CHAPTER 1

Mapping and the Citizen Sensor

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Abstract

The role of citizens in mapping has evolved considerably over the last decade. This chapter outlines the background to citizen sensing in mapping and sets the

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scene for the chapters that follow, which highlight some of the main outcomes of a collaborative programme of work to enhance the role of citizens in mapping.

Keywords

Volunteered Geographic Information, mapping, citizens, sensors

1 Introduction

Accurate and timely maps are a fundamental resource for a vast array of applications. Maps are, for example, central to everyday activities ranging from route planning and the legal demarcation of space through to scientific undertakings such as the design of nature reserves for species conservation or the monitoring of terrestrial carbon pools in support of climate change policies. Maps, therefore, provide a range of services, including ones that support economic activity (e.g. location-based services) and enhance human health and well-being (e.g. damage maps for disaster relief and humanitarian aid programmes). Maps underpin popular location-based augmented reality mobile games such as Pokémon Go, and gaming activity can be used to help acquire geographic information for mapping (Antoniou and Schlieder, 2014). Map production and updating in a rapidly changing world is, however, a major scientific and practical challenge. The US National Academies, for example, highlight a key strategic question for the geographical sciences, which is: how can we better observe, analyse and visualise a changing world? (CSDGSND, 2010). This book is focused on the potential of citizen sensors, typically volunteers, to help in mapping activities. In the context of this book, we use the term mapping to refer to the process of creating maps. This term aims to be inclusive and thus covers any activity from the process of data gathering to the production of spatial and cartographic products.

Citizens have considerable potential as a source of geographic information and this activity is itself a further strategic priority identified by the US National Academies (CSDGSND, 2010). Citizens have been collecting georeferenced data of several types for some time (Boyd and Foody, 2014) but this activity, and its possible usefulness, is not well understood and therefore its potential remains unfulfilled. To help advance the role of citizens in mapping, a Cooperation in Science and Technology (COST) Action – where COST is a European framework to support research on topics of global relevance – called TD1202 Mapping and the Citizen Sensor[1] was launched. This book presents some of the work that has arisen from the Action's activities.

Mapping has a long history, and 'best practices' for authoritative mapping have been established and used for many years. For example, standards for topographic mapping have been defined and used by major government agencies (Olteanu-Raimond et al., 2017). Similarly, in relation to thematic mapping from remote sensing, best practices for map validation have been defined (Strahler et al., 2006; Olofsson et al., 2014). The various bodies engaged in authoritative mapping, however, often cannot meet mapping requirements or 'best practices', which can be impractical to implement (Rahmatizadeh et al., 2016) – for example, data collection that follows a strict probabilistic sample design or the need for large sample sizes for thematic map validation. In this situation there are a variety of ways in which mapping activity could progress. The problems of authoritative mapping could simply be recognised and standards lowered. This rather negative approach would appear to be a retrograde step. It would, for example, leave thematic maps unvalidated, representing no more than one possible representation, one untested hypothesis, of contestable value (Strahler et al., 2006; McRoberts, 2011). Alternatively, and more constructively, techniques that require only relatively limited amounts of reference data could be used. For example, semi-supervised techniques that can make use of unlabelled information could be used in the production of thematic maps from remote sensing (Bruzzone et al., 2006) and model-based rather than standard design-based inference could be adopted in map evaluation (McRoberts, 2010; Foody, 2012). A further alternative is to utilise the enormous potential of citizen sensors. For example, data from citizen observations have already been used as a cost effective alternative to collect reference data for hybrid map generation (Schepaschenko et al., 2015; See et al., 2015).

