Threshold Devices: Looking Out From The Home

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ABSTRACT
Threshold devices present information gathered from the home's surroundings to give new views on the domestic situation. We built two prototypes of different threshold devices and studied them in field trials with participant households. The Local Barometer displays online text and images related to the home's locality depending on the local wind conditions to give an impression of the sociocultural surroundings. The Plane Tracker tracks aircraft passing overhead and imagines their flights onscreen to resource an understanding of the home's global links. Our studies indicated that the experiences they provided were compelling, that participants could and did interpret the devices in various ways, that their form designs were appropriate for domestic environments, that using ready-made information contributed to the richness of the experiences, and that situating the information they provided with respect to the home and its locality was important for the ways people engaged with them.

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Ubiquitous computing, home, threshold devices

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
In this paper, we introduce the notion of *threshold devices*, and elaborate the concept with examples of two deployed prototypes we have built.

Threshold devices look out from the home, gathering information from its surroundings to suggest how *here* is connected to and situated within a *there*. In supporting appreciation of the home's setting in a wider physical and social environment, the devices provide resources for inhabitants to think about where they are, what and who is around them, and may occasion their attitudes towards these facts. Such an appreciation may be rich and complex, potentially involving utilitarian, aesthetic and emotional elements, and thus the devices are best seen as *resources* rather than *tools*.

A focus on the situation of the home within its surroundings complements more traditional applications for domestic computing. Many systems for the home focus on bringing content *into* the home, to provide entertainment, opportunities for commerce, or more broadly as information to be consumed in a variety of ways. But the content such technologies provide is often relatively placeless and generic, and people are either expected to consume it as such (e.g watching a television show) or do the work to localize it themselves (e.g. searching the internet for a nearby shoe-store). Threshold devices, in contrast, bring content into the home *that is linked to the home's physical location*. Insofar as this relationship is integral to the experience, even generic and placeless content may gain new impact.

An emphasis on creating electronic thresholds linking the home to its surroundings also complements trends in domestic computing towards capturing, revealing, or acting on information gathered from within the home itself. For instance, smart home systems, e.g, [14, 7, 12], are used to automate aspects of the home's infrastructure according to predetermined timings, sensed activities within the home, or remote control. Increasingly, such technologies are being proposed to help care for vulnerable inhabitants such as older people or children, e.g. [9, 6], in part because the prospective benefits of such technologies may help justify their expense and potential privacy intrusions. In any case, such systems maintain a narrow focus within the home's built enclosure and tend to ignore its larger situation, whereas threshold devices look out from the home and cast its situation as of primary interest.

Threshold devices can be thought of as new sorts of windows for the home. Why do buildings have windows?

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There is no single answer. Windows allow light and air to enter the home, without permitting easy ingress (though beware of mosquitoes and burglars). We can look through them to see who's lurking on our property, or to check for an eagerly awaited guest. We can hang curtains to prevent being looked at ourselves, then peer around them to spy on neighbourhood doings. But the appeal of windows goes beyond utility. Windows blur the boundaries between inside and outside in ways that are aesthetically and emotionally enriching as well as useful. Few of us would choose to live in a home without them: we enjoy a good view. A sunny sky might cheer up the room, or we might gaze disconsolately at a rainy one. Windows are simple constructs physically, but the values they embody are complex. In a similar way, our threshold devices our intended not to fulfil single needs or solve simple problems, but to enrich their users' lives in multiple ways.

An Introductory Example: The Video Window

A simple, and early, example of a threshold device draws directly on the analogy to traditional windows. Several years ago, the first author mounted a small analogue video camera on a long, flexible pole attached to the outside wall of his home, and fed the output to a monitor hung on his bedroom wall [2]. The resulting Video Window is left continuously running, providing a new view from the home only a few centimeters from an actual window (Figure 1).

Several aspects of the Video Window are relevant for this paper. First, it does not simply imitate a real window. Characteristics of the camera and monitor combine to give the image a wider field of view, increased contrast, and different colouring than the view from the physical window. The orientation of the camera has been chosen to be similar to that of the viewer towards the monitor, but adjusted to compose the image aesthetically. More obvious effects are created by the technology itself, as when raindrops cause coloured refractions, or the sun causes lens flare. Because the camera is mounted on a flexible mast, the image sways notably (even dramatically) with the wind. It is important to note that the differences between the Video Window and the actual view are not perceived as deficiencies: on the contrary, some (e.g. extending the height of the camera as well as its field of view) provide its motivation, while others (e.g. lens effects, wind-induced sway) provide unexpected aesthetic enjoyment. Threshold devices, from this perspective, are not meant to emulate the physical world; instead, new forms of appreciation, both conceptual and aesthetic, come with the technologies.

Figure 1. The Video Window outside and inside.

