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Connected Seeds and Sensors: Co-designing Internet of Things for Sustainable Smart Cities with Urban Food-Growing Communities

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ABSTRACT

We present a case study of a participatory design project in the space of sustainable smart cities and Internet of Things. We describe our design process that led to the development of an interactive seed library that tells the stories of culturally diverse urban food growers, and networked environmental sensors from their gardens, as a way to support more sustainable food practices in the city. This paper contributes to an emerging body of empirical work within participatory design that seeks to involve citizens in the design of smart cities and Internet of Things, particularly in the context of marginalised and culturally diverse urban communities. It also contributes empirical work towards non-utilitarian approaches to sustainable smart cities through a discussion of designing for urban diversity and slowness.

CCS CONCEPTS

• **Human-centered computing** → **Interaction Design** → Participatory design

KEYWORDS

Participatory Design; smart cities; Internet of Things; sustainable cities; urban agriculture; civic IoT[1]

1 INTRODUCTION

As cities become fertile grounds for embedded Internet of Things (IoT) technologies and services, researchers have become increasingly interested in what has become known as the smart city [13,16,26]. For example, environmental concerns have driven an interest in *sustainable* smart cities through the optimisation of urban processes and resources, services and infrastructures, making them more efficient and therefore more sustainable [13]. The building of eco-cities is now at the "forefront of national and global agendas" [30]. Typical examples use networked sensing and tracking technologies for low-carbon infrastructure e.g. smart energy metering [24], water recycling and automated collection systems [30].

Like other modernist, top-down, efficiency-based, techno-solutions to the problem of sustainability, critics argue that eco-smart cities are subject to particular types of breakdown, because they are unable to deal with the complexities of real, messy cities [30], and sustainability gets performed in a specific way that leaves little room for political participation or citizen agency [9,13,30]. Furthermore, there are concerns over: who owns, controls, benefits from [3] and has access to the proprietary smart city [1,10,13]; privacy, surveillance and censorship [1,7]; inequalities in terms of representation, and participation [1,37]; and the encroachment of algorithmic culture into government, civics and public life [7,13].

Participatory Design and other civic-minded researchers are responding to these concerns by questioning "Whose right to the smart city?" [1,10,36], recalling French philosopher Henri Lefebvre's call for the democratisation of urban space through resistance and political action [27]. For example, participatory sensing is used in [3] to explore how citizens from disadvantaged backgrounds can "participate in the collection, sharing and use of data to tackle issues of their own concern"; while civic IoT is being developed to address "matters of concern and care" [7]. Others are exploring how smart city infrastructure, services and data, such as urban sensing, or local DIY WiFi networks, should become part of a digital commons [1,3,12], and help empower citizens to claim their rights to privacy, freedom of expression, diversity, and self-determination [1]. Projects such as Smart MK in the UK explored approaches to the scaling up of participatory design for citizen engagement in sustainable smart cities [17]. While [37] are helping citizens gain the knowledge and skills to make use and sense of data, to overcome barriers of access and participation.

Our work builds on these efforts to increase citizen participation in the design of sustainable smart cities by presenting empirical research from a case study called Connected Seeds and Sensors. This project explored engaging urban agricultural communities in east London in the design processes of sustainable smart cities, for community-building and education, in the context of cultural diversity and food. In this paper, we describe our co-design process and reflect on

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how our case study suggests two ways – *designing for urban diversity* and *designing for slowness* – to broaden the design space beyond efficiency. Our study highlights how working with urban agricultural communities can surface new visions for what more socially just and environmentally sustainable smart cities could be [6].

2 CONTEXT: SPITALFIELDS CITY FARM

Our case study of sustainable smart city design was developed together with our project partner, Spitalfields City Farm in east London. Through its community gardens, volunteer opportunities, its various educational programmes, and fresh produce sales, the farm encourages local communities to grow and consume healthy fresh food. Food is grown all-year round in rotation, with seeds being planted to replace the crops that will soon be harvested. It has a diverse base of volunteers and visitors in terms of age, ability, socio-economic background and ethnicity. As discussed in [20–22], and like the other gardens involved in the project, Spitalfields Farm places a high value on inclusivity, education and health and well-being of people and the Earth. Its environmental work not only revolves around food-growing onsite (thereby reducing CO2 produced in "food-miles" [32]), but also involves capacity building by strengthening knowledge and skills within nearby communities, as well as an integrative approach to the management of food production and waste cycles.

