Mining Event-Related Knowledge from OpenStreetMap

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Abstract With an explosive growth in the number of contributors for creating and assembling of spatial data, freely available databases and open source products have drawn the attention among decision makers for facility management and service planning. Many location-based services are using Volunteered Geographic Information (VGI) as spatial data sources. The key motivation of this work is to mine hidden patterns of social activities and the interests of contributors to share event-related knowledge within OSM community as one of the most prominent examples of user generated spatial data. In this study, the term event referred to anomalous user activities, number of contributors plus number of contributions, which happened at a time point or within a specific period of time. We focused on events which have happened and the events for which we had prior knowledge. For the purpose of retrospective event detection, it is necessary to analyse the history of OSM for the area of the event. In our case, the entire OSM history of Vechta, Munich, Los Angeles, and Sendai, around the area where the events happened was extracted to

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examine the potential of OSM database for event detection. Our experimental analysis reveals that while changes to OSM can be effectively rendered on the globally visible OSM maps in a few hours, citizens would not naturally use OSM as a tool to mark an event. In fact, the contributors do not treat this community in the same way as they do with other user-friendly electronic exchange platforms such as Twitter, Face book, or Flickr. The obtained results also show that for big events such as tsunami in Sendai during which the geometry of objects is affected, post-disaster, structural and environmental damages (demolished buildings, road infrastructure changes, etc.) are detectable through OSM.

Keywords Event detection · Volunteered geographic information (VGI) · OpenStreetMap (OSM) · Location-based services (LBS) · Web 2.0

1 Introduction

With the rapid spread concept that uses web as "participatory platform", a growing amount of information is uploaded on the internet. This "participatory platform" provides colloquial read-and-write functionality for individual users to collaboratively generate the content. Texting, social networks, photos, video, blog entries are amongst the most popular forms of user generated contents. In parallel, advances in location-aware devices, web mapping technologies and mobile cartography have facilitated the contribution of none professional volunteers in providing and distributing geographic information around the world (Goodchild 2007a; Coleman et al. 2009; Goodchild and Glennon 2010). VGI the term coined by Goodchild (2007a, b) refers to the recent empowerment of citizens in the collaborative collection of geographic information. He argues that VGI has enormous potential to become a "significant source of geographers understanding of the surface of the Earth". Crucially, "by motivating individuals to act voluntarily, it is far cheaper than any alternative, and its products are almost invariably freely available". Considering advantage of comprehensive knowledge, consumed time and budget of local contributors, a transition phase of none specialists contributing to the collection of geo-referenced information has occurred. Crowd-sourced and volunteered data are in many cases more up-to-date and often broader and richer in the meta-data than the authoritative sources of information. They are capable of incorporating features of interest which are not covered by mapping agencies (Goodchild and Glennon 2010).

VGI can range from simple user generated contents where geographical coordinates are automatically embedded in a digital photograph made available in some online repository to most complex forms of spatial data such as annotated GPS trajectories. OpenStreetMap (OSM) as one of the most prominent examples of user generated spatial data on the Internet in recent years has been subject to analysis by many leading GIS researchers (Fritz et al. 2009 , Mooney et al. 2010a, b). OSM aims to build a freely accessible, open map database for the entire world. Anyone can be a contributor to OSM. The contributors to OSM form a very large community of citizens collecting (and subsequently editing) spatial data. Volunteers in the OSM community collect geographic information and submit this to the global OSM database (Ciepluch et al. 2009). Most studies focus on a current snapshot of the OSM but when a longer term historical view of OSM data is considered, patterns of crowd contribution and OSM completeness become evident (Mooney and Corcoran 2012).

Changes occur in OSM due to the upload of new spatial data and/or the updating of existing contributions (location and attributes) by the original creator or another contributor. Some of the reasons for these changes could be: contributor disagreement, changes to geometry (shortening of roads, resizing, etc.), actual real-world changes reflected in the data, combination of polylines/polygons into multi polygon relations. Mistakes can be made by contributors due to insufficient understanding of spatial data handling operations or incorrect use of the editor software. For the time being, OSM is primarily used for the rendering of various map visualizations (Auer et al. 2009) and it provides a highly dynamic source of spatial data for Location-based Services (LBS) (Jacob et al. 2010, Mooney and Corcoran 2011).

