Citizen observatories for effective Earth observations: the WeSenseIt Approach

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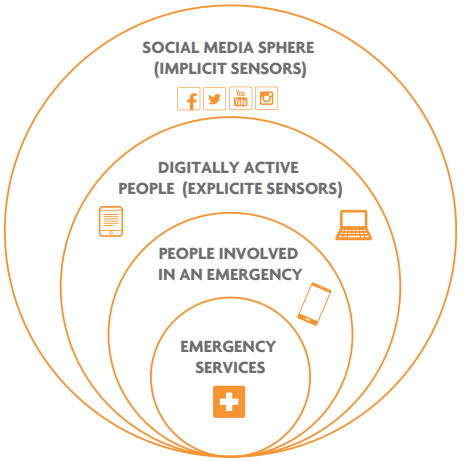
The WeSenseIt project defines citizen observatories as "A method, an environment and an infrastructure supporting an information ecosystem for communities and citizens, as well as emergency operators and policymakers, for discussion, monitoring and intervention on situations, places and events"[1]. A collaborative approach has been taken to develop solutions that involve an exchange of information and expertise from all participants and where the focus is on arriving at practical solutions with a clear vision and direction. This has created a shared ownership scheme, and shifts power to the process itself rather than remaining within authorities, developers or decision-makers[2]. The project's emphasis is on delivering highly innovative technologies to support citizens, communities and authorities in developing a real-time situation awareness while ensuring all stakeholders play their part. Implementation has been through a combination of crowdsourcing, custom applications and dedicated web portals designed to foster collaboration, and which has created a shared knowledge base that facilitates decision-making processes and engages with communities. Data is captured via innovative sensors that are used directly by citizens and crowdsourcing from social networks (or by collective intelligence). We illustrate the different players and stakeholders in **Figure 1.**

The concentric circles in **Figure 1** indicate the different types of information that are collected and shared[3]. Among each concentric circle, a variety of stakeholders are indicated - emergency services, people involved in an emergency, explicit sensors (people actively contributing information via mobile and online systems through participatory crowdsourcing), and implicit sensors (people sharing information via social media, opportunistically crowdsourced to identify critical relevant information). A variety of applications and systems have been developed in the project to address each type of information need and stakeholder.

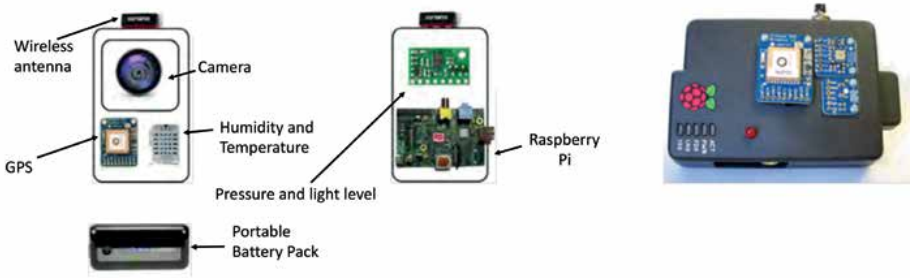


▲ **Figure 1. The WeSenseIt Citizens' Observatory Model**

CITIZENS AS SENSORS

Real-time high quality sensors provide "live" ground information on the current environmental conditions of a locality, and hence are critical to the understanding of areas of interest. Data from sensors are processed in a variety of ways and made available to decision makers as visualisations, predictive analyses or real-time alerts and triggers. All of these approaches together help inform decision makers of the existing and predicted conditions at specific locations. High precision sensors are highly expensive, need constant maintenance and are static, but can provide high volumes of data regarding areas that have been previously determined to be of interest. However, with the rapidly evolving environmental conditions and landscapes, critical areas of interest can be dynamic and different areas in cities can be of interest at different times. This challenge has been addressed by the development and deployment of low-cost sensor technology, as well as maintaining communication between citizens and the authorities.

A variety of information can be provided by citizens and key to their participatory role is the large scale installation of low cost analogue devices across wide geographical areas. Examples of such devices are water depth gauge boards and snow depth gauge boards, which need to be manually 'read' by counting clear numerical markings on the boards. They are relatively cheap to manufacture, require very little maintenance and can be installed at a large number of locations such as, rivers, canals, locks, waterways and so on. Citizens can quickly visually read the gauge boards and provide the information to the authorities via a smartphone or desktop application (app). In addition to the visual observation of analogue sensors, the WeSenseIt project has also developed several low cost electronic sensors using Raspberry Pi and Arduino platforms. These have been developed as small mobile devices which can provide data on local air temperature, barometric pressure, light levels as well as estimating water course flow rate **(Figure 2)**. The devices are lightweight, portable, easy to adapt and flexible, and the data collected is periodically transmitted to the WeSenseIt data hub. A variety of user communities can use such sensors and citizen scientists, hobbyists and enthusiasts can build their own sensors using technical details provided by the project. A large number of sensors have also been distributed to volunteer flood wardens.



