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Action and Interaction in Volunteered Geographic Information: A Workshop Review

Peter Mooney^{a*} and Karl Rehr^b and Hartwig Hochmair^c

^a*Department of Computer Science, Callan Building, National University of Ireland
Maynooth (NUIM), Maynooth, Co. Kildare, Ireland;*

^b*Salzburg Research Forschungsgesellschaft mbH, Jakob Haringer Strasse 5/3, A-5020
Salzburg, Austria;*

^c*Fort Lauderdale Research and Education Center (FLREC), University of Florida, 3205
College Avenue, Fort Lauderdale, FL 33314-7799, United States of America*

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This paper presents a summary of the Action and Interaction in Volunteered Geographic Information (ACTIVITY) international workshop which was held as a one day pre-conference workshop to the 16th Annual Association of Geographic Information Laboratories in Europe (AGILE) conference in Leuven, Belgium in May 2013. This paper summarizes the important outcomes of workshop presentations and key discussion statements from participant contributions to an open-floor discussion on the most pertinent issues in VGI research. Participants engaged this discussion focused on what are the most likely problems which could form the basis for a research agenda in VGI composed of both short- and long-term research objectives. Whilst the development of a VGI research agenda will require the involvement of the broadest possible spectrum of disciplines this paper is, none-the-less, an important first step on this journey.

Keywords: VGI, ACTIVITY, Action and Interaction, OpenStreetMap, AGILE Workshop, Research

1. Introduction

How is Volunteered Geographic Information (VGI) generated, collected, assessed, managed, and ultimately used? As the amount of VGI being generated constantly increases, in addition to the rapid rise in sensor data streams, it is now appropriate to assess the research challenges faced by this “profound transformation on how geographic data, information, and knowledge are produced and circulated” (Sui, Goodchild, and Elwood 2013, Chapter 1). This paper presents a summary of the Action and Interaction in Volunteered Geographic Information (ACTIVITY) international workshop which was held as a one day pre-conference workshop to the 16th Annual Association of Geographic Information Laboratories in Europe (AGILE) conference in Leuven, Belgium in May 2013. The workshop focused on the activities and interactions which occur during VGI collection, management, and dissemination. One of the primary goals of this workshop was to foster discussions amongst the various communities involved in VGI research on understanding how

*Corresponding author. Email: peter.mooney@nuim.ie

the current challenges in VGI are being tackled. Some of the questions which were considered for discussion at the workshop are as follows:

- How do VGI communities evolve?
- What are the types and patterns of contributions to VGI projects?
- When, where, and how is VGI generated?
- What do we know about the actual contributors to VGI projects?
- What types of applications and use-cases is VGI useful for?

This workshop is not the first workshop of it's kind. Amongst several workshops on VGI in the recent past the most notable examples include:

- USGS Workshop 2010: *U.S. Geological Surveys Volunteered Geographic Information Workshop* (Usery, Bearden, and Poore 2010). Workshop Goal: The purpose of the workshop was to gather information on the potential use of volunteered geographic information as part of The National Map, the USGS' source for topographic information for the United States.
- AAG 2011 Workshop: *Volunteered Geographic Information (VGI) Research progress and new developments* (Hardy 2011). Workshop Goal: Discussion of progress to date, identification of ongoing research questions, and discussion of new directions. Topics included: The use of VGI in time-critical situations, innovative methods of analyzing, synthesizing, and visualizing VGI, and data quality and credibility issues in VGI
- GIScience 2012 Workshop: *The Role of Volunteered Geographic Information in Advancing Science: Quality and Credibility* (Bhaduri and Devillers 2012). Workshop Goal: To investigate research into assessment of the authenticity, validity, and uncertainty of volunteered geographic information and developing steps towards rendering VGI as a valuable and usable component for scientific research.
- ACM GIS 2012 Workshop: *First ACM SIGSPATIAL International Workshop on Crowdsourced and Volunteered Geographic Information* (Goodchild, Pfooser, and Sui 2012). Workshop Goal: To investigate questions that are fundamental for future developments in VGI. These questions include: What data structures, algorithms and implemented systems are appropriate for the management of VGI? What are appropriate benchmarks for measuring the performance and comparing existing systems? How can we crowdsource high-quality geospatial datasets? What are candidate data fusion techniques?

Our workshop is novel in that it is primarily focused on the production of VGI and on the action and interaction of VGI contributors. It is very important to understand how VGI is produced and generated and how these VGI contributors interact. An open access journal was chosen for this publication so as to ensure that the outputs in this paper were accessible to the widest possible audience. It is hoped that this paper will be disseminated amongst the VGI community, the citizen science community, and the open source and open data movements. Sui, Goodchild, and Elwood (2013, Chapter 1, page 2) argues that the phenomenon of volunteered geographic information is part of a profound transformation in how geographic data, information, and knowledge are produced and circulated. VGI is now situated in the context of the "big-data deluge and data-intensive inquiry". Critical to supporting the goals of our workshop this book contents "that future progress in VGI research depends in large part on building strong linkages with diverse geographic scholarship". We feel that our workshop programme reflects a diverse set of geographical skills and domains. During early 2013 an open call was made

for contributions to the workshop and we collected contributions which included full papers and position papers. The workshop welcomed presenters from research institutions in North America, Europe, and Australia. Peter Mooney and Karl Rehrl acted as workshop chairs. There were two overview presentations provided by Mooney and Rehrl at the beginning and closing of the workshop. There were ten paper presentations, organised into three sessions, where all presenters were given approximately twenty minutes to present their work. After each presentation questions and comments from the participants in the audience were welcomed.

The remainder of this paper is organised as follows. Section 2 provides a summary overview of each of the presentations at the workshop with a brief commentary on the key statements highlighted by the presenter in each case. In section 3 we outline some of the main discussion points from the open-floor discussion amongst all thirty participants in the workshop. In section 4 we close the paper with some concluding remarks and research objectives for planned future work.

2. Workshop Presentations Overview

In this section we provide a brief overview of the key research results outlined by each paper presentation at the workshop. We organised the following subsections into a similar structure to how these papers were presented at the workshop.

2.1 *Session 1: Patterns of Contribution and Understanding the Activity of the Contributor*

Many researchers are primarily interested in the geographic information generated in VGI projects. The volunteers who collect this information play a central role as they are responsible for generating this information in the first place. Predominantly the work in collecting and contributing data and information in VGI is performed on a purely voluntary basis. However, analysis by authors such as Willett, Heer, and Agrawala (2012) indicate that for certain tasks paid crowd workers can reliably produce high quality results or solutions and they believe that their results suggest that larger scale tasks could be solved using this method. So why do so many people become active contributors, without obvious financial rewards, to VGI projects? Coleman, Georgiadou, and Labonte (2009) outline a list of motivating factors which they believe underlines the motivations for contributors to volunteer their time for the collection and management of VGI. These include altruism, professional or personal interest, intellectual stimulation, social reward, pride of place, enhanced personal reputation, and an outlet for creative and independent self-expression. There has also been significant and influential work published in Budhathoki, Nedovic-Budic et al. (2008) and Budhathoki, Nedovic-Budic, and Bruce (2010) which provides steps towards understanding contributors and contributor patterns in VGI. The authors emphasise the need for a multidisciplinary approach which draws from different disciplines including GIScience, information science, social psychology, political economy, and leisure studies. Contributors can also be responsible for the import of freely available geodata to VGI projects, such as OpenStreetMap (OSM) called bulk imports. Zielstra, Hochmair, and Neis (2013) and Hochmair and Zielstra (2013) analyze the effect of imported road data (e.g. TIGER/Line) and points of interest (e.g. the U.S. Geological Survey's Geographic Names Information System (GNIS)) on OSM data quality and they conclude that one-time data imports into OSM may be beneficial to the OSM project if these

kind of data have not been previously collected in the geographic area of interest. This session investigates the motivations of contributors to VGI projects including OSM. The session also attempts to identify the patterns of contributions to VGI projects to attempt to understand how contributors collect information.

