

Suspicious Boxes and Friendly Aliens: Exploring the Physical Design of Urban Sensing Technology

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ABSTRACT

This paper explores how the physical design of urban sensors (i.e. shape, appearance) can change city dwellers' attitudes and perceptions towards being sensed. We illustrate different physical designs of urban sensors that were created by participants during a design workshop. We then describe how actual citizens reacted to the different designs during short-term deployments in the city. Based on this data and related work, we reflect about more general implications for the physical design of urban sensors. For example, we found that anthropomorphic and zoomorphic designs resulted in greater engagement and trust while neutral or less visible designs created rejection and anxiety. We illustrate our implications in the form of a fictitious urban sensing device. This device uses zoomorphism to create trust but also lets citizens exert control over what is sensed and when it is sensed.

Categories and Subject Descriptors

H.5.2 [User Interfaces]: Prototyping.

General Terms

Design, Human Factors, Theory.

Keywords

Smart cities, internet of things, sensors, physical design, privacy, anthropomorphism, zoomorphism.

1. INTRODUCTION

Our world is becoming rapidly urbanised with over half of the world's population already living in cities and a forecasted 5 billion to be city dwellers by 2030. As this fast urbanisation continues across the globe, researchers are looking towards "smart" cities to solve the arising scalability and social issues in ever-growing cities. This shall partly be achieved by blanketing cities with pervasive sensors connected by the 'internet of things' (IoT) to sense the state of infrastructure, the flows of resources, and the actions of individuals, groups, or organizations [1]. By

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Urb-IoT 2014, October 27-28, Rome, Italy
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DOI 10.4108/icst.urb-iot.2014.257307

this, the IoT becomes a citywide 'electronic nervous system' that lets cities become smart like 'higher organisms' [1] and enables them to sense and react to events (e.g. optimizing traffic flows, managing breakdowns, rewarding sustainable behaviour). Such ubiquitous, yet invisible, urban sensing technologies can easily feel intrusive and as if they have an undue influence over our lives [2]. They raise important questions [3] on whether citizens could feel disempowered or even disengaged or if they will fear and worry about the effects of smart technology on themselves.

Already today city dwellers are rightfully wary of being observed in communal and urban spaces by an invisible network of sensors typically controlled by government, law enforcement, or corporations. It would be unacceptable, if future top-down technologies made city dwellers feel that they are spied on and restricted in their privacy and choice of actions without being able to, at the very least, temporarily opt out of being sensed, tracked, or analysed. Therefore future sensing technology should be designed to avoid unnecessary anxiety and suspicion, for example by always clearly communicating what is sensed and when it is sensed and, whenever possible, enabling citizens to opt in or out.

This is also true, when sensing becomes 'crowd sensing' and a part of a bottom-up community effort (e.g. Smart Citizen Kit [4], Fukushima Wheel [5], Copenhagen Wheel [6], Air Quality Egg [7]). In a world in which a phone, a watch, a small smart device, or even a pair of glasses can contain powerful sensing and recording technologies, it is necessary to always clearly communicate to fellow citizens when data is collected and what data is collected. It therefore lies in the responsibility of the community and the providers of crowd sensing technologies (no matter if large corporations, small startups, or not-for-profit initiatives) to design technologies that achieve a high-level of trust and transparency and do not disrupt the self-determined private and social life of urban communities.

In this paper, we therefore explore how the physical design of urban sensors (i.e. shape, appearance) can change city dwellers' attitudes and perceptions towards being sensed. We illustrate different physical designs of urban sensors that were created by participants during the SenCity design workshop at UbiComp 2013 in Zurich, Switzerland. We then describe how actual citizens reacted to these designs during short-term deployments in the city. Based on this data and related work, we reflect about more general implications for the physical design of urban sensors. For example, we found that anthropomorphic and zoomorphic designs resulted in greater engagement and trust while neutral or less visible designs created rejection and anxiety. We illustrate our implications in the form of a fictitious urban sensing device. This device uses zoomorphism to create trust but also lets citizens exert control over what is sensed and when it is sensed.

