Volunteered Geographic Information

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Glossary

Application Programming Interface (API) A set of tools and methods to build or configure software packages. APIs make programming easier by providing the building blocks for developers, so they do not have to build components and code from scratch each time they develop a new app. APIs make it possible to create mobile applications and map mash-ups.

Ontology Refers to types of data, properties, and interrelationships among data. Ontologies in GIS also refer to categorizations and definitions of data. For example, native communities in the North often have multiple land classifications for different types of ice and snow, whereas other people may only have one classification.

Web 2.0 (or the "Read/Write Web") refers to the transition from when only a few people were able to share content on the Internet to when people were able to both read content and post content. This transition happened starting around 1999 and really gained momentum in the early 2000. Being able to share content on the Internet is now seen as normal.

Increasingly, citizens are tethered to their mobile devices. The first smartphones were released in 2007. These mobile devices are equipped with global position system (GPS) receivers, accelerometer, compass, and a suite of other sensors.

This means that anyone with a smartphone can access locationally relevant information. With the right apps, users can also collect and annotate spatial data. When an unpaid worker documents and shares a locational observation, it is termed volunteered geographic information (VGI); citizens are now the sensors. VGI is a data collection mechanism. VGI is providing the ability to record content about local activities in various geographic locations around the world. These data can then be transformed into information that may have traditionally gone unnoticed by the rest of the world's media. VGI contrasts traditional approaches to geographic information collection in that the quality standards are highly variable and the social process that mediate its creation are not always professionally motivated.

Traditionally, equipment and expertise required for collecting relevant spatial data to make (and update) maps were expensive and labor and skill intensive. Large GPS receivers and other tools associated with surveying were compulsory. To annotate data and enter them into a geographic information system (GIS) required specialized training and expensive difficult-to-use software. To do so, detailed spatial data needed to be significantly justified for financial backing to purchase the equipment and personnel to collect it.

VGI commonly refers to social media contributions about a place or some sort of content that has a geotag attached to a place, requiring that latitude and longitude coordinates are registered with media of some sort, either a string of characters, a photo, or recording. These data are typically vector data, points, lines, and polygons that can be overlaid on a base map.

Used in combination with mobile applications, mobile devices are used to collect and deliver location-based information to and from web and mobile users. For example, mobile applications like Waze offer the fastest driving directions to the user based on current traffic conditions. The up-to-date traffic information is collected from other Waze users. This is but one example of how mobile devices with creative apps are bringing about opportunities to collect new and more spatial data from mobile device users that was until recently unfathomable.

More and more people have been producing spatial data both knowingly and unknowingly. Examples of knowingly contributing VGI are restaurant reviews, adding places of interest in OpenStreetMap, or contributing an observation to a citizen science initiative. Examples of contributing VGI unknowingly include an app that tracks a user's location arguably to deliver location-based advertising or repurposing data collected from one application and it being sold to another which is a significant ethical question to be considered.

Background

VGI refers only to the *contribution* of content. VGI provides a unique opportunity to collect ideas, experiences, and perceptions of place and space and link them to a specific timestamp in that place. VGI is data with geographic coordinates attached, offered in a purposeful and informed way by individuals.

VGI is also harnessed for other forms of media such as location-based services (LBS). LBS are services that offer information about where a location aware device user is situated, while VGI are spatial data that are offered voluntarily by individuals. These two terms are sometimes conflated, but the distinction between the two is important. Mobile computer users may receive information relevant to their current position through the use of LBS. VGI is for data collection or contribution to the cloud, whereas LBS distribute information to the transient mobile device user or consumer. The advent of VGI has created a new relationship between the data producer and the subsequent consumer of the information; however, there are far more consumers of geographic information than producers. Relatively few people actively and knowingly contribute spatial data online. It is easier for a mobile device user to consume information via LBS, than it is to contribute or create VGI.

