Geo-fence driven crowd-sourcing for Emergencies

Suvodeep Mazumdar
Department of Computer Science,
University of Sheffield,
s.mazumdar@sheffield.ac.uk

Stuart N. Wrigley
Department of Computer Science,
University of Sheffield,
s.wrigley@sheffield.ac.uk

Neil Ireson
Department of Computer Science,
University of Sheffield,
n.ireson@sheffield.ac.uk

Fabio Ciravegna
Department of Computer Science,
University of Sheffield,
f.ciravegna@sheffield.ac.uk

ABSTRACT

For some emergency situations an effective response can be reliant on sensor data (e.g. river level, traffic flow, weather conditions) to provide situation awareness, in order to help authorities make informed decisions. Gathering data in a traditional approach, i.e. using precise physical sensors, is a highly expensive task, involving procurement, installation and maintenance of a number of sensors. As a result, the coverage of sensors is limited and only the regions deemed most important by authorities are monitored. However, regions currently not being monitored can have an urgent need to be sensed depending on emergencies or situations. We present a high-level overview of the Locaware system, which employs a flexible geofencing approach to enable crowdsourcing by requesting citizens and volunteers to help authorities formulate a greater situation awareness of a region under consideration. While the Locaware system is motivated for water monitoring, our approach can be applied in other contexts.

Keywords

Geofence, situation awareness, emergency management, crowd sourcing.

INTRODUCTION

The deployment of physical sensors to provide comprehensive coverage across a geographical region, including both cities and rural areas, is a highly challenging task. In order to ensure the accurate and consistent coverage of sensor information, highly precise and 'always on' sensors need to be distributed across a region, feeding live information to information systems that analysts and authorities rely on to develop a good situation awareness (Endsley, 1995). This requires a large number of high quality sensors deployed across locations automatically feeding live data, which is a highly expensive process. Automated processes such as these often rely on engineers to install expensive equipment and maintain them regularly. The task is significantly more difficult during emergencies, where critical information is urgently needed at locations where sensors may not have been deployed earlier. Employing citizens and local volunteers as sources of information in such situations can provide authorities with access to essential information (Boulos et. al, 2011). The essence of our work lies in harnessing the power of crowdsourcing and enabling citizens and communities to contribute towards building a clear picture of an evolving situation, or even their local environment. As a part of the WeSenseIt[1] project, we focus our work in particular on water-related environmental issues such as flooding and water quality. In light of these motivations, we present the Locaware system, which is developed in the project for authorities to generate geofences based on their information requirements. A geofence represents a virtual perimeter

[1] http://wesenseit.eu/

for a real-world geographic region (Namiot, 2013). This enables communities to respond to evolving information requests depending on the geofenced areas in which they are present. Geofencing has been employed to different applications earlier such as advertisements (Earley, 2014; Butcher, 2011), location-based reminder services (Ludford et. al., 2006), telematics and vehicle routing (Reclus and Drouard, 2009; Schneider, Dreher and Seidel, 2008) and so on. The use of geofencing in emergency and disaster management has also been explored recently (Szczytowski, 2014). However, mostly to monitor the flow of people entering and exiting 'at-risk' geofences and coordinate rescue efforts. In our approach, the geofences are deployed in real time during emergencies as well as typical periods in regions deprived of sensors (or where sensors are temporarily unavailable). We do not limit our approach only to disasters or emergencies, but also consider scenarios during typical times where authorities may want to monitor a location to improve their situation awareness and be aware of impending disasters. Citizens and volunteers can contribute by sending sensor readings, video, audio or images to help authorities build an understanding of a region.

REQUIREMENTS

Focus groups and interviews with authorities, citizens, volunteers and decision makers from three cities helped us initially identify several requirements. The logistical issues surrounding the installation of large number of high-quality sensors across large geographical regions pose a significant challenge to authorities. Hence, the primary motivation for our solution is a highly cost-effective approach. This also stems from the need to significantly reduce expert time on the ground, particularly for maintenance and installation of high quality sensors. Analog sensors (such as gauge boards for water and snow levels, Figure 1, are highly affordable and simple alternatives for water and snow level sensors and can be distributed across large regions to cover a greater area – citizens and volunteers can contribute by sending observations from such gauges. Providing images and videos of relevant areas upon request would also provide an excellent alternative for authorities when an urgent need arises. Three main requirements were identified:

Figure 2 Analog gauge board examples

1) The primary requirement would be to provide an inexpensive and affordable mechanism for citizens to collaborate with authorities to upload sensor readings and media along with other user generated content.

