CHAPTER 3

A Review of OpenStreetMap Data

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Abstract

While there is now a considerable variety of sources of Volunteered Geographic Information (VGI) available, discussion of this domain is often exemplified by and focused around OpenStreetMap (OSM). In a little over a decade OSM has become the leading example of VGI on the Internet. OSM is not just a crowdsourced spatial database of VGI; rather, it has grown to become a vast ecosystem of data, software systems and applications, tools, and Web-based information stores such as wikis. An increasing number of developers, industry actors, researchers and other end users are making use of OSM in their applications. OSM has been shown to compare favourably with other sources of spatial data in terms of data quality. In addition to this, a very large OSM community updates data within OSM on a regular basis. This chapter provides an introduction to and review of OSM and the ecosystem which has grown to support the mission of creating a free, editable map of the whole world. The chapter is especially meant for readers who have no or little knowledge about the range, maturity and complexity of the tools, services, applications and organisations working with OSM data. We provide examples of tools and services to access, edit, visualise and make quality assessments of OSM data. We also provide a number of examples of applications, such as some of those

How to cite this book chapter:

Mooney, P and Minghini, M. 2017. A Review of OpenStreetMap Data. In: Foody, G, See, L, Fritz, S, Mooney, P, Olteanu-Raimond, A-M, Fonte, C C and Antoniou, V. (eds.) *Mapping and the Citizen Sensor.* Pp. 37–59. London: Ubiquity Press. DOI: https://doi.org/10.5334/bbf.c.

used in navigation and routing, that use OSM data directly. The chapter finishes with an indication of where OSM will be discussed in the other chapters in this book, and we provide a brief speculative outlook on what the future holds for the OSM project.

Keywords

OpenStreetMap, geodata, open data, Volunteered Geographic Information (VGI)

1 Introduction

The OpenStreetMap (OSM) project was founded in 2004 and has now positioned itself as the most famous example of Volunteered Geographic Information (VGI) on the Internet (Jokar Arsanjani et al., 2015). While OSM is only one of many well established and well known VGI projects (See et al., 2016), it holds a dominant position in the VGI landscape. Chapter 2 of this book, by See et al. (2017), gives an overview of different sources of VGI in the context of its usage and characteristics. In recent years OSM has attracted very significant research attention (Mooney, 2015) and could almost be considered a field of research in its own right (Jokar Arsanjani et al., 2015); given the influence of OSM on the VGI and citizen sensor research landscape, this chapter will provide an introduction to and overview of the OSM project.

OSM was founded in 2004 by then MSc student Steve Coast, who created the idea as part of a thesis dissertation. Around that time the concept of crowdsourcing, collaboration and Web-based co-production or creation of knowledge was beginning to gain momentum. Coast's idea was simple: if I collect geographic data about my area – where I have local knowledge – and you collect geographic data about your area – where you have local knowledge – then these can be combined, and we can begin to build a spatial database of a region. If this scales up to a larger *crowd* of people, then it is very possible to crowdsource the mapping of the entire world. The OSM mission statement grew out of this simple idea, which was to be a collaborative project that created a free editable map of the world. Rather than the focus being on outputs in the form of cartographic products and maps, the core of OSM is a spatial database, which contains geographic data and information from all over the world. Many authors and commentators have speculated on the ingredients for the rapid and sustained success of OSM since 2004. A number of factors are seen as having been influential in OSM's development. In the first instance one of these factors is Web 2.0, or the interactive web (O'Reilly, 2007), which facilitates the development of large scale collaborative projects that can see hundreds or thousands of people contributing simultaneously – the most famous example of this is Wikipedia. Secondly the availability of low-cost, high-quality and high-accuracy Global Positioning System (GPS) means that consumers or citizens can now collect geographic information using smart devices such as their smartphones or dedicated GPS units; these geographic data can then be uploaded and contributed to OSM. The third factor is related to the citizen contributors: the OSM project welcomes anyone to register and take part as a contributor. Contributors can span the entire spectrum of geographic and Information Technology expertise: from beginner or newcomer to expert level geographer or software developer.

1.1 How Does One Contribute to OSM?

The OSM data model is very straightforward to understand. There are three primitive data types or objects: nodes, ways (polygons and polylines) and relations (logical collections of ways and nodes). A way is made up of at least two nodes (for polylines) or three nodes (for closed polygons). A node represents a geographic point feature and its coordinate is usually expressed as latitude and longitude. Within OSM, every object must have at least one attribute or tag (a key/value pair) assigned to it to describe its characteristics. There are many guides and tutorial documents on how one begins to map with OSM; recently the company Mapbox provided an updated set of documentation for this[1]. The OSM Map Features pages on the OSM wiki (OpenStreetMap, 2016) represent the reference document describing the officially adopted OSM tags. These tags have been agreed upon over the years and there are wiki pages written to describe the likely usage and use case scenarios of each tag. OSM follows a folksonomy approach to tagging, and, in theory, any tag can be associated with any object (Ballatore and Mooney, 2015). Contributors are free to create their own tags. As several authors have shown (Ballatore and Mooney, 2015; Ballatore and Zipf, 2015), this can lead to disagreements amongst contributors or confusion on how to use specific tags in certain geographic scenarios (for example tagging an object representing an unpaved pedestrian footpath). Services such as taginfo[2] allow exploration and visualisation of the most frequently used tags and their keys for the entire OSM database. The taginfo service is particularly useful for understanding the style or structure of tags used on specific object types, conceptualising the very wide range of values some keys are assigned in tags and the spatial distribution of tags. Taginfo is constantly updated in near real-time and stores the tags from every object in the global OSM database. There is no theoretical limit on the number of tags that can be assigned to any object. Nodes that have a tag with a key name are usually called Points of Interest (POI) and usually represent the position of some object or structure of general interest. Keys in OSM can be internationalised to accommodate languages other than English, which, due to OSM's origins, has established itself as the *lingua franca* of the project (Ballatore and Mooney, 2015).

