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CHAPTER 2

Sources of VGI for Mapping

Linda See*, Jacinto Estima†, Andrea Pődör‡, Jamal Jokar Arsanjani§, Juan-Carlos Laso Bayas* and Rumiana Vatseva¶

*International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, 2361 Laxenburg, Austria, see@iiasa.ac.at

†NOVA IMS, Universidade Nova de Lisboa, 1070-312, Lisbon, Portugal

‡Institute of Geoinformatics, Óbuda University Alba Regia Technical Faculty, Székesfehérvár 8000, Hungary

§Department of Planning and Development, Aalborg University Copenhagen, A.C. Meyers Vænge 15, DK-2450 Copenhagen, Denmark

¶National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Bulgaria

Abstract

The concept of Volunteered Geographic Information (VGI) is often exemplified by the mapping of features in OpenStreetMap (OSM), yet there are many other sources of VGI available. Some VGI is very focused on the creation of map-based products, while in other applications location is simply one attribute that is routinely collected, due to the proliferation of Global Positioning System (GPS) enabled devices, e.g. mobile phones and tablets. This chapter aims to provide an overview of the variety of sources of VGI currently available, categorised according to whether they can contribute to framework data (i.e. the type of data that are commonly part of the spatial data infrastructure of national mapping agencies and governments) or not and whether the data have been actively or passively collected. A range of examples are presented to illustrate the different types of VGI in each of

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these main categories. Finally, the chapter discusses some of the main issues surrounding the use of VGI and points to chapters in the book where these issues are described in more detail.

Keywords

Volunteered Geographic Information, framework data, active data collection, passive data collection, crowdsourcing

1 Introduction

Crowdsourced mapping and citizen-driven spatial data collection are radically changing the relationship between traditional map production and those individuals and organisations that consume the data. In the past, authoritative maps such as road networks and building footprints were firmly in the domain of national mapping agencies (NMAs), where the maps were created by professionals. Today NMAs still fulfil this role but they face a relatively new, citizen mapping community, armed with online mapping tools, open access to very-high-resolution satellite imagery/aerial photography and mobile devices with GPS (Global Positioning System) for geotagging features. The result has been an abundance of maps that are created by citizens and a blurring of the traditional boundaries between map producers and consumers, as citizens take on the dual role of production and consumption (Coleman et al., 2009; See et al., 2016b).

At the same time, citizens have become empowered to collect and map features and objects that are not traditionally mapped by NMAs, such as sentiments and hiking/biking routes, among many others. OpenStreetMap (OSM) is one of the most successful and most commonly cited examples (e.g. Fan et al., 2016; Hagenauer and Helbich, 2012; Haklay, 2010; Jokar Arsanjani et al., 2015b; Mooney and Corcoran, 2013) of this new phenomenon, referred to in the geographical literature as Volunteered Geographic Information (VGI), a term originally coined by Goodchild (2007). Numerous other terms have been proposed that refer to similar phenomena, all of which have citizens and citizen participation at their core. In the field of geography and urban planning, public participation in Geographic Information Systems (PPGIS) appeared in the late 1990s, as a way of improving the public consultation experience and fostering public engagement (Kingston et al., 2000; Sieber, 2006) and can be thought of as a precursor to VGI, when Web 2.0 technologies and online mapping were still in their infancy. In other fields, for example in ecology, conservation and biodiversity monitoring, there has been a long tradition of citizen involvement in science, such as the Audubon Society's Christmas Bird Count, which started in the 1900s (LeBaron, 2007). In these domains, citizen involvement has commonly been referred to as public participation in scientific research

(PPSR) (Bonney et al., 2009a) and more recently as citizen science (Bonney et al., 2009b), where data collection, often geotagged, is only one component of citizen participation. In yet another domain, i.e. that of the business world, the term crowdsourcing has emerged to refer to the outsourcing of tasks to the crowd (Howe, 2006). Crowdsourcing can be used for financial remuneration (Buhrmester et al., 2011) or for other, more altruistic reasons, e.g. searching for the remains of the Malaysian Airways plane that went missing in 2014 (Whittaker et al., 2015) or providing hotel and restaurant reviews on sites like TripAdvisor; other initiatives can be found in Sester et al. (2014).