The aim of this study is to detect retrospective events from OSM for the specific sites in Vechta and Munich in Germany, Los Angeles in USA, and Sendai in Japan. Indeed, this work concentrates on the detection of different types of events, which are bound to a specific time and place and hidden in the information generated by internet users. In order to examine the potential of the OSM history for event detection, two annual social events— "Stoppelmarkt" in Vechta and "Oktoberfest" in Munich, one temporary event—freeway closure in San Diego (I-405) for 2 days, and one natural event—Tsunami in Sendai, Japan were studied. By social events, we refer mostly to those planned or attended by people. People tend to use social media to capture, document, or discuss around these events.

Following this introduction, the next section is devoted to investigating the importance of event detection. Section 3 describes the spatial data and contributor characteristics of Vechta, Munich, Los Angeles and Sendai. Section 4 presents the experimental analysis of the OSM historical data. Finally, Sect. 5 presents the key findings of the paper with a discussion about some of the issues for future work on this topic.

2 Even Detection

The continuous increase in the number of contributors and the huge amounts of uploaded information on the internet has drawn the attention of decision makers to utilize this information for facility management and service planning (Sieber 2006; Coleman et al. 2010; Jiang and Mcgill 2010; Starbird and Stamberger 2010; Mclaren 2011; Ostermann and Spinsanti 2011). From the scientific point of view, the availability of accurate and/or up-to-date mass data stimulates the development of innovative approaches for the assessment of spatio-temporal processes and detailed change detection. Many studies have been already conducted concerning the detection, monitoring and visualization of changes from time series data (Coppin et al. 2004; Liu et al. 2008; Tanatho et al. 2009). Still, open questions remain on how the detected changes should be decomposed and formulated to reveal an event.

Events and their behavior patterns represent a higher level of knowledge than changes, and thus more valuable for decision makers. To explore the mechanism of changes, one must investigate the mechanism of events. Indeed, events underlie changes (Chrisman 1998; Worboys and Hornsby 2004). Highly complex and irregular patterns can still be represented visually for further analysis or exploration. In addition, for the efficient planning and management of a complex system composed of engineering, natural and social components, it is necessary to consider the relationships between an event and the reactive behavior of different involved components. For instance, various types of spatiotemporal events such as volcanic eruption and storms as examples of "natural events" while parliament election and civil demonstration are examples for "social events" that can also occur in a complex system. On the other hand, each event may require or trigger a decision, for example, opening or closing dam gates or the presence of police in the streets as operational controls.

Event detection is an interesting concept in the era of Web 2.0 and ubiquitous Internet. The wide distribution of simplified editing tools and user-friendly electronic exchange platforms (blogs, wikis, etc.) has led to a steep rise in the availability of user generated content. In some cases they are used by academic researchers who look for access to large databases of user generated content. To extract, information, meaning and knowledge from these collections of user-generated content is a challenge. The classical data mining and knowledge discovery strategies are confronted with large databases of heterogeneous and volatile online contents which do not respect any a priori classification schemes (Glassey 2012).

"Tags" are a crucial key of the data from which we want to detect events. As Glassey (2012) argues; "tags" are almost universal in user-generated content as a user-driven means of indexing their information. Without "tags" the information is essentially meaningless. Tags, in user generated content and VGI, do not follow any preset rules other than the ones chosen at the moment of their creation by the contributors themselves. As there is no formal norm for generating tags (OSM for example has a guide but these are not strictly enforced rules), users generally utilize colloquial terminology and other informal language.

As events play a prominent role in various research areas such as physics, philosophy, psychology, linguistics, literature, probability theory, artificial intelligence, deductive databases, and history, one can find many technically refined concepts of events and objects in each discipline. Conversation about events is vague; they are located in space and time but in ordinary circumstances it is difficult to determine their exact spatiotemporal extents (Borghini and Varzi 2006). Many scientists are searching to find a commensurable notion across disciplines about events and objects, and their properties (Lewis 1986; Casati and Varzi 2008; Casati 2005). Events can be studied on various scales (local, national, global) and consequently in different level of details. But in the context of this study, the term event refers to anomalous user activities, which happened at a time point or within a specific period of time. The term "User Activity" is used as the number of contributors plus number of edits/uploaded GPX traces. It is assumed that the number of visitors would increase for a specific region and its surrounding areas during the event time, which should consequently lead to an increase in the contributions to VGI datasets and projects.