There are many software tools available to automate the process of contributing data or editing existing data. The most widely used and popular is the JOSM (Java for OSM) tool[3], followed by the Web-based iD editor[4]; JOSM is acknowledged as being a software tool more suited to more experienced OSM contributors while the iD editor is very straightforward to use and is integrated into the OSM map homepage. New data submitted to OSM or existing data edited within the OSM database are available for access almost immediately, and the OSM map on the OSM homepage will render changes quickly (within 30 minutes). As we shall discuss in Section 2, there are many ways in which one can access and download OSM data for other uses. On a more technical level, every object within the OSM database (nodes, ways or relations) has several data attributes including: a globally unique ID; a version number, which indicates how many times the object has been edited; a timestamp of the most recent edit; and the user ID and the username of the contributor who created (or last edited) the object.

Anyone can sign up and register for free as a contributor to OSM. In July 2016, there were over 2.7M registered contributors, as outlined on the OSM wiki[5]; upon sign-up, a contributor can begin contributing or mapping new data in OSM or editing existing data stored in the OSM spatial database. However, it is not easy to automatically access attribute or demographic information about these user contributors from the OSM database or associated services. Several researchers (Neis et al., 2013 and references therein) have attempted to classify and understand *who* the contributors are to OSM through analysis of their editing and contribution patterns over a long period of time.

There are multiple ways users can contribute data to OSM. The simplest one is through the digitisation of objects (such as buildings, roads and rivers) that are visible on openly licensed satellite imagery. The most used imagery, available by default in the OSM iD editor, is the one provided under a compatible licence by Microsoft (Coast, 2010). While this way of contributing data allows volunteers to map places even when remote from the mapped place, other instruments, such as GPS receivers and paper-based tools like Field Papers[6], allow users to physically survey an area and then upload or insert the information into the OSM database. One of the more controversial methods of contributing data to the OSM database is through the bulk import of suitably licensed geographic data. The pros and cons of taking a geographic dataset produced outside of OSM and importing it into the OSM database have been discussed by many authors (Zielstra et al., 2013), and the issue remains a contentious one amongst the OSM community. One of the most powerful arguments against this bulk import is that it goes against the very ethos of OSM that data be collected or mapped by OSM contributors based on an ability to verify the quality of the data, ability itself founded on local knowledge, physical collection of the data or geographic expertise. Many examples of bulk import are available on the OSM wiki website[7], with the TIGER data import of roads and highways into OSM United States and the CORINE LandCover map import into OSM France amongst the most well known and controversial.

The remainder of this chapter is organised as follows: in the next section, we provide an overview of how OSM is accessed, visualised and used in research, software development and other applications. In the final section of the chapter, we provide some concluding remarks and points for discussion on OSM; we also outline where the reader will find more discussion of and information on OSM in the proceeding chapters of this volume. The overall purpose of this chapter is to introduce readers unfamiliar with OSM to the project and the types of applications it is currently used for. We let other chapters in this volume to describe specific aspects of OSM (data quality, visualisation of OSM, motivations of contributors, etc.) in more technical detail.

2 Applications Using OSM Data

In the introductory section of this chapter, we mentioned that, while much of the focus of OSM is on the maps and cartographic products derived from the OSM data, the core product of OSM is the spatial database. This second section will provide a comprehensive list of a number of projects, organisations, services, software and applications that make direct use of OSM data, with references and links provided at the end of the chapter. A number of such lists and descriptions are available on the Internet (e.g. on the OSM wiki[8]), but, to the authors' knowledge, this is the first list provided in an academic paper. Due to the free and open availability of OSM data and the increasing popularity of OSM worldwide, it would be impossible to list all of the existing projects and applications. Making use of OSM data has become so easy and immediate that new tools are created almost every day. Some of these applications become very popular and well known while other applications are limited to single languages or user groups. Therefore we limit the items on this list to what we consider from our knowledge of OSM to be the most popular, up-to-date and successful applications based on OSM data. The description of each item on the list serves as a reference and starting point for readers having no or limited experience in OSM.

We understand that links to online services and websites change over time and can become obsolete or broken. However, with this in mind, the list itself serves as a commentary on the diversity of application areas where OSM is used. We organise the list under the following headings: Data Download Applications and Services, Education and Research Use of OSM, Disaster and Humanitarian OSM, Government and Industry Usage, Visualisation of OSM Data, Software (OSM Editors, Routing Services, Vector Rendering, other services), Quality Assurance for OSM, and Games and Leisure. For more applications and services, a very extensive list is maintained on the OSM wiki[9].

