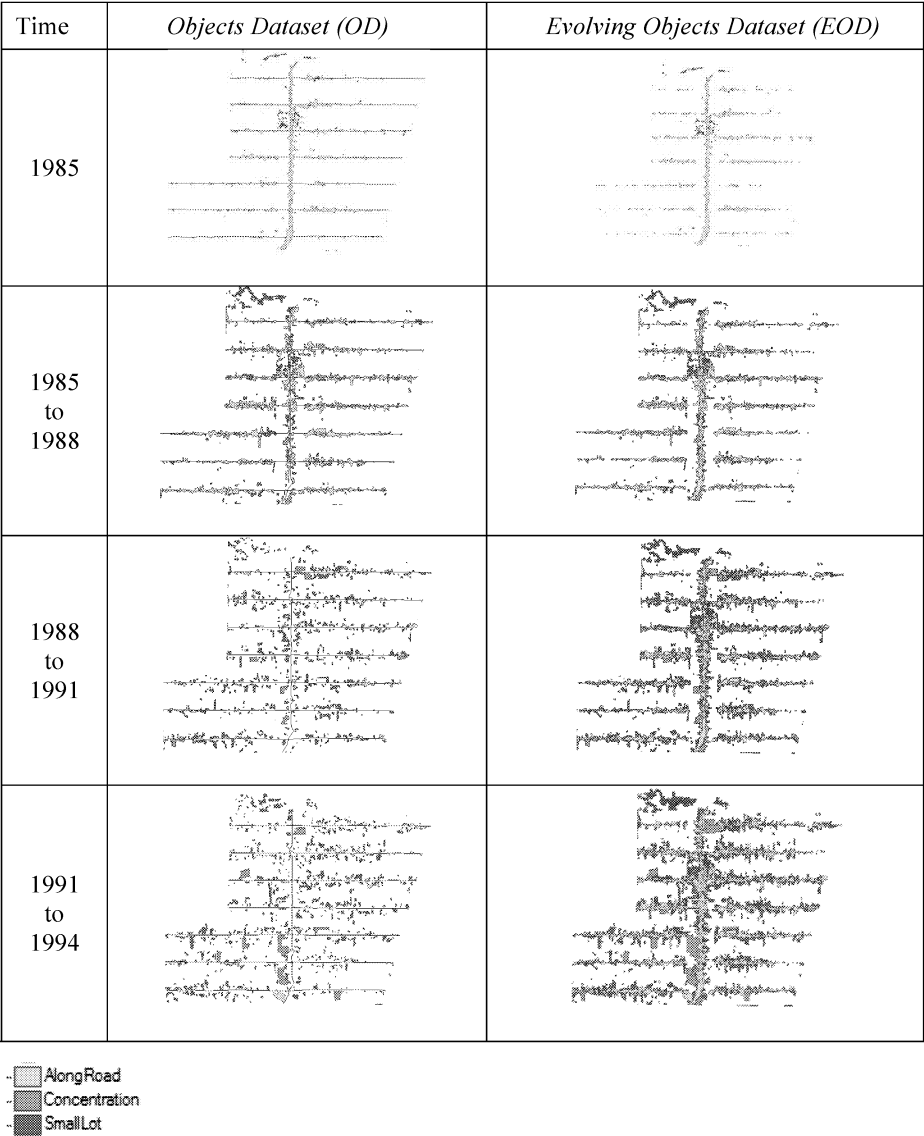zon. We identified land cover objects as evolving objects and were able of evolving them by applying the operations 'merge' and 'split', which are semantically adaptable to the application.

We can therefore verify the influence of land cover objects in close regions, discover patterns associated with the evolution histories and increase our ability to understand the land use changes detectable in remote sensing image datasets. Advances can be done to improve the model in the environmental domain and to use it to better support economics and policy making in the Brazilian Amazon. The evolution of objects provides insight into the broader scope and complementary perspectives. These methods can also be applied in other areas and scenarios.

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Ontology-Based Modeling of Land Change Trajectories in the Brazilian Amazon

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Abstract. Tropical deforestation is an example of geochange with massive impacts to the environment locally and globally. In the Brazilian Amazon deforestation has prevailed owing mostly to private investments in agricultural expansion, associated with large-scale cattle ranching, smallscale subsistence farming and soybeans expansion. Data on deforestation have been relied mostly on satellite remote sensing, mapping the extent of forest loss. Several existing data having diverse spatial and temporal resolution are maintained to analyze the whole land cover dynamics in the region. Although the extent of forest loss has been examined across the Brazilian Amazon, little is known about the transitions among land change pathways. Nevertheless, there is much information about site conditions available from different sources, such as land management and agricultural production, as well as existing settlements, land tenure and household assets. In this paper we propose the Process-oriented Land Use and Tenure Ontology (PLUTO) for semantically integrating and reasoning about data sets related to deforestation and land change trajectory in the Brazilian Amazon, and for publishing them as Linked Data.

Keywords. Linked Data, Semantic Web, GeoChange, Ontologies, Deforestation, The Brazilian Amazon Rainforest

Introduction

Tropical deforestation causes large greenhouse gas emissions to the atmosphere every year. In the Brazilian Amazon, the rates of deforestation have averaged 17,486 km2 per year [9], creating significant negative externalities as loss of bio-diversity, erosion, oods and lowered water tables [14,6]. Although considerable research has focused on estimating rates of forest conversion in the Brazilian Amazon, less is known about the fate of land that has been converted to human use.

Data on forest loss have been relied mostly on satellite remote sensing to reveal regions where deforestation has taken place. Several existing data having diverse spatial and temporal resolution are maintained to analyze the whole land cover dynamics in the region. For example, National Institute for Space Research (INPE) in Brazil has four operating systems for monitoring deforestation in the Brazilian Amazon: PRODES, DETER, QUEIMADAS and DEGRAD. These systems are complementary and were designed to meet different goals. Nevertheless, there is much information about site conditions available from different sources, such as land

management and agricultural production, as well as existing settlements, land tenure and household assets.

Regarding land management and agricultural production, agricultural census data are a rich archive of regional information on land use. Agriculture censuses constitute the most complete survey of agriculture production, including the area under different land use categories (temporary versus permanent agriculture, for example), crop production, levels of mechanization and agricultural inputs. In addition, planning dimensions, including creation of protected areas, indigenous lands and settlements, and land tenure and household assets, have been crucial in shaping the land change trajectories in the region.

However, integration of all different data about different pathways of the whole land change trajectory. is not straightforward for several reasons. First of all, there is often a lack of syntactic interoperability. But even more crucial problem is the lack of semantic interoperability [10] between data sets regarding tropical forests (see e.g. [4,11]). It is necessary to analyse causal links in order to explicate relationships between events and environmental changes [12]. Essentially, different data sets maintain information about different pathways of the whole land change trajectory. The problem hence is how to formally define these pathways, and relate them to each other. Ontologies provide mechanisms for interconnecting concepts|e.g. functions, purposes, activities, and plans [5]|in a machine-processable way, and hence together with reasoning mechanisms offer a potential solution for modeling spatiotemporal semantics of land change pathways.

In this paper we are interested in giving an ontological foundation to essential land change trajectories, and to model them with formal semantics. To achieve this we propose the Process-oriented Land Use and Tenure Ontology (PLUTO)| built as an alignment to the top-level ontology DOLCE [8]| for semantically integrating several data sets related to deforestation and land change trajectory in the Brazilian Amazon, and to publish and share these data sets as Linked Data[1].

1. Modeling Semantics of Land Change Trajectories

1.1. Background

The most compelling reason to monitor land change in the Brazilian Amazon is the strong effect of land change trajectory on the state of converted areas. Concepts of land change trajectories have been used to identify some dominant pathways leading to specific outcomes, and have been presented as typical successions of causes of tropical deforestation across the region. The potential transition pathway from forest to other uses depends on the state of the human occupation and site conditions, such as distance to roads [1], presence of settlements and land tenure [13], soils and environmental weather, and market conditions. Therefore, land use and tenure issues have been affecting deforestation in the Brazilian Amazon in several ways, and they are related to recent controversies about detriment impact of land law on deforestation [2]. Since the 1970s, the Brazilian federal government has set up agricultural settlement projects that constrain the ways of use of natural resources and territorial occupation. These offcial

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[1] http://linkeddata.org

colonization incentive policies|and the associated agricultural and cattle expansion|remained dominant until the end of the 1980s [4].

A growing environmentalist trend took shape during the 1990s, allied with rules enabling local populations to take part in natural resource management. Since around year 2000, the federal government has created policies about land management, including policies about the creation of settlements. In this scenario, government policies have played a significant role in the agricultural colonization frontier. Generally speaking, settler farms have in common a production system characterized by intense use of family labor and simple agricultural technologies joined to a strong drive for cattle ownership and overexploitation of land.

As a result, areas destined to settler farms move through a similar progression of land use pathways over time. The role of the land change trajectory is quite complex since it involves social and institutional arrangements that need to be better understood [3].

1.2. Process-oriented Land Use and Tenure Ontology (PLUTO)

For the purpose of this paper, we will describe a minimum process that represents the most signiffcant pathways related to settler farms. It starts when farmers get parcels (Figure 1-Land reform) and require some initial deforestation to establish ownership and produce food crops to meet immediate food needs (Figure 1-Subsistence). Farmers then clear additional lands for more crops, and at some point they start to purchase cattle (Figure 1-Extensive cattle raising). From this point, the activities of farmers planting subsistence crops are currently small relative to the clearing for cattle raising. After an intensive use of the pasture, the land can be recuperated (Figure 1-Recuperation) or abandoned (Figure 1-Abandonment).

Considering these main descriptions we present below the main concepts of PLUTO.

Land reform Redistribution of land.
Deforestation Forest is removed from an area.
Subsistence Land stays in subsistence until the portion of the deforestation
    reaches a critical amount.
Extensive Cattle raising Extensive cattle raising after which pasture typically
    gets exhausted.
Abandonment Regrowth of the forest.
Reclaim Public repossession.
Recuperation Removal of stumps and logs, and plowing, fertilizing,
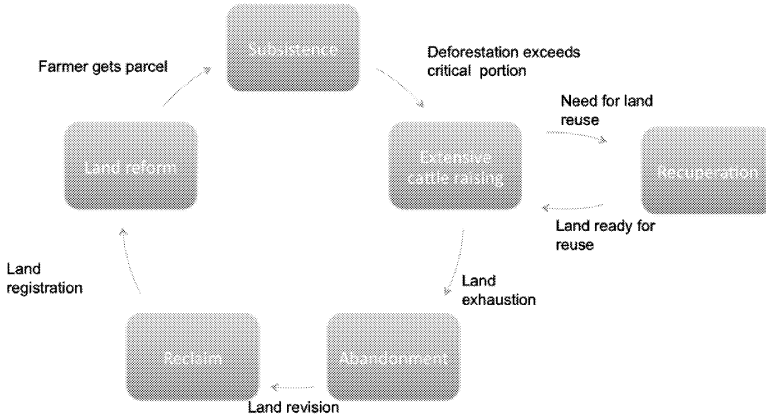
Figure 1. Land tenure model.

These concepts were defined[2] using DOLCE [8]. They are perdurants in the sense of DOLCE and were introduced as subclasses of process. In addition, in the ontology there are endurants that participate in perdurants. These include concepts such as farmer, land and parcel.

The intended use of PLUTO is to spatio-temporally annotate land regions in the Brazilian Amazon and model land change trajectories related to them. This allows for analysis of different regions, and of the characteristics of the land change trajectories in each land region. The hypothesis is that these characteristics may be used to find similar pathways around the Brazilian Amazon and hence to help to predict the future of regions based on similar pathways found in other regions. Combined with further data sets about regions (e.g. distance to market, distance to a river or road system, policies regarding the region) this analysis can reveal new knowledge about land change trajectories and help to create better policies for sustainability.

1.3. Rules for Reasoning about PLUTO

In this section we define rules for reasoning about PLUTO ontology. Essentially, these rules are used for asserting new facts concerning endurants and perdurants. The syntax of the rules is as follows. The rules consist of lefthandside (before "→") and righthandside (after "→"). The idea is that if the lefthandside of the rule matches to some individuals in the knowledge base then the facts in the righthandside are asserted to the knowledge base. The notion parcel (⬚) means that ⬚ is an individual of parcel, i.e. is A-relationship holds between ⬚ and the category parcel. Slots (properties) for each class are defined inside brackets. For example, deforestation(d){participant ⬚} means that there is an individual d of the class deforestation, which has a participant ⬚. The rules are as follows:

parcel(⬚) ∘ land-reform(⬚) {participant ⬚ }   (1)
→ farmer-gets-parcel(g) {participant ⬚ },

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[2] PLUTO is downloadable at http://observedchange.com/

where if a parcel □ is a participant in a land-reform a then the parcel □ participates in an event farmer-gets-parcel g.

$$\text{parcel}(\square) \{\text{deforestedPortion} > 0\} \rightarrow \text{deforestation}(d) \{\text{participant } \square \}, \qquad (2)$$

meaning that if at least some portion of parcel □ is deforested then □ is a participant in deforestation process d.

$$\text{parcel}(\square) \{\text{deforestedPortion} < p_1\} \circ \text{deforestation}(d)\{\text{participant } \square\} \qquad (3)$$
$$\rightarrow \text{subsistence}(s)\{\text{participant } \square \},$$

where p_1 is a typical maximum portion of deforestation of a parcel □ such that the □ is still a participant in subsistence process s, i.e. the parcel is not (yet) used for extensive cattle raising.

$$\text{parcel}(\square)\{\text{deforestedPortion} \geq p_2\} \qquad (4)$$
$$\rightarrow \text{extensive-cattle-raising}(e)\{\text{participant } \square \},$$

where p_2 is a typical minimum portion of deforestation of a parcel □ such that if it is exceeded then the parcel □ will be a participant in extensive-cattle-raising e.

$$\text{parcel}(\square) \circ \text{extensive-cattle-raising}(e)\{\text{participant } \square \}\{\text{duration} \geq t_1\} \qquad (5)$$
$$\rightarrow \text{land-exhaustion}(e)\{\text{participant } \square\},$$

where t_1 = a typical time period of extensive-cattle-raising e after which pasture land normally gets exhausted (degraded) i.e. the parcel □ is then a participant in land-exhaustion e. For example, according to [7] "pasture degrades after about ten years", i.e. according to it t_1 = 10 years.

$$\text{parcel}(\square) \circ \text{land-exhaustion}(e)\{\text{participant } \square \} \qquad (6)$$
$$\circ \neg \text{recuperation}(c)\{\text{participant } \square \}$$
$$\rightarrow \text{abandonment}(\square)\{\text{participant } \square \};$$

where a parcel □ participates in land-exhaustion e and not in recuperation c then the parcel □ will participate in abandonment □.

2. Conclusions

A tremendous quantity of information related to land change|deforestation, creation of settlements, types of land use|that should be interoperable, linked and shared is still not effectively done. In this paper we addressed the need for information interoperability in the domain of deforestation research. The idea was to support the linking of information resources with the help of an exhaustive and rigorous ontology. We propose use of PLUTO for semantic information integration within the domain of deforestation research. PLUTO enables interconnection between disparate sources for the purpose of 1) processing them automatically, 2) reasoning about it in a way only

possible when information has been integrated, and finally 3) sharing and publishing information about deforestation as Linked Data for different organizations to use.

Acknowledgments

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Integration of dynamic environmental data in the process of travel planning

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Abstract. This article describes the research concerning the development of a web-based travel planner, which is used mainly for touristic purposes. The paper focuses on the integration of factors that are vital for the planning process. These factors are completed with dynamic environmental data. Interoperability, as well as the integration of data in the planning algorithm play an important role. The interplay between different GI services in combination with different influencing factors provides a potential solution for the optimization of a web-based and a mobile tool to support touristic leisure and travel planning.

Keywords. Travel planning, environmental data, tourism, web services

Introduction

The vulnerability study of the State of Saxony-Anhalt [1] presents several findings that are concerned with consequences of climate change for tourism. The climate is an essential and determining factor for outdoor activities, yet it is hardly taken account of in existing leisure and travel planning applications. Up to now, they focus mainly on adequate routing by different means of transport and itinerary as well as visualization through web-mapping services.

Dynamic weather data like probability of precipitation, temperature, wind chill factor and visual range as well as the daily sunrise and sunset times greatly influence the personal travel planning process. They currently require the user to investigate manually different media and then draw conclusions to match the personal needs with the travel route. This paper describes the automated integration of weather data using a web-based travel planner and its mobile version. It takes the dynamic environmental data into account during the planning procedure, combines it with further parameters and generates optimized route suggestions.

1. The Travel-Planner

The vantage point for this study is the Travel-Planner [2] which has been developed in a research project called "GeoToolsHarz-Advanced" (GOTHA) at the University of Applied Sciences Harz. It was designed to plan day and weekend tours taking into account individual requirements of users as much as possible. Based on a variety of points of interest (POI) within a desired travel period, and taking into account various parameters (e.g. means of transport, personal travel type) the system suggests possible accommodation (hotels, pensions, vacation rentals) for the region. The suggestions are generated according to the itineraries.

A distinctive feature of the Travel-Planner is a modified algorithm for solving the classical Traveling Salesman Problem [3]. It was developed in a previous project at the Martin-Luther-University Halle-Wittenberg (MLU). Here, a genetic algorithm [4] that performs optimizations based on time windows using the Euclidean distance was realized. On the one hand, time windows are created to plan the complete travel period (which may extend over several days). On the other hand, the individual travel time per day, which can vary between users and their desired start, end and break times, are considered.

Additionally, time windows are coupled specifically with the selected POI. Currently, major factors are the POI opening times because it makes no sense to include a POI in the travel plan if it is not accessible. The time spent to visit a POI is also a variable factor, depending strongly on the user type and his or her personal interests. For example, a family with children spends more time in a zoo and most likely less time in a museum. The travel times between destinations are also variable conditions, depending on the choice of transport means and its speed.

2. Provider for dynamic environmental data

In a first attempt it was decided to integrate dynamic environmental data into the planning process. Taking into account the two variations of the Travel-Planner, the web-based, and the mobile tool, the integration of such environmental data requires the definition of different use cases. We differentiated the integration of real time data for the mobile tool, and short-term and middle-term data for the web-based application. The data, however, come from different web sites that must be linked to the travel planner aiming at optimizing the planning procedure.

2.1. Real Time Data

The first opportunity is the use of real time data when the trip is planned on the current day. In such a context the user plans a tour and realizes it on the same day. The user must have access to real time weather data of a relevant measurement station. This use case represents an example for the application of the mobile, smartphone-based travel planning tool. Since smartphones are often equipped with GPS sensors, the appropriate measurement station can be determined directly in the context of the user's current location. Ideally, the data of the weather station are accessed automatically and

integrated into the planning algorithm which provides eventually a modified tour for the user.

2.2. Forecast

A second option to integrate external data is weather forecasts. If the user plans a trip applying the web-based travel planner, the integration of weather forecasts can lead to significant changes of the plan. The basis are middle-term local weather forecasts, which are remarkably accurate for a period of five to six days [5]. The German Weather Service (DWD), for instance, provides weather forecasts via its webpage. Such information can be accessed by the travel planner in a suitable way. In terms of interoperability, the usage of web services (e.g. the Google Weather API) is another opportunity. They are communicated through standardized formats which is an advantage.

2.3. Empirical weather data

If the tour is planned more than one week in advance, it is not possible to supply reliable forecasts. At this point, empirical weather data can indicate a trend and serve the user with a rough orientation. A freely available service with daily weather statistics of the recent years is offered by the site www.wunderground.com. Parameters like temperature, humidity, barometric pressure, visual range and wind speed are grouped by high, low and average values and supplied for the past ten to fifteen years. It also offers a probability calculation for day temperature, wind speed and precipitation.

3. Integration of weather data into the travel planning process

The next section presents an overview, how the integration of weather data into the tour planning process is realized.

3.1. Prototype implementation

The optimization algorithm was initially implemented as a Java application. To guarantee interoperability, the algorithm was provided as a SOAP web service. This enables an XML-based data exchange, independent of the programming language that has been used. Additional input parameters can be integrated easily. Providing the service for a multitude of mobile devices is therefore possible.

3.2. Influence on the data basis

The integration of weather data influences the content description of the POI data basis. To integrate weather related information into the POI description, the metadata need to be extended. Apart from a pure metadata-based approach, the development of an ontology for the purpose of semantically enriching the POI descriptions could also be an option that is currently under investigation [6].

3.3. Travel planning and tour optimization

The POI that are taken into account for a concrete trip, are chosen by the user from an interactive map or by directly searching for them through text or perimeter search. The application starts after the POI are determined, as shown in Figure 1.
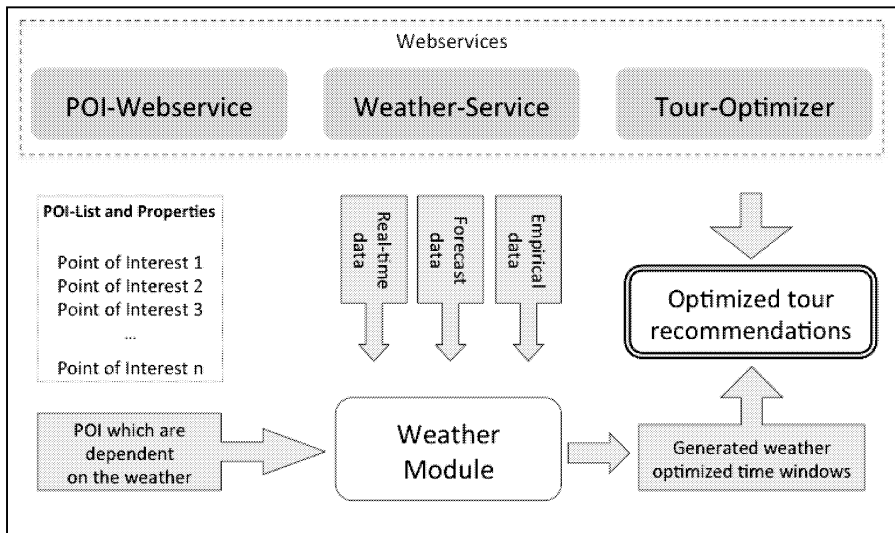
Figure 1. The Workflow of the tour planning process, considering weather data

After the POI were chosen, the weather module collects the data for the relevant destinations. Since not all POI are associated with an explicit location, the specific coordinates are used to find a weather station in the vicinity by reverse geocoding.

Real time, - predictive, or empirical data are used depending on the temporal distance toward the travel period. Based on this data a valid time window is generated for each destination. For example, periods of the day with minimal chance for rainfall are higher weighted for outdoor activities (a suggestion could be to take longer time in a zoo), instead of those day times, where rainfall has a large probability (where it could be proposed to visit a museum).For hiking tours, to give another example, it is worthwhile to consider not only weather related information, but also sunset times. In any case, the time windows proposed by the travel planner will be adjusted accordingly.

POI, including their time windows, and opening times, are sent via a SOAP request to the web service and the optimization procedure is performed during which the algorithm tries to consider as many parameters as possible. According to the chosen starting point (e.g. a hotel) one or more tour suggestions will be displayed as a result. The results can be visualized depending on the application. Within the GOTHA project, the travel planning prototype is developed as an extension [7] for the TYPO3 open source content management system. The web services architecture enables also the usage on mobile devices. In a first step, a series of optimized browser templates were created to provide a general presentation on smart phones. Due to security-related limitations, a mobile web application does not have direct access to the device

hardware and requires a permanent Internet connection. To solve this problem, a native application for the Android platform has already been developed.

4. Conclusion

In this paper the integration of dynamic environmental data into the automated process of travel planning was presented. An exemplary use case is the integration of weather data into the trip planning procedure. Further research is required on the individualization of the planning process, based on specific user groups. In order to get optimized planning results, the requirements must be queried with the help of dialogues and interactions with the user.

The next step is to include methods of recommender systems [8] into the planning process to get better suggestions for tours and destinations. The goal is the combination of different recommendation methods to develop a hybrid system for travel planning. This work will be part of a new project that started in January 2011 under the name "*KOGITON*".

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TransitDroid: Delivering real-time bus tracking information on mobile devices

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Abstract. The recent technological advances in mobile communication, computing and geo-positioning technologies have made real-time transit vehicle information systems an interesting application area. In this paper we present a transit application system which displays the transit information on an OpenStreetMap (OSM) web interface and delivers this information on the Google Android mobile device. The content is in the form of predicted arrival/departure times for buses at user-selectable geographic locations within a transit region. This application uses the real-time information such as current location and timestamp of both bus and users to provide bus route information. The public interface provides a graphical view which used to display and updates the vehicle locations and to allow users to see routes, stops and moving buses. The mobile device provides the user with the expected arrival/departure time of the next bus at the bus stop based on the user's current position.

Keywords. Real-time data, OSM, AVL, Android, Openlayers.

