Environmental ‘live’-monitoring utilizing geoKnowledge Design principles

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Abstract
Within the scope of this paper, we present a new and enhanced strategy in organizing ‘live’ GIS enabled monitoring of environmental parameters based on ‘geoKnowledge Design patterns. This approach is able to enhance the broad and sustainable availability of environmental sensing information for an increasing spatially enabled society. The proposed concept is based on and combines the principles of GeoDesign, Open Knowledge and Open Government Data to leverage the potential of environmental resources collected and monitored by public and private organizations around the world. It aims to realize the full potential formalized processes, tools and components utilizing distributed spatial information infrastructures. This is especially important for opening vast amounts of environmental monitoring ‘live’ data and derived information to different domains and user groups in a structured and harmonized manner. The approach is based on generic building blocks that can be (re)used, (re)combined, (re)scaled and cognitively (re)assembled in an iterative manner, sharing formalized information and knowledge pieces. To validate this strategy in the context of environmental monitoring with regard to a transparent integration into geographic information systems, the ‘SenSer Toolbox Family’ as a set of service components for environmental ‘live’ monitoring has been developed showing the strengths, benefits and challenges of this new formalization principles for the sustainable availability and utilization of environmental information.

1. Introduction
Environmental and especially up-to-date, quality assured information is getting a more and more important role in everyday life for spatially enabling societies (WILLIAMSON ET AL 2011) and, in particular for enhancing integrated risk assessment and risk management. The access and integration of existing digital spatial information and (environmental) monitoring data being reliable, consistent and up-to-date shall support decision making across many domains at all scales, and for various purposes. Additionally these resources are expected to create manifold innovative opportunities for everyone.

Supported by the broad availability of sensor-monitoring-systems integrated in service oriented environments (SOA) new strategies are needed for realizing the full potential of these vast information sources. In our new strategic approach combining organizational needs and technical concepts, we aim for bundling service-oriented geo-information strategies, technologies and tools for creating and sharing “live” (environmental) monitoring data and information in pools of formalized, reusable knowledge pieces that are tailored to the needs of the proposed ‘end users’ within and across organizational information infrastructures.

To develop an answer for these challenges from the research perspective, we introduce the ‘geoKnowledge design’ pattern idea in this paper. In our opinion this approach provides a new promising sustainable strategy, delivering concepts and tools to support replying some of today’s immanent challenges by opening up large and ever increasing amount of ‘live’ environmental monitoring data and its derived information for various domains and user groups in a structured and harmonized manner.

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In this context, the term “live” data describes data that is made available in service oriented architectures (SOA) in a near-real time period after sensing has been completed.

The proposed conceptual design pattern regarding the overall information workflow strategy is used to provide the foundation for contextualizing environmental sensing information and opening it up to end-users, the spatially enabled society. It provides methods that allow using geographically enhanced knowledge in different contexts and environments, either as structured base data or visualized as derived information patterns in their spatial context. In that way, spatial information can be flexibly combined with other information sources like demographic data, digital elevation models, satellite imagery etc. Additionally the resources can be integrated and processed in automated simulation models leveraging the exploitation of the information resources and its added value.

2. geoKnowledge Design

The newly introduced term ‘geoKnowledge design’ positions itself upon a broad definition and description of a novel trend, opening and sharing any location aware content, information or data of public or private origin. This includes geo-information of manifold resources like satellite imagery, cadastral information, statistics, topography, etc. The concept is well suited for derived users’ needs, the spatially enabled society realizing the potential of environmental ‘live’ sensing knowledge (e.g. as situational awareness content for mobile phone apps). Overall the term embraces workflows, processes and standards on an organizational and technical level.

This new strategy is partially combining concepts and methods of GeoDesign, Open Knowledge and Open Government Data. GeoKnowledge design relies on a design pattern that describes an iterative workflow allowing sketching, developing and re-assembling generic building blocks of knowledge provision.

Prerequisites for generic geo-aware building blocks supporting various tasks and research questions are data that are derived from newly acquired knowledge. Therefore the knowledge is structured, analyzed and presented in a way the addressed community can directly benefit from. The ultimate goal of geoKnowledge design is to develop efficient geographic toolsets and infrastructures that also consider organizational contexts and processes. Those components are regarded as fundamental for user-centered and task-oriented presentation and application of spatial information.