VGI did not emerge independently. VGI began to materialize during the advent of Web 2.0 (or the "Read/Write Web"). Google Maps released its Application Programming Interface (API) which invited developers to overlay different content on top of Google Maps. Google Maps offers seamless aerial imagery at the global level, referred to as slippy maps because the user can slip around them to navigate the entire globe. Google Maps made it possible for the first time for anyone with internet access to see an aerial image of their own house, their own neighborhood, without having to search for, download and stitch together large satellite images on their own. Google Maps could be used as a base map to be shared on other websites or in apps and people started to create mash-ups, overlaying multiple unique datasets, generated by distributed Internet users, laid on top of these interactive maps. One of the first examples was Craigslist apartment rentals (volunteers had contributed this information) overlaid on a Google map. The ease in which programmers could make and tailor these new forms of maps was one driver of the popularity and enablement of VGI, the other was largely driven by advances and miniaturization in computation and the social uptake thereof. Suddenly more and more people had access to Google Maps and other slippy maps on their smartphones while on the go. These maps are updated based by representing the user's current location using a blue dot placed in the center of the map. The user no longer had the cognitive burden of finding themselves on the map, as they were simply placed in the center of it.

These advances in technology lowered the costs of creating platforms to facilitate VGI production and distribution, which has led to a huge influx of information and information sources available on the web. Social media that offer locational information and context are referred to as spatial media. The convergence of Geographic Information Science and GIS with spatial media is introducing new challenges and considerations for researchers, both technical and ethical. Scientists have been quick to see the value of a diverse and dispersed locational sensor wielding population. VGI for citizen science is particularly promising because inviting a spatially distributed public to contribute to collecting scientific data presents a new opportunity to stockpile larger sample sizes with a wide geographical distribution. This requirement introduces new concerns about data collected by citizen scientists, such as credibility of the data, political implications, and transitioning the role of the participants that these new modes of interactive mapping present. This process will be described further in subsequent sections.

VGI is often seen as playful and fun, with the primary goal simply to bring attention to oneself. Commonly, people like to share their experiences in place, as tourists or to document their daily habits such as the food they eat in different places. This contribution of VGI can be made while having a direct experience or when the user is back home or in the office (or café). Volunteers can add content from a desktop computer or from a mobile device. VGI contributions are often egocentric, meaning volunteers contribute on what they know and value, typically focusing solely on content that is directly near them. Contributors are able to report on conditions in a specific region in real time or not. Humans are intelligent synthesizers and interpreters of local information and can act as valuable sensors of geographic information.

LBS are designed specifically for mobile users, to be used anywhere with a data connection and access to a GPS or other locational signal. Turn by turn directions, finding the closest restaurant that serves milkshakes or other point of interest are examples of LBS. Information of such a wide variety and availability at such a wide spatial distribution is largely only possible due to VGI. It would be too expensive and laborious for an individual to collect data and populate enough points all over the world.

Georeferenced restaurant reviews are another example of VGI. These reviews are qualitative in nature, and they are subjective interpretations from individuals. This sort of content could be harmful to a business that received an unfair or poor review. It is becoming increasingly important to distinguish ways to ensure that contributions are credible with locational accuracy and some projects are putting mechanisms in place to support this effort.

Technologically, for LBS to work, the mobile device and connected database will need to know the location of the user so that the most relevant information can be distributed to the person making a locational query. The platform being used should support real-time information positioning and location awareness, relevant content and context (i.e., traffic updates, business opening hours, or holiday closures), while typically putting the user in the center the map. Access to this new information while situated in an unfamiliar place may contribute a user's experience in a place.

A wide range of individuals are able to leverage VGI, to contribute content since it does not require excessive computer programming abilities or expensive computer hardware. In theory, VGI can be assembled and disseminated freely. VGI holds great potential to engage citizens and collect data relevant to a wealth of diverse users. There is hope that VGI could potentially encourage large-scale social and/or environmental movements (i.e., Arab Spring, Occupy Wall Street). Efforts made by individuals, businesses, and groups to upload and access information about their local environments and to follow up with reflection, discussion, and debate. Topics in which VGI could be deeply valuable for scientific data collection include, but are not limited to, urban planning and political participation, education, environmental science, tourism, epidemiology, health, and disaster management. For a VGI project to succeed, certain characteristics, including motivated citizens, sensing devices, and organized back-end information, need to be present.

Different (Data) Types of Volunteered Geographic Information

To be useful for data analysis and to be mapped, VGI need to be well organized. VGI can be collected in many different data types, qualitative data or quantitative data, actively or passively, multimedia data with or without latitude and longitude coordinates attached, raster or vector data. Additionally, the ontology of the data must be defined, meaning the types of data, their properties, and their interrelationships must be useful for later data analysis and aggregation. Originally GIS incorporated primarily (arguably only) quantitative data, more recently there have been efforts to include qualitative data into GIS as well. People can now more easily share qualitative information about their special experience or place in the world through VGI. There are countless ways of creating and sharing VGI.