2.1.1 *Individuals' contribution to cells: a cellular automata approach for simulation of collaboratively mapped areas*

Arsanjani et al. (2013) analyzes mapping dynamics in OSM as a geo-referenced time-series with a cellular automata (CA) approach. Amongst the aims of this work is to predict forthcoming contributions to the OSM project and to discover latent patterns behind contributions to OSM in a given area or region. The case-study area is Heidelberg which has a significant amount of OSM contributions and a reasonably heterogeneous landscape (urban and rural). The case-study landscape is divided into fifty meter square grid cells across six time periods. A spatio-temporal analysis of contributions was then carried out. The history of edits and contributions to OSM in this area during 2009, 2010, and 2011 were used to train the CA-driven model. A visualisation of the contribution dynamics is shown in Figure 1. The authors find that this analysis predicts that the whole urban fabric of the Heidelberg region will be contributed to OSM by 2013. Interestingly there are some orthogonal findings from the study which indicate that the earliest and most prevalent contributions originate in the campus area of Heidelberg university. This raises some very interesting sociological questions about the motivation to contribute to VGI. The university setting provide contributors with unlimited access to Internet, cutting edge technologies, and different socio-economic variables, etc.

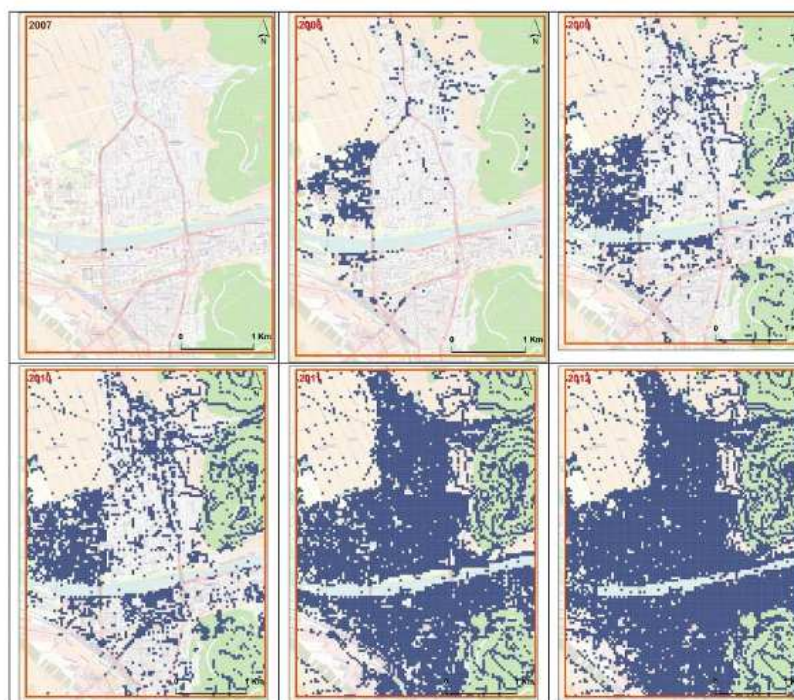


Figure 1. This set of maps is an overview of the increasing activity of OSM contributions in Heidelberg, Germany since 2006 (to 2012) as produced by the CA-driven model of Arsanjani et al. (2013)

Summary: The production of VGI appears to be strongly related to the location of the activity and the socio-economic environment. Feick and Roche (2013) emphasise that VGI is now an evolving process (both its creation and usage). This

process has become less tractable as one considers that the nature of social relations across the Geoweb are very often transient, and issue- and place-specific. This raises issues related to a digital divide in geographic data collection and access (Cinnamon and Schuurman 2013).

2.1.2 Contribution Profiles of Voluntary Mappers in OpenStreetMap

The work presented by Steinmann et al. (2013) attempts to build contribution profiles of contributors to OSM through an analysis of the entire editing and contribution history of OSM. The OSM Full History Planet File contains every version of each OSM feature ever contributed to OSM. The high-level research question is stated informally as “who contributes what to this VGI project?” The paper reviewed some previous studies outlined in the literature which assess contributor activity of VGI projects (Mooney and Corcoran 2012; Neis and Zipf 2012; Coleman 2013; Mooney and Corcoran 2013; Rehl et al. 2013). There are also similar studies carried out which analyse contributor behaviour and activity in Wikipedia (such as Hardy (2013)). The authors use this information to compute “action profiles” which provides information about the type of edits of individual contributors. The overall methodology involves: statistical analysis, profile definition, profile calculation, k-means clustering, and interpretation of results. The authors carried out their analysis on the entire OSM history dataset. Previous analysis of this type was restricted to smaller geographic regions. The authors found that just 3% of contributors are active on more than 100 days (over several years of the project lifetime). The clustering of actions reveals a number of distinct categories of contributors including:

- CREATOR: These contributors predominantly create data.
- UPDATER: These contributors predominantly perform update actions.
- DELETER : These contributors are predominantly involved in the deletion of data from the OSM database.
- Premium Creator: These contributors have performed a very large number of actions over a long period of time.
- Basic Creator. These contributors have created data in the database but have done little else.
- Basic Allrounder: Contributors in this cluster have close to the mean number of contributions for the OSM community and are involved in all types of actions: update, delete, create, and edit.

In addition to the exaction of action profiles the authors investigated the types of geographical features being edited by contributors over the history of OSM and it was found that in 2005 over 90% of all geographic features contributed to OSM were highway or road features which in 2012 had reduced to about 36%. The clusters for both contributor types and geographic features appear to be very distinct and display a fluent transition from year to year.

Summary: Building contribution profiles in OSM is necessary to understand how, what, when, and where people contribute geographic data and information. The clustering approach does not, as yet, explicitly include a spatial component. Steinmann et al. classifies contributors based on their activity in the OSM project based on extraction of this knowledge from the history of all OSM edits. This work can lead to very useful information regarding the types of contributions that specific contributors make. The work fits nicely into a series of related work (e.g. Neis and Zipf (2012)) and adds some new aspects in terms of contributor profiles.

2.1.3 Gender and Experience-Related Motivators for Contributing to OpenStreetMap

Schmidt and Klettner (2013) report the results of a survey distributed to contributors to OSM. Typically the contributors to OSM are male, well-educated, and technologically savvy. The paper discussed some of the motivations for these contributors work including the findings from Haklay and Budhathoki (2010) that there were 97% male and only 3% female contributors to the OSM database. The diversity of our society is certainly not reflected in the results of the survey. The authors ask if there are advantages to a VGI project of having a broader contributor group? This would result in a larger group of potential contributors for collecting, updating and editing data in VGI projects and would lead to a more diverse digital map view of the world around us.

