Challenges for quality in volunteered geographical information

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Abstract

The University of Pretoria in South Africa and the Wrocław University of Environmental and Life Sciences in Poland have a joint research project under the SA/Poland Cooperation Agreement on Cooperation in Science and Technologies, entitled *Volunteered Geographical Information (VGI) for Spatial Data Infrastructures (SDIs) and Geoportals*. The Internet, the World Wide Web and cheap computing resources have spawned the creation of *user-generated content (UGC)* in general, and *volunteered geographical information (VGI)* in particular. A key aspect of such data, when compared against professionally-generated and/or official content, is the provenance or *quality* of the data, and the documenting thereof – the *metadata*. We consider here some of the quality challenges for VGI, and how these might be addressed.

1. Introduction

The Internet has spawned the development of *virtual communities* or *virtual social networks* which share data with one another, and with the public at large. The first phase of the evolution of the *World Wide Web* is known as *Web 1.0*, with network resources, information and services being delivered and developed only by professional programmers and the administrators of websites. Users are only passive receivers of what is delivered to them in the web and do not have a major impact on the published content. The transformation to the next stage, identified as *Web 2.0*, largely revolutionized the perception of the Internet. The start of Web 2.0 is associated with the rise of social networking portals. With the advent of mechanisms for publishing content in the Internet, without having specialized knowledge, anyone can become a provider of information on the web. Web 2.0 is often characterized as a transition from a "read-only Web" to a "read-write web", where the user is no longer perceived as just a passive consumer, but becomes a creator of resources. Web 2.0 can be considered by taking into account the technological and social dimensions. The technological one is connected with the achievements in software and applications in the area of the Internet, while the social one involves the active participation and involvement of users. We do not address here the social dimension of Web 2.0 that relate to how social patterns of behaviour might be affected (and are being affected) by Web 2.0.

This *user generated content* is most obvious in web sites such as Wikipedia (Wikimedia, 2011), the free, online encyclopaedia in many languages, consisting of contributions mainly from the public at large, rather than from domain experts (though it does also include much content from encyclopaedias that are out of copyright and other expert sources). Similarly, virtual communities have also facilitated *folksonomies* or *collaborative tagging*, which entail the classification and identification of content by the general public, rather than by domain experts. This is explored further in Section 2.1 below.

Within *geographical information science (GISc)*, user generated content is also known as *volunteered geographical information (VGI)* and is made available as base maps on public websites, such as Tracks4Africa (2011) and OpenStreetMap (2011), or as third party data overlaid on *virtual globes*, such as Google Earth (Google, 2011). The term VGI was introduced in 2007 by Goodchild (2007), but without actually providing a definition. He suggested that it combined elements of *Web 2.0*, *collective intelligence* (also termed the wisdom of the crowd) and *neogeography* (new geography, going beyond the traditional scope of professionals). This is explored further in Section 2.2 below.

One of the consequences of the Internet and the World Wide Web (WWW) is the massive explosion in raw data available to anyone with a computer connected to the Internet – far too much for any human to manage or absorb. This has led to the development of portals and search engines to help users find relevant information. It is also the motivation behind the development of the concept of the *semantic web* or *Web 3.0* (Berners-Lee *et al*, 2001).

A *virtual globe* is an application that presents masses of digital geospatial data over the Internet, typically in the form of a globe, and a *geobrowser* is the interface to geographical information over the Internet, typically allowing users to zoom into the data, switch data layers on and off, create three-dimensional views and add their own data, such as geospatial features (eg: roads and places of interest), tags (with text or links to web sites) and photographs. Virtual globes and geobrowsers are a major conduit for disseminating VGI, and hence are closely coupled with VGI.

The University of Pretoria in South Africa and the Wrocław University of Environmental and Life Sciences in Poland have a joint research project under the SA/Poland Cooperation Agreement on Cooperation in Science and Technologies, entitled *Volunteered Geographical Information (VGI) for Spatial Data Infrastructures (SDIs) and Geoportals*. An SDI is an evolving concept about facilitating and coordinating the exchange and sharing of spatial data and services between various stakeholders (Hjelmager *et al*, 2008). Typically, an SDI is populated with data from official sources, such as national mapping agencies. As discussed below, VGI can also be contributed to an SDI, for which we have developed a preliminary formal model, through the Commission for Geospatial Data Standards of the International Cartographic Association (Cooper *et al*, 2011b). However, in such a context there would typically be concerns over the quality of VGI. We explore here some of the challenges regarding the assessment and documentation of the quality of VGI.