3 Methodology

OSM has been chosen as the case-study VGI dataset. For the purposes of retrospective event detection, it is necessary to analyze the history of OSM for the area of the event. It might be very difficult to detect any traces of events, if the analysis is limited to the currently available snapshot of OSM that only shows the most up-to-date version of the OSM database. The OSM History is a very rich spatial database as every edit for the entire planet is recorded in this database, where an edit is referred to as the creation of objects and their subsequent update. In most cases the history of OSM stretches back to 2006. So, it provides a good opportunity to study how OSM has evolved during specific periods of time (including overlapping with specific events).

3.1 Case Studies

The following case studies were selected for a number of specific events:

The first case was devoted to detecting event from the "Stoppelmarkt" in Vechta, Germany. The Stoppelmarkt is a folk festival and one of the oldest funfairs in Germany (since 1298). The market is held once a year from Thursday to Tuesday in the week of 15th August. It has a size of approximately 160,000 m^2. In terms of size, it is one of the biggest folk festivals in Germany. At the time of event, the market area is filled with about 500 stands and fairground booths. More than 800,000 people annually visit the "Stoppelmarkt" in "Vechta".

The second case was related to the "Oktoberfest" held in Munich, Germany. It is one of the most famous events in Germany and also the world largest folk festival. It begins every year from mid-September and lasts until first week of October. More than 6 million people attend this fair annually and celebrate the Oktoberfest. The Oktoberfest has been held since 1810, and is considered as an important part of the Bavarian culture. An initial assumption we made was that there would be an increase of editing items in OSM during the festival each year. The reason of selecting two different festivals like "Stoppelmarkt" and "Oktoberfest" is to evaluate the impact of event popularity and the number of participants on the possibility of event detection from OSM history. These two locations were chosen for the study as Germany is considered as one of the most active OSM communities in Europe (Mooney and Corcoran 2011).

The third case refers to an unexpected temporary event which was not a result of any social or natural factors but highly effected the local and regional motion patterns of moving objects (cars, trucks, people, etc.). The unexpected temporary event is the closure of Interstate 405 in Los Angeles, United States. Because of the I-405 Sepulveda Pass Improvements Project, 10 miles of the 405 Freeway was closed between 15 and 18th July in 2011. Interstate 405 is a north–south highway in Southern California, connecting western and southern parts of Los Angeles to the northern San Fernando. This highway is ranked as one of the most “heavily” traveled freeways in the United States with an average daily traffic of more than 300,000 vehicles. The traffic was very congested for the 16 and 17th of July. Many people were forced to either stay at home or change their moving behaviors during these days.

For the fourth case, the earthquake and tsunami in Japan, 2011, was selected as a natural event in which the geometry and the semantic information of affected objects dramatically changed after the event. It is one of the most devastating earthquakes in the world since the introduction of modern seismological measuring technologies. As a consequence of the earthquake, the powerful tsunami waves traveled up to 10 km inland in the Sendai area and caused extensive and severe damage to roads, railways, and other infrastructures. Over one hundred thousand of buildings collapsed totally or partly.

3.2 Experiments

The OSM historical data for the entire world in XML format was downloaded from planet OSM history files. These history files are globally updated every 2 or 3 months. Considering the size of entire history and required time for processing it is necessary to extract the area of interest (Mooney and Corcoran 2011). Each history file was divided into two separate parts containing Nodes and Ways (OSM terminology for polygons and polylines). The extracted OSM-XML was then stored and processed in a Postgresql PostGIS database for further analysis. For each element (node, way), geometry and corresponding semantic information were extracted for the entire history period. The collected information consisted of the history of the contribution, location of elements (latitude and longitude coordinates), OSM user id, timestamp when the information was uploaded, embedded tags and corresponding change set number. We hypothesize that there is an increase in the number of contributions in OSM during the events outlined in the previous section.