The role of citizens has been noted in a variety of subjects, from astronomy to zoology (Raddick and Szalay, 2010; Dickinson et al., 2010; Wiersma, 2010; Muller et al., 2015; Rossiter et al., 2015). Citizens have also already contributed greatly to mapping activities, including, for example, to major programmes such as bird species distribution mapping (Dickinson et al., 2010; Wiersma, 2010) and to the pioneering production of national land cover datasets such as the first land utilisation survey of the UK in the 1930s (Parece and Campbell, 2015). The role of citizens in mapping has, however, benefited greatly from recent advances in geoinformation technologies. Technological advancement has fostered the emerging role of the citizen as a source of data. Due to the proliferation of location aware devices and the opportunities of Web 2.0, it is now possible for citizens to easily acquire, share and use geographical information. This activity has been named or described in a variety of ways, notably as crowdsourcing, volunteered geographic information (VGI), user generated spatial content, neogeographies and the pervasive media (See et al., 2016). These various terms are often used to help differentiate between activity that is passive or active, and between information that is truly volunteered or that is being provided for a modest, and possibly non-financial, reward. In this book, there is no particular desire to distinguish between the different approaches, although the detail can sometimes be important, and the focus is simply on citizen-derived geographical data. The citizens contributing data may be anyone: they could be children or adults, they may be amateurs or experts, they may have differing motivations and may even be contributing without knowing so.

Citizen sensing has dramatically affected mapping and map use, impacting on routine daily life activities such as gaming and tourism as well as on science and technology more generally. Resources such as Google Earth, Bing Maps and even maps that are citizen-generated through projects such as OpenStreetMap (OSM) are now widely and routinely used by diverse amateur and professional communities. Furthermore, possibly radical impacts on mapping activity are likely to occur (Olteanu-Raimond et al., 2017) and some argue that a new data-rich paradigm is emerging with VGI (Jiang and Thill, 2015; Li et al., 2016). These future developments should arise from the trend for continued technological advances but also from an increased provision of free, or at least inexpensive, remote sensing data and increasing access to official government data resources. These tremendous opportunities do, of course, come with challenges. In the big data era, there is now, paradoxically, so much data that problems in mapping may arise. The curse of data volume can be likened to the widely encountered Hughes phenomenon, in which map accuracy declines as data dimensionality increases for a fixed ground dataset (Richards, 2013). Immense volumes of data from future remote sensing will amount to a deluge; for example, Sentinel 2 satellites alone will produce 1.6 TB of data per day, and yet they are just one pair of the over 350 Earth observing satellites that are to be launched by 40 different countries by 2023 (Foody et al., 2015). There are also clear challenges with citizen-derived data. These datasets can be voluminous, as with other components of the developing field of big geospatial data, and their size and dynamic nature may need to be recognised explicitly if they are to be used efficiently and effectively (Herrera et al., 2015; Li et al., 2016). Citizen-derived data are also often of varied (and typically unknown) quality and trust levels (Goodchild and Glennon, 2010). Moreover, the data generated may be poorly described and associated with little if any metadata. To realise the full potential of citizen sensing, there is a need to establish good practices and perhaps even protocols for some activities (Schade and Tsinaraki, 2016). This will be a challenging task, not least due to issues such as the diversity of datasets generated, the range of devices used and sensitivities to error and uncertainty, which are often application-specific. Additionally, there are a suite of other major considerations in the use of VGI, including ownership rights, as well as privacy, legal and ethical issues (Granell and Ostermann, 2016). As a further complication, there may be tensions between different parts of the community, with, for example, some calling for anonymity and privacy as an essential feature (Mozas-Calvache, 2016) while others want information on volunteers to be available to aid assessments of trust (Zhao et al., 2016). There is also clearly a strong desire to not 'kill off the golden goose' by laying down strict rules and procedures that end up making volunteering an onerous task and ultimately deter the provision of citizen-derived data. A variety of priorities have been identified that must be addressed in order to facilitate citizen sensing, including issues such as standardisation and interoperability (Brown et al., 2013), and groups are working on defining good practices to encourage mapping-related applications (Pocock et al., 2014a; 2014b). This book reports on some of the activities of one group, the participants of COST Action TD1202. This Action has addressed a wide range of issues connected with citizen sensing in mapping, from advice on photography that might be uploaded to social media sites (Antoniou et al., 2016) to informing the activities of European national mapping agencies (NMAs) (Olteanu-Raimond et al., 2017). The production of the book involved considerable input from the Action and beyond. We are grateful to all who helped bring this book to fruition from authors to publishers but we wish to also highlight here the significant inputs from Bénédicte Bucher who reviewed the manuscript for publication and Nourane Clostre who copyedited it.