2.1 Data Download Applications and Services

Regardless of the types of applications and visualisations that can be produced with OSM, the applications and services that provide access to the data within the OSM database are arguably the most important part of the OSM's data architecture. Geofabrik is one of the best known providers of access to OSM data and provides access to continental-, national- and regional-sized data extracts[10]; the data are uploaded very frequently (at least hourly) and are provided in a number of different formats. The OSM wiki provides access to the so-called Planet.osm file[11], which is the entire OSM database contained in one very large XML or compressed format file. This file is updated every few days. The wiki page lists many mirror servers providing access to the Planet.osm file, with many of these servers providing the file updated on an hourly basis. OSM also provides an API[12] that allows extracting and saving raw data from/to the OSM database. There are API calls to create, read, update and delete map data for OSM, and this provides software developers and applications with the most up-to-date data available. However, queries for very large amounts of data (such as city- or country-sized) are discouraged and disallowed. The Overpass API service[13], with its popular frontend Overpass Turbo[14], is a read-only API that allows access to selected parts of the OSM map database; clients send queries using a special API query language or using the graphical interface provided by Overpass Turbo. The Overpass API also allows programmatic calls for data extracts of arbitrary geographic size. The commercial company Mapzen provides OSM data for download in city- or region-based extract sizes from their Metro Extracts[15] service: a number of data formats are provided and their data extracts are updated on a weekly basis. A simple and popular way to download small amounts of OSM data is provided on the OSM homepage and consists in using its 'export' feature[16]. This allows users to browse the OSM map and select small regions using a bounding rectangle, which can then download OSM data to the calling device. All of the services mentioned so far provide, as standard, OSM data in the default OSM XML data format[17]. As most types of XML, OSM XML requires special software tools in order to be processed, and there are many options available for this task[18]. Data providers such as Geofabrik[19] and Mapzen[20] also provide OSM data in common formats, such as SHP files: this allows users to process and visualise the data using desktop GIS tools.

2.2 Education and Research Use of OSM

The ability to access the entire OSM spatial database on an hourly basis or even more frequently has proved a great attraction for the research community over the past number of years (Jokar Arsanjani et al., 2015). There has been a steady increase year-on-year of the number of papers being produced by the academic community in the domain of VGI, and OSM forms a major component of this work. In 2015, one of the first edited volumes on OSM as a research topic was published (Jokar Arsanjani et al., 2015); the volume considered OSM's role in GIScience and contained a very wide range of research topics, from navigation and routing to data quality and visualisation. Similarly, two EU COST Actions focused on VGI that ran from 2012 to 2016, TD1202 'Mapping and the Citizen Sensor' (from where this volume comes)[21] and IC1203 'ENERGIC'[22], have produced some excellent research around OSM. In other educational settings, a repository such as TeachOSM[23] provides a set of community- contributed resources for teachers, trainers, educators and instructors who want to bring OSM into their classrooms. The classroom can be a very important setting for educating the next generation of OSM mappers or contributors. There are many examples, including 'a world-record humanitarian mapathon that took place at the Politecnico di Milano in northern Italy in March 2016'[24]: This mapathon event involved over two hundred children from six elementary schools in the Milan province. This mapathon resulted in the mapping of over 5000 buildings in Swaziland (Ebrahim et al., 2016). More information can also be found in Chapter 5 of this book, by Fritz et al. (2017).

2.3 Disaster and Humanitarian OSM

OSM data and mapping has been used extensively in recent disaster and humanitarian emergencies and operations all over the world. The Humanitarian OpenStreetMap Team (HOT)[25] is a nonprofit organisation leading the international efforts in community mapping projects. Through its open source Tasking Manager[26], HOT coordinates online collaborative mapping based on OSM when major disaster strikes anywhere in the world, such as during the Nepal earthquake in 2015 and the Japan and Ecuador earthquakes in 2016; in regions such as Nepal, OSM very often is the only available source of mapping data and cartography that rescuers and aid agencies can use. The Missing Maps project[27] is an open, collaborative humanitarian project aiming to map the most vulnerable places in the developing world. Missing Maps founders and members are mainly humanitarian organisations (e.g. the American Red Cross and Doctors Without Borders) and NGOs; the project's volunteered mapping is again based on OSM data and the HOT Tasking Manager. The University of Heidelberg hosts the disastermappers project[28], which aims to educate and train university students about mapping in OSM for humanitarian purposes. Reaction time is often very quick and successful with OSM. Examples include a 5-day period of mapping where the Humanitarian OSM Team and volunteers mapped over 100,000 buildings and hundreds of miles of roads in Guinea when Ebola broke out in 2014[29]. The efforts of the OSM community in times of humanitarian crisis are easy to visualise, as snapshots of OSM data can be extracted to show the effects of mapping before and after a particular event. HOT shows the changes[30] in the OSM map that occurred after the city of Tacloban in the Philippines was devastated by the super typhoon Haiyan in 2013.

2.4 Government and Industry Usage

OSM is being used in industry and by government agencies around the world. Indeed there is a large number of companies listed on the OSM wiki[31] who provide consultancy based on OSM data. This consultancy has a wide range of applications, including Web-based mapping, Web GIS, data analysis, routing and navigation, and data extraction. There are several leading companies in this domain including: Mapbox[32], MapQuest[33], Stamen[34], Mapzen[35], CampToCamp[36] and Geofabrik[18]. Most of these companies also provide OSM services back to the OSM user community, including OSM data extracts, web-map layers for online mapping and specialist visualisation.

Government usage of OSM is more difficult to track unless it is advertised and highlighted by the government agencies involved. From the opposite direction, there has been significant use of government data in OSM, with several high-profile data imports having been performed over the years. These imports are based on the imported data having an acceptable open data licence allowing the corresponding geodata to be inserted into the OSM database. The imports include: the TIGER (the Topologically Integrated Geographic Encoding and Referencing system) data, produced by the US Census Bureau, in the USA; plan.at in Austria; GeoBase as a complete map of Canada; and the CORINE Land Cover map in France.