2. Related Work

As sensing devices become more prevalent in urban public spaces, it is necessary to understand how to design and deploy non-intrusive technologies that will be trusted and accepted by the public. In contrast to Weiser's vision of 'disappearing' and 'indistinguishable' technologies [8], this cannot be achieved by simply embedding or 'hiding' sensors in the surroundings, even if the collected data is non-sensitive.

2.1 Sensing in Urban Spaces

A recent example in London highlights how important transparency and form factor are with regards to sensing in public spaces. Monitoring devices were fitted into 'smart bins' to collect footfall data by logging nearby phones [9]. After a media exposé, the scheme was met with huge public backlash and was eventually halted by the local council authority. People were outraged that they were not made aware of the new capabilities of the bins and felt that their privacy had been violated by what they believed to be benign street furniture.

Bins have also been enhanced with other surveillance technologies such as BinCam: a camera that takes pictures of your rubbish and uploads them to Social Media sites for your friends to judge [10]. Although it is aimed at 'revolutionising the recycling process' it has also drawn criticism [11] for its intrusive nature. A commonality between the two projects is the use of highly recognizable, benign objects as the form factor to house sensing technologies. In doing so, the developers can (often unintentionally) evoke feelings of being duped or spied upon in underhand ways. Trust is lost regardless of what data is being collected or how it will be used.

Greenfield suggests the use of icons to raise awareness about what is being sensed and actuated in our ubiquitous computing environments [12]. However, research has also explored how the sensing devices themselves can be more transparent by expressing sensing capabilities through their own form factor. For example, air quality sensors have been integrated into large, illuminated helium balloons [13]. The resulting devices are highly visible with a metaphoric link to the air they are sensing. In addition, their eye-catching form factor leads to curiosity and intrigue prompting further investigation and enquiry about the device and air quality.

In another study investigating participatory sensing in public spaces, four different groups of stakeholders were given mock sensing devices to place around their everyday environments for one week [14]. As well as thinking about what they might sense, stakeholders also considered what real sensing alternatives should look like. The majority agreed that high visibility was important, preferring sensors that would 'stand out' in their environment while also giving feedback as to what they were sensing.

2.2 Form Factor

Although previous research has touched on the placement and visibility of sensing technology, little work has been done to understand how the form factor of sensing technologies affects public anxiety or acceptance. However, much literature in human-computer interaction exists on how the form factor affects engagement with other types of technology such as interfaces, virtual agents, and robots. Affordances in design [15] are visual clues to the function or use of a technology, which if applied to the form factor of sensing technologies may ease anxieties by providing greater transparency of what is being sensed.

Additionally, anthropomorphism or zoomorphism have long been exploited to reduce anxieties when interacting with technology as well as making the experience more enjoyable and engaging [16]. In particular, many technology-based educational toys or on-screen agents and tutors have been designed to look and interact as if they were human. Turkle [17] comments on how users 'enter into the roleplay' when engaging with such technologies, projecting emotions and additional human characteristics onto them to explain erratic behavior due to technical limitations or faults. Research also shows how we even react to social cues from anthropomorphic technology in the same way we would react to social cues from humans [18].

To gain a better understanding of how such concepts may apply to the design of sensing technologies we organized the one day design workshop "SenCity: Uncovering the Hidden Pulse of a City" at UbiComp 2013 in Zurich, Switzerland. The following sections describe the workshop, its outcomes, and the resulting design implications for future urban sensing technologies.

3. THE SENCITY WORKSHOP

The SenCity workshop was organised to further explore sensing in urban environments with particular focus on the form factor of sensing technologies. The workshop was part of a scientific conference on ubiquitous computing and over 20 people participated on the day including designers, social scientists, technologists, and sensor experts from all across the world.

3.1 Workshop Activities

Participants were divided into five working groups and each was provided with two sensing kits; the first was the Smart Citizen kit (Figure 1) from FabLabs Barcelona and the second was the SenCity kit (Figure 2) which was custom built for the workshop by workshop organiser Vaiva Kalnikaite.

