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International Journal of Spatial Data Infrastructures Research, 2018, Vol.13, 101-108
Special Section: Citizen Data Science

Harnessing Location-based Services for Effective Citizen Observatories*

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Abstract

The essence of a city is its citizens and communities. A city's infrastructure and associated services play a vital role in citizens' day-to-day living and their overall quality of life. Traditionally, services are deployed in a top-down approach where authorities, councils and public bodies take a reactive approach to address community needs and concerns. In this paper, we propose our 'Citizen Observatory' approach to enable citizens to take a proactive role in the management of their local communities and environment by supporting their engagement in the decision-making process. We discuss how to empower citizens and communities to engage with and assist authorities to establish a more informed understanding of residents' needs and the status of their local environments. Through the WeSenseIt project, we employ a location-based crowdsourcing and communication strategy to develop a resilient, efficient and collaborative information ecosystem for decision-making in urban and rural areas.

Keywords: Citizen Observatories, Geofencing, Crowdsourcing

** After completing the work that is presented in this paper, the affiliation of Suvodeep Mazumdar changed to Sheffield Hallam University, UK (e-mail: S.Mazumdar@shu.ac.uk).

DOI: 10.2902/1725-0463.2018.13.art10

1. INTRODUCTION

Citizens and communities are traditionally considered as merely `passive' consumers of services at the very end of the information chain. In an ever-changing technological landscape this view is, however, continuously challenged. Citizens and communities demand and expect newer forms of communication and democratic processes to aid further engagement with policy makers. While there is a greater need for transparency, engagement, collaboration and information sharing, traditional approaches are increasingly unable to address such expectations (Conrad, 2011). We address this gap by employing Information and Communications Technologies (ICT) to enable new forms of interaction, knowledge exchange and participation of the general public, decision-makers and experts. This creates a shift from a traditional one-way communication paradigm (where organisations gather information from internal or trusted sources and communicate this to citizens) towards a two-way collaborative environment (citizens become active members with respect to the provision of information and authorities have a duty to consider, respond and react to citizens' communications). Informal social networks and Web 2.0 technologies have already facilitated wide scale adoption of crowdsourcing where citizens act as information providers across a broad range of domains from collaborative traffic and navigation to environment monitoring (Heipke, 2010). The proliferation of Web 2.0 services and applications, along with 'always-connected' mobile technology, has paved the way for highly successful crowdsourcing-based knowledge creation ventures. Wikipedia, Flickr and OpenStreetMap serve as excellent real-world examples where crowdsourcing has provided an immense wealth of information to be used by organisations and communities worldwide. In fact, most popular websites, such as TripAdvisor, Amazon, eBay and other ecommerce platforms, exploit the potential of crowdsourced data to provide customers with a greater understanding of the value of the purchases they intend to make. While such ventures have been proven to be highly successful in websites and applications, employing crowdsourcing for city-scale planning and policy-making is a more complex process.

In the WeSenseIt project, we employ various forms of crowdsourcing techniques designed to empower and foster participation. Our objective is to create a highly enriched, real-time knowledge base to aid decision-making processes focused around water and flood management. Our approach facilitates citizen cooperation, engagement and participation in various forms of decision-making. We term this framework from a holistic point of view as a `Citizen Observatory' (CO). While several definitions exist, we formally define a citizen observatory as ``a method, an environment and an infrastructure supporting an information ecosystem for communities and citizens, as well as emergency operators and policymakers, for discussion, monitoring and intervention on situations, places and events'' (Ciravegna et al., 2013). COs are enormous resources for data collection and classification at a granularity and frequency that is unreachable with traditional methods. The majority of CO and citizen science projects stem from scientists and authorities that have strong organisational support. Research has shown that crowdsourced data can equal or even exceed that produced by professionals

(Zaidan et al., 2011). COs are emerging as a means to establish interaction and co-participation between citizens and authorities during day-to-day management of fundamental resources (Lanfranchi et al, 2014).

This paper presents how the WeSesenseIt project employs crowdsourcing to gather information from sensors and citizens. Additionally, we present our location-based geofencing approach to solicit and share information. In our implementation, a geofence is a virtual, enclosed area (bounded by a regular or irregular polygon), which, when entered, triggers an alert on a citizen's mobile device. The alert informs citizens of potential hazards or encourages them to seek local information, media or data.