2. Background

2. 1 User generated content

The Internet, the World Wide Web and the many applications available on them have encouraged decentralized and bottom-up generation of content made publicly available. There is no widely accepted definition of *user-generated content (UGC)*, and maybe there never will be. For a report on the participative web, the Organisation for Economic Cooperation and Development (OECD) defined *user-created content* (UCC, their term for UGC) as:

- Content made publicly available over the Internet,
- Which reflects a "certain amount of creative effort", and
- Which is "created outside of professional routines and practices" (Wunsch-Vincent & Vickery, 2007).

Their second criteria could be considered to be controversial, as much content contributed by the public might be done so without any creative effort, such as the material on file sharing sites. Further, it appears to exclude content where the person uploading the content is not the creator of the content but is doing so legitimately, which would be the case of a tribute site, such as for the late Andries Naude (2009), who established the site that was later populated by his wife and friends. The third criteria is nominally useful for differentiating user-created content from professionally generated content, though they do acknowledge that it is getting harder to maintain this distinction as some amateur content providers obtain sufficient status to then get paid for providing the same content for a media web site. This also excludes the content that the likes of De Longueville *et al* (2009) consider to be user generated, namely where the data are collected, synthesised and posted by a professional research team, derived from interviews with stakeholders (Cooper *et al*, 2010a).

Of course, UGC is not confined to the Internet and was not invented on the Internet – though the Internet brings UGC to a much wider audience and much more quickly, than would otherwise be the case. People generate content whenever they document something or tell someone something. Much of the content is discarded quickly, because the other person was not listening or the document (eg: scrap of paper with a shopping list) is used and thrown away. There are no minimum criteria for value, availability or use for considering whether or not content can be deemed UGC. Of particular interest here is the UGC that is made widely available, such as through the Internet.

Pervasive, cheap (or free), easy-to-use and intelligent web services empower users to develop, rate, combine (eg: mashups) and distribute content on the Internet; collaborate with peers (known and unknown, with common interests or not); and customise Internet applications. This is the basis of the participative web (Wunsch-Vincent & Vickery, 2007). Gervais (2009) feels that even as a mere conceptual cloud, the term UGC is useful for considering the societal shifts in content creation due to the participative web.

2. 2 Volunteered geographical information

Already, quite a bit has been published on VGI, especially in the context of an SDI, eg: Craglia *et al* (2008); Budhathoki *et al* (2008); Coleman *et al* (2009); and McDougall (2009). An indication of the novelty of the field is that a comprehensive classification of municipal websites from as recently as 2005 did not cater for VGI, however the concept might be labelled (Caron *et al,* 2005). The emerging research on VGI is multifaceted, taking into account industry, technology, discipline, social, political, and other aspects (Elwood 2008).

Nevertheless, this does not mean that the concept of VGI is well understood. For example, with Tracks4Africa, the data are contributed voluntarily, directly and on their own initiative by individuals (Tracks4Africa, 2011). Similarly, in a citizen-science project such as the 2nd South African Bird Atlas Project (SABAP2), the data are gathered by pentad (areas 5' by 5') by individual, amateur birders and contributed directly to SABAP2, according to the published protocol (Harrison *et al,* 2008; Animal Demography Unit 2011). Some of these birders also contribute the coordinates of their species records on their own initiative directly to another web site, NaturalWorld (2011).

However, as mentioned above, De Longueville *et al* (2009) have a different perspective, considering VGI to be data collected, synthesised and posted to the Internet by the research team from interviews with stakeholders. Expressions that their interviewees used in relation to a location were extracted from transcribed interviews in order to assign a location to the environmental phenomena described by the interviewees. Many of these stakeholders could be considered to be professionals or experts in their respective fields (environmental data, in this case), though not necessarily GISc professionals (Cooper *et al*, 2010a). This dichotomy can have a major influence on the quality of VGI.

Because of the costs of official mapping programmes and the volume of quality and up-to-date VGI becoming available, the custodians of SDIs are starting to admit VGI into their SDIs. This could be in the form of revision requests or notices submitted to an SDI through its web site by the public (Guélat, 2009), or potentially even using large quantities of VGI (Cooper *et al*, 2011a). An obvious concern with VGI is how its quality compares with official information (Haklay, 2010).