Introduction

In transportation information, different mappings interfaces are used to provide cartographical means for displaying, monitoring, and improving transit vehicles performances. In a pilot project between National University of Ireland Maynooth (NUIM) and Blackpool transit (Great Britain) a prototype of a working web-based real-time bus tracking transit system is developed using OpenStreetMap(OSM). In real-time bus tracking systems data is collected in real-time and transmitted to a central server for analyzing and extracting transit information. Computer software technologies such as Ajax is used to update the map-based display without interrupting the users by switching pages or screens as they view the map[1]. The developed transit system pro-vides services that take advantages of modern technologies to displays bus Arrival/departure time information on the platform of Google Android mobile devices. Doing so will enable passengers to enquire about bus-arrival/departure time to a selectable geographic locations of their interest.

For Bus Arrival/departure time estimation, three prediction models (namely, a historical-data-based model, a multiple linear regression model and one-dimensional Kalman filter model) were implemented and their performance is evaluated using the mean Absolute Percentage Error (MAPE) [2] [3]. In this paper, the process for

downloading data to platform of the Google Android device and mobile interfaces were designed using the Android operating system for mobile devices and java programming language. The utility of displaying bus arrival/departure times to selectable geographic locations can be applied to both a fleet management context and a bus information system environment. The developed system provides real-time information about bus routes and bus locations for those how have a mobile device with internet accessibility. They can link to the web site and get the current transit information such bus arrival time to the nearest bus stop.

1. Related works

Real-time arrival information for bus, subways, light rail, and other transit vehicles are displayed in a significant number of cities worldwide at places such as rail stations, transit centers, and major bus stops. With the possibility that real-time transit information will not be available on a public display at every stop, the smart mobile devices are being used to help manage the complexity of using transit information. Whether it is a simple phone or SMS interface, or a more complex native mobile application, these systems can provide schedules, routes and real-time arrival information. Google Transit, which was started as a Google Labs project in December of 2005, is now directly integrated into the Google Maps product and provides interfaces to Google Transit which are exist on a variety of mobile devices, making use of location sensors such as GPS and WiFi localization on the device to improve the usability of the transit application. Various mobile-phone-based transit information systems have been developed to provide users with transit information.

The Intelligent transportation system research group at university of Washington has developed a real time-system for predicting bus-arrival time, based on access to transit agency data. The prediction times made available to the traveling public via web site known as MyBus. The usability of public transit system can be enhanced by providing good traveler information system. OneBusAway [4] is a set of transit tools focused on providing real-time arrival information. This application made use of increased availability of powerful mobile devices and the possibility of displaying transit data in machine readable format. In OneBusAway systems, transit information such as bus arrival time to a particular bus stop is displayed on internet-enabled mobile devices. In [5] the usage of a transit vehicle information system that delivers estimated departure times for a large transit fleet is described. Due to the physical restriction of mobile devices which affects the user interaction and data presentation, the WML, has been introduced as the new language for WAP-enabled device.

Transitr is a transit trip planner (TTP) system from the University of California, Berkeley [6]. The system provides the shortest paths between any two points within the transit network using the real-time information provided by a third party bus arrival prediction system, relying on GPS equipped transit vehicles. Users submit their origin and destination points through a map-based iPhone or through a Java script enabled web browser. Services such as 511.org and Google Transit allow users to plan public transit trip by generating routes based on static schedule data where as with the proposed Transitdroid system, dynamic transit information is received via web services. In [7] a mobile public transportation information service was developed to provide map-based information of the nearest mass rapid transit station, the nearest bus stop of the bus route chosen by the user, that can take the user to his/her chosen

destination. The developed systems can deliver a map marked with the nearest mass rapid transit station on a Nokia 6600 cell phone. Bertolotto *et al* [16] describe a BusCatcher system. The main functionality provided include: display of maps, with overlaid route plotting, user and bus location, and display of bus timetables and arrival times. Barbeau *et al* [13] describe a Travel Assistance Device (TAD) which aids transit riders with special needs in using public transportation. Turunen *et al* [14] present approaches for mobile public transport information services such as route guidance and push timetables using speech based feedback. Bantre *et al* [15] describes an application called "UbiBus" which is used to help blind or visually impaired people to take public transport. This system allows the user to request in advance the bus of his choice to stop, and to be alerted when the right bus has arrived. In [8] a transit information system was developed to implement a bus arrival time predictor on a Google Android mobile device. The developed system provides relevant bus routes information with arrival time to users in order to explore the possibility and capability of various sensors and GPS on the device. In the developed system, the users' current location is collected and, together with a stored bus schedule, a bus arrival time is calculated on the server and was displayed on the mobile device on a built-in Google Maps display.

2. Real-time Bus Tracking Systems

Intelligent transportation systems provide the technology to enables people to make smarter travel choice. Better transit information allows users to make better decision about their travel options. One of the first online bus tracking systems, BusView, was developed at the University of Washington [9]. Nowadays, many public bus services provide on-the-fly information to their users, including the current locations of buses and the predicted arrival times at bus stops. These buses typically use the Global Positioning System (GPS) for positioning and use wireless communication such as radio or GSM/GPRS for communicating their position to a central server. Real-time prediction of accurate bus arrival times has been studied in literature for a couple of decades. Different methods are used for predicting bus arrival time, some researchers use simple statistical/mathematical models, e.g. prediction according to deviation from the schedule [10]. Kalman filter and more sophisticated artificial intelligence and machine learning algorithms have also been used [11] [12]. In this project, three bus arrival models were tested, namely a historical-data-based model, a multiple linear regression model and a one-dimensional Kalman filter model. The Automatic Vehicle location (AVL) data is used to track vehicle location while the other vehicle data is used to predict arrival time to a certain bus stop or the selected transit area along the route. Figure (2) shows the tracking and predicting components of real-time bus tracking system.
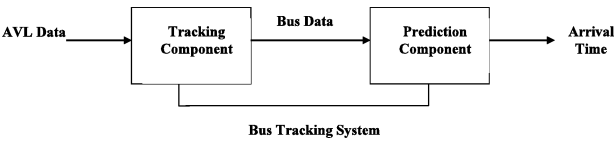
Figure 1. Tracking and Predicting Components of real-time bus tracking system.

The historical data model predicts travel time using the average travel time for the same journey over similar conditions obtained from the data archive. The Kalman filter is a multi-dimensional model based on the numbers of state variables to be estimated [11]. The regression models predict a dependent variable with a mathematical function formed by independent variables. In order to evaluate the performance of the three models, the mean Absolute Percentage Error (MAPE) was used as a measure of closeness between predicted and observed values.MAPE represents the average percentage difference between the observed value and the predicted value. Table (1) shows MAPE values of the three prediction models on the same sample test data.

Table 1 MAPE Values of Bus Arrival Times Prediction Models

Model	MAPE
Historical Data Model	13 %
Kalman Filter Model	20 %
MLR Model	29 %

The historical data model has the least MAPE as the number of observarions (samples) to predict bus travel time is sufficient and higher as compared to the other two models. The drawback of this model however is that the accuracy of the results depend on the smiliarity of travel patterns. Thus the historical data model will not perform well in case of an unexpected event like an accident or traffic and congestion.

3. System Implementation

In Blackpool real time bus tacking system and to increase the satisfaction of among transit users, the system delivers transit information via standard web browser and mobile devices. The system uses off-the-shelf GPS/GPRS integrated units programmed to transmit location at regular intervals (45 seconds approximately) while the vehicle is in motion. The data is stored on a server and is then visualised through a standard web browser to show views representing current locations of vehicles in close-to-real-time.

3.1. Web interface development

The system uses web technologies such as JavaScript, MySQL, XML, PHP and Ajax. The position of the bus along with the timestamp and bus details is sent to the server using GPRS. The remote server inserts the data into a MySQL database. An interactive public interface was developed to allow user more interaction with the transit system Figure (2) shows the public interface of Blackpool transit system with updated vehicle location on an OSM interface developed using OpenLayers.
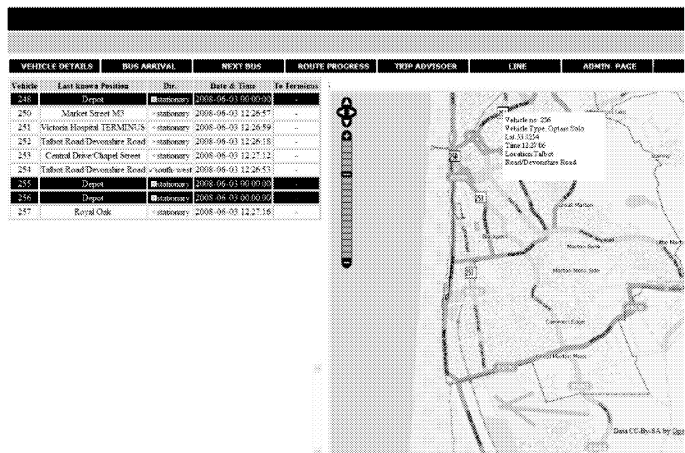
Figure 2. The Public interface showing updating textual display plus moving locations on OSM.

4. **Mobile Interface**

The wireless communication technology is designed to utilise existing internet protocols and standards. A URL address is used for the identification of a resource, and HTTP is used as a protocol between WAP gateways and content server. Wireless content can be served using existing web server software.

   The smart mobile phone interface was developed using the open source android operating system for mobile devices. In this project an HTC Magic smart phone that runs on the Android operating system was used to communicate with the transit project server. The mobile device uses a HTTP protocol to connect with the MySQL database on server. Data between Android and PHP could be coded in JavaScript Object Notation (JSON) format which has built-in JSON functions in both languages. To view arrival/departure time on the mobile device, the user selects his/her preferred destination; the transit system collects his current location from built-in GPS. The user's current location along with the destination selected by the user is sent using the HTTP protocol to the server by appending it to the URL which connects to the server. The URL from the mobile device is transmitted and the response is displayed on the mobile screen. The nearest bus stop to his/her current location is suggested and Bus Arrival time is displayed on the device. Fig. (3) shows a sequence diagram of the interaction between users, mobile Devices ad the web.
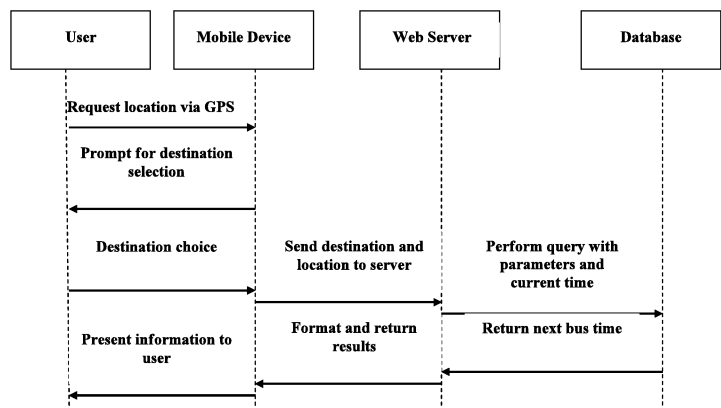
Figure 3. A sequence diagram showing the interaction between users, mobile
Devices ad the web.
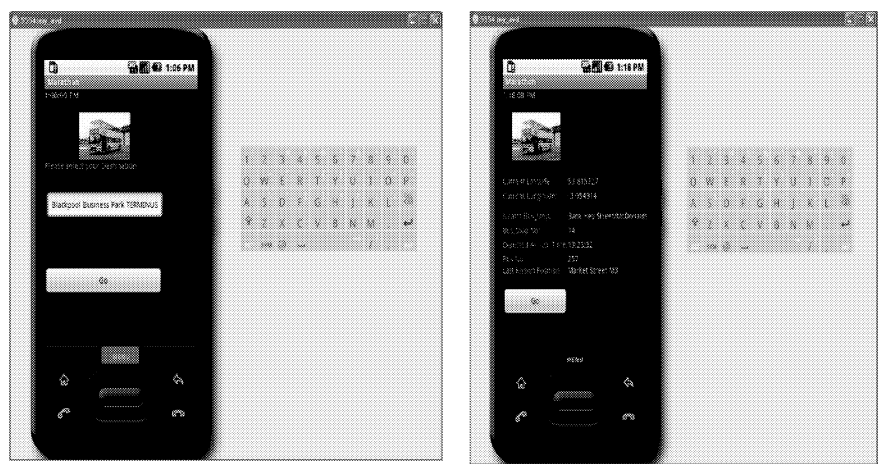
Figure (4-a) shows a desire destination selected by user   **Figure (4-b)** shows the response from server

5. Conclusions and Future Work

In this work we have shown that transit information collected in real time can be shown
on OSM for tracking and monitoring purposes. Internet enabled mobile phones can
receive real-time transit information. Android software for smart mobile phones offers
the ability to overcome the physical restriction of interface design on mobile phones.
To further improve bus arrival time prediction accuracy, transit data from other sources
can be incorporated into the predictor algorithms. Future work on this project includes

development of a feature which alerts a user when bus is a specified number of minutes away.

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DGPS- and INS-Based Orthophotogrammetry on Micro UAV Platforms for Precision Farming Services

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Abstract. Small unmanned aerial vehicle (UAV) sensor platforms like a multicopter develop to important auxiliary tools in the scope of close range remote sensing. They provide new opportunities of data acquisition for various environmental- and geoscientific purposes. One of the objectives of the ifgicopter project is to produce CIR images as classified input data for subsequent procedures of precision farming. Therefore, the projects' multicopter is equipped with a modified digital camera to record high resolution aerial CIR images. In a subsequent step, the captured images are processed to orthophotographs. Focal distortions are eliminated and the positions of the images are calculated relative to a desired frame of reference. This processing usually requires a certain amount of known Ground Control Points (GCP) to acquire information about the parameters of exterior orientation of the images. The measurement of these points is cost-intensive and time-consuming. For this reason the ifgicopter navigation system is extended with DGPS-devices in order to determine the essential parameters of the exterior orientation without the need of GCP's. Moreover, sensor data from on-board sensors such as gyroscopes, accelerometers and a magnetometer is combined to an inertial navigation system (INS) and coupled to the GPS position solutions. Therefore trajectory and orientation of the multicopter and its camera system are tracked at each point in time. The now available information allows the calculation of CIR orthophotographs as part of a sensor web-enabled service for subsequent procedures of precision farming.

Keywords. Micro UAV, color infrared (CIR) orthophotographs, DGPS, INS, sensor-web services, precision farming

Introduction

The spatial and temporal versatility of Micro UAVs, due to small size, low weight and little operating costs, makes them an attractive tool especially for monitoring and observation tasks in application fields like landscape ecology, forestry or disaster management (see [1] and [3]). To explore the applicability of a multicopter as a platform for the acquisition of various types of sensor data such as orthorectified aerial images, the interdisciplinary *ifgicopter* project aims on establishing techniques,

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workflows and communication frameworks for collecting and processing data as well as providing it in real time via sensor web services.

1. Color Infrared (CIR) Aerial Photography for Precision Farming

One promising application field for this technique is small-format aerial photography within the scope of precision farming. Here the adoption of capital equipment like crop protection products (also fertilizer) can be adapted to the spatial and temporal dynamics of soil and population parameters to reduce costs and keep processes more environmentally-compatible [11]. To exploit these capabilities effectively, accurate information on the varying site-specific conditions is necessary. Other authors have already shown that UAV's are able to provide such substantial information and geobase data to precision farming processes [13].

In this context, an objective of this project is to produce CIR photographs and other remote sensing products in the visible (VIS) and near infrared (NIR) range as classified input data for subsequent procedures of precision farming and for the conduction of efficiency tests in a user defined spatial and temporal resolution. Therefore the *ifgicopter* is equipped with a modified compact digital camera now capable of capturing radiation ranging from about 330nm to 1100nm [8]. Combined with a special color filter the camera provides a setup for generating high resolution aerial CIR photographs [6].

In order to conduct further image analyses it is necessary to calculate accurate orthophotographs. Consequently, the aerial images need to be rectified and georeferenced as prerequisite for getting coordinate and scale information. Regarding the distortion correction it is necessary to have a digital terrain model of the survey area. The interior and exterior orientation of the camera are needed for georeferencing the photographs [7]. While the parameters of interior orientation of the camera are defined by calibration regarding the focal distortion, the parameters of exterior orientation have to be determined during image post-processing. In remote sensing two different approaches are usually applied, the direct and the indirect georeferencing method.

During the indirect georeferencing method Ground Control Points (GCP's) are required [4]. GCP's represent terrain points, whose 3D positions are known and which are clearly identifiable in the images. However, creating and measuring GCP's in the field is a very time- and cost-intensive work.
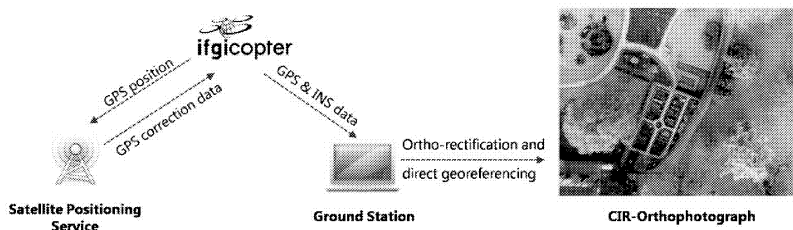

Figure 1. UAV georeferencing system applying DGPS/INS for orthorectified aerial images

In order to reduce the field work to a minimum (and in regions, where GCP's are hard to establish) it is possible to calculate the exterior orientation directly by exploiting the onboard sensor data of the *ifgicopter's* (D)GPS position (Figure 1) and the inertial navigation system (INS) [7].

2. DGPS and INS for Determination of Exterior Orientation Parameters

The majority of currently used UAVs are equipped with standard low-cost GPS receivers which provide an absolute position accuracy of about 2m to 15m. Since these measurements are too inaccurate for the purposes of determining the precise focal 3D position of the mounted camera, the GPS system is improved by upgrading the *ifgicopter* with a GPS receiver, capable of using various differential GPS (DGPS) techniques. Consequently a L1 C/A receiver with carrier phase smoothing is installed to track satellites on L1-frequency and to calculate the position by considering pseudoranges and carrier phase measurements. Additionally, the navigation system is improved by establishing communication between the GPS receiver and the German SAPOS Ground Based Augmentation System (GBAS). As a consequence, the accuracy of the absolute GPS position solution is increased approximately by a factor of 10 [5].

Since the orientation of the *ifgicopter* and its camera system is known by making use of the onboard gyroscopes, accelerometer and magnetic sensors (INS), it is possible to transform the detected values into angles that indicate the absolute orientation of the *ifgicopter* axis in an earth centered, earth fixed coordinate reference system. Furthermore the improved position of the DGPS and the sensor values of the INS are loosely coupled. Then the parameters of exterior orientation (position and orientation) are calculated via a strapdown navigation algorithm for each point in time [15]. These values determine the exterior orientation of the taken images and are used in a following step for the processing of orthophotos.

2.1. Architecture of the ifgicopter's Navigation System

The architecture of the *ifgicopter's* navigation system is based on different components which are introduced in the following: In this study, a *md4-200* quadrocopter serves as Micro UAV sensor platform [9] and is extended by an *OEMStar GPS* Receiver [10] and a *come2ascos* radio modem [2]. These three navigation components are essential to generate adequate sensor data for the determination of a reliable exterior orientation.

Having established a first position fix, the GPS receiver transmits its position information via a serial interface to the radio modem using a standardized NMEA GGA message. Then the modem establishes a GPRS connection, logs on to SAPOS GBAS and forwards this message to gather standardized RTCM 3.1 correction data from the Satellite Positioning Service. In a next step, the RTCM data is handed back to the GPS receiver which then calculates its improved 3D position as a function of time. Following, it passes this information to the md4-200's Navigation Control through a second serial interface. There, 3D position, gyroscope, accelerometer and magnetometer data is analyzed and processed by using a strapdown navigation algorithm [15]. In a final step, this set of navigation information is committed to the md4-200's Flight Control which offers a 2.4 GHz wireless downlink connection to a ground station where this data is logged (Figure 2).
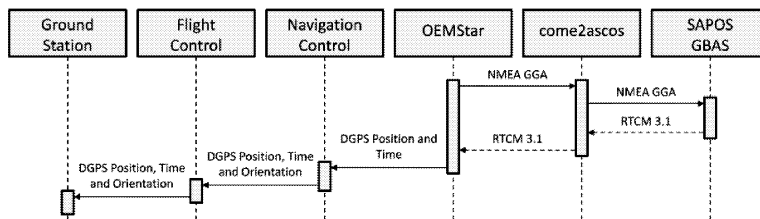
Figure 2. Navigation data workflow and communication

2.2. Future Integration into a Sensor Software Framework

As this procedure still requires extracting exterior orientation parameters from the collected navigation data log, the *ifgicopter* sensor platform has to be integrated into an already existing software framework. This specific framework is designed to simplify sensor integration, synchronization of sensor data streams and to support multiple output formats [12].

It is aimed to connect the *ifgicopter's* data downlink as one possible data source to the sensor platform framework, where the data is processed, interpolated and then provided by an output plugin in an appropriate format for consequent calculation of orthophotos (Figure 3).
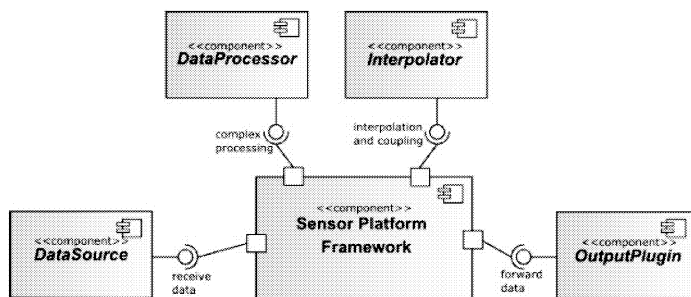
Figure 3. Framework model for *ifgicopter* sensor data integration [12]

3. Applications and Outlook

Given the exterior orientation and a digital terrain model (DTM) the images obtained from the aerial surveys can be orthorectified using the direct georeferencing method (provided by various photogrammetric image analysis software packages). Subsequently they are subjected to object-orientated texture analysis for supervised classifications regarding the distinction of different vegetation types like weed and crop, or different states of vegetation health due to soil dryness, precipitation damages or pest infestation. The classified images are processed to generate accurate vector and position data (centroid) of examined areas and objects.

The results of the analysis can then be provided to the user (farmer) as web mapping services (orthophotographs, Figure 4), web feature services (vector data) or via an open geo data portal like the *StudMap14* (http://gdione4all.uni-

muenster.de/GeoExt/index.html). This geo data portal, realized and maintained by the faculty of geosciences of the University of Muenster, is a web-application which can be used not only to browse various types of geo data and web services, but also supports the up- and download of specific user data [16]. Another near future application is to include the orthophotographs as a subsidiary WMS source within the prototypical flight planning and communication software of the *ifgicopter* project (http://bandit.uni-muenster.de:8080/Flugplanung/Flugplanung.html). Latter one has been developed concurrently as an open source and web-based product for the operation of UAV's [14]
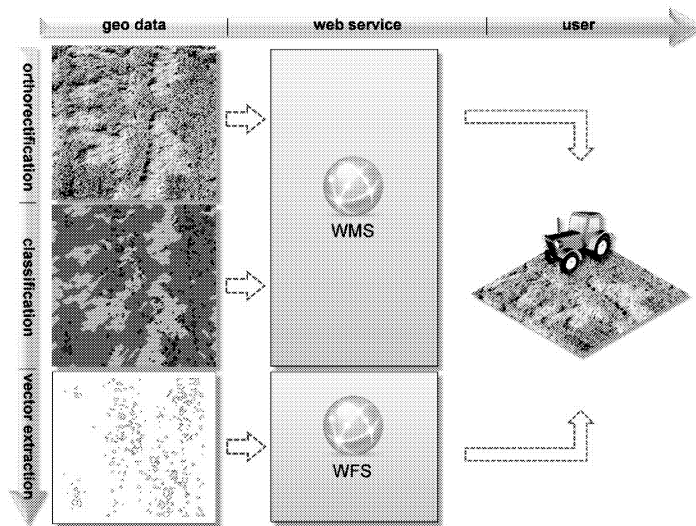
Figure 4. Decision support in precision farming via web mapping services (WMS) and web feature services (WFS)

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http://zdmweb.uni-muenster.de/index.php?option=com_content&view=article&id=39&Itemid=151.
2011-03-17

RM-ODP for WPS Process Descriptions

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Abstract. Web-based geoprocess models are currently published through Web Processing Service interface. For interoperability of these models, profiles of these geoprocess models have been developed. However, these profiles are rarely documented and are not human-readable. Based on the lack of well-documented profiles and the absence of adequate semantic descriptions, this article presents an approach how to document profiles using the viewpoints of the *Reference Model for Open Distributed Processing* (RM-ODP). The presented approach is described exemplary in a walkthrough.

Keywords. Web Processing Service, WPS, profiles, RM-ODP, interoperability.

1. Introduction

Geoprocessing on the web is often described as the next evolution step of Spatial Data Infrastructures (SDIs) from data serving to information provision [1]. Information provision on the web is enabled by web-based geoprocess models, which transform web-based data as currently available in SDIs into web-based information. These geoprocess models are available as distributed and loosely-coupled resources on the web encapsulated as Web Services. In this context, interoperability is a key requirement to make use of such Web Services. To provide geoprocess models as interoperable Web Services, the Open Geospatial Consortium (OGC) specified the Web Processing Service (WPS) interface [2]. In particular, profiles are regarded to enhance the interoperability of geoprocess models which are available through WPS interface. Profiles are web-based descriptions of common interfaces of a geoprocess model. If one profile is referenced by different geoprocess models providing the same functionality and using the same interface, the different geoprocess models become semantically equal from an interface point of view. Besides some elements for linking and providing machine readable information, a profile contains of a textual description, which is the only source for humans to retrieve the semantics of the specific process. Currently, this textual description is unstructured but highly relevant for inspecting the semantics of the specific process, as semantic descriptions are still missing. However, a coherent and structured approach to document the functionality of a process in such textual descriptions has not been proposed yet.

