11th International Conference on Hydroinformatics
HIC 2014, New York City, USA

VOLUNTEERED GEOGRAPHIC INFORMATION FOR WATER MANAGEMENT: A PROTOTYPE ARCHITECTURE

MARIA ANTONIA BROVELLI (1), LUCA DOTTI (2), MARCO MINGHINI (1), MASSIMO PANCALDI (2), GIORGIO ZAMBONI (1)
(1): DICA, Politecnico di Milano, Geomatics Laboratory, via Valleggio 11, Como, 22100, Italy
(2): Autorità di Bacino del fiume Po, via Garibaldi 75, Parma, 43100, Italy

Driven by Web 2.0 and GeoWeb 2.0 technology and the almost ubiquitous presence of mobile devices, Volunteered Geographic Information (VGI), and specially citizen science, is knowing an unprecedented growth. These notable advancements have opened fruitful perspectives also in the field of water management and protection, raising the demand for a reconsideration of policies which also takes into account the emerging trend of VGI. This research investigates the opportunity of leveraging such a technology to involve citizens equipped with common mobile devices (e.g. tablets and smart phones) in a campaign of report of water-related phenomena and points of interest. The work is carried out in collaboration with AdbPo - Autorità di bacino del fiume Po (Po river basin Authority), i.e. the entity responsible for the environmental planning and protection of the basin of the Italian river Po. A FOSS (Free and Open Source Software) architecture was designed to enrich AdbPo official database with user-generated contents. More in detail, Open Data Kit suite allows users to collect georeferenced multimedia information using mobile devices equipped with geolocation sensors (e.g. the GPS). Users can report a number of environmental emergencies, problems or simple points of interest related to the Po river basin, taking pictures of them and providing other contextual information. Field-registered data is sent to a server and stored into a PostgreSQL database with PostGIS spatial extension. GeoServer provides then data dissemination on the Web, while an OpenLayers-based viewer is built to allow Web data access. Besides proving the suitability of FOSS in the frame of VGI, the system represents a successful prototype for the exploitation of user local, real-time information aimed at managing and protecting water resources.

INTRODUCTION

An astonishing sequence of technical and technological developments has deeply affected the world of Web applications over the last decade. The advent of Web 2.0, a term successfully coined by O'Reilly [1], marked the birth of a new generation of dynamic Web applications with whom users could interact by creating and sharing their own contents (e.g. blogs, wikis, social networking sites, and media sharing sites). The most meaningful technological revolution of Web 2.0 was AJAX (Asynchronous JavaScript and XML) which enabled a smooth interaction with Web applications making them more and more similar to their desktop counterparts [2]. It was thanks to this technology that GeoWeb, i.e. the collection of services and data supporting the use of geographic information over the Internet [3], after only ten years from its birth [4] was accordingly renamed GeoWeb 2.0 [5]. Together with the diffusion of GPS receivers AJAX ushered in the era of neogeography [6], in which, in contrast to the traditional practices of map making (a prerogative of experts involving professional expertise and strictly-defined methods), mapping became a discipline within reach for anyone (even non-experts and untrained people).

This context offered the fruitful premises for what has been a crucial step in the history of GeoWeb, i.e. Volunteered Geographic Information or VGI. The concept was introduced [7] and explained [8] by Goodchild, who compared human beings to intelligent mobile sensors able to acquire geospatial information (e.g. placenames, topographic features and transport networks) which cannot be extracted neither from the collection of available maps nor from remote sensed images. Human sensory capacity can be dramatically enriched by a number of available mobile devices, particularly the common smart phones and tablets equipped with up to nine sensors including different transceivers (mobile network, WiFi, and Bluetooth), FM and GPS receivers, camera, accelerometer, digital compass and microphone.