The development of Web 2.0 in the field of geographical information science is strongly related to the activities of commercial companies, which bear the huge costs associated with the creation and maintenance of products such as Google Earth or Microsoft Virtual Earth. Ironically, then, while the web encourages data democratization, it also facilitates centralization of the control of data such as VGI. With the development of the Web, not only the way of publishing spatial information changes, but also the way of acquiring such information. Until recently, the creation of spatial data was a task reserved only for professionals, such as photogrammetrists, cartographers and geographers. Thanks to the dynamic development of web services and consumer GPS receivers, GIS has a new dimension. There are services which allow an ordinary user on the Internet to create, analyze, process and publish spatial data. GIS is becoming available from a web browser and its functionality is becoming richer, such as through GeoCommons (2011) and GIS Cloud (2011).

Several attempts have been made to develop taxonomies of VGI (eg: Coleman *et al*, 2009; Budhathoki *et al*, 2010). Currently, we are exploring the possibility of using *formal concept analysis* (Wille, 1982) to assess the adequacy of such taxonomies at discriminating between repositories of VGI, through *stability exploration* (Cooper *et al*, 2010b). Figure 1 presents two possible dimensions of a taxonomy for VGI that are particularly important for understanding quality issues regarding VGI. On the horizontal axis, we have the continuum of responsibility for determining the specifications for the data, ranging from a user on the left (effectively, near-anarchy) through to an official data custodian on the right (with tightly controlled specifications). The vertical axis ranges from base data at the top to points of interest (PoIs) at the bottom – it is a continuum because classifying data as base or PoIs can depend on one's perspective and applications of the data. The grid in Figure 1 is populated with examples of repositories of VGI:

- Bottom left is *Panoramio* (Google, 2011), with arbitrary photographs of places added to Google Earth, sometimes incorrectly labelled and positioned. *Google Earth* itself is an undifferentiated repository of data, spanning both base data and PoIs, and including both VGI and from official sources.
- Top right is a *crowd-sourced SDI* (which probably does not yet exist), where users contribute data according to a tight specification from the custodian, who would then subject the VGI to their usual quality assurance processes.
- Also in the top-right quadrant are repositories of VGI that are primarily base data, particularly road and street networks, that are subject to fairly tight specifications (eg: *OpenStreetMap* and its mapping parties) and/or rigorous quality assurance (eg: *Tracks4Africa*, which uses statistics to produce a best fit from multiple contributions for each road, street or track segment).
- On the lower right are repositories with tightly-defined specifications for PoIs, such as *in-vehicle navigation systems* (traffic densities) and *citizen-science* projects such as SABAP2.
- In the lower-left quadrant are the likes of *Mobilitate* (2011), for logging complaints about service delivery in South Africa, *NaturalWorld* and *Wikipedia*, which relies on open peer review of its articles. *Precinct Web* (2011) has more rigorous specifications for mapping crime in South Africa and *Padkos* (2011) is Tracks4Africa's site for PoIs (accommodation, restaurants, shops, etc).
- The specifications and data for *asset-based community development (ABCD)* will evolve as the community discovers what is important to them.
- The *public participatory geographical information system (PPGIS)* is in the middle because it

includes contributions from both custodians (eg: local authorities) and community members (the VGI), and both base data and PoIs.

- Unsurprisingly, the top-left part of the grid is empty, because base data are widely used and hence need specifications.