OSM provides access to all of the GPX traces uploaded by contributors over time to the OSM database. Unfortunately the GPS traces are not organized in the same structural manner as the OSM history. One must execute calls to the OSM API service to download these GPS traces. A Python script with an assigned bounding box was developed to handle this step automatically. The script downloaded all of the GPS traces which were inside or intersected with the bounding box. Since the GPS traces were not time stamped in their exchange format GPX, it was impossible to ascertain their temporal relevance. The downloaded GPX was directly imported to QGIS for further exploration and visualization.

4 Results and Discussions

This section is devoted to illustrating and discussing the results obtained from the four case studies. The overall characteristics of contributor activities in terms of the number of contributors and the number of contributions for all cases will be investigated in this section.

4.1 Stoppelmarkt in Vechta

Figure 1 illustrates the number of contributors (y-axis) and contributions (size of the bubbles) over time for the area where the Stoppelmarkt is held. It was expected that potentially the influx of visitors to the event might encourage those with an interest in OSM to edit the base-map to reflect the fact that a large event would be taking place. The history of OSM between 2006 and 2010 for the market and surroundings area shows that there was not any easily detectible indication of unexpected increases in the amount of contributions for the time of event. The number of contributions and contributors only change slowly over time. In January 2011 a significant increase in the number of contributions (1805 edits) can be seen, which has been done with five contributors. According to the definition of event, this phenomenon does not correspond to any event (Fig. 1).

Mining the tags showed that different contributors have provided some relevant information about temporal characteristic of stands and the markets. However, the corresponding tags were only available in the history of OSM or in the advanced editing modus. Since they are not automatically displayed on the map, the OSM users cannot simply find the temporal information without going to the advanced editing modus of the map. The tags indicate that the event started in August 11th and ended in August 16th, 2011 and they do not convey any information about annual pattern of the event (objects exist constantly on the map). Although the Stoppelmarkt in Vechta is a very famous and big fair in Germany with more than hundreds of thousands attendants yearly currently, there is no possibility to detect any pattern of the event in the history of OSM.

Figure 2 and Table 1 illustrate the “Stoppelmarkt, Vechta” in view and editing modus of OSM with the corresponding tags respectively.

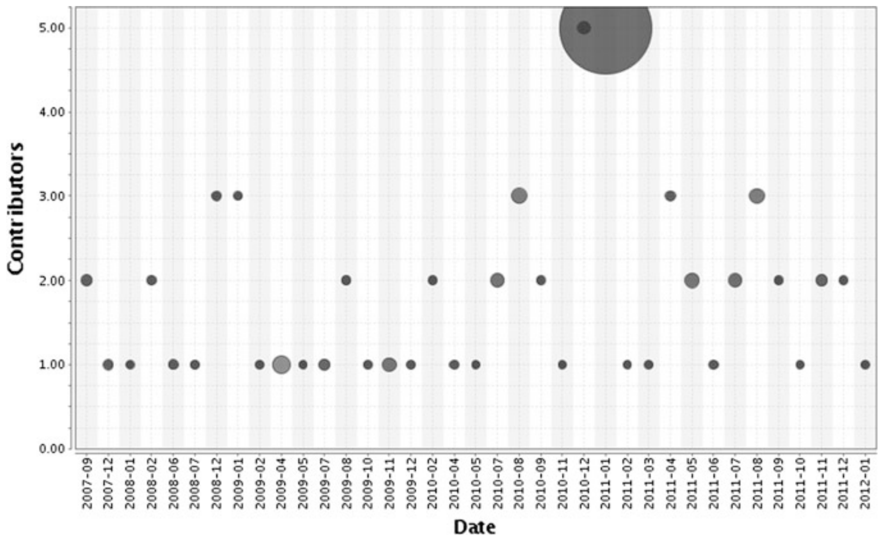

Fig. 1 Contribution characteristics of surrounding areas of Stoppelmarkt in Vechta

