Bringing Sustainability-Sensitivity into the Design of Public Interfaces: Opportunities and Challenges

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Abstract
Pervasive displays and other public interfaces in urban environments offer great opportunities for improving access to information and services, allowing people to make better informed decisions, and generally contributing to the smart city agenda. However, what is often overlooked are the impacts of such interventions on the environment and on underlying ecological systems – both because of the short-lived relevance of computing devices as well as resources needed to maintain their operation, such as power. In this position paper, we analyse representative examples from real-world deployments and research projects that attempt to address some of these sustainability issues in different ways. Based on these examples and a reflection on one of our own research studies, we discuss opportunities and challenges for moving towards sustainable and self-powered interfaces in urban environments.

Author Keywords
Sustainable smart environments, sustainable public interfaces, pervasive displays, physicalised displays, urban robots.

Introduction
The smart city enabled through the Internet-of-Things (IoT) comes with the promise to make urban life more efficient and sustainable [16]. Governments, tech companies and

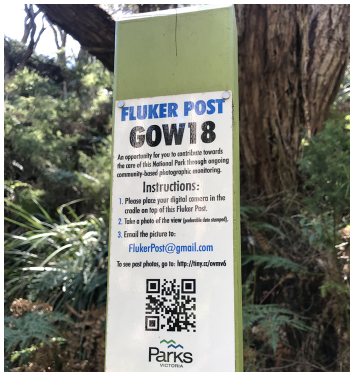

Figure 1: The *Flucker Post* project deployed along the Great Ocean Road in Australia facilitates community-based environmental monitoring. The top of each stand features a cut-out to hold any kind of personal camera or mobile phone enabling passers-by to take and upload monitoring images from a pre-determined perspective to a mobile app or website.

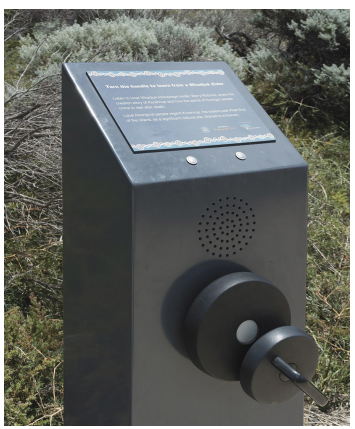

Figure 2: Hand powered storytelling audio boxes on Rottnest Island (WA, Australia). By turning the crank, people can listen to audio recordings about the local area's aboriginal heritage. Image credits: Rottnest Island Authority

researchers worldwide investigate and deploy technologies in a wide range of application contexts: from large-scale sensor networks for managing traffic and transportation, to pervasive displays and urban interfaces acting as an information gateway and enriching urban experiences [13, 15] – collectively referred to as "public interfaces" in this paper. However, what is often overlooked is the fact that these pervasive technologies themselves – aiming to make cities smart and sustainable – can have unintended negative impacts on the environment [4, 5]. First, the exponential growth of IoT devices has a significant effect on energy consumption in cities – highlighted by a growing body of work investigating energy-efficient models for IoT (e.g. [14]). Second, considering the entire product life-cycle, the devices used to create public interfaces not only require resources during operation, but also during production and to facilitate their disposal once they have become obsolete. In particular when it comes to augmenting the physical world with digital information, there is a mismatch in the lifespan of materials used in public interfaces: while traditional infrastructure is made from materials lasting for decades, hardware and software systems are outdated within few years, which makes maintenance more complex or impossible [12]. Third, public interfaces in the form of pervasive displays and large-scale architectural illumination (such as media architecture), contribute to light pollution potentially causing long-term harm to humans, animals and plants [17, 4].

In times of inevitably moving towards a human-made ecocide – with extreme weather conditions and natural disasters such as the recent bushfires in Australia being a harbinger of the planet's future – it is critical to rethink the design of pervasive technology for smart environments, including urban, regional and rural areas. As highlighted in the CHI workshop proposal [9], new innovative materials and emerging technologies, for example bio-hybrid sensors [11] and urban robots [6], form an important pillar towards more sustainable and environmentally integrated interface solutions. We add to this discourse and argue that the responsible use and implementation of these emerging technologies for the design of public interfaces is equally important. We propose that there are opportunities to create more sustainable solutions for smart environments by exploring alternative materials and a more-than-human perspective during the design process. We pose that these are critical considerations towards avoiding the next escalation stage of the "zero-sum game" in smart city developments [12]. Building on examples from research and real-world deployments, we scrutinize how also low-tech approaches can be used to enable "smart" solutions and create rich user experiences. We then present one of our own research deployments, in which we investigated how to scale-up such low-tech approaches through a robotic platform, and critically reflect on our design through the lens of sustainability.

Contextual Review

In this section we review examples of sustainable public interfaces from real-world and research deployments. We grouped the examples according to the underlying approaches to sustainability.