The most common type of VGI contribution is through social media. Social media data occur in the form of text, photos, video, and any type of geotagged data. Through this type of VGI, it is possible to incorporate multimedia content linked to places that can be mapped. When users share locational information via social media, the result is referred to as *spatial media*.

Social media outlets have a huge audience, both in terms of contributors and passive viewers, but these are the most difficult type of data to try to pull relevant information. Social media were designed to share whatever a person is thinking or doing at any point in time. There are not always locational coordinates attached to their contribution, or if the content has some sort of locational description, it is not always certain if the person is describing the place or actually in the place describing their experience. For example, if someone writes about a soccer game at a specific large city stadium, are they at the game or simply sharing thoughts about the match? If there were some sort of disaster at the event, would this information then be useful for disaster response? Or would it be considered noise? Semantic mismatches, inaccurate time stamps, ontological challenges related to data classification, are a few more examples of how social media are messy to map. Finding or pulling relevant VGI from social media platforms for a specific purpose can sometimes be difficult if a researcher is not using the same terms to search for the topic as the person who created the information. This difficulty refers to a mismatch between ontological approaches to meaning based on values, education, and connection to place, whereby people will classify the same data with different descriptive attributes or classifications. Additionally, people may call the same place by different names. Even people who speak the same language have different spellings and place names for the same places or ideas. This variation could also be considered an ethical consideration. Who gets to name a place on the map? These are examples of ontological and semantic challenges commonly associated with VGI.

VGI harvested from social media is known to be messy, particularly if not organized well upon data collection. Messiness is both its value and barrier to using VGI effectively. It is a value in that it is possible to collect a variety of data and perceptions about a place or issue, but it can be a barrier when it takes so much time to clean data to make them possible to analyze. Also, social media data can be interpreted in many different ways. What data are collected, and specific data types will dictate what can be done with it in terms of analysis or service delivery. If VGI is necessary for a specific purpose or goal, for data curation purposes, it is much easier to build a custom app or website for volunteers to contribute data directly. A custom app will save those doing data analysis time and help them collect only relevant data.

There is a range of software available to build a basic VGI application relatively quickly and easily. Open Data Kit (ODK) is an open source framework to create a mobile survey tool that can be used while the end user is on- or offline. The risk is that fewer people will participate because it is harder to recruit volunteers to download and use a specific app or website. Social media platforms are already widely and regularly used. A balance is required between a very well organized back-end infrastructure to collect exactly the data wanted for a specific project, and a usable attractive front end for data entry. Without the usable and efficient frontend people might not find utility in the app and want to use it.

Whatever the aims or the data type being collected in a VGI project (qualitative or quantitative, raster or vector, float, string, other), there is a number of technological considerations, including but not limited to selection of a database and deciding what data types to collect. Attention needs to be paid to the size of the database and the number of contributors at one time. It is important to have a server with enough power to facilitate multiple editors and contributors at one time. Ideally, a VGI project will be organized to be able to analyze the contribution of the volunteers quickly, in order to make meaning from their contributions. If a service is not easy, accessible, and useful, people will not participate.

VGI can be contributed via a desktop computer or a mobile device. A volunteer can add data while sitting at home after they have had an experience in a place or by actively tracing their path or a specific road on a remotely sensed aerial photo using a desktop computer. If data are contributed by the user while on a mobile device, the location can be added by an app, directly from the mobile devices' locational sensors. Sometimes this process happens passively, when it is known as ambient data collection, without the user needing any direct input. Examples include when a photo has locational information added by an app, or when users' locations are monitored through cell phone towers for crowd control at a big event. Waze is an example, in that traffic data are collected based on how quickly users are moving based on the sensors in their phone.

Data collected ambiently require no direct attention or input required from the user. Such data are often thought to be more accurate due to less risk of human data entry error. From a desktop, if the locational data were not automatically collected, the contributor can add them later, but this later addition sometimes offers room for data entry error if the data enterer adds a wrong number to the coordinates or accidently georeferences the wrong feature.