2. SENSING THE PULSE OF THE CITY: THE WESENSEIT APPROACH

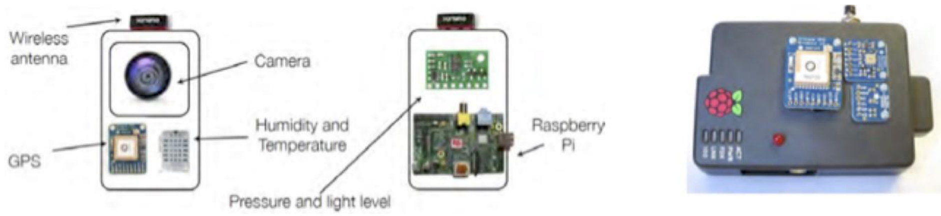
Our Citizen Observatory model incorporates two layers of sensing to enable authorities to gain a multifaceted insight into the city: a hard layer and a soft layer. The hard layer includes static and portable devices and sensors that sense physically quantifiable parameters such as water levels, soil moisture, occupancy etc. These devices are either installed as professional sensing equipment in weather stations or observation points or built into portable devices controlled by or resident within citizens' mobiles or tablets (e.g. pervasive sensing). The soft layer aims at harnessing the `collective intelligence' of citizens; this is gathered from purpose-built mobile and web-based applications and harvested from social networking platforms (e.g. social sensing) and the wider web. The ability to `listen' to citizens is the first step in developing a collaborative framework for a citizen-centric smart city. The soft layer also provides `hard data,' where citizens can provide raw readings as observed from a sensor (e.g. the room temperature, as read from an analog unit). The hard and soft layers complement (and correlate with) each other, providing two different views on an observed phenomenon. As a result, this provides a greater understanding of the spatial and temporal evolution of human behaviour based on various observed phenomena.

2.1. The Hard Layer

Two main types of sensors dominate the hard layer: professional sensors and pervasive sensors. In our approach, the hard layer provides data about phenomena that are measurable and quantifiable. Examples of such devices are weather stations measuring wind speed, wind direction, precipitation etc. The professional sensors are high quality and high precision sensors installed at very few locations across cities. While in an ideal scenario such sensors should be highly distributed within the city area, the high costs are often prohibitive. Such sensors are therefore installed sparsely across large geographical spaces, in high priority locations as defined by authorities. Pervasive sensors, on the other hand, are more economically viable, but at the cost of reduced quality and precision. Despite the lower precision and data quality, a large number of pervasive sensors can be deployed by authorities and citizens that can provide a highly granular set of data. The high coverage of the sensors, viewed in unison, can provide significant insight into the phenomena under consideration. The hard layer therefore consists of:

- A set of traditional, professional-grade sensors and weather stations designed and installed for remote sensing of physical variables. These are installed in high priority locations, providing a stream of high quality data.
- A set of innovative low-cost sensors (Figure 1) for reading a variety of phenomena and physical variables such as water levels. These sensors are available as pre-installed, pre-programmed units or as design plans. Enthusiasts can use the design plans to build their own sensors with readily available software. Citizens can then install such sensors in their own premises and start providing data to the platform[1].

Figure 1: Examples of low-cost sensors provided to citizens for installation. Image from Lanfranchi et al. 2014



2.2. The Soft Layer

The soft layer aims to generate data directly from citizens' activity. Based on the amount of activity, there are two types of soft layer sensing: active and passive. Active sensing requires citizens to actively provide direct feedback on topics of interest. Authorities can contact citizens and request that they provide specific information. One of the most well-known examples is the FixMyStreet app, where citizens can submit a geo-located form to report issues such as street cleaning, lighting issues, etc. On the other hand, passive sensing provides a means to understand the user's opinions and perceptions based on their activity elsewhere. For example, when a user comments on social media that they are upset due to a late bus, those comments provide feedback on the operation of that bus service, even though the intent was simply to express disappointment and frustration regarding the delay. The soft layer consists of:

- A set of mobile applications that support communication and information sharing. Citizens can receive critical information and alerts to be informed of situations around them. They can also provide physical readings of sensors or observations. The applications also provide citizens with a means to comment, report or highlight their concerns.