2) The next most important requirement is to provide mechanisms for authorities to shift their focus on to new areas as an event is evolving, and communicate this current information need to citizens. While sensors are deployed only in regions deemed most important to monitor, during widespread or highly dynamic situations the ability to shift attention to new, unmonitored areas is reported as an important requirement. This allows a decision-maker to keep track of evolving situations across

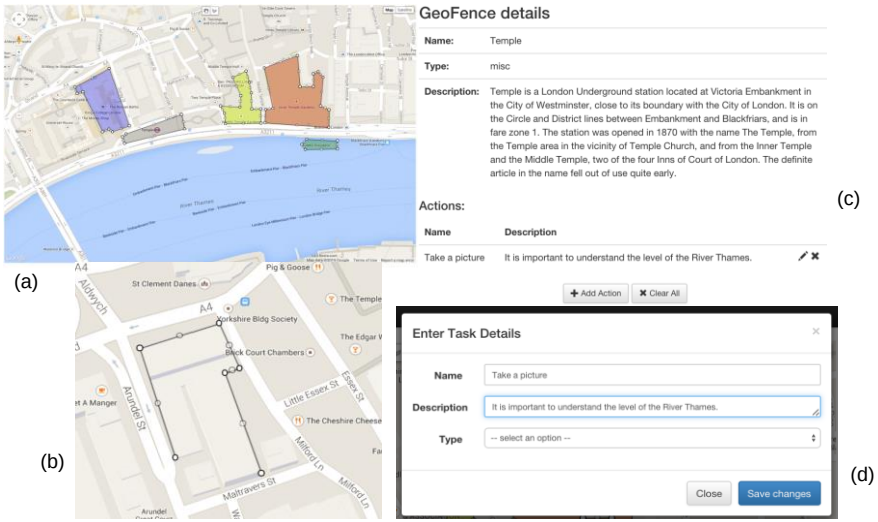

Figure 1 Boundary manager – (a) the initial view for authorities displaying the different types of geofences; (b) creating a new geofence; (c) list of respective actions for a geofence; (d) creating a new action (task)

different geographical locations.

3) The need for a flexible system, deployable across various authorities was identified as the third most important requirement. Therefore the system must be able to provide authorities and citizens with usable, intuitive and efficient means of generating geofences and communication.

SOLUTION

The Locaware system is comprised of two major components: a geofence managing service and a mobile app. Each component is described as follows:

Geofence Manager for Authorities

The backbone of our solution is the geofence manager, which provides authorities with means to generate geofences. The authorities can access a web service and are presented with a geographical map of the locations of their operation. The users can then either view the existing geofences or create new ones. The Figure 2 (a) shows a screenshot of the application from the perspective of the authorities, when they load an initial set of geofences that had previously been created, with each type of geofence being color-coded based on its type. Geofences can be of several types: danger, warning, artefact, poi and misc. Authorities tag geofences as either of these types, to indicate the associated action for the respective geofence.

- **danger** geofences represents a *'no-go'* area, where a citizen would be alerted if they enter a region deemed to be too risky by the authorities. Upon entering such geofences, citizens would be provided with further information on the areas to avoid and the safe zones.
- **warning** geofences alerts citizens of an impending danger, and provides them with further information on how they could prepare themselves and what actions they could take to help authorities (e.g. click a picture/record a video of a river bank).
- **artefact** geofences relates to a region that hosts sensor (e.g. which could be an analog water gauge or a snow-level sensor that may have failed to upload readings) that is in the vicinity of a citizen and can be accessed for a recent reading. In such cases, citizens can be provided with precise locations of the individual sensors (and navigation directions) along with directions of the action that is requested.
- **poi** geofences mark areas that can be of interest, such as historical areas, new developments and projects, areas of social activities such as festivals and so on. The citizens are provided with a description of the areas for their interest and also popular tourist spots. Such regions are mostly not important for emergency response scenarios, but help provide users with interesting information about the region surrounding them.
- **misc** geofences consist of any other types that have not been categorized or identified yet. These are provided in case a scenario arises where authorities are unsure of how a geofence can be typed. We believe the possible types of geofences will be updated after periodic reviews of the 'misc' type.