Many other terms exist and the reader is referred to a recent review by See et al. (2016b) for a broader overview. For the purpose of this book, we use the term VGI to mean geotagged data contributed by citizens, whether map-based or where location is simply an attribute in a much larger dataset. The term covers many different domains of activities, from monitoring the weather to species identification and georeferencing old historical maps contained in digital libraries. This chapter aims to provide an overview of the variety of sources of VGI currently available, categorised according to whether they are framework data (i.e. the type of data that are commonly part of the spatial data infrastructure of national mapping agencies and governments) or not and whether the data have been actively or passively collected, as outlined in Section 2 below. A range of examples is then presented in Section 3 to illustrate the different types of VGI in each of these main categories. Finally, the main issues that currently surround VGI are highlighted, providing a link to different chapters in the book that describe these issues in more detail.

2 Categorisation of VGI Sources for Mapping

To help organise the diverse range of VGI sources available for mapping, we have categorised them based on two main criteria. The first one is whether the data fall into the territory of NMAs; we refer here to such data as 'framework data'. Framework data are typically data that are collected by government agencies, and which can be organised into the following themes: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units and cadastre, and comprise the basic components of a government's spatial data infrastructure (SDI; Elwood et al., 2012). These data will be collected by professionals and have minimum levels of error specified in their production, with update cycles that depend on national budgets but will generally range from one to five years. Depending on the country, the content of these datasets may also vary; for example, some countries do not have cadastres, while others may include a gazetteer as part of their SDI. In the European Union, the INSPIRE (Infrastructure for Spatial Information in Europe) Directive specifies the types of framework data that all EU member states should collect (EC, 2007); the type of data specified in the Directive's Annexes I and II corresponds to the types of data outlined in Elwood et al. (2012), but Annex II additionally includes land cover and geology, and Annex III contains much more detail in terms of land use and socio-economic data. For the purpose of this chapter, however, we take framework data to mean the most basic components of an SDI as outlined by Elwood et al. (2012).

The second criterion is whether the data have been contributed actively or passively (Harvey, 2013). Active data collection includes campaigns that call for participation or where people sign up to complete micro-tasks with the full knowledge that they are contributing the data for a specific purpose, e.g. the active mapping of features in OSM. In passive mode, participants may be providing geotagged information willingly, e.g. through social media, but the data may then be used for purposes, such as for behavioural studies or marketing purposes, that contributors are unaware of since they did not read the terms of participation in detail or modify their privacy settings (if available). Examples of this are geotagged tweets from Twitter, geotagged photographs from Flickr and Instagram, etc. There is a tradeoff between the two data sources; active data are often easier to process since they were collected with a specific purpose in mind and often with some type of protocol or minimum data requirements, while passive data may not meet the minimum requirements of an application. In addition, passive data can be 'big data' in terms of volume and complexity, but may thus also require considerable post-processing before use. Regardless of how the data are collected, the importance of this new wave of data collection, i.e. VGI, for the public and private sectors and for scientific research is yet to be truly exploited.

Using these two criteria to categorise VGI, i.e. framework vs. non-framework data and active vs. passive data collection, there are four categories in which VGI can fall. The first category is VGI that can contribute to framework data and that is actively contributed by volunteers. In this category fall projects that can be used to update or correct the types of data routinely collected by NMAs; the category is represented by the upper right quadrant of Figure 1. The second category is non-framework data (or data that are not routinely collected by NMAs but are useful for other agencies and scientific research) where active participation by volunteers is evident; it is located in the bottom right quadrant of Figure 1. The left half of Figure 1 contains the other two categories, i.e. framework and non-framework data that are passively collected, e.g. through social media or sensors such as the GPS of a mobile phone. The four quadrants in Figure 1 are then populated with different sources of VGI; examples of these sources are provided in Section 3. Note that the exact location of the VGI examples within each quadrant has no significance – they are simply arranged for optimal readability. A fifth category has been added to consider three-dimensional VGI; although this type of VGI could also be characterised by the two criteria introduced in this section, we provide a separate discussion of it, focused on height data, OSM and publicly available sources of elevation, in Section 3.5, since this is a new area of VGI.