All things considered, geoKnowledge design facilitates the integration of location information in organizational workflows through the use of semi-automated, recurring and flexibly adoptable tasks within the scope of a defined template. The following parts focus on introducing the underlying principles of the conceptual ‘geoKnowledge Design pattern.

2.1 Introduction Service Oriented architecture

Service-Oriented Architecture (SAO) is based on SOA design principles that basically help to organize software to meet user or business requirements in a highly flexible way. It constitutes a model for establishing and utilizing distributed capabilities that can be under control of different domains. The encapsulation of individual services yields benefits as regards interoperability, agility, and costs. In addition, it helps in breaking up monolithic systems to be beneficial to a wider range of stakeholders. In that, SOA is not only related to technical aspects of software engineering but also has strong implications as regards conception and adaptation of software in general (STAL, 2006).

SOA-based services are building blocks for applications, where permutations of individual services are not pre-defined but can be achieved by orchestration with little effort. This helps end users to gain more influence in the creation and maintenance process, as their expertise will have stronger impact on a rather granular service level. Domain experts no longer need to work themselves into the complexity of whole
applications but can rather focus on individual parts or services. This is precisely the point, where conceptual geoKnowledge design patterns (Figure 1) match the conceptual framework of SOA as well as the current methods of agility in software creation (Dyba T., T. Dingsøyr, T., 2008). For various activities – ranging from structuring to re-assembling – respective domain experts can provide their specific knowledge for the implementation of specific services, whereas the respective interfacing could or even should be specified by end users.

As an example, the structuring of geo-referenced information can be isolated in a SOA-like service building-block. The internal structure of this service is informed by the domain expert (e.g. spatial metadata expert), whereas the external properties that determine the (business) added-value of the service are defined by informed end users (e.g. public body representative). When orchestrating several services that way, an elevated level of agility in adaptation of the core features of the individual services can be achieved with a low number of side effects. This approach enables highly iterative and incremental development with a considerable level of self-organization on a more local scale (e.g. on service level), what is characteristic for ‘agile and adaptive software development’ in general (Highsmith, 2000).

Specifically in phases of adaptation of existing SOA-based solutions, this agility-orientation helps in optimizing resource utilization and timeliness as regards testing of newly added features in the underlying services. Thus the methodology of geoKnowledge design benefits from current concepts of agile software development for service-based architectures.

2.2 The GeoDesign concept

One of the major underlying fundamentals of geoKnowledge design is the GeoDesign concept. Flaxman (2010) defines GeoDesign as a “[...] design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts” (Flaxman 2010, http://www.geodesignsummit.com/videos/day-one.html), while Steinitz (2012) more generally regards it as “changing geography by design” (http://www.esri.com/news/arcwatch/0412/a-conversation-with-carl-steinitz.html). The definitions of GeoDesign have share their nature as systematic methodology for planning and decision-making that focuses on the integrative connection between GI science and general design processes which aim to create things as they are imagined by the designer. GeoDesign now brings geographic analysis into any design process. It thereby expands the role of geospatial technologies in the entire lifecycle of projects and makes spatial thinking central to all stages like engineering, planning, feedback analysis or presentation. Miller (in Artz, 2010) therefore even regards GeoDesign as “[...] the thought process comprising the creation of entities in geographic space.”

While the term GeoDesign has recently been introduced by Carl Steinitz of Harvard University in 2009 (http://www.esri.com/news/arcwatch/0412/a-conversation-with-carl-steinitz.html), the basic concept behind GeoDesign has been widely used in various application domains in the past. Existing methods and tools in GIS, CAD or the Geo Web are all considered parts of GeoDesign. Considering GeoDesign itself as an implementation practice, however Artz (2010) collected all processes from data to information and finally to knowledge under the umbrella of GeoDesign. GIS therefore can be regarded as enabling framework of GeoDesign, as it is an integrative tool that allows analyzing the interplay between various interdisciplinary factors and merging various different data pieces from disparate sources into one single project (Artz, 2010).

Similar to geoKnowledge design, the central enabling concept in any GeoDesign strategy is: interoperability, as it supports the idea of collaboration and interdisciplinary cooperation that allows finding and using the best and most suitable design for a desired outcome of a workflow process.

