A Classification of User Contributions on the Participatory Geoweb

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Abstract "Volunteered geographic information" (VGI) is the term most widely used to describe a variety of user contributions on the participatory Geoweb. These contributions range from coordinate locations and geometries to categorical observations, attribute tags, numeric measurements, and content ratings, as well as complex narratives, photos, and videos. Although researchers are creating and studying Geoweb applications, different types of VGI, and the related phenomena of neogeography, citizen science, and crowdsourcing, systematic characterizations of user-contributed local knowledge are scarce. In this paper, we propose criteria to distinguish types of user-generated data and contents, and relate these to types of Geoweb applications. The proposed classification provides a conceptual framework to examine the participatory Geoweb, facilitate the processing of user contributions, and identify possible gaps in the data/content types currently used. This approach could help improve the effectiveness of current Geoweb applications, and increase the uptake of the valuable geographic information they generate.

1 Introduction

The Geospatial Web, or short "Geoweb", is a network of Web 2.0 applications that enable two-way communication of geospatial data among and between citizens and organizations, including government (Leszczynski and Wilson, 2013). This participatory Geoweb consists of an ever-increasing number of mapping applications that collect user contributions (Johnson and Sieber, 2012). These geographically referenced user contributions take on very different forms, including coordinate locations, geometries, categorical observations, attribute tags, numeric measurements, and content ratings, as well as complex narratives and multimedia items, such as photos and videos (Coleman, 2010). To date, there is no agreed-upon terminology to distinguish these different types of user contributions, although the term "volunteered geographic information" (VGI) is widely used for a variety of contributions (Elwood, Goodchild and Sui, 2012). In addition, researchers have noted that the processes, from which VGI emerges, also differ from each other. This led to additional characterizations such as involuntary geographic information, ambient VGI, and facilitated VGI (Tulloch, 2008; Seeger, 2008; Stefanidis, Crooks and Radzikowski, 2011).

In an attempt to comprehensively classify VGI, Deparday (2010) distinguishes types of VGI along a continuum of scientific knowledge, local knowledge, and personal knowledge. He associates these three types with multiple criteria, including the technique used to capture location information; the supported geographic feature type; the structured vs. unstructured nature of attribute data; subjectivity vs. objectivity of contributed information; degree of "volunteeredness" of contributions; and quality of participation. The mechanism for capturing location information is viewed as a key determinant for the nature of user contributions. Sources of location information include GPS recording, cellular phone positioning, address geocoding, and manual drawing on a map (Deparday 2010). Some of these mechanisms (e.g., GPS recording) are automatic, while others (e.g., map drawing) require the user's intention to locate their contributions. The supported geographic feature type, including points, lines, and polygons, also determines the nature of user contributions. A fundamental distinction has to be made between contributions linked to geographic coordinates, contributions linked to user-defined shapes, and contributions linked to geographic features representing real-world objects (Rinner 2001).

In addition to the location component of VGI, Deparday (2010) reviews the "text component", which he also terms "attribute data". Deparday (2010) distinguishes structured from unstructured attribute data, where structured attributes are defined as those "that conform to a range of values on nominal, ordinal, interval or ratios scales" (p.21). With reference to Tulloch (2008), Deparday (2010) makes another important distinction: that between subjective and objective information provided by users. Likewise, Rinner et al. (2011) separate observations (i.e., objective information) from opinions (i.e., subjective information). Finally, the degree of interaction in the VGI collection process can be characterized as a one-way or two-way flow of information according to Deparday (2010), although since the completion of his thesis, the two-way information flow has been identified as a critical component of participant engagement on the Geoweb (e.g., Walker and Rinner, 2013).

In this paper, we attempt to systematically classify Geoweb contributions by their data type. We believe that Deparday's (2010) linear classification misses some combinations of classification criteria and does not consider volunteered quantitative data. We therefore review the user contributions to current Geoweb applications from a variety of domains, including citizen science applications in weather mapping and invasive species monitoring, collaborative basemap creation and maintenance, crisis mapping initiatives, geosocial media and business review Web sites, and map-based discussion forums in urban and regional planning. From these examples, we identify different types of contributions in terms of their spatial and attribute dimensions; their data measurement levels; and their content types.