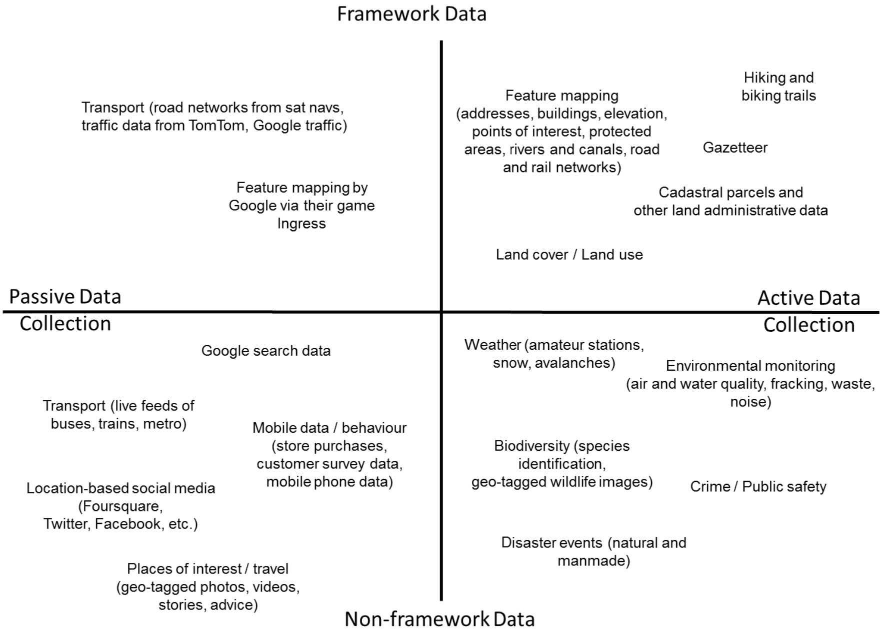

Fig. 1: Categorisation of VGI based on whether it consists of framework or non-framework data and whether the data have been actively or passively collected. This figure is modified from See et al. (2016b).

3 Examples of VGI Sources for Mapping

3.1 Active Framework Data

OSM, as already mentioned, is one of the most successful and commonly cited examples of VGI sources, and aims at creating a world map freely available to anyone (Jokar Arsanjani et al., 2015b). OSM is a prime example of feature mapping and covers data types often found in topographic databases and transportation networks; an extensive overview of this initiative is provided in Chapter 3 of this book (Mooney and Minghini, 2017). Google Map Maker[1] is another example of an application that allows volunteers to map features such as roads and points of interest (POI). These are then displayed on Google Maps in certain countries where the review process is well developed enough to ensure a minimum level of quality.

A second example of active framework data contributed by citizens is the mapping of cadastral boundaries and properties (Kalantari and La, 2015). This is particularly relevant for developing countries where land rights are not well documented. This is also relevant in places where surveying is very expensive and time-consuming and so has not been carried out in all areas, which leads to a stagnation in the property market. An example from Greece is outlined by

Basiouka and Potsiou (2012), who conducted an experiment in the rural part of the village of Tsoukalades, on the island of Lefkada, where fifteen volunteer land owners used a handheld GPS to delineate their land parcel boundaries. When the results were compared with an official survey, the locations and shapes of all parcels were found to be correct and the majority of the parcels had area calculations that were within the tolerance limits of the specifications set by the Hellenic Cadastre. Moreover, the land owners wanted to be involved in the collection of these data and hence motivation was high. Thus, citizen involvement holds great potential for helping to gather this type of framework information. In a more recent study by Basiouka et al. (2015), surveying students were tasked with assessing the feasibility of using OSM for cadastral mapping in Athens, Greece. The results showed good accuracy, low costs, and ease-of-use for non-experts, indicating that OSM is one possible solution for crowdsourcing land parcels and features, particularly if adopting a hybrid solution in which surveying experts are used in training and quality assurance. Mobile phones can also be used for securing land rights; GeoODK (Geographic Open Data Kit) is an Android-based mobile phone app for spatial and attribute data collection that is being used by the Cadasta Foundation[2] to help people map their lands and resources and assert their rights.

In the area of gazetteers, Wikimapia[3] is a very well known initiative that aims to describe places in the world (Goodchild, 2007). It is freely available and all the content is provided by volunteers. Users can mark places, add descriptions with links and upload and categorise photos. Entries are then voted on by a group of peers. To access the raw data, the Wikimapia API and Motomapia[4] are available. GeoNames[5] is another gazetteer, containing over 10 million geographical names and available to download free of charge: volunteers can contribute by editing existing names or adding new names through the GeoNames website.

