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Reconceptualizing the role of the user of spatial data infrastructure

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Abstract Spatial data infrastructures, which are Internet-based mechanisms for the coordinated production, discovery, and use of geospatial information in the digital environment, have diffused worldwide in the last two decades. Currently, there are about one hundred spatial data infrastructures at the national level and many other at supra- and sub-national levels. These contemporary spatial data infrastructures operate with two main assumptions: formal organizations are the producers and suppliers of geospatial information; users are the passive recipients of information. The recent phenomenon of volunteered geographic information departs from these assumptions. In this paper, we argue that reconceptualizing the user of a spatial data infrastructure can accommodate this new phenomenon. Such a reconceptualization creates a middle ground between spatial data infrastructure and volunteered geographic information, which has important implications for future research.

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Introduction

Proliferation of information and communication technology—the Internet and the Web in particular—and the parallel development in geospatial technologies led to the notion of spatial data infrastructure (SDI) about two decades ago. After President Clinton's executive order 12,906 to establish a national level SDI in the United States (Executive Office of the President 1994), SDIs have diffused across the world. There were 83 SDIs at the national level by the end of 2005 (Crompvoets and Bregt 2007); this number has likely grown to more than one hundred by now. Other SDIs are being developed at regional, state, and local levels. Billions of dollars are spent worldwide on these activities each year (Rhind 2000; Onsrud et al. 2004). These infrastructures are created to facilitate the coordinated production, access, and use of geospatial data among producers and users in an electronic environment (Groot and McLaughlin 2000; Masser 2005a). SDIs use electronic media to connect distributed repositories of geospatial information (GI) and make these available to users through a single entry point often called 'geoportal'. This is a major development

towards capitalizing modern technologies for wider access and sharing of GI in the societies.

With the emergence of Web 2.0, ordinary citizens have begun to produce and share GI on the Internet. The trend increased after Google, Microsoft and Yahoo! made their web mapping application programming interfaces (APIs) public (Rouse et al. 2007). Some of the common tools in use include Google Map, Google Earth, Common Census, WikiMapia, OpenStreetMap (Goodchild 2007b; Tulloch 2007), Microsoft Virtual Earth, Yahoo! Maps, and The Open Planning Project. These new tools are receiving a large response from users. For example, there were about 5.9 million place entries on WikiMapia (www.wikimampia.org) at the time of the writing, an initiative that aims to eventually describe the whole world; about 500 thousand places were submitted between mid December 2007 and mid January 2008 alone. These Web 2.0-based geospatial activities show that users are willing to engage more actively in the production and supply of GI.

The user's potential to supply GI is promising enough that researchers are now exploring the role of citizens in augmenting the means of geospatial data collection: "the six billion humans constantly moving about the planet collectively possess an incredibly rich store of knowledge about the surface of the Earth and its properties" (Goodchild 2007b, p. 26). Others, too, have recognized the wealth of GI that individuals hold. For example, in the context of municipal activities, Carrera and Ferreira (2007) propose to capture and utilize the 'city knowledge' from those who are close to a particular phenomenon with richest geospatial knowledge. This gives rise to a new phenomenon, which has been variously named 'neogeography' (Turner 2006), 'cybercartography' (Tulloch 2007), or 'voluntary geographic information (VGI[1])' (Goodchild 2007b).

The VGI phenomenon is intriguing for both SDI researchers and practitioners in several ways. One question concerns why millions of people participate in VGI while some SDIs are facing a major challenge to attract users. Whereas VGI participants freely contribute GI, the participants in SDIs are often reluctant to share information. What factors lead to these differences? Are SDI and VGI separate phenomena or do they have some relation? Will their harmonization be better for the society? If yes, how can this be accomplished?

Several authors have begun to explore the connection between VGI and SDI (For example: Craglia 2007; Goodchild 2007b). Others, for example Elwood (this issue), have suggested that we seriously explore the utility of long-standing experiences with SDIs for understanding VGI issues. In this paper, we trace the relationship between SDI and VGI. In doing so, we look at the VGI phenomenon from the SDI standpoint and find that there are two assumptions within SDI that are problematic when it comes to handling VGI.