Crowdsensing

The Flucker Post[1] is a community-based environmental monitoring platform, developed by researchers from Victoria University in Melbourne and supported by the Victorian Government [1]. The aim of the project is to enable tourists to contribute to the care and management of national parks by making records of visual changes in the nature and the landscape. Instead of installing fixed camera and sensor

[1] http://www.flukerpost.com/, accessed February 2019

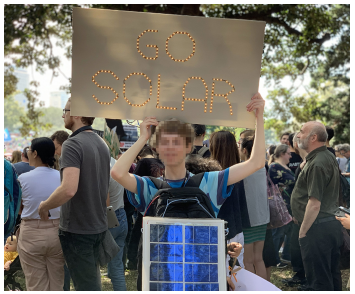

Figure 3: Participant at a *Fridays for Future* protest in Sydney with a solar-powered banner.

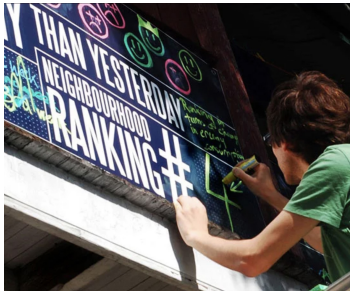

Figure 4: Research project investigating the public exposure of domestic energy usage on house facades. Instead of using a digital screen, chalkboards were installed as feedback displays and manually updated each day.

systems, which would require infrastructure measures in remote areas and nature reserves, the Flucker Post builds on the concept of crowdsensing. Simple wooden posts (see Figure 1) are installed, serving two purposes: first, a cut-out on the top of the posts helps people to place their personal cameras or mobile phones, to ensure that pictures are taken from a fixed position. Second, the posts have attached a printed sign to raise awareness of the project and provide instructions for how to send the pictures via e-mail or upload to the project's mobile app. The researchers report that besides contributing to the historical photographic record of the landscapes, community engagement was highlighted as an important aspect when tourists where asked to assess the perceived benefit of the project.

Self-powered Public Interfaces

Previous research has taken a critical look at the ubiquitous nature of pervasive display deployments, considering the high amount of energy usage in 24/7 operation situations and the actual benefits thereof [3]. However, there are also examples of public interfaces that break with the predominant "always-on"-mindset: On Rottenest Island in Western Australia (WA), the tourism authority deployed hand powered storytelling audio boxes (see Figure 2) to inform visitors about the aboriginal heritage of the land. The audio is activated by turning a crank, which powers the electronic components inside the box. This simple mechanism not only serves the functional purpose of powering an interface located in a remote area, but also creates a more conscious interactive media experience that is consumed on-demand instead of being always on.

With the advent of commercial photovoltaic systems, there has been also an increased usage of solar power for public interfaces, such as parking meters. With solar panels becoming cheaper and available off-the-shelf, interaction designers and do-it-yourself enthusiasts have also begun to create self-sustainable public interfaces (see Figure 3). Besides saving energy resources, solar-powered interfaces provide the advantage of being infrastructure independent and enabling the design of portable and self-moving public interfaces [6].

Non-digital Public Displays

Several studies also investigated and documented the use of non-digital displays using more natural and sustainable materials, such as chalk [8, 10]. For example, this involved installing chalkboard-like signage on residential houses for comparative energy feedback within a local neighbourhood (see Figure 4). While the data in those projects is collected through digital sensing technology (e.g. electricity meter), the output is updated manually, which the researchers reported to provide experiential qualities through their transient nature and the periodic update cycles.

All of those examples approach the aspect of sustainable public interface deployments in various ways: energy saving measures are apparent in all three concepts through self-sustaining systems, the use of non-digital materials or crowd-sourcing existing resources. The aspect of reducing resources in production, avoiding the use of harmful materials and facilitating disposal – also in consideration of the life-span mismatch between physical infrastructure and IoT-technologies – is pursued by the crowd-sensing Flucker Post project and the non-digital public display deployments. From a user experience perspective, all approaches provide a meaningful experiential aesthetic that is either embodied through the ephemeral qualities of the materials used, the proximity and close intertwining of energy generation and output, or the strong sense of community participation.

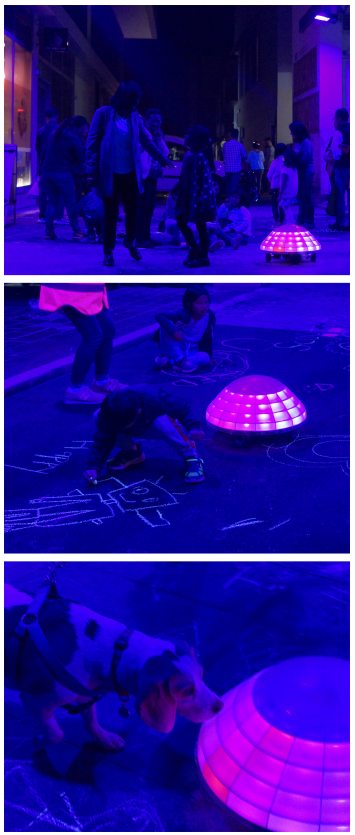

Figure 5: The chalkdrawing robot *Woodie* deployed as an urban robotic probe during a public festival: while the robot was drawing various designs on the ground, visitors were encouraged to add their own drawings.

