Quo Vadis SDI?

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SUMMARY

In this paper we propose a user-centric and evolution-oriented understanding of spatial data infrastructures (SDI) as an alternative approach to contemporary SDI definitions. This novel perspective induces a set of SDI implications, which in turn shed additional light upon the research agenda. In this context, we refer to dynamic chaining of geographic information (GI)-services, semantic interoperability of GI-services, the user need for spatial decision support services, as well as security and commercial marketing issues. We conclude that these topics will constitute the crucial SDI research directions in the future.

KEYWORDS: *Spatial data infrastructure, GI-Service, Service-Chaining, Semantic Interoperability, Spatial Decision Support, Research Agenda*

INTRODUCTION

Since the first international conference on "Emerging Global Spatial Data Infrastructure" held in Bonn in 1996 the concept of spatial data infrastructure (henceforth SDI) has rapidly experienced a rising awareness in the geographic information community. Numerous academics and practitioners have provided a vast amount of work on this topic and made SDI an 'en vogue' acronym. Most of those approaches led either to a number of stakeholder-specific framework specifications defining the objectives and structural building blocks of individual – mostly national or regional – SDIs or were part of selective research and development activities investigating very specific SDI-related issues. A common understanding about the nature of a SDI is still missing. Instead, we are faced with a patchwork of definitions, which certainly have much in common. Nevertheless they very clearly reflect the different views and objectives of their constituting organisations. Having this in mind, this paper tries to give a more general understanding of the term SDI by stressing out its dynamic and heterogeneous nature. To strengthen future SDI activities, it is the overall goal to derive a SDI-related research agenda, which is more based on SDI evolution and diffusion trends than on recent shortcomings of individual specifications and implementations.

SDI DEFINITION REVISITED

Popular SDI definitions emphasize a normative approach *(see table 1)*. A SDI is thereby defined in terms of durable elements (e.g. communication network, software and hardware technology, distributed databases, policy, standards, institutional arrangements) and functional parts (e.g. discovery, evaluation and application mechanisms) which together typically facilitate the access to *spatial data*. Stressing a more *spatial information*-oriented point of view, mainly technicians put focus on the emerging technology of discoverable geographic information (web-) services that becomes an integral element of

SDI concepts (e.g. Bishr & Radwan, 2000; Bernard & Streit, 2002; Harrison, 2002; OGC 2003a; Alameh, 2003).

Source	SDI Definition
Nebert (2001)	"[…] the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general."
Groot & McLaughlin (2000)	"[…] encompass[es] the sources, systems, network linkages, standards, and institutional issues involved in delivering spatially related data from many different sources to the widest possible group of potential users at affordable costs."
Smits (2002)	"[…] delivers to the users integrated spatial information services. These services should allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an inter-operable way for a variety of uses."
CGDI (2003)	"[…] is the technology, standards, access systems and protocols necessary to harmonize all of Canada's geospatial data bases, and make them available on the internet."
FGDC (2003)	"[…] the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and non-profit sectors, and the academic community."

Table 1: Exemplary sample of SDI definitions

However, this type of definition is a rather static one and conceals the evolutionary nature of the various, more and more upcoming SDI initiatives. Furthermore, potential user needs are not addressed at all. Thus, based on the fact that the final purposes, functionality, and composition of SDIs cannot be defined finally, Chan et al (2001) argue that the introduction of SDI concepts can be seen as an innovation process[2] which diffuses in a dispersed, non-focused manner. This leads to a productional perspective that describes a SDI in terms of interrelated business activities and production processes which change over time. Those business and production processes are carried out by an array of information consumers and suppliers[3] to form a value chain (see e.g. Porter, 1985; Krek & Frank, 2000), which can be located on different stages of a multi-levelled, hierarchical compound SDI. In contrast to politically or administratively justified SDI-hierarchies (Rajabifard et al., 2000) like the Infrastructure for Spatial Information in Europe (INSPIRE; Smits, 2002), the idea of interconnected SDIs is here derived from the needs of cooperating entities to execute one or more business processes. The resulting implication is an extensively increased user centrism.

Going on from this more flexible viewpoint and bearing in mind the shortage of a normative approach, we propose a more comprehensive understanding of Spatial Data Infrastructures by emphasizing the role of the user and the evolutionary nature of SDIs.