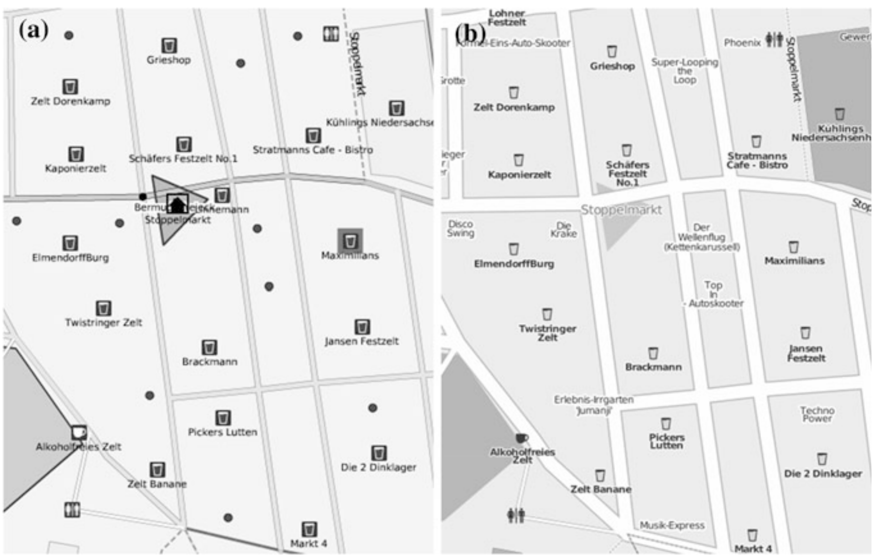

Fig. 2 Vechta Stoppelmarkt in **a** view modus and **b** editing modus

Table 1 Maximilian's Pub OSM history in "Vechta Stoppelmarkt"

Edited at:		04 Aug 11	05 Aug 11	05 Aug 11	28 Jan 12
Edited by:		Duetzer	Duetzer	Duetzer	Nolbelt San
Version:		1	2	3	4
In changeset:		8916581	8925849	8925909	10524834
Comment:		–	–	–	Small changes
Tags:	Amenity	pub	Pub	Pub	Pub
	Name	Maximilian's	Maximilian's	Maximilian's	Maximilian's
	Opening_days	–	–	11–16 Aug 11	11–16 Aug 11
Coordinates		52.74777, 8.29669	52.74777, 8.29669	52.74777, 8.29669	52.74777, 8.29669

4.2 *Oktoberfest*

The Oktoberfest in Munich is the theme of our second case study. The results of our analysis on this theme are almost the same as Vechta Stoppelmarkt. This shows that the size or popularity of an event does not have any impact on the possibility of event detection in OSM.

An initial assumption we made was that there would be an increase number of editing activities in OSM during the festival each year. However, our analysis showed that this was not actually the case. Figure 3 illustrates that in general there is an upward trend in the number of contributions and amount of contributors over time for the area of Oktoberfest. Actually it is the same trend with general increases in the number of unique contributors to OSM for Germany over time since 2006 for both ways and nodes (Mooney and Corcoran 2011). As can be seen in Fig. 3 the ratio between the number of contributions and the number of contributors decreases over time. This could be a result of the fact that the majority of

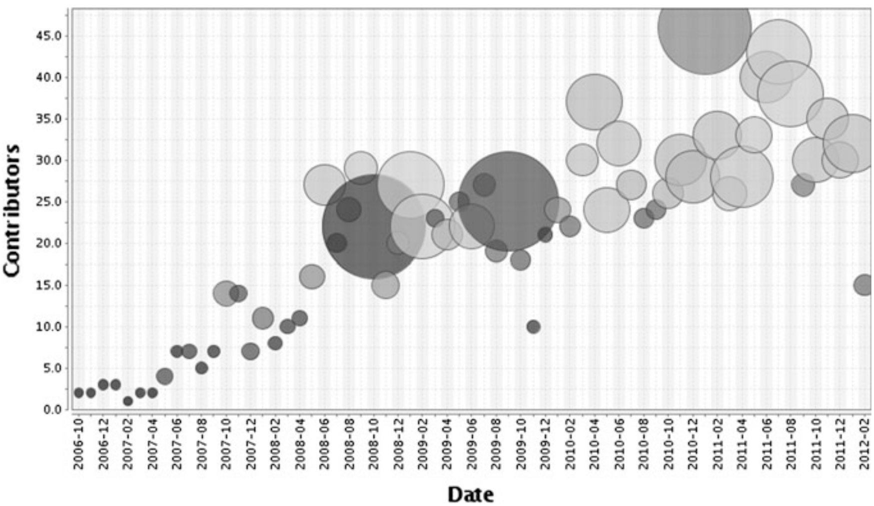

Fig. 3 Contribution characteristics of surrounding areas of Oktoberfest in Munich

