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Making participatory sensing meaningful

Participatory Sensing – origins and definition

The proliferation of mobile devices in the past three decades has changed the way in which we conceive of the city as a shared social space. Early mobile telephony brought with it the ability to have intimate conversations in public spaces. This was followed by the ability to transmit short textual messages, while still remaining in the realm of inherently personal communication. However, as the computing power of mobile devices increased, the potential to use them for other purposes increased. Of critical importance to the realisation of mobile devices as 'sensing platforms' was the removal of the 'selective availability' of Global Positioning System (GPS) on 1st May 2000[1]. Viewed from the distance of 15 years, this single administrative action (as opposed to technical alteration of the system) unleashed a cascade of technological developments that, around 2005, reduced the costs of integrating GPS receivers in mobile devices to such a degree that it was possible to incorporate them within phones and cameras. Together with advances in additional location technologies (e.g. triangulation of Wi-Fi or mobile signals), it became possible to capture the geographical coordinates of the device as it was used around the city. While some literature has called this 'location awareness' of the device (e.g. Hazas et al.[2]), in reality the device has no consciousness that will make it capable of true understanding and awareness. Yet, this phrase captures the ability to calculate the geographical location and use it with other information to provide services to the person who uses the device.

Thus, about a decade ago, mobile devices and in particular mobile phones morphed into 'smartphones', which slowly became more sophisticated sensing machines, with sensors for sound (microphone), visible light (camera), location (GPS receiver), direction (compass), speed of movement (accelerometer), air pressure (barometer) and many other functions. Importantly, as smartphones became widespread and popular, the costs of sensors dropped and they became widely available. These sensors were engineered around specifications that mostly concern the operation of the phone. Thus, the microphone is designed to capture the human voice and to provide a good quality call even in a noisy environment. Beyond the smartphone, other industrial activities developed sensors that increasingly became cheap while being technically suitable for a specific function. For example, the automotive industry's pollution sensors were developed in response to air quality regulations, so they can be located near the exhaust of cars and monitor its emissions.

This background explains the emergence of 'Participatory Sensing'. Originally suggested by Burke et al.[3], the term has gained much attention over the past decade, mushrooming into thousands of papers that provide examples, methodologies, algorithms and technologies in this area. Participatory Sensing is described by its creators as data collection and interpretation activities that emphasise

> *"the involvement of citizens and community groups in the process of sensing and documenting where they live, work, and play. It can range from private personal observations to the combination of data from hundreds, or even thousands, of individuals that reveals patterns across an entire city. Most important, Participatory Sensing begins and ends with people, both as individuals and members of communities. The type of information collected, how it is organized, and how it is ultimately used, may be determined in a traditional manner by a centrally organized body, or in a deliberative manner by the collection of participants themselves." (p.4)*

The original identification came from researchers in the area of electronics, computer science and new media at the University of California, Los Angeles (UCLA), who also identify it as being related to Urban Sensing[4,5]. However, computer scientists, urban planners, geographers and civil engineers have adopted concepts and approaches from this area (e.g. StreetBump, an app to identify potholes[6]). Later on, Participatory Sensing has evolved to be linked to the Internet of Things (IoT)[7] in which various objects are being linked to the Internet and use it transmit their data to central repositories, so they can be controls or sense something. This linkage between Participatory Sensing and IoT is especially pertinent in

cases that involve an external sensing device, in addition to the smartphone, or a sensing device that has limited computing capacity, such as the Air Quality Egg, which uses cheap sensors and DIY technology to allow participants to build and install a monitoring station in their homes[8,9].

Interestingly, the internal culture of the disciplines that are involved in Participatory Sensing has a strong element of 'not-invented-here syndrome', which encourages development of new applications by each developer, instead of building on the work of others through reusable code[10]. As a result, there are multiple applications for smartphones that utilise the same sensor for a very similar task. For example, since the microphone is the most obvious sensor and noise is an easily recognisable environmental problem, there is a proliferation of applications that deal with noise and, by 2012, Stevens[11] identified 11 documented efforts from noise mapping that were developed independently and do not share their data or make it interoperable. However, while this might seem like duplication of efforts (and to some extent it is), because Participatory Sensing is relying on the recruitment of participants with different motivations, technical knowledge and social networks, there are some advantages in proliferation, as it enables people to find an app that suits their needs and context.

