Co-discovery for Uncommon Insight: Making and Sharing Public Goods with Pervasive Computing Technology

Alice Angus, Giles Lane, and George Roussos

Abstract. Pervasive computing technology enables social mapping and sharing of local knowledge to create relationships beyond established social and cultural boundaries and the development of new practices around place, identity and community. For over a decade we have explored the potential costs and benefits of this approach to co-discovery with communities across London with a view to support grassroots activities enabling urban communities to take action towards environmental sustainability. A core ingredient of these explorations is the making of artefacts to provide both the focus for communal experiences and as a way to create tangible representations of the intangible things we value most about the places and communities we belong to, which we refer to as Public Goods. Specific projects explore alternative material representations of stories, skills, games, songs, techniques, memories, hyper-local lore and experiential knowledge of the environment. The work presented in this article investigates how Public Goods can provide the focus for the development of such groups around hyper-local concerns. Further more, we show how using made objects constructed as a means to communicate the activist message of these communities in a tangible manner provides more affective and illustrative ways to facilitate such co-discovery of uncommon insights.

Keywords. J.9 Mobile Applications < J Computer Applications, J.9.d Pervasive computing < J.9 Mobile Applications < J Computer Applications

Pervasive computing technology enables social mapping and sharing of local knowledge to create relationships beyond established social and cultural boundaries, and the development of new practices around place, identity and community. For over a decade Proboscis, an artist-led studio, and collaborators have explored the potential costs and benefits of this approach to co-discovery with communities across London (Lane 2003, Angus *et al* 2008). A core ingredient of these explorations is the making of artefacts both as a means to provide focus for communal experiences, and as a way to create tangible representations of the intangible things we value most about the places and communities we belong to, which we refer to as Public Goods.

A specific strand within this programme of research investigates ways to support grassroots activities enabling urban communities to take action towards environmental sustainability. To this end, we have developed specific projects to explore alternative material representations of stories, skills, games, songs, techniques, memories, hyper-local lore and experiential knowledge of the environment. All share a commitment to an alternative experience commons sustained through Public Goods, where citizens and urban dwellers are presented with the opportunity to be agents, actors and creators.

Pollution mapping

London Fields is a popular park in Hackney, East London, and an important resource for local communities in a built up area. The first recorded mention of the park is in 1540 as Lammas land, an area for communal grazing, when it was the last piece of common land for livestock on a drovers route from Essex to London Town. In the 1860s, agents for landlords began promoting the site for development, dismissing the Lammas rights as rarely used and pointing to the neglected state of the Fields. However, their importance as one of a handful of large open spaces close to the City was recognised and they became a public park in 1872. Today the park is used by local people for a variety of activities: as a space to play and socialise in, for championship cricket and football games, dog walking, and as a popular walking and cycle route. In its relatively long history, London Fields have adapted to accommodate the evolving needs of the surrounding population.

Background and Rationale

Air quality in London is monitored on an hourly basis by the London Air Quality Network (LAQN), through observation stations in fixed locations across its Boroughs. With its Victorian heritage, Hackney is regularly in breach of the European air quality thresholds and nitrogen dioxide levels are often twice the legal limit. Although LAQN is an important resource Hackney only has one observation station covering the entire Borough and hence there is clearly ample opportunity to investigate air quality at a much finer resolution. Yet, the collection of this kind of information by non-experts is often seen as lacking scientific rigour and some would argue that evidence collected in this way cannot be comprehensive or authoritative (Conrad *et al* 2011). Others claim that citizen scientists lack the knowledge to interpret results. Nevertheless, collection of detailed pollution data at the grassroots level can trigger an open dialogue about environmental issues, help

develop the arguments on how pollutant-sensing technology placed at the grassroots level can function, and identify its potential applications for community action and interaction.