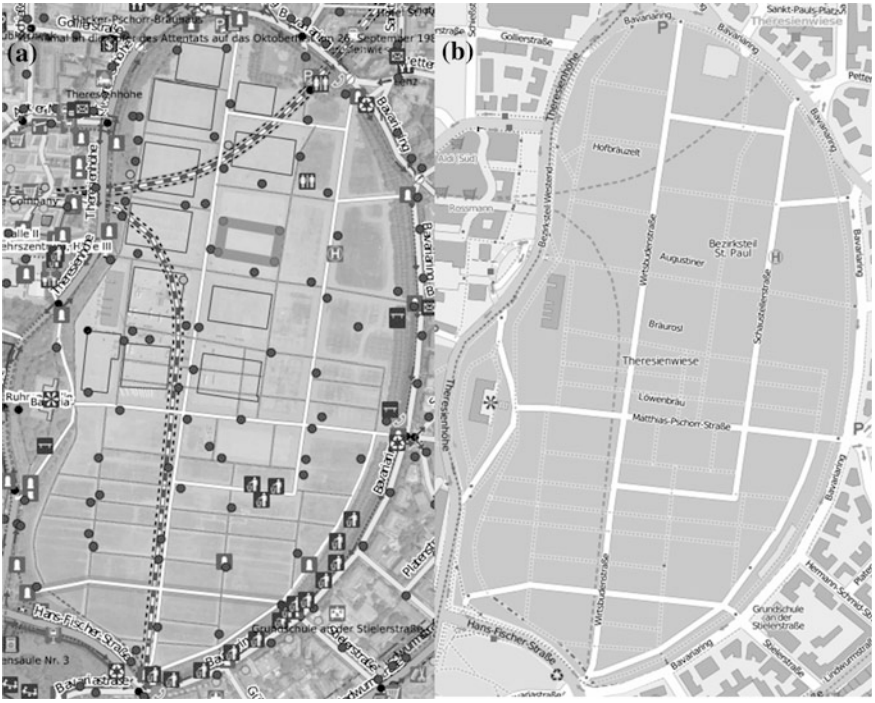

Fig. 4 Oktoberfest in **a** view modus and **b** editing modus

features in Munich are mapped and the new generations of OSM contributors are busy with enhancing and maintenance of OSM maps.

As can be seen from Fig. 4 the tents of the fair are not visible in the view modus of the map but they exist in the editing modus. The volunteers who have mapped this event have identified the start and end dates of the event, and have hidden the temporal tents in the place of Oktoberfest. It illustrates that although neither Stoppelmarkt nor Oktoberfest could be detected through our initial definition of events, there is a great potential for the tracing of these events through tag mining. In the case of Oktoberfest the innovative way of mapping and tagging the tents makes it possible to visualize the temporal buildings only during the fair. In addition, the process of updating the status of the tents (being hidden or not) can convey the spatio-temporal pattern of the event.

Table 2 shows the description of the Tent Augustiner. A note has been also added to this Tent which says that during the fair, the hidden tag must be altered from “yes” to “no” and after the event the date must be adapted for the next year. Table 2 presents that the tents were created for the first time in September 2010 by Mackerski (a mapper from Ireland who has lived in Germany) and has been subsequently updated regularly for the next events by different users.

Table 2 Augustiner tent OSM history in "Oktoberfest" Munich

Edited at:		27 Sep 10	28 Sep 10	04 Okt 10	04 Nov 10	01 Jan 11	17 Sep 11	26 Sep 11	07 Nov 11
Edited by:		Mackerski	Mackerski	Mackerski	Sendelhorst	Spunsel	Chan	Mackerski	Swus
Version:		1	2	3	4	5	6	7	8
In changeset:		5894426	5901895	5954479	6292634	6828639	9326733	9402214	9766624
Comment:		–	–	–	Hide	Update dates	Unhide	Unhide	Hide
Tags:	Start_date	–	01 Sep 10	01 Sep 10	01 Sep 10	17 Sep 11	17 Sep 11	17 Sep 11	22 Sep 12
	End_date	–	20 Okt 10	20 Okt 10	20 Okt 10	03 Okt 11	03 Okt 11	03 Okt 11	07 Okt 12
	Hidden	–	–	–	yes	yes	No	No	Yes
	Name	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner
	operator	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner	Augustiner
	building	beer_tent	beer_tent	beer_tent	–	–	–	beer_tent	–
	seasonal_building	–	–	–	–	–	–	–	beer_tent
	temp_building	–	–	–	beer_tent	beer_tent	beer_tent	–	–
	note	–	update	update	update	update	update	Update	update