Accordingly, *a SDI can be understood as a multi-levelled, scalable, and adaptable collection of technical and human services, which are interconnected across system, organisational, and administrative boundaries via standardized interfaces. Those services enable users from different application domains to participate in value chains by gaining a seamless access to spatial information and geo-processing resources.*

Scalability and adaptability reflect here the evolutionary nature of a SDI where stakeholders join or leave, technical or human services are launched, substituted, or discontinued, and novel means are integrated without any interference with already existing SDI operations. It also mirrors the need to allow

[2] in the sense of innovation diffusion theory (Rogers, 1995)

[3] whereby information consumers often act as information suppliers and vice versa

users to adjust their usage behaviour as well as to reconfigure the processes executed in their application domain. In this context, technical services refer to interoperable and modular software entities that provide users with an access to distributed geo-processing functionality and spatial information resources through an open and standardized interface. Geographic information (GI) services are a subset of technical services. They enable the discovery, retrieval, processing, manipulation, analysis, and visualization of spatial data from multiple sources via a communication network (ISO/TC 211 & OGC, 2002). Human services, in contrast, refer to intangible activities that usually, but not necessarily, take place in personal interactions between the user and the provider, and which are complementary with technical services.

IMPLICATIONS

The continuous diffusion of SDIs leads to an increasing heterogeneity and dynamics at the demand and supply side. It has to be kept in mind, however, that heterogeneity at the demand side cannot materialize without an increasing heterogeneity at the supply side, and vice versa. Without claiming completeness, the resulting implications are sketched in the following.

On the demand side a steadily increasing number of spatial information requestors – from first movers through adopters to followers – will form a growing number of homogenous user groups (e.g. from public bodies through commercial organizations to citizens in general) which are likely to expose different needs with regard to spatial information, e.g. from basic mapping facilities through SDSS capabilities to (near) real time information acquisition. Along with the differentiation of user needs and an expected specialization at the supply side, users will rely on interoperability in order to integrate different suppliers into their value chains while requiring heterogonous SDI access means from commercial-of-the-shelf desktop software through web client applications to mobile and ubiquitous access and processing capabilities.

On the supply side continuous SDI diffusion opens up markets for heterogeneous information supplier groups like National Mapping Agencies, commercial information providers, and regional and local authorities. An increasing competition will lead to differentiated and specialized spatial information resources. This competition will stimulate heterogeneous terms for information access (e.g. from freedom of information policies through contract-based access to sophisticated price models) and will result in different products and services with heterogeneous data models and semantics including different multilingualism capabilities. Along with the differentiation and specialization at the supply side spatial information suppliers will establish and maintain standardization alliances to assure interoperability.

OPEN RESEARCH TOPICS

The above mentioned implications induce high requirements on current and future SDI-related research-activities. Especially the expectation of an increasing heterogeneity, complexity, and dynamics of user requirements as well as the increasing diversity, availability, and interconnectivity of SDI-resources lead to a number of fundamental research topics which are crucial to investigate. It depends on the outcome of these research activities if flexible, user-centric SDI concepts become *technologically*[4] feasible in the future. Against this background the authors propose an intensification of the following – partially more and more arising, partially already established – research activities, especially with regard to SDI-needs.

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[4] Institutional, organisational and legal aspects are not covered herein. Concerning these aspects see e.g. Craglia & Masser, 2003.

Dynamic Chaining of GI-Services

The composition of individual GI-services to complex GI-service chains is a hot topic currently under discussion in the geographic information community (see e.g. Bernard et al., 2003b; Einspanier et al. 2003). The composability of GI-services is often seen as one of their greatest values, as compositions of services can support complex, easily reconfigurable processing tasks and form the technical backend to provide user specific *spatial information.* With such value-adding service chains customers are able to automate, rationalize, and optimize business processes. Though OGC and ISO/TC 211 acknowledge the importance of service chaining, at present most GI-services remain isolated, stateless applications. Future research should address prerequisites that are crucial for making progress toward an automated composition of GI-services, which is based on user queries and can be executed in an ad hoc manner.