A class of VGI activities which has gained much success is the so-called citizen science, i.e. the set of scientific activities in which non-professional scientists (i.e. amateurs) voluntarily participate in data collection, analysis and dissemination of a scientific project [9]. The growth of Web and GeoWeb 2.0 has enabled a new and successful dimension of citizen science, termed citizen cyberscience [10] and involving the use of computers, GPS receivers and mobile phones as scientific instruments. Citizen cyberscience can in turn be distinguished into: a) volunteered computing, which requires users to locally install some software, and use the Internet to receive data, automatically process and send them back to the main server; b) volunteered thinking, in which users are required to carry out some classification work on images or information that are presented in a website; and c) participatory sensing, which is centered on the high capabilities of modern mobile devices mentioned above.

Case study and motivation

This work presents a citizen cyberscience (specifically a participatory sensing) case study in the field of water management and protection. The project is the result of an ongoing collaboration between the Geomatics Laboratory of Politecnico di Milano, and AdbPo - Autorità di bacino del fiume Po (Po river basin Authority, http://www.adbpo.it), namely the Italian institution responsible for the environmental planning and protection of the hydrographic basin of river Po. This is the longest Italian river (652 km) and its basin is as well the largest one in Italy, spreading over eight among the twenty administrative regions on an area of about 74000 km^2, which in turn includes about 3200 municipalities, a population of almost 16 million inhabitants, and a highly heterogeneous territory characterized by complex environmental issues. Established in 1989, AdbPo is a mixed institution involving the State, the administrative regions, and all the institutional bodies concerned with protection, management, and development of Po river basin. Headquartered in Parma city, AdbPo pursues the mission of setting up interventions of integrated planning at the basin scale under four main objectives: a) protecting the hydro-geological system and the hydrographic network; b) safeguarding water bodies quality; c) rationalizing the use of water resources; and d) regulating land use.

The proposed citizen cyberscience application is intended to enlarge AdbPo consciousness of its territory through the collection and valorisation of the multiple local experiences and knowledge of all the individuals that either live or simply come across the territory of interest.

In detail, the application seeks to involve volunteers in using their mobile devices (e.g. tablets and smart phones) to report a range of both points of interest and problems/emergencies related to water management. The ideal recipients of the application should be not only the technicians of AdbPo and other water-related agencies, but also the general public.

Apart from allowing users to perform field-data collection, the purpose of the work is to build an integrated system able to automatically Web publish user-submitted data and make them accessible and queryable through an ad hoc Web viewer.

METHODOLOGY

To fulfil the objective stated above Free and Open Source Software (FOSS) has been used. This is software recognizing users the four essential freedoms of: a) running it for any purpose; b) modifying its source code; c) redistributing it; and d) distributing modified versions of it [11]. The implemented FOSS architecture showing all the packages used (distinguished in the server-side and the client-side) and the related functionalities is depicted in Figure 1.