These assumptions are that formal organizations are the ones which produce and supply GI, and users are the passive recipients of information supplied by providers. In order to enable SDIs to accommodate VGI and derive utility from their synergy, we propose to reconceptualize the notion of the SDI user from a passive recipient to an active information actor, which we propose to call *produser*. We show that such a reconceptualization allows the user to produce and share GI, whereby the production functions are expanded from formal organizations to individuals and loosely formed groups of individuals. Further, we argue that the harmonization of SDI and VGI can, in fact, create a very rich and fertile middle ground between these two.

The following section examines the production and use of GI in contemporary SDIs and identifies some of the challenges for accommodating VGI. In the section "Alternate view of the user and VGI phenomenon", we propose an alternative view of the user by drawing on the information science literature, primarily on appropriation of technology, use and user studies, the open source software movement and Wikipedia. The section "Towards a hybrid SDI model: creating the middle ground between SDI and VGI" presents a hybrid SDI model, with tenets of both contemporary SDI and VGI, and discusses how it accommodates VGI. We conclude the paper with key issues and their implications for future research.

Current view of SDI user

The production of paper maps is an expensive task. Because of its capital-intensive nature, many

[1] The term 'VGI' is used in the remainder of this paper to keep it consistent with the theme of this special issue.

governments have financed organizations to produce and supply geospatial information (GI) with certain mandates in order to meet the key GI needs of a society (Goodchild et al. 2007). Often, these organizations have evolved as national mapping agencies (NMAs) such as geodetic, topographic, cadastral, environmental, and agricultural mapping agencies. These NMAs have led in handling GI because of economies of scale of production and the development of expertise.

The SDI concept, which originated in the early 1990s, encompasses a framework of technology, policies, standards, and human resources required for acquiring, processing, storing, disseminating, and effectively utilizing GI (Groot and McLaughlin 2000). In the early 1990s, the initial capital investment—cost of computer and other devices—required for producing digital information was still high (Benkler 2006), and the Internet and the Web were in their infancy. Therefore, large organizations continued to enjoy the economies of scale of production with the development of SDIs. Further, the expertise NMAs had developed in the paper era was largely transferred over to digital GI in the SDI environment. These helped NMAs maintain their lead in the production and supply of GI in SDIs. This is illustrated in Fig. 1, where a circle representing the GI production centers is located in the upper right quadrant in the producer-user and expert-amateur axis. Thus, the expert organizations are the producers of GI in contemporary SDIs. Often, these are government agencies, which operate in a formal and top–down environment. The more expert an organization is, the farther it is from the producer-user axis in the upper right quadrant.

In contemporary SDIs, users are also largely expert organizations, as shown in the upper left quadrant in Fig. 1. The thick line connecting upper right and left quadrants depicts this. A very thin line is used in connecting upper right quadrant to lower left quadrant to signify that amateurs and individuals are not the target users in current SDIs. Contemporary SDIs are created *for* expert organizations *by* expert organizations (Craglia 2007). Furthermore, the unidirectional lines connecting the producer to users in Fig. 1 depict the underlying assumption about the conception of the user. This assumption leads an SDI to a one-way transmission model where the user can only receive GI from an expert producer. In this model, producers make two related assumptions: first, their products/services satisfy users' needs; second, users employ these products/services in congruence with the producers' intent. Thus, users of an SDI are often referred to as *'end-users'*—a term which itself reflects their marginalized role as mere recipients of GI.

The majority of SDIs worldwide have been led by NMAs (Williamson et al. 2005), which traditionally view the user as a passive recipient of their products. NMAs collect geospatial data, design maps, and then