System Development

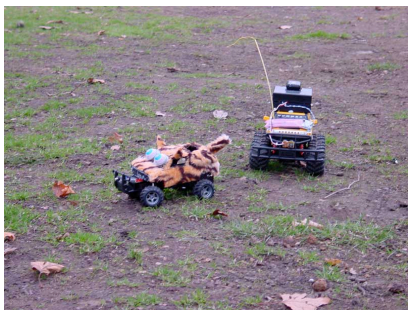
We explored the issues around fine-grain hyper-local air quality monitoring in collaboration with Natalie Jeremijenko by extending her Feral Robotic Dogs (Figure 1a) with location and augmented environmental sensing, and the capability to wirelessly linked to the internet via a mesh network and to the Urban Tapestries platform. Feral Robots (Lane *et al* 2006) provide a blueprint for the reconfiguration of toy robot-pets with a variety of low-cost chemical sensors typically used in fire and carbon monoxide alarms and home and car ventilation systems to trace environmental pollution (Cuff *et al* 2008). Our priority was to develop an easy to assemble low-cost platform using widely available commodity components (Figure 1b). All software and hardware designs are open sourced for anyone to freely re-use, build or modify at http://socialtapestries.net/feralrobots/.

Participant Perceptions

In addition to their rich heritage as common land, London Fields was selected as the location for a series of experiments due to its strengths as public space used by distinct local communities. Community pollution mapping workshops were organised in collaboration with SPACE Media Arts, a local arts and education charity. Feral Robots provided the focus for these workshops, with participants exploring wider concerns about pollution both visible and non-visible, and the potential application of technology to detect it. We discovered that grassroots pollution mapping is not necessarily about producing accurate scientific data. Instead, it is a tool to highlight concerns, to map knowledge, to enable involvement in the data collection process thus reinforcing perceptions of the area, and provide the focus for communities to come together. As one workshop participant remarked: "we have come to accept air pollution because we are culturally habituated in it -- that's got to change and if this doesn't happen at a grassroots level with tools that we can handle ourselves, governments will not shift."

Nevertheless, not all workshop participants took the same view, and others expressed the opinion that ordinary people do not have any control over their local environment. For example, vehicle emissions are the major cause of air pollutants in London and in many cases they are due to pass-through traffic, about which local people have little power to intervene. This point of view can lead to passivity and resigned acceptance of the situation as expressed by one participant who said that "the more I think about it, the less I want to have any access to any data about air pollution in my locality, or information about this park. I don't have a garden, I have a kid, and I'll always use it."

In addition to views of the here and now, community mapping workshops prompted participants to reminisce about the history of the Fields, highlighting past activities in the area, which could have left an environmental footprint. This type of local knowledge is invaluable and can help locate pollution hotspots that would otherwise require an external expert and the investment of considerable resources for surveying.



(a)

(b)

(c)

Figure 1. (a) The original Feral Robot (left) followed by the augmented version developed for RFPA. (b) A close-up of the sensor modules at the front of the toy car. (c) Feral Robot workshops with students of the Jenny Hammond School.

Self-publishing

Building on the use of made objects to provide the focus for co-discovery, subsequent work emphasised the concept of Public Goods that is, tangible representations of stories, memories and experiential knowledge of the urban environment. We further explored these ideas with Loren Chasse, an artist and educator, at the Jenny Hammond School in Waltham Forest. A weeklong workshop with 30 students aged between nine and 10 years old involved several activities including extensive use of Feral Robots to gather evidence about the world around them (Figure 1c). The activities were linked to specific modules within the national curriculum, in particular transport, architecture and climate, and allowed the students to develop and understanding of how these subjects fit with the environmental sustainability agenda.

Background and Rationale

"Know your way to the school," one of the activities developed, invited students to observe and record every morning different types of pollution they encountered. A long list was put together: rubbish on the road, litter and dog poo, car fumes, factory smells, plastic bags, cars, trucks, vans, lorries and buses. Such evidence collection was at the centre of the workshop and attempted to make its gathering fun and engaging. Students were introduced to the idea of being an archaeologist and to find ways of collecting evidence about the environment and the world around them in a way not entirely dissimilar to that advocated by Paulos *et al* (2008). Students worked in rotating groups so that all had a chance to experiment with the different ways of collecting evidence both in the playground and at a nearby park. They used a variety of tools in addition to the Feral Robots to capture images, audio and samples in Urban Tapestries (Figure 2, right).

Storytelling and reflection was an equally important aspect of the workshop. Throughout the week the students were encouraged through drawing and writing to imagine their own robots to help the environment and to design an actual space that they would like to live in – thinking about what would be included and excluded from it. They were encouraged to think freely and become architects of their own environment. Each student used their own electronic notebook in which to write and draw as a personal means of ongoing reflection on specific activities from each day and to build up knowledge over the week.