In this article, we will apply the *Reference Model for Open Distributed Processing* (RM-ODP) to structure the textual description of profiles. RM-ODP is a widely accepted model to document complex structures such as web services comprehensively by using several views. RM-ODP will help to enhance the existing descriptions and

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thereby tackle the problem of semantic descriptions, which is identified as one of the challenges in web-based geoprocessing [3].

Section 2 describes the related work of web-based geoprocessing and RM-ODP. Based on this, the proposed approach is described (Section 3), which is then exemplified by a walkthrough regarding profile interaction (Section 4). The article ends with a conclusion.

2. Related Work

This section describes the related work as applied in this article to create comprehensive textual descriptions of profiles and puts the presented work into context.

2.1. Web-based Geoprocessing

Geoprocessing is the application of functionality representing real-world processes (e.g. hydrological runoff models) or processing of geodata (e.g. generalization, (coordinate) transformation). Providing these models and functionality on the web is a relevant topic in research and industry, as it allows users to generate web-based information to support decision making.

The WPS interface specification is OGC´s attempt towards a standardized interface for web-based geoprocess models. The WPS specification describes three operations. *GetCapabilities* provides service metadata, *DescribeProcess* provides process metadata with input and output parameters of the designated process and *Execute* allows the client to perform the specific process according to the process metadata. The process metadata currently only consists of syntactic information about the input and output data (e.g. schema, datatype). Profiles are used to address semantic interoperability of processes. A profile has the following properties [2]:

- An OGC Uniform Resource Name (URN) that uniquely identifies the process (mandatory)
- A reference response to a DescribeProcess request for that process (mandatory).
- A human-readable document that describes the process and its implementation (optional, but recommended).
- A WSDL description for that process (optional).

A few profiles are available and are listed in Table 1. All these profiles focus on a specific classification of processes and input and output parameters (second property of a profile), but are rarely described in a structured and comprehensive way (third property of a profile).

Table 2: Overview of published WPS profiles.

Profile topic	Editors
Vector and raster-based processes	Nash 2008 [4]
Analysis of 3D data	Lanig & Zipf[5]
Geomarketing	Walenciak & Zipf [6]
Decision support	Ostlaender [7]
Feature and Statistical Analysis	Foerster & Schaeffer [8]

Besides the design of profiles, semantic annotations and semantic descriptions of geoprocess models have been investigated. For instance [9] investigated the use of fine-granular ontologies for Geoprocessing Services, whereas [10] proposed a course-granular semantic descriptions of Geoprocessing Services based on the service classification of ISO 19119 [11].

2.2. Reference Model for Open Distributed Processing

RM-ODP is a standardized approach from International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) to develop distributed systems. RM-ODP´s realization consists of object modeling, viewpoint specification, distribution transparency and conformance [12]. Object modeling allows building abstractions of the basic system concepts. Viewpoints are used to specify a system from different perspectives (Figure 1). Distribution transparency of specific distributed components and conformance supports interoperability of the components. For this work, viewpoints have been selected, as they allow describing a component (such as a profile) comprehensively.
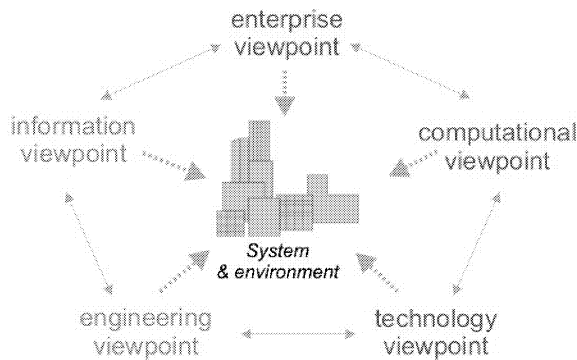
Figure 1: RM-ODP viewpoints.

3. **The Approach**

To enhance the description of WPS Profiles, an approach is required, which provides a comprehensive view on the specific process. It can thereby be seen as human-readable metadata, which helps users to reason about the specific process. RM-ODP and its viewpoints have been identified as appropriate to help developers and communities in designing and documenting profiles. Table 2 describes the different viewpoints (areas of concern) and how they can be used (main concepts). The engineering viewpoint is not listed in the table, as it provides implementation specific information, which is not considered due to the encapsulation of web service interfaces. The Feature and Statistical Analysis report of the OGC testbed phase 7 [8] can be considered to be a first attempt to structure textual process descriptions by RM-ODP viewpoints.

Table 3: RM-ODP viewpoints and their function in WPS profile development.

Viewpoint	Enterprise	Information	Computation	Technology
Areas of Concern	Objectives of processes	Information models and information manipulation	Logical decomposition of processes	Technical artifacts and solutions
Main concepts	Artifacts, roles	Data schemas	Computational interfaces	

The documented viewpoints can be linked as a plain file in the metadata element of profile or directly be included in the profile to support search regarding the different viewpoints. In particular, we propose a new set of XML elements in the WPS DescribeProcess document extending the *ProcessBriefType* as presented in Figure 2.
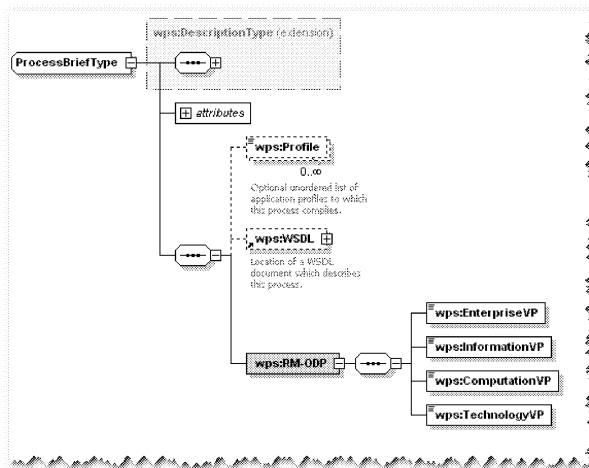
Figure 2. Profile with RM-ODP extension.

A top-level RM-ODP element contains four child elements labeled according to the corresponding viewpoints. Each child elements holds a human readable description of the view point according to the description from above. It is thereby possible for a client to query specific parts of the metadata.

4. Walkthrough

This section exemplifies a walkthrough for interacting with web-based geoprocess models using profiles from a user´s perspective. This perspective, already assumes, that the profile is described accordingly (based on RM-ODP, Section 3) and has been registered officially. This walkthrough (Figure 3) does not take a catalog search into account, as profiles are not considered in catalogs yet. Thus, given a WPS entrypoint,

the WPS user accesses the GetCapabilities and the DescribeProcess documents of a specific WPS. The Profile URN included in the DescribeProcess is used to retrieve the profile information using an official URN resolver. The URN resolver returns the WPS profile with the documented RM-ODP viewpoints. Based on the WPS profile, the user can inspect the syntactic interface. The documented viewpoints (Section 3) provide specific information about the process and its application. Based on this information the user can decide, if this process fits his needs and can specify the request to perform the process with the designated data.
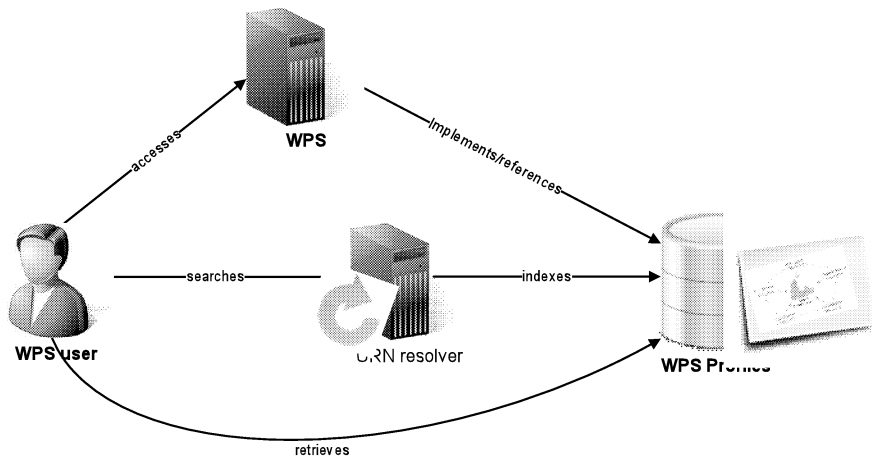
Figure 3: WPS profile walkthrough.

5. Conclusion

Based on the lack of well-documented profiles (as also shown in the overview of available profiles in Section 2), this article proposes the use of RM-ODP to document profiles of geoprocess models. RM-ODP allows documenting distributed architectures using a viewpoint analysis. These viewpoints have been adopted in the approach for profile description (Section 3). Based on the structured way of viewpoint analysis, RM-ODP helps to create comprehensive and well-designed descriptions, which are human-readable. Using this approach to document well-known and referenced profiles will increase the interoperability of the profiles and will limit misinterpretation by the specific user. This becomes especially important in the Model Web [13], which exposes many different models as standardized Geoprocessing Services. The RM-ODP document can be referenced as a separate metadata file or be included as an extension of the structure of the profile. Using such a structure and the proposed encoding, is a first step for querying of profiles. The walkthrough (Section 4) shows the course of action involved for using a profile and how RM-ODP can support it.

However, the approach is also limited in terms of establishing semantic interoperability for automatic web service interaction. Consequently, future research needs to enhance the proposed structure by including semantic descriptions using ontologies [9], [10] or the Object Constraint Language (OCL) from object-oriented

modeling [14]. As demonstrated in the walkthrough, a unified approach for the interaction with profiles is not yet specified. Future research will need to investigate the handling of URNs and the querying of profiles for instance in catalogs. The presented approach here can be used as a starting point.

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Towards Linking the Digital and Real World with OpenThingMap

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Abstract Currently digital inventories of outdoor features evolve such as OpenStreetMap. A digital inventory of real-world things is still missing, but is required to enable full search and interaction in the digital world. This article presents an approach to link any real world object to a georeferenced digital representation, thus suggests a concept for location within the areas of Web of Things, Ubiquitous Computing and Ambient Technology. The approach is twofold based on a) OpenFloorMap as an inventory for buildings and b) OpenThingMap as an inventory for things. The inventories are based on a lightweight data model and are populated through the knowledge of the crowd using advanced mobile devices.

Keywords: Crowdsourcing, Spatial Inventories, Mobile Applications.

Introduction

Building inventories of real-world features in databases can be realized by Crowdsourcing. Projects such as OpenStreetMap [1] use mobile devices which are able to measure the location context (i.e. GPS), the knowledge of the crowd and a lightweight data model to build an inventory of outdoor features. This supports outdoor wayfinding and search for locations, represented as POIs. So, every real-world object outside is represented in the digital world, which is described through tags. However, as most of our daily life is spent inside, an approach to map the inside of buildings as well as things residing within the building, has not been proposed yet.

Therefore, this article a) describes the OpenFloorMap for modeling buildings and b) proposes OpenThingMap as a way to link any entity in the real-world to the digital world. Thereby, the interaction between the things in real-world and the digital world will be seamlessly.

The presented approach is based on smartphone technology, which provides a set of sensors to measure the real-world in such a way, that digital representations of things can be created easily. The approach is based on light-weight data models and the Web of Things.

Section 1 presents OpenStreetMap and Web of Things as the main building blocks of the presented approach. Section 2 describes the OpenFloorMap and OpenThingMap, respectively. Section 3 presents a conclusion and provides an outlook for future work.

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1. Related work

1.1. OpenStreetMap

The OpenStreetMap project [1] was found in 2004 and has a rapidly growing data inventory of streets and POIs. Its access and use is free of charge (Creative Commons license). The data is reported by so-called mappers, who use digitizing tools or mobile devices with GPS capabilities to capture the data. OpenStreetMap is used for several applications such as mapping or routing. The data model is based on three types of objects, nodes, ways and closed ways (to represent polygons). The thematic data is captured through tags (key value pairs). The set of available tags is thereby unlimited. Specific renderers use a set of designated tags to create cartographic representations.

1.2. Web of Things

The Web of Things [2] evolved from the Internet of Things ([3]) and integrates real-world "things" with the Web. Examples for such things are household appliances, embedded and mobile devices, but also smart sensing devices. Often, the user interaction takes place through a cell phone acting as the mediator within the triangle of human, thing, and Web. Applications of the Web of Things are influenced by the idea of ubiquitous computing [4] and range from smart shoes posting your running performance online, over management of logistics (e.g., localization of goods in the production chain), to insurance (e.g., car insurance costs based on the actually driven kilometres).

   The Web of Things leverages existing Web protocols as a common language for real objects to interact with each other. HTTP is used as an application protocol rather than a transport protocol as it is generally the case in web service infrastructures such as OGC's SWE framework [5]. Things are addressed by URLs and their functionality is accessed through well-defined HTTP operations (GET, POST, PUT, etc.). Hence, Web of Things applications follow the REST paradigm [6]. Specific frameworks (e.g. [7, 8]) offer REST APIs to enable access to things and their properties as resources. These REST APIs may not only be used to interact with a thing via the Web, also website representations of things may be provided to display dynamically generated visualizations of data gathered by the thing. Then, the mash-up paradigm and tools from the Web 2.0 realm can be applied to easily build new applications. An example application may use Twitter to announce the status of a washing machine or may let a fridge post to an Atom feed to declare which groceries are about to run out.

2. Approach

The proposed approach establishes an ubiquitous, tight coupling between our real life and web content that is connected with things in our environment. This is based on two aspects – OpenFloorMap and OpenThingMap.

2.1. OpenFloorMap

The OpenFloorMap is based on the need for a location referencing model for all human accessible spaces, and because current flagship smartphones are capable to measure room extent up to an applicable degree of accuracy. To enable easy data capturing and data management, the data model of OpenFloorMap (Figure 1) applies the simplicity of the OpenStreetMap data model (Section 1.1). In particular, the data model of the OpenFloorMap consists of two-dimensional levels and three-dimensional rooms inside those. A set of levels, a set of geographic coordinates and a unique identifier are the representation of a building in the real world. Each building is associated with a set of POIs in OpenStreetMap, which represents the entries to the building.

BUILDING_ID   BUILDING_ID/LEVEL_ID   BUILDING_ID/LEVEL_ID/ROOM_ID
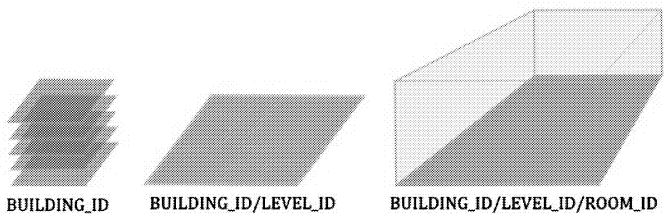
Figure 1: Data model of OpenFloorMap.

The OpenFloorMap is based on an Android application (Figure 2). The user can capture the layout of the rooms and report the data to the server. Modern smartphones provide APIs to access their build-in sensors that are capable to provide parameters for a system of equations based on trigonometric functions to determine room extend: Proximity sensors measure the distance between the camera and room corners, gyroscopes and orientation sensors determine the device's attitude. An assisted user interface adds building and level information. In a browser-based application, reported rooms can be arranged via drag-and-drop to represent the floor's actual layout.
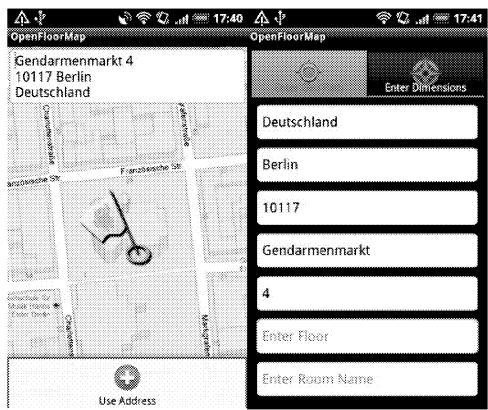
Figure 2: Android application user interfaces

2.2. OpenThingMap

The OpenThingMap integrates web content into our every day`s environment. It is based on the OpenFloorMap (Section 3.1). Persons are able to access the OpenThingMap via gateways and explore the digital world in terms of an in-world knowledge browser. This means that the user is able to set the gateway's position to any human accessible space inside buildings (http://ofm.url/buildings/<building_id>/levels/<level_id>/rooms/<room_id>) or the outside-world (Latitude, Longitude) to gather a catalogue of surrounding things and their linked content in the web. Photos may link to social network profiles, the microwave to its manual and the air conditioner to its remote control web service. Things that expose their capabilities in a standardized format become localizable through spatial queries as physical entity, no more just as URIs. This enablement of spatial queries within Mashups of things [2] is a great practical achievement of the OpenFloorMap integration towards personalization ambient spaces within universal environments.

We propose that things act as gateway between the real and the digital world and thereby link them (Figure 3). A gateway is the most specified class within OpenThingMap. It does not only represent itself, but the user as well. Smart things are generalized gateways with no user log in, but differ from things because they host embedded or attached computer components to provide direct connectivity with the web. The generalization of a smart thing class is the thing class. The thing class can hold everything in the real world that can be referenced either with geographic coordinates or a room in OpenFloorMap with local room coordinates. Things can be linked with static web resources e.g. for descriptive purposes and with web feeds to announce a thing's status.
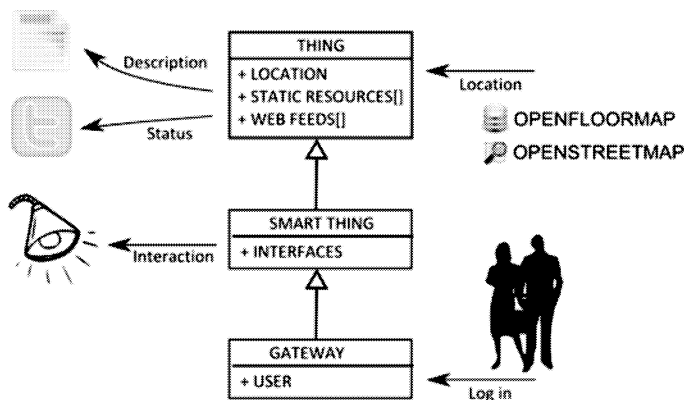

Figure 3: Concept of OpenThingMap.

3. Conclusion

This article presents an approach how to incorporate real-world things into the digital world for search and interaction. The approach is twofold using a) the OpenFloorMap

and b) the OpenThingMap. Both concepts are based on a light-weight data model, the knowledge of the crowd and the capabilities of current smartphones.

The presented approach on light-weight data models and protocols is a complementary to the existing semantic approaches for annotating data [9]. Future research questions should address machine readable search and bind capabilities in OpenThingMap and the inclusion of other digital sources which are not modeled as things, such as noise and air quality (phenomena).

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Konzeption von akustisch unterstützten animierten Karten zur Präsentation raumzeitlicher Informationen

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1. Einführung

Die statische Kartengraphik ist zweifelsohne die zentrale Form zur Präsentation von Geoinformation, da sie eine platzsparende und in einem Koordinatensystem verortete Informationswiedergabe gewährleistet. Daneben sind aber auch andere Formen der Informationskodierung denkbar (z.B. Animationen, Videos oder akustische Darbietungen), die bei Bedarf zu *multimedialen Darstellungen* zusammengefügt werden können.

Vor dem Hintergrund, dass die Notwendigkeit von Darstellungsmöglichkeiten für raumzeitliche Veränderungen *(change detection and analysis)* weiter stark ansteigen wird, soll der Fokus dieses Beitrages auf die Kombination zweier spezieller Kodierungsformen – *Animationen und akustische Darbietungen* – gelegt werden. Die zugrunde liegende Hypothese für diese, bisher wenig untersuchte Kombination lautet, dass die multikodale bzw. multimodale Vermittlung eine umfangreichere und flexiblere Kommunikation von zeitabhängigen Geoinformationen ermöglicht. Idealer Weise werden die Nachteile dieser beiden Kodierungsformen durch die jeweils andere Form aufgehoben.

2. Stand der Entwicklungen

Aufgrund ihres dynamischen Charakters sind *animierte Darstellungen* zur Abbildung raumzeitlicher Veränderungen prinzipiell sehr gut geeignet. Andererseits weisen sie aber auch eine Reihe von Nachteilen auf. Hierzu gehört aufgrund der zeitlichen Taktung die hohe Informationsdichte, die zu einer Überforderung des Kurzzeitgedächtnisses führen kann. Ferner kann beim einfachen Ablaufen der Animation nicht ohne Weiteres auf vorhergehende Zustände zurückgegriffen werden, sodass Vergleiche schwerfallen. Aus diesen Gründen ist auch darauf zu achten, dass weder zu viele Werte (z.B. je ein Wert für jeden US-Bundesstaat), noch gegenläufig verändernde Werte repräsentiert werden (z.B. teilweise Abnahme, teilweise Zunahme von Durchschnittstemperaturen). Idealer Weise sollten Animationen also nur zur

Vermittlung eines einzigen thematischen Attributs mit einem einheitlichen Trend verwendet werden.

Akustische Darbietungen (Töne, Klänge, Geräusche, Knalle) werden zur Vermittlung von Geoinformationen selten eingesetzt – sieht man einmal vom Fall der ergänzenden Sprachausgabe (z.B. in Navigationssystemen) ab. Zwar kann das menschliche Gehör sehr geringe Unterschiede in Lautstärke, Tonhöhe, etc. gut unterscheiden, dafür ist aber die Erfassung absoluter Werte unmöglich. Auch die gleichzeitige Darbietung von zwei oder mehreren, unterschiedlichen Quantitäten ist praktisch genauso wenig realisierbar wie die Repräsentation von geometrischen Eigenschaften.

Erste detaillierte Untersuchungen im Zusammenhang mit akustischen Darbietungen für die Präsentation von Geoinformationen stammen von Krygier (1994), der analog zu den graphischen Variablen (Größe, Farbe, etc.) *Soundvariablen* definiert (Lautstärke, Tonhöhe, Dauer, Tempo, etc.). Diese sind grundsätzlich zur Vermittlung von ordinalskalierten Daten geeignet. Praktischen Einsatz finden akustische Signale in Karten für Blinde, z.B. in der Software *iSonic* (www.cs.umd.edu/hcil/audiomap). Für die sonstige Nutzung multimedialer kartographischer Darstellungen mit Sound-Unterstützung gibt es nur wenige Implementierungen und entsprechende Bewertungen. Ausnahmen stellen z.B. die Arbeiten von Krygier (1993; Thema: AIDS-Fälle in den USA), Fisher (1994) bzw. Lodha et al. (1996; beide zum Thema: Unsicherheiten), Lodha et al. (1999) bzw. Harding et al. (2002; beide zum Thema: Seismische Ereignisse) oder Brauen (2006; Thema: Wahlen in Kanada) dar. Hierbei werden jeweils *statische* (und teilweise auch interaktive) thematische Karten mit akustischen Elementen erweitert und in den meisten Fällen auch eine verbesserte Gebrauchstauglichkeit propagiert.

Die *Kombination von akustischen Darbietungen mit animierten Karten* wurde in der Literatur bisher kaum bzw. nur wenig systematisch behandelt. Buziek (2003) schildert den Entwurf einer audio-visuellen Darstellung eines Überflutungsereignisses, bei dem wichtige Merkmale des Prozesses durch musikalische oder sprachliche Elemente verstärkt werden. Eine tatsächliche Kodierung quantitativer Werte findet hier aber ebenso wenig statt, wie eine fundierte Bewertung aus Nutzersicht. Aus der Wahrnehmungspsychologie sind generelle Untersuchungen bekannt, die sich auf Überlastungs- und Interferenzgefahren konzentrieren (Goldstein, 2002).

3. Experimente

Im Rahmen des vom GiN e.V. unterstützten Forschungsvorhabens „a^{2}maps" werden verschiedene, neuartige *akustisch unterstützte animierten Karten* erzeugt, die im WWW frei verfügbar gemacht und dort getestet werden sollen, u.a. durch einen Vergleich zu alternativen, statischen Darstellungen (Zeitserien, Zeitkarten). Bei diesen Implementierungen, die auf Basis der *Adobe Flash*-Software erfolgen, sollen zwei Grobkonzepte multimedialer Karten zur Vermittlung quantitativer Merkmale berücksichtigt werden - die Doppel - sowie die Zusatzkodierung (siehe auch Abb. 1).

Bei der *Doppelkodierung* eines Merkmals (z.B. der Ausbreitung von Algen oder der Veränderung der Bevölkerung Deutschlands) werden die entsprechenden Werte sowohl durch typische graphische Variationen in einer Choroplethenkarte, als auch synchron dazu durch die Variation von Tönen (z.B. durch Lautstärke) repräsentiert. Hierbei wird zwischen einer globalen Darstellung (d.h., einem akustischen Wert für die

gesamte Szene) und einer objektbezogenen Darstellung (d.h. separaten akustischen Werten für einzelne räumliche Bezugsgrößen) unterschieden. Im letzteren Fall ist hierfür eine interaktive Auswahl der jeweiligen Bezugsgrößen (z.B. Flächen) notwendig (z.B. durch Vorab-Definition oder on-the-fly-Selektion per mouse-over).