The farm and the other urban agricultural sites we engaged with are located in some of the most economically deprived areas in the UK. The borough where the farm is located is characterised by high population density, large-scale immigration, ethnic diversity, poverty, and huge divides between rich and poor. The farm supports Somalian, Zimbabwean, Bengali and Turkish community gardening groups, as well as school children, people suffering from post-traumatic stress, and mental health service users. There are high levels of racial segregation in the borough with around 50% of secondary schools being entirely non-white. The borough suffers from a range of food-related illnesses, such as high levels of childhood obesity, and adults in the borough are more likely to have diabetes compared to the rest of London [25].

It is against this background of ethnic diversity, economic deprivation, ill-health and marginalization that we recognised an opportunity to leverage local understandings of sustainability to explore what sustainable smart cities *could be* when we employ more democratic and inclusive ways of doing design. What would it mean to design a sustainable smart city intervention grounded in the values and practices of such communities?

3 CONNECTED SEEDS AND SENSORS

Connected Seeds and Sensors was an 18-month participatory design research project that took place between October 2015 and March 2017. The project was developed collaboratively with Spitalfields City Farm and researchers at Queen Mary University of London. Through previous long-term embedded PD research at the farm [18] we identified opportunities for IoT technologies to support the practices of food-growing and seed-saving in east London. The project explored these opportunities through four design strategies described in this section: i) participatory workshops; ii) engagement with the community of practice; iii) technology driven design exploration through the design, development, and deployment of networked environmental sensors and visualizations of their data; and iv) the co-creation of a digitally-augmented interactive Connected Seeds Library.

We were interested in seeds as a vehicle to explore the role of IoT in sustainable cities, and the practices of seed saving and sharing as a way to explore the complex interrelations between the environment, health and wellbeing, economic, political and social aspects that impact on sustainability, particularly with regards to seed-sovereignty and biodiversity. The term *seed sovereignty* refers to the control of seed production and supply [23], which was a pressing concern at the farm and elsewhere when we developed the proposal due to proposed changes to EU law that would make it mandatory to register seed at substantial cost [38]. Campaigners claimed that this change, as well as being disastrous to biodiversity, would play into the hands of big business such as Monsanto, at the expense of farmers' rights and livelihoods [ibid].

3.1 Initial Workshops

The project started with a series of four workshops aimed at better understanding the needs, practices and values of urban growers and seed-savers. For example, we wanted to know what kinds of information would be useful and meaningful to include on seed packets (beyond the standard information that commercial seed companies provide), including exploring what data we usefully could collect from IoT sensors. Workshop activities included participatory mapping, a cultural probe pack [15] seed-saving trainings, and creative activities that explored the cultural, social, environmental, and political entanglements of saving seeds and growing food in the city. For example, participants were asked to choose a seed and tell its story as a way of foregrounding the role of seeds in community and culture that is obscured by the technical details of the seed production when viewed from an industrial and commercial perspective. The probe pack contained a single-use 35mm film camera, a notebook and a series of open-ended instructions aimed at eliciting responses about growers' values and practices. The materials produced were used to facilitate further discussions and to collaboratively form what we called "data categories", which related to the information our growers would find interesting or useful to know about seeds. These discussions highlighted the practical, but also the personal, cultural, social, economic and political aspects of growing food and saving seeds, and would inform our designs.

3.2 Engaging Seed Guardians

From February-December 2016 we recruited and engaged 15 seed guardians who committed to grow 1-2 crops for seed, and to donate some seeds they harvested at the end of the growing season to the nascent seed library. Because we were interested in co-design in the context of cultural diversity, as well as to reflect the diversity of east London and the inclusive values of the farm, we actively recruited participants from different backgrounds, including Bangladeshi, British, Trinidadian, Turkish, Zimbabwean, French, Belgian, Australian, Chinese, Irish, Mauritian, German, Slovenian, Italian and Taiwanese. Guardians grew their crops in different kinds of gardens including communal plots at the farm, community gardens, common land on housing estates, and private back yards. Crops grown for seed included many not typically grown in the UK, e.g. kodu, lablab beans, Zimbabwean pumpkin and maize, calaloo, orach, chickpeas, pak choi, achocha, and black mustard. Guardians took photos of their gardens, plants, harvests and meals cooked. We recorded audio interviews with them at the start of the season, and again at the end, structured around the data categories that we elicited in the workshops. These captured the considerable knowledge and skill often required to grow such crops successfully in a UK climate.