Mapping of land cover and land use is another area of framework data. Some of the current authoritative products have been created globally, e.g. GlobeLand30 (Chen et al., 2015); regionally, such as CORINE land cover[6] for EU countries or AFRICOVER for some African countries (FAO, 1998); and nationally by NMAs, e.g. the land cover map of Great Britain produced by the Centre for Ecology and Hydrology (Fuller et al., 2002). These authoritative products use satellite and aerial imagery in combination with different types of classification algorithms, and there is often a long period of time between updates due to the difficulty of the task. One problem that has been highlighted by researchers is that when these maps are compared spatially, there are often areas where they disagree (Fritz et al., 2011). Several efforts have been undertaken to tackle this problem, with a promising contribution from VGI. For example, the Geo-Wiki tool[7] for crowdsourcing land cover data asks volunteers to interpret very-high-resolution satellite imagery from Google Earth and Bing to increase the amount of in-situ data for producing and validating land cover products (Fritz et al., 2012; See et al., 2015). One of the latest Geo-Wiki applications is called Foto-Quest Austria[8], and, in contrast to the online Geo-Wiki applications, encourages volunteers to go out into the field and collect land cover and land use information using a mobile app. The idea behind the project is to see whether volunteers can collect in-situ data based on the Land Use and Coverage Area frame Survey (LUCAS) protocol (Eurostat, 2015) and complement this authoritative data source. LUCAS is currently the only official validation dataset for products such as CORINE land cover and the very-high-resolution (VHR) layers produced as part of the Copernicus land monitoring service (Büttner and Eiselt, 2013; Gallego, 2011). Thus, any additional in-situ data have great value for calibration and validation of products from Earth Observation, especially in terms of density and frequency of updating (See et al., 2016a). Initial results from a comparison of land cover and land use data collected from the app with the authoritative LUCAS data indicate that volunteers are able to identify basic land cover and land use types on the ground but that more detailed land cover types will require some training (Laso Bayas et al., 2016). The app is currently being rolled out to other EU countries. Similar tools to Geo-Wiki have been developed by other research teams. For example, the VIEW-IT application (Clark and Aide, 2011) is a collaborative effort to record reference information on land use and land cover, while Google Earth Grids (Jacobson et al., 2015) allows users to create an interactive and user-specified grid over Google Earth imagery and identify the land cover in each square of the grid.

As shown in Figure 1, a final area where VGI has been used to actively map framework data is that of biking and hiking trails (which may or may not appear in the topographic databases of NMAs; thus this category could also be included in active non-framework data). An example of such an initiative is MapMyFitness[9], which is a suite of mobile apps and websites that provide interactive tools to map and share fitness activities including running, walking, cycling and hiking[10]. Each of these provide paths and trails that could be incorporated into the topographic database of an NMA. Bikemap[11] and Bikely[12] are other examples of initiatives to map bike routes, with many more examples to be found online. Bikemap has more than 2.8 million cycling routes available, where the routes are accessible via the web interface and also through the API, while routes in Bikely can be accessed via the web interface or downloaded in GPX and KML formats. Finally, there are many hiking sites available. An example is AllTrails[13], which is a platform for sharing geotagged user-generated travel content. Travel experiences are shared through an interactive map and can include photographs plotted along the trip route; mobile apps and a developer API are available to access the platform and manage the data. Wikiloc[14], with more than 2 million users, around 5 million outdoor trails and 8 million photographs, is very popular for discovering and sharing the best trails for outdoor activities, and offers routes and waypoints (POIs) along with elevation profiles, distances and images taken.

3.2 Active Non-framework Data

In contrast to active framework data, there are many diverse examples of initiatives for active non-framework data. It is not possible to comprehensively list all of them or even touch upon every domain in which these initiatives are emerging, as this is a very dynamic area: the reader is referred to sites such as those of SciStarter[15] and the Citizen Science Alliance[16], which are portals to many other citizen science projects. Not all are spatially-oriented but location is usually a key attribute collected by citizens. Here we have chosen to focus on five main areas shown in Figure 1: weather, biodiversity, environment, disasters and crime.

Amateur weather stations are a prime example of active data contributions and have become important sources of information for applications in hydrology, drought, agriculture, engineering and architecture, among others (Doesken and Reges, 2010). The US National Weather Service Cooperative Observer Program is a weather and observing network of more than 8,700 volunteers who provide observations from farms, urban areas, national parks, coastlines and mountaintops within the US (Leeper et al., 2015). There are other similar initiatives, such as the Citizen Weather Observer Program[17], which collects data from more than 7,000 stations in North America and sends around 50,000 to 75,000 observations every hour, and Weather Underground[18], which is a weather service that provides real-time weather information for free over the Internet and incorporates data from more than 200,000 personal weather stations around the world. Other notable initiatives include CoCoRaHS, which is a community-based network of volunteers who measure and map precipitation in the form of rain, hail and snow, and a mobile app called mPING[19], which allows users to contribute weather reports. As of mid-2015, CoCoRaHS volunteers have submitted over 31 million daily precipitation reports and tens of thousands of reports of hail, heavy rain and snow (Reges et al., 2016), while the data collected through mPING are used to fine-tune weather forecasts.