In 2013, New York City opened up many 'high-value datasets to the public, making it possible to use these data to improve OSM'[37], facilitated and assisted by Mapbox[30]. 'In return, New York City's GIS team is informed of changes made in OSM related to their datasets, which helps keep their map data current.' This effectively made the New York City municipality a participant and contributor to OSM in the United States. MapGive[38] is an initiative of the US Department of State's Humanitarian Information Unit, 'mak[ing] it easy for new volunteers to learn to map and get involved in online tasks'. Portland's TriMet traffic authority uses OSM to power their multi-modal traffic planner[39]. The Gendarmerie Nationale (one of the national police forces in France) uses OSM maps inside their police cars[40]. The CROWDGOV report by Haklay et al. (2014) has a number of examples of governmental use of OSM around the world. There is still some reluctance by government agencies to use VGI and OSM as a complement to their own sources of spatial data (Olteanu-Raimond et al., 2017b); however, examples do exist, such as the French National Address Database (BAN), which 'associates each address listed on the French territory (25 million addresses) with its geographic coordinates' (the database 'does not contain any nominative data'). BAN is the result of 'an innovative collaboration model between public authorities' in France and OSM France 'to build an essential reference for the economy, society and public services'[41].

2.5 Visualisation of OSM Data

From anecdotal evidence, visualisation of OSM data is certainly one of the most popular applications of OSM data. Visualisation of OSM data is facilitated by the flexible availability of the OSM data (see Section 2.1) and the very wide range of visualisation tools available, which can natively process OSM data directly or from a spatial database. There is a vast number of examples, and we provide a small selection here for the purposes of illustrating the breadth of applications.

OpenTopoMap[42] provides a topographic visualisation of OSM data combined with SRTM elevation data. The map tiles in OpenTopoMap are available for use as a web-map layer in other applications. OpenCycleMap[43] is an OSM rendering 'primarily aimed at showing information useful to cyclists'. The OpenCycleMap global cycling map is based on data from OSM and is updated frequently. The OpenCycleMap website indicates that 'at low zoom levels, it is intended for overviews of national cycling networks; at higher zoom levels, it should help with planning which streets to cycle on, where cyclists can park their bikes, etc.' It is also available for use as a web-map layer in other applications. In a similar fashion, the Hike & Bike Map[44] visualisation of OSM data highlights hiking and biking routes by using a specific cartographic style to highlight these routes. The OpenSnowMap[45] is an OSM-based map rendering of ski slopes and lifts. It integrates OSM data, MODIS/Terra Snow Cover 8-Day Global data[46] and SRTM 90m Digital Elevation data. As of December 2016, over 100,000 km of skiing trails have already been mapped. OsmHydrant[47] is a special map showing the position of hydrants, water tanks and suction points, with the purpose of assisting local authorities and fire departments. While there is an emphasis on visualisation, it allows OSM contributors to map new hydrants and edit the existing ones. As of July 2016, almost 45000 hydrants had been added. OpenFireMap[48] is an OSM rendering, highlighting 'fire stations, hydrants, water tanks, and ponds used for firefighting (suction points)'. It does not provide editing facilities directly. The Stamen company in the United States provides several cartographic variations on the standard OSM map representations. These are available for use as web-map layers in other applications. Three of the most popular web-maps provided by Stamen are the terrain representation[49], the black and white representation[50] and the very artistic watercolor representation[51]. There is also a good deal of visualisation of OSM in 3D: one of the best examples is the OSM Buildings[52] JavaScript library for visualising OpenStreetMap building geometry on 2D and 3D maps. F4map[53] is a French company providing cartography and visualisation services: one of its products is a 3D visualisation of the world using OSM data. In other types of visualisation, Kothic JS[54] is an in-development new technology that renders OSM data 'on the fly' using HTML5 without the need for raster tile images. Mapbox Studio[55] is a suite of free and paid-for tools to produce 'vector tiles', which can be rendered either server-side or client-side, with many different customisations available according to the OSM data being used.

2.6 OSM-based Software

As mentioned above, the OSM community has created a vast ecosystem of software tools and services. As is the case with the visualisation of OSM data, it is not possible to give an in-depth list of software. We have organised this section into three subsections: OSM data editors, OSM-based routing services and other services.

2.6.1 OSM Data Editors

OSM is an openly accessible spatial database which any contributor can supply geodata to and whose existing data any contributor can also edit. It is therefore very important that software tools be available to support this editing work for contributors. The OSM wiki contains an extensive list of OSM data editing tools[56] and a comparison of their characteristics. In this section we outline five of the most famous and well known OSM editors. The iD editor[57] is a Web-based editor for OSM and is the editor that is integrated into the OSM homepage. The JOSM editor[3] is a Java editor for OSM and is considered an editor for skilled OSM contributors. It 'supports loading GPX tracks, background imagery and OSM data from local sources as well as from online sources and allows' direct editing of the OSM data; a number of plugins provide other advanced functions. Potlatch[58] is a flash-based web editor for OSM. Vespucci[59] is the first OSM editor specifically developed for small and large Android-based devices; it provides a reasonably extensive set of editing functionalities, which makes it usable on the field by novice and experienced OSM contributors. Merkaartor[60] is a desktop-based software editor for OSM that is available for installation and use on most operating systems; similarly to JOSM and Vespucci, Merkaartor provides a wide range of functionalities.