Second, the experience of the Video Window integrates both aesthetic and utilitarian concerns to the point that separating them is difficult. To be sure, a colourful sunrise can be beautiful, and the tiny speck of an airplane slowly crossing the screen is somehow entrancing. Equally, the system supports a quick assessment of the weather and can help with such mundane chores as choosing ones clothes for the day. But the system does not distinguish utilitarian and aesthetic engagement itself (e.g through the functionality it offers), nor are these forms of engagement experienced phenomenally as separate. Instead, the Video Window is better conceived as providing a set of resources that can be appropriated in service of a variety of different interests to create a range of different experiences.

Third, the fact that the Video Window shows the view from the system's own location seems crucial to the experience it offers. Although an obvious extension would be to show the views from remote cameras (e.g. scenic or personally meaningful locations), there is a sense of personal ownership and consequence that comes with the view from the home. The tight connection with a reality just beyond the wall prevents the view from seeming 'virtual', the object of impersonal interest or appreciation. Rather than being experienced as a replacement for palpable reality, the view from the Video Window appears as a slightly abstracted or fictionalized version of the real thing.

Fourth, the Video Window relies on very simple technology, but produces a rich and ever-changing experience. This is because the content it provides is extracted from the wider environment rather than being stored or generated within the system. The setup is stable, but the view never repeats because the sky and city never repeat. As we will describe below, recontextualising found data to a particular location is a powerful method for developing engaging systems, and key to the strengths (and some of the weaknesses) of those we report here.

In the rest of this paper, we describe two prototypes we built to investigate the possibilities for threshold devices further. This takes the form of two case studies in which, for each design, we describe the basic concept, its original motivation, how we developed and implemented the idea, and the results of long-term field deployments. Finally, we end the paper by drawing conclusions about our experiences in particular and the prospects for this genre of device more generally.

THE LOCAL BAROMETER

The Local Barometer consists of six brightly coloured devices, each containing a small screen (see Figure 2). Across the screens scroll edited versions of images and texts that currently appear in an online classified advertisement site (Loot.com). The local wind conditions determine which advertisements appear: ads are selected from areas that are upwind from the home, and the harder

the wind blows, the greater the distance becomes from which the ads 'travel'.

The idea behind the Local Barometer was to provide people with a new sense of the sociocultural texture nearby their home. In London, where the system was developed, nearby neighbourhoods may house strongly contrasting ethnic and economic groups, and we speculated that advertisements from different neighbourhoods might be symptomatic of these differences. Like many of our designs, though, we did not stress this motivating narrative in the design or to our volunteers, instead allowing the system to remain open to interpretation [10].

Implementation

Wind direction and speed are determined using a commercially available anemometer mounted outside the home. This is used by the Postcode Radar, a software module that gathers a list of postcodes in a triangular region extending upwind from the home's location. Web ripping software uses the postcodes to extract content from selected sites. We found that classified advertisement sites contained a great deal of succinct, localised content evocative of local circumstances. Images are resized so that their shorter dimension fits the screen, and scrolled along their longer one. Text is also processed to decontextualise the ads (i.e. make them less like ads) by removing punctuation and inserting line breaks at set intervals. We hoped to allow the latent poetry of the advertisements to emerge, inspired by the deceptively simple poetry of William Carlos Williams. It didn't always work, but occasionally a mundane sentence would reveal hidden depths – a glimpse of wry humour, or exuberance, or sadness.

It proved to be extremely difficult to implement small screen devices that could receive text and image data wirelessly and scroll them in the ways we had envisaged. We developed prototypes using a variety of available mobile phone screens and microprocessor boards, even collaborating with our colleagues in the Equator IRC on the design of new hardware which we hoped would underpin

Figure 2. The Local Barometer. Devices were located in the hallway, a shelf in the bedroom office, the kitchen, a living room shelf, the bedside table, and a TV cupboard.

the system. Unfortunately, nothing emerged that was robust enough to work without frequent maintenance. In the end, we used Mobile Processing (mobile.processing.org), an open-source software environment for developing mobile phone applications, to program inexpensive and sturdy Nokia handsets. We stripped the outer shells, removed unnecessary features (e.g., cameras, speakers) and rehoused them in new forms built out of laser-cut acrylic shells covered with brightly coloured cardboard skins. The results were robust yet informal, giving the impression of well-crafted prototypes rather than technical experiments on the one hand, or commercially available products on the other.

The result was a series of objects designed to be appropriate for various locations in the home: an upright structure for the mantelpiece, an L-shaped structure that hangs over the edge of a bookshelf, a short squat model for a tabletop, a rolling shape that hides its screen for the bedside table, a hook-style construction for hanging, and a plug-style model that fits directly into a power socket.

The Field Trial

R lives in a small one-bedroomed apartment in Camden in North London. He shares this with his wife, who also has the use of another residence, and two cats. R is in his forties and has lived in London all his life. He suffers from arthritis and is registered as a disabled person. Formerly a touring professional musician, he now works from home as a web site designer. While interested in computing and technical affairs, R has no special knowledge of the mobile technologies and programming environments we were using in the Local Barometers. The Local Barometers were deployed in R's home for a one month period. After consultation with R, six devices were distributed around the apartment. Two were placed in the sitting room and one in each other room except the bathroom.