The authors performed a further smaller focus group study of 12 females equivalent to the typical OSM (male) contributor. This allowed for a qualitative study to generate hypotheses on what are the barriers for females to participate in VGI and the required motivations for future participation. The participants in the focus group listed some requirements of a VGI project (such as OSM) which would cause them to participate. These included items such as improved help and support options and dedicated tutorials for beginners. The participants also felt that there should be some positive feedback and rewards for editing. There was also a feeling that meeting new people could be a motivating factor rather than working or contributing in complete isolation. Finally, the participants in the focus group felt that the VGI project needed to have clearly defined aims and objectives as there needs to be a “a dedicated purpose” for mapping. The larger survey (with over 500 respondents) stated that mapping for a dedicated purpose, better help and support in tutorial form, and less time consuming mapping options (ie smartphone applications) would encourage more people to participate.

Summary: This presentation helped focus the minds of participants on their perception of who is contributing to VGI projects such as OpenStreetMap. Elwood (2008, Page 175) comments that “the phenomenon of VGI pushes us to re-think our conceptualization of *the user* and there seems to be a co-productive relationship between knowledge and gender identity in VGI”.

2.1.4 Crowdsourced Metadata supporting Crowdsourced Geospatial Data

The work presented by Kalantari (2013) addressed the issue of metadata in crowdsourced geospatial data production. The author comments that much of the research effort in VGI is focussed on the actual spatial data itself. It is very often the case that the contribution of metadata is lagging behind data production in VGI projects. Metadata is important and is a crucial prerequisite for interoperability and its meaning has to be widely understood. VGI contributors need to understand what metadata needs to be produced and what should be provided to help users understand a VGI resource (Danko 2012). Poore and Wolf (2013) stress that metadata production must be made more interactive and effective. This is the driver for what Kalantari calls crowd-sourced metadata. The users of VGI do not have any real say in the process of metadata creation and at present they do not play a major role in the process of metadata creation. They cannot contribute metadata information without subscription or registration to most VGI projects. The users who end up using the VGI could potentially add metadata about how they used the data, what the data was suitable for, problems with the data or specific objects/features, etc. Kalantari describes an add-on tool built on GeoNetwork (<http://geonetwork-opensource.org/>) allowing users to supply metadata for

features in VGI datasets or services. Users are not required to register or subscribe to the metadata collection service. In initial trials this approach showed the potential that users of VGI from can use VGI for their own purposes and then optionally contribute metadata about the VGI.

Summary: The active inclusion of users in the crowdsourced collection of metadata for VGI is a promising and novel concept. The approach attempts to *close the loop* which transforms users into Coleman, Georgiadou, and Labonte’s *prod-users* and *prod-sumers*. This approach has great potential to assist in providing additional metadata to VGI datasets and also in the provision of statements about a dataset’s spatial and temporal accuracy, fitness for use, and fitness for purpose.

2.2 *Session 2: Social aspects - Connecting contributors and communities*

Social media generated from many individuals is playing an increasing role in our daily lives and provides a unique opportunity to gain valuable insight on information flow and social networking within a society. Through data collection and analysis of its content it supports a greater understanding of the evolving human landscape (Stefanidis, Crooks, and Radzikowski 2013). Location-based games (LBGs) have been shown to be one successful method in motivating non-expert users to collect and tag geospatial data (Elwood and Leszczynski 2011; Parker, May, and Mitchell 2013). With respect to data quality, previous studies (such as work by Bell et al. (2009); Grant et al. (2007); Matyas et al. (2011)) have shown that games which reward players for in- or post-game data reviewing can achieve a validation rate of about 40% of the data. Researchers such as Matyas et al. (2011) have attempted to further improve VGI data quality by introducing a new LBG design pattern, based on game rules that encourage players to take the decisions of other players into account while making their own data collecting decisions. The “gamification” of the collection of geo-data is closely linked to the increased influence of social media technologies which have been shown by some authors, such as Naaman et al. (2012), to affect citizens’ real world behaviour.

2.2.1 *What, When and Where: The real-world activities that contribute to online social networking posts*

McKenzie, Deutsch, and Raubal (2013) describes work in progress on extracting patterns of real-world activities from social networking posts and then validating these patterns against the actual real-world activities. The authors remark that there is promise in an approach of passively extracting this type of information from the active participation of citizens on social networking websites such as Facebook. Is it possible to quantify the relationship between online activities (posts) and non-online activities (actual physical activities such as shopping, going to the park, travelling to work, etc). The paper attempt to classify activity types by: *what* the activity is, *where* it could occur, and *when* it occurs. The research question is then one of how close to an activity does a post occur on social media in relation to the actual physical start of an activity? From their focus group they find that the mean time of “post-to-activity” is 9.3 hours before the activity. 91% of posts about an activity are within 24 hours of the activity. Long distance travel and vacation have been posted most frequently relative to related real-world activities. The authors point out that this high percentage of posting could be related to a perceived increase in social value from travel and vacation. The authors indicate that their initial results proved successful to predict future events from one’s social networking activities.

Summary: The extraction of spatial information from social media websites and postings could be helpful in understanding the future activities of participants. Stefanidis, Crooks, and Radzikowski (2013) comment that harvesting ambient geospatial information from social media feeds is resource intensive. However if this is performed with the permission of participants there could be very useful information extracted about participants' future activities. However, privacy and access limitations are very important issues and have to be seriously considered. Extracting and recreating the movements of citizens from openly available data sources has been demonstrated in work by authors such as Girardin et al. (2008). Another key issue is concerned with the validation of extracted patterns and trends.



Figure 2. An screenshot of a stage of the VGI data collection smartphone game developed and presented by Davidovic (2013)

2.2.2 Using Location Based Game 'MapSigns' to motivate VGI data collection related to traffic signs

The presentation by Davidovic (2013) outlined the use of gamification techniques to motivate high levels of participation in VGI data collection related to “less interesting” types of data. The author develops an Android smartphone application which provides a smartphone game to encourage citizens to collect information about traffic signs, park benches, trash cans, pedestrian crossings, etc. The paper argues that much of the emphasis in VGI is on the collection of spatial data and information related to more “popular” features such as highways, shopping and leisure, and buildings. The MapSigns game is a chase-type game with two teams (thieves and cops) and they are racing to the same destination. Each team collects traffic signs and other information with the smartphone application. Points are awarded using a set of rules depending on the types of data collected. Gamification is a very promising approach (Mart et al. 2012). As outlined in work such as Mart et al. (2012) smartphones have become low-cost measuring devices that many citizens have in their pocket. The techniques implemented here are used to evaluate the potential for gamification to encourage the collection of “unpopular” spatial data which are frequently found all around us but not always collected

in VGI projects. Gamification techniques in crowdsourcing of spatial data could certainly lead to increasing the scalability of these crowdsourcing campaigns. A sample screenshot from the smartphone game is shown in Figure 2.

Summary: Gamification approaches have great promise. As shown in this application presentation the citizen’s smartphone is used as the gamification device. This could lead to lower barriers to participation in VGI projects for many citizens.

2.2.3 Automated Quality Improvement of Road Networks in OpenStreetMap

The work presented in the paper by Jilani, Corcoran, and Bertolotto (2013) aims to extend some of the work presented by her colleagues in Corcoran, Mooney, and Bertolotto (2013) and Corcoran and Mooney (2013). These papers emphasise the application of a computational modelling approach to understanding the evolution of OpenStreetMap and then potential extensions to making statements about the quality of the OpenStreetMap database. Jilani, Corcoran, and Bertolotto suggest that machine learning techniques could be applied to OpenStreetMap databases. These machine learning techniques could learn how to distinguish “good” and “bad” mapping practices such as how tags and attributes are associated with objects such as street networks. The authors propose using a graph-based representation for the OSM street networks and developing an Artificial Neural Network (ANN) to learn the detection of good and bad mapping practices. Through the analysis of the growth of small areas within larger OpenStreetMap regions these machine learning techniques could automatically identify if the area represents an urban street network, a residential street network, etc. Upon identification of the specific area type automated quality evaluation could be performed. The outputs from this quality evaluation could be used to advise OpenStreetMap contributors that there are quality issues associated with a given area such as incorrect tagging, missing tags, and spatial or topological problems such as minor roads intersecting with motorways. Machine learning techniques have been applied to OpenStreetMap data and VGI data before. In Hagenauer and Helbich (2012) the authors attempt to predict urban areas in Europe that are currently not well mapped or only partially mapped in terms of landcover mapping. This involves mining information from OSM and other VGI data sources.