4.3 Closure of Freeway 405 in Los Angeles

The closure of freeway 405 in Los Angeles is the theme of our third case study. Changes in the map database, such as changes to road infrastructure could imply changes in motion patterns of moving objects and vice versa. With the case of I-405, we aimed to find the trace of freeway closure within the OSM database. Due to the nature of the event and the place where event happened, no anomalous activity was explored in the number of contributions. Tag mining of OSM history for the area where the freeway was closed showed that no one recorded anything to update the status of the freeway for the time when event happened in L.A. Only two contributions were recorded during July 2011, which were not referred to the event. In addition, uploaded GPS traces into OSM within the area of event were downloaded as auxiliary data for further exploration. Only one GPS trace was uploaded for the given bounding box within the duration of this event, but it wasn't related to the event in question.

4.4 Sendai Tsunami

Figure 5 illustrates the edits in OSM history for a period of 13 months from December 2010 to 2011. In this example, an obvious increase in the number of contributors and contributions over a very short period of time was detected. It implies that "something" has caused these people to contribute to OSM on a large scale. Figure 6 presents the OSM activity before (February, 2010) and after (March 2010) the event. The community of contributors was quick to reconstruct the OSM map of Sendai to indicate the scale of the destruction caused to infrastructure by the earthquake and tsunami. The OSM maps were then made available to aid agencies and local government officials to provide an accurate base-map of the on-the-ground reality. Although OSM activity levels in terms of the number of

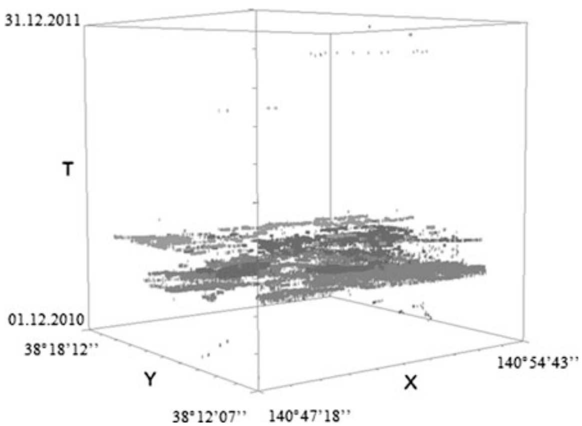

Fig. 5 Contribution characteristics of surrounding areas of Tsunami in Sendai

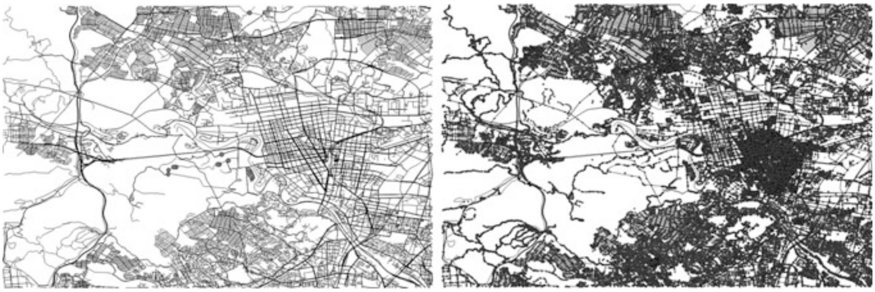

Fig. 6 Contribution characteristics of OSM activity before (February, 2010) and after (March 2010) the event

edits and the number of editors, would naturally increase as well in any other given area over a given length of time, it is very unlikely that such an increase would match the scale in the case of the Sendai earthquakes.