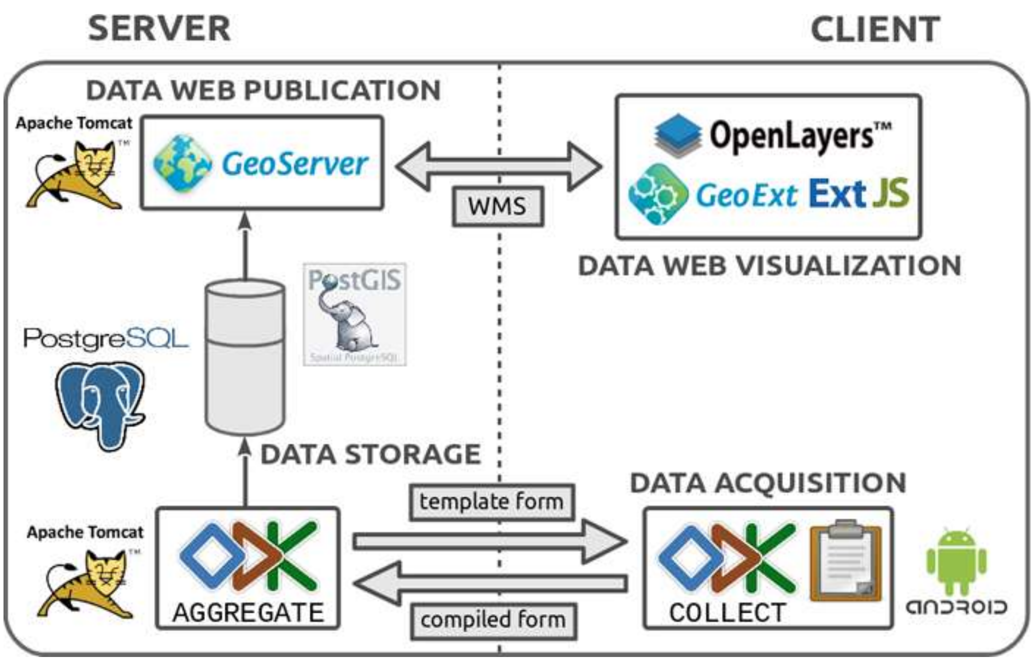

Figure 1. FOSS architecture of the citizen science system for water management.

Field-data collection was obtained with the Open Data Kit (ODK) suite (http://opendatakit.org). It includes a set of complementary modules for planning, performing and managing mobile data collection [12] and it makes use of the XForms open standard from W3C [13]. The initial step consisted in designing the form (i.e. the questionnaire) that users would have later exploited to collect data related to water management. This was achieved through the ODK XLSForm tool (http://opendatakit.org/use/xlsform), which allows to build complex forms with the aid of just a spreadsheet. Once created, the form was uploaded into the server-side module ODK Aggregate, that was installed under an Apache Tomcat server (http://tomcat.apache.org) and coupled with a PostgreSQL database (http://www.postgresql.org). Besides managing user profiles and the related permissions on data access, ODK Aggregate interacts with the ODK Collect Android application. Representing the client-side module of the suite, ODK Collect receives blank forms from, and provides compiled forms to the Aggregate server.

The designed form consists of the following fields: type of user, name of the user, place of the report, type of the water body, name of the water body, means of transportation to reach the water body, type of the water-related element to report, comment/reason of the report, position of the report, first and second picture of the element to report. Some of these questions provide multiple-choice options, which were defined in agreement with AdbPo: the available types of user are local inhabitant, tourist, occasional visitor, technician in the water field, and *other*; the available types of water bodies are river, lake, torrent, channel, spring, valley/lagoon, branch of the Po river delta, bag of the Po river delta, sea, and *other*; the available means of transportation are feet, bicycle, horse, car, boat, motorbike, and *other*; finally, water-related elements that can be reported are natural emergency, historical/architectural emergency, panorama, refreshment point, rest area, info point, interesting artifact, dockage, intersection with path/bicycle path, party, sports event, meeting, recreational area, problem/criticality, and *other*. The ODK Collect screenshots representing the form compilations related to these multiple-choice questions are shown in Figure 2. Conversely the user name, the place of the report, the name of the water body, and the comment/reason of the report have to be input as free texts. Finally, the location of the report is registered through one of the geolocation techniques available on the device (e.g. GPS, A-GPS [14] or WiFi positioning [15]), while the two pictures of the reported element can be either taken in real time using the device camera or uploaded from the device archive.

Figure 2. Screenshots of the ODK Collect application showing some steps of form compilation for reporting water-related elements.

Forms compiled by users are sent to ODK Aggregate and their contents are stored in the synchronized PostgreSQL database. Thanks to the PostGIS spatial extension (http://postgis.net), user reported data can be read by the spatial Web server GeoServer (http://geoserver.org) and published as a Web Map Service (WMS) layer. Finally a Web viewer was developed through the JavaScript libraries OpenLayers (http://openlayers.org), GeoExt (http://geoext.org), and Ext JS (http://www.sencha.com/products/extjs) which provides intuitive access and interaction with this WMS layer representing the reported water-related elements (see Figure 3). A number of base maps served by commercial providers (OpenStreetMap, Google, and Bing) can be used as background maps within the viewer. The layer showing the boundary of Po river basin (in blue) can be also turned on/off in the layer tree. The layer of water-related elements was properly styled through the SLD (Styled Layer Descriptor) standard [16] so that different icons (the same used also in the ODK Collect form) identify the different types of water-related elements. When a reported element is clicked, a WMS *GetFeatureInfo* request is performed and a popup shows the information originally entered by the user during form compilation. Map browsing within the Web viewer is finally aided by some ancillary OpenLayers controls placed in the bottom left corner of the map panel, i.e. a scalebar, an indicator of current map scale and a tool displaying the coordinates of the mouse pointer as it is moved about the map.

