Northumbria Research Link

Deploying Pervasive Sensing for Evidence-Based Management, Services and Sustainable Policy

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Abstract

Services which make use of low-cost pervasive sensor systems have the potential to support evidence-based management, decision support, service provisioning and sustainable policy design in non-domestic buildings. My research aims to understand the sociotechnical factors in the investigation of such systems through deployment case-studies with facilities managers, office workers, and students. I provide recommendations for the design of repurposeable, redeployable and retrofit-table sensor toolkits for understanding conditions within the local built environment, utilising that understanding in digital services to provide new perspectives on environmental complaints (e.g. thermal comfort), and creating policy recommendations towards the sustainable management of building infrastructure.

Author Keywords

Pervasive sensing; audits; building management; sustainability; data; sensor toolkits

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

Introduction

I am currently concluding my 2nd year of research as a PhD candidate at Open Lab, Newcastle University, and expect to defend my doctoral thesis in early 2018. The CSCW Doctoral Colloquium presents an opportunity to discuss my research with peers and experienced CSCW academics, and my research is well positioned in CSCW due to its alignment with pervasive sensing, sustainability and interaction design. As such, I expect to engage with other researchers and contribute to discussions around technologies for driving change,

Figure 1: *BuildAX* sensor toolkit comprising of a base unit and low-cost sensor nodes, which sample temperature, humidity, light, movement and magnetic switch (for doors and windows).
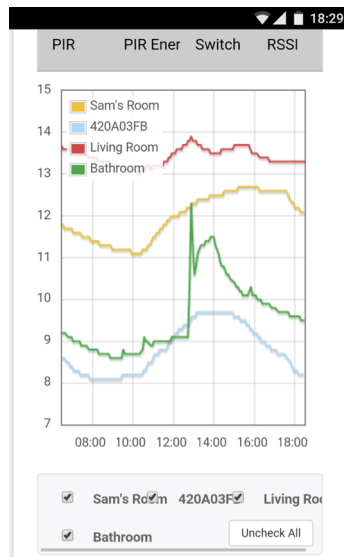

Figure 2: BuildAX Mobile screenshot. The inclusion of multiple streams makes for a highly re-purposeable toolkit, leverageable in a variety of situations.

collective action, and the complexities that arise and may be studied as a result of deployment of sensor toolkits in non-domestic contexts.

Pervasive sensing technologies are now commonplace, and have found use in non-domestic contexts by building professionals to better understand these environments. However, these have dramatically dropped in price in recent years, leading to lower barriers to access and new paradigms of use, presenting new opportunities for CSCW. My doctoral research seeks to understand how the deployment of pervasive sensor systems, or *sensor toolkits,* and their related platforms might be used for evidence-based management, decision support, service provisioning and sustainable policy design. I also look at the socio-technical factors (and barriers) present in the deployment and adoption of such technologies. In participating in the doctoral colloquium I hope to reflect on my approach to addressing these concerns in the non-domestic context, and gain insights into how other researchers are addressing them through their work in and around social computing.

Sensor toolkits are inherently mobile and temporary platforms (e.g. Internet of Things (IoT) technologies), as opposed to fixed, permanent infrastructures (e.g. Building Management Systems (BMS)). The transient nature of these toolkits and the benefits and drawbacks they confer have not been critically examined in CSCW or wider HCI. This tension between fixed and mobile systems also raises different questions for design, as each configuration is different. For example, there are advantages to not having permanent infrastructure (low maintenance, reuse, and flexibility in how it is used and by whom), but one challenge for design is in

making this useful from a technical perspective while not overwhelming users with data. The BuildAX environmental monitoring kit (Figure 1,2), the development of which I contributed heavily to during the first year of my PhD, contains sensors for logging environmental temperature, humidity, light and movement and has been an enabling technology for this work. The design of this system is documented at http://buildax.co.uk/.