▲ **Figure 2. A Raspberry Pi sensor for water flow and depth: the schema (left) and the actual sensor (right) that are used by hobbyists, enthusiasts, and citizen scientists.**

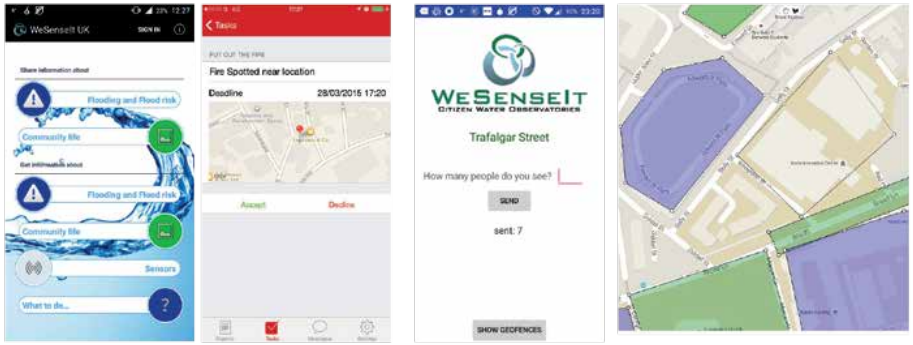
CITIZEN TECHNOLOGIES FOR DATA COLLECTION

Citizens and communities participate in two ways; explicitly by providing information via mobile and online portals that were developed in the project, and implicitly by using social media platforms, opportunistically sourced to provide an assessment of evolving situations. Explicit data collection is undertaken by participatory sensing, where citizens are encouraged to report if they observe anything of relevance. Two dedicated WeSenseIt mobile applications have been developed during the lifetime of the project, which have been provided to citizens and to community volunteers (for example, civil protection volunteers). While conducting their daily activities, a citizen or a volunteer can inform authorities of any concern and can transmit the information via the smartphone app (**Figure 3** left), which is submitted to the WeSenseIt data hub. At the same time, owing to evolving situations, if decision makers identify locations that are of interest (for example, reports of a river being flooded or roadways disrupted), they can highlight such areas (geofences) on an online interface (**Figure 3** right), which is automatically fed into the smartphone app[4]. Upon entering any of such geofences, a notification will be triggered to the user, prompting for critical information; the user can then quickly provide any observational data. Authorities can similarly highlight areas of interest that can trigger alerts to users if they enter those areas that are deemed "at-risk" or "in danger" to request them to be safe and exit the area at their earliest opportunity. Being in such areas can also provide essential information for authorities, however, the very nature of emergencies provides their own challenges for citizens to communicate.

To improve the support to emergency services, WeSenseIt developed an app that creates a direct video channel between citizens and authorities in order to reduce the risk of inaccurate responses[5]. This system, called "Eyes on the Ground"[6], is a real-time live platform **(Figure 4)** that provides a flexible way for operators and decision makers to view an area from the control room, but still allows communication with citizens. A conversation between citizens and authorities can be initiated in several ways - a citizen can choose to contact the authorities at their command and control centre to explain an emergency scenario. Alternatively, depending on the need for information upon receipt of a report, authorities can contact citizens via a mobile app or text message. Finally, entering a dangerous geofence can trigger a request for communication via messages containing a URL. Upon clicking the URL, the mobile automatically starts streaming a live video feed to the control room. The control room operator can provide instructions to the citizen on any immediate actions needed or even move them to a different location to provide a different view. This helps provide the control room with views of affected areas, so an appropriate response can be organised in times of emergencies

CITIZENS AS DECISION MAKER

As discussed previously, citizens have multiple roles as data providers - however, with the democratisation of public policies, decisions can be made with true conviction when citizen data is included in the decision making processes. This requires citizens to have access to the data decision-makers use, so they can be more informed about situations in their regions of interest. A variety of data sources are hence provided to citizens such as weather and tide data, citizen generated reports, high precision weather station and sensor data, low cost sensors and social media. The data is presented in multiple ways - an initial home screen **(Figure 5,** Section 1-3) provides detailed information on subjects most relevant to typical user communities. For example, weather forecasts, flood warnings, official news reports, and citizen generated flood risk data, are pieces of



▲ **Figure 3. (1) The WeSenseIt smartphone app - users can provide information about flooding, flood risk or community life (left); community volunteers can submit reports on critical issues (right); (2) - The WeSenseIt geofencing approach home screen - informing users that they have entered a geofence, prompting for information regarding the location (left); authorities defining geofenced areas of interest (right).**

information that users need to be immediately concerned with; any impending concerns can be identified from such information. Additionally, a "community wall" provides access to historical images previously uploaded by members of the community. This section provides ways for communities to remember past events which were significant in the lives of their communities for example, historical flooding events, or community charity events.