The described GeoDesign strategies influence the geoKnowledge design concept. Important are main concepts of interoperability and open accessibility of the underlying data and information resources, which serve as core components to foster the creation of new geographic knowledge.
2.3 The Open Knowledge strategy

“Open knowledge is any content, information or data that people are free to use, re-use and redistribute – without any legal, technological or social restriction” (Open Knowledge Foundation, 2011, http://okfn.org). Hence, the goal of the OpenKnowledge idea is to share its content for free in a reliable manner, regardless of the publishers or users usage context (SIEBES ET AL, 2007).

The term itself is mainly promoted by the Open Knowledge Foundation, a non-profit organization that aims at increasing broad access to knowledge and thereby also increase transparency and benefits for governance, research, economy and a culture of sharing and openness (http://okfn.org/about/vision/, http://okfn.org/about/faq/) through establishing tools and communities that create, use and share content and open data standards.

Usually, the creation of “knowledge” is defined by cognitively deriving patterns out of contextualized information that answers the question “how” and thereby can be applied as foundation for decision-making (http://www.systems-thinking.org/dikw/dikw.htm) processes (BARTELME, 2005).

According to the concept of knowledge management, knowledge is gained by first contextualizing data pieces in order to obtain information, and consequently extracting patterns from information to create knowledge. In the sense of this definition, the term “knowledge” is clearly distinguished from data and information.

In the context of the Open Knowledge definition however, knowledge is generalized as all kinds of content, no matter if they are data or information. In this sense, music, movies, books, scientific, historical or geographic data and government or administrative information are all subsumed under the term “knowledge” (http://opendefinition.org/okd).

2.4 The role of Open Government Data

Open government data is “[…] data and information produced or commissioned by government or government controlled entities” (http://opengovernmentdata.org/about/). In its intention ‘Open’ in this case is equivalently used like ‘open knowledge’, with regard to: free to use, re-use and re-distribute according to the Open-definition (Open Knowledge Foundation, 2011). Open government data is a specific subset of Open Knowledge. However, not all data created and captured by government agencies are intended to be open government data as data sharing is only most useful for data that are of public interest and can be distributed without the approval of the originator. Thus, confidential and person-related data as well as industrial secrets are not covered by the definition of open government data (VON LUCKE, J., C. GEIGER, 2010).

The term open government data is considered to be an important example of Open Knowledge dissemination, since governments collect huge amounts of high-quality data as recurring working tasks. Making this data, information and knowledge pool available for use and reuse is opening new benefits for a spatially enabled society (RAJABIFARD ET AL., 2011), such as increased transparency, possibilities for public participation, improved private services and optimized government efficiency.

The idea behind open government data is not limited to providing raw data, but also focuses on derived information and context specific knowledge. In the European Union, these efforts will be increasingly promoted in the next years. One major driver therefore is the EU directive 2003/98/EG Public Sector Information (PSI) and its proposed amendments that foresees the re-use of public sector data supporting the development of today’s aspired information and knowledge society (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:345:0090:0096:DE:PDF).

The benefits of open government data are now slowly being recognized in Europe, while in other countries open government data initiatives have been formed earlier and are already contributing societal benefits for democratic transparency, effective administration and promoted innovation. Popular examples of
established open government data portals are data.gov in the United States and data.gov.uk in the United Kingdom.

3. The 'geoKnowledge design' - approach

The idea behind geoKnowledge design is based on the philosophy that, for gaining sustainability, a structured approach is necessary, to be able to manage spatially aware information, knowledge and solutions from its creation, over its dissemination and usage to its disposal. The strong point of this approach is based on the modular design pattern consisting of generic building blocks which can be adjusted and reassembled independently, instead of developing a monolithic solution. It is an approach of great flexibility that links design and technology to provide modular, generic and reusable tasks and templates for geoKnowledge creation, management, dissemination and use.

The geoKnowledge design pattern is a framework ensuring the development of tasks and tools according to a defined framework and therefore targeting at a specified design goal. Still, it is flexible enough to be used and combined in an unconstrained variety of applications and use cases.

Based on the concepts of GeoDesign, OpenKnowledge and Open Government Data, the concept of geoKnowledge design is introduced for leveraging service-oriented strategies that support the creation, management, sharing and use of spatial information as modular, formalized but highly customizable components.

The base idea is the formalization of a generalized framework leveraging distributed service architectures that consists of different building blocks of tools, methods and technologies. This strategy can be compared with some distinct goals and concepts formalizing integrative sketching and designing processes in a GeoDesign framework.

