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Kuckuck – Exploring Ways of Sensing and Displaying Energy Consumption Information in the Home

Abstract This position paper overviews a study where we identified energy consumption as a potential candidate for ubiquitous computing technologies in the home. It then goes on to describe the 'Kuckuck' project where we developed custom-sensors to monitor energy usage and are in the process of trialling them in a participant's home along with an interim graphical representation.
Keywords Sensors, energy monitoring, domestic

1 Introduction

"I want to live in a yurt with internet access" – Felicity

One of the challenges around the application of ubiquitous technologies in the home is to identify those applications, beyond the more common automation and care agendas, that people actually want to live with and that will fit in with their current values and lifestyles. In this position paper, we give an overview of a project that has sought to explore alternative uses of ubicomp technologies in the home. Through a user-centred process (that we describe below) we identified the monitoring and management of energy consumption as a candidate area and have been exploring this. The description below sets out the project to the current point in time.

This work fits into a set of more overarching agendas around energy consumption, including: how do we create configurable and sustainable sensor-based toolkits that people can use to monitor their own energy consumption; what do people want to monitor and at what level of granularity both in terms of time and devices; how do people want this information fed back to them and how do they make sense of it; and will it result in longer term increased awareness and hopefully behaviour changes?

2 Background

As part of a study of experiences of domestic technology in the home we visited 10 houses in Brighton in the United Kingdom and asked the participants to walk us around their houses and talk to us about the experiences that they'd had with the technologies in their homes. One of the findings of this study [1] was that householders tended to use technology as a way of expressing more general values, as a way of demonstrating how they saw their standing ethically and socially, for example: "*I printed this out (tide tables) because I want people to think we're the kind of family that goes sailing. We're not.*" This was particularly true of two households, both of which expressed concern for environmental issues and played out this concern through significant expenditure of both money and time/effort. Many people saw their choice of technology as a fundamental expression of their beliefs but wanted technology to fit in with rather than transform those beliefs: "*I want to live in a yurt with internet access*".

2.1 Household A – Felicity and Jake

In Household A, there was a couple in their mid-twenties. Jake was a computer programmer, Felicity worked as an administrator for a University. They were both very keen on environmental issues and had carried out several technological modifications of their house to make it more environmentally friendly. They had installed taps that mixed air with the water that flowed out of the bathroom taps to increase the volume and efficacy of the water for hand washing, and hence reduce the total amount of water used. They had installed a system which allowed them to use rain water for flushing their toilet. They had also purchased electricity-generating solar panels, but had not yet managed to have them installed on the roof of the house.

Concern for their personal use of carbon-emitting fossil fuels had also caused Felicity and Jake to put together a spreadsheet, into which they fed data from gas and electricity bills and the amount of travel by bus, train, car and aeroplane that they did to calculate the total amount of carbon emission for which each of them was responsible. This spreadsheet had made them very aware of the disproportionate contribution that air travel made to their individual carbon footprint.

2.1 Household B – Karen, Ivan and Josh

In Household B, there was a couple in their mid forties, Ivan and Karen, with one fourteen-year old son, Josh. Ivan had been politically active in the Green Party – a political party in the United Kingdom which focuses mainly on ecological issues. He had

several concerns about the use of energy in his house. He was particularly concerned with the amount of energy that might be being used by household appliances left on "standby" and explained that each night he would tend to walk around the house and turn off all of the appliances that he could that weren't being used but had an LED light showing that they were on stand-by. Ivan also worried about whether boiling a kettle on the gas stove used more or less energy than boiling an electric kettle.

3 Design

The aim of the domestic technology study was to identify areas of domestic life that might be fruitful for ubiquitous computing research. Having identified environmental concerns and specifically concerns about energy consumption as a possibly fruitful application area we produced a series of possible designs for interfaces to display energy consumption in the home, four of which are shown in figure 1.