Figure 2. Communicating local environmental information scavenged with our participatory sensing platform: DIFFUSION notebooks and Story Cubes (left), Story Cubes constructed by the students at Jenny Hammond (middle), and social networking website with data from Snout (right).

Public Goods design

Story Cubes, a tactile thinking and storytelling tool developed by Proboscis, were used to build structures reflecting their ideas of their ideal environment (Figure 2, middle). Each face of the cube can illustrate or describe an idea, a thing or an action, placed together it is possible to build up narratives or explore the relationships between them using this three-dimensional representation. Initially each student constructed their own cube choosing six of the images they collected during the week and then they came together in groups to illustrate their ideal environment. Through this process of discussion and negotiation the cubes were put together to create a single structure. The lively discussions about how individual choices affect the structures, arguing their case and making compromises as part of the group effort was their direct experience with the workings of a grassroots community.

Story Cubes are one of the two DIFFUSION foldable designs invented by Proboscis to combine the ease of sharing of digital media with the tactile pleasures of material objects and represent one of our first experiments with Public Goods. The second design, DIFFUSION notebooks, similarly allows participants to author stories and record their experiences which are automatically converted in the DIFFUSION format (an open platform for automatic notebook generation is available at

http://bookleteer.com/). This can be printed and folded into a book thus extending their reach where it would not be economical, or physically possible to distribute traditional books. This approach takes the reader away from the computer screen and engages them with the collected information in a different context and medium.

Participant Perceptions

Teachers were not immune to the excitement that the project generated with the head teacher observing that "there is a buzz generally with Year 4 that is infectious around the school." Their experiences during the workshop helped them develop their academic skills but also allowed them to understand the link between individual actions and their impact on the local environment. The class teacher recognised this by saying that "I've seen them progress throughout the week and they're understanding about pollution and what they need to do to care for the environment are really clear in their minds now."

In the students' own words, it is important to think about the environment "because you live in it," "so we can stop global warming" and because "without the stuff, earth is very dull." Indeed, the workshop encouraged students to feel that they could kick-start change and improve society. They were encouraged to think of real ways that they could achieve this starting with their immediate environment, or as one student suggested: "I would write a letter to the Queen so the people from the Houses of Parliament would put more bins in the city."

Performance

Aiming to attract a wider cross-section of local communities we developed Snout, a community art project (Airantzis *et al* 2008). Community art is fundamentally participatory and rooted in a shared sense of place, tradition and spirit; it is as much about the process of involving people in the making of the work as the finished object itself; and it is situated in public, accessible and resonant places, geared to a specific audience and a specific time. Moreover, community art fits well with an activist agenda as it is developed around commonalities and the collective rather than the pursuit of strictly individualised expression that is typical in other art forms. In this context, art is seen as the catalyst that illuminates a political issue in a way that leads to mobilization and action. For these reasons Snout was seen as an opportunity to develop a community around environmental sustainability by providing both the practical recipes for action and a supporting conceptual framework. Snout brings together community art and grassroots activism through their shared concerns about knowledge and building social capital in the form of the grassroots networks that enable people to move information and ideas to a broader audience and make change happen.

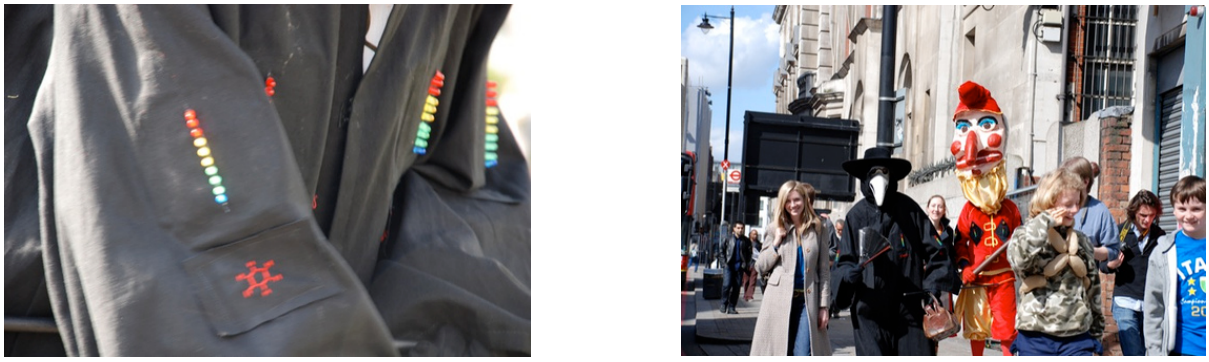


Figure 3. Left: The Plague Doctor costume displaying sensed data. Right: Public participation during the Snout performance around Hoxton Square and Rivington Street.