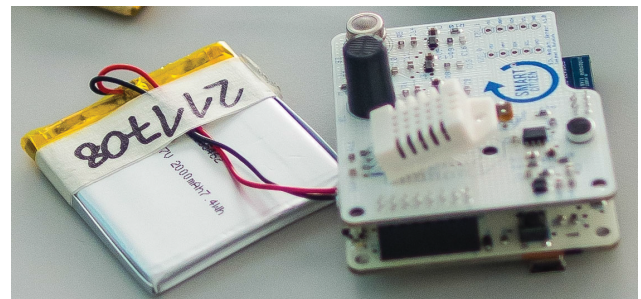


Figure 1. Smart Citizen Kit.

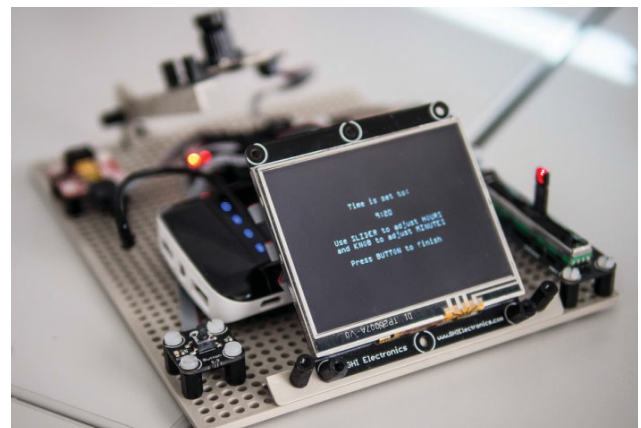


Figure 2. SenCity Kit.

The Smart Citizen kit is Arduino based and can be configured programmatically via the Arduino IDE; however these kits were pre-configured before the workshop so this was not a requirement for participants. The kit is aimed at environmental sensing and has a number of on-board sensors including temperature, humidity, NO₂, CO, light, and sound. All sensed data from the kit can either be sent directly to the cloud or stored locally on an SD card.

The SenCity kit is based on Microsoft Gadgeteer and provides a screen and several knobs, buttons, and sliders that enable the kit to be configured on the fly without the need to interface through a programming IDE. The kit includes sensors for temperature, humidity, light, vibration, tilt, and moisture which can be connected to the unit one at a time. In addition, it also includes a camera that can take pictures and shows them on the screen when sensor readings go above or below configurable thresholds.

Each group was given some time to familiarise themselves with the technology. They then brainstormed what they wanted to sense with the kits, where they would position them in the city, and what the kits should look like. The groups were then given time to build casings for their kits and a variety of different materials, from cardboard and masking tape to fake leaves and moss, were provided so groups could be as creative as possible. Some groups chose a simplistic box-like casing design while other groups explored various creative form factors including duck and alien shaped casings. In addition, some groups chose traditional environmental sensing goals while other groups chose to encourage public participation with their sensor kits.

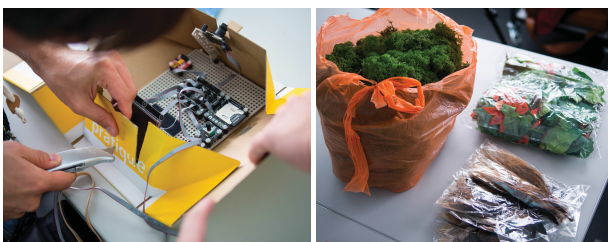


Figure 3. Designing casings (left). Unconventional materials, e.g. fake leaves, feathers, moss (right).

An important part of the workshop was to actually get some hands-on experiences in a real urban environment, so the groups were then given time to leave the classroom and go out into the city to explore the space and deploy their sensor kits. Each group was shadowed by a workshop organiser, who monitored how the kits were deployed and how the public reacted to them. Upon returning to the classroom each group presented their experiences to the others and open discussions were held.