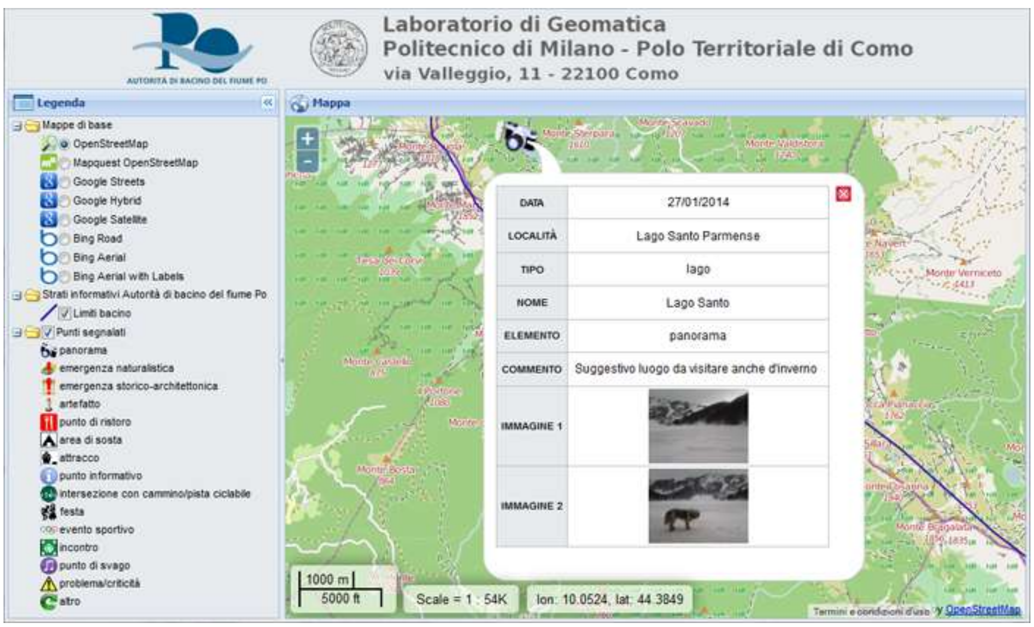

Figure 3. Web visualization and query of the water-related elements reported by users.

CONCLUSIONS

VGI, and specifically citizen science, has become a precious source of geospatial information in a number of disciplines including water management and protection. This research investigated the chance of leveraging mobile device technology to involve users in a citizen cyberscience activity aimed at collecting water-related phenomena and points of interest. A prototype FOSS architecture was built which manages user-generated data from its initial field-collection to its final Web publication and interaction. Jointly run with the AdbPo institution which is in charge of planning and protecting the basin of the Italian river Po, the project is presently at its early stage. The form for gathering data was designed in agreement with AdbPo, and the remaining architecture was set up afterwards. Up to now the system has been only tested by technicians of AdbPo in order to report possible issues from both the hardware and software perspectives. The next step is to extend its use to first involve the group of water-related agencies and operators with which AdbPo collaborates, and then to enlarge the recipients even to the general public.