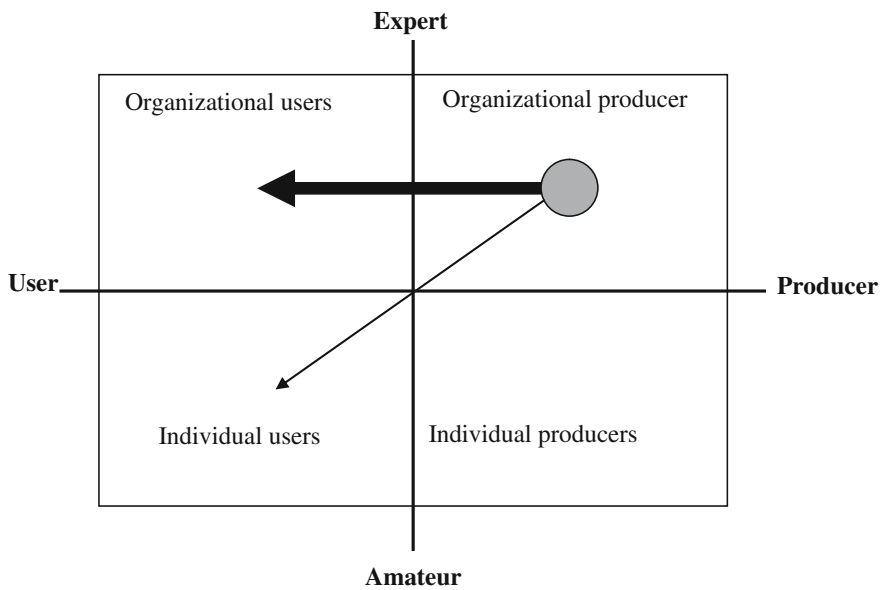

Fig. 1 GI production center and conception of the user in contemporary SDIs (*Adapted from Eglash* 2004)

distribute these to users. SDIs have inherited this legacy view of the user, especially the first generation SDIs where the focus has been on making public geospatial data available to users (Masser 1999). At present, almost all geoportals, including the one for the United States (www.geodata.gov), are based on this conception of the user. These do not allow the user to upload GI or alter the content.

There are indications that current SDIs, which follow this top–down model, are underutilized. For example, some of the European SDIs are not fully operational (Bernard et al. 2005; Masser 2005b); data-centric implementation of the Indian SDI is not encouraging (Georgiadou et al. 2005); inadequate access infrastructure and capacity of participating agencies have impeded the uptake of the Nepalese SDI (Budhathoki and Chhatkuli 2003). The limited use has been attributed to the passive role of the users and inadequate attention to users' work practices and information behavior (Tulloch and Fuld 2001; Nedovic-Budic et al. 2004; Harvey and Tulloch 2006; Elwood 2007).

> "First-generation SDI, particularly the US NSDI, seems to have less success than desired because its concepts and policies, while technically sound and institutionally meaningful for agencies with a mandate to share and coordinate GI, failed to fully address the needs, requirements, and perspectives of local governments" (Harvey and Tulloch 2006, p. 765).

Second generation SDIs have capitalized on the advancement in information and communication technologies (ICTs) and have made substantial progress. The focus in these SDIs has shifted from the provision of data to services with web services as their key component (Bernard and Craglia 2005; Maguire and Longley 2005). However, even these new generation SDIs have not progressed beyond the view of the user as a passive recipient. The provision of services alone has made little difference in overall effective use. As Elwood (2007) finds, one of the major issues associated with use of SDIs is the difference between the provider and the user's perceptions of space. These differences are often deeply rooted in the socio-cultural reality and knowledge systems of a society in which the SDI operates. If geospatial objects have been captured and represented in databases using the supplier's priorities and perceptions, the disparity between the supplier and the user continues even with services generated from these objects. Puri (2006) finds widespread perceptual differences among different SDI stakeholders—including suppliers and users—of the Indian NSDI.

Users' involvement in the SDI development process has been proposed as a way to attract a greater number of potential users. There is an assumption that the users' involvement ensures identification and capture of their unmet requirements. When users, and other stakeholders, are involved in SDI development, they feel empowered to express their requirements (Craglia and Annoni 2007) and their divergent technological frames get converted into a shared understanding (Puri 2006). The call for this participatory discourse is similar to the shift from system-centered to user-centered approach to information service design in the 1980s (Dervin and Nilan 1986; Wilson 1994, 2000). The central premise behind this call is to capture the users' requirements and thereby design more useful information services.

A relatively more popular user-centered information system approach is the participatory design (PD), in which users are involved in system design exercises. PD has roots in union empowerment culture in Scandinavia as well as the socio-technical approach for information system design in Britain. Involvement of those who are affected by a new computer system is important both for ethical reasons and for avoiding failures of techno-centric information systems (Mumford and Henshall 1983). However, despite its attractive rhetoric, even PD suffers from several challenges in the design and use of information systems. Byrne and Sahay (2007) cogently describe their experience in developing an information system for public health care in South Africa and argue that participatory approach in information system design adds only a little unless the capability of participants to meaningfully participate is enhanced. Spinuzzi (2005) provides a systematic analysis of participatory system design, including its limitations.