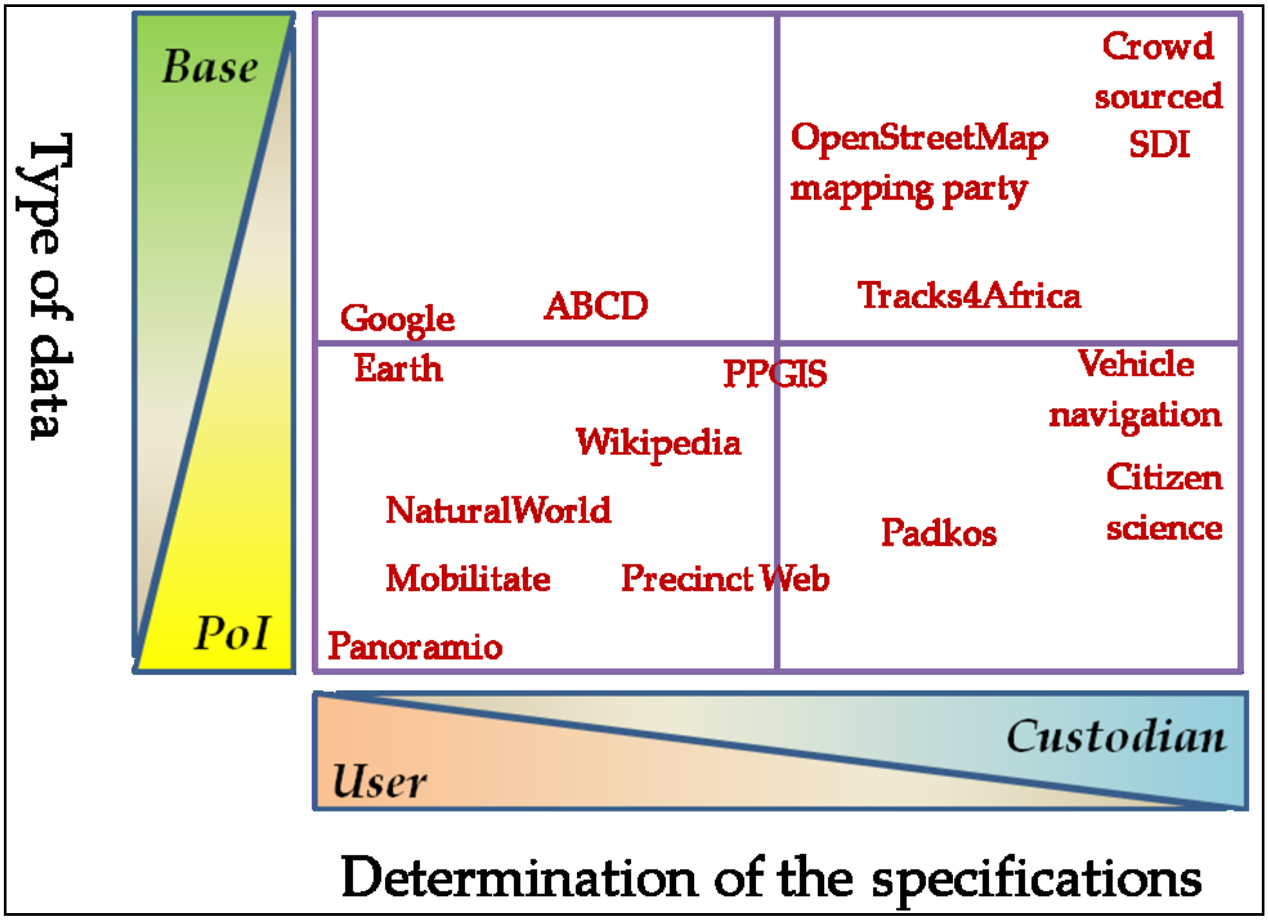

Figure 1: Types of VGI

2. 3 Data quality

When considering the quality of spatial data, most naive users consider only the *positional accuracy* of the data. However, there is more than just this aspect to the quality of spatial data, which is considered here from the perspective of VGI:

- **Positional accuracy**: describes how close locations of objects represented in a digital data set correspond to the true locations for the real-world entities (Bolstad 2005). Positional accuracy comprises both planimetric accuracy (in the plane representing the surface of the Earth) and vertical accuracy (above or below the plane).
- **Attribute accuracy**: summarizes how different the attributes are from their true values (Bolstad 2005) and includes the classification of feature types. Attribute vales can be on nominal, ordinal,

interval or ratio scales (Stevens, 1946), free text or even multimedia.

- **Currency**: the time period(s) for which the data are valid. It is critical to realize that the most recent data set is not necessarily the best, as it might be of a lower resolution or otherwise inferior. Further, historical data are needed for time series, archaeological or historical purposes.
- **Completeness**: describes how well the data set captures all the features it is intended to represent (Bolstad 2005), that is, errors of omission.
- **Logical consistency**: reflects the presence, absence or frequency of inconsistent data (Bolstad 2005), such as inappropriate attributes for a feature or mismatches across dataset boundaries. These are errors of commission.
- **Lineage**: provides the history of the data, describing the sources, methods, timing and persons responsible in the development of a data set (Bolstad 2005).

Unfortunately, there is also a tendency to confuse the terms *accuracy*, *resolution* and *precision*, which can make it complicated for a less experienced user to assess the quality of their VGI:

- **Accuracy**: the closeness of observations, computations or estimates to the true values or the values that are accepted as being true (Moellering, 1985). Higher accuracy therefore implies that a measurement is nearer the truth, with the truth being either absolute or relative. Accuracy is the final measure of the worth of the data (Clarke *et al*, 1987).
- **Resolution**: the smallest unit that can be detected. Resolution provides a limit to precision and accuracy (Moellering, 1985). Spectral resolution is the width of different bands of the electromagnetic spectrum in which a multi-scanner operates. The spatial resolution of digitizing equipment is the minimum distance that the equipment can detect between any two points, while the spatial resolution of a plotter is the minimum distance between plotted points (eg: dots per inch, or DPI).
- **Precision**: a statistical measure of repeatability. It is usually expressed as the variance or standard deviation of repeated measurements (International Cartographic Association 1980).