Biodiversity monitoring is the second area where volunteers have been actively contributing non-framework data. There are hundreds of different citizen science projects in this area, mainly because there is a long history of citizen involvement in conservation, as mentioned previously. Some of these are local projects, collecting data on a small scale, while others have more global reach. An example of a more local project is the Invaders of Texas Program, where citizen scientists are trained to detect the arrival and dispersal of invasive species and report them using the online mapping database (Gallo and Waitt, 2011). iSpot[20] and iNaturalist[21] are initiatives with global reach and both have mobile apps for data collection, where the data collected by citizens have been used in scientific research (e.g. Silvertown et al., 2015).

Citizens are also active in monitoring the environment. Global Water Watch[22], which is a voluntary network that monitors surface waters for the improvement of both water quality and public health, is a prime example of such monitoring. Another example is the Global Learning and Observations to Benefit the Environment (GLOBE) Program, which aims to increase environmental awareness and to actively involve schools in science; there, students perform measurements that are of research quality and report their observations to archives designed for the study of the Earth. Since 1995, the GLOBE network has grown to include representatives from 112 countries. One of the environmental parameters measured in the framework of the GLOBE Program is air pollution in terms of aerosols. In addition to creating awareness about aerosols and their role in climate and air quality, the measurements can be of significant value for validation of satellite products (Brooks and Mims, 2001; Boersma and de Vroom, 2006). More recently, the EU has funded four citizen observatories[23] covering different aspects of citizen-based environmental monitoring: Citi-Sense (air pollution); Omniscentis (odours); CobWeb (land cover and land use); and WeSenseIt (flooding).

Another environmental issue in cities, especially in dense urban areas, is noise, which can become a public health issue in extreme cases. NoiseWatch[24] is a citizen science project supported by the European Environment Agency that integrates noise data from official scientific sources with noise data collected from crowdsourced observations. A mobile application can be used by citizens to measure the level of noise in their location, which is automatically uploaded to a central database. These data can then be used to develop noise maps for decision-making. Finally, in the area of light pollution, the Cities at Night[25] initiative is a citizen science project to help georeference photographs of cities taken by astronauts on the International Space Station at night. Using these images, it is possible to compare the efficiency of lighting across different cities on the planet as well as study their light pollution, which can have a negative effect on ecosystems and health (Falchi et al., 2011).

The fourth area of active non-framework data collection is in disaster mapping. The Humanitarian OpenStreetMap Team (HOT)[26] is an initiative that rallies a huge network of volunteers when disaster strikes to create maps that enable responders to reach those in need. HOT was launched after the January 12, 2010 Haiti earthquake, when 600 remotely located volunteer mappers built a base layer map to support the aid effort (Soden and Palen, 2014). HOT volunteers were also effectively mobilised during the November 8, 2013 Typhoon Yolanda in the Philippines (Palen et al., 2015). Going back to earthquakes, Did You Feel It?[27] is an initiative from the United States Geological Survey (USGS) that maps where earthquakes were experienced by individuals and the severity of the damage. Any citizen who feels an earthquake can report it online by selecting the earthquake from a real-time map of earthquakes and filling in a survey with detailed questions on their experiences as well as their location.

The final area being considered here is crime and public safety. Citizens are willing to contribute especially when they feel threatened. Alertos[28] is a citizen observation platform to report crime and similar events to the legal authorities in Guatemala, Latin America. An interactive map showing reported events by category and time is also available on the website. WikiCrimes[29] is a collaborative wiki-type initiative to report crime events of different categories through the website. Such events can then be visualised and filtered using an interactive map. Mobile apps are also available to provide users with information on the safety of a place based on the analysis of the reported events. CrimeReports[30] and SpotCrime[31] are examples of similar initiatives for reporting data on different types of crimes in the US, Canada and the UK. Emotional and perception mapping is another area where initiatives have emerged to understand the level of security perceived by citizens and their spatial distribution. Measuring the fear of crime has been undertaken as part of a research project developed at Óbudai University Alba Regia Technical Faculty Institute of Geoinformatics: contributors are asked to fill an online survey[32] and draw a red or grey polygon to report that they are feeling respectively unsafe or safe. Finally, the Ushahidi platform[33] has been used to map reports of violence in Kenya after the post-election violence in 2008. Since then several initiatives have used this platform to empower citizens to report different events, e.g. the Map it. End it[34] initiative to map technology-related violence against women and the Egyptian Zabatak[35] initiative.