3.2 Group Designs

3.2.1 Group 1

Group one decided to create a sensing device that required user interaction. They designed and built an anthropomorphic, alien casing for the SenCity kit (Figure 4). The idea was to encourage playful urban community engagement by inviting members of the public to shake the hand of “Willy the Alien” to have their picture taken which was then also shown on the kit’s screen.



Figure 4. “Willy the Alien” design of group 1.

3.2.2 Group 2

Group two also included some element of user interaction. The idea was to ask people about their mood, capturing responses through coloured post-its and expressive photographs for later comparison against environmental sensor data. Therefore the group combined face-to-face questioning with the photographic and sensing capabilities of the SenCity kit and designed a box-like enclosure in which to house it (Figure 5). They also collected objective sensor data (such as humidity, noise, and temperature) with the Smart Citizen Kit.



Figure 5. Mood sensing box of group 2.

3.2.3 Group 3

The third group adopted a more traditional, passive sensing use case. They used the SenCity kit to develop a device that sensed road surface conditions. The enclosing form factor was a simple box shape (Figure 6) and the idea was to take the box onto various forms of public transport to capture vibrations from the road surface and to take a picture as soon as vibrations exceeded a threshold.



Figure 6. Vibration detector box of group 3.

3.2.4 Group 4

Group four wanted to sense how satisfied citizens were with public transport near a river. They adopted a zoomorphic design to enclose the SenCity kit and commented that the duck shape of their creation was a link to the river (Figure 7). Again, there was an element of public engagement where the idea was to ask members of the public to shake the duck's foot with an intensity that reflected how satisfied they were with the transport system.



Figure 7. Duck design of group 4.

3.2.5 Group 5

Group five decided to go to a local funfair in the city. They opted to use some of their own sensing technology (on their smartphones) in addition to the kits provided. They designed a box shaped enclosure for the SenCity kit (Figure 8) and the idea was to take it on fairground rides to sense their movements.



Figure 8. Fairground ride sensing box.

3.3 Observations in the City

All groups moved around the city sensing in different locations. While one group travelled to a local funfair, the other groups mainly chose everyday places and walked around the streets or captured data on various forms of public transport including trams, buses, and a funicular railway. In most cases the kit was held by a group member or placed in a suitable location (such as a bus seat or park bench). In general, the kits were not used at a single location and for passive sensing of the environmental data but rather as tools for active mobile sensing at multiple locations and for triggering actions within the environment, e.g., taking pictures of the persons interacting with them.

3.3.1 Choice of sensors, sensing context

Workshop participants enjoyed using both sensing kits around the city, however the sensor experts preferred the Smart Citizen kit with its more typical design and capturing of several simultaneous data streams from different environmental sensors. For non-experts the SenCity kit with a screen, a single data stream, and a camera was much less intimidating and many commented on the benefits of being able to configure it without any programming knowledge. Participants also commented that the camera was useful to capture the spatial and social context of data in addition to the purely quantitative sensor readings of the Smart Citizen kit. All groups created their casings for the SenCity kit but they also took the Smart Citizen kit into the city without any outer casing.

3.3.2 Reaction to visibility and the physical design

Although provided with materials such as fake leaves or moss, none of the groups tried to 'hide' sensors or to create casings that blended into the background; instead all were very visible and brightly coloured. However, there were significant differences with how citizens reacted to the devices depending on their shape.

For example, the box-like casing (Figure 6) evoked a negative suspicion with one bus driver confronting the group about spying and monitoring with references to his past experiences before emigrating from East Germany. His anxiety was at such a level that he almost asked the group to leave his bus. Outside the bus, the group was closely observed by a group of children who apparently felt that the box was suspicious but did not approach the group to ask for its purpose. In contrast, the duck and alien casings (Figure 4 & 7) evoked a positive curiosity among the public and people would approach to interact or ask more about the purpose of the device.

3.3.3 Privacy concerns

The design of the casings in the likeness of living things and their perceived playfulness apparently overshadowed concerns about privacy. Indeed privacy concerns were only raised in regards to the box-like designs even though the sensing and monitoring capabilities of all kits were the same or even more intrusive in the case of the alien that took pictures of all users interacting with it and would have in principle allowed biometric recognition.