Wider engagement included community events that we organised throughout the growing season, including seed-swaps, seed-saving workshops, garden visits and design sessions. These activities aimed to build a community of practice, where seed guardians could share skills and knowledge, maintain motivation, and participate in design decisions about the Connected Seeds Library. Additional engagement was through a documentary film [28], a book [19], an exhibition [40], and a final celebration [39].

3.3 Sensors and Data Visualisation

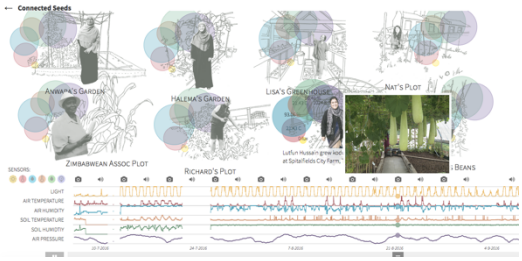

Figure 1: Timeline showing visualisation of sensor data

Networked environmental sensing technologies are increasingly used in industrial agriculture to monitor growing environments in order to increase the efficiency of mass crop production [2,14]. In contrast, our project aimed to explore how such IoT sensors could be used in the context of small-scale urban agriculture to support sustainable food practices, knowledge-sharing and community building. As there was no wifi available in the gardens, we designed and custom-built IoT devices from open-source systems, and deployed them in eight of the seed guardians' gardens to explore both the kinds of data that could be collected and to act as a prompt to allow us to explore how people might respond to such devices. The sensors collected information about air temperature, air humidity, air pressure, soil moisture, soil temperature, and ambient light. A reading was taken from the sensors every hour, and, in order to save on battery life, sent once a day to a web server over a 3G network. We collected data for 2 months and overcame many technical and pragmatic hurdles in the deployment of our IoT sensors such as dealing with unreliable networks and theft of sensor units. An interactive webpage presents the sensor data along a timeline along with photos and audio from the gardens [41] (see Figure 1), and allows viewers to compare data from the different gardens.

3.4 Connected Seeds Library

The Connected Seeds Library concept was collaboratively envisaged from the start as a way to collect and share the knowledge from guardians, connect people to their heritage through food, and to make available locally-grown seeds. Such seeds are highly valued as they have adapted to local climates, and may be of unusual or heritage varieties not available in commercial catalogues. In order to be as inclusive as possible, we designed the library as an engaging, interactive and playful artefact that does not require any particular technical skill or ownership of smartphone or computer. We enlisted the help of an artist, Franc Purg, to design and build the physical cabinet. The library contains seeds that guardians donated, as well as the digital records (audio and photographs) associated with those seeds. Visitors to the library can select a jar of seeds and place it on a designated pad in order to start a slideshow of images from the gardens. They can turn a wheel to play 1-minute-long audio tracks of the guardian talking about their experiences of growing. There are ten different categories, based on the data categories from the initial workshops, on the wheel to select: five relate to the grower (Who I am; Why I grow my own food; Why I save my own seeds; Connections to my heritage; How I feel when I'm working in the garden) and five relate to the particular seed (Where these seeds came from; How I grow them; Tips and tricks; Recipes; How to save seeds). Visitors can join the library (for free), take seeds home, and bring some back at the end of the season to maintain the living stock. The seeds also come in packets with QR codes

that link to webpages with the digital content. The Connected Seed Library continues to be used as a community resource at its permanent home at Spitalfields Farm.

Figure 2: Children interacting with the seed library.

4 DISCUSSION

We focus this discussion on two ways in which the co-design process surfaced new possibilities for inclusive and sustainable smart cities, beyond the dominant efficiency-based narratives of sustainability. We examine how the 'Right to the Smart City' is co-produced among the assemblage of human, non-human and technological actors, as a resistance to the hegemonic narratives of homogeneity and temporally bound efficiencies. The data we draw on includes materials produced in the initial workshops and transcripts from audio interviews with seed guardians.

4.1 Designing for Urban Diversity

Design often perpetuates the visions of sustainable smart cities as full of "Resource Men", white, middle-class technofetishists, "cast in the image of the male-dominated industries of engineering and economics that permeate energy management" [35] and who dream them into being. If people even exist within these visions of homogeneity they are alienated from nature, from each other, and from the production of food. Communities of colour such as those in multi-ethnic neighbourhoods where our project took place, are often marginalized from these visions, so we would argue that the right to the smart city is enmeshed in the struggles against marginalization [34].