The following Section 2 examines current research on the Geoweb, geospatial crowdsourcing, VGI, and user-generated geographic content (UGGC). Section 3 embraces a systems perspective of VGI and discusses the core functional groups of data/content input, management, analysis, and presentation along with examples of existing VGI systems. Section 4 proposes a framework for types of user contributions on the Geoweb, while Section 5 discusses possible uses of the framework and concludes the paper with an outlook on future research.

2 Research Context: Geoweb, Crowdsourced Data, VGI, and UGGC

With the emergence of expandable Web mapping interfaces such as Google Maps, more people have become entrenched in using maps for personalized directions as well as mapping data of interest in “map mashups”. These significant developments can be viewed from a number of perspectives, including the blended roles of producer and consumer of user contributions, the non-expert nature of contributors, their motivations, and the number of participants and quality of their contributions.

Coleman, Georgiadou and Labonte (2009) and Sieber and Rahemtulla (2010) have discussed the dual role of “produsers” or “prosumers” in the context of interactive Web mapping. The term neogeography has been used to describe the new expanded range of citizen non-experts involved in mapping enterprises based on their local knowledge rather than formal training (Haklay, Singleton and Parker, 2008). The underlying technical infrastructure was termed the “geospatial Web” (Scharl and Tochtermann, 2007), or “Geoweb”, although a clear definition of the Geoweb is still missing. An important distinction between the informational Geoweb and the participatory Geoweb is made by Johnson and Sieber (2012). The informational Geoweb enables a one-way flow of information from producers to consumers, whereas the participatory Geoweb enables two-way communication. The participatory Geoweb relates to earlier developments in Geographic Information Systems (GIS) research and practice, such as public participation GIS, participatory GIS, collaborative GIS, and Sieber’s (2004) call for a second-generation, bottom-up GIS.

With respect to contributor motivation, the concept of volunteered geographic information (VGI) was coined by Goodchild (2007) as a type of user-generated content on the Web, which was also termed as user-generated *geographic* content (UGGC) (Goodchild 2008). Goodchild (2007) considers three types of sensors that are creating location-specific “information”: static and mobile physical devices as well as human individuals themselves. Goodchild (2007) also discusses citizen science as a context, in which VGI requires some skill level of contributors. To refine the “humans as sensors” perspective, we argue that citizens rather act as conduits, aggregators, or interpreters of their local observations. In addition, we have to consider user contributions taking the form of opinions in addition to observations (Rinner, Kumari, and Mavedati 2011).

Another perspective on user contributions on the participatory Geoweb is reflected in the concept of crowdsourcing, and ultimately, big data. Crowdsourcing implies the notion that the contributors' combined local knowledge (the "wisdom of the crowd") will guarantee the emergence of high-quality information (Zook, Graham, Shelton, and Gorman, 2010). Conceptually quite different processes can result in crowdsourced data, including "involuntary VGI" (Fischer, 2012), "ambient VGI" (Stefanidis, et al., 2011), and "facilitated VGI" (Seeger, 2008). Geographers have noted recently that facilitated VGI settings often result in limited participation and therefore anything but big data. In contrast, the collection of ambient and thus involuntary VGI can result in very large databases, such as millions of geographically referenced tweets or photographs. Consequently, big (geographic) data are increasingly discussed from the perspective of locational surveillance and spatial privacy.

Geo-tagged social media items are perhaps best characterized by Goodchild's (1997) "information with geographically determined interest". Goodchild (1997) noted that library items such as books or photographs often have a geographic footprint, which determines a user's interest, as we are typically most interested in material referring to nearby areas. The geospatial information in such independent items is only implicitly defined, such as through place references in a novel.

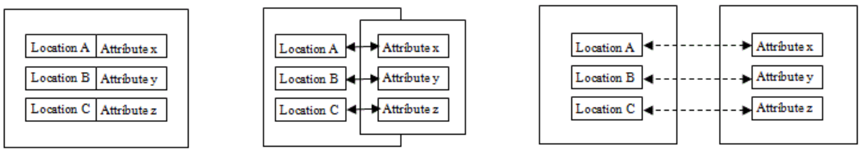

Fig. 1. Degree of connection between location and attribute components of VGI, associated with the link between location and attributes in traditional GIS data models

Overall, there is a range of ways, in which the location and attribute components of VGI can be connected. Figure 1 shows the traditional GIS data model on the left with tightly linked location and attribute information, as it occurs in both the vector and raster data model. The right-hand side of Fig.1 shows loosely linked VGI consisting of geospatial and non-spatial elements that exist independently in their respective realms, but can be connected automatically (geocoding) or by user interaction (geotagging). The centre of Fig.1 characterizes an in-between situation, in which somewhat independent data/content items can readily be connected, as it occurs when an external data table is spatially joined to a feature dataset in GIS.