2.6.2 OSM-based Routing Services

OSM-based routing services are software-based solutions that use the data in the OSM database for the purposes of generating routing and navigation solutions. Routing and navigation is possible when objects in OSM have attributes (tags) that are helpful in solving these problems. The ability to apply attributes from different thematic areas on the same object (such as a road or a street) means that different routing applications can be easily developed.

The Open Source Routing Machine (OSRM)[61] is a C++ routing engine for finding 'shortest paths in road networks'. It supports car, bicycle and walk modes and is 'easily customized through profiles'. GraphHopper[62] is a company based in Germany focused on delivering the 'fastest possible routing algorithms' and 'privacy protection' using open source software for their customers. Their open source routing library and server includes elevation data and allows routing for several difficult vehicle types. The MapQuest Directions API[63] is offered by the US company MapQuest and calculates 'point-to-point, multipoint, and optimized routes'. The API can be used by any application, and the directions are based on OSM data. OpenRouteService[64] is a routing service developed by the GIScience Research Group at Heidelberg University (Germany); it provides routing capabilities for different categories (including wheelchairs users), features an advanced graphic interface and is also available in a mobile version. Kurviger[65] is a specialised routing service for motorcyclists, which computes optimal paths considering the topography of the terrain. It is only available in German. Cruiser for Android[66] is an Android-based mapping and navigation application. Wheelmap.org[67] is an open and free online map of wheelchair-accessible places. While it is not actually a routing application per se, it provides information on the wheelchair-accessibility of public places, which is very useful for wheelchair users, by allowing contributors to directly edit OSM to provide accessibility information. ViaMichelin[68] is a 'wholly owned subsidiary of the Michelin Group'[69]; it 'designs, develops and markets digital travel assistance products and services for road users in Europe', and the German version of their route planner uses an OSM Outdoor Layer visualisation[70]. INRIX Traffic[71] is a commercial product for navigation and traffic information that uses OSM data; the application learns the preferences and daily routines of the user, and, based on the learned activities, makes a daily personalised itinerary with the anticipated tours and frequently used routes.

2.6.3 Other Services

In this section, we provide some links to other services that use OSM but do not necessarily fit neatly inside our classifications. In OSM, nodes that have specific tags are often called POI amongst contributors and users of OSM. There is no absolute set of tags that qualify as indicating a POI, but usually a POI will have tags related to amenities, such as buildings, shopping, education or buildings with cultural and historical significance. The OpenPoiMap[72] provides a map-based visualisation of all POI in OSM for any part of the world: POI are presented as individual layers, which can be turned on or off, and, based on what visualisation information the map provides, contributors can then edit the POI data directly in OSM using the links provided on the interface. The

Places! service[73] attempts to present a visualisation of the analysis of patterns in place names within given countries based on the OSM database for those countries. For example, Places! tries to find patterns in the spatial distribution of places in Switzerland containing the term 'berg' or places in the United Kingdom containing the term 'hill' in their name. The analysis is performed offline and updated regularly.

The OSM Analytics[74] application recently launched by HOT provides interactive functionality to analyse how specific OSM features are mapped in a specific region. This tool allows the user to select the geographic region of interest and shows a graph of the mapping activity in that region. It is possible to select a specific time interval to view the number of newly mapped or edited features in that period; the map will highlight the matching buildings, as related to this time interval. This tool is a very useful way to obtain a high-level view of how OSM developed in a particular region. Finally, the Show-Me-The-Way application[75] is an interactive web application that displays near real-time edits performed by contributors to OSM. The application loads recent edits and displays them by jumping to the particular region where the edit was made. This type of visualisation is possible owing to the fact that very recent edits submitted to OSM by contributors are immediately available for access by anyone who connects to the OSM API or other services listed in Section 2.6.

2.7 Quality Assurance for OSM

The quality of OSM data is under constant scrutiny by the scientific community. The quality of data in OSM is one of the major concerns that industry and authoritative agencies such as National Mapping Agencies (NMAs), Land and Cadastral Agencies and other types of government agencies have about OSM (Olteanu-Raimond et al., 2017b). In practice, there is no single set of metrics or criteria against which OSM can be measured that will satisfy all users for the myriad of possible end applications. The quality of the OSM data and suitability for a particular application, purpose or use case is very much dependent on the characteristics of the problem being tackled. The OSM community recognises the importance of data quality, and a very wide range of tools and applications have been developed to tackle this issue. In this section, we provide some introduction to a small number of these. A comprehensive list is maintained on the OSM wiki[76].

BBBike and Geofabrik deliver the OSM Map Compare tool[77], which allows visual comparison of OSM map layers with other popular mapping systems such as Google, Bing, HERE, ESRI, etc. The web map interface allows users to visually compare any region in OSM with the corresponding mapping in the other popular systems. IGN France (French National Institute of Geographic and Forest Information) provides a very similar system to Map Compare with their Ma Visionneuse[78] application, which allows OSM to be compared with IGN layers, amongst others; this is particularly useful for comparison between French web map layers. The OSM Inspector[79], also by Geofabrik, provides an overlay of potential errors or data quality problems onto an OSM map. These problems include: very long ways (polylines); self-intersecting ways, polygons or polylines, which are represented by only one node; and polygons or polylines that have duplicate nodes contained within them.