Summary: Enhanced automation of approaches for quality assessment and problem identification in VGI could lead to the potential for larger scale intrinsic quality assessments and more rapid identification of data quality issues.

2.3 Session 3: Research on Quality Analysis and Semantics in VGI

The three papers below provided presentations on on-going research work on approaches to quality analysis of OpenStreetMap databases. Assessing the quality of OpenStreetMap data is receiving increased attention from the research community. Quality is multi-faceted. Spatial data quality includes geometric accuracy, semantic accuracy and interoperability, topological correctness and temporal validity (Al-Bakri and Fairbairn 2012; Koukoletsos, Haklay, and Ellul 2012). Goodchild and Li (2012, Page 118) argue that VGI often fails “as an alternative source of data for scientific research but may play a useful role in the early, exploratory, and hypothesis-generating stages of science”. The authors emphasise that clearly there would be great benefit if its quality could be improved and assured. This is the essence of this session. While the data quality of VGI has in most previous studies been determined through comparison with a reference dataset (e.g. Neis, Zielstra, and Zipf (2011a), Haklay (2010), Zielstra and Hochmair (2013)), some recent papers suggested intrinsic data quality assessment methods (e.g. Rehrl et al. (2013),

Mooney and Corcoran (2012)), which become useful where ground-truth data are not available for comparison. One of the workshop papers (Jilani, Corcoran, and Bertolotto 2013) adds a novel method to this group of quality assessment methods.

The papers in this session present ideas regarding intrinsic quality evaluation of OpenStreetMap data, semantic interoperability issues whilst integrating OpenStreetMap data with authoritative spatial datasets, and active collection of ground-truth spatial data to assess OpenStreetMap data.

2.3.1 Towards intrinsic Quality Analysis of OpenStreetMap Datasets

This work presented by Barron, Neis, and Zipf (2013) proposes a framework called *iOSMANalyzer*. The idea behind *iOSMANalyzer* is that it could indeed be possible to assess the quality of OpenStreetMap datasets without a reference dataset. The quality assessment is performed intrinsically by looking into the OpenStreetMap dataset itself. This concept has been proposed before by authors such as Mooney and Corcoran (2012) who have suggested that it might be very beneficial to consider the lineage or evolutionary history of OpenStreetMap data as part of quality assessments. *iOSMANalyzer* investigates the full edit history of OpenStreetMap for a given region or area. The software implementation of *iOSMANalyzer* is based on open source components. The concept for *iOSMANalyzer* has grown from significant previous work by the research group of Barron, Neis, and Zipf and previous work on OpenStreetMap historical analysis in literature such as Neis and Zipf (2012) and Neis, Zielstra, and Zipf (2011b).

iOSMANalyzer aims to provide an overall report on various aspects of intrinsic OpenStreetMap quality analysis whereby potential users could use this report as part of their fitness for purpose evaluations. *iOSMANalyzer* will provide:

- General area information, routing and navigation information, address-searching, points of interest searching, map-applications, contributor information and behaviour (from Neis and Zipf (2012)).
- Information reports on factors such as: total road network length, OSM road network lengths by road type (from Neis, Zielstra, and Zipf (2011b)).
- Positional accuracy of highway junctions.

The future work of *iOSMANalyzer* will concentrate on the development of these methods and other quality indicators. There will also be scope to integrate related work on the potential detection of acts of vandalism performed on the OpenStreetMap dataset in a given area (see Neis, Goetz, and Zipf (2012)). Eventually it is hoped that *iOSMANalyzer* will build a metadata repository of indicators of quality which is not solely focussed on spatial positional accuracy.

Summary: Intrinsic quality analysis of OSM has the potential to yield very promising outcomes. In particular *iOSMANalyzer* could generate very informative “fitness for use” and “fitness for purpose” reports for regions of OSM. This work is complimentary to work done by researchers such as Rehl et al. (2013) and Mooney and Corcoran (2012) on investigation of the patterns of activities and operations performed over the entire history of the OSM database.

2.3.2 Integrating Authoritative and Volunteered Geographic Information - An Ontological Approach

Whilst VGI provides a very rich resource for academic research activities we must also consider how VGI datasets could be integrated with authoritative spatial datasets. This work presented by Ramos and Devillers (2013) tackles the problem of integration of VGI data with authoritative national mapping spatial data with specific emphasis on the problems of semantics and ontologies. Many previous anal-

yses of VGI are based purely on the positional and geometrical accuracy of a VGI dataset in comparison to a reference dataset. The authors propose an ontological approach for integration of VGI data with authoritative national mapping spatial data. Ramos and Devillers emphasises that national mapping agencies (NMAs) are in these times finding it difficult to justify the cost of traditional data maintenance mechanisms. The integration of VGI with these NMA datasets could be a compromise solution to offset the costs of traditional data maintenance. However, the semantics of VGI datasets is a complex issue. Ballatore, Bertolotto, and Wilson (2012) mentions that because of its simple and open semantic structure, the OSM approach often results in noisy and ambiguous semantic data, limiting its usability for analysis in information retrieval, recommender systems and data mining. Simple examples were provided of these types of problems. For example three different spatial datasets might put the same concept (a road) into different classes or three different ontologies. Ramos and Devillers speculate that we can potentially perform geodata integration using ontologies. Whilst the work is in its early development stage it posts some interesting challenges. The number of tags per object class tends to increase with the scale and the relative percentage of these tags is important. As the dataset is edited and changed in a collaborative manner the dataset evolves towards approaching a certain level of agreement.

Summary: The type of spatial data integration outlined by Ramos and Devillers (2013) is ambitious but potentially very beneficial for NMAs. One of the most serious difficulties is that the integration will require an explicit semantic conceptualisation. This is possible in an NMA dataset but not necessarily in a crowdsourced geospatial dataset. In fact the semantic concepts in the crowdsourced dataset could be subject to change over time. Time and spatial scale are crucial factors affecting semantic heterogeneity in OSM datasets.

2.3.3 Collecting a Ground Truth Dataset for OpenStreetMap

In the presentation by Kessler (2013) the author outlines some ideas related to collecting a ground truth dataset specifically for OSM. This work leads on from other work by the author which tries to assess an OSM geographic feature's quality based on its trustworthiness (Kessler and Groot 2013). Kessler asks if there is actually a "gold standard" against which we can measure a geographic feature's quality? Kessler explains that assessing the geometric accuracy of OSM against another dataset has been demonstrated by several other researchers. However, ensuring thematic accuracy, consistency, temporal accuracy, and completeness are much harder but are also more interesting research problems. There is an issue that while OSM attempts to capture spatial information on "anything mappable" there may be features in OSM where no external ground-truth dataset exists (or at least is easily accessible). Kessler proposes two approaches to create a suitable ground-truth dataset for OSM quality analysis. These are outlined as follows:

- (1) **Combine existing datasets:** There are many geodata services explicitly providing information about places (Waze, Wikipedia, Foursquare, etc). These offer different thematic angles and could be used to complement commercial reference data for better overall scope. There are problems regarding the sometimes restrictive API usage and potentially complex semantic problems in this conflation process.
- (2) **Crowdsourcing - in the spirit of OSM:** Ad-hoc collection of required reference data in the same way as OSM. There is then potential to use the data for much more than just comparison. However there are serious issues regarding motivation of current OSM contributors, or new contributors to

essentially re-map an area.