- A set of social media analytics technologies. These tools reside in the background and can be used in multiple ways: proactively seeking information related to critical issues reported by citizens or trigger alerts when urgent scenarios emerge (e.g. reports of earthquakes or house fires in neighbourhoods).

[1] An excellent example of such initiatives is the senseBox project http://www.sensebox.de/

Figure 2: Examples of analog gauge boards

3. GEOFENCE-DRIVEN CROWDSOURCING

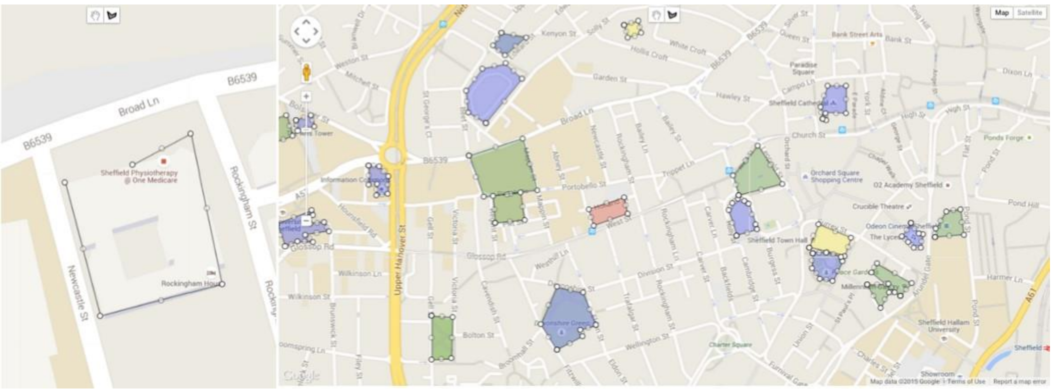
Professional and pervasive sensing technologies provide a large amount of information on areas covered by sensors. The sensors are largely limited to static locations pre-determined by authorities or citizens based on an information need or citizen-interest. Despite the availability of cheaper sensors, obtaining higher levels of coverage in a large geographical area is still a highly complex and expensive process. This is primarily due to the fact that such sensors require maintenance (i.e. batteries, occasional restarts, vandalism, herds/cattle disturbing alignments etc.), particularly if installed in open spaces as opposed to private property under the supervision of a citizen.

In a city-wide infrastructure, authorities are challenged with dynamic scenarios every day, and this creates an urgent need for a broad network of sensors. For example, large-scale events organised in cities create massive movement of citizens across various areas. Daily commuting activities also produce wide variability in mobility where citizens travel to/from work at different/fixed times every day. Emergencies such as floods and fires require real-time understanding of evolving situations; heavy rain in neighbouring areas, tidal forces, sustained periods of rains, flood plains overflowing etc. have different impacts on locations. In such cases, the area of interest changes dynamically and rapidly; however, these newly-created areas of interest are not well-covered by existing sensor networks and hence authorities remain poorly informed regarding a rapidly evolving event in a 'dark-spot'.

It is common for authorities to install low-cost analog sensing devices in a large number of locations (Figure 2); for example, rain/snow gauge boards, wind speed devices, etc. However, the issue with such units is that they are `dumb': they cannot transmit data autonomously and therefore require manual intervention to communicate their readings to help authorities understand local conditions. In a period of budget cuts and, in turn, reduced staff at government organizations, it is increasingly common for authorities not to have the resources (e.g., staff numbers) to send employees to read and record the values of such analog sensing devices.

In urban environments, a large majority of locations are covered by citizens and communities. We aim to exploit this by empowering citizens with crowdsourcing techniques to expand to new regions as and when a demand for information is established. This provides authorities with a better understanding of new regions, supported by a collaborative partnership with citizens. Citizens can contribute significantly by acting as the `eyes and ears on the ground'. They can directly inform authorities of the analog sensor values, send an image or video, or stream audio/video to control units etc. We describe our approach (Mazumdar et al., 2014) from two perspectives:

Figure 3: Creating Geofences (left) using mouse gestures to define boundaries. Colour-coded geofences for different related tasks (right): red indicating danger, green indicating points of interest, blue indicating areas with analog sensors.