3 Functionality of VGI Systems

Rinner and Fast (2013) argued that the term "information" is improperly used in many publications on VGI, since information is a higher-order concept than the original user contributions suggest. In fact, many researchers are using the contradictory term "VGI data" (Coleman, 2010; Cinnamon and Schuurman, 2013; Sui, Elwood, and Goodchild, 2013). In analogy with Tomlinson's (2007) recommendations for successful GIS implementations, information should be regarded as the output of a VGI system rather than its input. Along the continuum of data-information-knowledge (e.g., Meeks, 2007), VGI emerges from the processing of volunteered geographic data. This systems perspective still leaves the distinction of data from content up for debate. Therefore, this paper focuses on the handling of volunteered geographic data and volunteered geographic content as input to VGI systems.

Key to the definition of Geographic Information Systems (GIS) is the geospatial nature of the data being handled in these computer systems. By extension, key to VGI systems is the volunteered as well as the geospatial nature of their data/content. Examining the functionality of VGI systems serves to frame the sequence of tasks necessary for handling user contributions. Although VGI systems functions could be classified in different ways - for example, Turner discussed the production, consumption, analysis, visualization, and sharing of VGI (Wilson and Graham, 2013) - we employ the functional groups of GIS as found in typical GIS definitions: input, management, analysis, and presentation, also known as the "IMAP" model (Bill and Fritsch, 1999).

3.1 Input

VGI evolved around the concept of "citizens as sensors" (Goodchild, 2007), using people as the primary input mechanism, and signaling a major shift from GIS input functions. Traditionally, the data stream began with either analogue or digital data, supplied by authoritative sources such as national mapping agencies. These data were captured using digitizing, scanning, data transfer, or key coding (Heywood, Cornelius, and Carver, 2006). In the VGI systems framework, the data stream shifts from authoritative data sources to asserted data sources, where data capture mechanisms are often digital. In fact, while data had to be actively collected yesterday, some datasets are emerging as a byproduct of collaborative volunteer efforts today (Longley, Goodchild, Maguire, and Rhind, 2011). For example, Google Maps for Mobile harnesses real-time traffic conditions from location data contributed by way of GPS-enabled smartphones (Barth, 2009). In this case, the data input mechanisms are designed to be effortless on the part of the contributor; Google Maps for Mobile is "easy to install and use, […] making it easy for people to provide information about their own vehicle speed. There's no extra device to plug into your car and no extra software to buy" (Barth, 2009). This example highlights the new mechanisms through which data can be collected from location-enabled devices.

While data input is becoming more automated, human intervention is still necessary and we still rely on data input tools (Goodchild and Li, 2012). For example, anyone is invited to submit or edit the data of the OpenStreetMap initiative, but doing so still requires input devices (keyboard, mouse) and "ancient" input functions for geometric and attribute data, such as on-screen digitizing and categorization of geographic features. Nearly effortless input, as with the case of Google Maps for Mobile, could be the key to tapping into a broader source or user contributions.

3.2 Management

Similar to traditional GIS projects, VGI system require database management functions to facilitate the storage, organization, and retrieval of user contributions. A VGI system represents a multi-user environment, and requires a database management system that can accommodate its unique conditions. In addition to the spatial data and content, metadata are important to VGI systems. For example, contributor profiles stored in the metadata could assist project organizers in learning about the sample population contributing content, and lead to a more robust understanding of who is contributing, and why.