3.3 Passive Framework Data

There are not many examples of passive framework data collection but such collection does exist, e.g. through the Google Traffic application: through a smartphone with the Google Maps app installed and the location functionality activated, users continuously send Google anonymous data on how fast they are moving. Google then analyses the data coming in from the same location and sends back accurate information on traffic conditions. Such information on traffic volumes and hotspots can be used to improve road planning (see e.g. Barth, 2009) as well as road mapping (Ekpenyong et al., 2009). Satellite navigation companies also gather traffic and travel data from their customers' devices in a passive mode. In addition, the TomTom satellite navigation company has developed the Map Share Reporter[36] as a way of allowing customers to make active changes to the map and share these with other TomTom users. Thus, they are crowdsourcing improvements to their product.

Another example is the crowdsourcing of features using gamification via the Google Ingress game[37] to improve Google Maps. The idea behind the game is to find a portal and capture it. In the process of doing this, players are asked to travel on specific routes and photograph locations or features along their way to the portal. In this way Google gathers information from the players. The main goal of the players is to gain control over the portals and have fun, so the data collection has been seamlessly integrated into the game.

This is an example of a very cleverly disguised way of updating map features through crowdsourcing.

3.4 Passive Non-framework Data

Several examples can be found in the category of non-framework data contributed passively by citizens, and can be mapped and analysed for different applications. The Google search engine is used approximately 3.5 billion times per day[38], where Google collects the search terms along with other data such as the location where the search has been made. This allows Google to analyse a vast amount of data, e.g. trends in influenza based on frequency of searching (Ginsberg et al., 2009). To allow researchers to analyse the data using their own queries, Google has developed some online tools. For example, Google Trends[39] is a tool that shows the frequency of a particular search term relative to the total search volume across various regions of the world, and in various languages. Choi and Varian (2012) demonstrated how Google trends can help to predict current phenomena much quicker than the usual reporting process in diverse areas such as motor vehicles and parts, initial claims for unemployment benefits or travel planning. Another tool called Google Correlate[40] works in the reverse way. Users upload a time series or spatial pattern of interest and the software returns the queries that best mimic the data (Mohebbi et al., 2011): Google calculates a correlation coefficient between the uploaded time series and the time series of every query in their database, and the results displayed are those queries that generate the highest correlation with the uploaded data.

Another big-data source of passively collected non-framework data is real-time transport information such as live feeds from buses, metro stations, bike scheme data, trains, etc. APIs are available to retrieve the data and can be brought together in dashboard type applications that provide information on the status of different transportation systems in real-time, the weather, air pollution, electricity demand, etc. For example, the CityDashboard project[41] was developed by the Centre for Advanced Spatial Analysis at UCL, London, and is available for a number of UK cities. The CityDashboard data have also been used to extract useful information for other purposes such as generating insights into sustainable transport systems (O'Brien et al., 2014) or the health impact of bicycle sharing systems (Woodcock et al., 2014); for example, the Bike Share Map[42] shows the status of biking system docks in real-time for several cities around the world. Uniman et al. (2010) used data from the Oyster Smart Card (public transport card for the London Underground) to determine the reliability of the Underground system. Using data on the entries and exits to/from London Underground stations, they developed metrics based on the travel time of passengers. This type of big data (where there are more than 1.3 billion metro and 2.4 billion bus journeys annually in London; Transport for

London, 2015), has great potential for improving passenger experiences and for planning future transport projects.

Mobile phone data from communication network operators represent another big-data source of passively collected non-framework data. These data have been analysed to investigate applications in areas such as transportation planning (Di Lorenzo et al., 2016), user behaviour (Bianchi et al., 2016), public health (Oliver et al., 2015), the spatial spread of diseases such as cholera (Bengtsson et al., 2015) or population displacement after a major disaster (Wilson et al., 2016).