Die Kernfrage dieses Experiments ist, ob durch diese Dopplung eine verbesserte Erfassung eines quantitativen Attributs seitens des Nutzers erzielt werden kann, oder aber umgekehrt ein „Overload"-Effekt zu beobachten ist. Konkrete Untersuchungsaspekte, die durch Befragung von Nutzern der WWW-Version und EyeTracking-Analysen beantwortet werden sollen, beziehen sich auf die Usability-Kriterien

- Effektivität (Werden Werte korrekt bzw. korrekter erfasst?),
- Effizienz (Kann die Animation u.U. schneller ablaufen?), und
- Zufriedenheit (Führt die akustische Darbietung zur Motivationssteigerung oder aber zur Ablenkung?)

In diesem Zusammenhang stellen unterschiedlichen Varianten der Legenden-Gestaltung einen zentralen Untersuchungsaspekt dar – zum Beispiel ist eine komplette und ausschließliche a-priori-Darstellung oder aber eine selektive (u.U. interaktiv aufzurufende) Legende der jeweils dargestellten Zeichen möglich.
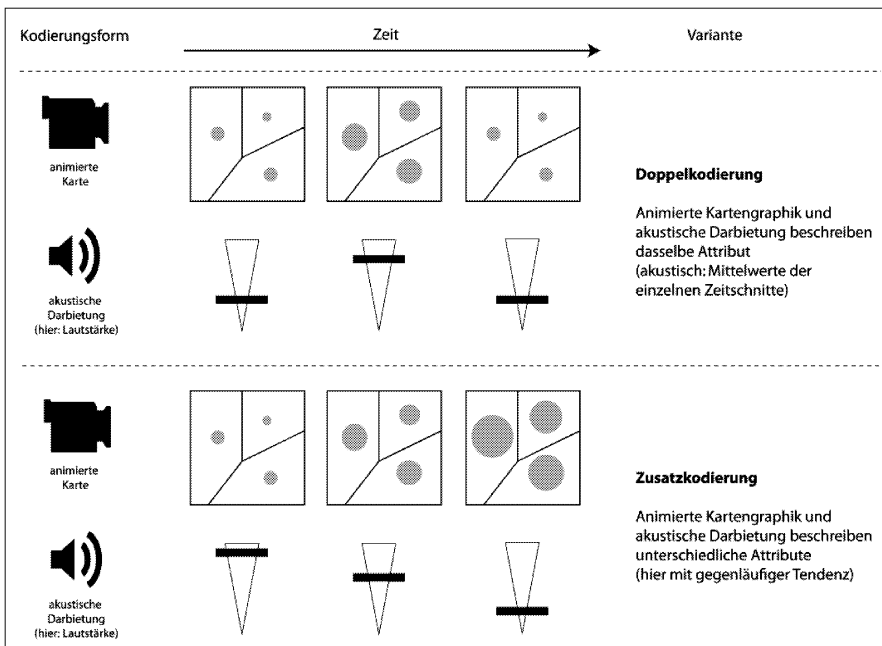

Abbildung 1. Schematische Darstellung der multimedialen Kombination aus animierter Karte und akustischer Darbietung zur Kodierung von quantitativen Merkmalen von Geoobjekten

Bei der *Zusatzkodierung* wird die räumliche Ausbreitung eines Phänomens erneut in einer Choroplethenkarte visualisiert, während die globale (oder interaktiv für Teilregionen auszuwählende) Veränderungsrate durch Variationen von Tönen (z.B. Lautstärke für Quantität, Tonhöhe für das Vorzeichen der Änderung) beschrieben wird. Auch hier steht neben den o.g. Aspekten der Usability die Frage nach der wahrnehmbaren Informationsdichte im Mittelpunkt der Untersuchungen. Hierbei erfolgt auch eine Unterscheidung bezüglich inhärent korrelierter Werte (z.B. visuelle Darstellung der Veränderung der Bevölkerungszahl der Bundesländer und akustische Wiedergabe der Veränderung der Gesamtbevölkerung) und lediglich potenziell korrelierten Werten (z.B. visuelle Darstellung der Veränderung der Bevölkerungszahl der Bundesländer und akustische Wiedergabe der Veränderung der Verkehrstoten in Deutschland).

Danksagung

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WebGIS-Technologien im Einsatz für den ehrenamtlichen Naturschutz

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Zusammenfassung. Ehrenamtliche tragen mit ihrem Engagement und den von ihnen erfassten Daten wesentlich zur Arbeit des Naturschutzes bei. Angesichts der rückläufigen Zahlen der ehrenamtlich im Naturschutz Aktiven wird es umso wichtiger, ihre Tätigkeit durch die Bereitstellung geeigneter Werkzeuge zu unterstützen. WebGIS-Technologien können hier gewinnbringend eingesetzt werden. Anhand verschiedener Praxis-Beispiele werden deren Anwendungsgebiete und Vorteile für die Unterstützung der ehrenamtlichen Arbeit im Naturschutz vorgestellt.

Schlagworte. Naturschutz, Ehrenamt, WebGIS, Artenerfassung, Informationssystem, mobile Anwendung, GPS, PDA

Einleitung

Das Engagement Ehrenamtlicher besitzt eine große Bedeutung für den Naturschutz in Deutschland, dabei ist die Erfassung von Tier- und Pflanzenarten einer der Haupttätigkeitsbereiche [1]. Verbände und naturschutzfachliche Vereinigungen tragen Informationen zum Vorkommen von Arten zusammen und liefern so eine Grundlage für wissenschaftliche Auswertungen, die Bewältigung naturschutzfachlicher und planerischer Aufgaben sowie für die Umweltbildung. Aufgrund verschiedener gesellschaftlicher und wirtschaftlicher Entwicklungen (u. a. Überalterung, Individualisierung, wirtschaftliche Unsicherheiten) nimmt die Bereitschaft, sich ehrenamtlich und langfristig für den Naturschutz zu engagieren, jedoch ab [2]. Neben der Beschreitung anderer Wege zur Motivation für ein ehrenamtliches Engagement und die Rekrutierung „neuer" Ehrenamtlicher wird daher auch die Bereitstellung geeigneter Werkzeuge zur Unterstützung einer effizienten Datenerfassung und -weitergabe forciert.

WebGIS-gestützte Systeme können bei entsprechender Ausgestaltung zum einen die Anforderungen der Datenverwerter an eine wissenschaftlich auswertbare, qualitativ hochwertige Datenerfassung aufgreifen. Zum anderen entsprechen sie den Erfordernissen der ehrenamtlichen Nutzer, die intuitiv bedienbare Werkzeuge, Kommunikationsmöglichkeiten und eine anschauliche Datenpräsentation favorisieren. Wie diese Anforderungen umgesetzt werden und welche Anwendungsbereiche durch entsprechende Systeme praktisch unterstützt werden können, erprobt die IP SYSCON GmbH derzeit in Kooperation mit verschiedenen ehrenamtlichen, behördlichen und

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wissenschaftlichen Partnern in Niedersachsen. Die Herausforderung besteht vor allem darin, vorhandene GIS- und Internettechnologien so zu kombinieren und durch neue Funktionen zu ergänzen, dass die vielschichtigen Anforderungen an die Datenerfassung und -auswer-tung, die Bereitstellung von Informationen via Internet sowie an die Zusammenarbeit der Nutzer untereinander umgesetzt werden.

2. Der Einsatz von WebGIS-Technologien für …

2.1. … die Datenerfassung und –auswertung durch ehrenamtliche Nutzer

Eine vom NABU Laatzen e.V. und der IP SYSCON GmbH gemeinsam entwickelte WebGIS-gestützte Lösung greift vor allem die Anforderungen an die Datenerfassung aus ehrenamtlicher Sicht auf [3] [2]. Das auf freier Software basierende Portal *eMapper* bietet Werkzeuge zur einheitlichen, digitalen Erfassung von Artendaten und berücksichtigt dabei vorhandene fachliche Standards. Um eine redundante Datenhaltung zu vermeiden, können neben Fachdaten des Verbandes weitere Geo(basis)daten in Form von WebDiensten (WMS, WFS) integriert werden. Verschiedene Filter- und Exportmöglichkeiten stehen zur Datenauswertung und -weitergabe zu Verfügung. Usability-Tests zeigten, dass das Portal den Anforderungen der ehrenamtlichen Nutzer gerecht wird. Gelobt wurden vor allem die intuitive Bedienbarkeit, die übersichtlich gestaltete Benutzeroberfläche sowie die automatische Plausibilitätskontrolle der Eingaben.

2.2. … die Zusammenführung heterogener Daten auf behördlicher Seite

Ein flexibler Systemaufbau ermöglicht die Nutzung des Portals *eMapper* auch für die Datenerfassung auf behördlicher Seite. Gemeinsam mit der Region Hannover erfolgte eine gezielte Anpassung an die Anforderungen einer Behörde. So kann ein digitales Artenkataster etabliert werden, das bei unterschiedlichen Planungsaufgaben Unterstützung leisten kann und auch einzelne Meldungen aus Kartierungen einer übergeordneten Auswertung zugänglich macht. Über die standardisierte Datenerfassung wird zudem der Datenaustausch mit dem Niedersächsischen Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN) von Seiten der ehrenamtlichen Melder und der Region Hannover optimiert. Wesentliches Ziel der Entwicklung war neben der Integration von Daten unterschiedlicher Herkunft auch der Aufbau eines Rollen- und Rechtemanagements, das der angestrebten, heterogenen Nutzerstruktur und den daraus resultierenden Anforderungen an die Datenweitergabe gerecht wird. An die Entwicklung schließt sich nun eine einjährige, praktische Erprobungsphase an.

2.3. ... die Integration mobil erfasster Daten

Das Forschungsvorhaben ARDINI (Artenschutz digital in Niedersachsen) [3], eine Kooperation mit der Universität Oldenburg, der Jade Hochschule Wilhelmshaven / Oldenburg / Elsfleth, dem NLWKN sowie mehreren Naturschutzverbänden, zielt auf die drahtlose Übertragung von erfassten Daten direkt aus dem Gelände, unter Nutzung der Mobilfunktechnologie, ab. Kartenmaterial und Artbestimmungsfunktionen im Gelände sind ebenfalls Teil der geplanten Anwendung. Die bereits erprobten WebGIS-Technologien des *eMapper* werden zur zentralen Sammlung und weiteren Bearbeitung der GPS-gestützt erfassten Daten verwendet. Das System wird anhand ausgewählter Artengruppen bis zur Anwendungsreife entwickelt und in Hinblick auf inhaltliche Validität und praktischen Nutzen für eine zukunftsfähige, digitale Unterstützung der Artenerfassung durch Ehrenamtliche evaluiert.

2.4. ... die öffentlichkeitswirksame Präsentation von Naturschutzfachdaten

Gemeinsam mit dem BUND Landesverband Niedersachsen e.V. erfolgt der Aufbau eines niedersachsenweiten Informationssystems für Streuobstwiesen[4]. Es soll zukünftig allen Interessierten die Möglichkeit bieten, Informationen zu Obstwiesen via Internet zu erfassen und abzufragen. Die Entwicklung des WebGIS-gestützten Informationssystems erfolgt auch auf Basis der bestehenden Erfahrungen mit der WebGIS-gestützten Artenerfassung. Das System soll neben räumlichen Informationen zu den Streuobstwiesen auch Informationen zu Vermarktung und Veranstaltungen, dem Zustand der Wiesen und dem Vorkommen alter Obstsorten enthalten. Zudem werden Werkzeuge für eine einheitliche Datenerfassung bereitgestellt. Der Aufbau der Plattform geschieht schrittweise: Die Erprobung und auch die Einbindung vorliegender Informationen sowie der unterschiedlichen, beteiligten Akteure erfolgt zunächst anhand von vier Modelllandkreisen. Mit Abschluss dieser Erprobungsphase steht die Plattform dann in vollem Umfang allen interessierten Nutzern zur Verfügung.

3. Fazit und Ausblick

WebGIS-gestützte Lösungen leisten einen wichtigen Beitrag zur effektiveren Vernetzung im Naturschutz und führen die Ergebnisse der ehrenamtlichen Arbeit vielfältigen Anwendungszwecken zu. Sie können nicht nur als Daten- und Kommunikationsplattform zwischen Verband und ehrenamtlich Kartierenden fungieren, sondern binden je nach Einsatzbreite auch Behörden, andere Verbände sowie die Öffentlichkeit ein. Für einen Ausbau der Anwendungsfelder und Zielgruppen lassen sie sich auch mit bestehenden technischen Lösungen (z. B. Fachportalen, Fachkatastern) verknüpfen. Ebenso sind sie in technologische Infrastrukturen und Metadateninformationssysteme integrierbar sowie zur Veröffentlichung von Umweltfachdaten entsprechend der Umweltinformationsgesetze nutzbar. Die Integration von mobilen Technologien und ein Ausbau der

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[3] Das Projekt wird von der Deutschen Bundesstiftung Umwelt gefördert. Weitere Informationen unter www.ardini.de.

[4] Das Projekt wird von der Niedersächsischen Bingo-Umweltstiftung gefördert. Weitere Informationen unter www.streuobstwiesen-niedersachsen.de.

Kommunikationsmöglichkeiten im Sinne von Web 2.0 bieten zudem gerade jüngeren Ehrenamtlichen mehr Anreiz, sich ehrenamtlich zu engagieren.

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XErleben – Datenmodell für ein kommunales Freizeitkataster

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Abstract. XErleben beschreibt ein Datenmodell für den standardisierten Datenaustausch von Orten von Interesse mit kommunalen Freizeit- und Infrastrukturinformationen. Ziel ist die interoperable Bereitstellung und Verwendung in regionalen, landesweiten oder fachlich spezialisierten Portalen und die interoperable Einspeisung in Portale der Nachbarkommunen oder Nachbarregionen. Das Modell wurde im Auftrag der kommunalen Spitzenverbände in Nordrhein-Westfalen von einer Arbeitsgruppe erarbeitet und mit verschiedenen Akteuren des Landes abgestimmt.

Keywords. Datenmodell, Orte von Interesse, kommunale Geodateninfrastruktur

1. Einleitung

„Wo ist eigentlich die Veltins-Arena?" „Welches ist die nächste UBahn-Haltestelle dazu?" „Wo ist das nächste Freibad?" „An welchen Sehenswürdigkeiten komme ich auf der Römerroute vorbei?" Dies sind Fragen, auf die Bürger und Touristen Antworten in kommunalen und regionalen Geoportalen suchen, und die an kommunalen Grenzen keinen Halt machen. Technisch stellt der Datenaustausch kein Problem dar. Was bisher jedoch fehlt, ist eine Verständigung über die Struktur der Daten auf Ebene der Objektarten und ihrer Eigenschaften. Die Arbeitsgruppe „Kommunales Freizeitkataster" der kommunalen Spitzenverbände in Nordrhein-Westfalen hat auf der Basis nationaler und internationaler Standards[1] ein fachlogisches Modell namens „XErleben" erarbeitet und in UML sowie als GML-Schema dokumentiert[2]. Mit diesem semantischen Modell können dezentral gehaltene Daten in Portalen zusammengeführt und regelbasiert einheitlich dargestellt werden.

Als wichtige Akteure auf diesem Gebiet wurden der Regionalverband Ruhr und die Bezirksregierung Köln, Abteilung GEObasis.NRW in die Arbeitsgruppe eingebunden. In einem zweiten Schritt wurden Tourismusverbände, Landschaftsverbände und weitere Akteure mit Bezug zum Thema Tourismus und Freizeit in die fachliche Abstimmung einbezogen.

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[2] Informationen und Datenmodell auf der Homepage http://www.XErleben.de.

2. Inhalte des Datenmodells XErleben

Orte von Interesse können nicht nur klassische, touristisch relevante Points of Interest wie Museen oder Hotels, sondern auch Objekte der kommunalen Infrastruktur wie Schulen, Kindergärten, soziale Einrichtungen oder Standorte von Wochenmärkten und Gewerbegebieten sein. Auch Objekte mit linien- oder flächenförmiger Ausdehnung wie Freizeitwege oder Szeneviertel wollen in Portalen gesucht und gefunden werden. Das Modell sieht auch Veranstaltungsobjekte sowie Unternehmensstandorte mit Branchenschlüsseln für YellowPages-Anwendungen vor.

Ausgangspunkt für das Modell war das bereits unter dem Namen TFIS[3] existierende semantische Modell des Tourismus- und Freizeitinformationssystems der AdV[4]. Während sich TFIS jedoch auf Freizeit- und Tourismusinformationen beschränkt, bildet das kommunale Datenmodell XErleben zudem die wichtigen Bereiche der kommunalen Infrastruktur ab. Neben der Erweiterung des Objektkatalogs um zusätzliche Objektarten wurde auch die Tiefe der Information im Hinblick auf geeignete Suchkriterien ausgebaut.

3. Aufbau des Datenmodells XErleben

Vergleichbar mit CityGML, Xplanung, OKSTRA XML und anderen fachspezifischen Standards[5] ist XErleben ein GML(3.1)-Anwendungsschema. Es ist jedoch bewusst einfach gehalten und beschränkt die verwendeten Geometrien auf einfache zweidimensionale Primitive und verzichtet vorerst auf topologische Beziehungen.

Die zentrale Objektklasse des Datenmodells ist die Objektart XE_OrtVonInteresse (OVI). Sie bündelt alle von der Art des Objekts unabhängigen Stammdaten. Jedem OVI kann eine touristische und eine fachliche Bedeutung zugeordnet werden. Das ermöglicht in Geoportalen eine einfache maßstabsgerechte Selektion. Dem XE_OrtVonInteresse muss mindestens ein Punkt als Geometrie zugeordnet werden, zusätzlich können weitere Punkt-, Linien- oder Flächengeometrien erfasst werden. Außerdem besteht die Möglichkeit, auf vorhandene Geometrien zu referenzieren.

Es können beliebig viele verschiedene Beziehungen zwischen einzelnen Orten von Interesse bestehen, die eine organisatorische, thematische oder räumliche Zugehörigkeit zu einem anderen Ort von Interesse ausdrücken. So können Sehenswürdigkeiten oder Gastronomiebetriebe einer touristischen Route, Unternehmen einem Gewerbegebiet zugeordnet werden. Beliebig viele Synonyme können für Suchanfragen, aber auch für die Eliminierung von Duplikaten verwendet werden.

Dem XE_OrtVonInteresse muss mindestens eine XE_Kategorie zugeordnet werden. Es können dabei beliebig viele Kategorien gewählt werden. In Abhängigkeit von der Kategorie werden weitere Attribute zugeordnet.

Damit die Datenpflege nicht zu aufwändig wird, gibt es nur eine kleine Menge an Pflichtattributen, aber eine ganze Reihe optionaler Attribute. Die Attributausstattung ist im Hinblick auf Suchkriterien erarbeitet und ersetzt keine Fachdatenbank.

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[3] Flocke, Berthold und Wolf, Peter: Touristik- und Freizeitinformationssystem – Konzeptioneller Ansatz zur Führung von raumbezogenen Fachinformationen und praktische Realisierung, zfv 2009/04 S. 229
[4] Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland
[5] www.citygml.org, www.xplanung.de, www.okstra.de
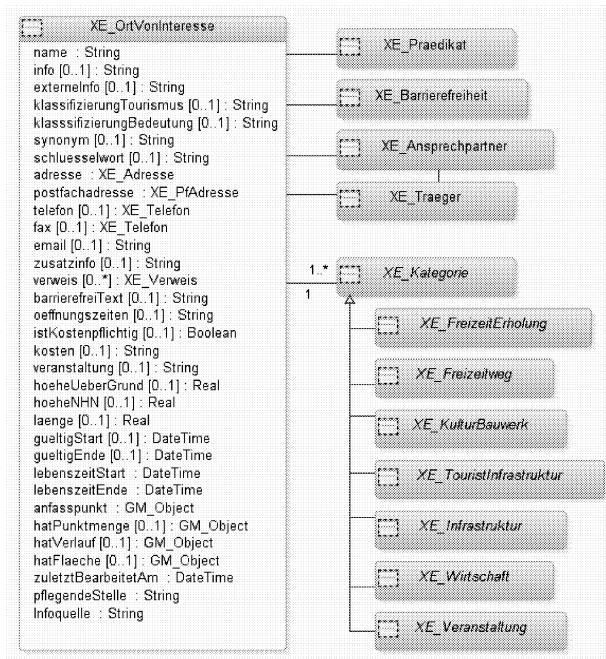
Abb. 1: Zentrales Objekt des XErleben-Modells ist die Klasse XE_OrtVonInteresse.
Aus dem Kategorienbaum sind nur die obersten beiden Ebenen dargestellt.

4. Realisierungen des Modells

Ziel der Modellierung ist die Definition eines Übergabeschemas in GML. Die technische Umsetzung in ein relationales Modell bleibt den Kommunen oder regionalen Kooperationen überlassen. Das Modell wurde bewusst einfach gehalten, damit auch kleine Kommunen ihre Daten mit einfachen Mitteln vorhalten und bereitstellen können. Anspruchsvollere Realisierungen können durch regionale Kooperationen geleistet werden. Der Regionalverband Ruhr und das Geoportal Münsterland arbeiten an Implementierungen. Erste Ansätze zeigen, dass das Datenmodell mittels Weboberflächen pflegbar ist.

In Nordrhein-Westfalen stellen verschiedene regionale und landesweite Akteure wie Geobasis.NRW, der Radroutenplaner NRW, die Landschafts- und Tourismusverbände ihre Freizeit- und Infrastrukturinformationen über Geodienste bereit. Mit dem Standard XErleben liegt nun ein gemeinsamer Nenner vor, der die Zusammenführung dieser dezentral gehaltenen Informationen in Portalen und die Darstellung über regelbasierte Signaturierung ermöglicht.

Wünschenswert ist eine weite Verbreitung auch über die Grenzen von Nordrhein-Westfalen hinaus. Dies wird auch durch eine Empfehlung der kommunalen Spitzenverbände an ihre Mitgliedskommunen erfolgen. Die Aufnahme in die Familie der XÖV-Standards[6] wird angestrebt

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[6] www.xoev.de

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Risikobewertung von Sichtbehinderungen durch niedrige Sonnenstände für das Verkehrswegenetz

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Zusammenfassung. Wir stellen eine Modellierung und Implementierung zur Risikobewertung durch niedrige Sonnenständen für niedersächsische Autobahnen unter Verwendung von OpenStreetMap Daten und einem zeitlich hoch auflösenden Sonnenstandsmodul vor. Sichtbehinderungen durch niedrige Sonnenstände führen im Straßenverkehr wiederholt zu teilweise schwerwiegenden Unfällen. Durch einen Abgleich der für einzelne Straßengeometrien berechneten Sonnenwinkelpaare mit den empirisch ermittelten Sichtfeldwinkeln eines Versuchsfahrzeuges werden gefährdete Straßenabschnitte in einer zeitlichen Auflösung von 15 Minuten identifiziert. Die hier vorgestellten Analysen stellen damit eine Pilotstudie für ein Frühwarnsystem für derartige Gefährdungssituationen im Bereich des Individualverkehrs dar.

Keywords. Risikobewertung, OpenStreetMap, Verkehr

1. Einleitung

Sichtbehinderungen durch niedrige Sonnenstände stellen für den Individualverkehr ein erhebliches Risikopotenzial dar. Dies zeigt nicht zuletzt die Massenkarambolage im Juli 2009, die sich auf 30 Kilometern auf der A2 ereignete, 80 Verletzte in über 250 beteiligen Fahrzeugen forderte und einen Sachschaden von mehr als 1,5 Millionen Euro verursachte (Welt 2009). Vor diesen Gefährdungen im Straßenverkehr wird zurzeit weder allgemein von amtlichen Stellen noch individuell von kommerziellen Navigationssystemen gewarnt.

Vorhersagen von Sichtbehinderungen durch niedrige Sonnenstände für das Verkehrswegenetz sind dabei prinzipiell möglich. Während Daten über die Geometrien von Straßen teilweise sogar frei vom OpenStreetMap Projekt zur Verfügung gestellt werden (OSM 2011), lässt sich die Sonnenbahn an beliebigen Orten zu jeder Tageszeit berechnen. In Kombination mit einem Fahrzeugmodell zur Einschätzung des Fahrersichtfeldes kann eine Risikoanalyse erfolgen.

Wir stellen hier eine solche Risikoabschätzung für den Individualverkehr durch niedrige Sonnenstände vor. Durch Kombination astrophysikalischer Berechnungen und freie Geodaten über niedersächsische Autobahnen wird, zunächst offline, eine räumlich und zeitlich hoch aufgelöste, geometrisch basierte Einschätzung der Sichtbehinderung durch niedrige Sonnenstrände analysiert.