Urban Robots for Physicalised Displays

In the following we present an example of our own research, in which we investigated how emerging technologies, such as urban robots, can be applied to the design of novel public displays that are more intertwined with the physical environment using non-digital materials for the creation of content [7]. We provide insights on the experiential qualities that the interaction afforded, discuss to which degree our design meets previously outlined sustainability criteria for public interfaces, and retrospectively reflect on some of our design decisions regarding the aspect of sustainability.

Design Intervention

Speculating on urban robots as agents for scaling up physicalised displays, such as those previously investigated in [8, 10], we designed *Woodie*, a free-moving urban robot which draws on the ground with conventional chalk sticks, using the public space as a large horizontal canvas (see Figure 5). The robot was designed using DIY hardware platforms and off-the-shelf electronics (i.e. Arduino, Raspberry Pi, stepper motors, Lithium batteries), digital fabrication techniques (i.e. 3D-printing, laser cutting) and vacuum forming for designing the robot's outer shell. For aesthetic purposes and to visually communicate the robot's internal status and intent, we integrated a low-res lighting display in the outer shell. To investigate urban interactions afforded by our design, we deployed Woodie as an urban probe for three weeks in a quiet laneway situated within a highly urbanised area. To set the scene for a sublime experience, we illuminated the area in which the robot was drawing with six high-power ultraviolet (UV) lamps, which would light up the drawings made of luminescent chalks.

Reflection

The slow rendering process of the created content increased the dwell time of people around the intervention and enticed them "to come back to see the finished drawing". Manipulating the physical environment, and making this process visible, particularly attracted children who were often lying on the floor to see the chalk stick touching the ground. In this sense, the ability to directly manipulate, copy and adapt the robot's content through chalk sticks that were handed out to passers-by, made the intervention to be perceived as "tangible" and "more human than only a robot drawing".

Additional to the experiential qualities of this intervention, we argue that physicalised displays created by the means of urban robots provide benefits in terms of more sustainable (although not entirely self-sustaining) deployments of public interfaces: robots can be deployed in an ad-hoc manner without the demand of construction work applied to the underlying physical infrastructure. In this sense, physicalised displays are not subject to the lifespan mismatch between physical infrastructures and therein embedded IoT-technologies. Further, if self-moving robots, such as Woodie, become pervasive in the future, they can be regarded as a shared resource that can be deployed in and out of specific locations, and potentially carry out various tasks.

Given the context for which we designed our intervention – a large-scale public festival – we acknowledge that our design was driven by the aim of designing for the "spectator experience". This aim led to design decisions increasing the aesthetic appearance of the intervention (e.g. the low-res lighting display, illuminating the area with UV light), while diminishing the sustainable footprint.

Future Directions

The discussion of examples for various approaches used in research and real-world deployments point to two particular opportunities for a future research agenda in HCI towards

creating sustainability-sensitive public interfaces.

Investigating experiential qualities
The examples outlined in this paper showcase that low-tech approaches – while being sustainability-sensitive – also provide aesthetic experiential qualities despite or because of their technical limitations compared to conventional smart city applications. For example, the chalkboard-style energy feedback signage was reported to have successfully attracted the attention of passers-by [10], likely more than conventional public displays would have been able to. Through our case study, we demonstrated how those approaches could be scaled-up through emerging technologies, such as urban robots. For a successful paradigm shift towards self-powered and sustainable interfaces, it is essential that they are accepted by a wider population. Therefore further research needs to investigate: How can we refine and enhance those qualities? What can we learn from "smart" solutions in regional and rural areas, and how can they find acceptance in the context of the city? How can we convince stakeholders of this interface and interaction paradigm shift, and align with their interests?

More-than-human perspectives
An additional direction to explore within the context of urban interfaces for pervasive technologies and smart cities are alternative processes that consider and involve more-than-human perspectives [4, 2]. Human-centred design has evolved to include diverse perspectives, which has created inclusive outcomes. However, these perspectives tend to preference the well-being and needs of people, neglecting what the impact of a design process or intervention may be on the underlying ecological systems. As the field of self-sustaining HCI matures, it will be important to investigate: How can such alternative processes be integrated in the design of public interfaces? How can sustainability-sensitive considerations become embedded in the design process, and what are potential tensions that might emerge from such a new approach that may be in conflict with aesthetic and other human-need-focused concerns?

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