Of particular interest is the dynamic and sometimes real-time nature of the database construction. For timely updates on the map, especially in the case of emergency management where immediate response is necessary, the database management requires automatic storage and immediate retrieval. Databases can either be built for one project (e.g., emergency response) or be continuously maintained (e.g., OpenStreetMap). Another management consideration is verification procedures to control the input of UGGC, including contributor logins, trusted contributors, and approval mechanisms. Ushahidi, for example, requires system administrators to moderate and approve all contributions before they are published online. In this instance, users input geographic content but in turn, the system administrators manage, analyze, and present it as volunteered geographic information. Although data input is technically open to anyone in the Ushahidi platform, the management of the data gives administrators control over the information produced and shared (Baker and Neu, 2013).

Exploring how VGI fits into existing spatial data infrastructures (SDIs) can assist in the management of VGI. Mooney and Corcoran (2011) asked, from a computer science perspective, whether VGI is ready to be a part of SDIs, stating that SDIs are typically institutionally sanctioned, top-down approaches to data dissemination. Initially, it seems difficult to translate this top-down systems planning approach to the realm of VGI, since VGI initiatives are commonly characterized as “grassroots” or community-based, emerging, and minimally constrained. Sui and Goodchild (2011, 1742) similarly asked: “What protocols and procedures can be developed to link asserted, crowd-sourced social-media data with authoritative data to fill gaps in spatial data infrastructure?” Budhathoki, Bruce, and Nedovic-Budic (2008) explored the complementary nature of VGI and SDI, highlighting that future research is needed to reconceptualize the role of the user as the producer in SDI. Determining how VGI fits into existing SDIs could be the first step toward balancing both authoritative and assertive data frameworks (Elwood et al., 2012; Coleman, 2010).

3.3 Analysis

Goodchild (2008) highlighted that the analytical functions of GIS is what made it such a powerful tool, revealing insights not otherwise evident. Information with geographically determined interest has “patterns that are well behaved and therefore amenable to modeling; and of sufficient variability to impact locational decisions” (Goodchild, 1997, 387). However, data analysis in VGI systems is generally less developed than the other functional groups. Bowker (2005) advised that the mass amount of data being generated daily necessitates deciding what data are important and then paring them down to usable information, or risk all the data being useless. Due to the sheer amount of user contributions on the Geoweb, geospatial data mining is emerging as a popular method of classifying and consolidating predominantly qualitative contributions (Mennis and Guo, 2009; Elwood et al., 2012). De facto however, VGI as the system output is constrained by the hardware and software used in a particular initiative, as well as by the number and engagement level of participants and the amount and quality of contributed data/content.

Some platforms are enabling the discovery of trends and relationships in emerging dataset. SwiftRiver, made available through Ushahidi, filters and verifies real-time data while providing some analysis capabilities, including semantic analysis to auto-classify contributions (Baker and Neu, 2013). More advanced geospatial analysis functions, such as buffering or interpolation, are not widely implemented in VGI systems. On the one hand, the users of a VGI system are rarely trained in geographic problem solving, thus limiting their ability to properly apply such functions. On the other hand, many geospatial analysis functions require numeric data that are not the focus of typically qualitative VGI initiatives (Fogliaroni, DeFelice, and Wallgrun, 2010), 2010), or that would need to be generated from raw data (e.g., counts of contributions per area). An alternative to analysis within VGI system, particularly suited for those trained in spatial analysis, is exporting the dataset to be used in GIS or statistical software. Integrating the strengths of VGI system with existing GIS analysis capabilities has the potential to produce more complex VGI from user contributions.

3.4 Presentation

Effectively presenting the information derived from VGI systems is an important function, ultimately enhancing our spatial understanding of the world around us. Similar to the information products resulting from the data-to-information transformation described by Tomlinson (2007), we need to consider information products as the output of VGI systems. In a Geoweb environment, these information products are extending beyond traditional static maps to dynamic and interactive methods for sharing and visualizing VGI (Wilson and Graham, 2013). Elwood et al. (2012) define "VGI as geographic information acquired and made available to others." (p.5) The Geoweb is not only enabling the collection of user contributions through increasingly simplified and interoperable mapping interfaces, but also leads to a wake of new options to make geographic information available to others (Sui and Goodchild, 2011). The Geoweb provides an "intuitive view of spatial phenomena for a wider audience than conventional maps" (Li, Veenendaal, and Dragicevic, 2011).