An active way to contribute VGI directly to a map is by adding content in OpenStreetMap (OSM). OSM is a platform where volunteers can add geometry in the form of points, lines, polygons, and vector data, to represent points of interests such as fire hydrants, roads, and buildings, as well as text descriptors and metadata associated with each mapped element. Fig. 1 presents a screenshot of an example of OSM presenting only points, lines, and polygons representing roads and buildings. OSM invites volunteers to add points of interest (POI), and other relevant information. People familiar with an area may add locational information about a place, while others who are unfamiliar may depend on aerial or satellite imagery to trace roads, buildings, and other POI. These vector data are typically generated based on the satellite imagery available which are raster data. (See Fig. 2 a screenshot

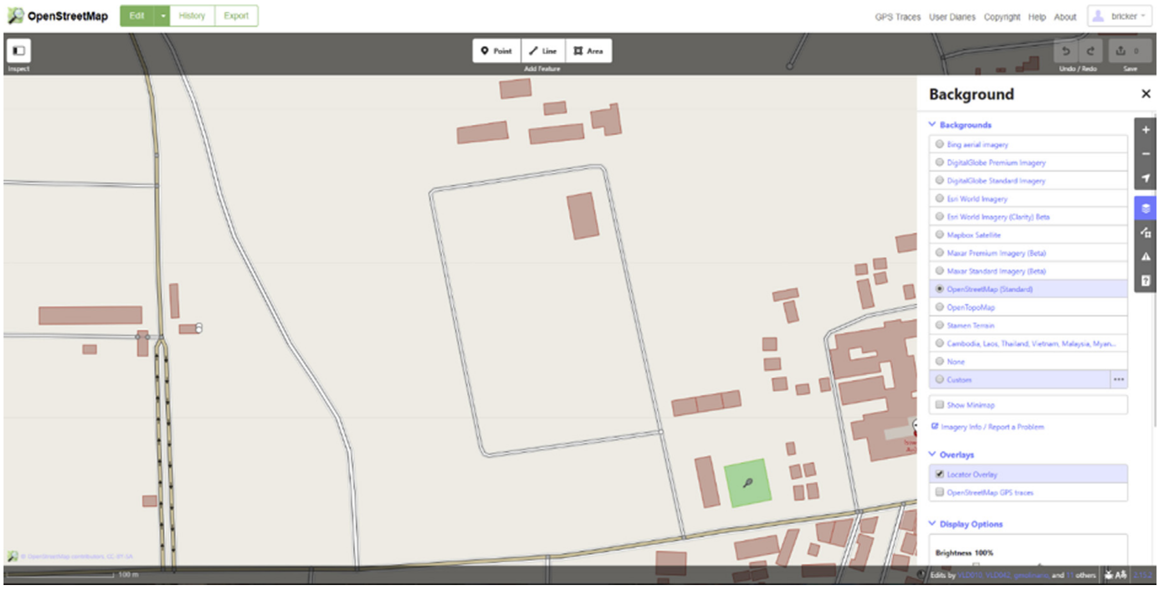

Figure 1 OpenStreetMap is made up of vector data, points, lines, and polygons that represent points of interest. This information alone describes this place in a very specific way.

Figure 2 OpenStreetMap data are largely generated by tracing features found using satellite imagery and aerial photos. When comparing **Figs. 1** and 2, it can be seen that not all of the buildings found on the image (raster data) are represented on the map (vector data).

of an example of an image offered by OSM to be used to trace imagery. The right side of the image shows a variety of sources for basemaps.) The data are dependent on frequency by which a satellite passes over, the time of day, the time of year. Aerial imagery from planes generally has higher spatial resolution, meaning more detail, making it even more expensive and difficult to gain access. With the advent and popularity of unmanned aerial vehicles (UAV) it is becoming feasible to collect one's own aerial imagery at a time interval useful to the end user and feature being mapped.

Different types of data analysis and subsequent information can be generated from vector versus raster data. All of the examples of VGI presented here thus far have been vector data, points, lines and polygons, or multimedia with associated points. But raster data is another data format that VGI can be contributed. Collecting and sharing aerial images from UAVs result in an example of VGI in the form of raster data. Raster data are grids of information instead of scalable vectors. They require a different type of geocoding and different types of databases. The satellite imagery base maps offered by digital globe providers such as Google Maps API, Mapbox, and others, are rasters. On these base map rasters, API users are forced to use aerial imagery provided, making it difficult or impossible to change the timestamp of that base map image. With aerial imagery captured by

Figure 3 Open Aerial Map (OAM) offer imagery captured by UAVs that are volunteered by individuals and organizations, these data are typically very high spatial resolution. This is a screenshot of an image from OAM overlaid in OSM ready to be traced from the same region as Figs. 1 and 2 for comparison purposes.