Public Goods design

The performance developed for Snout explored relationships between the body, community and the environment (Galloway 2004). The Carnival was selected as the setting as it is a time of suspension of the normal activities of everyday life – a time when social hierarchies are inverted and when everyone is equal, a point of view that is highly compatible with the Snout objective to invite participation. Two costumes were built and instrumented with sensing, processing and actuation capabilities: the English puppet theatre character Mr Punch and the Venetian Plague Doctor (Figure 3, right). Our open-source platform was extended to provide longer autonomous operation and support for LED-based displays that provided immediate feedback of the sensing data (Figure 3, left).

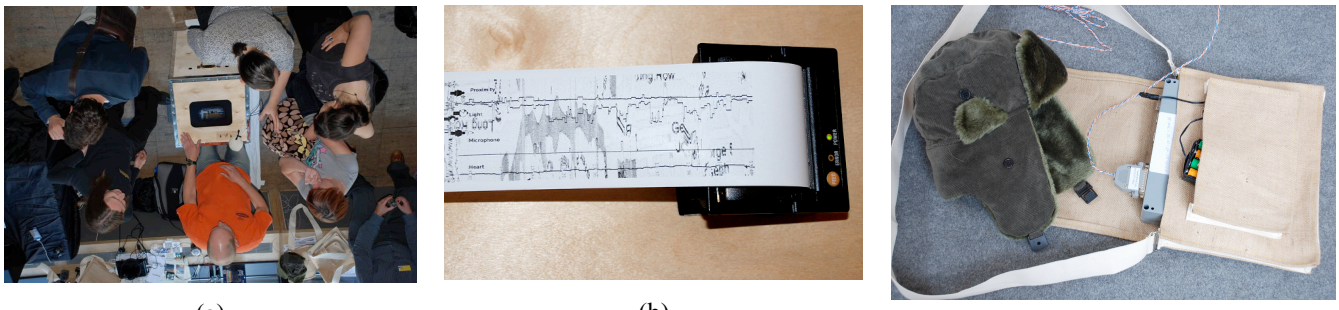
The costumes were designed and built by Proboscis with the electronics worn inside the garments and the sensor arrays embedded into the masks. Snout was performed by Jordan Mackenzie and William Aitchison around Hoxton Square and Rivington Street, and involved a community forum in the evening of the same day. Since there is no audience at a carnival, only carnival-goers, the performance was based on improvised interactions with local residents, office workers, drivers of pass-through traffic and anyone who happened to be in the area at the time. Improvisations engaged hundreds of individuals and facilitated self-reflection on everyday practice and its consequences for environmental sustainability. The event concluded with a workshop were local participants recruited during the performance earlier in the day and online explored making their own devices using our open source system (all source code and hardware designs are available online via http://socialtapestries.net/snout/).

Sharing sensory experiences

In Sensory Threads (Bryan-Kinns *et al* 2009, Marshall *et al* 2010) we turned our attention from Public Goods that are external to the participants, to investigations of the human body as a vital part of the environment: Combining environmental and bio-sensing technologies we probe the imperceptible patterns and rhythms that occur when a individuals explore the urban environment as a unit. Sensory Threads events involve two groups: four expedition participants that carry wearable sensing technology incorporating real-time audio feedback; and, gallery visitors that interact with an installation representing the sensory experiences of the expedition group using a combination of tactile feedback, visuals and audio. Contrary to other technologically mediated urban experiences such as pervasive games and urban participatory sensing (Burke *et al* 2008), Sensory Threads focuses on co-discovery by explorers and remote participants through the experience of the urban with no specific end goal such as finding a target location.