Although interactive maps extend visualization and presentation capabilities for communicating geographic information, we also need to consider outputs that are accessible, succinct, and easily integrated into existing information channels. Authoritative stakeholders (including government, academic, and private sectors) require information that can be incorporated into reports, publications, and policy. In this case, datasets should also be considered an information product derived from VGI systems, as they are more easily converted into traditional tabular, graphic, textual, and static map outputs. In particular, developing VGI systems derived datasets to integrate into various SDIs can be of most benefit, as the dataset could be the starting point for a host of research and development. For example, Johnson, Sieber, Magnien, and Ariwi (2012) focus on using UGGC as a data source to support tourism research. Creating a variety of information products, both interactive and static, to meet the information needs of a project and its stakeholders should be an area of attention moving forward with VGI systems.

4 Types of User Contributions on the Geoweb

With a view on the VGI systems outlined in the previous section, the following data types/formats of user contributions on the Geoweb can be identified:

A. Locations (coordinates, geometries, geographic objects/features)
B. Categorical observations (species; earthquake; R/S classification)
C. Numeric measurements (e.g., temperature, flood water level, noise)
D. Parameter settings in models (e.g., multi-criteria evaluation weights)
E. Annotations, narratives, stories

F. Media (audio, photos, video)
G. Opinions (thumbs-up/-down, ratings, arguments, commentary)

Type A represents a purely geospatial type of user contributions while all other types represent the geographically referenced attribute component discussed in Section 2. Types B through G can be further distinguished in different ways. For example, types B, C, D, and part of type G are structured with fixed value ranges as defined by Deparday (2010), while types E, F, and arguments/commentary of type G are unstructured. Additionally, types B and C represent data at the nominal and numeric (including ordinal, interval, and ratio) levels of measurement. In contrast the remaining types are not easily understood as measurements but rather as the output of human assertive or creative activity. Finally, a pattern of increasing complexity of the information underlying types B through G can be observed, as well as within types C (from ordinal to ratio), E (from short annotations to extensive stories), F (from audio only to static images to animated images with audio), and G (from one-click ratings to extensive commentary).

On the basis of these observations, our proposed classification distinguishes two groups in each of the geospatial and attribute dimensions of user contributions on the Geoweb. In the attribute component (horizontal dimension of Fig.2), we distinguish contributions akin to "data" in a narrower sense from those more appropriately described as "content". In the geospatial component (vertical dimension of Fig.2), we distinguish contributions referring to coordinate locations from those referring to geographic features.

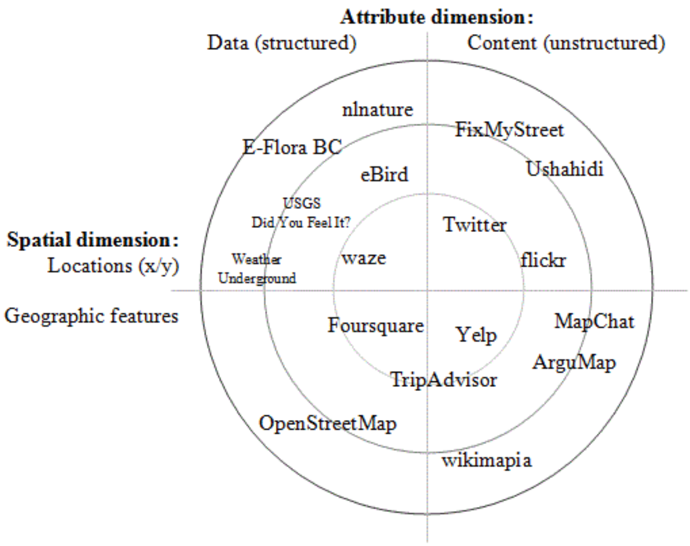

Fig. 2. Examples of Geoweb applications distinguished by the spatial and attribute dimension of user contributions

Within the "data" component, the different levels of measurement are found: quantitative (interval, ratio) and qualitative (nominal, ordinal). Within the "content" category, a similar distinction is not obvious. However, contents items can be distinguished by the complexity of their information, or the information needed to create them. Although the entire "content" component could be characterized as nominal, the scope of contents is different as seen in the abstract types discussed above. Content items such as audiovisual media are independent objects with only a loose geospatial link, as outlined in Fig.1 above.