Interestingly, rather than being concerned about having their picture taken by a strange alien or duck shaped device that was built and operated by a group of strangers, members of the public were thrilled to see their picture on the small display screen. Several expressed disappointment at not being able to print a hard copy as a souvenir but no one raised questions of why their picture had been taken or how it would be used.

4. DESIGN IMPLICATIONS

In the following, we reflect about the implications of our observations for urban sensor design. Clearly, our observations must be considered anecdotal and not a generalizable result, in particular given the small sample size and informal nature of our study that happened exclusively in the prosperous Swiss city of Zurich with just about 400,000 inhabitants. Nonetheless, our findings resonate with already existing literature about human-computer and human-robot interaction and can serve designers of urban sensing technology as an inspiration and starting point for their own design explorations.

4.1 Zoomorphism

As reported, people reacted more positively to designs in the likeness of living things. They trusted such designs serve a good purpose and felt less anxious about privacy. Therefore these designs seem to be a good choice whenever greater community engagement and trust shall be achieved.

However, a too detailed imitation of natural physiological features or movements is likely to be counterproductive. The ‘uncanny valley’ is a hypothesis in robotics and computer animation which holds that an almost natural-looking but imperfect robot or virtual agent will seem overly strange and will fail to evoke the intended empathic response [19]. In the case of our workshop, the rather crude and playful look of the duck and alien ensured the designs did not enter this uncanny valley. However, using more elaborate designs like realistic puppets or animals would most likely not result in the same positive effect.

An example for a good level of realism can be found in one of the earliest examples of IoT appliances from 2006: Violet’s Nabaztag and its successor Karotz (Figure 9). This connected ambient device in the shape of a rabbit (height: 230mm) is not used for urban sensing but contains a camera, microphone, loudspeaker and RFID reader to interact with users in their home. Its body, face, and its wiggling ears contribute to a cute and playful appearance without trying to imitate the features of a real rabbit, e.g., size, anatomy, color, fur.

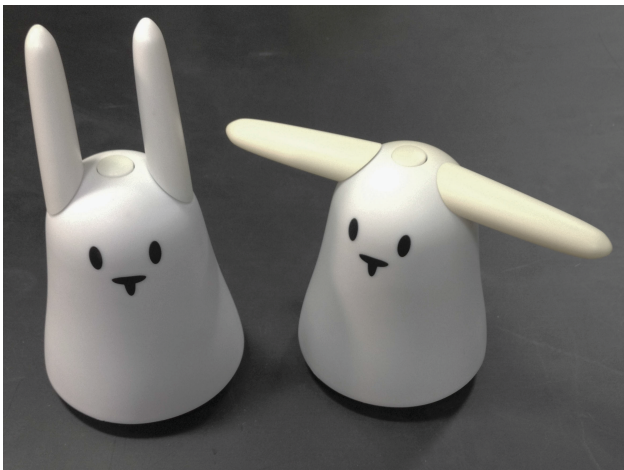


Figure 9. The Nabaztag device has the shape of a rabbit.

4.2 Visibility and Control

Using the zoomorphism of Karotz from Figure 9 does not necessarily mean ‘tricking’ citizens into the belief that a sensor is harmless and that there is no need to be concerned about privacy. Zoomorphism can not only be used to manipulate citizens’

perceptions but also to increase transparency of sensing and better convey what is sensed and when it is sensed.

For example, a sensor device could use a face like in Figure 9 to indicate what sensing technologies it is equipped with. Devices with recognizable eyes, ears, or noses are obviously capable of recording video, audio, and sensing particles in the air. This indication of what is being sensed can be easily understood, even by a non-technical audience.