UAVs, this is changing. Now, anyone with a UAV mounted with a camera and associated software can generate an aerial image of an area of interest and share it online.

OpenAerialMap (OAM) is a repository for users to download and share aerial imagery. These images are often (but not always) captured and then shared in areas that have experienced natural disasters. There are many organizations that host mapping parties using OSM, to populate areas on the map in need of more information particularly for humanitarian efforts, disaster relief, or cases that just need more information in general. Humanitarian OpenStreetMap Team (HOT) is an online community of volunteers that enhances base maps and uses both vector (OSM) and raster (OAM) data for humanitarian efforts. OAM does not host the imagery; the volunteer who is contributing the data is required to host it. Aerial imagery files are often very, very large. Hosting data is cost intensive and these costs are often driven by data size and by site traffic. OAM is a non-profit organization and does not have the funds to host all of the imagery people may want to share. OAM is more of an inventory where users can browse imagery by location, view thumbnails and descriptions (date of acquisition, spatial resolution, name of the contributor) of imagery and links to download the imagery straight from the site, or access link to a web mapping service (WMS) or tile mapping service (TMS) to obtain a base map without requiring the user to download the imagery and host it again themselves. These data can be used to trace vectors in OSM (See Fig. 3). In addition to aerial imagery collected from UAVs, NASA and other government agencies have offered links to their recent imagery taken from satellites. Fig. 4 displays the use of an image from OAM being used as the basemap to digitize a running track in OSM, and then add relevant attributes to the database.

Another example of VGI is Mapillary, where users can set up a dashboard camera, 360-degree camera images, or share images around roadways or hiking trails. It is an open source alternative to Google Street View. These data are open source and can be downloaded or repurposed. Scientists have used these images to monitor land use change over time, or to monitor growing seasons, invasive species, and other environmental patterns. Mapillary is building machine-learning tools into their platform. These images available on Mapillary can be viewed online and in virtual reality as well. See an example in Fig. 5.

Again, different information can be derived from vector data versus raster data. Vector data are largely associated with geometry and topological relationships between them. Raster data in terms of VGI are generally used for reference purposes, the presence or absence of objects over time. In Fig. 6, examples of metadata associated with both vector and raster data associated with VGI are displayed. The raster image is made up of open data from the Global Forest Watch showing the absence and presence of forest worldwide. Each pixel has a data value representing how much of that pixel contains forest cover. The example on the right in Fig. 6 is a screenshot from the Wild Utah citizen science project, displaying vector data. These data were collected by volunteers. The point on the map represents where the data were collected, and attribute data include number of participants, purpose of the project, and photos.

Motivation and Barriers to VGI

Collecting and sharing VGI take a volunteer's time and attention. There are several motivations for contributing to or using VGI. Contributors may offer information to gain access to a service in return, for self-promotion, or have a passion for the particular content