A fourth area of passively collected non-framework data is travel websites and travel blogs, where all of the information provided is attached to a location and can therefore be mapped. TripAdvisor is the world's largest travel site, where users rate their accommodation, restaurants and attractions, providing their collective intelligence to the system. Any users can then access this information for free to make informed decisions. There are many examples of booking sites that draw upon TripAdvisor or have their own rating system based upon user feedback, e.g. Booking.com and Trivago, among many others.

Social media websites such as Facebook and Twitter are also prime examples that fall within this category of passive non-framework data collection; information can be shared with location data, depending on whether users enable this option in the application. Geotagged tweets are now being used in a number of applications, mostly related to crisis events and disaster management. For example, Twitter was used during the 2010 Pakistan floods (Murthy and Longwell, 2013) and tweets were an active source of information during flooding in Jakarta, allowing for the creation of open source flood maps through the Peta Jakarta initiative[43].

Finally, websites that allow users to share geotagged photographs are included in this category. Panoramio, Flickr and Instagram are a few examples of such initiatives. Users upload their photographs along with additional information such as date and time, textual tags and geotags, among others, making it possible to map the photographs. Research has been conducted to explore ways to use such data for different applications including land cover and land use mapping (Estima and Painho, 2014; Antoniou et al., 2016).

3.5 3D VGI

The third dimension in geospatial data is height or elevation. Height is now being added by volunteers to mapping initiatives such as OSM, e.g. the heights of buildings and roof geometry, which means that 3D models of cities can be created from VGI (Goetz and Zipf, 2013). Height values of GPS traces in OSM also show a promising way of retrieving 3D information for elaborating height information from SRTM and ASTER DEM models (John et al., 2016). A 3D model of a city can be generated using a GIS package or via OSM-3D, which allows OSM to be visualised as a 3D model on a virtual globe (Over et al., 2010). However, height information is still not commonly added to buildings on OSM, with less than 1.5% of buildings having height information available in November 2011 (Goetz and Zipf, 2013). If more height data were added to OSM, it would open up many possibilities for urban planning, transportation planning, navigation and disaster management, among others, particularly in locations where an SDI is currently lacking.

Elevation data are publicly available through the NASA's Shuttle Radar Topography Mission (SRTM) at a resolution of 30m. A new source of higher resolution elevation data, which are being collected by volunteers, is Unmanned Aerial Vehicles (UAVs). When DEMs generated using UAVs were compared with DEMs from LIDAR in the context of hydrological modelling (Leitão et al., 2016), the results were promising and UAVs represented an affordable option for 3D mapping. UAVs are also used in mapping damages after a disaster event (Adams and Friedland, 2011). To accommodate the growing source of aerial imagery from UAVs and other freely available satellite imagery, Development Seed and HOT have developed OpenAerialMap[44], which is a new service for contributing to and accessing this new source of data from volunteers.

4 Issues Related to VGI for Mapping

One of the main issues that is always raised with VGI, and is often perceived as a barrier to its further use, is the quality of the data. For this reason a considerable quantity of literature has appeared on this topic (see e.g. Antoniou and Skopeliti, 2015; Bordogna et al., 2015; Flanagin and Metzger, 2008; Jokar Arsanjani et al., 2015a). There is an ISO standard for spatial quality that can be applied to VGI, but additional quality indicators are required due to the characteristics that are specific to VGI. This ISO framework, along with additional quality indicators, is discussed in more detail in Chapter 7 by Fonte et al. (2017). Quality is of particular interest to NMAs, some of which see the possibility of using VGI as a way to potentially update maps that would otherwise only be re-surveyed professionally every few years, or view VGI as a complementary source of information of a richer nature, e.g. footpaths and cycle paths that may not be mapped. NMA experiences of VGI for these purposes is documented in Chapter 13 by Olteanu-Raimond et al. (2017), including the barriers to the adoption of this source of information. Demetriou et al. (2017) in Chapter 12 consider the broader question of integrating VGI with SDIs and how this might be achieved in the future.

Another key issue that is commonly discussed in relation to VGI, in particular active VGI projects, is how to recruit participants, keep them motivated and sustain the project in the future (see e.g. Coleman et al., 2009; Nov et al., 2010; Reed et al., 2013). However, more research is still needed that looks into what constitutes effective incentives for participation and how citizens can be mobilised to participate in ways that are mutually beneficial to them while contributing VGI. These aspects of recruitment, motivation and sustainability are covered in detail in Chapter 5 by Fritz et al. (2017), where the authors review a series of crowdsourcing initiatives in a comparative analysis on recruitment strategies, techniques for motivation and, more generally, issues of sustainability.