Semantic Interoperability of GI-Services

Existing SDI concepts already incorporate approaches that ensure syntactical interoperability of GI-Services. However, the information that is created within a special application field is often of limited use when trying to use it in different contexts (Bernard et al., 2003a). An important reason for this fact is the semantic mismatch especially across different information communities (Bishr et al., 1999). To overcome those semantic heterogeneities and to map between different understandings, recent research activities led to first promising – especially ontology-based – approaches (see e.g. Wache et al., 2001; Hart & Greenwood, 2003; Kuhn & Raubal, 2003; Lemmens et al., 2003; Lutz et al., 2003). From a SDI-related point of view this ongoing research has to be intensified, especially with regard to the explicit description of query-semantics and service capabilities for semantically enriched search and composition capabilities as well as concerning a further investigation of semantic translation methods.

Spatial Decision Support Services

While solving spatial problems, traditional GIS applications are often utilized to support decision making processes. That is why many of these GIS applications can be described as spatial decision support systems (SDSS). However, a closer examination reveals that spatial decision support requires specialized analytical functions (e.g. for optimization and multi criteria evaluation purposes), which typically exceeds the functional range of common GIS (Rinner & Jankowski, 2002). Against the background of a cross-system and cross-institutional connectivity of GI-resources as well as their easy accessibility through simple user interfaces, evolving SDI concepts form a promising approach for future SDSS, even if standardized analytical GI-services are not available yet. Beside a significant demand for interoperable and chainable services for analysis, optimization and evaluation purposes (see e.g. Rinner & Malczewski, 2002; Bernard et al. 2003), future research activities should also focus on an improved and up-to-date availability of spatio-temporal information – either measurement-born or simulation-born (Simonis et al., 2003) – to enable SDIs to be suitable backbones for decision support processes in temporal critical application areas (e.g. in emergency management use cases). Based on a seamless accessibility of (near) real-time spatio-temporal information, pro-active approaches like SDI-integrated, knowledge-based alerting functionalities could raise current SDI-concepts to a next level (OGC, 2003a; Simonis & Wytzisk, 2004).

Authentication, Authorization, and Accounting – Security and Commercial Marketing in SDIs

The execution of business and production processes, which are carried out by heterogeneous information consumers and suppliers on different stages of a multi-levelled SDI, requires profound security mechanisms to protect confidential or chargeable information and processing resources against unauthorized access[5]. Even if standardization bodies like OGC and ISO recognized the necessity for authorization and authentication functionalities to secure multi-institutional operations through access control that depend on the verified identity of a requesting client (ISO/TC 211 & OGC, 2002; OGC, 2003b), corresponding service specifications and application patterns are still insufficiently elaborated

[5] Further major security issues like e.g. denial of service attacks (DOS) and corruption of information (Peng & Tsou, 2003) are typically issues of general Internet security efforts and don't have to be addressed in a certain SDI-related research agenda.

within the geo-domain. First steps towards a specification of single-sign-on authentication and authorization procedures, which are applicable to loosely coupled OGC compliant GI-services have been taken by Drewnak and Gartmann (2003). However, security issues are a prerequisite for the commercial exploitation of geo-information und geo-processing resources by means of chargeable GI-services.

The endeavour of establishing an electronic market for geo-information and geoprocessing products is an appealing objective that is presently pursued by many national and regional SDI initiatives in Europe. It is considerably motivated by market reports that forecast a high demand for such products, in particular in business-to-business markets. With respect to Germany and Switzerland see recent markets reports issued by Fornefeld and Oefinger (2001, 2002), Fornefeld, Oefinger et al. (2003), and Frick, Keller et al. (2002). Consequently, the necessity to conduct a concurrent research on technological, economic, and marketing issues appears to be essential. However, neither the marketing nor economics of GI-service technology nor the technological requirements of electronic markets for spatial information and geoprocessing products have been targeted in depth by interdisciplinary, yet integrated academic research.

CONCLUSION

In the past years, numerous SDI initiatives settled down in the spatial information community and each of them typically came along with an individual definition, what a SDI has to be. However, most of them emphasize a normative approach, focussing on terms of durable elements and functional parts, but evidently lack user-centrism as well as fail to mirror the evolutionary and diffusive nature of SDI. Therefore, we proposed a novel SDI understanding, which focus more on scalability as well as adaptability issues and derived implications that come along with this re-orientation. This allowed us to distil five interrelated topics for a research agenda on SDI. We conclude that dynamic chaining of GI-services, the semantic interoperability of GI-services, the specification and development of spatial decision support services, as well as security enhancements and commercial marketing issues will constitute the key pillars of future research on SDI.

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