MiniOrb: A Sensor Interaction Platform for Indoor Climate Preferences

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Abstract
We introduce the MiniOrb platform, a combined sensor and interaction platform built to understand and encourage the gathering of data around personal indoor climate preferences in office environments. The platform consists of a sensor device, gathering localised environmental data and an attached tangible interaction and ambient display device. This device allows users to understand their local environment and record preferences with regards to their preferred level of office comfort. In addition to the tangible device we built a web-based mobile application that allowed users to record comfort preferences through a different interface. This paper describes the design goals and technical setup of the MiniOrb platform.

Author Keywords
Ambient Interface; Tangible Interaction; Indoor Climate; Individual Control; Peripheral Awareness

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation] User interfaces: Input devices and strategies

Introduction
Environmental factors, such as lighting, temperature and humidity are central to the perception of comfort in office environments. Increasingly these factors are

Figure 1: Sensor device (with case)

Figure 2: MiniOrb interaction device (foreground) connected to sensor device (background)

controlled by automated Building Management Systems (BMS). The automatic, sensor-based, adjustment of these comfort factors can potentially affect large numbers of office inhabitants, in particular in open office environments. Generally, centralised systems like BMSs do not account for individual inhabitant's preferences regarding indoor climate and environmental office conditions.

Buildings are also increasingly utilising ubiquitous sensing technologies to control the functioning of indoor climate systems in 'smart' ways [3]. This often translates into increased automation of indoor climate systems, however it has also been shown that building occupants' satisfaction levels are strongly negatively affected by lack of control over the environment [2]. Allowing people to control the indoor environment not only improves their overall satisfaction [2] but also can be an effective means to reducing energy consumption [1].

In our research we explore the design and evaluation of sensing and interaction devices that aid office inhabitants in controlling their localised office environments, as well as support the process of negotiating shared preferences amongst co-located inhabitants. In this paper we describe the MiniOrb platform, a combined sensor and interaction platform build to understand and encourage the gathering of data around personal indoor climate preferences in office environments. The MiniOrb platform combined the use of ambient display and tangible interaction techniques to allow users to understand their local environment and record preferences with regards to their preferred level of office comfort. In addition to the tangible device we built a web-based mobile application that allowed users to record comfort preferences through a different interface. This paper describes the technical setup of the MiniOrb platform. The design of the system aimed to address the following design goals:

- The interactions should be quick and unobtrusive
- The device should provide an ambient awareness of a range of sensor readings
- The device should allow setting of individual preferences in relation to each sensor reading
- The device should allow comparison between individual and group (average) preferences
- The device should allow for user feedback on their level of "social connectedness"
- The device should be minimal and provide input and output through a small set of interaction mechanisms

"Social connectedness" was introduced as a soft measure to allow people to relay information about their social status alongside other office comfort factors. The platform consists of three components: a) a local **Sensor Device** situated on the users' desks that locally measures temperature, humidity, light levels and noise levels; b) an ambient and tangible interaction device, called **MiniOrb** (see Figure 3 for a design concept and Figure 2 for the actual device), that displays the locally sensed environmental conditions and allows users to select and submit their preference ratings; and c) a mobile application, **MobiOrb**, that provides for display of the sensed information and input of user-preferences as precise measurements. We introduce each component in turn.

Figure 3: MiniOrb concept design

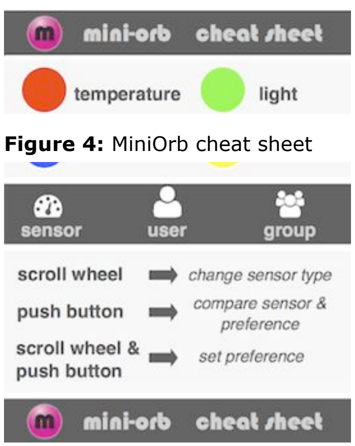

Figure 4: MiniOrb cheat sheet

Sensor Platform

The MiniOrb sensor device is an Arduino-based, USB-powered, sensing platform that measures temperature, humidity, light levels and sound levels via an array of digital and analogue sensors (see Figure 1). Each device communicates wirelessly with a dedicated server via a ZigBee mesh network. The sensor platforms were placed in a relatively fixed position above user's desk, typically on a partition or a cabinet, in order to achieve consistency and comparability of sensor readings between desks. Sensor readings were taken continuously and an average value for each sensor type was sent to the server approximately every 30 seconds.

MiniOrb Interaction Device

The MiniOrb device is an ambient and tangible interaction device that is connected directly to the sensor device. It records user's office comfort preference values, displays sensor readings from the user's local sensor device, as well as average comfort preferences across all users (see Figure 2).