Geofences can be created by click-and-drag gestures on precise positions on a map by authorities (Figure 2 (b)). Upon defining a region, the user is provided by a pop-up form that requests details of the geofence (e.g. name, type and description). Future versions of the system will prompt authorities for another detail, period of validity. We believe this is an important feature, particularly for authorities who are aware of regions that can be significant at a particular time in the future (or even regions that will cease to be important after a particular event). When a geofence is created, users can then create the respective actions, which includes (for the first implementation) taking a picture, recording an audio/video, send a sensor reading and 'any other action'. The 'any other action', similar to 'misc' geofences provides a way for authorities to request a type of action that has not been categorized yet. The present version of the Locaware system provides only three categories, while leaving 'any other action' as an open option, which will periodically be reviewed to add new categories. Creation of new actions is done by clicking the 'Add Action' button (Figure 2 (c)), which loads a popup prompting for name, type and description of a the action (Figure 2 (d)).

Mobile App for citizens

Currently volunteers involved in the evaluation exercises are provided with the Locaware app, which we manually install on Android and iOS phones. The app will be made more widely available to citizens via Google Play and App Store in the future, once an initial evaluation has been conducted. The mobile app provides the citizens with means to communicate with the authorities and contribute with sensor readings and act as a source of information. Additionally, the app provides users with important information that authorities would like to relay to citizens. For example, during an emergency (e.g. floods) the app would act as an additional source of information and an alerting mechanism if a citizen happens to 'wander' to an area deemed to be high-risk by authorities.

Figure 3: The Locaware app, left – a notification a user gets when they arrive at a point of interest and an action is requested; right: an action request to provide a picture of a location

The mobile app initialises by downloading a 'compressed' list of geofences and actions, based on user preferences (such as 'show only actions which require me to take a photo' or 'show me only actions that need a sensor reading' etc.). Communication overhead is minimal as 100 geofences are typically described in less than 30Kb. Currently, all geofences are downloaded (apart from the ones filtered out by the user) – however, in the future we will investigate on selectively downloading geofences that are within a particular range of distance (e.g. 1, 10 or 100 miles around the users present location). We must also consider the situation where users may choose to visit a new geographical location the next day, and may want to pre-download the geofence data relevant to the areas they visit. This list is locally stored and periodically refreshed depending on the user's choice of refresh rate (e.g. users can choose to download geofences every few hours/days or whenever connected to a WiFi access point). If the updates are not automatic then users are requested to ensure the app refreshes regularly to be updated with the latest geofences. The app runs in the background, periodically comparing the user's location with the list of available geofences. Upon entering a geofence, the user is prompted for the action that is requested by the authorities. The user can choose to ignore or act upon the request and provide authorities with the information they request.

Data processing

All data and metadata submitted by citizens are processed according to the type of data. Exif metadata, if available, is extracted from uploaded images. Named-Entities (e.g. locations, organization names, etc.) are extracted from text entries such as free-text comments accompanied with forms submitted by users. Sensor readings are validated (based on comparison with expected values and acceptable ranges). The data is stored in a searchable triplestore, as well as transmitted to the WeSenseIt project sensor service. Authorities then use the information stored, and further investigations (or requests) can be initiated if necessary.

Dealing with network performance issues

The Locaware system is designed to be used in cases where users are out of the reach of a data network. Analog sensors like rain and snow gauges, and river level gauges can often be installed in areas that are not covered by data networks. Citizens, who are present in such locations would still be receiving notifications for requests as the pre-loaded list of geofences would be locally cached within the app. Acting upon the request would cache the user's sensor readings, recorded media and so on along with timestamp of the reading and all relevant metadata. This information is then transmitted at the earliest instance a data connection is available. It is also important to note the necessity for regularly updating

geofences as it provides up-to-date information for citizens. As a result, if lack of connection means the geofences have not been updated for a certain period (determined by the authorities) users are advised to take precaution when they are in the area, since the actions they are responding to may be outdated.