Our co-design process suggests an alternative vision for sustainable smart cities: as "sites of encounter" [34], with difference, with other people, and other species. For example, participants in the workshops and engagement activities drew attention to community gardens as sites that draw people together in commons spaces, help break down social barriers and overcome racism, and contribute to social cohesion. "*We really love to come here and meet other people from our home. And other people from other places. We introduce them to our crops and we see their crops here.*" (Basilia). "*When I came to this country it was very difficult for me. All the neighbours spoke English, just me, Bengali. I was scared and thought how can I go outside and meet people and talk to them? After twenty years I started gardening. Now I'm not scared of anything. Gardening changed my life*" (Anwara). These stories of encounter are augmented, amplified, and celebrated through the Connected Seeds Library artefact, reflecting "matters of concern" [8]. As one seed guardian reflected on the project as a whole: "*I think one of the real strengths of this project is how it brought together lots of different people from different backgrounds and harnesses that expertise of the migrant communities*" (Richard). The library contributes to the digital urban commons [12] by making the seeds freely available along with the expertise of their growers through the IoT technology. It also participates in the struggle for the right to the smart city by narrating and amplifying these stories, thereby helping them proliferate.

The co-design process also surfaced how urban encounters with difference extend to other species: *"I keep the seeds and I keep plants living their whole life for the animal biodiversity so there's insects coming in and the birds eat the seeds. So, there's enough for everyone*" (Kate). Reflecting on the future development of the data sensing, one seed guardian envisaged a city-wide pollen-sensing smart city network, which would allow growers to coordinate their plantings to ensure sufficient food for urban pollinating insects. This suggests that our sensing system worked as a speculative participatory design tool allowing participants to engage with design futures of sustainable smart cities. Such futures counter efficiency-based understandings of sustainability by taking into account our interdependencies with other species, suggesting opportunities for more-than-human participation [4,11,29] in the smart city.

4.2 Designing for Slowness

Rather than valuing efficiency, throughout the workshop and engagement phases of the project, participants spoke of the slow timescales of growing, e.g. waiting for the right time to plant seeds, to replant, to harvest and to save seeds, in time with the seasons, as well as an awareness of a changing climate. Some guardians spoke of how they've turned the clock back to slower, less "efficient" practices from their parents' generations because they recognise that supporting biodiversity, seed-saving, and practices that nourish the soil should be valued in the long term: "*Modern agriculture came in and slightly devastated all traditional farming methods. The concept of saving seed went out the window. I've gone back to more organic production and traditional farming and gardening methods"* (Kate).

By offering the seeds as a community resource, along with such stories and advice of plant-care, the seed library artefact functions as a proposition to challenge the "predominant timescales of technoscientific futurity and their reductive notion of innovation" [33] inherent in sustainable smart city visions. Rather than putting a networked sensor in the soil to extract data for increased productivity and efficiency, the project engages with soil "as a living community" [33]. The soil sensor data taken together with the human stories tell of mutually caring human-soil relations [ibid] that progress over time. For example, one guardian reflected that the value of the sensor data was in its validation of his climate-adaptive gardening practices that involved mulching the soil, without accessing mains water: "*It is nice to have those numbers there, to consolidate your feeling that it doesn't need watering*" (Richard).

The benefits of the slow care for gardens were described by guardians. For example, a counsellor, working with immigrant communities who have endured torture, said: "W*orking in the soil, with soil, these things can change moods easily*" (Ahmet). Another said: "*It gives headspace. Especially in an urban environment where there is very little space for people. And time. It is all about space and time to think*" (Debbie). Participatory designers working in the smart city space must be careful not to compromise opportunities for care time [33] nor opportunities for face-to-face interactions, e.g. by automating the labour that provides such opportunities, as argued previously in [5,21,31].

5 CONCLUSION

There is increasing interest in providing alternatives to the visions of the top-down, managerial, efficiency-led smart city, through the participation of diverse citizens in the co-design of Internet of Things technologies and services. In this short paper, we have presented a case study that involved co-design of IoTs in the context of cultural diversity, for more sustainable urban food practices. We described our engagement and design processes, and reflected on two ways – *designing for urban diversity*, and *designing for slowness* – in which our study suggests alternatives for what a sustainable smart city could be.

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