The challenge of meaningful participation

Like many words and phrases that have been 'hijacked' by technology companies over the past decade (among them 'sharing economy', 'democratisation', 'friend'), the terminology of Participatory Sensing merits scrutiny. While, as Shilton demonstrated[12], the group that originated the concept of Participatory Sensing was taking the concept of participation seriously, paying attention to methods of participatory design that engage the people throughout the development process, this is not how the concept mutated across the wider literature. To understand this, it is useful to consider the definition of the term. Since dictionaries provide an authoritative starting point, we can examine the definition of 'participation' from the Oxford English Dictionary, where the most suitable explanation of participation is

> *"The process or fact of sharing in an action, sentiment, etc.; (now esp.) active involvement in a matter or event, esp. one in which the outcome directly affects those taking part."*[13]

The crux of the matter is the need for active involvement, and the issue of how the outcomes directly affect those taking part. This puts into question relatively passive modes of Participatory Sensing, where the participants' active involvement is limited to downloading an app and letting it run and collect data (as in StreetBump), as well as the cases where the data is collected and sent to scientists or city officials, with outcomes only indirectly affecting those who contribute. We also need to contemplate the level of meaningful participation in the act of using navigation apps such as Google Maps since, at the time the user uses the map and sees up-to-date information about traffic, they are also submitting information to Google about their location, which is used to assess the current traffic conditions. Thus, the user is directly affected by the outcomes and is sharing information – matching well with the definition above. Yet, as Arnstein identified in 1969[14], participation has different gradations. The famous image from Paris in 1968 (Figure 1), which Arnstein also used, is a reminder that participation needs to be meaningful. For the sake of the discussion here, we can consider similar levels to those proposed in Haklay[15], which suggested different levels of 'hacking' that correspond to the ability of technology users to appropriate it to their needs and context: in particular, noticing that most people are only capable of using the technology as is, while a tiny minority can be involved at a deep technical level where they can take control over the code itself and shape the project both technically and socially. Moreover, by putting the relationship between the contributor as an individual, without ability to connect and link to other contributors and make a collective decision about the use of the data, the power relationship are set in favour of the aggregator, who will frame consultation and sharing power over decision with hundreds or thousands of individual participants as 'impractical'.

Figure 1 - I participate, you participate, he participates, we participate, you participate...they profit (students' poster, Paris 1968)

I suggest that, to understand and critique Participatory Sensing from a participatory pespective, we can make a start by looking at the following aspects: who participates, who owns the data, and the meaning of the information that is being collected and shared. While these are not the only challenges, they allow the development of general principles that can make the process socially meaningful and responsive. In all these, political, economic and technical powers provide a suitable lenses through which we can notice fundamental problems with the definition and the practice of Participatory Sensing.

First, the methods of recruitment and level of engagement with participants are good indicators of the level of commitment of the project initiators to inclusiveness and true democratisation of participatory activities. In some cases, the data sensing app is developed for a specific platform – such as the WideNoise application, which was originally developed only for iPhone smartphones making it exclusive to the segment of the population that owns such phones (a later version that was also adapted to Android phones is described in Becker et al.[16]). More generally, as smartphones are now only available to 70% of households, there is still a large minority who cannot participate in sensing activities unless they are provided with devices. In addition, many of the recruitment schemes for Participatory Sensing are based on advertising in existing media and in social media, with the assumption that people will find the

information and will decide to join of their own accord. Such recruitment is based on self-selection of participants but might fail in terms of inclusiveness of under-represented groups who do not follow the media that was used to promote the scheme, or are concerned with the implications of downloading and using the application. As Crawford noted[17], StreetBump, which was mentioned above, could have caused a significant bias towards the detection of potholes in wealthy neighbourhoods where people own cars and have smartphones and the social capital to feel that they can participate and report about urban issues. Part of the problem with Participatory Sensing is the conflation of the number of data point submissions with large engagement and inclusive participation. To achieve the latter, special attention is required to overcome spatial, socio-economic and technological barriers that discourage people from participation.

The second challenge to Participatory Sensing emerges from the imbalance in ownership and control over the data being collected. There are significant technical expertise in setting up the system that will collate the sensing results, as well as financial resources to run the servers, advertise the participatory sensing programme, and eventually both financial and technical resources are needed to utilise the resulting data and analyse it. The most common relationship between the contributor and the system developers is that the data that emerges from the process is owned by the latter. Only in rare cases does the data remain under the control of those who created it. The biggest benefits accrue to the system owners, where they can repurpose the data and sell it on, despite the fact that the participants invested their time and potentially their money to support such effort.