The term “design” for geoKnowledge emphasizes the conscious process of structuring, tasking and presenting geographic knowledge in iteratively organized workflow to support a commonly defined goal comparable to agile and adaptive software development strategies.

geoKnowledge is thereby regarded as any kind of data of public interest, service or derived information, as introduced in Chapter 2.

The conceptual geoKnowledge design pattern foresees eight steps for adapting and providing any kind of spatial information, like sensor measurements as one example, by tailoring generic building blocks, or modules, to user needs and context following the iterative design pattern to structure, integrate, sketch, analyse, template, task & automate, present and on demand to cognitively re-assemble.
The result of each step contributes to the shaping of generic, reusable solution components. Table 1 describes eight base modules:

### Table 1
conceptual geoKnowledge Design Pattern

| structure | The first step in provisioning of spatial knowledge is structuring available content that is aimed to be processed, analysed or presented based on harmonized data specifications. Documentation plays an important role in this structuring process and provides the foundation for semantic and technological interoperability in information infrastructures. |
| integrate | In order to be used, content needs to be integrated and thereby made available in information infrastructures. A fundamental prerequisite for content integration is interoperability of information and information systems. Standards tackling semantic and technological interoperability are needed in order to make geographic information usable. In this context, the knowledge management process is enhanced with spatial characteristics like location information. |
| sketch | Before solutions are planned or even implemented, they have to be sketched like described in the concept of GeoDesign. In the sketching process, possible scenarios are defined, implemented, validated and refined. This approach allows the comparison of the derived solutions prior implementation. Sketching marks the classical “design” part in a workflow carried out by geo-information systems. This approach regards sketching the content, analysis workflows, system architecture, information flow and organisational embedding. |
Before sketches are approved or discarded, their impact needs to be analysed. The “sketch” and “analyse” steps therefore are in mutual dependency, evaluating changes in short, iterative feedback cycles before selecting a final solution template. In this sense, certain features of sketches are leveraged while their undesired impacts are minimized (ARTZ, 2010). While in more traditional approaches, analysis is part of the final stages of developing processes, in the context of geoKnowledge design it allows shortening cycle times and improving the quality of results.

After sketches and their impacts have been verified through analyses, an appropriate sketch is selected and formalized into a technical and organisational template. The template can be regarded as the framework for subsequent design and implementation steps.

Tasking refers to the building of modular components out of the template. It means breaking the overall template design into small, reusable pieces for partial or full automation of operations and workflows. Those tasks describe and define the handling and sharing of geo-knowledge. It sets specific solutions within the template framework for the creation, integration, structuring, access, use and modification of information.

For leveraging benefits for human end users from information processed by tasks, it is necessary to present tasking results accordingly. The appropriate provision and visualization of information is crucial as it bridges the gap between information, reality and decisions (Brodersen & Nielsen, 2006). Based on the defined tasks the extracted ‘geoKnowledge’ will be presented based on users needs and context (Wealand et al. 2007).

The possibility to re-assemble, adapt and contextualize modular tasks and presentation formats illustrates the benefits of the flexible geoKnowledge design approach. It means that systems and solutions are no longer seen as monolithic implementations of one piece, but modular tasks and templates that can be reused and reassembled according to context, user groups, use cases and other changing characteristics over time.

Following this approach, environmental sensing information can be fit and opened to the end-users, in a sustainable manner, regardless of the pursued domain usage as original structured data and as (automatically) presented derived geo-information results. This can be achieved by combining the sensing-information with existing geo-information layers (e.g. DEM etc.) and/or integration in simulation models. The arrangement of the geoKnowledge Design pattern in an iterative Workflow model introduces adjustment capabilities over time using cognitive reassembling building blocks.

### 4. Discussion

The paper introduces the term geoKnowledge Design and gives a broad description of a novel trend, to open and share any location aware and up-to-date content, information or data of public or private origin. This includes geo-information of manifold resources like satellite imagery, cadastral information, statistics, topography, etc. and would be well suited for derived users’ needs focused environmental ‘live’ sensing knowledge (e.g. as situational awareness content for mobile phone apps). Additionally, the term embraces workflows, processes and standards on a technical and organizational level.

The main argument for the geoKnowledge Design concept is in the flexibility, dynamic behavior and the ability to iteratively integrate changes in the lifecycle of the development of an application. As it is based on SOA principles, technical and organizational standardization and harmonization efforts for in-
formation exchange it qualifies to be formally integrated into organizational and technical workflows of public and private institutions beyond the borders of classical Geographic Information Systems.

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Bibliography