5 Conclusion and Further Work

In this study, we analyzed different event types which have happened and for which we had knowledge (spatial size, impact, type of event). Changes to OSM can be effectively rendered on the globally visible OSM maps with a delay of only a few hours. In addition, OSM, like other sharing open source platforms, allows tagging the mapped objects. These functionalities have made OSM a powerful community for collecting both geometry and semantic information of physical mapped objects. The key motivation of this work was to mine hidden patterns of social activities and the interests of contributors to share event-related knowledge within OSM community. We attempted to detect events from OSM in the same way as from other social platforms. We used the number of active contributors as an indicator combined with an analysis of the history about the number of contributions.

The obtained results revealed that OSM is not a tool which internet users would naturally turn to mark an event or even provide the attributes for the involved spatial objects. The contributors do not treat this community in the same way as they do with the user-friendly electronic exchange platforms such as Twitter, Face book, or Flickr. According to the results, in the cases of Munich and Vechta, the activities of contributors (the number of contributors plus the number of edits) for a specific period of time cannot be considered as an appropriate indicator for detecting social/temporary events in OSM community. There was no detectible indication of unexpected increase in the number of contributions and the number of contributors during the lifespan of the event. Mining the tags for both events showed that the contributors have mapped the temporary objects and reported the events in their tags and comments but unfortunately the information is only available in the advanced editing modus of the map for the registered contributors. This implies that in the context of OSM, a new definition for this kind of event must be considered.

For the case of tsunami in Sendai, a natural event in which the geometry of objects is affected, post-disaster, the structural and environmental damages (demolished buildings, road infrastructure changes, etc.) were detectable from OSM platform. It can be concluded that for the natural events the “activity” is considered as the first pre-processing step towards event detection. While the tags mining is used for further exploration such as the type of events, the required facilities for the understanding and the management of the events. In this case, an obvious increase in the number of contributors and contributions over a very short space of time show that “something” had caused these people to contribute to OSM at a large scale.

Regarding pattern recognition, the mapped objects of “Vechta” festival are constantly displayed on the map while they are only available during the festival time. Indeed, no repetitive pattern was recognized from constant existence of the involving objects. Based on the history file, the mapped objects are static objects which have been created after a sudden event (not repetitive). In the case of Oktoberfest, the tents are not visible in the view modus of the map as the volunteers have identified the start and end dates of the event, and have hidden the temporal tents in the place of Oktoberfest. In fact, pattern of the event can be identified as the contributors have regularly updated the status of the tents for being hidden and unhidden regarding the event time. It can be a good starting point for the management of event-related knowledge in OSM but this attempt has a number of deficits:

- Unregistered users do not have any access to the embedded information (e.g., start and end date of events) as they are only visible in the editing modus.
- Continuous maintenance is needed to update the map for each period of time. For the Oktoberfest and Stoppelmarkt, the maintenance interval is yearly but for ir/regular daily events, the maintenance is almost impossible.
- Mapping of temporary objects for repetitive periodical events affects the quality of OSM for the users who are not frequently updating their downloaded maps.
- Some events such as a meeting in a hall, are difficult to manage by means of the hiding and unhiding mechanism. In these cases, the event is unidirectionally connected with an object. A meeting needs a building to be held, but a building can exist without the meeting event.

Our experiments have revealed the fact that there appears to be a lack of event detection and pattern recognition possibility for OSM community, especially for the social and temporary events. This disability may be explained with two reasons. The first is the way people treat OSM for creating spatial data and sharing corresponding information which are bound to the objects at specific time and space. There are many physical objects that could be mapped in OSM if contributors are willing to do. The second refers to the functionality of OSM for collecting this knowledge and making it accessible to other users. One might be interested in mapping the temporary objects and reporting the relevant events, but OSM is unable to properly provide the information to the users. The temporary objects either are displayed constantly on the map (Vechta case) or have to be continuously manipulated by contributors before and after the events (Oktoberfest case). One remedy for handling the task might be to add a new attribute layer and adequately design it for the management of temporal semantic information based on a new ontology for temporary objects.

Overall, we just stirred up the surface of the VGI community with our case studies. There are many different forms of data beyond OSM that could also be considered. However, to make the best use of the huge amount of information hidden in these databases, we need the development of new information retrieval systems with the capability of reasoning and representing latent knowledge.

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