Finally, we can look at the meaning of the information that emerges from Participatory Sensing. As noted before, because of the ambitions of system creators and the promise of large-scale monitoring, there is over-reliance on the sensors that are integrated in smartphones or cheap sensors that are emerging from other industrial activities. The result of these design decisions is that sensors that have been put in place with an aim to provide certain data that can be used for a specific purpose (e.g. the example above of monitoring pollution near the exhaust of a car) are being utilised in other contexts for which they were not designed. Many times, such appropriation is carried out without careful testing and calibration to ensure that the information is meaningful and fit for purpose. Here, the power of technological assemblages to produce information that is quantitative and is presented with a familiar measurement unit leads to a mistaken assumption that the information is relevant and accurate. For example, many of the noise monitoring applications use of dB for decibel – a common unit in sound measurements, while, as noted, it is unclear how the algorithm to calculate this from the microphone's input or to what degree this has been tested and calibrated remain hidden. Therefore it might be the case that the number on the screen, is not representing the value of the unit that it is associated with (see Figure 2). In both research and commercial applications of Participatory Sensing, there is a tendency to downplay the limitations of the sensors and the sensing and not to highlight them as that is perceived to have a negative impact on the level of engagement and the scale of the activity.

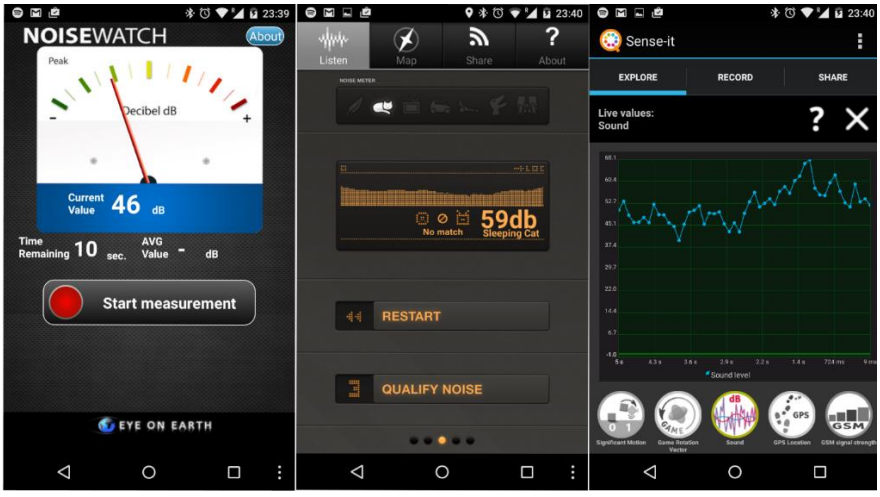

Figure 2 - Noise monitoring applications - What do the numbers mean?

Towards meaningful Participatory Sensing

One of the answers to the tensions that Participatory Sensing grapple with is to reconsider how to bring back the elements from its origin that emphasised the involvement of the participants in developing the process from start to finish. The participants can be involved in designing the process and piloting the data collection process. They can also get involved in the process of testing the sensors and ensuring that they are fit for purpose, or redefine the aim of the project around these limitations. For example, the use of WideNoise around Heathrow[18] (Figure 3) was carried out using an app that could not be assumed to produce accurate readings similar to standard noise meters. However, through a discussion with the local community, the meaning of the activity was reframed, from accurately recording the level of noise in decibels to recording complaints about noise disturbances and expressing community concern. The process of agreeing what it is that is being measured and to what end the recording will be put are central to imbuing meaning into the whole exercise[19]. Similar evidence for meaningful Participatory Sensing is provided by the work of Keysar[20], who worked with Palestinian neighbourhoods in Jerusalem to record their area using balloon and kite mapping, which resulted in high quality imagery of the area. The images are then assembled and annotated by the local community to ensure that the meaning of the exercise is captured and preserved together with the information that came from the sensors. More generally, the control over the sharing of information and its distribution is a critical aspect of such projects. Therefore, an important principle that can be promoted to encourage deeper participation is to emphasise the ability of participants to own and control their data, and make decisions on how it is going to be used. Of course, there is space for delegation of decisions about future use to trusted organisations and individuals, but it is critical to keep in mind how the data came about and to maintain the obligation of respecting and engaging the participants in how their effort will be used.

Figure 3 – Community Noise Monitoring workshop in Isleworth, 2012

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