Some of these applications included in Fig. 2 collect data using a reporting feature via the Geoweb, while others rely on checklists, checkins, and other input mechanisms, from which user contributions subsequently get added to a Geoweb environment. For example, OpenStreetMap, ArguMap, MapChat, and waze collect data directly on maps, while eBird, USGS Did You Feel It?, and E-Flora BC use forms, checklists, and checkins to gather data.

The group of applications that collect structured data for x/y coordinate locations (top left in Fig. 2) includes NLNature, E-Flora BC, eBird, USGS Did You Feel it?, Weather Underground, and Waze. These are often characterized as citizen science applications, and typically require participants to actively contribute data. As an example, eBird builds on over a century of successful citizen science-based Christmas bird counts and collects data on where, when, and how long participants went birding, along with the bird species observed (seen or heard) via a checklist (Sullivan, Wood, Iliff, BOnney, Fink and Kelling, 2009). The developers then map those observations, arranged with other more authoritative data. In the same class of applications, the electronic atlas of the flora of British Columbia, E-Flora BC, is compiled from a variety of (authoritative) databases with relevant flora information, and supplemented with mapped photo records from citizen scientists (Klinkenberg, 2014); NLNature, or Newfoundland and Labrador Nature, encourages participants to observe wildlife and then post details and pictures of the plants, animals, and other interesting features (e.g., rocks, landmarks) they sighted to the online atlas (Lukyanenko et al., 2011); Weather Underground integrates measurements from over 34 000 personal weather stations to provide local weather forecasts; with its "Did You Feel It?" application, the United States Geological Survey (USGS) taps into information from people experiencing earthquakes. Organized by ZIP codes, the information collected includes a description of people's observations during the earthquake, the extent of the damage, and a questionnaire that aims to crowdsource the relative intensity of the event; and finally, Waze has been called a "social traffic app" that automatically collects travel times from users' smartphones and encourages users to manually submit information on other road conditions.

The class of Geoweb applications using unstructured content and x/y locations (top right in Fig. 2) includes Flickr, Twitter, FixMyStreet, and Ushahidi. Flickr is the world's largest photography community, allowing users to search, organize, and share photos, which includes an option for geotagging and organizing photos on a map. As an online social networking and microblogging service, Twitter allows particpants to upload short 140-character messages, or "tweets", which can be geolocated by the position of the user's mobile device. FixMyStreet allows residents to report, view, and discuss problems in their city (e.g., graffiti, potholes, garbage hotspots) by reporting the problem on a map. Finally, Ushahidi is a map-based platform to report incidents via mobile phones (short message service) or the Web. It supports textual observations, photos, and video uploads.

OpenStreetMap, Foursquare, and to some extent TripAdvisor represent a class of apps that collect structured data referring to geographic features (bottom left of Fig. 2). OpenStreetMap uses crowdsourced GPS data and manual digitization to create a collaborative digital map of the world. Foursquare allows people to virtually check-in to real-world locations. TripAdvisor is based on user reviews of travel amenities such as hotels. It includes both structured (e.g., price paid, star rating) and unstructured (e.g., free-text review) attribute data, and therefore also belongs to the following class of Geoweb applications.

A final class of Geoweb applications with unstructured content as their attribute dimension and geographic features as their spatial dimension (bottom right of Fig. 2) includes wikimapia, Yelp, MapChat, and ArguMap in addition to TripAdvisor. Wikimapia aims to describe the world by having users mark objects on a satellite image and provide textual and photographic documentation of the feature or area. Yelp collects reviews of local business from its users. A Google Map is one way of browsing the existing reviews, albeit not the primary point of access. Although the map uses markers at coordinate locations, these markers are geocoded from the addresses of business and therefore indirectly represent geographic features. In ArguMap (Rinner and Bird, 2009) and MapChat (Hall, Chipeniuk, Feick, Leahy and Deparday, 2010), participant contributions in the form of annotations or commentary are linked directly with objects in the digital map environment.

5 Discussion and Conclusion

In reviewing the examples of Geoweb applications included in Fig. 2 and the corresponding types of user contributions, it seems that user contributions are determined to some extent by the purpose and the context (field of study) of the respective project. The schema in Fig. 2 suggests groups of applications that share similar contribution types as follows:

- **Crowdmapping:** OpenStreetMap; wikimapia.
  These applications require users to refer to real-world geographic features when submitting attribute data/contents, which can be structured (OpenStreetMap) or unstructured (wikimapia).
- **Citizen sensing:** Weather Underground, waze, USGS Did You Feel It?
  In these applications, user contributions are in the form of structured data attached to x/y coordinate locations.