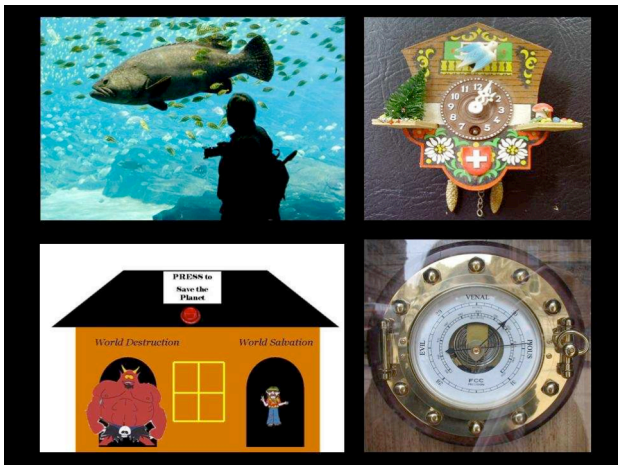

Fig. 1 Examples of initial design ideas for visualization of energy consumption in the home.

We then went back to several of the households that had been involved in our original study on experiences of domestic technology and showed them a presentation of these different ideas for representation of energy usage to and asked for their feedback as well as more general ideas. From these sessions, we decided to focus on the cuckoo clock idea as a candidate interface for implementation and began developing software to implement this interface. One idea was that the cuckoo would 'cuckoo' every time 1 kilo of carbon was emitted to the atmosphere because of electricity usage. Since cuckoo clocks are a German invention (not Swiss as Orson Wells might have you suppose), and the member of our team who was implementing the interface was also German, we named the project "Kuckuck" – the German word for Cuckoo.

4 Sensor Installation

To develop the prototype, we first set up a system to monitor energy usage in the home via sensor-based hardware and then trialled its usage in one of our participant's homes. We then developed an interim representation to provoke discussions about how to display the information. The emphasis at this stage is not on behaviour change per se but on exploring the sensors and displays that could be used in subsequent studies to monitor bahaviour changes in energy consumption. We describe our process to date in the following.

4.1 Hardware Setup

For the hardware we decided to use a custom-built electricity current sensor which can fit around the live wire of the mains supply to a house. This is connected to a particle Smart-It [3] which has been loaded with custom software to increase the battery life of the smart-it (from 12 hours to several weeks). Custom-built water-temperature sensors were also installed and attached to all of the pipes that flowed in and out of the gas-fuelled hot water boiler. Again, these sensors were attached to a particle Smart-It which had custom software installed to ensure that readings were only sent when there were significant changes in temperature readings, thus radically increasing the life of the particle Smart-It's battery. The particle Smart-It wirelessly broadcasts the sensor readings and they are received by the particle Smart-It data bridge which is attached to a laptop.

4.2 Real-World Installation Issues

Fig. 2 Service pipes in the immersion heater cabinet where sensors were attached.

Having identified a family – Karen, Ivan and Josh - who were willing to allow us to put electricity flow and water temperature sensors in their home (figure 2), we embarked on a lengthy process of design and test of sensor hardware, together with development of health and safety, ethical and testing procedures. One surprise for us was how much longer this process took than we had originally anticipated, due to a number of practical technical as well as logisitical issues, pointing to the value of testing in authentic environments. We have detailed this experience elsewhere [2]. Having overcome many technical obstacles, we have now managed to gather several

weeks' worth of data from Ivan, Kate and Josh's house about their electricity and water use.

4.3 Prototype Display Installation

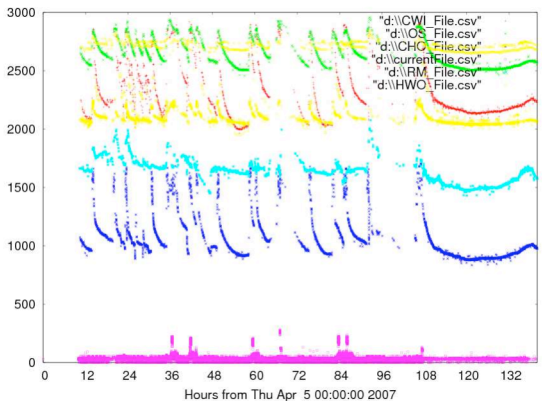

Fig. 3 Graphical readout of sensor data for six days. Electricity readings in purple at the bottom of the graph.