However, participation in the design of infrastructural systems such as SDIs poses additional challenges. First, since an infrastructure evolves over time (Edwards et al. 2007), it has neither a well-defined design period nor fixed user groups. There is

a lack of knowledge about who the users are, which users best represent the potential user community, and when to involve them. Even if users can be identified and involved, it is difficult for them to provide input without a sense of the SDI; they would need to use it if they are to express their requirements to producers. It is only through the process called *innovation-in-use* that users interpret and appropriate the innovation (Bruce and Rubin 1993). Further, since the user's GI needs are changing, the involvement of users cannot ensure knowledge of future needs. Thus, the users' involvement in design exercises is no panacea for increasing the use and utility of SDIs.

In summary, the assumptions that only formal organizations could be the producers of geospatial information and that the users are passive recipients are problematic and restrictive to the development of useful SDIs. Moreover, operating an SDI with these assumptions misses the new opportunities created by the VGI phenomenon. In the next section we look at the alternative concept of the user that draws from the literature on appropriation of technology, open source software movement, and the Wikipedia experience. We propose a reconceptualization of the existing view of the SDI user, which expands the range of GI producers from formal organizations to individuals and groups of people. The inclusion of users in GI production allows building upon the *funds of knowledge* (Moll et al. 1992), which users already possess or they can create.

Alternative view of the user: appropriation of technology, open source software, and Wikipedia as precursors

Appropriation of technology

Understanding of the user requires analysis of the ways in which the user's information needs arise and the process through which the user seeks, searches, and puts information in use. The gap between what the user already knows and what s/he needs to know in order to complete the task, called anomalous state of knowledge (ASK), leads the user to information seeking (Belkin et al. 1982). Dervin and Nilan (1986) similarly note that when an individual's internal sense runs out, s/he experiences information need that arises from the gap between her/his current and desired situations and leads to the use of information. Both the tasks and related information seeking, search and use are often undertaken in complex social, cultural and technological situations. Moreover, information is not something that is transmitted invariably from database(s) to users to be directly used; it acquires a specific meaning given by the user at a certain time and space. "Information mediates between objects in the natural world, as data, and the inner workings of the human mind, as knowledge and wisdom" (Poore and Chrisman 2006, p. 511). In this process, users are required to continuously act and construct information in order to bridge the gaps. Thus, users' information behavior suggests that they are the actors of information.

Several studies in information science have investigated the notion of the user as information actor. For example, Hippel (2007) reports that up to 40% of the user population interviewed have come up with some kind of innovation to suit their own use. Similarly, Eglash et al. (2004), and Oudshoorn and Pinch (2005) present a collection of case studies of appropriation of technologies by users. Eglash et al. (2004) discuss the notion of the user as an active actor in settings as diverse as innovative uses of information technology during Tiananmen Square protests in China and learning computer skills by African-American women.

Appropriation of innovation by users occurs at several levels of increasing sophistication (Fig. 2): *reinterpretation, adaptation, and reinvention*. Reinterpretation is the weakest case of appropriation, where the use of functional and structural properties of technology remains congruent with the designer's intent. A stronger case of appropriation is adaptation, where users discover latent functions of technology in

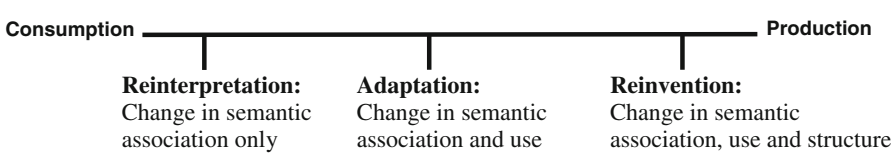

Fig. 2 Categories of appropriation in the consumption production dimension (Eglash 2004)

addition to its semantic change. Reinvention is the strongest case, where users create new functions through structural change in the technology. The degree of appropriation of an innovation is influenced both by characteristics of the innovation as well as the user. For adaptation to happen, users need to violate the producers' intended purpose and technology should offer flexibility (Eglash 2004).

Open source software

The open source software (OSS) movement provides compelling examples of users' active contribution towards software development. In the OSS production, dedicated computer programmers spend several hours per week on developing software components. In OSS development, users are considered co-developers where they have access to the software source codes, are encouraged to add to the original codes and report bugs (Raymond 1999). VGI phenomenon could draw from the OSS experience, since the users' activities in OSS and VGI are similar in nature, except that users produce software in OSS while they produce spatial data in VGI. In fact, there are indications that VGI is influenced by OSS. For example, the Open Planning Project states: "TOPP draws inspiration from the ideas, processes, and successes of the open source software movement" (http://topp.openplans.org/, June 2008).