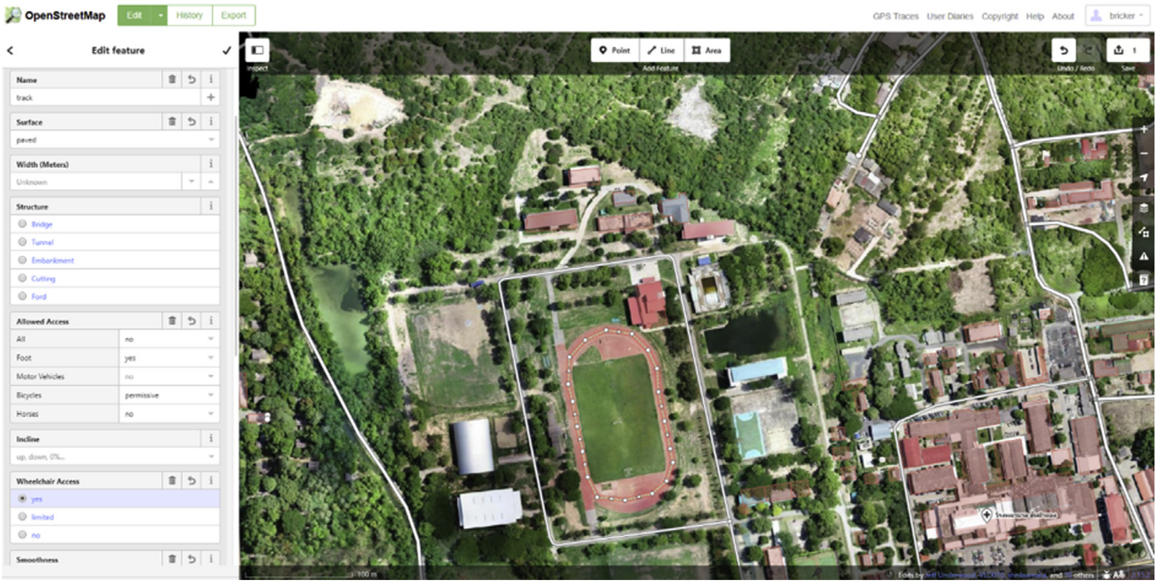

Figure 4 Same region, here the track has been digitized based on the aerial imagery, in the left pane the different attributes associated with the new geometry can be seen. These attributes, the ontology associated with them, the classification, are decided on collectively among the OSM community.

Figure 5 Screenshot from Mapillary, displaying images showing the ground view. This platform is comprised of georeferenced images (360 images and normal images) that have been contributed via VGI.

or initiative. VGI may include documentation of individual experiences (i.e., Instagram, Yelp), to record user movements (i.e., Strava, MapMyRun), social interactions (i.e., Dating apps), and citizen science data collection (i.e., Christmas bird count, Zooniverse). Citizen science has long invited participation from spatially dispersed populations, and mobile devices have made carrying out citizen science projects much easier. Nevertheless, citizen science and VGI are not identical; citizen science predates mobile devices. Citizen science projects depend on motivated citizenry.

Barriers to contributing VGI include digital and spatial literacy, as well as access to technology and time. Barriers influence who is able and willing to contribute spatial information. Other obstacles include questions of data accuracy, reliability, and quality. Good intentions do not ensure accurate geospatial data. Planners and other professionals may not prefer or be permitted to use geospatial data that is unverified, uncertified and publicly produced. An increasing number of people are embracing