After our initial period of data collection without any kind of information display in the home, we then took along a graph of the data as an initial discussion tool to explore representation issues and to see what sorts of things they were interested in knowing about their own usage (figure 3). Even this minimal display of electricity data caused Ivan and Karen to have a very interesting discussion around the cause for the peaks that they saw in the data. They quickly began to realise that by far the most significant appliance, in terms of creating peaks on the electricity consumption graph, was the washing machine.
In response to this promising feedback we created a zoom-able graph interface which showed the graph of electricity usage in Ivan, Karen and Josh's house in real-time (figure 4), reading from the log of data collected from the electricity current sensor. We installed this in their house and left them to use it for a week.

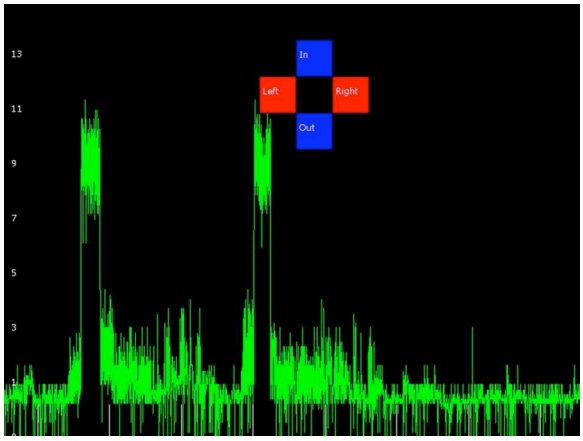

Fig. 4 A zoomable interface to the graph of electricity use showing two noticeable peaks associated with washing machine operation.

On our return we recorded our interview with the family noting their reflections on the use of the graphical interface. Ivan described how he tested the response of the system by switching on the immersion heater and being pleased with the timely response that the output graph showed. He also spent some time watching the interface respond the vacuum-cleaner being used upstairs.
All the members of the family sought to map activity to the graph output profile, often wishing to further extrapolate cost or carbon footprint to the data shown. It was also noted that having this information displayed in the home became a talking point for visitors.

5 Future Work

Building on our experience of installing energy consumption sensors and displays in the houses of "real" people we intend to prototype some of the less literal and more provocative interfaces that we initially envisaged, for example the cuckoo clock interface.
What we design and what information will be displayed will also be informed by a parallel strand of work currently in progress where we are taking alternative forms of energy displays - from literal to ambient - into peoples' homes as part of an in-home study to understand the values that motivate different energy-related behaviors, as well as asking their feedback about what displays they like and why, what questions they would want to ask of the displays, and more practical issues such as where they would place them and so on.
In providing energy consumption information with the content shifting between qualitative to quantitative representations, we are curious as to what role the more ambient display might take. Can energy usage behavior be changed by these displays and if so, will these be temporary or more longer-lasting? And can people be well enough informed about the particular effects of devices in the home to make choices through having ambient displays or do they need more detail to better inform them? What sort of information do they want: relative information, e.g., relative to their own or others' past usage is the level of detail they need or want; current usage within an historical/temporal context; aggregated information or information broken down by appliances?
Ubiquitous computing has the potential to make a substantial contribution to sustainability in people's homes. We need to ensure that the choices we make in the design and implementation of the devices are also sustainable – we have started to explore this in dealing with the battery life issue of the Smart-Its but will be exploring other ways of addressing this agenda in our future work.

References

1. Stringer, M, Fitzpatrick, G. and Harris, E. Lessons for the Future: Experiences with the Installation and Use of Today's Domestic Sensors and Technologies, Proceedings, of Pervasive 2006, Springer-Verlag, 383-399 (2006)
2. Harris, E., Krishna, R., Chalmers, D., Fitzpatrick, G., and Stringer, M. From development in the laboratory to deployment in the home: Trouble and strife with sensor networks. To appear Proc LCN (SenseApp Workshop) 2007, IEEE Press, (2007).
3. http://particle.teco.edu

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