- **Citizen reporting:** eBird, E-Flora BC, nlnature; FixMyStreet, Ushahidi.
Here, users provide structured (eBird, E-Flora BC, nlnature) or unstructured (FixMyStreet, Ushahidi) data/content linked to coordinate locations. The difference of the structured citizen reporting applications to the citizen sensing group above is the active nature of the users' contributions.
- **Map-based discourse:** TripAdvisor, Yelp, Argumap, MapChat.
These applications operate on real-world geographic features, but unlike the crowdmapping group above, their contents represents user opinions rather than facts (a distinction not currently captured in the diagram).
- **Geosocial media:** flickr, Foursquare, Twitter.
The typical geosocial media applications (flickr, Twitter) use automatic geocoding of user contributions, the main interest in which is in the attribute dimension (photos, tweets). However, Foursquare distinctly focuses on the spatial dimension with references to real-world features.

Beyond purpose-specific determinants, additional characteristics of Geoweb applications seem to be associated with certain types of user contributions. With respect to the spatial dimension, Deparday (2010) already discussed the difference between manual geocoding (e.g., markers set by users in crowdmapping or map-based discourse applications) and automatic geocoding (e.g., location recordings from cellphone or camera position in geosocial media). In addition, the different meanings of the location component are of interest: home location, current position when contributing, or location of the object of a contribution. While the user's home location is rarely captured explicitly due to privacy and safety concerns, citizen reporting applications would often locate contributions at the user's current location, while map-based discourse requires the location of the object of a contribution (e.g., restaurant being reviewed or urban planning project being commented on), irrespective of the user's location.

Brandusescu et al. (2014) discuss effects of temporality on the use of a crisis mapping platform, Ushahidi, in acute (short-term) and chronic (long-term) community development. The examples in Fig. 2 include large-scale, continuous projects (e.g. OpenStreetMap) as well as platforms (e.g., Argumap, MapChat, Ushahidi) for project-specific applications. Project-specific applications appear to allow for more complex, unstructured contents. This could be owing to a typically limited geographic scope, and a smaller number of users and contributions, which allows users to make sense of complex contributions that would not be possible to digest in a larger-scale application. In contrast, larger scale applications with more homogenous contents (e.g., photos on flickr) and those with structured data are limited to automatic summaries and reports, such as on the number of contributions per user. The influence of the type of user-generated data/content on its processing within the VGI system is an important observation towards developing more effective Geoweb applications.

The types of user contributions also have a relationship with the degree of user involvement in the Geoweb application. With respect to citizen science, Haklay

(2013) proposes a new ladder of participation that culminates in “extreme citizen science”, where users are involved in all steps from problem definition to data collection and analysis. A related distinction can be made between Geoweb applications that only collect original input vs. those that allow for maintenance, corrections, and updates in the wiki sense (notably the above crowdmapping group). Additionally, some applications allow for direct communication between users about contributions (map-based discourse group above, as well as Twitter). Both of these types of Geoweb applications tend to be associated with more complex types of user contributions, such as unstructured content referring to geographic features.

In order to guide the development of future Geoweb applications, the fit of the types of user contributions with geospatial data models should be examined. Tentatively, volunteered geographic *data* do fit with traditional spatial data handling in GIS, while volunteered geographic *content* requires new models and tools in order to become compatible with GIS. A participatory Geoweb data model would need to represent anything from points with attached narratives to complex geometries with attribute tags, and from isolated map annotations to structured geographically referenced argumentation. Such a data model could help with accuracy assessment of VGI and quantifying data quality on the Geoweb. It would also highlight any gaps in current Geoweb applications, where some type of user contribution may not be supported yet but present opportunities for citizen engagement.

Further examination of the types of user contributions on the participatory Geoweb should also refer to open data and e-government and their impact on citizen-government interactions. Spatial data infrastructures may increasingly rely on user-generated (or user-verified, -updated, -maintained) information. Ultimately, this research can assist with valuing VGI for societal decision-making.

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