There are several motivations for users to actively contribute towards the production rather than just passively use software. One of them is the producer's failure to meet the users' requirements, which eventually stimulates the user to develop software. Users can create "precisely what they want, rather than being restricted to a set of options on offer that have been produced by others" (Hippel 2007, p. 310). Another is the free answers to queries provided by contributors in OSS development, who in turn receive valuable information (Lakhani and Hippel 2003). Additionally, some contributors are motivated by the enjoyment and reputation they gain from completing the work (Lerner and Tirole 2002). Furthermore, although the software code becomes public good, the participatory experience and learning stays with the contributor (Hippel and Krogh 2003).

Some explanations of the desire to contribute take the perspective of social movements. For instance, analyzing the survey responses of a large number of contributors to Linux kernel project, Hertel et al. (2003) suggest a parallel between the open source software movement and other social movements. They state that the "engagement for the Linux kernel community seemed to be driven by similar motives as voluntary action within social movements such as the civil rights movement, the labor movement, or the peace movement" (p. 16). Open source software allows the user to enjoy her/his freedom to express and use—the most fundamental human desire—which propriety software does not.

Proprietary and open source software also differ in their development models. By contrasting the two, Raymond (1999) calls the former 'cathedral-style' and the latter 'bazaar-style.' The 'cathedral model' is hierarchical; the 'bazaar model' is more democratic. In the 'bazaar model', everyone can watch, create, and contribute. Discussing the 'bazaar model' development of widely used operating system 'Linux', Raymond suggests that "[g]iven enough eyeballs, all bugs are shallow" (p. 29). Users' collective intelligence is the driving force behind the bazaar model. Thus, no matter what the motivations and processes are, users do not passively use an innovation provided by the producer. Hippel (2007) concludes that users have sufficient incentive to create the 'users innovation network', and to participate in the innovation process. In a successful innovation, users are not treated as passive recipients, but as co-developers.

Wikipedia

The conception of the user as an actor of information is more obvious in the case of Wikipedia. Wikipedia project was created in 2001 and by 2008, it holds millions of articles that are uploaded by millions of contributors in hundreds of languages (www.wikipedia.org, May 2008). It is a collaborative knowledge production project, which allows anyone to edit, contribute, and use its content (Bryant et al. 2005; Kuznetsov 2006; Nov 2007). Most importantly, the reliability of the material is well maintained. A recent study finds that the quality of the articles in the Wikipedia is equivalent to those in the Encyclopedia Britannica (Nature 2005). Despite the difference in the nature of content—Wikipedia focuses on text information whereas VGI focuses on GI—both follow a similar process of knowledge production. Indeed, some VGI projects reveal an influence from Wikipedia, for example, the name 'Wikimapia'. Therefore, based on

the phenomena discussed above and GI community's recent experiences with VGI, we can begin to reconceptualize the user of SDI in the following section.

SDI user reconceptualized: produser

Recently, millions of ordinary people have been actively engaging in the production, sharing, and creative use of GI (Boulos 2005; Miller 2006). While the use of geospatial knowledge held by ordinary citizens is not new in itself—we have been using citizen input for tasks such as cadastral adjudication, topographic map updating, for driving directions, and during travel in new places—the ease of use of Web 2.0 based tools and the sense of empowerment people feel from using these tools, have created a new wave of possibilities. In the aftermath of Hurricane Katrina, Google Earth images were more useful than the United States Geological Survey (USGS) maps for rescue workers attempting to locate victims and collaboratively describe the surrounding geospatial situation (Nature 2006).

Clearly, these VGI activities conflict with the traditional view of the user as a passive recipient. In order to explain and accommodate these activities, we propose to reconceptualize the user of SDI as an actor of GI. This is illustrated by changing unidirectional lines connecting producers to users in Fig. 1 to bidirectional as shown in Fig. 3. As the notion of the user is reconceptualized, small circles that were not present in the upper and lower left quadrants in Fig. 1 appear in Fig. 3. This means that the production functions are now expanded from expert organizations to user organizations and individuals. Accordingly, the user's roles transcend from recipient to produser, and therefore we call them *produser*. The produser may choose to receive, appropriate, creatively use, share, and/or produce GI independently or in collaboration with others. Furthermore, the produser need not be limited to the organization; individuals and groups can also take part in the production and supply of GI.