Kessler concludes that option 2 provides the best incentives for data reuse. VGI projects, such as OSM, he concludes, “should define their own quality requirements and limitations”. A connection is made with the work of Kalantari (2013) from this workshop where this type of metadata could also be provided by the users of a VGI dataset?

Summary: Using external datasets for ground-truth quality comparison of a dataset is a well known method for assessing the data quality of that dataset. The physical collection and survey of geographical features to make a ground-truth dataset is a resource intensive task. There is also the issue that the initial dataset was created as a crowdsourced dataset. However as Kessler emphasises this could assist in delivering a better understanding of the overall quality of OSM data and how it is collected and maintained.

This concludes section 2 which has outlined the presentations from the workshop. In table 1 we have provided a simple overview of the key topics presented in the workshop and as a simple lookup table of which papers touched upon these topics and challenges. We feel that the presentations in the workshop provided a very good overview of current work in these areas.

3. Open Floor Discussion and Debate

In this section we summarise the open floor discussion and debate. During the workshop it was decided to aim for a single mode discussion involving all participants as a single group. We collected the report notes and collated them in a manner which best summarises the general discussion flow. To focus the open floor discussion and debate dealt with a number of key issues we suggested to the participants that the conversation be focussed on the following three questions:

- (1) What is the research community planning to do?
- (2) Can we propose items for consideration on a research agenda for VGI?
- (3) How can we align or combine our efforts?

We did not impose a strict plan to follow these key issues. Rather we used these as initial guideline. We felt that the discussion was very engaging, wide-ranging, and informative. The key points are outlined as follows:

- (1) **The citizen as a sensor:** While discussing VGI we must not forget the “citizen as sensor” (Goodchild 2007) concept and vision. Participants suggested that, to maintain VGI success, it is necessary to become more connected to citizens with sensors. This could involve connecting VGI producers (or projects) on social media and then reaching out pro-actively to citizens. This would also encourage an extension of sensor support in VGI. Currently static geographical features are captured very successfully in VGI. Dynamic processes such as: traffic flows, environmental factors such as seasonality in rivers, river-basins, lakes, etc are not properly captured or understood. In the future the subtlety of data contributed passively by sensors will be much richer than we can probably imagine now.
- (2) **Improved understanding of users and user contexts.** Where do users want to use VGI for? What type of applications and use-case scenarios do users have in mind? Who are the potential users?. As stated by authors such as Schade et al. (2013) and Coleman, Georgiadou, and Labonte (2009) there

Table 1. This table outlines some of the key topics presented at the workshop and a cross-check of which papers dealt with these topics. An 'X' in a table cell indicates that the corresponding paper had a strong focus on the topic outlined in the column heading.

Paper	<i>VGI data</i>	<i>Meta-data</i>	<i>User Profiling</i>	<i>Data Quality</i>	<i>Gamification</i>	<i>Contribution Activity</i>	<i>Modelling and Simulation</i>
Arsanjani et al. (2013)						X	X
Steinmann et al. (2013)			X			X	
Schmidt and Klettner (2013)			X			X	
Kalantari (2013)	X		X	X			
McKenzie, Deutsch, and Raubal (2013)			X		X		
Davidovic (2013)					X	X	
Jilani, Corcoran, and Bertolotto (2013)				X			X
Barron, Neis, and Zipf (2013)	X			X		X	
Ramos and Devillers (2013)	X			X			X
Kessler (2013)	X			X			

are now very blurred lines between “prod-users/prod-sumers”. There is now a heavy emphasis on producing VGI, checking data quality, and data integrity. But do we really know the user contexts? Little is known about user groups who are only consuming VGI. It would be very valuable to the research community and their understanding of these issues if the dialogue between VGI contributors, VGI users and the VGI research community could be strengthened. One example could be the motivation of VGI users to contribute their feedback on their usage of VGI and in particular their specific information needs.

- (3) **Enhanced Collaboration.** Many of the delegates felt that there was something of an “Us-against-them” mentality in VGI. There are many different types of communities and actors involved and everyone could actually benefit from joint exploration of commonalities rather than differences. This includes Google Map Maker, OpenStreetMap, Wikipedia, Wikimapia, National Mapping Agencies, etc. At the core of the work of all of these communities (be they commercial interests or crowdsourced projects) is an objective for better spatial data, more diversity in the features collected, greater participation, etc. There could be great benefits to mutual collaboration. The long-term future of the geospatial data industry could very well be built upon a platform which shares geospatial data collection through a mixture of traditional approaches (INSPIRE driven, National Mapping and Cadastral Agencies, commercial mapping and survey companies) and today’s “disruptive technologies” (Hughes and Cosier 2001, Page 24) such as VGI and sensor-webs.
- (4) **The value of passive crowdsourcing.** One of the most powerful of the “disruptive technologies” is the ability to carry out “passive crowdsourcing” which happens as a background activity. The smartphone has made this possible and spreads to millions or even billions of potential devices. Ed Parsons from Google commented that one of the industries biggest geospatial dataset is where Google extracts travel and traffic speeds from mobile phone sensing. This activity is completely passive for the smartphone user. Similar passive crowdsourcing can collect data and information on noise, weather variables, energy usage, etc (Karnouskos 2011) .
- (5) **Incentives for passive crowdsourcing.** As mentioned in the previous point passive crowdsourcing of information is very popular and offers very high potential for the future collection of VGI. But what are the incentives for contributors? The incentives come from industry. The technology industry embed applications on our mobile devices and leaving these passive applications “switched on” becomes woven into the fabric of using that device. We must understand how to incentivise the active participant to continue participating whilst ensuring that the passive participant will also continue to collect and contribute information passively.
- (6) **Should we accept uncertainty in VGI?** There was a long discussion about uncertainty in VGI data and information. Managing spatial data uncertainty requires a very precise knowledge of the sources of uncertainty. Uncertainty is introduced into VGI in many different ways. There is uncertainty surrounding: the accuracy of equipment used by contributors, the differing levels of expertise of contributors, the levels of accuracy to which contributors are willing to measure, model, or map, etc. It was agreed that the crowdsourced collection of geodata will always be likely have a high degree of uncertainty. This produced a number of self-examination questions for the research community in regards to uncertainty in VGI. These questions are summarised as follows:

- (a) Are we as GIScientists trying to obtain very high levels of certainty in VGI when we should just accept uncertainty is an inherent characteristic of VGI? This would be a radical change in direction and is certainly not a comfortable direction for the users nor for the scientists involved!
 - (b) How can we communicate this uncertainty in VGI?
 - (c) How do we communicate uncertainty in VGI for different VGI datasets and different applications and usage scenarios?
- (7) **Understand what VGI is being used for:** There appears to be a lack of understanding of what problems VGI can actually help solve. Automobile routing is a very frequent application domain of VGI. The research community needs to understand the types of problems which VGI is being used for. By understanding these use-case scenarios it could become easier to establish indicators of quality. We must be cognisant of updating cycles in both VGI production and within NMAs.
- (8) **Play to the strengths of Crowdsourcing VGI.** VGI has demonstrated through Google Map Maker, OpenStreetMap, Wikimapia, etc an incredible ability to collect the types of information which National Mapping and Cadastral Agencies have been doing all over the world for the past 200 years. One of the possible strongest aspects of VGI could lie in the types of information and data which is only possible to collect using a VGI/crowdsourced approach. These are data and information streams on a very large even global scale. This could include indoor information (Goetz 2012), noise mapping (Maison-neuve et al. 2009) or very dense collections of environmental information (temperature, atmospheric pressure, etc).

