Integrating Volunteered Human Sensor Data into Crowd-sourced Platforms: A Use Case on Noise Pollution Monitoring and OpenStreetMap

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1. Introduction

Local and national governments deploy environmental monitoring to improve decision making for sustainable development. Especially the monitoring and management of pollution such as noise is of local, national and European relevance, as expressed by the European Noise Directive (END) (European Parliament, 2002). The European Environment Agency (EEA) asks all its member and collaborating countries for information required by the END. However, it is expensive to deploy and maintain a network of sensors or to periodically measure the city with a moving sensor network. Hence, most of the reported data is based on computed models and only some data is captured by reference sensors deployed in the field. According to the END, the reported data is available as strategic noise maps. So far, these noise maps remain still in silos although they are managed in a Geographic Information Infrastructure (Murphy & King, 2010). Concurrently, crowd-sourced information is collected by citizens for environmental monitoring and specific platforms such as for collecting crowd-sourced noise measures become massively populated (Goodchild, 2007). However, this environmental information is rarely accessible to the public such as in the case of eye on earth[1], due to a lack of applicable interfaces.

This paper describes an approach to publish the captured crowd-sourced environmental information such as noise data to a more popular and open platform for increasing visibility and improving information access. In particular, this approach integrates the world-wide network of human sensors into an existing VGI platform such as Open Street Map. Using this platform allows users to directly integrate static data (captured roads) and dynamic data (e.g. noise).

2. Background

In our previous work, users captured noise data with sensor-enabled smart phones (Foerster, Bröring, & Pebesma, under review). A customized mobile application has been developed to capture this data that is modeled to cover the aspects represented in the END. The recorded data includes for instance the numeric measurement of noise, the specific location of the measurement and the time. Additionally, the user can tag his recordings or rate them according to their annoyance. Finally, the gathered noise data is published to a Sensor Web Enablement (Bröring et al., 2011) infrastructure for human sensors. Another example of a

[1] Eye on Earth website: www.eyeonearth.eu.

VGI application for noise is NoiseTube (Maisonneuve, Stevens, Niessen, & Steels, 2009) or for more general sensor-related information pachube[2].

The OpenStreetMap (OSM) project (Haklay & Weber, 2008) was found in 2004 and has a rapidly growing data inventory of streets and points of interest (POIs). Its access and use is free of charge (Open Database License). The data is reported by so-called mappers, volunteered users who use digitizing tools or mobile devices with GPS capabilities to capture the data. OpenStreetMap is used for several applications such as mapping or routing. The data model is based on three types of objects, nodes, ways and closed ways (to represent polygons). The thematic data is captured through tags (key value pairs). The set of available tags is thereby unlimited. Specific renderers use a set of designated tags to create a cartographic representation. Moreover, OSM has a versioning system, which records any creation or update of a node, way and their tags with a timestamp in the history. OSM data can be created, updated and retrieved through a web service interface, the so-called OSM API. The retrieved data is encoded in an OSM-specific XML encoding. Editing of OSM data is realized through changesets for potential rollbacks.

3. Approach

Inspired by the END, our approach considers the measurement of noise values for the day and the night frames. In the presented approach, the environmental data is directly attached to the nodes that form the road segments of the OpenStreetMap dataset. Therefore, the noise data is processed to calculate the average decibel value for an OSM node. Considering the two time frames, noise_day and noise_night will be added as new tags of a specific OSM node.

The approach is based on a Web Service-based architecture (Figure 1) to publish the noise data into the OSM database. We apply the Publication Service (Díaz & Schade, 2011) for integrating the environmental data into the crowd-sourcing platform. First, the noise values are captured and stored in a database (i.e. the existing VGI platform for noise). This platform is extended to forward the data to the Publication Service, which is based on the OGC Web Processing Service interface. The Publication Service queries the OSM backend through the OSM API to retrieve the closest corresponding OSM node to which the calculated noise value can be assigned (Step 3 and Step 4). Next step is to calculate the noise measurement that corresponds to this node, based on the available noise data in the database and the existing noise values in the OSM database in case of an update (Step 5). Step 6 and Step 7 create or update the tags (noise_day or noise_night) for the corresponding node in the OSM database.