Taginfo[2] is a very popular Web-based application that displays up-to-date statistics about the tags used in the OSM database, e.g. which tags are used, how many times they are used, where a certain tag occurs, etc. Taginfo is particularly useful for finding problems with the keys or values in tags, the popularity of tags, where specific tags are used and which other tags are used in combination with them. The use of taginfo to find problems with tagging relates to its very comprehensive listing of the ranking of popularity/application of values to specific keys in tags. This can quickly allow an OSM expert to identify instances of an incorrect assignment of values in tags that has an overall effect on tag data quality. Taginfo does not provide any information on errors relating to geometry or topology. Osmose[80], an acronym for OpenStreetMap Oversight Search Engine, is a quality assurance tool available to detect issues in OSM data; it is also useful for integrating third-party datasets. It tries to detect anomalies in the data and then display them on an OSM map, from which contributors can fix or update them. Keep Right[81] is one of the oldest quality assurance tools in OSM. It displays automatically detected errors on the OSM map or in a list format, and it detects a very wide set of error types, including geometry errors, topological errors, attribution errors and other general OSM errors.

MapRoulette[82] is a Web-based application that proposes challenges to fix errors in OSM. Each challenge represents a set of tasks, and OSM contributors can fix the errors by performing edits in OSM in the usual way. The challenges vary in difficulty, allowing contributors to choose the types of errors that they feel confident about fixing. The fixing is very heavily focused on the contributors' interpretation of information from aerial imagery. DeepOSM[83] attempts to detect problems in OSM road networks using neural networks. The system downloads satellite imagery and the corresponding OSM data that show roads/features for that area. This allows DeepOSM to generate training and evaluation data for the neural networks, which then calculate predictions of mis-registered roads in OSM.

The Grass&Green project (Ali et al., 2016) asks OSM contributors to correct tagging or classification of land use features involving grass or green areas. This application provides a two-screen interface, where an OSM feature is highlighted on the standard OSM web-map layer and in aerial imagery. The user (who needs to have an OSM account) must then provide an appropriate classification for this entity by choosing what he/she believes is correct from the list of classifications: grass, park, garden, forest and meadow. The JOSM

Validator[84] 'is a core feature of JOSM which checks and fixes invalid data' that have been contributed to OSM or are being contributed for the first time. The validator checks and fixes a wide variety of problems, including topological errors, unclosed polygons and overlapping areas.

Academic research has produced a wide range of quality assessment and comparison tools for OSM (Ostermann and Granell, 2017). One of the most recently published is that of Brovelli et al. (2017): this open source software tool provides an automated comparison of street network data in OSM with that in an authoritative dataset. Users of the tool must provide the authoritative dataset for comparison.

2.8 Games, Leisure and General Public Information

In this final section of applications for OSM, we describe a mixture of applications that use OSM for the purposes of games, leisure or general public information.

'Collapse – The Division Game'[85] is a simulation game based on open datasets (including OSM data), created by Ubisoft to introduce the environment upon which the new online action game 'TomClancy's The Division' (for Windows, Playstation and Xbox)[86] is based. The user is the first person in the world infected with a virus, and the game realistically simulates the diffusion of the virus until the collapse of society; OSM data relating to health facilities, societal infrastructure and transportation are used in the simulation. The OSM game Kort[87] is very similar to MapRoulette[79], with the exception that Kort drives a gamification approach to OSM error fixing. Kort was developed for usage mainly on mobile devices but also works well on most browsers. For both solving tasks and checking existing solutions, points (so-called Koins) can be earned. The goal is to continually rise through the ranks of the high-score list. Additionally, players are also awarded medals for their efforts. At the time of writing, there are over 2,000 active players having solved almost 50,000 tasks. The solutions to tasks must be evaluated and accepted by other users before they are submitted to the OSM database.

In a YouTube video[88], an OSM contributor provides a video-based visualisation of the contribution of nodes to OSM over the period 2004–2016. Nodes in OSM that have had more editing activity on them are coloured using a heatmap approach. This timelapse video and many others listed on the OSM wiki[89] provide a very good high-level overview of how OSM has developed since its inception. The node density map by tyrasd[90] provides a static visual overview of how many nodes are mapped within any OSM region. Lukas Martinelli[91] produced a Global Noise Pollution map based on the urban infrastructure data in OSM for cities and urban areas. GoodCityLife is a group of freelance researchers in urban dynamics who use OSM to produce visualisations. One such visualisation is their Smelly Maps[92], which uses the underlying OSM data for a city or region to calculate if there is likely to be nasty odours or smells in a locality. Bahnhof.de[93] is the website providing information about railway stations in Germany; OSM is used as the base layer for the mapping on this information website. The flight simulation software World2XPlane by X-Plane[94,95] is also worth mentioning; this software takes OSM data and converts the data into scenery for X-Plane. It uses as much information as possible to generate highly realistic scenery.

3 Conclusions and Discussion

In this chapter, we have provided an overview of the OSM project. As mentioned in the introduction, OSM is probably the most famous example of VGI on the Internet today. Even at the time of writing (during the summer of 2016), the project continued to grow and expand, with over 2.7M registered contributors/users and almost 3.4B nodes of data, which made up almost 350M polygons and polylines. Around 37,000 contributors are active in OSM during a typical month. OSM can certainly claim to be the largest freely and openly accessible database of geographic data in the world. Indeed its rate of growth in terms of geographic data and frequency of contributions and editing brings OSM into the realm of geographic big data (Leonelli, 2014). When one considers the extended OSM ecosystem of open source software, data download services, data visualisation services, wiki help systems, mailing lists and forums, OSM serves as a very suitable starting point for any discussion on VGI. Indeed one could speculate on how VGI would have developed if OSM had been absent from this space. This chapter has attempted to give the reader who is new to OSM an introduction to the OSM ecosystem while providing the reader familiar with OSM an overview of where OSM currently stands in the world of VGI.

