Investigating the Challenges of Crowd Sensing: Lessons from Zurich

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ABSTRACT
Crowd sensing has the potential to empower urban citizens in the current trend of "Smart City" research and development. In compliment to top-down initiatives tackling infrastructure and resource issues, crowd sensing can support a bottom-up movement where urban citizens have the potential to impact and drive change. However, there are many social and practical issues that must be addressed to expand the current crowd sensing communities beyond sensor and technology experts and into the wider general public. The SenCity workshop [1] explored the use cases and opportunities for crowd sensing in urban environments. It also investigated the various challenges in a hands-on and practical way, moving out of the classroom and into the city to get first-hand experience. In this paper we present the workshop itself and the key observations and outcomes that could influence further work in this area.

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Crowd sensing; workshop; cities.

ACM Classification Keywords
H.4.0 [Information Systems Applications]: General.

INTRODUCTION
Our world is becoming increasingly urbanised with over half of the world's population already living in cities and a forecasted 5 billion to be city dwellers by the year 2030 [2]. As this urbanisation trend continues across the globe, research is looking towards solutions to the scalability and social issues that are arising in ever-growing cities.

Organisations such as IBM [3] and Cisco [4] promote views of the future "Smart City" where sensors blanket our cities and smart grids, smart transportation systems and smart water networks all contribute to a more efficient, dynamic and scalable urban environment. These are extremely complex and important challenges to address and support a top-down implementation of improvement. However, our research is also inspired by the view that "*sociability, not efficiency, is the true killer app for cities*" [5] and that top-down visions tend to "*ignore the enormous innovative potential of grass-roots efforts*". We believe that there is a need to address the equally complex and important everyday challenges at street level and to unleash the creative potential of urban citizens to solve problems or create business opportunities. While infrastructure moves forward towards the "Smart City" vision it is also important to provide urban dwellers with technologies and tools to impact and drive change in a bottom-up fashion and to provide them with the necessary tools to become smarter citizens.

Figure 1. The SenCity Workshop at Ubicomp 2013

A prerequisite is to empower urban citizens with the ability to capture and understand real-time data of their environments. By understanding their current situation, citizens can better identify local issues and drive for change. Additionally, by bringing together the data from multiple citizens it is possible to build rich pictures of the current situation across entire communities and neighbourhoods. The increasing availability of small, affordable sensor kits, such as the Smart Citizen kit [6] and the Waspmote [7], supports this concept of crowd sensing where each citizen becomes a data producer contributing to an open data community. However, the contributors to current communities such as Xively [8] and Smart Citizen

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are typically technically literate and familiar with the crowd sensing field. Reasons for participation are often research related and may be to further individual knowledge or to initiate scientific practices and modes of enquiry [9]. Therefore accessibility is a key to opening such communities and crowd sensing practices up to the general public and encouraging long-term participation. In addition, incentivisation and many other practical issues must also be considered.

In this paper we present the findings of the SenCity workshop, illustrated in Figure 1, where a hands-on, practical approach was adopted to investigate several key challenges of citizen sensing. The next section presents some of the key challenges that were addressed in the workshop followed by a description of the workshop itself. This is followed by a section outlining the key observations and outcomes of the workshop. Finally, a discussion of the results and future work plans concludes the paper.

THE CHALLENGES OF CROWD SENSING

The following challenges of crowd sensing were addressed through the SenCity workshop:

Accessibility: To engage the general public with crowd sensing the current generation of sensing kits must become much more accessible to less technically competent individuals. Current kits are typically quite technical in appearance and intimidating to novices. Configuration is through a programming IDE which requires knowledge of the IDE itself and a programming language.

Incentivisation and Sustained Participation: In order to encourage citizen sensing participation and sustain it in the long term it is necessary to consider what rewards or incentives should be passed onto participants. Current kits are typically "turn on and forget" devices that give no visual feedback on what is being sensed. Additionally, current kits do not provide any direct benefit or reward to the user. The key incentive for use is community membership and the sense of contribution through the data uploaded from the user's sensing kit. Although this is enough to satisfy the initial up-takers who are typically sensor experts or technologists it is unlikely that this will be enough to sustain participation among novice users and the general public.

Deployment Practicalities: There are many practical issues that must be addressed when deploying sensors in urban spaces. At the basic level, essentials like power and connectivity must be sufficient and easily managed (e.g. it is not realistic to expect the user to recharge a battery every night). In addition, the kit should be able to withstand the elements and be located in the optimum positions for sensing. At an aesthetic level, consideration must be given to what the kits should look like in their surroundings. Should they blend in or stand out? At first the implications of this decision may seem trivial but suspicious objects can cause great disruption and panic. In addition the monitoring capabilities of such kits are likely to raise privacy concerns.