4. Conclusions

In this paper we have summarised the presentations and discussions at the Action and Interaction in Volunteered Geographic Information (ACTIVITY) international workshop 2013. Overall the workshop was a great success and the feedback to the workshop co-chairs and the AGILE organisation has been very positive. This workshop could become a catalyst for future workshop and conference events and further research collaboration. We set an objective of seeking to begin discovering and defining key research issues in VGI. In this capacity we feel that the workshop has made a contribution. In section 3 the open floor discussions provided a very broad range of issues which will require cross disciplinary solutions. The presentations outlined in section 2 provided an overview of the types of research being carried out by GIScientists in VGI and the types of research themes they are investigating. There are four key research themes which have emerged from the presentations and discussions. We provide them here and they form substantial and valuable input for ongoing future work. Beside each research theme we provide a high-level description of a research challenge which is directly related to this theme.

- *A shift from static to dynamic data:* There must be a greater connection made with the “citizen as sensors”. Citizens using their social networks, their smartphones which have sensors, etc. What are their roles as passive/active contributors of VGI?

Research Recommendation: There will need to be better conceptualisation and understanding of the roles of citizens as active and/or passive generators and collectors of geodata and information for VGI projects.

- *Better understanding of users and user contexts:* The “prosumers” are emerg-

ing in greater numbers but there are also communities who are only consuming VGI. There is surely value in users of data feeding back information about their experiences. In essence these users would then become contributors.

Research Recommendation: There is an urgent need for a greater understanding of the different use-cases for VGI. Which applications or domains can VGI make a significant long-term contribution? What motives both the active and passive contributors in VGI?

- *Current research work being carried out is performed in a slightly disconnected manner:* VGI is a relatively young research area. However, there needs to be a shared approach which combines the VGI communities, the NMAs, the users, legally mandated spatial data instruments such as INSPIRE, and the geospatial industry.

Research Recommendation: A VGI research agenda or set of grand challenges, similar to those outlined by Goodchild (2008) several years ago for the GIS community.

- *Integrating traditional GIS processes and “disruptive technologies” in VGI.* We must seek a common ground between data collection methodologies through traditional approaches (INSPIRE driven or legally mandated, NMA, etc) against “disruptive technologies” (such as OSM, Wikimapia, etc). Both domains have many things in common most notably their mission to collect and distribute high quality geodata. Will there be a convergence in 5, 10, or 15 years time?

Research Recommendation: There must be investigation of whether coordination or cooperation is possible between these two methodologies and if some areas of mutual benefit can be found.

The workshop information and the contributed papers (Mooney and Rehrl 2013) provide a very valuable knowledge resource. We feel that our workshop is both a logical continuation and complimentary activity to several key workshops which have been organised in the recent past. The participation of delegates from both academia and industry ensured that issues and future research requirements were identified in a collaborative manner. It is our hope that these workshop outputs provide a true reflection of the quality of the workshop, the presentations given at the workshop, and the potential for future work and collaborative which it fostered.

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These will be provided for the final submitted article.

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References

- Al-Bakri, Maythm, and David Fairbairn. 2012. “Assessing similarity matching for possible integration of feature classifications of geospatial data from official and informal sources.” *International Journal of Geographical Information Science* 26 (8): 1437–1456. <http://www.tandfonline.com/doi/pdf/10.1080/13658816.2011.636012>. <http://www.tandfonline.com/doi/abs/10.1080/13658816.2011.636012>.
- Arsanjani, Jamal Jokar, Lukas Loos, Mohamed Bakillah, and Marco Helbich. 2013. “Indi-

- vidual's contribution to cells: a cellular automata approach for simulation of collaboratively mapped areas." In Mooney and Rehrl (2013). 1–6.
- Ballatore, Andrea, Michela Bertolotto, and David C. Wilson. 2012. "Geographic knowledge extraction and semantic similarity in OpenStreetMap." *Knowledge and Information Systems* 1–21. <http://dx.doi.org/10.1007/s10115-012-0571-0>.
- Barron, Christopher, Pascal Neis, and Alexander Zipf. 2013. "Towards intrinsic Quality Analysis of OpenStreetMap Datasets." In Mooney and Rehrl (2013). 43–48.
- Bell, Marek, Stuart Reeves, Barry Brown, Scott Sherwood, Donny MacMillan, John Ferguson, and Matthew Chalmers. 2009. "EyeSpy: supporting navigation through play." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Boston, MA, USA. CHI '09. 123–132. New York, NY, USA: ACM. <http://doi.acm.org/10.1145/1518701.1518723>.
- Bhaduri, Budhendra L., and Rodolphe Devillers. 2012. "Workshop: Role of Volunteered Geographic Information in Advancing Science: Quality and Credibility." A workshop in conjunction with GIScience 2012: Proceedings available online at <http://www.ornl.gov/sci/gist/workshops/2012/index.shtml> (checked July 2013).
- Budhathoki, N, Z Nedovic-Budic, and B Bruce. 2010. "An interdisciplinary frame for understanding volunteered geographic information." *Geomatica* 64 (1): 11–26.
- Budhathoki, Nama Raj, Zorica Nedovic-Budic, et al. 2008. "Reconceptualizing the role of the user of spatial data infrastructure." *GeoJournal* 72 (3-4): 149–160.
- Cinnamon, Jonathan, and Nadine Schuurman. 2013. "Confronting the data-divide in a time of spatial turns and volunteered geographic information." *GeoJournal* 78 (4): 657–674. <http://dx.doi.org/10.1007/s10708-012-9458-6>.
- Coleman, David J. 2013. "Potential Contributions and Challenges of VGI for Conventional Topographic Base-Mapping Programs." In *Crowdsourcing Geographic Knowledge*, edited by Daniel Sui, Sarah Elwood, and Michael Goodchild. 245–263. Springer AK Houten, Netherlands. http://dx.doi.org/10.1007/978-94-007-4587-2_14.
- Coleman, David J., Yola Georgiadou, and Jeff Labonte. 2009. "Volunteered Geographic Information: The Nature and Motivation of Producers." *International Journal of Spatial Data Infrastructures Research* 4: 332–358.
- Corcoran, Pdraig, and Peter Mooney. 2013. "Characterising the metric and topological evolution of OpenStreetMap network representations." *The European Physical Journal Special Topics* 215 (1): 109–122. <http://dx.doi.org/10.1140/epjst/e2013-01718-2>.
- Corcoran, Pdraig, Peter Mooney, and Michela Bertolotto. 2013. "Analysing the growth of OpenStreetMap networks." *Spatial Statistics* 3 (1): 21 – 32. <http://www.sciencedirect.com/science/article/pii/S2211675313000031>.
- Danko, David M. 2012. "Geospatial Metadata." In *Springer Handbook of Geographic Information*, edited by Wolfgang Kresse and David M. Danko. 191–244. Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-540-72680-7_12.
- Davidovic, Nikola. 2013. "Using Location Based Game MapSigns to motivate VGI data collection related to traffic signs." In Mooney and Rehrl (2013). 31–36.
- Elwood, Sarah. 2008. "Volunteered geographic information: future research directions motivated by critical, participatory, and feminist GIS." *GeoJournal* 72 (3-4): 173–183. <http://dx.doi.org/10.1007/s10708-008-9186-0>.
- Elwood, Sarah, and Agnieszka Leszczynski. 2011. "Privacy, reconsidered: New representations, data practices, and the geoweb." *Geoforum* 42 (1): 6 – 15. <http://www.sciencedirect.com/science/article/pii/S001671851000093X>.
- Feick, Rob, and Sthpane Roche. 2013. "Understanding the Value of VGI." In *Crowdsourcing Geographic Knowledge*, edited by Daniel Sui, Sarah Elwood, and Michael Goodchild. 15–29. Springer AK Houten, Netherlands. http://dx.doi.org/10.1007/978-94-007-4587-2_2.
- Girardin, F., F. Calabrese, F.D. Fiore, C. Ratti, and J. Blat. 2008. "Digital Footprinting: Uncovering Tourists with User-Generated Content." *Pervasive Computing, IEEE* 7 (4): 36–43.
- Goetz, Marcus. 2012. "Using Crowdsourced Indoor Geodata for the Creation of a Three-