Citizens can choose to delve into more detail if they desire by accessing the raw data provided from the sensors (explicit or implicit). A map displays all the sensors at their current locations and clicking on each one provides historical sensor data. Users can also subscribe to each sensor (**Figure 5**, Section 3a), and set conditions to trigger alerts to notify them of any urgent readings (for example, if the river level is greater than five metres). Using a large amount of information can help citizens take better decisions regarding their personal activities as well as their community life. For example, immediately understanding the presence and locations of flood risks helps them plan their daily routes for walking, help citizens and communities be prepared for impending emergencies, as well as organise and coordinate rescue efforts by authorities and disaster response teams.

LESSONS LEARNT

The role of citizens in citizen observatories is key - not just as mere data providers or consumers, but as participants in a broader initiative and collective effort

▲ **Figure 4. Top - Eyes on the Ground control room (1 - geolocation of citizen, 2 - notes taken during video conversation, 3 - video stream from citizen's camera, 4 - media recorded during conversation). Bottom - Citizen camera view (1 - view of the content being streamed, 2 - call connection controls, 3 - a live text messaging area for detailed instructions).**

▲ **Figure 5. Citizen tools for decision support. 1 - Home page for citizen portal, displaying essential information critical to the citizens' needs. 2 - Community wall displaying memories and images of historical events in the community. 3 - Sensor data visualisations and sensor notification subscriptions (3a). 4 - Citizen application providing the same information, but in a mobile phone format.**

on the greater management of local environments. Hence, the first lesson learned during the WeSenseIt project was the need for active citizen involvement and engagement. Over the period of the project, many iterations of technologies have been developed, each closer to the final product. This inclusive development process helped citizens and communities to co-design and develop final technologies, and as a result, share ownership in the technologies. Depending on the case studies, different sets of citizens were also involved. For example, flood wardens in Doncaster provided essential feedback and ideas to develop the technologies. Given the greater interest in the technology as a result of a co-design process, the technologies are now being advertised by the citizens within their communication channels; for example, the flood wardens have access to several hundred volunteers who are approached via their mailing lists, to advertise the technologies that are to be adopted by the citizens.

Hence, a key finding in the project was identifying the need to involve different players at different levels, with a variety of contributions.

One of the practical issues identified related to the installation of sensors - given the remote location and nature of sensors, they are typically located in harsh environments and as a result, often need regular maintenance and revisits. Such environments are also prone to seasonal variations and hence may be difficult to reach at times. **Figure 6** shows the challenging locations sensors may need to be installed in. Growth of vegetation, bird droppings and loose foliage can block the sensor areas. Citizen volunteers are often unable to perform complex troubleshooting, and as a result, the availability and physical presence of support staff is essential. Volunteer communities also have a wide range of technological requirements that may evolve over the scope of the project since engagements of communities are dynamic (with respect to volunteer members' time, as well as technical needs and preferences). Furthermore, physical sensors require a reliable source of power in order to ensure a consistent stream of data is generated. Depending on the type of sensor and the amount of power required, this can be often challenging – batteries require constant monitoring and replacement while electricity and power lines are not always readily available and accessible. Solar panels, on the other hand are affected by weather conditions and obstruction by foliage and overgrowth (as seen in **Figure 6**). This is an important consideration that needs to be addressed, in order to ensure a continued and engaged participation from citizen communities.

During the lifetime of the project, all stakeholders and participants expressed concern regarding the longer term sustainability of Citizen Observatories. In addition to making available tools and technologies developed within the project as freely available open source code, several avenues are also being explored, such as identifying exploitation opportunities, providing post-project technical support, as well as code and data sharing initiatives with other citizen science and crowdsourcing projects.

The WeSenseIt project is in its final stages now, and the technologies developed are currently undergoing evaluation. The results are expected to provide a rich set of findings and a lot of interesting results, particularly in the way citizens and communities can work together to build a greater understanding of their local environment, their communities, as well as collaboratively developing solutions and taking decisions to improve water management and governance. ES

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Dr. Suvodeep Mazumdar is a researcher at the OAK Group in the University of Sheffield. His primary research interest is in facilitating query and exploration of large-scale real-time data, by employing highly interactive and visual mechanisms applied in the context of Organisational Knowledge Management, Emergency Response and Decision Support Systems.

▲ **Figure 6. Seasonal variation and harsh weather conditions may cause issues to citizens in accessing sensors as well as affect sensor readings. This needs the physical presence and availability of trained personnel and sensor developers. The image shows the same sensor at different times of the year (left - March., right - November).**

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