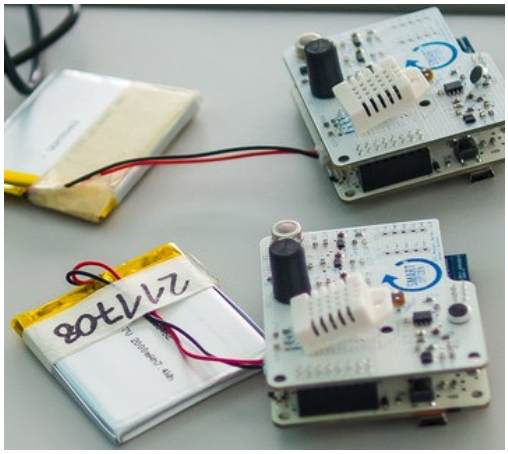
Applications: What are the killer apps?

THE SENCITY WORKSHOP

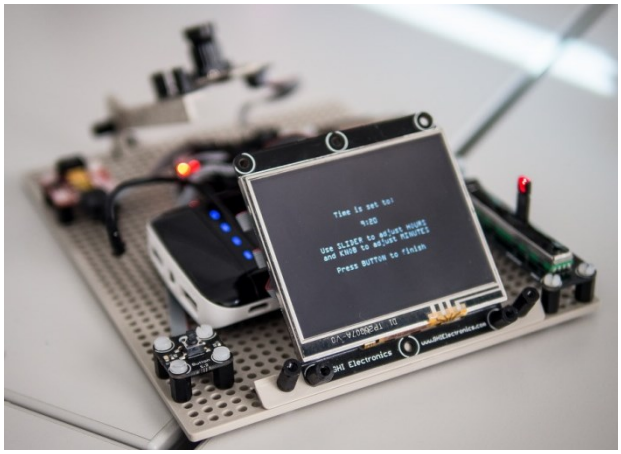
The SenCity workshop was held at Ubicomp 2013 in Zurich, Switzerland. The aims of the workshop were to explore the use cases and opportunities for crowd sensing in urban environments and the surrounding challenges outlined above. Over 20 people participated on the day including designers, social scientists, technologists and sensor experts from all across the world. Participants were divided into five working groups and provided with two sensing kits; the first was the Smart Citizen kit, shown in Figure 2a, from FabLabs Barcelona and the second was the SenCity kit, shown in Figure 2b, which was custom built for the workshop by co-organiser Vaiva Kalnikaite.

The Smart Citizen kit is Arduino based and can be configured programmatically via the Arduino IDE; however these kits were pre-configured before the workshop so this was not a requirement for participants. The kit is aimed at environmental sensing and has a number of on-board sensors including temperature, humidity, NO2, CO, light and sound. All sensed data from the kit can either be sent directly to the cloud or stored locally on an SD card. The SenCity kit is Microsoft Gadgeteer based and provides a screen and several knobs, buttons and sliders that enable the kit to be configured on the fly without the need to interface through a programming IDE. The SenCity kit includes sensors for temperature, humidity, light, vibration, tilt and moisture. In addition it also includes a camera which can take pictures when sensor readings go above or below configurable thresholds.

Each group was given some time to familiarise themselves with the technology. They then brainstormed what they wanted to sense with the kits, where they would position them in Zurich city and what the kits should look like. The



a) Smart Citizen Kit



b) SenCity Kit

Figure 2. Sensing Kits

groups were then given time to build casings for their kits and a variety of different materials, from cardboard and masking tape to fake leaves and moss, were provided so groups could be as creative as possible. Some groups chose a simplistic box-like casing design while other groups explored various creative form factors including duck and alien shaped casings. In addition some groups chose traditional environmental sensing goals while other groups chose to encourage public participation with their sensor kits.

An important part of the workshop was to actually get some hands-on experiences in a real urban environment so the groups were then given time to leave the classroom and go out into Zurich to explore the space and deploy their sensor kits. Upon their return all collected data from each group was uploaded to a server so it could be explored through a visualisation toolkit developed by workshop co-organiser Hans-Christian Jetter. Groups were then given time to analyse their data and create a presentation of their day including their brainstorming outcomes, their time spent around Zurich and the story told by the data that they collected. These group presentations and resulting discussions concluded a successful and fun workshop. The key observations and results are presented below.

OBSERVATIONS AND OUTCOMES

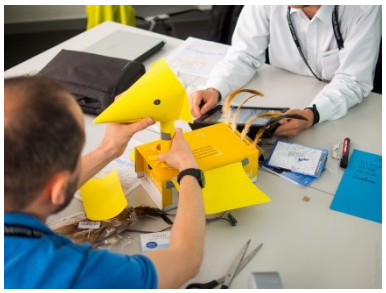
In addition to the final group presentations and collected data, observations were noted throughout the day by workshop organisers. Videos and pictures were taken of brainstorming and development activities and groups were shadowed when out in Zurich. Notable observations and outcomes are described below.