Continued Community Effort in the Longer Term

One of the key challenges for the success of the Locaware system (or any crowd-sourcing effort) has always been ensuring the continued participation of the citizens. Using the Locaware system, we aim to motivate citizens and volunteers to use the system as a part of their regular activities to ensure they have a vested interest in continuing to use the service. We are currently exploring how we can employ a two-fold approach where the system serves as (i) a localized information hub and (ii) a social platform for direct interaction with authorities and co-citizens. Localized information provided to users (based on their present geo-fences) could comprise of various types: entertainment, news, warnings, alerts and information. The kind of information being delivered to a user would depend on their explicit personal preferences or their evolving interest collected over a period of time. On the other hand, the Locaware service, via the mobile sensing/crowd-sourcing approach can also provide means for citizens to contact authorities (as presented in this paper). In addition, citizens can be provided with means to connect to individuals within their social circles (via their Social Media channels) that are also present in their current geo-fence. Exploring the social aspect further, we are also investigating how we can employ and incorporate features such as recognizing citizens who have been active contributors to the system by awarding them with badges and roles (such as 'care-taker' of River X, Sensor Y), eventually envisioning scenarios where citizens could competitively participate to win badges as employed by several existing services such as Foursquare. We are also exploring how authorities and service providers can motivate citizens by providing small financial incentives. Finally, we are also investigating how communities, volunteer and citizen groups (such as runners, flood wardens, nature groups etc.) can be provided with financial benefits to provide information in areas where volunteers are sparse.

USER EVALUATION

The Locaware system presented in this paper is now in its final stages of technical development. Based on initial discussions with the authorities and use cases at the WeSenseIt project, several decisions have been taken that attempts to mitigate some of the possible issues and risks highlighted. We plan to start initial evaluations in the next few weeks, with a larger evaluation scheduled within six months. The first evaluation will be focused on usability and user satisfaction for the geofence manager and Locaware app, as well as understand how seamless the various processes of the system are (e.g. adding new geofences in the geofence manager, creating actions, mobile notifications, performing activities etc.). Feedback from the evaluation would be analysed to improve the system for the next version, before the larger evaluation in six months. The evaluation would be designed to fit a scenario within Sheffield, UK, which could involve either students or local residents in a simulated game-based scenario. One of the scenarios is a 'treasure-hunt' game where users (or groups of users) would be given clues (upon entering a particular geofence) to go to the next geofence, eventually reaching a specific geofence where the game would conclude. QR codes located in each geofence would provide a way for each participant to 'register' either a sensor reading or upload an image. The time required for the completion of the game, user interaction logs generated from the app and geofence manager, screen recordings, in-person interviews, user feedback and focus groups would provide the data for analysis. The next evaluation is planned to include emergency services personnel from several authorities who are a part of the WeSenseIt project, with the app being distributed within a citizen volunteer group in a simulated exercise. The objective of this evaluation would be to understand how the system would perform in a realistic scenario.

REFERENCES

1. Endsley, M. R. (1995) Toward a theory of situation awareness in dynamic systems: Situation awareness. Human factors 37, 1

2. Reclus, F., & Drouard, K. (2009). Geofencing for fleet & freight management. In Intelligent Transport Systems Telecommunications,(ITST), 2009 9th International Conference on (pp. 353-356). IEEE.
3. Schneider, G., Dreher, B., & Seidel, O. (2008). Using GeoFencing as a means to support flexible real time applications for delivery services. In 5th International Workshop on Ubiquitous Computing (IWUC-2008). Barcelona, Spain.
4. Earley, S., "Mobile Commerce: A Broader Perspective," IT Professional , vol.16, no.3, pp.61,65, May-June 2014
5. Butcher, D. (2011). Location-based marketing can increase average order value, frequency, loyalty. Mobile Commerce Daily.
6. Pamela J. Ludford, Dan Frankowski, Ken Reily, Kurt Wilms, and Loren Terveen. 2006. Because I carry my cell phone anyway: functional location-based reminder applications. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06), Rebecca Grinter, Thomas Rodden, Paul Aoki, Ed Cutrell, Robin Jeffries, and Gary Olson (Eds.). ACM, New York, NY, USA, 889-898.
7. Boulos, M. N. K., Resch, B., Crowley, D. N., Breslin, J. G., Sohn, G., Burtner, R., ... & Chuang, K. Y. S. (2011). Crowdsourcing, citizen sensing and sensor web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples. International journal of health geographics, 10(1), 67.
8. Szczytowski, P. (2014). Geo-fencing based Disaster Management Service. ASE Stanford University Conference International Workshop SMARTLIFE 2014 & CLOUDCOM 2014, May 2014
9. Namiot, D. (2013). GeoFence services. International Journal of Open Information Technologies, 1(9), 30-33.