Background and Related Work
Sustainable HCI research provides much of the philosophical underpinning of this work, with recent trends shifting away from persuasive approaches which place responsibility on individuals' actions, towards examining the policies and processes which influence collective behaviours in the real world. Dourish [3] provides an illustration of this point, noting a theme in SHCI framing sustainability "*as an issue of personal choice for rational actors,*" a result of the neoliberal economic values which affect how we design interventions. Brynjarsdóttir [1] also highlights the need for researchers to distance themselves from this persuasive approach to sustainability, which generally refers to decreased resource consumption (examples include: electricity, water, CO2, paper). Papers generally attempt to address these problems via increasing awareness (methods included ambient displays, pervasive technology, computer widgets, social networking, persuasive games). Technology to aid conscious decision making in persuasive sustainability can be explained as a modernist design; modernism being the philosophy that people can (and should) change the world through technology and scientific advance. Goodman [5] too views this as limiting the scope of sustainability research, as behaviour change interventions do not address poverty, politics, and so on).
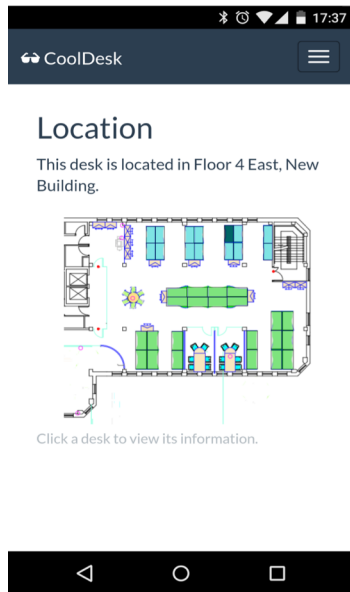
Figure 3: *CoolDesk*, a desk sharing system built to address the first research question, was used as a probe to investigate environmental concerns within the office (e.g. noise, temperature, "stuffiness" or humidity) by allowing occupants to exchange desks. Understandings of these factors may allow facilities managers to optimise how they provision heating services, reducing wasted energy and improving occupant comfort.

These studies highlight a need for work within SHCI and CSCW which makes meaningful contributions to policy, which my work will address through the provision of services and prototype systems which use data collected from pervasive sensor networks. CSCW in turn highlights avenues for investigation of these concerns in novel ways, bringing perspectives on *collective action* [2], *sharing economies* [7], *playful technology* [4], among others. Through the studies presented in my PhD work I consider how data might be used as part of participatory processes such as negotiation, sense-making and activism, and make recommendations for the design of future systems.

Dissertation Outline

My dissertation proceeds through the investigation of 3 case studies relating to the application of pervasive sensing to workplace sustainability in novel ways, addressing three interrelated research questions:

1. Can sensor toolkits empower people in the workplace to make sustainable choices by supporting negotiation of office space use? (Figure 3)
2. How might sensor toolkits be deployed to support the audit practices of professional facilities managers and motivated amateurs?
3. Can we build technologies which leverage pervasive sensing to support grassroots and formal auditing in informing policy change?

These studies are collected under the aim of understanding the design of pervasive sensing applications for appropriate resource use, and exploring roles for understanding, reconfiguration, and empowerment. This involves technical challenges, but also challenges for design, which are mostly about understanding the social context in which technology use is imagined.

Methods

The methodology I have employed so far has been influenced by the methodologies presented in Zimmerman's [8] uniting of HCI with *Research Through Design* (RTD). This helps engage HCI problems within a model of interaction design research, through the production of design artefacts *"as outcomes that can transform the world from its current state to a preferred state"*. An RTD approach fits particularly well with the production of Sustainable HCI knowledge, as it allows *"the HCI research community to engage with wicked problems"*. I also maintain an awareness of elements of Hayes' work [6] in Action Research (AR) within HCI, which demonstrates an iterative process or spiral between successive designs (or interventions), thereby constructing *"a platform for HCI researchers to conduct socially meaningful and scientifically rigorous research"* when working with groups of people.

AR fits well with the contexts I am examining through my PhD work, which involve prototype development (which is iterative and produced in collaboration with the target groups), deployment and study of said prototype, and evaluation through qualitative methods. These systems and platforms include *CoolDesk,* a system for negotiation of office comfort between occupants, *VoteBox,* a toolkit for the collection of subjective annotations on objective environmental sensor data, and various related toolkits and data feeds which prompt discussion and enable research, using interviews and focus groups to collect qualitative data.

Expected Contributions

I expect to contribute understandings of sensor toolkit use within the context of Sustainable HCI, and how systems and processes can be built around these that

Figure 4: *VoteBox*, a system to collect subjective annotations on environmental data. The faceplate may be swapped out to update the categories under investigation, tailored to the individual concerns and needs of participants. As experiences of environmental (particularly thermal) comfort are inherently subjective, such a system provides a way of annotating how people actually feel, regardless of the sensed condition within the space.

feed back into the evidence-based management of buildings. My first-authored paper currently under consideration at CHI2017 introduces my framing of sensor toolkits as a repurposeable, redeployable, and retrofittable tool to augment current infrastructure such as BMS, and studies their use by a collective of specialised facilities managers and students undertaking professional development in buildings auditing. Services which make use of sensor toolkits could inform green policy through greater understanding of buildings conditions, but their consideration must include the surrounding practices and processes to address the concerns of prior work, and provide actionable recommendations for sustainable policymaking.

Acknowledgements

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