System Development

Each expedition member carries a device that records data from sensors (heart rate, light and sound, electromagnetic radiation, and spatial density) streamed to a personal server also carried by a member of the group (Figure 4c). The data is aggregated at the server to create a soundscape that is broadcast back to the whole group via wireless headphones. Each sensor influences a different aspect of the generated soundscape which has been developed to create a complex group dynamic (Stowell *et al* 2009) where participants engage with their own actions in the space as well as the communal sensing experience (cf. Bryan-Kinns *et al* 2009 for details on the generative algorithm). All sensor data, the soundscape and the location of the group are recorded locally on the mobile server and concurrently transmitted to the Urban Tapestries system so that the information becomes available to the gallery installation components. More information can be found at the project website via http://proboscis.org.uk/projects/2005-2010/sensory-threads/



(a) (b) (c)

Figure 4. Components of the Sensory Threads experience: (a) the Rumbler installation, (b) sensor printer, and (c) wearable sensor kit (spatial proximity sensors located on the hat).

Public Goods design

The Rumbler, shown in Figure 4a, is the main element of the Sensory Threads installation: it consists of a spring-mounted wooden box approximately three feet in height made from a tea crate, with a video screen embedded at its top displaying the map of the places explored by the expedition group. The Rumbler also contains a large subwoofer speaker that creates very low frequency sounds that cause the box resonate, with its movement intensified by the spring foundation. This in turn creates a nuanced set of vibrations that participants can experience through touch. Four mini resonators extend to the sides of the Rumbler, constructed from repurposed computer game control pads each using vibration to represent the data from a

different sensor source. Speakers positioned around the exhibition space provide audio playback of the soundscape generated by the mobile server. In this way phenomena normally imperceptible to the human senses are transformed into vibrations that can be sensed as audio or through resonance. Finally, a small, embedded printer mounted on a second wooden box produces a visual representation of the sensor information in a manner reminiscent of an electrocardiogram (Figure 4b).

The Rumbler can be used in two modes: The live mode embeds expedition experiences into the gallery while the expedition group is actively exploring; and, the playback mode allows participants to journey through time and space to explore the sensory data repository previously recorded. In the former case, the Rumbler is non-interactive with the displayed map moving according to the location of the expedition group with the actual sensor readings visualised on the map. The large and small resonators provide tactile feedback to the sensor readings, and the soundscape is performed as the explorers hear it. In playback mode, the Rumbler becomes an interaction device so that tilting the box causes the map to scroll. This allows the exploration of pathways through the sensor repository selected by gallery visitors. The form factor of the Rumbler is such that it affords multiple people tilting concurrently, engendering a new form of co-discovery of the imperceptible. Experiencing the mini resonators requires two or more people to collaborate, so that one is tilting the Rumbler to discover new data whilst the other holds the device. This design encourages the formation of groups around the Rumbler in a manner intended to correspond to the shared experience of the expedition.

Sensory Threads events have been staged on several occasions such as at the Dislocate Festival in Yokohama, Japan, and extensively during the Surface Tension exhibition at the Dana Centre, Science Museum London. One particular aspect of these events that appeared especially engaging for remote participants in live mode was the experience of biosensed data harvested in real-time by the expedition. Specifically the experience of holding the mini-resonator relaying the heart beat of one of the expedition members and its changes in response to the experiences they had seemed to create a sense of intimacy between the two groups and a strong affective response for those interacting with the Rumbler.

Discussion

In Feral Robots, Snout and Sensory Threads we employed Public Goods to mediate the assembly of grassroots groups around local environmental sustainability issues through the facilitation of appealing co-discovery experiences. We found that their material nature can be more engaging for group members than purely screen-based information representations since they weave themselves into the narratives of everyday life that people construct for themselves. Indeed, Public Goods are part of the material environment and as such appropriated as material culture, which dictates the ways in which they are experienced and acquire meaning (Pearce 1994).

In this context, Public Goods function as a source of inspiration for the development of open-ended activities rather than to epitomize the goal of tightly prescribed pursuits. For example, while we initially considered our open source maker platform as the main ingredient for community projects around participatory authoring, we quickly discovered that the complexities of hardware customization ---despite our modular approach and design for accessibility--- caused significant difficulties to participants. Instead, our designs offered ideas, directions and encouragement for others to assemble collections of devices that achieve the same functionality but which did not necessarily require such expertise. Indeed, the most significant contribution of the platform is in providing concrete proof that the development and operation of a low-cost public sensing and authoring platform is feasible with limited resources and restricted specialist skills. Nevertheless, the rapid proliferation of hackerspaces and fablabs may in the longer term address the spread of the required skills, a situation that would warrant a reassessment of this strategy.