2 Outline of the Book

This book is intended to closely reflect the main research themes of COST Action TD1202. One of the first themes addressed was how VGI is acquired, managed, stored and disseminated. Building upon a review that systematically evaluated VGI websites and mobile applications to characterise VGI (See et al., 2016), Chapter 2 provides an overview of different sources of VGI for mapping. The sources are first distinguished by (i) whether the VGI can be considered as framework data (i.e. of the type generally collected by NMAs) or whether they fall into 'other' types of data (e.g. weather and traffic data) and (ii) whether the VGI is actively or passively collected. The chapter then provides a range of examples that illustrate these four types of citizen-contributed data, as well as a brief discussion on 3D VGI. Chapter 3 then discusses one of the most successful VGI projects, which is OSM, and provides a comprehensive introduction to this data source, including how it is being used in a range of services and applications in education, mapping, visualisation and research. The current status and positioning of OSM as a VGI project is also evaluated. The chapter then closes with discussions on future issues that need to be considered by contributors to and users of OSM in order for it to continue its success and growth. In Chapter 4, the emphasis shifts to exploring automated mapmaking with the use of OSM data. The chapter starts by examining why traditional automated mapping processes are not adapted to VGI and describes attempts to solve this problem. The focus then turns towards the level of detail of OSM features and how it can be inferred and harmonised for different features, which aims to aid map generalisation. How other VGI sources, such as geotagged photographs, can help to evaluate the quality of OSM prior to the application of any automatic mapmaking processes is also presented. Finally, issues related to advanced map stylisation with VGI are discussed.

Another prominent theme of the Action has been to gain a better understanding of the motivations of contributors to VGI, and this theme is outlined in Chapter 5. This chapter reviews the literature on motivation and incentives for participation in VGI projects and then presents case studies to reflect on what motivations and incentives have worked well, including how to sustain participation in VGI activities in the longer term. When considering citizens as part of the VGI equation, legal issues and issues such as data privacy and the ethics of data use and reuse immediately come to the forefront. These are discussed in detail in Chapter 6 with specific reference to VGI as a unique source of information.

The quality of citizen-sensor-derived VGI is often a problem, as sources range from naïve, poorly trained citizens to authoritative experts and may even include people contributing erroneous data maliciously. Hence another major theme of the Action has been data quality. It is important to note that VGI can be as good as, if not better than, authoritative datasets in terms of quality (Antoniou and Skopeliti, 2015; See et al., 2013; Dorn et al., 2015). However, even if the data collected could be trusted in terms of features such as their accuracy, there are a variety of other concerns, relating to issues such as the spatial sampling and bias of data collection (Brown, 2017) and the ability to repeat and replicate studies, that may limit the scientific value of the data (Ostermann and Granell, 2017). Much VGI is collected opportunistically and is spatially biased, for instance by digital divides between urban and rural regions or between developed and developing countries (Estima et al., 2014; Neis and Zielstra, 2014). There are also social divides, with most contributions made by young citizens who are technologically savvy (Haworth et al., 2015). Some of the Action's work has focused on how VGI could be usefully used in map validation (Fonte et al., 2015), taking quality considerations into account. In this book, Chapters 7 to 9 all deal with quality-related issues of VGI. Chapter 7 is dedicated to the assessment of VGI quality, and presents the challenges that are raised by this type of data for quality assessment. It provides an overview of how the data quality elements included in the ISO 19157 standard can be applied to VGI as well as of the limitations of these elements. A description of additional indicators that can be used to assess VGI quality is then made. Efforts developed to establish workflows to assess VGI data quality are then presented and discussed, as well as efforts to combine data quality indicators to assess VGI fitness-for-use.