3. Quality challenges for VGI

3. 1 The nature of the challenges

Drawing on our observations about user-generated content, volunteered geographical information and data quality, we identified several challenges for assessing the quality of VGI.

One of the biggest challenges is that due to the nature of VGI, it cannot necessarily be assessed at the time of contribution. The quality of spatial data is subjective, i.e. data quality depends on the data user, purpose and the context in which it is used. Therefore, the contributor cannot assess the quality of their contribution in isolation. Rather, the user should assess the quality based on their intended purpose and context, and document these in the information provided by the contributor about the data, i.e. the metadata. However, despite metadata software utilities and a widely-used international metadata standard (ISO 19115:2003), metadata is still not readily available for many datasets and/or their features. There is even less metadata available for VGI because users are seldom forced to capture or disseminate metadata – or are even aware of metadata.

A further complication is that in general, users are not involved in the development of standards, such as for assessing quality or documenting metadata. The result is that even if they are aware of the relevant standards, they do not necessarily "buy in" to the standards nor understand their context or utility. Additionally, in our experience, even GISc professionals can struggle to read a standard without some training because of the formal requirements for a standard and the necessarily repetitive structure of the text – a standard is not a novel!

Not all aspects of data quality can be assessed quantitatively, and there are important types that have qualitative aspects to them. While quantitative measures can be understood in many languages (e.g root mean square error for positional accuracy), qualitative assessment is language dependent (e.g. a statement about what should be included in the data set, for assessing completeness).

VGI can also be contributed anonymously, as in the annotation of sites allegedly connected with the pirates of Somalia, as contributed by "expedition" (2009) – see Cooper *et al* (2010a) for a discussion of the issues.

Unfortunately, in addition to "normal" errors, not all contributions of VGI are made altruistically or without bias. Contributions could be made to promote a particular political, religious or social agenda; out of malice (e.g. to denigrate someone or some community); with criminal intent (e.g. to manipulate asset prices); or simply out of mischief (Coleman *et al*, 2009). Such malevolence can be in both commission and omission. Whereas poor data are likely to be poorly documented, malicious data might well have detailed metadata, albeit fraudulent! Of course, these problems can also apply to official data, particularly from a repressive regime.

3. 2 The risks

While mandated organisations (such as national mapping agencies) should produce data of higher quality than VGI, their mandates and priorities (eg: the need to provide national coverage or the need to support a specific national priority) might result in significant delays before they update data in certain areas. On the other hand, the public at large might be the best available source to keep local data up to date, such as verifying street names and addresses, or documenting changes when they happen and simultaneously submitting revision requests to the relevant agency,

The risks of using poor quality VGI are primarily the same as the risks of using poor quality data from an official or commercial supplier – the source of the data will not affect the results of using the data. The key difference might be that an official agency or commercial vendor could possibly be held legally accountable for their data, though in practice, this hardly ever happens because of disclaimers of liability.

3. 3 Addressing these challenges

As with user-generated content in other contexts, such as Wikipedia, a key aspect of the quality assurance of VGI will be peer review and peer pressure to adhere to norms and standards, and to provide metadata. The latter can be facilitated by the provision of automated tools for metadata capture and/or discovery. For example, the European Union's Joint Research Centre has recently released the European Open Source Metadata Editor (EUOSME), a web application to create metadata in any of 22 European languages, that conforms to the requirements of INSPIRE, the European Union's SDI, and also of ISO 19115 (JRC, 2011).

Another solution is to develop tools that automatically assess the quality of a specific VGI contribution, such as for logical consistency (e.g. valid attribute values), or against other data sources (as Tracks4Africa does). If these tools are deployed as web services, they can be used by more than one VGI repository.

In our research project we aim to explore potential solutions for these challenges. We have already started with assessing published taxonomies of VGI (Cooper *et al*, 2010b) and with the development of a taxonomy for VGI. This taxonomy could be used to evaluate the quality of a specific VGI contribution. Aspects of quality could be part of a taxonomy of VGI, such as the rigour of the screening based on quality; the availability and type of metadata; the quality dimensions; and the extent to which liability for the data is accepted. The quality of the VGI contribution could then be assessed based on its associated class in the taxonomy. If a taxonomy of VGI-based repositories has inadequacies, that suggests that there is a deficiency in the VGI quality itself - perhaps in terms of its completeness and/or in terms of not meeting needs of certain users.

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