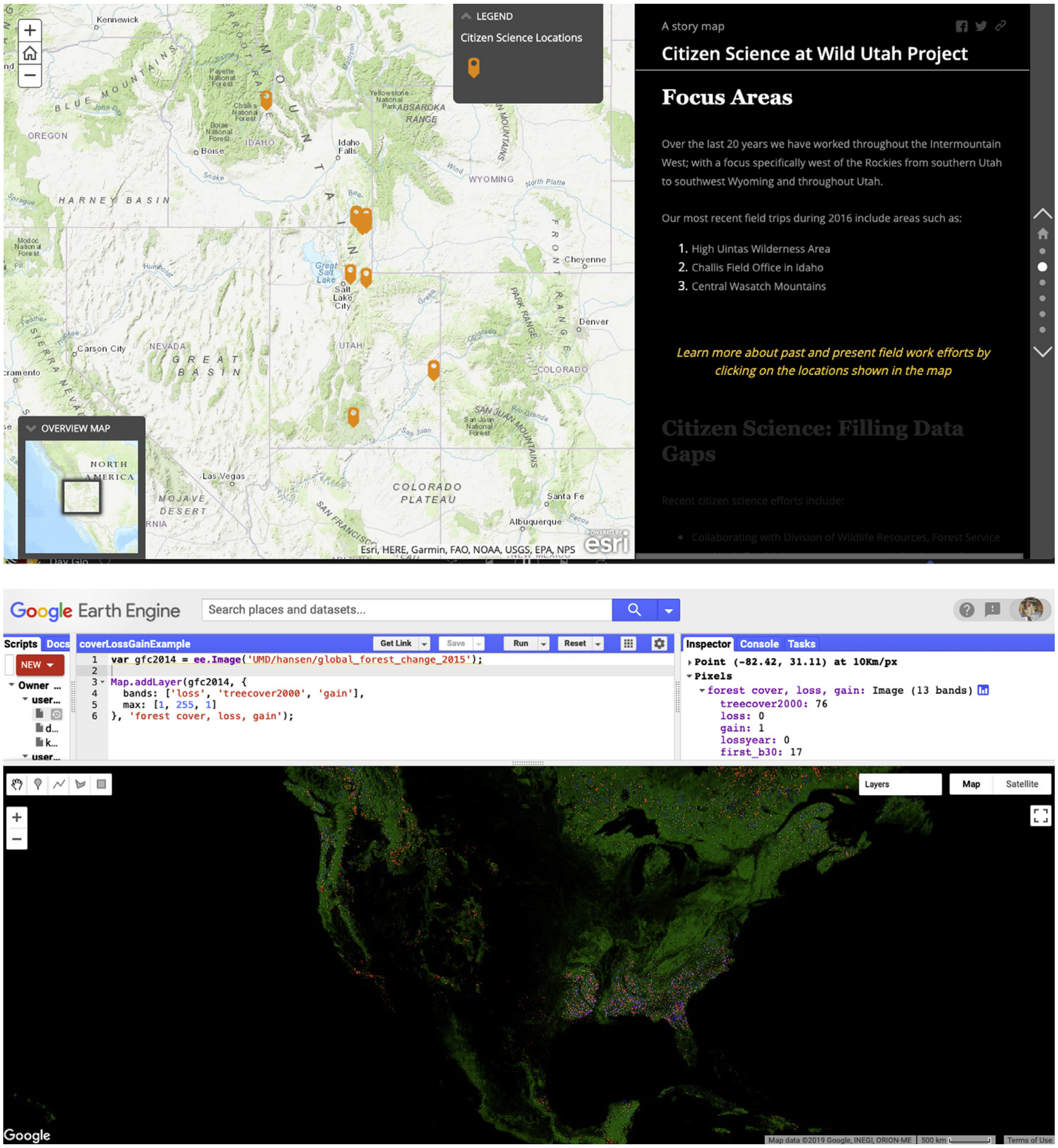

Figure 6 The left is an example of a raster image; each pixel has a digital number representing % of tree coverage in each pixel. The map on the right shows and example vector data from a citizen science project.

mobile technology and contributing VGI. Presently the technology is driving the functionality and representation of VGI rather than the demands of the contributors.

Ethical Considerations

While VGI offers much promise, there are a number of ethical considerations. VGI participants can be characterized into three categories, which are not mutually exclusive: hosts, contributors, and users. All involved should be aware of the ethical responsibilities and implications of their practices and the intended use of these data. VGI website and mobile application operators need to explicitly state the intended use of the content being collected. Ethical considerations related to VGI include: privacy, data ownership, active versus passive contribution, missing voices/data, effects of automated processes on spatial cognitive abilities, and data and power.

There are debates on the ethical considerations associated with VGI related to privacy and anonymity because VGI poses an obvious risk of privacy loss. For example, privacy may be compromised where personally identifiable information (PII) is used for location-based advertising, spam, or an infringement on personal safety such as health information. When volunteers contribute information, they often disclose their locations or movement patterns. Therefore, there is a significant risk that VGI can be used for surveillance. Some companies have argued that PII is "volunteered" via opt-in, Terms and Conditions, or use of services, although use (and reuse) of PII can be less than transparent. An example of a privacy threat from VGI is that from Strava, which tracks user runs or bike rides and shares their metrics. Strava shares heat maps showing popular running routes. In one case, Strava data were used to identify military bases in the Middle East since users were jogging around the perimeter of the bases and the general public was not using the app.

Privacy may also be lost when content is used for law enforcement. Social norms, perceptions, and values of privacy vary and evolve with the availability and acceptance of technology. It is not clear that "volunteers" are always aware how they contribute locational data. It has been suggested that crowd-sourced geographic information would be a better umbrella term, with subclasses such as volunteered, automated, scraped, or tracked; however, the distinction between contributed (unknowingly) and volunteered (knowingly) information is also not clear.

Data ownership is another ethical concern. Who owns the data: the person who contributed the data, or an agency providing the infrastructure to collect and house the data? Who has the ability to reuse the data being collected? Who has access to the data going in and access after it has been collected and for what purposes? Answers to these questions vary based on each project and data collection mechanism, project, and/or social media platform. For example, OSM data are open source; contributors can freely download the data in a variety of data sources and format. OSM data are also ingested in opaque ways into Google Maps, Apple Maps, Mapbox, and other proprietary maps. Google Maps, Apple Maps, Mapbox offer API so that users can add data on top or use their turn-by-turn directions, but the data themselves cannot be downloaded because they are owned by the agency.