Returning back to OSM, Chapter 8 discusses the evolution of OSM quality from a novel point of view; the chapter deviates from the more traditional quality measurements or quality statistics used in most OSM quality studies and examines the evolution of OSM data quality as a function of the OSM micro-environment, such as OSM specifications and OSM editors. The evolution of OSM specifications, taking into account a number of different factors that directly affect the quality of contributions, is examined. The evolution of OSM editors is also presented, as they are literally the entry point for all OSM contributions. Finally, the combined impact of these two factors on the overall OSM quality is discussed. In Chapter 9, a framework for VGI quality visualisation is presented that supports both the communication and the exploration of VGI quality. This framework is based on four factors: the available methods for quality visualisation of spatial data; the nature of VGI data quality; user profiles; and the visualisation environment. The chapter then discusses how the framework can be implemented with VGI data.

One critical issue related to the diversity and quality of spatial data is the need to develop good practices. Here, there is a tension between the desire to encourage volunteers without constraining their involvement and the desire to acquire useful data. The latter could be aided by the specification of best practices or even protocols, but if these become too onerous they may actually act to deter volunteers. Since, for example, much current VGI is derived from geotagged photographs and from vector data, such as in the OSM project, the proposal of good practices for key mapping-related activities is one major way in which the Action has helped contribute to the development of the subject. Thus, Chapter 10 explores the role of protocols as tools to guide data collection in VGI projects with the purpose of increasing the quality of user contributions. With the help of technology, protocols should balance the opposing needs of providing VGI contributors with detailed instructions and keeping intact their enthusiasm and motivation. With this in mind, a general protocol is formalised, and specific, real-world applications of the protocol are presented. In Chapter 11, the means by which citizen-generated data may be published and documented to make these datasets discoverable and reusable for robust and reproducible science is investigated. The current state of the art is assessed, with particular attention to the role and adoption of Data Management Plans for citizen science initiatives and observatories. The relevance and availability of existing data and metadata standards, vocabularies and tools which can be employed to support interoperable storage and dissemination of VGI are evaluated, and reference is made to examples of good practice from existing infrastructures. Finally, in Chapter 12, the challenges of integrating VGI with the Infrastructure for Spatial Information in the European Community (INSPIRE) directive are discussed, contrasting Spatial Data Infrastructures (SDIs) with VGI. This is followed by a discussion of the set of critical issues that arise when integrating INSPIRE and VGI and of what the prospects for integration are, providing illustrative examples. Finally, a conceptual framework is presented for what an SDI-VGI integrated GIS platform could look like.

A final theme in the Action has been the role of citizen sensing in map production. The research undertaken was aimed at defining the needs of the map producing community, identifying the sensitivity and tolerance of mapping methods to different types of error and uncertainty in VGI, and assessing the potential role of current VGI efforts as well as of active citizen sensing in the activities of NMAs. A survey of key map producers, notably European NMAs, was undertaken to establish their current and potential future use of VGI to inform their work (Olteanu-Raimond et al., 2017). Chapter 13 builds upon this work and provides an overview of the experiences of some European NMAs in engaging with VGI. It also provides recommendations to support wider engagement with the VGI community and to help ensure that the potential of VGI in mapping is fully exploited and used in the workflows of NMAs in the future. Switching to another public stakeholder, i.e. urban planners, Chapter 14 discusses the value and opportunities of VGI, and of its more passive equivalent, social media geographic information (SMGI), for urban planning. A number of examples are provided to illustrate how this new source of information can be used to improve visualisation, planning processes, evaluation of plans and decision-making. The use of VGI and SMGI in smart cities initiatives is also examined. One recent trend has been towards the development of citizen observatories and hence Chapter 15 discusses their increasing role in engaging citizens in science, environmental monitoring and policy-making. The chapter provides an overview of existing and planned citizen observatories and of where further developments are happening at the European front. The chapter closes with a discussion of the key challenges and development needs for policy- and decision-makers in the future.

The term VGI has been in existence for only a decade, yet the number of new applications and the increased involvement of citizens in mapping and environmental monitoring has literally exploded. The final chapter of the book examines what the future trends in VGI might be and the increasing role that smart cities and society will play in this innovative area. It is clear that the future for VGI is very bright; the key is to not waste these valuable citizen-based resources but to find ways to maximise the synergies between stakeholders across multiple levels of society.

Notes

[1] http://www.citizensensor-cost.eu/

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