Thus, the reconceptualization of the user establishes a two-way interaction between the producer and the user, which blurs the boundary between them. However, some individuals produce more than others. Therefore, we can place them in the lower right quadrant as in Fig. 4. This distributes the production centers in all the quadrants. Because organizations or individuals in any quadrant can produce and share GI with others located in any other quadrant, all the circles in Fig. 4 are connected with each other.

In the reconceptualized notion of the user, an SDI provider may ask the produser: 'what situation has brought you to access and use SDI?', rather than asking: 'what do you want from SDI?' This helps to understand the produser's information seeking and potential uses. The provider may also ask: 'how can

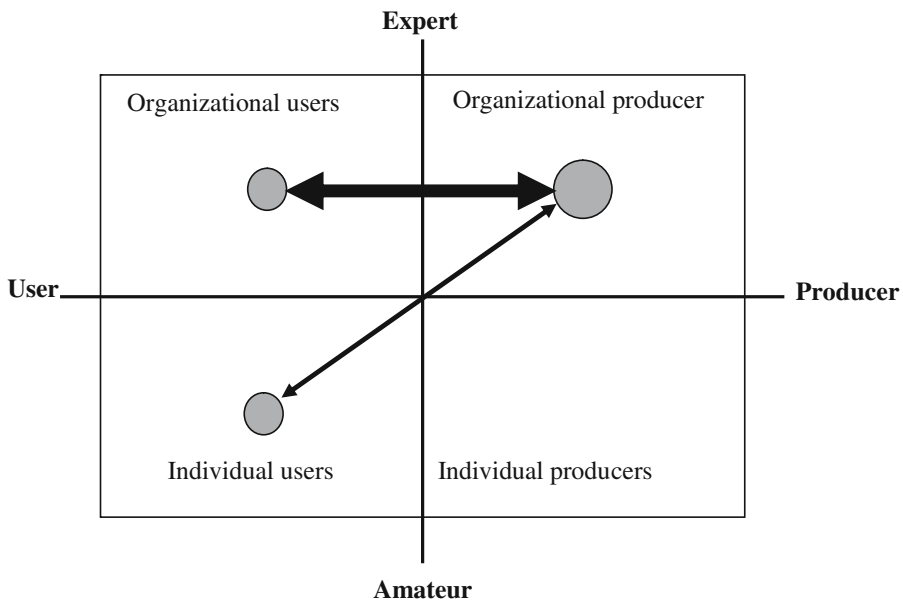

Fig. 3 Reconceptualized notion of the user

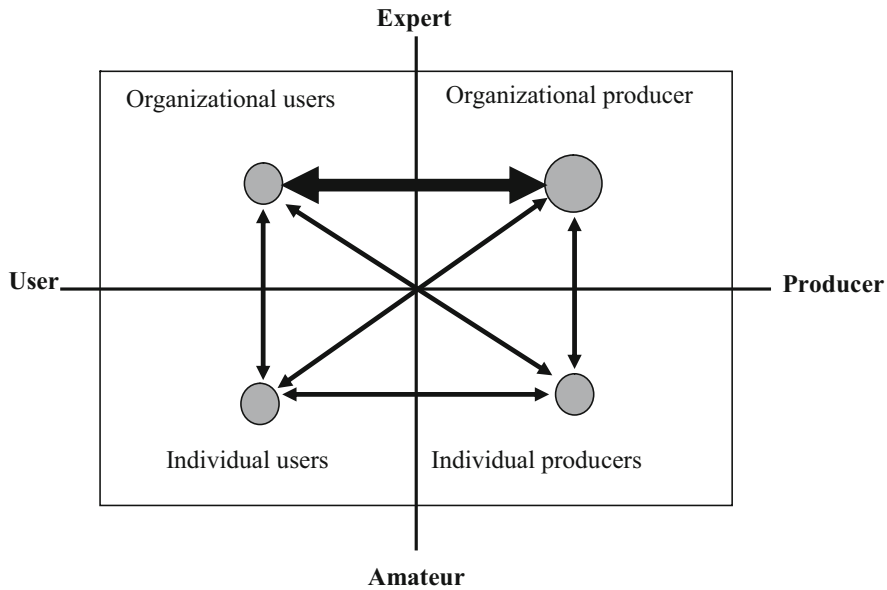

Fig. 4 Production-use dynamic resulting from the VGI phenomenon

this infrastructure enable your easy production, sharing, access, and use of information?', rather than asking: 'how can I provide information to you that best satisfies your needs?' One who considers the user as a passive recipient is likely to ask the second type of questions, whereas one who considers the user as a produser is likely to ask the first type. These seemingly small shifts in the way questions are framed may bring potentially large change in the conceptualization, design, and implementation of an SDI.