In the remaining chapters of this book, OSM will be mentioned and discussed in many different ways. In Chapter 4, Touya et al. (2017) address the challenges of automated mapmaking using VGI as the input data, and the authors consider OSM as a key source, but not the only source, of this VGI data. Chapter 2, See et al. (2017) has already indicated that there are many sources of VGI available today. While OSM is open data and is licensed under the Open Data Commons Open Database License (ODbL), there are privacy and ethical issues around the reuse of OSM data. In OSM, one is free to copy, distribute, transmit and adapt OSM data, as long as credit is provided to OSM and its contributors. If one alters or builds upon the data, then the resultant data must also be distributed under the same licence. Chapter 6 tackles some of these issues for OSM and VGI in general (Mooney et al., 2017). In Chapter 8, Antoniou and Skopeliti (2017) consider how the concept of quality has evolved in OSM over time through the analysis of the evolution of OSM data specifications and of OSM editors. The very evolution and changes over time to the OSM ecosystem can influence the quality of OSM data. Related to this theme, Chapter 9, by Skopeliti et al. (2017), considers how quality in VGI can be visualised and communicated effectively, with significant research work having already been carried out on this topic using OSM as the case-study. As discussed earlier in this chapter, OSM has a very flexible and easy-to-understand approach to the contribution of new geographic data or editing of existing data in the OSM database. Chapter 10 considers best practices for VGI data collection, and Minghini et al. (2017) propose in that chapter that the lack of protocols and the flexibility of contribution is not necessarily a good thing in terms of producing consistently high-quality VGI data. Chapter 11 (Bastin et al., 2017) considers VGI data management and suggests ways in which OSM can be integrated into the so-called Semantic Web, where all OSM's data would be converted to Linked Data. Finally, Chapter 13 (Olteanu-Raimond et al., 2017a) discusses VGI and the role of NMAs, with OSM often seen as a rival or competitor to the geographic data services provided by these agencies. As is obvious from this overview of the remaining chapters of the book, a deep scientific discussion of VGI is impossible without reflecting on and considering the impact and influence of OSM. This is certainly very likely to continue for many years to come.

3.1 The Future of OSM

OSM's greatest strength will always be its huge pool of contributors. Thousands of these contributors have collected and generated some of the world's best street and topographic data without expensive teams of professional surveyors or world-class equipment. As the world and the urban and natural environment change every day, OSM contributors have the ability to depict this changing world in a map and a database that belong to them. OSM may not yet have the advanced types of features that Google Maps has – street-view images, multimodal navigation, social recommendations, etc. – but it may soon have. Mapillary[96,97], which is a service for crowdsourcing street-level photographs using smartphones and computer vision, has almost 70 million geotagged street-level photographs at the time of writing. Mapillary shares the open data ethos of OSM and they can work well together (Juhász and Hochmair, 2016). Very similarly, efforts are in place to link OSM elements with their corresponding Wikipedia pages and Wikidata items. As an example, the WTOSM[98] (Wikipedia To OSM) service developed by the Italian OSM community automatically identifies Wikipedia pages that can be linked (by means of tags) to OSM elements. Mature services such as OpenRouteService provide navigation services based wholly on OSM's database. One of the factors in the evolution of OSM over the past decade or so has been the ability of the project to adapt and expand in the face of technological advancements in other areas of ICT and Open Source Software. Web service access to the OSM database or its mirrors has improved and is very stable, allowing developers to build an array of applications using the data directly from the database.

There are some challenges for OSM going forward. These challenges are a mixture of factors based on the social and technological aspects of VGI (Mooney, 2015). Contributors can make edits to the OSM global database without any real controls or moderation at the point of contribution. Despite the fact that there are many applications available for an a posteriori quality check (see Section 2.7), as long as edits can be made without initial controls the issue of OSM data quality will remain a contentious one. Relatively *unknown* contributors from an *unknown* crowd supplying geospatial data is a concern to end users and stakeholders such as NMAs, government agencies and commercial companies. There have been many instances in the past where large amounts of OSM data have been deleted by new or inexperienced contributors. Some authors have considered the problem of automated detection of instances of vandalism and of the purposeful deletion of data in OSM (Neis et al., 2012). Many local OSM communities have long debated the wish and need to implement tools for checking and approving contributions (e.g. by more experienced contributors or by the community itself). However, such an implementation would be clearly against the very same nature of the OSM project, and no formal actions are yet in place in this regard.

Several academic studies have shown that for specific regions of the world, OSM has reached a very high and mature level of completeness and spatial accuracy compared to data from sources such as NMAs (Dorn et al., 2015). One of the major challenges will be to sustain the contributor motivation for editing and maintaining the OSM database into the future (Budhathoki and Haythornthwaite, 2012). Every day sees less *white space* or empty places on the OSM map. Similar scenarios are being observed in Wikipedia (Jankowski-Lorek et al., 2016). The task of being an OSM contributor is changing from that of being the contributor of brand new geodata to OSM to that of *map gardening* (McConchie, 2016; Sinton, 2016); in this latter case, contributors are not necessarily involved in contributing new material to OSM but are attending to the upkeep and update of the existing geometry and attribute data (tags) in the database.