The device consists three small LED's that indicate different states (sensor, user, group), a piezo speaker, a button and a scroll-wheel potentiometer for user input, as well as a dome-shaped "orb", a frosted plastic cover which contains a bright RGB-LED (see Figure 4, for a match between colour and sensor categories). Each value is represented by the colour intensity of the RGB-LED, i.e. the higher the value the more intense the colour. For instance, to display temperature-related information the device would cycle through three states. First it would display the value read by the sensor device as a matching relative intensity of the colour red. The small LED under the "sensor" icon would light up to indicate the state. The device would then move to the next state displaying the last known user preference, again indicated by the corresponding status LED "user". The device then completes the temperature cycle by displaying the value for the "group" preference in a similar fashion. Each state would be displayed for approximately 5 seconds. Once the device completes the temperature cycle, it moves on to the next cycle to show the light-related information in a similar fashion, but using green as the output colour, and so forth. Once the device has cycled through all four sensor categories, it starts again from the beginning. The "social" category differs from the other categories, in that it is not based on input from the sensor device, but purely determined by user feedback. Thus, for this sensor category, the "sensor" value is identical to the "group" value. Each user was given a "cheat sheet" that outlined the colour codes, states and interaction mechanisms (see Figure 4).

The device offers users three interaction mechanisms by combining the push button and scroll wheel: 1) **scroll wheel**: when the wheel is scrolled, users can choose one of the four sensor categories manually, e.g. if they were interested in the sound reading they could scroll the wheel to get the device to display the corresponding cycle immediately, without having to wait for the device to complete other cycles. 2) **push button**: when the button is pushed, the device displays the user preference for the current cycle, and when released, the button displays the corresponding sensed value. This allows users to effectively compare their own preference against the sensed value. 3) **scroll wheel & push button**: this function allows users to enter preference values for any sensor category they

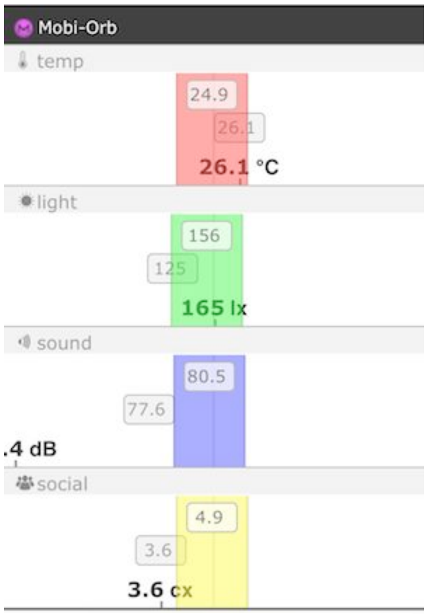

Figure 5: MobiOrb mobile interface

selected. To do so, they set the desired orb intensity by scrolling the wheel while the button is depressed. The preference was recorded as soon as the button was released. The device was designed so that this interaction could be easily achieved with a single hand, e.g. by pushing the button with a finger and scrolling the wheel with the thumb.

In addition to the visual output mechanisms the device employs a small number of audio cues to enhance the interaction. The interaction with the scroll wheel is enhanced with subtle "click" sounds that give users a sense of selecting discrete units. A slightly more pronounced sound is used when the wheel moved into the "middle" position. A separate "chirp" sound is used to notify the user that their preference has been recorded and sent off to the server. Lastly, once per day the device issues a short "remember me" "buzz" sound to encourage users to record their preferences. This sound has been specifically designed to be noticeable, yet inconspicuous in order not to annoy users.

MobiOrb Mobile Application

The MobiOrb mobile application is an alternative interface that provides the same basic functionality as the MiniOrb device and shows the same sensor values, but employs different interaction mechanisms (see Figure 5). Apart from the interaction approaches, the main difference between the two MiniOrb interfaces is that the mobile interface allows users to interact with specific sensor values (e.g. Temperature 26.1 C). MobiOrb is a mobile web application that can run on any smart phone and standard web browser. The system includes a basic user authentication screen and a main screen, which consists of four sections, one for each sensor type. Each section contains a colour-coded slider that matches the MiniOrb sensor colour scheme. Users can move these sliders to record their preferences, which are also displayed in plain text in a grey bar in the top part of the slider. The readings in bold at the bottom of each section show the actual sensor value using a sensor-specific unit. The detached grey bar in the middle of each section depicts the group average value. The mobile interface allows users to more accurately assess and set sensor values, but at the same time does not provide the same ambient accessibility as the MiniOrb devices that are situated on users' desks.

Conclusions

The MiniOrb platform was deployed as part of a field trial with 12 users in early 2014. The analysis of data from this study is ongoing, but preliminary results indicate that small interaction devices, combining ambient and tangible interaction approaches, can be well suited to engage users in the process of providing preferences. This process can be aided by the provision of alternative interface mechanisms that provide accurate sensor and reference values when required.

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