Towards a hybrid SDI model: creating the middle ground between SDI and VGI

Reconceptualization of the SDI user has led us to a framework with multiple GI production centers that are connected with each other forming complex networks of produsers (Fig. 4). This framework suggests that produsers contribute as well as derive from others' contributions. Individuals can supplement organizational GI production and at the same time they can use the expert organizations' products; this is illustrated by the bidirectional lines connecting the upper and lower right quadrants. Produsers may point out the official producers' erroneous or missing data, as in the case of USGS's National Map Corps program (Bearden 2007).

There can be variations among VGI participants depending on the level of contribution and the degree of expertise. This could be expressed as the placement along the producer-user and expert-amateur continuum in Fig. 4. For example, those individuals who choose to free ride (i.e. those who contribute little) are placed farther from the expert-amateur axis in the lower left quadrant; those whose contributions far outweigh their use are placed farther from this axis in the lower right quadrant; and those whose contribution and use levels are similar are placed near the axis. Similarly, individual produsers with more GI expertise are placed closer to the producer-user axis in the lower right quadrant than those with relatively less expertise. Participants may also vary across VGI projects depending on the nature and goal of the project. For example, produsers to the Open Street Map are likely to have more expertise than produsers to the Degree Confluence project. In Open Street Mapping, produsers contribute geometry and description of streets (www.openstreetmap.org, May 2008). In the Degree Confluence project, produsers just take pictures at the locations where the integer degrees of geographic latitude and longitude intersect (http://confluence.org/, May 2008).

The multiple bidirectional lines among produsers in Fig. 4 suggest that VGI and SDI are related phenomena. We argue that SDI can accommodate VGI with the reconceptualized notion of the user. Users' contributions of information in VGI fits quite well as patchworks to SDI (Goodchild 2007a). However, at present, it is unclear how the lines in

Fig. 4 will influence and shape each other, and in which direction. Some have called this current state 'a stage of anarchy' (Carrera and Ferreira 2007), as little is known about how amateurs and experts are interacting in the production and use of GI.

At the conceptual level, the emergence of SDIs is in itself a manifestation of the expansion of GI production centers from NMAs to a large number of other organizations. For example, the United States National SDI encompasses a network of hundreds of organizations (Goodchild et al. 2007) that acknowledges the distributed production of GI among these organizations. This distribution now needs to be widened from organizations to individuals to accommodate VGI. We argue that the conceptual foundation SDIs have developed over the last two decades can be useful in VGI context as well. Conceptual apparatuses such as metadata, standards, interoperability, policy, and organization have been evolving in SDI research (Budhathoki and Nedovic-Budic 2007). The concept of metadata, for example, could be applied to VGI, perhaps with reduced mandatory elements of metadata standards for amateurs or for certain GI types. In fact, the metadata is even more important for VGI than SDI, given that GI is supplied by a large number of produsers which is more difficult to discover. The long-standing experience in the contemporary SDI combined with the produsers' excitement in VGI can create a richer GI infrastructure, which we refer to as the hybrid SDI model.

In fact, the synergy between SDI and VGI has already begun to happen. For example, Google and Environmental System Research Inc. (ESRI) recently announced an intention to integrate ESRI's professional GIS product with Google's VGI product (http://radar.oreilly.com/, June 2008). The recent decision by Yahoo! to provide its high resolution aerial imagery to the Open Street Map (See http://www.opengeodata.org/, May 2008) is another evidence of the complementary nature of various approaches to SDI. Thus, VGI is forcing the expert producers to rethink their traditional approaches of GI production. Further, Google Map, which is considered as one of the most popular VGI tools, relies on a hybrid model. It is the synergy between the street networks produced by NAVTEQ and Tele Atlas (the expert producers) that Google uses (http://maps.google.com/, June 2008), as well as its produsers' contributions that has popularized the Google map. However, it is unlikely that VGI will completely replace SDIs. For example, amateurs would not be able to create maps, had Google Map not provided the streets as the basic frames. Along the same line, OSS and proprietary software have influenced each other and resulted in new models. For example, IBM is not only providing financial support to popular OSS products like Linux and Apache, but also adopting a different business model by selling products for which an increased demand is created by the OSS products (Benkler 2005). Also, VGI is unlikely to satisfy a vast majority of institutional and professional GI producers whose requirements in terms of data quality, timeliness, and completeness are not flexible.