- Dimensional Indoor Routing Web Application.” *Future Internet* 4 (2): 575–591. <http://www.mdpi.com/1999-5903/4/2/575>.
- Goodchild, Michael F. 2007. “Citizens as sensors: the world of volunteered geography.” *GeoJournal* 69 (4): 211–221. <http://dx.doi.org/10.1007/s10708-007-9111-y>.
- Goodchild, Mike, Dieter Pfoser, and Dan Sui. 2012. “First ACM SIGSPATIAL International Workshop on Crowdsourced and Volunteered Geographic Information.” A workshop in conjunction with ACM GIS 2012: Proceedings available online at http://www.geocrowd.eu/workshop_2012/ (checked July 2013).
- Goodchild, Michael F. 2008. *Geographic Information Science: The Grand Challenges*. 596–608. Blackwell Publishing Ltd. <http://dx.doi.org/10.1002/9780470690819.ch33>.
- Goodchild, Michael F., and Linna Li. 2012. “Assuring the quality of volunteered geographic information.” *Spatial Statistics* 1 (0): 110 – 120. <http://www.sciencedirect.com/science/article/pii/S2211675312000097>.
- Grant, Lyndsay, Hans Daanen, Steve Benford, Alastair Hampshire, Adam Drozd, and Chris Greenhalgh. 2007. “MobiMissions: the game of missions for mobile phones.” In *ACM SIGGRAPH 2007 educators program*, San Diego, California. SIGGRAPH ’07. New York, NY, USA: ACM. <http://doi.acm.org/10.1145/1282040.1282053>.
- Hagenauer, Julian, and Marco Helbich. 2012. “Mining urban land-use patterns from volunteered geographic information by means of genetic algorithms and artificial neural networks.” *International Journal of Geographical Information Science* 26 (6): 963–982. <http://www.tandfonline.com/doi/pdf/10.1080/13658816.2011.619501>. <http://www.tandfonline.com/doi/abs/10.1080/13658816.2011.619501>.
- Haklay, Muki. 2010. “How good is volunteered geographical information? A comparative study of OpenStreetMap and Ordnance Survey datasets.” *Environment and Planning B: Planning and Design* 37 (4): 682–703.
- Haklay, Muki, and Nama Budhathoki. 2010. “OpenStreetMap - Overview and Motivational Factors.” Presented at the Horizon Infrastructure Challenge Theme Day, the University of Nottingham, UK. Proceedings available online at <https://www.ideals.illinois.edu/bitstream/handle/2142/16461/Horizon%20March%202010%20%28Haklay%20and%20Budhathoki%29.pdf?sequence=2> (checked September 2013).
- Hardy, Darren. 2011. “Volunteered Geographic Information (VGI) Research progress and new developments.” A workshop held as pre-conference workshop to AAG (Association of American Geographers Annual Meeting) 2011. Proceedings are available online at <http://vgi.spatial.ucsb.edu/> (checked July 2013).
- Hardy, Darren. 2013. “The Geographic Nature of Wikipedia Authorship.” In *Crowdsourcing Geographic Knowledge*, edited by Daniel Sui, Sarah Elwood, and Michael Goodchild. 175–200. Springer AK Houten, Netherlands. http://dx.doi.org/10.1007/978-94-007-4587-2_11.
- Hochmair, H. H., and Dennis Zielstra. 2013. “Development and Completeness of Points Of Interest in Free and Proprietary Data Sets: A Florida Case Study..” In *GI-Forum 2013*, edited by Thomas Jekel, Adrijana Car, Josef Strobl, and Gerald Griesebner. Berlin: Wichmann.
- Hughes, PM, and G Cosier. 2001. “What Makes a Revolution? Disruptive Technology and Social Change.” *BT Technology Journal* 19 (4): 24–28. <http://dx.doi.org/10.1023/A:3A1013718227208>.
- Jilani, Musfira, Pdraig Corcoran, and Michela Bertolotto. 2013. “Automated Quality Improvement of Road Networks in OpenStreetMap.” In Mooney and Rehrl (2013). 37–42.
- Kalantari, Mohsen. 2013. “Crowdsourced Metadata supporting Crowdsourced Geospatial Data.” In Mooney and Rehrl (2013). 19–24.
- Karnouskos, S. 2011. “Crowdsourcing information via mobile devices as a migration enabler towards the SmartGrid.” In *Smart Grid Communications (SmartGridComm), 2011 IEEE International Conference on*, 67–72.
- Kessler, Carsten. 2013. “Collecting a Ground Truth Dataset for OpenStreetMap.” In Mooney and Rehrl (2013). 55–60.
- Kessler, Carsten, and RenTheodoreAnton Groot. 2013. “Trust as a Proxy Measure for