The involvement of citizens in VGI immediately raises critical questions regarding copyright, ownership, data privacy and licensing of the data, particularly when the data contributed by citizens are then integrated with third party base layers (see e.g. the work by Saunders et al. (2012) within a Canadian context). There are also ethical issues with VGI data use with respect to health and disease surveillance (Blatt, 2015). The chapter by Mooney et al. (2017) on privacy, ethics and legal issues tackles these concerns in more detail.

Finally there is a new trend in the development of citizen observatories, which are defined as a framework that combines participatory community monitoring (including policy-makers, scientists and other stakeholders) with technology such as web portals, mobile devices and low-cost sensors (Liu et al., 2014). This new trend is the subject of Chapter 15 by Liu et al. (2017).

5 Conclusions

This chapter provided an overview of sources of VGI for mapping, categorised according to whether the data are collected by government agencies as part of an SDI (i.e. framework data) or in other domains (e.g. weather or ecology, among others), as well as according to the mode of data collection, i.e. active or passive. A range of examples were then provided to illustrate the different types of VGI that fall into these categories. 3D VGI was discussed as a special case. With advances in technology, e.g. 3D mobile phones, and the increasing interest in UAVs, many new, low-cost solutions will emerge, from biomass mapping to hydrological modelling to smart cities applications. Finally, the chapter introduced some of the main issues surrounding the use of VGI, including, among others, quality, participant recruitment and motivation and the trend toward citizen observatories, which are the subjects of different chapters throughout the book. New advances in data mining and knowledge discovery techniques may also help to improve the quality of VGI in the future.

The wide range of VGI as a data source for mapping illustrates the growing interest in collecting and using these data for many different purposes. VGI has the potential to complement but also rival more traditional mapping sources in both quality and richness. What has been presented here is only the start of a growing citizen-based contribution to many different domains. Many of the sources listed in this chapter will disappear, only to be replaced by many other projects and initiatives in the future. For NMAs, the key will be the successful engagement of citizens in helping to update and correct the more authoritative sources in such a way that both entities benefit in the long run.

Acknowledgements

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Notes

[1] https://www.google.com/mapmaker
[2] http://cadasta.org/
[3] http://wikimapia.org/
[4] http://www.motomapia.com/
[5] http://www.geonames.org/
[6] http://land.copernicus.eu/pan-european/corine-land-cover
[7] http://www.geo-wiki.org
[8] http://fotoquest.at
[9] http://www.mapmyfitness.com/
[10] Respectively through MapMyRun (http://www.mapmyrun.com/), MapMyWalk (http://www.mapmywalk.com/), MapMyRide (http://www.mapmyride.com/) and MapMyHike (http://www.mapmyhike.com/).
[11] https://www.bikemap.net/
[12] http://www.bikely.com/
[13] https://www.alltrails.com/
[14] http://www.wikiloc.com/
[15] https://scistarter.com/
[16] http://www.citizensciencealliance.org/
[17] http://wxqa.com/
[18] https://www.wunderground.com
[19] http://www.nssl.noaa.gov/projects/ping/
[20] http://www.ispotnature.org/communities/global
[21] http://www.inaturalist.org/
[22] http://www.globalwaterwatch.org/
[23] http://www.citizen-obs.eu/
[24] http://discomap.eea.europa.eu/map/NoiseWatch/
[25] http://www.citiesatnight.org/
[26] https://hotosm.org/
[27] http://earthquake.usgs.gov/data/dyfi/
[28] http://alertos.org/
[29] http://wikicrimes.org
[30] https://www.crimereports.com
[31] http://spotcrime.com
[32] http://bunmegelozes.amk.uni-obuda.hu/MainPageEng.php?ln=1
[33] https://www.ushahidi.com/
[34] https://www.takebackthetech.net/mapit/

[35] http://zabatak.com/
[36] http://www.tomtom.com/mapshare/tools
[37] https://www.ingress.com/
[38] http://www.internetlivestats.com/google-search-statistics/
[39] https://www.google.com/trends/
[40] https://www.google.com/trends/correlate/
[41] http://citydashboard.org/
[42] http://bikes.oobrien.com/
[43] https://petajakarta.org/banjir/en/
[44] https://openaerialmap.org/

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