SDI researchers have called for a user-driven SDI model (Williamson 2003, Masser 2005a; Budhathoki and Nedovic-Budic 2007), which relates to the hybrid SDI that incorporates VGI. The synergy between SDI and VGI has a potential to lead to a third generation SDI in its development continuum proposed by Rajabifard et al (2006). This model of SDI could tap numerous VGI participants similar to Google map, Google Earth, and similar other products. It would enable SDIs to obtain and provide fine-grained GI produced by spatially-aware individuals. In such an SDI, produsers' collective intelligence and local knowledge are harnessed. Further, produsers are deeply involved and empowered, and a more bottom–up, incremental and evolutionary approach is adopted (Fig. 5).

Conclusions

In this paper, we argue that SDI and VGI are not separate, but complementary phenomena. Indeed, these can be brought within a single framework when the role of the user of SDI is reconceptualized to *produser* and VGI is included in the SDI-related processes. We show that such a reconceptualization distributes the production of GI among organizations, individuals, and groups of individuals. Such a reconceptualization creates a hybrid SDI model that draws on the synergy between the conceptual foundation of SDI and an extensive produser base of VGI.

The emergence of the hybrid SDI suggests several new research directions. Instead of being focused either on SDI or VGI, we now require research that

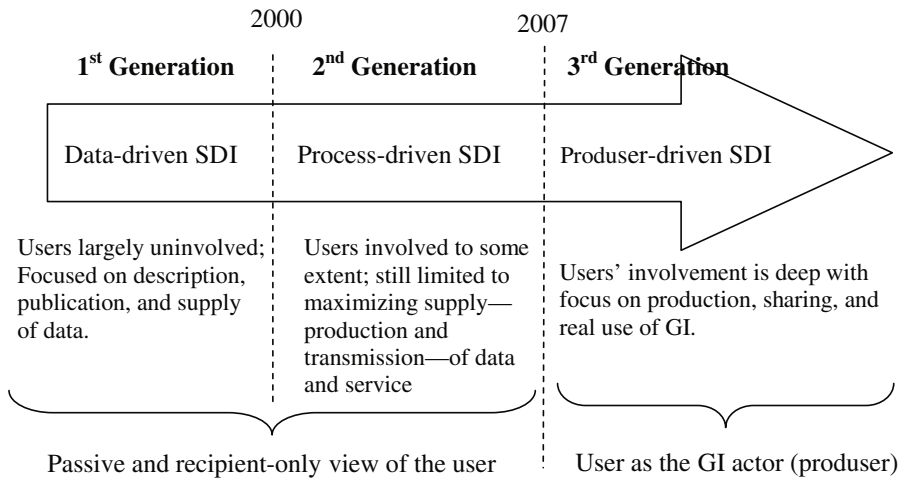

Fig. 5 Next generation SDI emerging from VGI (Adapted from Rajabifard et al. 2006)

focuses on the boundary phenomenon. Some questions might be: how should traditional GI producers now redefine their roles? Which of the GI production tasks are to be distributed to individuals or groups of individuals, and which are to be retained by traditional producers? Which aspects of SDI and VGI neatly synergize, and which of them conflict? Which SDI conceptual tools need to be extended or even redefined in the context of emerging VGI phenomenon? Such questions require a careful consideration of several issues: access to technology (penetration of the Internet in particular), cultural values, skills, and education, among others.

While the informational aspect has received greater attention, the infrastructural aspects need equal consideration in VGI research. How do back-end infrastructures—which are often invisible (Star and Ruhleder 1996)—emerge and evolve to support VGI activities? How can a large number of participants, without being coordinated by any formal organization, collaboratively produce something when there is no obvious monetary reward? What motivates them? What organizing principles do they follow? Are these principles transferable to the settings of formal organizations? In addition to accommodating VGI, addressing these issues could illuminate a wide range of organizational and institutional problems that limit the effective development and use of SDIs.

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