[2] Pachube website: www.pachube.com.

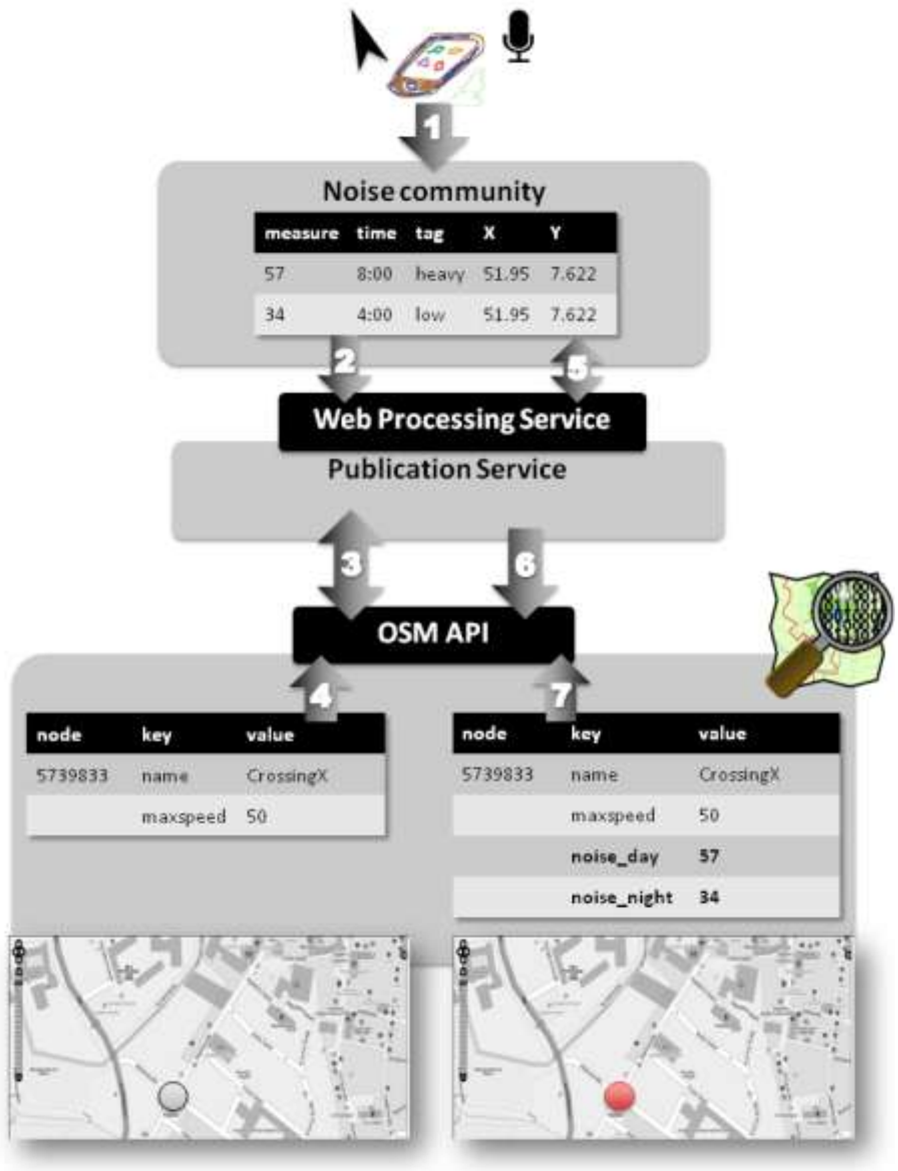

Figure 1: Integrating noise data into OSM.