Cultivating Participation

Reflecting on Feral Robots in particular, we found that although the artefacts themselves are widely appealing, especially to younger male users, they provide limited opportunities for interaction besides remote control. While collecting data they remain opaque and provide little indication that data transmission occurs. Operators are aware whether the different system components function correctly due to several LED indicators, but are unable to receive feedback on the currently detected levels of air pollution, which in the long run makes data harvesting sessions rather unexciting. Instead, we found that embedding feedback within Public Goods themselves in immediate response to data collection tasks, benefits participants considerably in terms of engagement and the quality of their interpretations.

Since the initial formulation in Urban Tapestries of participatory public authoring, the emphasis of our work has shifted from pollution mapping to what we today describe as everyday archaeology. This approach places less emphasis on the specifics of data collection and instead traces closely the process of excavating information about the local environment

and its relationship to communities. We discovered that it is the process of gathering such data is the most valuable as it can sustain the incentives for local people to campaign, thus becoming the locus of creative activity in itself.

Evolution of Public Goods

Public Goods specifically and physical outputs from digital experiences in general are a critical ingredient for the development of effective grassroots activities enabling urban communities to take action. Our exploration of such physical outputs began in the early 2000s with the tangible souvenirs of Urban Tapestries that subsequently evolved in the DIFFUSION foldables, and the *aides du memoir* produced by the Experience Recorder at Birkbeck. Many of these objects are made using materials such as paper that would be considered low-tech in this context, but we note that the process through which they are generated incorporates pervasive computing as the key enabler for their production. Unlike data visualisations, Public Goods are created through a process of data transformation that does not confine them to an instrumental purpose such as relaying the original data as information in a simplified and easy to comprehend manner. Instead, they are embodiments of the data, transformed from the abstract and ephemeral into the concrete and present (Cummings and Lewandowska 2000). They establish the potential for uncommon insights to be recognised in the setting within which the data was collected, such as individual lifestyle patterns, prompted through a process of tactile contemplation.

Public Goods and Materiality

Public Goods are simultaneously informational objects – representing a state gleaned from sensor data – and physical things which act as triggers for intuitive reflection by virtue of their material nature. As such, a single entity coalesces different traditions of investigation and meaning-making: both being and becoming. This capacity is maintained across use contexts and allows for the information qualities of Public Goods to transcend the screen and extend beyond the frantic pace of cyber-space thus permitting citizens to explore information constructs in a state not typically associated with computing. For example, the information represented by a specific artefact remains intelligible and present in periods of reflective contemplation thus reuniting pervasive computing with the concept of calm technology and its aspiration to reduce the stress of information overload.

To be sure, the most interesting development in this regard is the widespread availability of low-cost additive three-dimensional printers that allow the fabrication of objects in a form that closely traces their informational features. In particular, combining captured sensor streams with nature-inspired generative processes enables the organic growth through computation of structures that go beyond the representation of knowledge in the form of a transactional commodity. Instead, made objects become a path to knowing that arises from an ongoing process of continuous interaction with and intervention within everyday habits, an avenue for investigation that Proboscis currently explores within the Lifestreams project.

Conclusions

The motivation for the work reported in this paper is our desire to show how artists and engineers can collaborate to bridge the gulf between pragmatic technical solutions to social problems and the cultural interventions that artists bring to their communities. Through this collaboration we demonstrate how using affordable electronics and open source software it becomes possible to create engaging experiences around hyper-local concerns employing Public Goods to provide the focal point for community mobilization. The greater the emphasis on participation at every level of society and culture, the greater the diversity of voices, ideas and knowledge contributed to society at large. Indeed, stable and healthy democracies are the product of wider participation and the sense of responsibility that is often expressed through the formation of grassroots communities around specific issues. Public Goods capitalise on the inherent capabilities of citizens to construe material culture and provide an effective means to communicate the activist message of grassroots groups to a wider audience in a manner which is engaging and appealing and thus facilitates the co-discovery of uncommon insights.

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Bios.

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