Zoomorphism can also be used to enable better control of the sensing. To achieve this, the different sensors of a device could be positioned at the locations of their natural counterparts, i.e. microphones in the ears, cameras in the eyes, and air quality sensors in the nose. This enables also non-technical citizens to exert physical control over sensing, for example, by simply covering the eyes or nose with opaque adhesive tape. A similar practice can be observed today for many laptop or Kinect owners. They physically cover the lenses of built-in cameras as a reaction to recent cases and media coverage of unauthorized spying on users with hacked devices.

4.3 Sensors as Ambient Displays

The physical design of a sensor can also include elements of ambient displays. For example, Karotz contains LEDs to show different colors on its belly and the actuated ears can be moved into different positions to create ambient unobtrusive visual representations of information (Figure 10).

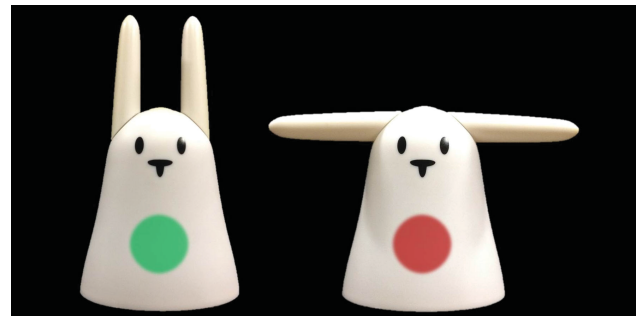


Figure 10. LEDs and actuated ears as ambient displays.

In an urban sensing scenario, such LEDs on a device could indicate if the sensor is currently active or if the sensor readings are within a recommended range. LEDs or ‘happy’ or ‘unhappy’ faces or ears could visually indicate ‘good’ or ‘bad’ readings, e.g., when CO₂ or noise levels exceed recommendations.

This kind of a zoomorphic ambient display can also be used to subtly reward sustainable or prosocial behavior. By showing that a likable or cute character feels happy or sad depending on the overall behavior in a room, building, or street, some individuals might feel a kind of emotional attachment and become more inclined to change their behavior than it is the case with less playful and more conventional feedback.

4.4 Sensors as Actuators

In principle, it is only a small step to move from LEDs and actuated ears as ambient displays towards a sensor which also acts as an actuator within the urban environment. To some extent, this was already the case for group 1 during our workshop: “Willy the alien” rewarded citizens for their participation by taking and showing a picture of them on the display of the SenCity kit. This principle could be further extended in future. In appreciation of the citizens’ participation and sacrifice of privacy, urban sensing

devices could provide a service to them and their community. This could be a playful service that is similar to taking a picture, for example using the devices to play small animations, sounds, or showing choreographies. More serious services could help to control lighting, air conditioning, or the volume of audio signals according to sensor readings in the environment. The devices could also alert citizens about exceptional events or potential dangers.

By bundling sensing and actuation in one visible physical device, the abstract concept of a 'smart city' would also become more graspable and tangible for citizens. They could observe what a device senses and how it reacts to it. This would also enable citizens to explore cause-and-effect relationships between sensor input and actuation output. We believe that this would contribute to higher levels of transparency and greater acceptance for urban sensing among city dwellers and would also create new incentive structures for crowd sensing.

5. CONCLUSION

In this paper, we have described our observations of how the physical design of urban sensing technology can change city dwellers' attitudes and perceptions towards being sensed.

First, we have argued for a considerate design of urban sensing devices since they are likely to become an integral, but also potentially disruptive, part of our private and social life in urban communities. Then, based on our observations from a design workshop and from the deployment of its results in Zurich, we have discussed implications for design. For example, we found that anthropomorphic and zoomorphic designs resulted in greater engagement and trust while neutral or less visible designs created rejection and anxiety. We have also illustrated our implications in the form of a fictitious urban sensing device. This device uses zoomorphism to create trust, greater visibility and control and highlights the potential of sensors as ambient displays and actuators in the urban space.

6. ACKNOWLEDGEMENTS

We would like to thank all participants of the SenCity workshop at UbiComp 2013 in Zurich for their active participation and their creative and inspiring designs. We would also like to thank Danny Harrison for his photos and his support throughout the workshop.

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