As geolocation is further embedded into social media, user-generated content on the Internet, etc., issues of privacy and ethics can be raised (Blatt, 2015), and the work outlined in Chapter 6 of this book (Mooney et al., 2017), highlighting these problems in relation to VGI, will become critical; currently, very little work has been undertaken by the research community into privacy and ethics in VGI. In the final chapter of one of the first edited volumes dedicated to OSM, Mooney (2015) advises that the academic community has a significant role to play in the future of OSM; through scientific research and investigation, the academic community is encouraged to feed its results and experiences back directly into the OSM community and become more closely involved in the day-to-day workings of the OSM ecosystem. This model has been very successful in the open source software community, and this can extend to the OSM world.

Notes

[1] https://www.mapbox.com/blog/redesigned-osm-mapping-guides/
[2] https://taginfo.openstreetmap.org
[3] https://josm.openstreetmap.de
[4] http://wiki.openstreetmap.org/wiki/ID
[5] http://wiki.openstreetmap.org/wiki/Stats
[6] http://fieldpapers.org
[7] http://wiki.openstreetmap.org/wiki/Import/Catalogue
[8] https://wiki.openstreetmap.org/wiki/Main_Page
[9] http://wiki.openstreetmap.org/wiki/List_of_OSM-based_services
[10] http://download.geofabrik.de/
[11] http://wiki.openstreetmap.org/wiki/Planet.osm
[12] http://wiki.openstreetmap.org/wiki/API
[13] http://wiki.openstreetmap.org/wiki/Overpass_API
[14] https://overpass-turbo.eu/
[15] https://mapzen.com/data/metro-extracts/
[16] http://wiki.openstreetmap.org/wiki/Export
[17] http://wiki.openstreetmap.org/wiki/OSM_XML
[18] http://wiki.openstreetmap.org/wiki/Software/Desktop
[19] https://www.geofabrik.de/
[20] https://mapzen.com/products/#data
[21] http://www.citizensensor-cost.eu
[22] http://vgibox.eu
[23] http://teachosm.org/en/
[24] https://hotosm.org/updates/2016-03-09_200_kids_map_swaziland_for_malaria_elimination
[25] https://hotosm.org
[26] http://tasks.hotosm.org
[27] http://www.missingmaps.org
[28] https://disastermappers.wordpress.com/
[29] https://www.mapbox.com/blog/ebola-mapping-progress/
[30] http://pierzen.dev.openstreetmap.org/hot/leaflet/OSM-Compare-before-after-philippines.html#12/11.2197/124.9925
[31] http://wiki.openstreetmap.org/wiki/Commercial_OSM_Software_and_Services
[32] https://www.mapbox.com
[33] http://www.mapquest.com
[34] http://maps.stamen.com
[35] https://mapzen.com
[36] http://www.camptocamp.com/en/
[37] https://www.mapbox.com/blog/nyc-and-openstreetmap-cooperating-through-open-data/
[38] http://mapgive.state.gov/

[39] http://trimet.org/#/planner
[40] https://twitter.com/Gendarmerie/status/691947889103392768
[41] http://www.modernisation.gouv.fr/sites/default/files/fichiers-attaches/ban_cp_150415_en.pdf
[42] http://opentopomap.org
[43] http://opencyclemap.org/
[44] http://hikebikemap.org
[45] http://www.opensnowmap.org
[46] https://nsidc.org/data/MOD10A2
[47] https://www.osmhydrant.org
[48] http://openfiremap.org
[49] http://maps.stamen.com/terrain
[50] http://maps.stamen.com/toner
[51] http://maps.stamen.com/watercolor
[52] http://osmbuildings.org/
[53] http://www.f4map.com/
[54] https://github.com/kothic/kothic-js
[55] https://www.mapbox.com/mapbox-studio/
[56] http://wiki.openstreetmap.org/wiki/Editors
[57] http://wiki.openstreetmap.org/wiki/ID
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[73] http://bgrsquared.com/places
[74] http://osm-analytics.org
[75] https://osmlab.github.io/show-me-the-way/
[76] http://wiki.openstreetmap.org/wiki/Quality_assurance
[77] http://mc.bbbike.org/mc/
[78] http://mavisionneuse.ign.fr/visio.html?lon=3.46539&lat=46.044673&zoom=15&num=4&mt0=ign-cartes&mt1=ign-scexstandard&mt2=google-map&mt3=osmfr

[79] http://tools.geofabrik.de/osmi
[80] http://wiki.openstreetmap.org/wiki/Osmose
[81] http://wiki.openstreetmap.org/wiki/Keep_Right
[82] http://maproulette.org
[83] https://libraries.io/github/trailbehind/DeepOSM
[84] http://wiki.openstreetmap.org/wiki/JOSM/Validator
[85] http://collapse-thedivisiongame.ubi.com
[86] http://tomclancy-thedivision.ubi.com/game/en-us/home/
[87] http://play.kort.ch
[88] https://www.youtube.com/watch?v=FdRO-QZaWX8
[89] http://wiki.openstreetmap.org/wiki/Timelapse_videos
[90] http://tyrasd.github.io/osm-node-density/
[91] http://lukasmartinelli.ch/gis/2016/04/03/openstreetmap-noise-pollution-map.html
[92] http://goodcitylife.org/smellymaps/
[93] http://www.bahnhof.de/bahnhof-de/Karlsruhe_Hbf.html?hl=karlsruhe
[94] http://www.flightsim.com/vbfs/content.php?16301-OpenStreetMap-Tutorial
[95] http://www.x-plane.com/desktop/home/
[96] http://blog.mapillary.com/update/2016/05/24/use-mapillary-editing-OSM.html
[97] http://www.openstreetmap.org/user/Blackbird27/diary/38711
[98] http://geodati.fmach.it/gfoss_geodata/osm/wtosm/en_US/index_2.html

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