3.1. Geofence Generation

Upon identifying the need for information related to a specific region in the city, the authorities create a geofence by drawing a polygon on a map. This prompts authorities to define the kind of geofence (area of interest, danger area, safe area, historical, etc.) the area represents. Authorities can further declare tasks and actions associated with each geofence, with a period of validity. Upon completion of the geofence definition, authorities can view the different types of geofences they have created and can finally publish them. Figure 3 shows a resulting screenshot of a geofenced region. The image on the left of Figure 3 shows a user defining an area of interest (in this case, a building) by drawing a polygon on a map. Upon completing the polygon, the user provides further details of the geofence (name, description, type, associated actions). The various geofences are then colour-coded to quickly help interpret the various types of geofences.

Red geofences represent unsafe zones and are marked as danger areas: in an emergency, such areas should be avoided by citizens. Blue areas represent areas where analog sensors are installed: citizens can provide data from these areas. Yellow areas indicate areas that are of historical significance. These categories of regions are often evolving and vary across different cities, scenarios and needs.

3.2. Citizen Response

Citizens are provided with mobile device applications that run in the background. These applications are a part of our typical `soft layer' of data collection which citizens can use to communicate with authorities. The `always-on' facility of the applications make timely queries to the geofencing services to understand if the citizen is present in a particular location. Upon entering a geofenced area, the device triggers an alert/notification. The citizen can choose to ignore or respond to the alerts accordingly. A variety of alerts are made available to citizens, based on their needs and the needs of the situation. For example, upon entering a danger area, a citizen is provided with a different alert than they would receive if they entered a historically significant area. In the case of the former, an alert like a notification message, vibration and sound would be more useful, while a simple popup to indicate an interesting `story' would be sufficient for the latter. Depending on their level of interest, users can manage notifications and alerts. If the citizen chooses to respond to the alerts, a variety of possible combinations are proposed based on the needs of authorities. Citizens can merely respond with a video/image of their surroundings. Alternatively, citizens could respond with an audio recording of what they can hear in their present location. Users can also provide analog sensor readings, if needed, by observing analog sensing devices, typing the value into the app and submitting their report. Once the citizen responds to the notification, authorities are immediately updated.

4. REAL-TIME ANALYSIS OF CROWDSOURCED DATA

While gathering large volumes of data is a significant challenge, it is only one aspect of a citizen-authority information processing workflow. Massive streams of data arriving from a variety of users, data providers, and sensors need to be processed in real-time to provide authorities with updated information. This is a critical need, since some scenarios may need the urgent attention of authorities (e.g. emergencies). We approach this by conducting multi-level analyses on different streams of data. Real-time sensor data are processed to be stored immediately in large datastores, which are then subsequently used by analytics modules (e.g. visualisations and real-time monitoring systems). Citizen-generated data, on the other hand, is processed based on their type. Named entities (locations, organisations, identities, names etc.) are extracted automatically from text entries such as comments, social media messages and form data. Sensor readings submitted by citizens are validated and stored in sensor data stores. Exif[2] data from images is extracted to provide further metadata. Images are also tagged with any additional information that a citizen provides to complement their observation. All information is stored in datastores, indexed and available to be quickly retrieved when needed.

5. CONCLUSIONS AND FUTURE WORK

In this paper, we presented the two-layered approach adopted in the WeSenseIt project to gather data from physical and social sensors. We also presented our location-based geofencing approach that is aimed at soliciting and communicating critical information based on a user's location. Finally, we presented how the collected crowdsourced information is analysed to help decision makers and

[2] Exchangeable image file format, https://en.wikipedia.org/wiki/Exif, Accessed 08.03.2018

authorities make critical decisions. The WeSenseIt project is in its final stages and at the time of writing this paper, has just entered into its final evaluation phase. These technologies will be evaluated over the next few months in several exercises across Europe. Future planned studies also include an evaluation of the geofencing approach with a non-geofence based approach in a comparative setting.

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