2. Modelarchitektur und Implementierung der Risikoanalyse

Die Modellierung des Risikopotenzials durch niedrige Sonnenstände für den Individualverkehr umfasst die Bereitstellung von Geometrien der niedersächsischen Autobahnen sowie die zeitlich hoch aufgelöste Berechnung der Sonnenstände im Viertelstundentakt für ein Jahr. Diese werden in Kombination eines Fahrzeugmodells, das die Sichtwinkel für einen Fahrer repräsentiert geometrisch analysiert. Als Ergebnis werden die fünf Risikoklassen für den Fahrzeugführer zu jeder Viertelstunde eines Jahres auf den gegeben Straßengeometrien berechnet.

Das Fahrzeugmodell (Abb. 1) berücksichtigt die Sichtbehinderung durch niedrige Sonnenstände von vorne und von hinten. Bei der Sichtbehinderung von vorne wird hier der Normalfall ($\alpha_O + \delta_O + \alpha_U$) von dem bei heruntergeklappter Sonnenblende ($\delta_O + \alpha_U$) unterschieden. Für Sichtbehinderungen von hinten sind Blendungen durch den Rückspiegel ($\beta_L + \beta_R$) und den linken Außenspiegel (γ_L) berücksichtigt worden. In diesem Ansatz wurden die entsprechenden Sichtwinkel an einem Skoda Oktavia ermittelt.
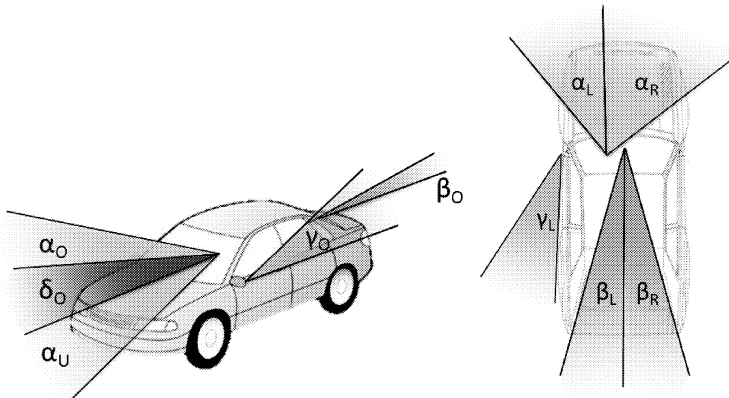
Abb. 1: Fahrzeugmodell mit den für niedrige Sonnenstände gefährdenden Sichtwinkel des Fahrzeugführers (Fahrzeugabbildungen links: Boellet-Formenbau 2001, rechts: Audiquattrofan 2001).

Die im Fahrzeugmodell identifizierten Sichtwinkel, bei denen eine Gefährdung durch niedrige Sonnenstände auftritt werden in den Gefahrenklassen „keine Gefahr", „Blendung von vorne", „Blendung von vorne, trotz Sonnenblende" sowie „Blendung von hinten" zusammengefasst.

Als Datengrundlage der in Abb. 2 skizzierten Implementierung dienen OpenStreetMap Daten der niedersächsischen Autobahnen, die über das Tool *osm2pgsql* in eine durch PostGIS erweiterte PosgreSQL Datenbank importiert werden. Nach Transformation des Google Mercator in das Gauß-Krüger Koordinatensystem sind die als Polylinien vorliegenden Geometrien zur präziseren Modellierung in ihre einzelnen Segmente unterteilt worden (in Abb. blau). Zwecks schnellerer Risikomodellierung wurden je Azimut und Mittelpunkt alle dieser Linien berechnet und in weiteren Spalten der Geometrietabelle gespeichert.

Abb. 2: Implementierung der Gefährdungsanalyse (siehe Text für Erläuterungen).

Die Berechnung der viertelstundengenauen Sonnenstände in Form von Azimutal- und Höhenwinkel nach (AstAlm 2006; Meeus 2000) sowie die Berechnung der Risikoklassen erfolgte in Java (in Abb. rosa). Die Ergebnisse wurden für jede betrachtete Geometrie als String codiert in der Datenbank abgelegt. In einem weiteren Schritt wurde die in den Risikoklassen definierten Schwellenwerte der Einstrahlungswinkel mit den Sonnenwinkeln abgeglichen und das Ergebnis ebenfalls in der Datenbank abgelegt.

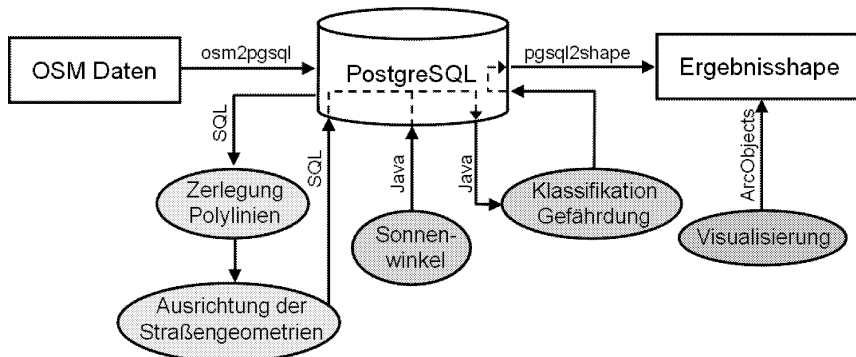Der Zugriff auf die Datenbank wurde dabei mit der *postgresql-jdbc* Schnittstelle realisiert, die entsprechend den Anforderungen erweitert werden musste (PG-Forum 2007). Hier zeigte sich, dass der lesende und schreibende Datenbankzugriff einen entscheidenden Kostenfaktor ausmacht, der bei Weiterentwicklung dieses Ansatzes dringend verbessert werden muss. Dieser Flaschenhals ist kaum zu vermeiden, da sämtliche hier zur Verfügung stehenden 280.000 Straßengeometrien mit 35.040 Sonnenwinkelpaaren verglichen werden müssen. Bei Vorgabe konkreter Routen und entsprechenden Zeitangaben fallen die Kosten der Datenbankabfrage nicht ins Gewicht. Hier wird sich die Datenbanklast etwa um den Faktor 1.000 bis 10.000 verringern.

Die Visualisierung der durch *pgsql2shp* exportierten Shapedateien erfolgte in ArcMap. Mittels eines dafür entwickelten Skriptes in VBA mit ArcObjects wurde für jeden Zeitschritt eine Karte der niedersächsischen Autobahnen erstellt und als Bild exportiert. Ihre Farbgebung wurde nach der Gefahrenklasse bestimmt. Das Ergebnis ist somit eine Zeitreihe von Bildern.

3. Ergebnisse

Die Ergebnisse der oben beschriebenen Modellierung ist eine 15-minütige Risikoklassifizierungen für alle verfügbaren Einzelgeometrien niedersächsischer Autobahnen. Die Abbildung 3 zeigt die Situation auf den Autobahnen um Braunschweig am 01.04.2011 um 16:00 (UT). Erwartungsgemäß wird der Autofahrer zu dem hier beispielhaft gewählten Zeitpunkt auf den von Ost nach West führenden Autobahnen von vorne geblendet, wenn er in Richtung Westen fährt. Das Autobahnkreuz Braunschweig-Nord, an dem sich die A2 und die A391 treffen, zeigt in dem vergrößerten Ausschnitt eine wechselnde Gefahrenlage in den Autobahnabfahrten.

Diese Situation ist besonders prekär, da der Fahrzeugführer von der Blendung durch die Sonne überrascht wird.

Weitere Ergebnisse sind in Form von Filmen ausgewählter Zeitabschnitte auf den Internetseiten des Instituts für Geodäsie und Photogrammetrie der TU Braunschweig unter http://www.tu-braunschweig.de/igp/forschung/risikosolar abrufbar.
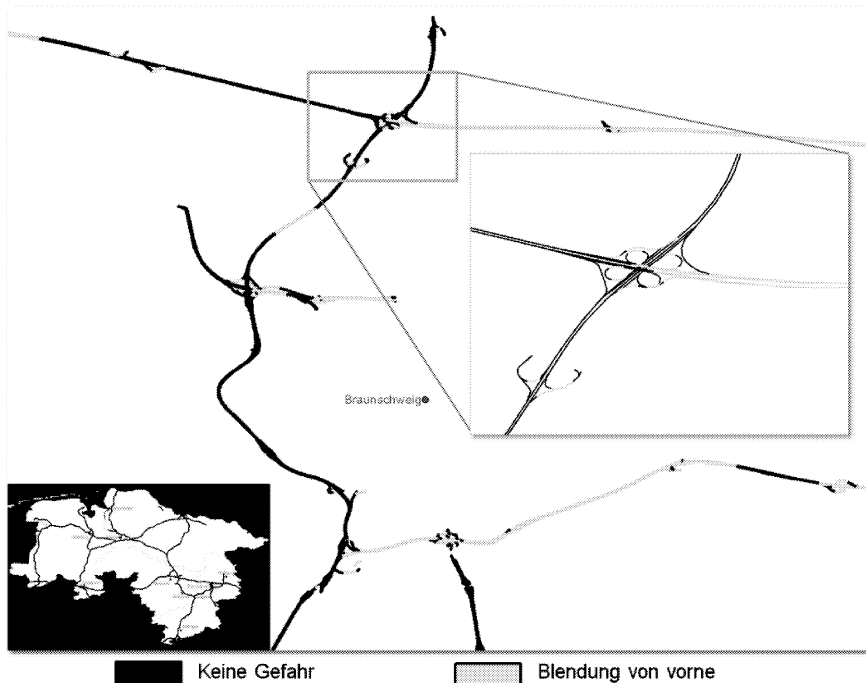
Abb. 3: Gefährdung des Autofahrers auf niedersächsischen Autobahnen am 01.04.2011 um 16:00 (UT).

4. Diskussion

Die Ergebnisse der hier durchgeführten Analyse liegen für 280.000 Straßengeometrien im 15-Minuten-Takt für ein ganzes solares Jahr vor. Es konnte gezeigt werden, dass eine Modellierung der Sichtbehinderungen durch niedrige Sonnenstände in einer hohen zeitlichen Auflösung unter Zuhilfenahme freier Geodaten prinzipiell erfolgen kann. Als Folge dieser Modellierung ist eine entsprechende Verkehrsleitplanung durch etwa temporäre Tempolimits oder die Vorschrift zum Tragen von Sonnenbrillen möglich.

Die oben gezeigten Modellergebnisse sind in der Folge einer stark eingeschränkten Geodatenlage entstanden. So ist weder das Relief noch andere Geometrien, wie Häuser oder Bäume, welche zur Verschattung der betrachteten Straßen führen können, berücksichtigt worden. Ebenso ist nicht auf die individuelle Sichtsituation anderer als der hier genannten Fahrzeugklasse eingegangen worden. Ebenfalls muss eine Evaluierung durch Testfahrten erfolgen, um die Modellergebnisse zu verifizieren und gegebenenfalls zu verbessern.

In den weiteren Schritten ist neben den oben genannten Modelverbesserungen auch die Modellierung für weitere Straßenarten, etwa im innerstädtischen Bereich geplant. Die in der hier vorgestellten, vereinfachten Betrachtungsweise kostenintensiven Datenbankabfragen werden dabei noch mehr in den Vordergrund gerückt werden müssen. Über eine entsprechende Algorithmik muss der Zugriff auf die Datenbank minimiert werden, um etwa auch für einzelne Routen eine realtime-Analyse zu ermöglichen. Allerdings ist, wie oben diskutiert, die Datenbanklast bei solchen Anwendungen erheblich geringer, als bei der Betrachtung aller Geometrien zu allen Zeitintervallen. Eine realtime-Analyse der Gefährdung kann dann in der Folge im Zusammenspiel mit Navigationssystemen und aktuellen Wetterinformationen individuell zum Einsatz kommen.

Danksagung

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Poster Abstracts

Unveiling the design framework behind transactional map symbols

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Abstract. Map symbols in general play a central role in cartography since they represent real-world entities on a map. Due to an increasing utilization of maps as Web 2.0 interfaces for several applications, especially point symbols have become "windows" to the real-world, allowing communication about and interaction with real-world entities. Although this functional shift is clearly observable for years, a sound formalization of graphical and functional design is still lacking. This paper tries to unveil currently applied concepts behind the graphical and functional design of so-called transactional map symbols based on an examination of several popular map-based web platforms. Furthermore this paper should serve as a starting point in a discussion about to which extent cartographic concepts could improve the point symbol design in a highly dynamical and interactive map environment.

Keywords. Cartography, map symbol, graphical user interface, design

Introduction

The growing popularity of digital maps in internet media and their use as a baseline for ubiquitous urban computing [1-4] has led to an alteration of the core purpose of maps. It is shifting from a static communication medium to a graphical user interface (GUI) for any application with location related content [5]. Whether objects, places or persons, everything can be located precisely and therefore be represented in maps, which in turn serve as an intuitive organizational structure and interface for any kind of communication (e.g. rating, commenting) or transaction (e.g. ordering, booking). In contrast to an interactive map use for exploratory spatial data analysis (ESDA), maps in such contexts serve as direct interfaces to real-world entities. In other words, they are the "stage" or "space" [6: p.2534] for any location-related communication and transaction.

In contrast to analog maps, digital maps offer the opportunity to integrate dynamic, interactive elements (e.g. hyperlinks). Within the last twenty years [7] enormous functional advancements could have been observed in this field. But with the establishment of the Web 2.0 concept [8], the utilization of maps entered a new era [9]. Techniques like mash-ups made it possible to use map elements as entry points to a nearly unlimited amount of location related information [10] available on any device. Due to the rising popularity of spatial information and the ease of use of map APIs and

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GI-tools [11], countless portals, websites and mobile applications have incorporated maps as interfaces for their content [12]. In this context map symbols (mostly point symbols) often represent not only the corresponding entity as such but possess connective abilities, blurring the boundary between the virtual representation of space and real-world settings (cf. Harrison & Tatar's interpretation of place construction in an pervasive environment [13]). Due to their role as an interface for a map-facilitated spatial communication and transaction, we accordingly call them "transactional map symbols". This term characterizes their function as a window to real-world entities and emphasizes the ability to directly interact with them [14]. Transactional map symbols are applied in several contexts:

- Collection of location relevant information (e.g. Google Places[2]): any information about a specific place, shop, restaurant etc. is collected and tagged. Most of these platforms are run commercially.

- Location related collaborative content (e.g. Qype[3]): any kind of information, ratings and comments are user generated and can be edited by any member of the platform.

- Location or object related real-time information (e.g. Public Transport[4]): real-time information is connected with symbols representing either locations, like bus stops, or moving entities. Platforms communicating real-time whereabouts of persons enjoy rising popularity (e.g. Foursquare[5]).

- Location related interaction (e.g. Booking Portal[6]): opportunities to interact with places/objects are directly bound to map symbols (e.g. "book now"-button in a map overview of hotels). Interaction with localized persons [15] is provided by several platforms (e.g. Trendsmap[7]).

- Augmented location-based information and interaction (e.g. Wikitude[8]): real-world environments are overlaid with location-specific information. Mobile devices with integrated positioning systems and active internet connection serve as tools for "mobile spatial interaction" [16].

All these examples have in common that transactional map symbols do not primarily code for a general type of object (like "restaurant", "post office" etc.) but collect and connect to a specific location and its relevant information or even allow to trigger real-world actions. In this sense the design of such symbols is not merely a matter of cartography, but of a more general geomedia- or geointeraction-design [5].

By now the graphical und functional design of such symbols is primarily driven by default options (like the already famous Google pushpin), although a well-established set of design rules for map symbology would exist (e.g. Bertin's work [17] is regarded as fundamental). The urgent question for cartographers arises to which extent they could contribute to a more effective and user friendly design of transactional map

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[2] http://googleblog.blogspot.com/2010/04/introducing-google-places.html [10.01.2011]

[3] http://www.qype.com/ [10.01.2011]

[4] http://transport.wspgroup.fi/hklkartta/defaultEn.aspx [10.01.2011]

[5] http://foursquare.com/ [10.01.2011]

[6] http://www.hrs.com [10.01.2011]

[7] http://trendsmap.com/ [11.01.2011]

[8] http://www.wikitude.org/en/ [01.02.2011]

symbols which are most often used in a not purely cartographic context. To put it the other way round: It seems to be worthy to discuss existing design-guidelines in the light of a broader application of maps [18].

As a first step this paper aims to unveil the conceptual design framework behind transactional map symbols as actually used in several representative examples (see e.g. footnotes above). Furthermore it should serve as groundwork for discussing the potential contribution of cartography in an enhanced user interface design.

The relevance of this has been expressed by Bilandzic & Foth [16: p.2606]: "Only if designers manage to create intuitive and easy-to-learn interfaces, mobile spatial interaction (MSI) applications might be adopted and used by the broad mass of users." By now the technical and conceptual standard of platforms and applications is quite high [19], but a cartographic design framework for this specific context is still widely lacking.

5. Unveiling the Design Framework

Since transactional map symbols possess interactive functions and therefore need to be selectable, they are nearly exclusively based on point geometries. A major reason, beside some technical advantages, for this is, that point symbols require little space on the map (or screen) and consequently more information associated to the displayed area can be communicated.

Take for example an urban park with several facilities like an ice-cream parlor, a fountain, benches, restroom etc. A communal information web-portal wants to tag all these entities with transactional map symbols for feedback or maintenance-requests. Given that the park is stored as a polygon-feature it would not be advisable to derive a polygonal hotspot or transactional symbol because entities within the park would be "covered" and could not be targeted distinctly anymore. The obvious and most practicable solution is to represent the park itself and every facility within as a point symbol, as shown in figure 1.
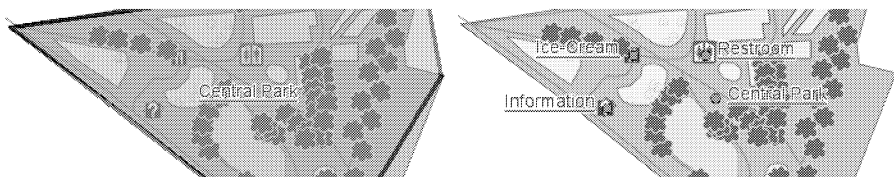
Figure 1: Transactional map symbol "Central Park" as polygon (left) vs. points (right); hotspots are indicated by grey shading/circles and hyperlinks. The usage of points as transactional map symbols prevents hotspots from overlapping.

The functional and graphical design of transactional map symbols strongly depends on the general map purpose. Nevertheless reviewing various popular portals of different types, five core aspects, influencing the design of transactional map symbols were identified as common denominator.

In the following the impact on the transactional map symbol design of these aspects is discussed and core concepts are collected at the end of each section.

5.1. Intention of the User

Initial (mostly textual) search and filter options allow the users to define the thematic and spatial range of their queries, leading to potentially interesting results. Depending on the design of the platform query results are presented either as textual lists or in combination with maps. Thus the map, in combination with a thematic database (e.g. yellow pages), is used as catalog where location is just one of several selection criteria. In contrast, map symbols in analog maps are often packed with as much information as visually possible in order to provide the map reader the option to extract individually relevant information.

The explicit focus on a predefined content through initial filtering makes the map legend more or less dispensable. Since in most cases only one thematic layer, according to the search – like "restaurants" – is mapped, in general unique symbols are used. A further graphical differentiation for the sake of additional information communication is not common, since it can lower the readability and additional information can be communicated in a consecutive step anyway. Despite this, some platforms discriminate among the symbols in order to reflect relevance, rating or popularity[9] although this is – depending on the general concept of a platform – usually reflected in the selection of results or ranking in a list. An example for a reasonable differentiation of symbols can be found in the next section.

In contrast to most provider-driven platforms, the design of map symbols (selection of shape, size, color etc.) in collaborative mapping projects [20; 21] is entirely up to the user.

- A graphical differentiation of map symbols is not common because of initial filtering or search. However in some cases differentiations are applied in order to communicate the intention of the provider.
- Most applications do not offer legends since the commonly used unique symbols show the result of an initial query and base map symbology (Google Maps, OSM, Bing Maps etc.) is widely known.

5.2. Intention of the Provider

The graphical and technical design of transactional map symbols depends highly on the intention and business model of the provider respectively. Ideally the user is guided to and attracted by the most relevant content from a provider's point of view. This can be mainly achieved by visual variables [22] like size, color hue, transparency and any kind of effects.

Effects can help to navigate the user to the intended target. Mouseover-effects, for example, change the appearance of symbols when touched by the mouse pointer and signal that additional information for a certain object is available. The typical application of visual variables for the design of transactional map symbols can be illustrated by the following example. A web-platform provides freely available directory searches and visualizes search results in an overview map. Any information related to resulting entries is address-based and consequently connected to the map symbol. The service is financed by commercial ads which in turn are higher rated and

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[9] http://www.herold.at/gelbe-seiten/vorarlberg/museen-ausstellungen/karte/ [13.01.2011]

displayed more prominently than conventional entries. In this sense, visual prominence is auctioned. In addition to a pure selection mechanism, commercial entries can be highlighted by more extraordinary or more noticeable map symbols. Shape, size and color hue variation are commonly used to meet this purpose. Analogous business models can be found behind real estate platforms[10], yellow pages[11] or city guides[12].

- Visual differentiation of symbols is used in some cases for guidance and attraction.
- Effects, like mouseover, are utilized for effective guidance of users and to enhance attractiveness. Quite often an excessive application leads to unfavorable visual noise.[13]

5.3. Resolution & Display Dimension

From a technical point of view the design of transactional symbols basically depends on the display resolution and dimension of the map medium. In the case of embedded maps the window resp. object size is decisive. Low resolution or small displays require simple and unambiguous map symbols. As the functionality of transactional symbols is often used for mobile apps, complex symbols with multiple information layers are generally put aside. Since the attractiveness and usability of map applications are of major interest, it is crucial to keep every single symbol selectable with any device (e.g. mouse, touchscreen). If too many locations or objects meet the initial search criterion a selection algorithm has to be applied. This will be dealt with in the next section.

In most cases the basemap exhibits a comparably high degree of generalization due to potentially small displays and/or low resolution. A clear cartographic hierarchy can be observed between the basemap and the actual content represented by transactional map symbols.

- Large and concise transactional map symbols are utilized on comparably quite generalized basemaps.
- Ideally, symbols are individually selectable.

5.4. Scale & Zoom Level

In most cases the size of transactional map symbols is not proportional to the scale or zoom level but retains as initially fixed[14]. Preventing the map image to be visually overloaded different selection algorithms can be applied. Google Maps, for example, maps a constant amount of POIs, whereas Bing Maps focuses on POIs, located in the central area of the map[15].

In the case of small scale representations sometimes more entries exist in the database than can be meaningfully mapped. This problem increases with low resolution or small display dimensions. Depending on the purpose of the map and on the

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[10] http://www.nestoria.co.uk/covent-garden/property/buy# [13.01.2011]

[11] http://www.herold.at/gelbe-seiten/vorarlberg/museen-ausstellungen/karte/ [13.01.2011]

[12] http://boston.citysearch.com/listings/boston-ma-metro/group_dining/82075_11269 [13.01.2011]

[13] http://www.pubguidedublin.com/ [13.01.2011]

[14] http://www.qype.com/ [10.01.2011]

[15] These different strategies can be easily observed when searching for any business in http://maps.google.com/ or http://www.bing.com/maps/.

provider's intention, different approaches are observable (cf. [23] for conceptual details):

a) Selection of a delimited number of symbols. The selection can be regulated by ratings, relevance, popularity, spatial distribution or commercial interests (ads purchase)[16].

b) A symbol represents several symbols on a higher zoom level. This can be communicated by annotations or effects[17].

c) All database entries are mapped despite overlaps in order to communicate the density of relevant locations, objects or incidences. In this case the principle of individually selectable symbols is violated, but additional information – comparable to dot density maps – is communicated. Most often this method is applied following commercial or political intentions (e.g. Crime Mapping[18]).

The extensive dissociation of symbol size and scale/zoom level indicates the discussed shift from a pure cartographic paradigm to a more general framework of geocommunication, dealing with specific, user-requested information. Consequently the map cannot be used for questions, like "How do I get from A to B?", but answers specific, user-generated requests, like "Where are the best rated restaurants in town?".

• Symbols have a fixed size and are not adapted to scale or zoom level.
• Depending on the scale/zoom level, selections or alternative graphical methods are applied in order to prevent the map from visual overloading.

5.5. Perception & Dwell Time

With regard to symbol quality (graphical and functional design) and quantity (number of POIs) two important factors have to be accounted for:

a) Visual perception is limited for physiological and cognitive reasons.

b) The mean dwell time on websites is relatively low.

To attract the user's attention for transactional map symbols resp. the connected information, it is fundamentally necessary to keep the visual communication simple and concise. Mapping too many objects at once leads to capacity overload in the short-term memory [24] and a decreasing attractiveness of the resulting map [25].

Virtually no study result is available about the mean dwell time on websites with maps or to what extent maps influence the dwell time. For news portals a mean dwell time of approximately three minutes per website and session is reported [26]. Given that the portals mentioned in this paper have comparable dwell times, the importance of a straightforward visual communication is obvious. Most providers of map-based portals tackle this challenge with a user-generated preselection and filtering and with a simple and concise design of transactional map symbols.