There is also concern that automated data affect spatial cognitive abilities. Perception of distance varies among individuals, which can affect search terms, or data that are entered and search criteria implemented by the system as well as data classifications. Research has revealed that the use of LBS may have negative consequences for spatial cognition and wayfinding. Additional challenges with LBS (and all spatial data collection, distribution and organization) are that an end user could misunderstand the information and not everything of relevance maybe documented in a geodatabase.

VGI is often used to make maps, or overlaid onto maps, to make judgments and decisions about the world. Maps hold power, they are seen as truth, as authorities. Therefore, those producing the data have power over the map. There has been promise of democratizing mapmaking through VGI. However, the tools and technology associated with VGI do not mean that process of map making has become available or more even. Previously, mapping was limited to agencies seen as authoritative and made for official purposes such as government monitoring of infrastructure and resource management, construction, ecology, engineering, biology, resource exploration and extraction, and other earth sciences. This limited the amount and the type of data that were collected. Only people with the money and power to collect the data to make maps did so. As a result, maps were only made by those in positions of power so, traditionally, maps reflected the views of those with power. LBS and VGI are technologies associated with GIS which are critiqued due to their appropriation for governmental power and image manipulation, surveillance, and pushing a technocratic view of social problems. Some of the same critiques are being applied to VGI. Those with the money and power to organize and manage VGI efforts hold the control of what content is used, how algorithms are written, and who they privilege.

VGI from social media and mobile applications has led to cartographic production that is increasingly in the hands of the amateur, rather than the professionals. Data are being produced by the mobile app users rather than the agency paying for the map production. This shift in data collection practice is altering the role of knowledge production. Now the masses are contributing large and diverse swaths of data daily, rather than only trained professionals. VGI is often used in reference to "the rise of the amateur" and this movement documented for the promise it may hold for collecting more data from varied perspectives, no longer only a top-down approach, now seemingly anyone can contribute data to a digital map. Critical geographers are quick to point out that there is still significant bias in the data.

Finally, there are ethical questions about who can and cannot contribute. When a person or group's lived experiences or priorities are missing from the map, so too are their needs and values. Efforts such as OSM increase access to maps and data. While this effort is truly impressive, those contributing are not diverse. VGI may reinforce existing power structures by being exclusionary, due to the digital divide and other social, economic, and cultural barriers. VGI may cover wealthy areas better than rural and poorer areas. Another challenge of VGI is the use of local place names versus official place names on a map. For a map viewer who is not familiar with the place, these types of challenges can be quite disconcerting. These critical Geographic Information Science (GIScience) perspectives provide valuable lenses through which to achieve a more balanced understanding of contemporary forms of mapping including VGI.

Conclusion: Present Challenges and Future Work for VGI in Human Geography

Geographers are particularly hopeful that mobile devices will be used to collect spatial data to reveal and impart knowledge about spatial phenomena using VGI. VGI provides an opportunity to record dispersed and diverse data about physical landscapes through citizen science initiatives on a scale that was previously impossible. Collecting VGI and then distributing it to others via LBS, is an interconnected cyclical process making it difficult to distinguish when and where each act begins and ends. VGI has brought about concerns associated with data quality and reliability, and several ethical considerations related to data ownership, and if users are knowingly or unknowingly contributing their locational information. There is contention between what is and is not considered participation or volunteered, what is and is not represented on digital maps created by the public, as well as a rationale for their contribution. Such contention leads to questions about accuracy, reliability, and data quality.

Human geographers, in future work, should continue to make recommendations for ethical use of VGI as the phenomenon continues to evolve. Other areas of research should include data provenance, how and where VGI data are used and reused. VGI is a field that will continue to evolve and will always have interesting research questions for human geographers.

See Also: Automation; Big Data; Citizen Science; Geolocation; Internet Geographies; Map Perception and Cognition; Mobile Mapping; Spatial Databases.

Further Reading

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OpenAerialMap, https://openaerialmap.org/.
Humanitarian OpenStreetMap Team (HOT), https://www.hotosm.org/.
Mapillary: Open source street view https://www.mapillary.com/.
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Zooniverse https://www.zooniverse.org/.