Sensing Locations and Applications: All groups moved around the city sensing in different locations. One group travelled to a local funfair where they captured data on several rides. Other groups walked around the streets or captured data on various forms of public transport including trams, buses and a funicular railway. In most cases the kit was held by a group member or placed in a suitable location (such as a bus seat or park bench). In general, the kits were not used at a single location and for passive sensing of the environmental data but rather as tools for active mobile sensing by groups and for triggering actions within the environment, e.g., taking pictures of persons interacting with them.

Form Factor: None of the groups created kits that blended into the background; instead all were very visible and brightly coloured. Two groups decided to use the SenCity kit to engage the public. The first group created an alien-shaped casing, shown in Figure 3a, and invited people to shake the alien's hand to get their picture taken. The picture was then made visible to the hand-shaker using the small screen. The second group created a duck-shaped casing, shown in Figure 3b, and invited people to shake the duck's foot to show their satisfaction with public transport in Zurich. In both instances involving public engagement the casings were designed in the likeness of living things and there were noticeable differences in public reaction towards these casings and the more box-like designs, as illustrated in Figure 3c. The duck and alien casings evoked a positive curiosity among the public and people would approach to interact or ask more about what the purpose of the device. In contrast the box-like casings evoked a negative suspicion with one bus driver confronting a group about spying and monitoring with references to his past experiences in East Germany. Indeed privacy concerns were only raised in regards to the box-like designs even though the sensing and monitoring capabilities of all kits were the same or even more intrusive in the case of the alien that took pictures of all users interacting with it.

Public Engagement and Benefits: Members of the public were keen to interact with the duck and alien shaped devices. They enjoyed the direct benefit of seeing their picture on the screen however several were disappointed that they could not print a hard copy to take with them as a souvenir.

a) Alien



b) Duck

c) Box

Figure 3. Sensor kit casings

Accessibility: Workshop participants enjoyed using both sensing kits around the city. The sensor experts preferred the Smart Citizen kit with its more typical design however one non-expert stated she was *scared* to touch the Smart Citizen kit as it looked so technical and intimidating. Other non-experts commented on the benefits of being able to configure the SenCity kit without any programming knowledge. In both cases the participants felt that the kits would benefit from GPS as an additional sensor and when out in the city several participants used their smartphones to monitor GPS for later mapping to the sensor kit readings.

Visualisation Context: GPS was also seen as a very important context to help understand the data post-sensing. Knowing where the sensor readings were taken helped groups to understand interesting spikes or patterns in the data, in particular in those cases where time alone was not sufficient or time stamps were inaccurate because of technical problems. The pictures that were taken by the SenCity kit also added valuable context to the raw data and made for interesting data stories in the final presentations.

DISCUSSION AND FUTURE CHALLENGES

The SenCity workshop at Ubicomp 2013 in Zurich was considered a success and many participants commented on how they enjoyed getting out of the classroom and into the city with sensing kits. In doing so they received first-hand experience of the challenges and practical issues associated with crowd sensing. Many interesting observations were made during the day including how the workshop groups decided to use their kits and how they designed the casings. It is particularly interesting to note that several groups included an element of public engagement with their sensor kits by encouraging the public to "shake the alien's hand" or "shake the duck's leg". Current sensing kits are typically "turn on and forget" devices yet here we see a desire to take them beyond this ambient use case.

It is also interesting to note the reactions of the public who interacted with these devices. For many the thrill of seeing themselves appearing on a picture was enough reward for usage but several individuals were disappointed that they could not receive a physical copy of the picture to take away with them as a souvenir for their efforts. In future work we hope to explore how other local actuators (in addition to a camera) could be used to provide direct benefits to the owners of sensing kits or the individuals who interact with such devices as a means to encourage long-term participation in crowd sensing. We also plan to take this further by developing a platform to support "Citizen Hackers". The goal is to empower urban citizens to bring together open data from sensing communities to create their own "city apps". Such principles are currently being explored at an individual level through apps such as "If This Then That" [10] where individuals can combine multiple data streams and apps on their smart phones to create new functionalities.

It is also interesting to note that the members of the public who interacted with the duck and alien shaped devices did not show any concern that a picture of them had been taken. It appears that the "friendly" form factor of the animal and human shaped sensing kits diverted attention from the monitoring functionalities within. We can see a stark contrast when compared with the box-like kits where the form factor did not distract and individuals immediately raised privacy concerns. In future work we plan to further investigate the impact of form factor and its potential to address issues such as accessibility, privacy and trust. Our intended test scenario is a "Living Lab" under deployment in Hyde Park, London. Rather than hiding sensors in grey boxes we suggest highly visible sensor nodes in the shape or birds or animals. As well as keeping with the aesthetics of the park we also hypothesise that park users will be more accepting of such devices.

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