By putting together limited perceptual abilities and a relatively short dwell time it can be deduced that:

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[16] http://www.yellowpages.com/boston-ma/barbecue [13.01.2011]

[17] http://vfdemo.idvsolutions.com/piracy/ [13.01.2011]

[18] http://www.crimemapping.com/ [13.01.2011]

- Selections are applied in order to focus the user on the most relevant content. Consequently the provider has to "understand" what the user is interested in; the other way round, the users must define what they are looking for.
- Map symbols are kept simple. In analog maps symbols often have several inherent information layers to transport a maximum of content. For transactional map symbols this approach does not seem to be conducive.

6. Conclusion

The shift from classical cartography to geomedia-design [5] is widely recognized and accepted [27]. However, many of the examples cited in this paper already foreshadow the next step towards geointeraction-design for an augmented space. Driven by enormous technical dynamics and the general availability of GI-tools and spatial data, new mapping techniques and map applications arise. This development fundamentally affects map symbols. Instead of representing specific objects in a coded form, they serve as entry points for the interaction with a vast amount of specific location-based entities. The map itself becomes a "Geographical User Interface" (GeoUI) for all applications that pervade the environment prospectively.

In short it can be said that the context of web-cartography as well as the graphical and functional design of map symbols has changed due to the establishment of the Web 2.0 concept [9]. Although transactional map sysmbols might contribute to a better functionality, traditional cartographic design-guidelines are virtually not considered yet in the process of symbol design. On the other hand cartographic design-guidelines will have to "compete" with the new transactional use of mass-market map applications (above all based on Google Maps) that experience an enormous rise of popularity.

The summary of major concepts behind the graphical and functional design of transactional map symbols, presented in this paper should serve as an input in a discussion about to which extent cartographic concepts could improve the point symbol design in a highly dynamical and interactive map environment. On the other hand it can stimulate a discussion about the role of cartography in a growing and very successful broader geo-interaction-design context.

Acknowledgement

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Geographical information systems for research biological resource of the World Ocean in climate fluctuation conditions

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Abstract. The results of GIS technologies application in researches of the World Ocean biological resource changes during climate fluctuation conditions are presented. The databases were created using ArcGIS 9.1 for three regions: Canary upwelling, Scotia Sea and South Pacific. During the analysis some parameters of seasonal and interannual fluctuations of oceanological conditions, as well as biomass fluctuations, and fishing objects distribution were received.

Keywords. Biological resources of the World Ocean, seasonal and interannual fluctuations, Canary upwelling, Scotia Sea (Antarctica), South Pacific, geoinformatic technologies, climatic changes

Introduction

A variety of remotely sensed, surveyed, statistical and species life history data can be integrated through extensive GIS analysis resulting in the seasonal mapping of species population dynamics. This dynamic GIS mapping provides valuable information for fisheries managers, who continuously require background information for developing management scenarios. [1]

Till present day the large amount of data about fishery statistics, biologic parameters of populations, interannual variability of biomass and distribution of bioresources was collected. The data which characterize environmental conditions in the Canary Upwelling region was collected as well. The Geographic Information System technology is the most appropriate instrument for maintenance and analysis of such database.[2]

In respect of monitoring ocean and fisheries dynamics and generating new information-based management schemes, GIS technology is closely related to several other technologies, such as Global Positioning Systems, Remote Sensing, modeling, image processing, spatial statistics as well as the Internet (Figure 1).[1]
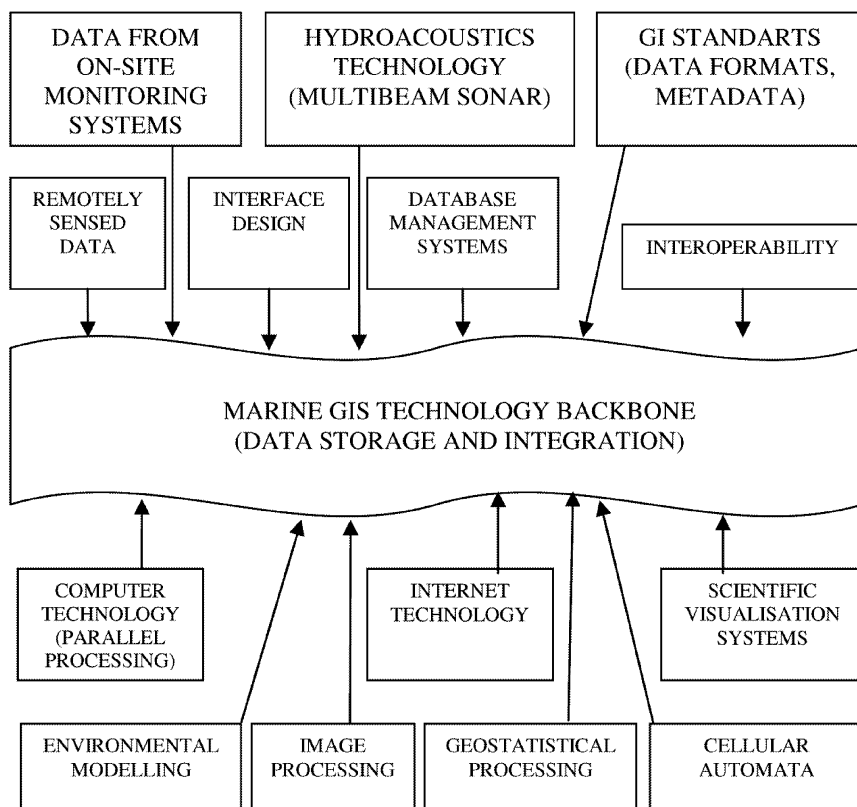
Figure 1. A diagram that show the variety of technological disciplines and issues, which are highly associated with the main core of marine GIS technology [1]

1. Data and methods

Biological resources of ocean suffer meaningful changes under influence of habitation environment (oceanological conditions). It is exactly strongly appears in Canary upwelling region(small pelagic fishes), Scotia Sea (Antarctic krill – Euphausia Superba) and in South Pacific (jack mackerel). So, therefore, exactly for that regions were created databases in the first order. Databases was created in AcrGIS environment and performed the researches of oceanologic conditions influence on the biological resources state. [3-5]

For the analysis were used multidimensional statistic methods: fields decomposition on main components and cluster analysis. The scheme of functioning of created system represented on Figure 2.

Remotely-sensed data
- Atmospheric pressure
- Sea Surface Temperature
- Climate value of
  temperature and salinity

Field data
- Temperature and salinity data
- Fishery fleet distribution
- Length composition of fish
- Age group of fish

| ArcGIS 9.1 ArcView | + | Spatial Analyst |

Enter, keeping and processing geodata
SQL – query
Spatial interpolation
Creating of inventory, synthetical and
analytical charts
Export geodata to user application

Anomaly processing
Gradient processing
Zoning
Mathematic functions
with geofields
Overlay operations

Figure 2. Using ArcGIS 9.1 for research biological resource

2. Results and Discussions

2.1. Canary Upwelling

First One of the main oceanographic features of waters off the Northwest African coast is boundary between North Atlantic Central Waters (NACW) and South Atlantic Central Waters (SACW), which occurs near Cab Blanc. Location of this boundary can be well defined on the basis of oceanographic survey. Multivariate statistical analysis of temperature and salinity data, which had bee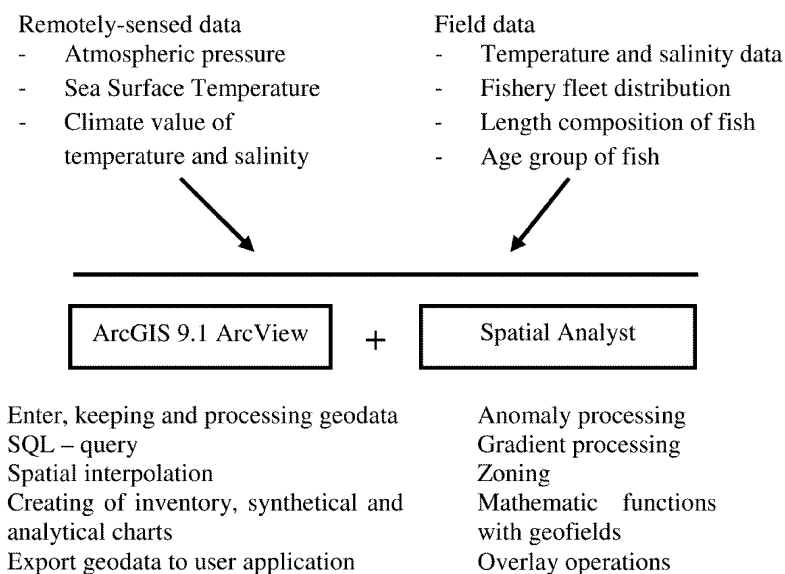n obtained in eight cruises in the Canary Upwelling region in 1994-2007, was applied to reveal spatial variation of the boundary in the upper layer. The main reason of the boundary shifts is dynamic factor, such as intensity of the North Brunch of Equator Counter Current (NECC) and Canary Current (CC).

Number of comprehensive surveys which were carried out off Northwest African coast in 1994-2007 demonstrated that interannual variability in recruitment abundance and distribution might be partly explained by environmental factors. The main factors are mesoscale physical processes (e.g. coastal upwelling, eddies and hydrographic fronts). Data of remote sensing (e.g. satellite altimetry) are good addition to the in situ measurements and allow revealing peculiarities of environmental conditions. The analysis revealed that in some cases interannual variability of the recruitment abundance index might be caused by cohort's abundance rate, while in the other cases the index was mostly influenced by survey conditions. Thus, it was quantitatively demonstrated that environmental share might prevail among all the other factors.[3,6]

2.2. Scotia Sea

In this work the variability of dynamic processes in the atmosphere and ocean (atmospheric transport, geostrophic circulations, water masses structure, krill drift) are considered in the western part of the Atlantic sector of Antarctic in relationship to pelagic ecosystem parameters and distribution of krill being the major element of this ecosystem and traditional fishing object . The available data for 1960-2008, including oceanographic and meteorological observations, data of acoustic and trawl surveys, catch statistics were used as initial material. Presenting the research results, the authors pay a special attention to historical and current areas of krill fishery in the Scotia Sea: Orkneys Subarea (Subarea 48.2), South Georgia Subarea (Subarea 48.3), Antarctic Peninsular Subarea (Subarea 48.1).

It is demonstrated that variability of oceanographic conditions in the Scotia Sea fishing areas are determined by large-scale atmospheric processes occurred within the latitude band 40°-65°S, dynamic regime of the central and southern branches of ACC, intensity of the western periphery of the Weddell Circulation. Inter-annual fluctuations of climatic conditions in the studied areas are characterized with long-term trends of 30-40 years in duration. The synchronous fluctuations have been revealed in the atmospheric pressure anomalies fields at the sea level and in SST anomalies in fishing grounds of the Antarctic sector of the Atlantic Ocean. These variations interpreted as quasi-four-year Antarctic circumpolar wave are typical to all areas researched.

The assessment of krill geostrophic transport characteristics in the Scotia Sea Subareas were fulfilled, and the impact of transport on the krill distribution and operational indices of commercial vessels in the fishing grounds were demonstrated. Typification of the water masses horizontal circulation and associated krill distribution based on long-term scientific observations and fishery data was provided; besides, biomass estimates and its commercial importance, factors of krill drift in different modifications of the Antarctic water masses were demonstrated.[4]

2.3. South Pacific

The cycles of 2.8, 3.6 and 5.2 years are clearly distinguished in the inter-annual trend of the first and the second PC of Sea Surface Temperature.

The area classification with the cluster analysis divides it into 5 classes.

Class 1 surrounds STO area from the South America coast at 35-40°S to the north-west, west and south-west up to 50°S and 175-180°W. Class 2 is located in the Peruvian Current and Southern Trade-Wind Current areas. Class 3 is situated closer to the central part of the subtropical circulation (30-40°S, 95-135°W). Classes 4 and 5 cover the most part of STO to the south of 40°S. The boundary between them is at 130°S.

In the inter-annual trend of the mean-class SST anomalies the cycles similar to PC are observed.

The ocean level anomalies provide information on the currents field. They allow to calculate the geostrophic velocity anomalies, absolute velocity of the geostrophic currents, kinetic eddy energy (KEE) being maximum in the jet flows with high velocities from 25 to 50 cm/s and higher.

Currents at the boundaries of STO subtropical circulation are characterized with velocities from 1 to 20 cm/s on average. On the map of average long-term eddy energy their velocity values do not exceed 25 cm2/c2 [5,7]

Analysis of the principle components and classification (Word's method) of the atmospheric pressure and sea-surface temperature fields allowed to reveal the areas considerably differed in the seasonal and inter-annual variability pattern in the South Pacific Ocean.

Analysis of the ocean level anomalies on the basis of satellite altimetric data allowed to determine zones of intensive eddies formation associated to the main frontal zones of the ocean upper layers.

3. Conclusion

Presented results are preliminary, though 3D temporal model of frontal zone which divides intermediate waters of Antarctic and Arctic origin were created for Canary upwelling region.

Antarctic waters contains much considerably more biogenic elements, so that model allows to estimate tendencies of biological productivity changes at the region of Canary upwelling, which in turn renders assistance for planning fisheries in climate fluctuation conditions.

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Individual Geographic Stream Processing for Driver Assistance

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Abstract. Today more and more sensors are available, that measure different obstacles on the street. However, these measurements of events are not available while driving a car. Sensor information and especially predictions and aggregations of these events could be used to assist our driving behavior, e.g., inform the driver about possible problems on the current street or problems in a next street closed by. In this paper, we introduce a way to allow the car to perform complex event processing on predicted sensor data. Hence this event processing allows the driver to change her driving behavior accordingly.

Keywords. Datastream Processing, Geographic Aggregation, Driver Assistant

1. Motivation

Today a wide range of information sources exists that could support driving behavior at the current or even future position. These sources include GPS data from transport vehicles, current weather data, measurements from induction loops, and information from the CAN bus of different car vendors. Even micro blogs and social networks provide traffic information to everyone. For example a fraction of 0.05% of the twitter messages include traffic information [5]. Even today traffic systems provide information on traffic problems nonetheless they only report just a few of such traffic problems and we as a driver combine these information to a scenario that probably will happen in the future. What is needed here is a way to process driver related data in a fast and flexible way, perform prediction of upcoming events, and allow a complex event processing on the individual predicted events to support the drivers.

2. Related Work

The goal of this PhD thesis is the complex event processing (CEP) of predicted geographic data from heterogeneous sensor sources in cars. The requirement for a processing of multiple data streams from heterogeneous sources in cars is the communication between the car or the driver to other cars and the environment. In the field of Vehicular AdHoc Networks (VANET) multiple communication standards and routing strategies are proposed [15]. These communication protocols are used in several projects [7,6] to provide location-aware services, traffic monitoring, and collision detection. However, these works only cover the communication of data between the cars and the environment and can only warn or inform drivers when an

event happened. A prediction and especially an individual geographic event processing are not possible yet.

Current work on the prediction and processing of moving objects are done using Moveable Object Databases (MOD) [11]. MODs store object information persistent in a database [8] and use index structures optimized for select and update queries. However, in driver scenarios a moving object is only a matter of concern for a short period of time resulting in continuously insert queries and delete queries at a high frequency [4].

An approach for flexible processing of data streams are Data Stream Management Systems (DSMS). A DSMS allows the processing of continuously incoming data through a temporal extended relational algebra [3]. DSMS systems like Stream Spinner [13] and PLACE [10] also tackle the processing of geographic data streams. However these systems do not provide prediction of geographic data and complex event processing of the geographic data is not supported. To perform processing and especially detection of multiple events based on predefined pattern different approaches like rule-engines and complex event processing engines exist. CEP languages like SASE [12] allow the definition of complex events through multiple operators like loops and sequences. However both approaches do only allow the detection of events on the current and previous events and do not support the complex event processing on predicted events and their different probabilities.

The prediction of events in data streams are targeted by several research groups especially from the field of data mining and machine learning using a concept model [14]. Other approaches use prediction functions either embedded into the data stream [9] or predefined in the query [2]. These works only cover the prediction itself and not the further processing on the predicted events and their probability.

3. Complex event processing on predicted geographic events

Current CEP engines use a non-deterministic finite automaton (NFA) to represent a pattern query [1]. This NFA is defined as $A = (Q; E; \square; q_1; F)$ and consists of a set of states, Q, a set of directed edges E, a set of formulas $\square$, labeling those edges, a start state, q_1, and a final state F. A changeover from one state to a successor state connected by an edge only happens when a given input event confirms the given formula on the edge. A changeover into multiple states can also happen in case of non mutually exclusive formulas. The naive approach to perform complex event processing on predicted events would be the continuous generation of events through a prediction function. This approach would lead to a high overhead for the CEP engine. Further the probability of predicted events is not handled by current CEP engines.

A more efficient approach would be the transformation of the prediction function into inequalities depending on time as a variable as shown in [2]. These inequalities in combination with the condition for a changeover of the state only have to be checked at a given time and not continuously.With ongoing time and new probabilities of predictions the states in the NFA can become invalid. This happens especially when the probability of a predecessor state has changed to zero or below the probability of the formulas on the edges. In this case all successor states become invalid too.

A further aspect to keep in mind is the definition of the pattern using a query language. Current query languages for defining complex event processing on data streams only target current events and previous events. To allow a query formulation

on previous, current, and future events different query languages will be analyzed and the grammar will be extended to define the event processing on predicted events.

4. Conclusion

The presented concept will support the driver of a car in the daily use. This will be achieved through an individual event processing of predicted geographic sensor data. Targeting research topics include the event processing of predicted geographic data with their different probabilities and the pattern definition using a query language.

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Virtuell kuren – mit einem WebGIS

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Abstract. Im nationalen und internationalen Wettbewerb um Kur- und Badegäste und um selbst zahlende Wellness-Besucher müssen traditionelle Kurorte ihr Alleinstellungsmerkmal schärfen und auch im Informationsangebot zeitgemäßere Wege gehen. Die hessische Kur- und Kreisstadt Bad Schwalbach will potenzielle Besucher mit einem WebGIS und dort integrierten thematischen Routen von den Vorzügen ihres Ortes überzeugen.

Keywords. WebGIS, Geoinformationssysteme, Bad Schwalbach, Kurort, Wellness, Geschichte

1. Motivation

Eine mehr als 400jährige Tradition als Kur- und Badeort liegt hinter der hessischen Kreisstadt Bad Schwalbach, nahe Wiesbaden. Diese Jahre waren bewegt. Anfangs noch ein Dorf, in dem man zufällig gesundheitsfördernde Quellen und Moore entdeckt hat, wurde es bald ein Kurort mitten im Taunus, der gekrönte und reiche Häupter anzog. Nach dem 2. Weltkrieg war es immerhin noch ein von den Gesundheitskassen bezahltes „Sozialbad", doch auch diese Ära verschwand mit dem inflationären Einführen von Gesundheitsreformen, verbunden mit immer größeren Kürzungen und Einschränkungen.

Jahrelang waren daher die Staatsbäder ein Zuschussbetrieb des Landes Hessen und die Bäder wurden privatisiert. Auch das Staatsbad Bad Schwalbach kam vor wenigen Jahren mit der Zusage mehrerer Millionen Euro an Fördermitteln vom Land Hessen in das Eigentum der Stadt. Nun, nachdem die Förderung ausgelaufen ist, steht das Bad unmittelbar im Wettbewerb zu vielen Bädern im direkten regionalen Umfeld (Bad Ems, Schlangenbad, Bad Soden, Wiesbaden, Bad Kreuznach), aber auch zur großen internationalen Konkurrenz und dem seit Jahren boomenden Markt der Wellness-Angebote.

Ein Instrument unter vielen, das die öffentliche Wahrnehmung für den idyllischen Ort im Taunus schärfen sollte, ist ein WebGIS mit für den Tourist oder Kurgast interessanten Routen rund um den Ort und innerhalb desselben.

2. Ein WebGIS für die Kur

Drei Rundgänge wurden in der Pilotversion implementiert: Die „Berühmten Köpfe" [1], die in der Stadt früher lebten oder kurten, die zahlreichen „Brunnen" [3] im

Stadtgebiet und bedeutende oder historische Gebäude (die so genannten POI – Point of Interrests).

Die Rundgänge werden in einer separaten Kartenansicht dargestellt, wobei die Popup-Funktion und der Aufruf der POI-Seiten via WFS geschehen. Hierfür wird ein
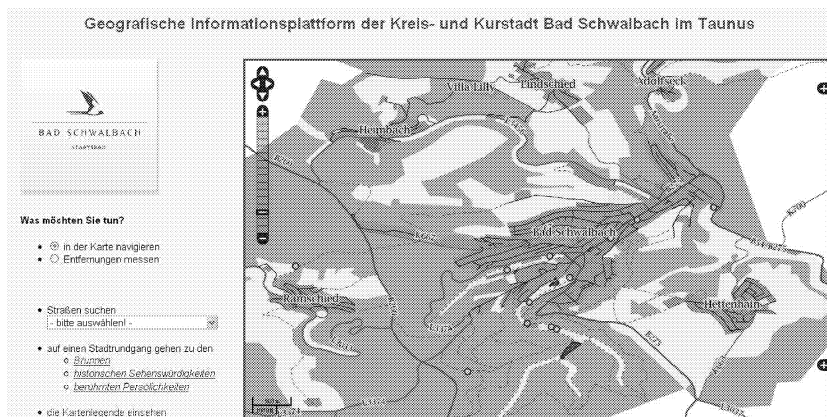

Abbildung 1: Eingangsseite von SchwalbIS, dem WebGIS der Stadt Bad Schwalbach

eigens dafür in JavaScript geschriebenes Programm verwendet, das im Programmpaket von GeoServer 1.6.4. mitgeliefert und für die hier beschriebenen Rundgänge adaptiert wurde. Um künftig nicht in die Abhängigkeit propietärer Anbieter zu geraten und darüber hinaus auf gängige Standards zu setzen, wurde das WebGIS komplett mit OpenSource-Software realisiert (siehe Abb. 2).

Als Kartenserver kommt ein GeoServer und als Webserver Apache Tomcat zum Einsatz. Die Geodaten werden entweder als Shapes und Coverages in Geoserver oder in der Datenbank PostgreSQL/PostGIS bereitgehalten, derzeit noch als Option, weil die Stadt mit ihren Informationen im „normalen" Webauftritt und dessen Provider eine andere Datenhaltung realisieren. Mittels WMS (Web Mapping Service) können weitere, frei verfügbare Informationen von externen Datenbanken eingebunden werden. Die Kartendarstellung erfolgt mit OpenLayers.

Das WebGIS ist über die Webseite der Stadt Bad Schwalbach zu erreichen (Subdomain). Die Startseite besteht aus der Kartenansicht der Kurstadt mit ihren Stadtteilen und den Funktionen „Navigation – Zoomen", „Straßensuche" und „Entfernungen messen" sowie jeweils einem separaten Link zu den drei unterschied-lichen Rundgängen. Zudem können Kartenlegende, Hilfe und Impressum eingeblendet werden (siehe Abb. 1).
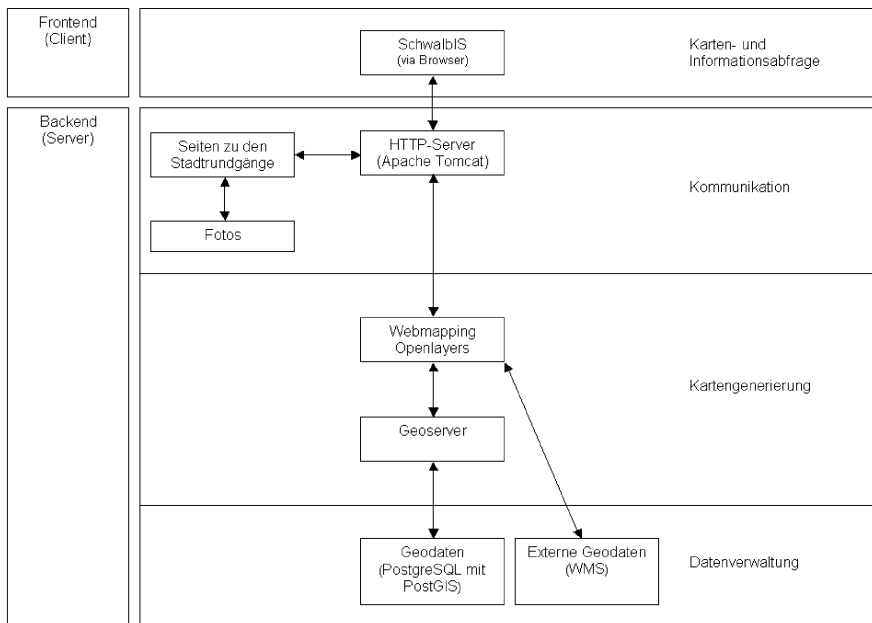
Abbildung 2: Systemarchitektur des WebGIS "SchwalbIS" (Grafik modifiziert nach [2])

3. Fazit

Da *SchwalbIS* erst im Frühjahr 2011 „online" ging, fehlen derzeit noch Ergebnisse der Anwender. Konzeptionell ist das WebGIS erweiterbar, so auch um Video-Sequenzen mit entsprechenden Landschafts- oder Straßenansichten oder mit Inhalten zur Geschichte, die z.B. direkt aus dem örtlichen Museum integriert werden könnte. Auch eine eigene Version für Smartphones wäre eine Option. Als Instrument potenzielle Besucher von Vorzügen und Einzigartigkeiten, sowie über historische Hintergründe vorab online zu informieren hat es aber schon heute einen Vorzug gegenüber klassischer Werbung von Kurorten.