A number of factors play a crucial role for the final success of citizen science activities and need thus to be carefully considered for the proposed application. First it is important to involve as much as possible the targeted users. This implies to both provide them with information and instructions on how to use the application (particularly the ODK Collect mobile application in the case study under consideration) and to promote the application itself [17]. Advertisement can be planned through the AdbPo website as well as other official websites, magazines, press and media relevant to the field of water, and it can also exploit the power of social networks and mapping parties. Data quality is finally a crucial element to take into account within any citizen science project. Besides positional accuracy, whose median values for current mobile devices are usually around 4-10 meters [18], other quality aspects of VGI data (e.g. logical consistency, semantic accuracy, temporal accuracy, completeness and up-to-dateness) still need to be further researched. Their potentially-high uncertainty must be thus always kept in mind when working with citizen science information.

REFERENCES

[1] O'Reilly T., "What is Web 2.0: Design patterns and business models for the next generation of software", (2005), available at http://oreilly.com/web2/archive/what-is-web-20.html (accessed: 2014-03-25).

[2] Zucker D. F., "What does AJAX mean for you?", *Interactions*, Vol. 14, No. 5, (2007), pp 10-12.

[3] Scharl A. and Tochtermann K. (eds.), "*The Geospatial Web: How Geo-browsers, Social Software and the Web 2.0 Are Shaping the Network Society",* London: Springer, (2007).

[4] Haklay M., Singleton A. and Parker C., "Web Mapping 2.0: The Neogeography of the GeoWeb", *Geography Compass*, Vol. 2, No. 6, (2008), pp 2011-2039.

[5] Maguire D. J., "GeoWeb 2.0 and volunteered GI", *Workshop on Volunteered Geographic Information*, Santa Barbara, CA, (2007), pp 104-106.

[6] Turner A., "*Introduction to neogeography",* Sebastopol, CA: O'Reilly Media, (2006).

[7] Goodchild M. F., "Citizens as sensors: the world of volunteered geography", *GeoJournal*, Vol. 69, No. 4, (2007), pp 211-221.

[8] Goodchild M. F., "Citizens as voluntary sensors: Spatial Data Infrastructure in the world of Web 2.0", *International Journal of Spatial Data Infrastructures Research*, Vol. 2, (2007), pp 24-32.

[9] Cohn J. P., "Citizen science: Can volunteers do real research?", *BioScience,* Vol. 58, No. 3, (2008), pp 192-197.

[10] Grey F., "Viewpoint: The age of citizen cyberscience", *CERN Courier*, April 29, (2009), available at http://cerncourier.com/cws/article/cern/38718 (accessed: 2014-03-21).
[11] GNU Project, "What is free software? The free software definition", (1996), available at http://www.gnu.org/philosophy/free-sw.en.html (accessed: 2014-03-25).
[12] Hartung C., Lerer A., Anokwa Y., Tseng C., Brunette W. and Borriello G., "Open Data Kit: Tools to build information services for developing regions", *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*, London, UK, (2010).
[13] World Wide Web Consortium, "XForms 1.1: W3C Recommendation 20 October 2009", (2009), available at http://www.w3.org/TR/xforms (accessed: 2014-03-28).
[14] Richton B., Vannucci G. and Wilkus S., "Assisted GPS for Wireless Phone Location—Technology and Standards", *Symposium on Next Generation Wireless Networks*, Newark, NJ, Berlin Heidelberg: Springer, (2002), pp 129-155.
[15] Zandbergen P. A., "Accuracy of iPhone locations: A comparison of assisted GPS, WiFi and cellular positioning", *Transactions in GIS*, Vol. 13, No. s1, (2009), pp 5-25.
[16] Open Geospatial Consortium, "Styled Layer Descriptor profile of the Web Map Service Implementation Specification", (2007), available at http://portal.opengeospatial.org/files/?artifact_id=22364 (accessed: 2014-03-29).
[17] Brovelli M. A., Minghini M. and Zamboni G., "Public Participation GIS: a FOSS architecture enabling field-data collection", *International Journal of Digital Earth*, ahead of print, (2014), pp 1-19, doi: 10.1080/17538947.2014.887150.
[18] Minghini M., "*Multi-dimensional GeoWeb platforms for citizen science and civic engagement applications*", PhD thesis, Politecnico di Milano (Italy), (2014).