4. Implementation

The presented approach of publishing sensor data in OSM (Section 3) is realized prototypically. To determine the closest node to the measured value in the noise database, the OSM API has to be queried through a geographic extent (bbox parameter). An example of the request is depicted in Listing 1.

```
http://api.openstreetmap.org/api/0.6/map?bbox=7.573375599999999,51.9294798,7.5753756,51
.9314798
```

Listing 1: OSM API query to retrieve nodes regarding a specific extent.

This operation then returns all the nodes accordingly. Internally, the closest node has to be found. This node is then updated using the *changeset* functionality of OSM API. The query is performed through HTTP PUT. An example query is depicted in Listing 2.

```
<?xml version="1.0" encoding="UTF-8" ?>
<osm generator="OpenStreetMap server" version="0.6">
<node changeset="8712284" id="273968126" lat="51.9310517" lon="7.5706349" time-
stamp="2011-07-12T14:25:37Z" uid="478890" user="A_user" version="3" visible="true">
<tag k="noise_day" v="50.1" />
</node>
</osm>
```

Listing 2: Example query to update a specific node with a noise_day value through HTTP PUT.

We propose to use one changeset for a complete set of transactions. Based on the different changesets, a temporal archive of noise data can be created.

For performance reasons, the workflow is performed as a batch process over night. The batch process can potentially invoked by the noise mapping platform, as described in Section 3.

5. Conclusion

Despite the efforts in standardization and coordination of initiatives such as INSPIRE, environmental data still remain in information silos. Also, crowd-sourced information for environmental monitoring is not easily accessible. The presented approach demonstrated how existing crowd-sourced platforms can be integrated into OSM. Thereby, OSM becomes open for dynamic content, which can be used for environmental monitoring. Through tagging and the versioning system, we demonstrated how environmental analysis can be achieved on top of OSM.

Still some issues remain open, such as the limitation to store and manage more dynamic data due to, for example, maintenance costs, its quality in areas with low participation, and its limitation to retrieve smaller street segments to define more accurate measurements. Moreover, a renderer for OSM could be created, which uses the noise tags described in this approach to create up-to-date noise maps.

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References

Bröring, A., Echterhoff, J., Jirka, S., Simonis, I., Everding, T., Stasch, C., Liang, S., et al. (2011). New Generation Sensor Web Enablement. *Sensors*, *11*(3), 2652-2699. doi:10.3390/s110302652

Díaz, L., & Schade, S. (2011). GEOSS Service Factory: Assisted Publication of Geospatial Content. In S. Geertman, W. Reinhardt, & F. Toppen (Eds.), *Advancing Geoinformation Science for a Changing World* (Vol. 1, pp. 423-442). Berlin, Heidelberg: Springer Berlin Heidelberg. Retrieved from http://www.springerlink.com/index/10.1007/978-3-642-19789-5_21

European Parliament. (2002). *Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise*. Directive, .

Foerster, T., Bröring, A., & Pebesma, E. (under review). Challenges for Crowd-sourced Noise Assessment inSpatial Data Infrastructures. *International Journal of Spatial Data Infrastructures Research*.

Goodchild, M. (2007). Citizens as Sensors: the World of Volunteered Geography. *GeoJournal*, *69*, 211-221. doi:10.1007/s10708-007-9111-y

Haklay, M. (Muki), & Weber, P. (2008). OpenStreetMap: User-Generated Street Maps. *IEEE Pervasive Computing*, *7*(4), 12-18. doi:10.1109/MPRV.2008.80

Maisonneuve, N., Stevens, M., Niessen, M. E., & Steels, L. (2009). NoiseTube: Measuring and mapping noise pollution with mobile phones. *Information Technologies in Environmental Engineering*, Environmental Science and Engineering (pp. 215-228). Springer Berlin Heidelberg. Retrieved from http://dx.doi.org/10.1007/978-3-540-88351-7_16

Murphy, E., & King, E. A. (2010). Strategic environmental noise mapping: Methodological issues concerning the implementation of the EU Environmental Noise Directive and their policy implications. *Environment International*, *36*(3), 290-298. doi:10.1016/j.envint.2009.11.006