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Flex-I-Geo-Web - ein dienstebasierter Softwarebaukasten zur Standortentwicklung

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1. Motivation

Unternehmerische, private wie auch behördliche (Investitions-)Entscheidungen, deren Folge Flächenversiegelungen auf bislang natürlichen oder naturnah genutzten Flächen sind, beruhen nicht selten auf unvollständigen Informationen über mögliche Alternativen in bereits erschlossenen Gebieten oder über brach liegende, umnutzbare Altflächen. Es erscheint häufig attraktiver, Gewerbegebiete oder Wohnbebauungen auf der viel zitierten „grünen Wiese" zu errichten, weil hier freier geplant werden kann als in bereits entwickelten und verdichteten Räumen.

Eine Ursache für Neuplanungen außerhalb von Siedlungsbereichen sind oftmals Schwierigkeiten die notwendigen Informationen und Rahmenbedingungen für die Nutzung innerstädtischer Brachen und Baulücken zu beschaffen. Solche Planungsvorhaben benötigen neben Geobasis- vor allem Geofachdaten. Diese reichen von sozioökonomischen Bevölkerungsdaten über Verkehrsdaten oder Informationen zur Anbindung und Kapazität innerstädtischer Ver- und Entsorgungsnetze bis hin zu Informationen über die umgebende Fassadengestaltung, um Neubauten harmonisch ins Stadtbild einzufügen oder mit ihnen Impuls gebende Akzente zu setzen.

Projektentwickler, Bauherren und Architekten stehen dabei vor der Abwägung sich auf einen möglicherweise langwierigen Prozess der Informationsbeschaffung und -bewertung einzulassen oder von vornherein auf der „grünen Wiese" zu planen. Die Waage neigt sich vor diesem Hintergrund häufig in Richtung Neuerschließung, was zu wachsendem Flächenverbrauch mit vielfältigen ökonomischen und ökologischen Folgen führt (vgl. Schiller et al. 2009).

Einen Beitrag zur Lösung des dargestellten Problems könnte ein webbasiertes Informations- und Analysesystem leisten, das die entsprechenden Daten bereit stellt und sie intuitiv verständlich darstellt sowie dem Benutzer erlaubt, seine lokalen Projektparameter einzustellen, um so attraktive Flächen für sein jeweiliges Vorhaben in einem individuell gestaltbaren, mehrstufigen analytischen Prozess eigenständig zu ermitteln. Dies kann aus vielerlei Gründen kein fertiges oder gar geschlossenes Onlineportal sein, weil kein Betreiber die Vielzahl denkbarer Informationswünsche der

Nutzer vorhersehen kann. Es liegt daher nahe, international anerkannte OGC Spezifikationen und Standards einer Geodateninfrastruktur zu nutzen, um einen Open-Source-basierten Softwarebaukasten zu entwickeln. Dieser erlaubt es interessierten Anwendern intuitiv, zu beliebigen Fragestellungen mit Raumbezug schnell und einfach webbasierte Onlineportale zu realisieren, die zahlreiche Software-Funktionalitäten ebenso zur Verfügung stellen, wie sie vorhandene GDI-Komponenten nutzen, um beliebige Daten einzubinden.

Flex-I-Geo-Web ist ein gemeinschaftliches OpenSource Entwicklungsprojekt von 8 Mitgliedern der Geo-Initiative der Region Bonn. Projektpartner sind das Fraunhofer Institut IAIS, das Geographische Institut der Universität Bonn, die Industrie- und Handelskammer, die Wirtschaftsförderung der Stadt Bonn und 4 innovative GIS-Unternehmen aus der Region (CPA, lat/lon, interactive instruments, WhereGroup). Das Projekt wird im Rahmen des Technologie- und Innovationsprogramm NRW aus dem Europäischen Fonds für Regionale Entwicklung (EFRE) gefördert. Die Laufzeit des Projektes beträgt 2,5 Jahre und endet im Oktober 2011.

2. Umsetzung des Projektes

Bei der Realisierung des Projektes wird vor allem auf die Integration und Interaktion serverbasierter Dienste gesetzt, sowohl bei der Bereitstellung der Daten als auch bei deren Verarbeitung. Dem entsprechend können Kartendienste über die OGC WMS Schnittstelle eingebunden werden, Datendienste über die OGC WFS Schnittstelle. Eigene Daten des Benutzers können georeferenziert über ein Interface in ein Karten- oder Datendienst überfuhrt und zur weiteren Verarbeitung bereitgestellt werden. (Abb. 1) Mittels transaktionalem Zugriffs auf einen WFS ist es möglich die eigenen Daten zu verändern und somit aktuell zu halten.
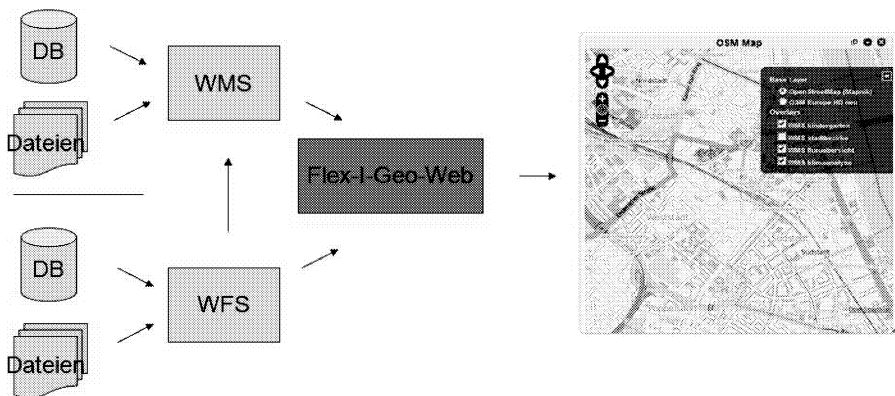
Abbildung 1: Bereitstellung von Datenquellen innerhalb von Flex-I-Geo-Web

Eine zentrale Rolle im Projekt nimmt die Integration des WebProcessingService (OGC WPS 1.0.0) in das Framework ein, über den beliebige standardisierte Geodatenverarbeitungsdienste und Analysefunktionen in Webportale integriert werden können. Damit ist das gesamte System in seiner Funktionalität sehr flexibel und durch das Einbinden weiterer, je nach Anwendungsfall benötigten, Prozesse unbegrenzt

erweiterbar, was auch eine Kombination einzelner atomarer Prozesse zu einer Prozesskette einschließt, beispielweise um einen wiederkehrenden Workflow abzubilden.

Ein im Rahmen des Flex-I-Geo-Web Projektes entwickelter WPS-Client soll dabei ermöglichen, dass Web Prozesse über eine graphische Oberfläche einfach angesprochen und konfiguriert werden können. Der WPS-Client fungiert dadurch als Bindeglied zwischen dem Webportal und den Prozessen, über die unterschiedliche (Berechnungs-) Funktionen für das Projekt bereitgestellt werden (Abb. 2).

Abbildung 2: Einbindung von WPS in das Flex-I-Geo-Web Framework

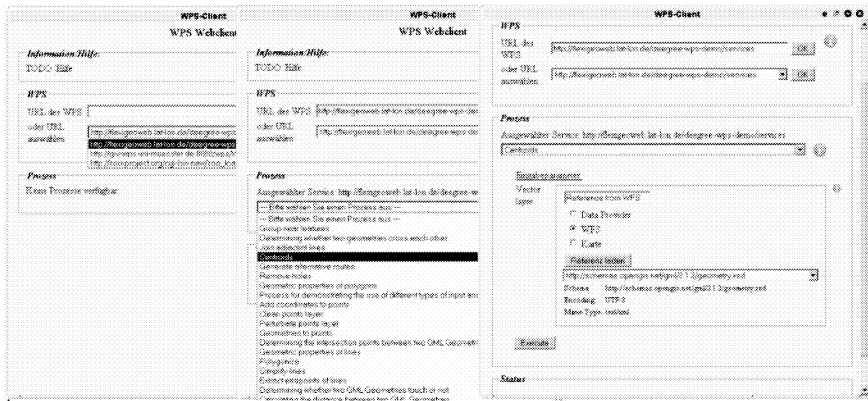Zu den weiteren Diensten und Funktionen, die innerhalb des Flex-I-Geo-Web Baukastens bereitgestellt werden, gehören neben den angesprochenen Werkzeugen zur Interaktion mit Karten- und Datendiensten wie auch zur Integration eigener Datenquellen weitere Analysewerkzeuge für Daten und Ergebnisse sowie ihre grafische Aufbereitung und Visualisierung. Sie bieten dem Nutzer die Möglichkeit ihre Daten oder Ergebnisse beispielsweise zu klassifizieren, gewichten, filtern oder zu sortieren. Ein entsprechendes Werkzeug hilft bei der Erstellung und Ausführung aus einzelnen Funktionen zusammengesetzten Workflows. Die verwendeten Daten und die aus ihnen gewonnenen Ergebnisse können anschließend mittels eines Reporting-Werkzeugs templatebasiert ausgedruckt oder als PDF exportiert werden.

Ein standardkonformes Rechtemanagement als Servicekomponente für den Zugriff auf Dienste und Daten sichert das Portal sowie die Nutzerdaten ab. Es basiert auf den einschlägigen Normen ISO/IEC 2700x sowie auf Spezifikationen des Bundesamtes für Sicherheit in der Informationstechnik (BSI). Für das Rechtemanagement werden die entsprechenden Standards des OGC (GeoRM) hinzugezogen, insbesondere für die Anwendungsfelder Authentifizierung (Identitätsprüfung), Authentisierung (Identitätsnachweis), Autorisierung (Prüfung der Zugriffsberechtigung), Unterstützung von Lizenzmanagement und Lizenzhandel sowie die Unterstützung von Abrechnungsprozeduren. Dadurch soll eine Interaktion mit lizenzpflichtigen und kostenpflichtigen Datendiensten über ein Abrechnungmodul übernommen werden können. Die Interaktion der Sicherheitskomponente mit dem Portal erfolgt über eine einfach konfigurierbare und intuitive Benutzeroberfläche.

Die technische Architektur des Projektes folgt seiner Konzeptionsidee einer Client-Server Architektur mit ausgelagerten Serverdiensten für Daten und Berechnungen und

einem Klienten im Browser, über den die Steuerung der Dienste sowie die Visualisierung das Daten und weniger rechenintensive Auswertungen vorgenommen werden können. Zudem werden in dem Framework teilweise unterschiedliche Lösungen der beteiligten Projektpartner integriert.

Der Web-Client basiert hauptsächlich auf HTML Seiten und JavaScript. Der die Anwendung steuernde eigene Anwendungskern ist ebenfalls in JavaScript programmiert. Zum Einsatz kommen weiterhin die Bibliotheken jQuery, jQueryUI und zur Visualisierung die OpenLayers Bibliothek. Serverseitig basieren die Komponenten auf Java. Zur Einbindung der Java Komponenten werden JavaServerPages (JSP) sowie JavaServerFaces (JSF) eingesetzt. Zusätzlich werden im Projekt auch externe Services, wie der WMS/WFS/WPS Service von deegree sowie eine Benutzerdatenbank eingebunden.

Zeitlich befindet sich das Projekt in seiner Fertigstellungsphase. Das bedeutet, dass noch fehlende Module zeitnah nachgeliefert oder modifiziert werden sowie die Interoperabilität der Module untereinander und mit der Anwendung getestet und nach Bedarf noch angepasst wird. Nach Abschluss dieser Arbeiten wird ein Demonstrator mit einer möglichen Benutzersicht auf das System erstellt, die den Workflow und die benötigten Funktionen abbilden soll und gleichzeitig die momentane Entwicklersicht auf das Projekt ablösen soll (Abb. 3). Die Fertigstellung des Demonstrators ist für das Frühjahr 2011 geplant. Anschließend erfolgt eine weitere Evaluierung des Ergebnisses mit ausgesuchten Zielnutzern, die bereits schon in einer früheren Phase des Projekts eingebunden waren.

Als Demonstrator für das Projekt soll ein Portal dienen, das Standortanalysen zur Suche und individuellen Bewertung von Baulücken, Brachflächen und Leerständen ermöglicht. Mit dem Demonstrator entsteht zugleich ein neues Instrument für Architekten und Bauherren, um eine flächenschonende Stadtentwicklung zu gestalten und ökonomische und ökologische Aspekte ausgewogen abzuwägen.
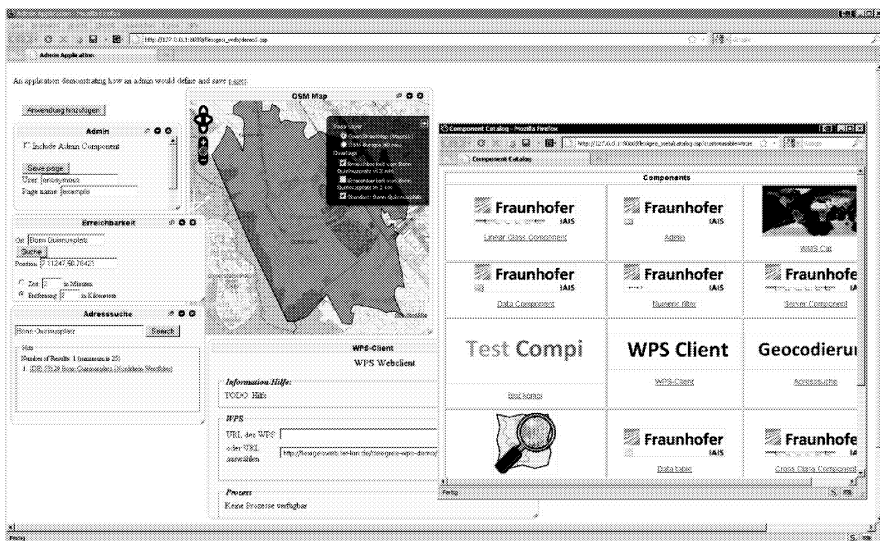

Abbildung 3: Admistrator-/Entwicklersicht auf die Oberfläche von Flex-I-Geo-Web

3. **Resümee**

Durch das Flex-I-Geo-Web Projekt werden die Möglichkeiten zur Analyse von geographischen Daten in einer webbasierten Lösung entscheidend weiter entwickelt. Der Anwender benötigt lediglich einen Webbrowser und Zugang zu einem Geodatenportal mit integrierten Fex-I-Geo-Web-Bausteinen. Mit dem Projekt bietet sich die Chance, eine beispielhafte, frei zugängliche Open-Source-Lösung für einen intuitiv verständlichen Geoinformations-Portal-Baukasten zu entwickeln.

Bei der Umsetzung des Projekts werden bestehende Standards des Open Geospatial Consortium (OGC) unterstützt und weiterentwickelt. Die entwickelten Bausteine sollen nach Projektende der Allgemeinheit verfügbar gemacht werden, um dadurch eine nachhaltige Wiederverwendbarkeit zu gewährleisten. Dabei folgt das Projekt mit der Idee eines flexiblen Baukastens bereits dem Opensource Gedanken, da es einerseits selbst aus Opensource Bausteinen besteht, die für diesen angepasst wurden wie auch auf einer erwarteten höheren Akzeptanz des Projektergebnisses, wenn es individuell auf die Bedürfnisse und den Einsatzzweck des Nutzers frei erweitert oder angepasst werden kann.

Flex-I-Geo-Web ist weiterhin so konzipiert, dass es mit bereits bestehenden Lösungen für Geodatenportale zusammenarbeiten kann. So basiert die Viewer-Komponente des in der Basiskonfiguration auf der OpenLayers API. Um Flex-I-Geo-Web jedoch auch in einer bereits bestehenden Infrastruktur einzusetzen sind Schnittstellen zu Portalen wie z.B. iGeoPortal oder MapBender vorgesehen.

Bei der Entwicklung des Flex-I-Geo-Web Baukastens wird zudem sichergestellt, dass kein Spezialsystem zur nachhaltigen Siedlungsentwicklung entsteht, sondern grundsätzliche Anforderungen an innovative raumbezogene und dienstebasierte Webanwendungen abgeleitet werden. Am Beispiel des Demonstrators in einem online zur Verfügung stehenden Software-Baukasten sollen in Zukunft zahlreiche weitere Nutzungsideen und neue Informationsportale initiiert werden, die eigenständig von Endanwendern oder auch durch Aufträge an beliebige IT-Dienstleister realisiert werden können. Es entsteht dadurch in gewisser Weise ein Katalysator für vielfältige Folgeprojekte. So können mit dem geplanten Demonstrator auch gesamtwirtschaftliche oder gesellschaftliche Fragestellungen angegangen werden, zugleich bewirkt jede neue aus dem Baukasten resultierende Anwendung gleich in zweifacher Weise wirtschaftliche Impulse, zum einen durch Nachfrage beim Aufbau eines Informations- und Analysesystems, zum anderen durch dessen Nutzung.

Ein zentraler Punkt im Projekt betrifft die Bereitstellung von Daten. Die mangelnde Bereitschaft vieler Datenbesitzer die erforderlichen Geofachdaten zur Verfügung zu stellen, birgt sowohl für dieses als auch vergleichbare Projekte Risiken mit sich. Es ist für den Erfolg des angestrebten Demonstrators entscheidend, Software-Services und Datendienste nicht nur technisch zu beherrschen, sondern von Beginn an verlässliche Zugriffe auf reale, möglichst flächendeckende Datenbestände anzubieten. Vielfach liegen die notwendigen Informationen als (Geo)-Fachdaten in der Verantwortung einzelner Fachämter, bei Stadtwerken oder in kommunalen Unternehmen vor, die häufig restriktiver als fachlich notwendig mit „ihren" Daten umgehen. Zahlreiche Forschungs- und Entwicklungsvorhaben einzelner

Projektbeteiligter konnten ihr Potenzial in der Vergangenheit deshalb nicht voll entfalten.

Damit kann dieses Projekt zugleich für die Beispiel-Region Bonn unter enger Einbindung der politischen Spitzen einen Prozess anzustoßen, der zu einer Grundsatzentscheidung der Entscheidungsträger führt, alle öffentlichen Daten im Rahmen und zumindest für die Dauer der Projekt-Entwicklung ohne Nutzungsbeschränkungen zur Verfügung zu stellen, soweit sie als personenbezogene Daten nicht unter datenschutzrechtliche Bestimmungen fallen. Für die Datenanbieter bietet das Projekt auf lange Sicht eine neue alternative Plattform um ihre Geodaten anzubieten, zugleich auch die Möglichkeit einfache Abrechnungsmodelle zu evaluieren und zu harmonisieren. Ein Erfolg dieses Vorgehens kann in Zukunft weitere Kommunen und Kreise dazu ermuntern ihre Daten ebenso auf einem vergleichbar einfachem Weg über Webservices anzubieten.

Eine zuletzt nicht zu unterschätzende Innovation ist die Möglichkeit des Flex-I-Geo-Web Baukastens, potenzielle Endanwender zu aktiven Entwicklern zu machen. Wenn man so will, sind dies erste Beiträge zu einem Web 3.0-Konzept, in dem nicht mehr nur der Content nutzergeneriert sein wird (Web 2.0), sondern auch Software und Prozesse. Sämtliche im Rahmen des Projektes entstandene Softwarekomponenten werden als Open-Source Lösung frei zur Verfügung stehen, sowie neue Standards und Spezifikationen in einen internationalen Abstimmungsprozess eingebracht. Dies regelt den allgemeinen wie gegenseitigen Zugang zu den in den Arbeitspaketen erzielten Ergebnissen

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Challenges and Advantages of using GPS Data in Outdoor Advertisement

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Abstract. A growing number of companies use mobility data in their day-to-day business. Especially in the area of outdoor advertising, GPS devices have been successfully applied in order to measure poster performance in recent years. Based on personal mobility traces, the quality and precision of performance measures has increased significantly. However, the usage of GPS technology poses several challenges when applied to critical business processes. We will present several challenges and solutions which we developed in the last years of our mobility research with GPS data.

Keywords. mobility surveys, GPS data, outdoor advertising, missing data

Introduction

Outdoor advertisement is one of the oldest advertising media and continues to play an important role in the advertisement industry. In 2008 the turnover was 684 million CHF (about 460 million Euros) in Switzerland and 805 million Euros in Germany.

In recent years the market has changed rapidly. The change is predominately caused by two factors, namely the competition with other advertising media and the emergence of digital media. First, outdoor advertisement competes with other media including the classic television, radio and press as well as the modern online ads and direct mailing. In order to become incorporated by media planners in an advertisement mix, transparent measures are needed for the performance of a campaign. Typical measures are (1) the reach of a campaign, which is the percentage of persons within a target group defined by socio-demographic attributes that has had contact with a campaign in a certain time interval (often one week), and (2) the number of total contacts this group has had.

Improved methods for audience measurement have become available in the last years due to technological advances and improved methodology. E.g., for performance measurement of cars and pedestrians on street, GPS technology has established itself as a new standard in Switzerland and Germany, greatly improving the possibilities of fine-grained media planning [1]. Other countries, such as Austria and the UK, are currently preparing GPS studies, and it can be expected to become a worldwide standard.

This paper is based on two industry projects of Fraunhofer IAIS that are concerned with audience measurement in outdoor advertising in Switzerland and Germany. Both projects have raised numerous challenging questions and led to many developments concerning the industrial use of GPS data. In this paper we give a collection of challenges and solutions that need to be addressed in similar applications.

1. Mobility Surveys in Germany and Switzerland

The Arbeitsgemeinschaft Media-Analyse e.V. (ag.ma), a joint industry committee of German advertising vendors and customers, commissioned a nationwide mobility survey as basis for an objective performance evaluation of outdoor advertisement. The survey was conducted using two different observation policies. In the first part a nationwide representative sample of 31000 persons was interviewed and queried about their movements of the previous day in a Computer Assisted Telephone Interview (CATI). In the second part 11700 persons were provided with GPS devices for a period of 7 days.

Swiss Poster Research Plus (SPR+) is a neutral research organization of the Swiss outdoor advertising branch. SPR+ equipped a representative sample of test persons with a GPS logger for a period between 7-10 days. In total, the survey includes more than 10000 participants.

In addition to mobility data both empirical studies contain information about the poster sites (235000 in Germany and about 55000 in Switzerland). Besides geographic coordinates, a visibility area for each panel is defined from within which the poster is likely to be seen. Given the trajectories of an individual and the visibility area of a poster panel, all resulting passages can be calculated by geographic intersection and the performance measures can be derived. A formal, application-independent description of the scenario has been given by Körner et al. [2]. Although the calculation sounds easy at first sight, several challenges, including missing measurements, small spatial variability and obfuscated movements within objects, have to be handled to derive valid values for poster performance.

2. Application Challenges

In this section we give a short introduction of the challenges in measuring poster performance with GPS data.

2.1. Missing measurements

GPS mobility studies contain different types of missing measurements. First, short interruptions occur due to tunnels, street canyons or the warm-up phase of a GPS device. Second, single trips within a day may not be recorded. For example, people may easily forget to carry the device during a short trip to the bakery. Third, complete measurement days may be missing due to several reasons. The GPS device may have been defective, or people drop out of the study early. Depending on the kind of missing data, different courses of action need to be taken. Short interruptions can be detected during data preparation and can be closed using routing algorithms. The second and third type of missing data pose serious problems, because they cannot be identified from the data itself. Usually, only completely missing measurement days are realistic to detect within a mobility study. May et al. [3] analyzed the effects that such a bias can introduce on data mining results.

Moreover one requirement of mobility surveys is that inference about population-wide mobility patterns can be made. Current monitoring technologies as mentioned above easily lead to missing measurements. Missing data is not only uncomfortable to handle but can also introduce a bias in the data sample, which questions the validity of

data mining results. Therefore it is necessary to provide a systematic approach to detect possible sample biases in mobility data due to missing measurements. Hecker et al. [4] show that dependencies between mobility, socio-demography and missing data are not unusual and need attention in the data mining process and apply the approach to a large GPS mobility survey. The core of our approach consists of subgroup analysis, which identifies dependencies in mobility surveys.

2.2. Modeling Micro-Movement Variability

One demand in mobility surveys, especially in outdoor advertising is the high level of spatial detail. The high dimensionality of geographic space, however, makes this requirement hard to fulfill. Even large mobility studies cannot guarantee to comprise all movement variation in large regions. For Germany this would mean to form a representative set of test persons that cover with their movements about 6.7 million street segments in a given period of time. In Germany 42780 test persons cover barely 26.7% of the German street network. However, as mobility studies are very laborious and expensive, it is not realistic to perform larger studies in the near future with GPS technology. It is thus necessary to increase the spatial variability of a given mobility data set while retaining important mobility characteristics of the sample. Hecker et al. [5] introduced a spatial aggregation of the mobility data and a subsequent simulation-driven disaggregation of the data based on information about the traffic distribution.