- the Quality of Volunteered Geographic Information in the Case of OpenStreetMap.” In *Geographic Information Science at the Heart of Europe*, edited by Danny Vandembroucke, Bndicte Bucher, and Joep Cromptvoets. Lecture Notes in Geoinformation and Cartography. 21–37. Springer International Publishing. http://dx.doi.org/10.1007/978-3-319-00615-4_2.
- Koukoletsos, Thomas, Mordechai (Muki) Haklay, and Claire Ellul. 2012. “Assessing Data Completeness of VGI through an Automated Matching Procedure for Linear Data.” *Transactions in GIS* 16 (4): 477–498. <http://dx.doi.org/10.1111/j.1467-9671.2012.01304.x>.
- Maisonneuve, Nicolas, Matthias Stevens, Maria E. Niessen, Peter Hanappe, and Luc Steels. 2009. “Citizen noise pollution monitoring.” In *Proceedings of the 10th Annual International Conference on Digital Government Research: Social Networks: Making Connections between Citizens, Data and Government*, dg.o '09. 96–103. Digital Government Society of North America. <http://dl.acm.org/citation.cfm?id=1556176.1556198>.
- Mart, IreneGarcia, LuisE. Rodriguez, Mauricia Benedito, Sergi Trilles, Arturo Beltrn, Laura Daz, and Joaquin Huerta. 2012. “Mobile Application for Noise Pollution Monitoring through Gamification Techniques.” In *Entertainment Computing - ICEC 2012*, Vol. 7522 of *Lecture Notes in Computer Science* edited by Marc Herrlich, Rainer Malaka, and Maic Masuch. 562–571. Springer Berlin. http://dx.doi.org/10.1007/978-3-642-33542-6_74.
- Matyas, Sebastian, Peter Kiefer, Christoph Schlieder, and Sara Kleyer. 2011. “Wisdom about the Crowd: Assuring Geospatial Data Quality Collected in Location-Based Games.” In *Entertainment Computing ICEC 2011*, Vol. 6972 of *Lecture Notes in Computer Science* edited by JuniaCoutinho Anacleto, Sidney Fels, Nicholas Graham, Bill Kapralos, Magy Saif El-Nasr, and Kevin Stanley. 331–336. Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-642-24500-8_36.
- McKenzie, Grant, Kathleen Deutsch, and Martin Raubal. 2013. “What, When and Where: The real-world activities that contribute to online social networking posts.” In Mooney and Rehr (2013). 25–30.
- Mooney, Peter, and Padraig Corcoran. 2012. “Characteristics of Heavily Edited Objects in OpenStreetMap.” *Future Internet* 4 (1): 285–305. <http://www.mdpi.com/1999-5903/4/1/285>.
- Mooney, Peter, and Padraig Corcoran. 2013. “Understanding the Roles of Communities in Volunteered Geographic Information Projects.” In *Progress in Location-Based Services*, edited by Jukka M. Krisp. Lecture Notes in Geoinformation and Cartography. 357–371. Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-642-34203-5_20.
- Mooney, Peter, and Karl Rehr, eds. 2013. *International Workshop on Action and Interaction in Volunteered Geographic Information (ACTIVITY)*. Leuven, Belgium: Online at <http://flrec.ifas.ufl.edu/geomatics/agile2013/programme.html>.
- Naaman, Mor, Amy Xian Zhang, Samuel Brody, and Gilad Lotan. 2012. “On the Study of Diurnal Urban Routines on Twitter..” In *ICWSM*, edited by John G. Breslin, Nicole B. Ellison, James G. Shanahan, and Zeynep Tufekci. The AAAI Press. <http://dblp.uni-trier.de/db/conf/icwsml/icwsml2012.html#NaamanZBL12>.
- Neis, Pascal, Marcus Goetz, and Alexander Zipf. 2012. “Towards Automatic Vandalism Detection in OpenStreetMap.” *ISPRS International Journal of Geo-Information* 1 (3): 315–332. <http://www.mdpi.com/2220-9964/1/3/315>.
- Neis, Pascal, Dennis Zielstra, and Alexander Zipf. 2011a. “The Street Network Evolution of Crowdsourced Maps: OpenStreetMap in Germany 20072011.” *Future Internet* 4 (1): 1–21. <http://www.mdpi.com/1999-5903/4/1/1>.
- Neis, Pascal, Dennis Zielstra, and Alexander Zipf. 2011b. “The Street Network Evolution of Crowdsourced Maps: OpenStreetMap in Germany 20072011.” *Future Internet* 4 (1): 1–21. <http://www.mdpi.com/1999-5903/4/1/1>.
- Neis, Pascal, and Alexander Zipf. 2012. “Analyzing the Contributor Activity of a Volunteered Geographic Information Project The Case of OpenStreetMap.” *ISPRS International Journal of Geo-Information* 1 (2): 146–165. <http://www.mdpi.com/2220-9964/1/2/146>.

- Parker, Christopher J., Andrew May, and Val Mitchell. 2013. "The role of {VGI} and {PGI} in supporting outdoor activities." *Applied Ergonomics* 44 (6): 886–894. <http://www.sciencedirect.com/science/article/pii/S0003687012000816>.
- Poore, Barbara S., and Eric B. Wolf. 2013. "Metadata Squared: Enhancing Its Usability for Volunteered Geographic Information and the GeoWeb." In *Crowdsourcing Geographic Knowledge*, edited by Daniel Sui, Sarah Elwood, and Michael Goodchild. 43–64. Springer AK Houten, Netherlands. http://dx.doi.org/10.1007/978-94-007-4587-2_4.
- Ramos, Jimena Martinez, and Rodolphe Devillers. 2013. "Integrating Authoritative and Volunteered Geographic Information - An Ontological Approach." In Mooney and Rehrl (2013). 49–54.
- Rehrl, Karl, Simon Grechenig, Hartwig Hochmair, Sven Leitinger, Renate Steinmann, and Andreas Wagner. 2013. "A Conceptual Model for Analyzing Contribution Patterns in the Context of VGI." In *Progress in Location-Based Services*, edited by Jukka M. Krisp. Lecture Notes in Geoinformation and Cartography. 373–388. Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-642-34203-5_21.
- Schade, Sven, Laura Daz, Frank Ostermann, Laura Spinsanti, Gianluca Luraschi, Simon Cox, Manoli Nuez, and Bertrand Longueville. 2013. "Citizen-based sensing of crisis events: sensor web enablement for volunteered geographic information." *Applied Geomatics* 5 (1): 3–18. <http://dx.doi.org/10.1007/s12518-011-0056-y>.
- Schmidt, Manuela, and Silvia Klettner. 2013. "Gender and Experience-Related Motivators for Contributing to OpenStreetMap." In Mooney and Rehrl (2013). 13–18.
- Stefanidis, Anthony, Andrew Crooks, and Jacek Radzikowski. 2013. "Harvesting ambient geospatial information from social media feeds." *GeoJournal* 78 (2): 319–338. <http://dx.doi.org/10.1007/s10708-011-9438-2>.
- Steinmann, Renate, Simon Grchenig, Karl Rehrl, and Richard Brunauer. 2013. "Contribution Profiles of Voluntary Mappers in OpenStreetMap." In Mooney and Rehrl (2013). 7–12.
- Sui, Daniel, Michael Goodchild, and Sarah Elwood. 2013. "Volunteered Geographic Information, the Exaflood, and the Growing Digital Divide." In *Crowdsourcing Geographic Knowledge*, edited by Daniel Sui, Sarah Elwood, and Michael Goodchild. 1–12. Springer AK Houten, Netherlands. http://dx.doi.org/10.1007/978-94-007-4587-2_1.
- Usery, Lynn, Morgan Bearden, and Barbara Poore. 2010. "U.S. Geological Survey's Volunteered Geographic Information Workshop." A workshop held at USGS Herndon, VA, USA. Proceedings are available online at <http://cegis.usgs.gov/vgi/results.html> (checked July 2013).
- Willett, Wesley, Jeffrey Heer, and Maneesh Agrawala. 2012. "Strategies for crowdsourcing social data analysis." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Austin, Texas, USA. CHI '12. 227–236. New York, NY, USA: ACM. <http://doi.acm.org/10.1145/2207676.2207709>.
- Zielstra, Dennis, and Hartwig H. Hochmair. 2013. "Positional accuracy analysis of Flickr and Panoramio images for selected world regions." *Journal of Spatial Science* 58: 251–273. <http://www.tandfonline.com/doi/abs/10.1080/14498596.2013.801331>.
- Zielstra, Dennis, Hartwig H. Hochmair, and Pascal Neis. 2013. "Assessing the Effect of Data Imports on the Completeness of OpenStreetMap A United States Case Study." *Transactions in GIS* 17 (3): 315–334. <http://dx.doi.org/10.1111/tgis.12037>.