2.3. Pedestrian Movement Model for Indoor Poster Campaigns

GPS technology has the drawback that it cannot be applied indoors due to signal loss. In Germany and Switzerland many valuable posters are situated in public buildings such as train stations or shopping malls and their evaluation is of high interest. Liebig et al. [6] introduced a method that allows performance measurements for billboards that are placed indoors. The approach is based on obtaining a number of relatively inexpensive frequency counts manually, and to generate a general model for indoor pedestrian movements based on frequency counts and a network of the possible pathways through a train station.

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Dynamische 3D-Zeitreihenvisualisierung in interaktiven Webmapping-Applikationen

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Einleitung

Die dreidimensionale Visualisierung räumlicher Daten findet spätestens seit dem vermehrten Aufkommen von 3D-Stadtmodellen rasche Verbreitung. Im Vordergrund steht hierbei die möglichst naturgetreue Darstellung real existierender unbeweglicher Geoobjekte wie Gebäude, Stadtmöbel etc., die sich über die Zeit wenig verändern. Darüber hinaus gibt es jedoch auch Möglichkeiten, in der dritten Dimension zeitliche Veränderungen von (auch beweglichen) Objekten und ihren Attributdaten zu visualisieren. Zeitreihen finden in einer Vielzahl wichtiger Anwendungsgebiete zur Analyse und Visualisierung langfristiger Daten und zur Erstellung von Trends Verwendung. Einsatzfelder sind z.B. Umweltbeobachtung, Visualisierung von Klimaveränderungen, wiederkehrenden Ereignissen und Naturkatastrophen. Hierbei gestattet und vereinfacht die Kombination von 3D-Darstellung und Zeitreihen bei komplexen Informationen die gleichzeitige Abbildung, Erfassung und Abfrage einer Fülle von Informationen [1][2]. Der Beitrag stellt am Beispiel des Geodatenformates KML und des Google-Earth Plugins aktuelle Möglichkeiten vor, 3D-Geodaten mit Zeitinformationen dynamisch im Browser zu visualisieren. Es werden Vorteile und Restriktionen von 3D-Darstellungen sowie zukünftige Entwicklungen skizziert.

1. Voraussetzungen

Gegenwärtig sind die Möglichkeiten der Visualisierung dreidimensionaler Geodaten unter Berücksichtigung der zeitlichen Komponente als Webanwendung noch wenig entwickelt, kaum standardisiert und erfordern derzeit noch die Installation eines Browser-Plugins.

   Im April 2008 wurde die Keyhole Markup Language (KML) vom Open Geospatial Consortium als offener Standard angenommen.[1] Ursprünglich für die Darstellung räumlicher Daten im Geodaten-Browser Google Earth entwickelt wird die XML-basierte Auszeichnungssprache für Geodaten KML nun auch verstärkt von Software anderer Anbieter und in Webmapping-Anwendungen verwendet. KML lässt die Darstellung zwei- und dreidimensionaler Geodaten, die Einbindung von 3D-Modellen sowie zeitliche Animation zu. Mit der Bereitstellung des für die gängigen Browser

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[1] http://www.opengeospatial.org/standards/kml/

verfügbaren Google Earth Browser-Plugins steht ein virtueller Globus für entsprechende Daten in Webmapping-Applikationen zur Verfügung.

2. Beispiel: Simulation eines Wetterballon-Aufstiegs

Exemplarisch veranschaulichen wir Möglichkeiten der 3D-Webvisualisierung mit Zeitkomponente am Beispiel des simulierten Fluges eines Wetterballons (Abb. 1). Es wird der zeitliche Verlauf des Aufstiegs vom Boden bis in eine Höhe von 30.000 m dargestellt, bei dem der Wetterballon in kurzen Zeitintervallen Messdaten (Ozongehalt, Luftdruck, Temperatur) sowie seine aktuelle Position erfasst.

Abb. 1: Wetterballon-Beispiel im ExtJS-Framework, Darstellung eines Zeitintervalls

Das Google Earth-Plugin ist in ein ExtJS-Layout[2] eingebettet, das die notwendigen Kontrollelemente zur Steuerung und beschreibende Informationen zur Verfügung stellt. Der Anwender hat die Möglichkeit, die Zeit zu kontrollieren (Start, Stopp, Geschwindigkeit, Zeitintervall) und die Ansicht (Blick- und Neigungswinkel, Zoom) in der aus der Google Earth-Desktop-Anwendung bekannten Weise frei zu wählen. Zudem lassen sich über die Google Earth-API[3] eine Vielzahl weiterer Funktionen des Plugins steuern (Layerauswahl, vordefinierte Ansichten, Ortssuche usw.).

Die erhobenen Daten werden in einer PostgreSQL/PostGIS-Datenbank gespeichert. Über die Google Earth-API wird eine KML-Datei aufgerufen, die einen Netzwerklink zu einem PHP-Skript enthält. Dieses generiert KML-Code, indem per SQL-Abfrage Geometrie- und Attributdaten aus der Datenbank abgerufen und in selbigen integriert werden. Räumliche Informationen können dabei sowohl in Spalten einer

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[2] http://www.sencha.com/products/js/

[3] http://code.google.com/intl/de/apis/earth/

beliebigen Tabelle vorliegen als auch mittels PostGIS-Funktion aus der die Rauminformationen beinhaltenden Spalte, z.B. eines in die Datenbank geladenen Shapefiles, gelesen werden.

Der Wetterballon sowie die Messwerte für Ozon und Luftdruck werden durch 3D-COLLADA-Modelle[4] symbolisiert, welche sich entlang der 3D-Punkte im Raum bewegen, wobei fehlende Zwischenwerte linear interpoliert werden, so dass eine flüssige Animation entsteht. Dieses wird mit Hilfe der KML-Extension <gx:track> erreicht. Beliebige Attributdaten lassen sich über Farb-, Größen-, und Formveränderung von COLLADA-Objekten visualisieren. Im Beispiel symbolisiert z.B. die Farbe des Ballons die Temperatur, die Größe der über dem Ballon befindlichen Kugel den Ozongehalt und die Länge des unter dem Ballon befindlichen Balkens den Luftdruck. Beliebige Informationen können mit einem Klick auf das Objekt abgerufen und in einem „Description-Balloon" angezeigt werden.

Das gezeigte Beispiel lässt sich beliebig auf andere Anwendungsgebiete, beispielsweise die Visualisierung von Verkehrs- und Warenströmen übertragen.

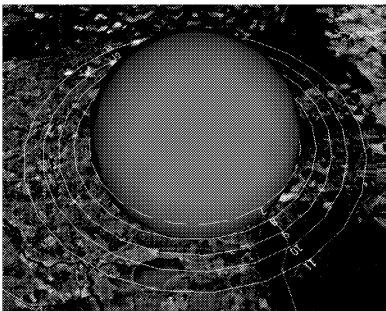## 3. Besonderheiten der 3D-Darstellung

Abb. 2: Objektbezogene Legende

Ein gewichtiger Vorteil der 3D-Kartographie besteht in der Aufrechterhaltung der Wahrnehmungsgewohnheiten und eines gewohnten Umfeldes – des 3D Raumes [3][4]. Aus diesem Vorteil der Pseudo-3D-Umgebung virtueller Globen ergibt sich eine Problematik bei der Visualisierung von Attributdaten durch die Größe von Elementen, da Größe im 3D-Raum zugleich der Wahrnehmung von Entfernungen dient. Ein Weg dieses zu umgehen besteht darin, Legenden fixer Ausdehnung mit dem Objekt zu verknüpfen. Dieses kann beispielsweise mittels COLLADA-Modellen (vgl. Abb. 2) oder Photo-Overlays realisiert werden [5].

Ferner sollte beachtet werden, dass die Sinnhaftigkeit der Verwendung eines 3D-Globus stark von den zu visualisierenden Daten abhängt und der Benutzer auch erst die Navigation im Plugin erlernen muss [1]. Nur mit der richtigen Kombination aus Aufgabe, Benutzer und Interface bieten 3D-Visualisierungen einen zusätzlichen Nutzen, der dann aber durch die simultane Erfassung und Visualisierung komplexer Daten immens sein kann. Gegebenenfalls kann auch die Kombination synchronisierter 2D/3D-Ansichten weiteren Informationsgewinn bedeuten.[5]

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[4] www.collada.org

[5] z.B. http://dev.geoext.org/sandbox/cmoullet/ux/GoogleEarthPanel /examples/GoogleEarthPanelExample.html

4. Zukunft/Ausblick

Die Notwendigkeit, zur Darstellung von 3D-Inhalten im Webbrowser zuerst ein (möglicherweise nicht auf allen Plattformen verfügbares) Plugin installieren zu müssen, welches dann noch beim Aufruf zeitraubend geladen werden muss, ist äußerst unbefriedigend und steht der Verbreitung und allgemeinen Akzeptanz dieser Art der Datenvisualisierung im Wege.

In (naher) Zukunft wird die 3D-Darstellung im Browser auch ohne proprietäre Plugins möglich sein. Der schon heute mit den gängigen Browsern nutzbare, aber noch nicht endgültig verabschiedete HTML5-Standard stellt dafür die Basis dar. Mit ihm lassen sich sog. canvas-Elemente definieren in denen mit dem freien WebGL-Format[6] 3D-Daten visualisiert werden können. Technisch gesehen ist WebGL die Verknüpfung von Javascript und OpenGL. Weiterhin wird das kartographisch interessante Vektorzeichenformat SVG [6] direkt in HTML5-Quellcode unterstützt, was bisher nur mit Plugin möglich war.

Im Bereich der 3D-Geodatenvisualisierung können diese neuen Techniken vorteilhaft angewandt werden, wie vielversprechende Beispiele[7] demonstrieren.

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WebGIS für kommunales Informationsmanagement

Hamburg`s Ansatz für die Integration von WebGIS in E-Government Infrastrukturen

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Abstract. Mit dem Hamburger Solar Atlas und dem Artenkataster werden in diesem Beitrag beispielhaft zwei vom LGV entwickelte WebGIS Lösungen für das kommunale Informationsmanagement im Themenbereich Klima- und Artenschutz im Hamburger Raum vorgestellt.

Keywords. WebGIS, Solar Atlas, Artenkataster, Hamburg, GDI-HH

Einleitung

Die Metropolregion Hamburg ist ein dynamischer urbaner Raum. Die Freie und Hansestadt Hamburg und die umliegenden 14 Landkreise bedecken eine ca. 20.000 Quadratkilometer große Fläche und beheimaten mehr als vier Millionen Menschen. In diesem Kontext begegnet die öffentliche Verwaltung verschiedene Handlungsfelder, die mit Geoinformationen verknüpft sind. Der Titel „Umwelthauptstadt Europas 2011" befördert den Klima- und Artenschutz zu einem der aktuell wichtigsten Handlungsfelder der Stadt Hamburg.

Der Landesbetrieb Geoinformation und Vermessung (LGV) Hamburg bietet in diesem Kontext umfangreiche Serviceleistungen zur Entwicklung individueller WebGIS-Lösungen an. Voraussetzung ist die Verfügbarkeit von Geoinformation in standardisierten Geodateninfrastrukturen (GDI). Die GDI-Hamburg und die GDI der Metropolregion Hamburg bilden mit ihrem dienstebasierten Ansatz die Grundlage für die Entwicklung von WebGIS beim LGV.

In diesem Beitrag werden mit dem Hamburger Solar Atlas und dem Artenkataster beispielhaft zwei innovative vom LGV entwickelte WebGIS Lösungen für das kommunale Informationsmanagement in dem Themenbereich Klima- und Artenschutz vorgestellt.

1. Hamburger Solar Atlas

Die Frage „Wie viel Sonne scheint auf Ihr Dach" sollte sich jeder Dachbesitzer stellen, bevor er die Installation einer Solaranlage in Erwägung zieht. Durch den Hamburger Solar Atlas (1), den der LGV in Kooperation mit HAMBURG ENERGIE SOLAR entwickelt hat, kann diese Frage einfach beantwortet werden.

Interessenten haben die Möglichkeit, sich mit dem Hamburger Solar Atlas zu informieren, ob ihr Dach für eine Photovoltaik- oder Solaranlage geeignet ist. Für einen Großteil der Hamburger Dachflächen wurden aufgrund des vom LGV entwickelten 3D-Stadtmodells Dachflächen mit zugehörigen Strahlungsmengen und Eignungsklassen abgeleitet. Wie in Abbildung 1 zu sehen, können über das entwickelte WebGIS diese Informationen zu jeder einzelnen Dachfläche online abgerufen und ausgedruckt werden.

Abbildung 1. Ausschnitt Hamburger Solar Atlas

Die Solarpotentialanalyse erfolgte unter Verwendung aller verschattungsrelevanten Objekte wie z.B. Topographie, Gebäude oder Vegetation. Als Datenbasis für die Analyse diente das digitale 3D-Stadtmodell (LOD2) von Hamburg, welches zum Zeitpunkt der Untersuchung ca. 130.000 Gebäude umfasste. Für sämtliche Dächer dieses Modells wurden die Parameter Größe, Ausrichtung und Neigung erfasst und anschließend ein hoch aufgelöstes Rechengitter mit 0,25m² großen Teilflächen abgeleitet.

Der Einfluss von Verschattungsobjekten wurde mit Hilfe von Horizontlinien ermittelt. Auf diese Weise konnte eine minutenfeine Berücksichtigung des Schattenwurfes realisiert werden. Durch die automatische Segmentierung der Dachflächen in räumlich hochaufgelöste Teilflächen konnte die jahreszeitlich wechselnde Dachabschattung durch umliegendes Gelände, Gebäude, Vegetation oder Dachgauben sehr detailliert erfasst werden.

2. Artenkataster – Webbasierte Erfassung von Tierartenvorkommen

Die Behörde für Stadtentwicklung und Umwelt (BSU) der Freien und Hansestadt Hamburg ist unter anderem für die Koordination staatlicher Aufgaben auf dem Gebiet des Umwelt- und Naturschutzes zuständig. So wird im Amt für Natur- und Ressourcenschutz zurzeit das IT-Vorhaben „Artenkataster" umgesetzt.

Dienststellen der Stadt Hamburg und Externe sollen über geeignete Intranet- bzw. Internetschnittstellen auf die Daten lesend und schreibend zugreifen. Zu diesem Zweck ist im Auftrag der BSU vom LGV für das Internet eine Webanwendung, bestehend aus einer Erfassungs- und einer Auskunftskomponente (2), als ein Baustein des Artenkatasters entwickelt worden.

Um eine Integration des Systems in die GDI Hamburg zu gewährleisten, wurde bei der Entwicklung der Webanwendung auf die Einhaltung bestehender Standards und Normen gemäß der Spezifikationen des Open Geospatial Consortiums (OGC) Wert gelegt. Die Visualisierung und Erfassung der Geofachdaten erfolgt über Web Map Service (WMS) bzw. transaktionale Web Feature Services (WFS-T). Sämtliche Datenbank, Dienste- und Clientsoftware basiert auf Open Source Software.
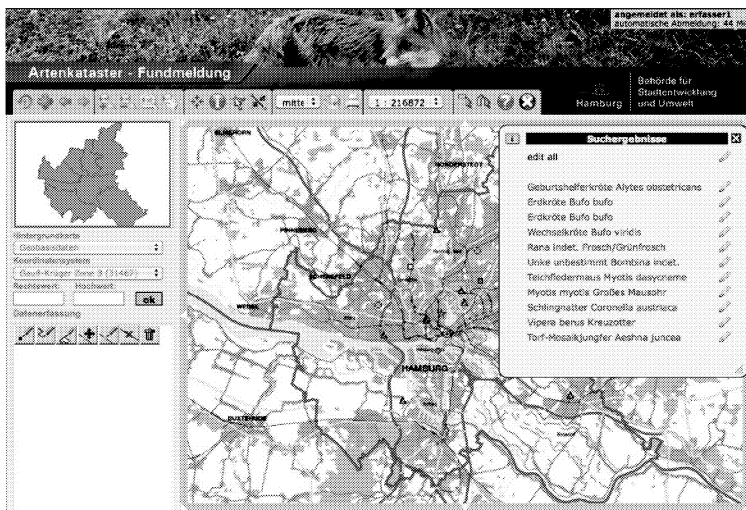

Abbildung 2. WebGIS Oberfläche des Artenkataster Hamburg

Abbildung 2 zeigt die grafische Benutzeroberfläche der Webanwendung. Neben den üblichen Standardfunktionen wie PDF-Druck oder Adresssuche verfügt das System über die Möglichkeit, Objekte zu kopieren und die Visualisierung der erfassten Daten hinsichtlich des angemeldeten Benutzers oder einer bestimmten Tierart zu filtern. So wird bei der Digitalisierung von Tierartenvorkommen automatisch der Name des angemeldeten Benutzers erfasst. Diese Information wird verwendet, um die Visualisierung und den Datenzugriff per WFS auf die selbst erfassten Datensätze zu beschränken.

Weiterhin hat der Benutzer die Möglichkeit, nach bestimmten Tierarten zu suchen und die übrigen Tierartenvorkommen derselben Artengruppe automatisch im Kartenausschnitt auszublenden. Für die beschriebenen Darstellungsfilter werden zur Laufzeit Styled Layer Descriptor-Dateien erzeugt und dynamisch in den Web-Client

eingebunden. Bevor die über die Oberfläche erfassten Daten endgültig in das Artenkataster übernommen werden, werden diese von Fachleuten einer Qualitätsprüfung unterzogen.

Mit dieser Web-GIS-Lösung steht seit Dezember 2009 eine Anwendung zur Verfügung, die eine dezentrale Erfassung strukturierter Daten bei zentraler Datenhaltung ermöglicht. Die Voraussetzungen zur Nutzung des Systems auf Anwenderseite beschränken sich auf ein Eingabegerät mit Internetverbindung und einen aktuellen Browser. Die erfassten Daten sind ohne Konvertierungsaufwand interoperabel nutzbar.

3. Fazit

Das Dienstleistungsangebot des LGV reicht von kompetenter Fachberatung zum Aufbau von Geodateninfrastrukturen über die Modellierung geeigneter Datenstrukturen mit zugehöriger Geoprozessierung bis hin zur konkreten Entwicklung passgenauer Online- Systeme für bestimmte Nutzergruppen. Die beiden vorgestellten Lösungen zeigen die erfolgreiche Integration von WebGIS in das kommunale Informationsmanagement der Stadt Hamburg.

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Creating the new "new": Facilitating the growth of neo-geographers in the Global South using emergent Internet technologies

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Abstract. This paper sets out to look at the how neogeography can operate within the framework of international development by evaluating emerging Web 2.0 technologies. The paper first elaborates on the problems of implementing traditional mapping platforms in the Global South and then moves on to solutions using open source technologies, open training and harnessing the cognitive surplus of individuals in the Global North. To accomplish these solutions, Web 2.0 technologies are highlighted using examples from the Mapping Across Borders project. The Mapping Across Borders project shows how a meta-mashup of neogeographers and Web 2.0 can work towards development in the Global South.

Keywords. Web 2.0, International Development, Social Networking, Micro Volunteering

1.   Introduction

Geographic Information Science (GIS) enables scientists, city planners, infrastructure developers, environmental consultants, venture capitalists and many other professionals to ask complex questions about the world around them. GIS is an expert's tool, with a skill base that is difficult to attain outside of post-secondary institutions. This has the effect of making GIS a particularly inaccessible technology for many.

While GIS is widespread in the Global North, its use in the Global South remains low, especially in East Africa. This is largely due to the formidable price tag that comes with software licenses and the cost of training staff. While some government agencies and international non-governmental organizations (NGOs) can afford these costs, smaller domestic NGOs are unable to use GIS. This is particularly frustrating as groups with larger budgets often subcontract the implementation of development initiatives to the smaller domestic NGOs who could benefit the most from using GIS in their work.

However, while the above paragraph may paint a pessimistic picture, there are a series of emergent opportunities that might support the broader implementation of GIS tools in local NGO environments. The recent surge and adoption of open source software, particularly in the GIS sector, is opening up new avenues. Open source stipulates that not only is the software free but also that it is maintained by a large

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community of helpful experts and the software is continually improving[13]. A number of governments in the Global North and South have already mandated the use of open source software across their ministries [11] and other industries are catching on as well.

Quantum GIS, GRASSGIS, Open Layers, Open Street Map and MapWindow[12] are all examples of open source software currently being developed. A significant opportunity exists to integrate this free software into domestic NGOs in the Global South if the question of training can be addressed.

2. Mapping Across Borders

Mapping Across Borders is a response that grew out of the need for GIS training to be integrated with open source software for domestic NGOs in East Africa. Specifically the research component of the project aims toidentify the challenges required to work towards a sustainable model for capacity development within NGOs in the Global South. Mapping Across Borders does this by offering both in-person training to NGOs and non-profit organizations using open source GIS Software [9].

Mapping Across Borders takes this idea of training one step further. Stresses of tight budgets and limited time for training sessions leave many NGOs unable to dedicate the time required to learn how to use GIS and practice the skills that Mapping Across Borders teaches. The result is that NGO staff members are challenged to retain the lessons learned or implement these skills in the field. Mapping Across Borders crosses this bridge by providing follow-up training for NGO staff – this includes return visits to trainees and facilitating correspondence between the trainer and trainees after the conclusion of the training sessions. This follow-up work may seem obvious, but in traditional models where training is commodified, few organizations can justify the expense of having an expert travel to their field site on a continuing basis.

There is a challenge with the model that has been presented so far – it does not lend well to rolling implementation outto a wider community of NGOs. The time spent conducting follow up training quickly becomes unmanageable for the trainer when multiple organizations are trained at the same time. To conquer this challenge, Mapping Across Borders directly addresses another community that is also facing challenges, though of a different nature.

Students and young professionals using GIS in the Global North often face difficulties finding employment after graduating[2]. This is primarily due to their lack of practical experience even though they have the skills and enthusiasm to apply to a needy project on the ground. This deficit of experience in the Global North is mirrored by the opposite problem in the Global South where there are not enough people with technical skills inGIS. Through the advent of the internet and online collaboration tools, the digital divide [17]can be addressed and crossed. It is the belief of Mapping Across Borders that both students and young professionals and NGOs can work together and strengthen their own skills as well as address pressing development related difficulties. By making these connections between students and young professionals and NGOs, the challenge of limited resources for field visits disappears and is instead transformed into an opportunity for both groups to benefit and grow.

3. The Changing Nature of Development/Volunteerism

Currently, the nature of development and volunteerism is changing. In the past, development has been applied in a top down, deficit driven model where outside forces enter into impoverished communities with the intent to create a 'better' reality for the people that they judge to be impoverished. This needs based approach has caused serious problems while trying to help, such as reinforcing deficiencies[10].

In *Cognitive Surplus,* Clay Shirky(2010) argues for another type of development that he identifies is changing the old paradigm. He argues that persons in the Global North have a surplus of time that has often been spent on massive media consumption such as television. Recently however, this surplus time has been converted from passive engagement to active involvement with the collaborative engine of Web 2.0. He goes on to say that this cognitive surplus, if managed correctly, can be spent not only on creating internet memes such as adding poorly worded captions to photos of cats called 'LOL-Cats,' but rather engaging creatively in philanthropic activities [16].

Shirky is not the only person thinking about harnessing the potential of online communities to engage in development work from the bottom up. ThinkCycle is a project that originated from students at the Michigan Institute of Technology and poses design questions faced by NGOs to engineering students[15]. ThinkCycle has achieved success by asking large communities of engineering students to face real problems that are faced by implementing organizations. Recognizing that brilliant ideas come from engaging with communities is not new, as participatory technology development has shown [1; 5]. Johnson notes that throughout history many eureka moments have actually come from group collaboration [8]. Taken with respect to the advent of the Internet and the ability of hundreds of millions of people to engage and collaborate with one another[2], development is about to get a big boost.

4. The New "New"

Today's emerging Web 2.0 technologies are what allow Mapping Across Borders to make GIS far more accessible as a technology and thus a beneficiary of cognitive surplus. An open wealth of educational resources combined with a growing community of practice and a working system for micro volunteering enables users to take education and application into their hands, quickly and effectively.

The Mapping Across Borders website utilizes a Wiki-based learning system that contains a constantly evolving and growing body of knowledge on GIS. The site also allows users to assume mentoring roles, as well as communicate with one another as they learn. For example, those who are learning from articles online can ask questions to the persons who have writtenthem – the expertson the subject. Furthermore, these two user groups, the mentor and mentee,can work together on shared projectsusing a project management system. This project management system allows the mentee to apply knowledge gained on the Mapping Across Borders website and as well as allowing the mentor a chance to engage with and solve real-world problems. By providing opportunities to integrate mapping projects directly with the learning system the social connections are strengthened.

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[2] Facebook.com reports over five hundred million users alone (www.facebook.com)

These technologies are some of the new ways that neogeographers operate. As Haklay and others note, Neogeographers who produce mashups and other geographical applications rely on Web 2.0 tools to put their ideas into practice [3; 4; 6; 7; 14]. Mapping Across Borders implements many of these web 2.0 technologies, it provides knowledge resources and tools, but more importantly supports the harnessing and sharing of the crowd-sourced intelligence of the GIS community, worldwide. The technologies utilized by Mapping Across Borders allow the question of sustainable capacity development in the Global South to be addressed in a more integrated fashion and in a way that is not currently being effectively leveraged.Thismeta-mashing, succeeds in placing development and neogeopraphy on a carefully orchestrated collision course for success.

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