R's life with the Local Barometers was studied using ethnographic field research methods. One of the team visited R throughout the trial period, spending, on average, half a day each visit observing how R used the Local Barometers and talking informally with him about them. As is customary with this style of research, a variety of materials were collected but principally field notes and photographs. A total of over 30 hours was spent on site at R's house.

Technical Troubles

We found that the Local Barometers failed every one to three days after restarting. Either a Java OutOfMemory error message would be displayed every few minutes or the phone would automatically shutdown and restart, whereupon, confusingly, the phone's screensaver image would be shown. These problems stemmed from a fundamental issue with the Java environment we used, which poorly implemented garbage collection. With use, then, memory on the phones became fragmented until the phones eventually crashed.

Not surprisingly, R's engagement with and feelings about the Local Barometer were mediated by his sense of whether

the system was working or not. When he felt the system was not working, he tended not to make interpretations about the Local Barometers, what they did, what they displayed and what all this said about his home's localities and others within range. Rather, the Local Barometers became ornaments and their visual form and disposition around the home and their relationship to other ornaments and artefacts became salient for him. As mere ornaments, the Local Barometers were a little inconvenient and raised problematic questions for R around matters such as power consumption.

In contrast, when the Local Barometers worked well, and texts related to objects in the vicinity were being regularly blown into R's home, R actively engaged with the system, reading and interpreting the displayed texts. While the phones were limited in the time they could operate as intended, this nevertheless allowed R (and us) to appreciate how the Local Barometers could fit in with his domestic environment and his sense of its locality.

Objects

A great variety of items for sale or rent were encountered by R displayed on the small screens of the Local Barometers: vehicles, property, toys, furniture, antiques, musical instruments, gardening equipment, books, sporting equipment, memorabilia, cameras, electric items, and so forth. Initially, R understood the Local Barometers' display of texts and images of such objects as akin to marketing or a new form of advertising. R regards himself as critical of consumerism and, at this stage of his time with the Local Barometers, preferred to resist extensive engagement with them. However, after noticing a number of unexpected items (e.g. a bedroom in NW8) and several which engaged with his interests (e.g. the image of a collectable guitar scrolling past), he began to reconsider the presence of such items in his home, seeing them less as intrusive advertising and more as tongue-in-cheek 'gifts' being offered to him or as 'surprises' which were informative of the socio-cultural texture of the world outside. Indeed, R, from time to time, developed quite impassioned connections to items displayed by the Local Barometers. While the guitar stimulated a kind of emotional attachment, for example, an Audi TT sports car was an object of dislike and distrust.

Localities

R has a strong sense of the history and socio-cultural character of the area around where he lives. For us as visitors, he often pointed out significant landmarks and even instructed us in the underlying physical geography of the area. R commonly interpreted the texts displayed by the Local Barometers in terms of his knowledge of his area and surrounding localities. The extreme expense of a studio flat prompted a discussion of the varied social status and economic prosperity of the different localities around his house. The postcodes associated with items and displayed on the Local Barometers gave R a key into an area's character. For example, some items were thought by R to be typical of the low value and possibly stolen goods that might appear in 'crack areas'.

How The Wind Blows

The Local Barometer's behaviour is shaped by measured windspeed. When the wind blows vigorously, more (and more distant) things are displayed as text or image throughout the home. In a manner unexpected by us, this actually enhanced R's awareness of local weather conditions. R was observed noticing a change in image on one of the small screens and then checking on the rain and gusts outside, remarking how the wind was causing a tree to arch. Indeed, the Local Barometer prompted R to consider how the local micro-weather changes over time and how this affects the Barometer's operation. While we anticipated that the device might enhance people's awareness of the local socio-cultural context of the home, because of the Barometer's manner of operation, R attended to changes in local weather conditions too.

Summary

The Local Barometer was designed as a threshold device linking the home to the socio-cultural and economic character of its environment through presenting small texts and images of things which are advertised for sale at the moment. Content is sourced in relation to measured wind speed to give an impression of items being blown into the home, with things from distant localities only appearing when the wind is high. Although the system had some technical problems, it worked well enough for our volunteer to engage with it as a resource for reasoning about and finding out things about the home's wider social and physical environment. As well as being interpretable in the light of existing local knowledge, the Local Barometer enabled occasional surprising connections to be made between the content displayed and the setting of the home. Living with the Local Barometer was also an aesthetic matter, both in terms of the (sometimes critical) appreciation of the design of the devices but also in the pleasure that was to be had in seeing a small guitar scroll past between two books on the shelf.

THE PLANE TRACKER

The Plane Tracker is a free-standing, polyhedral cabinet with a screen on the front and a large angular antennae on the top (see Figure 3). This device decodes radio signals from passing aircraft and uses this information to create imagined flights around the globe, shown onscreen as aerial imagery that flows smoothly from origin to destination.

We designed the Plane Tracker to serve several possible narratives. The original intention was to compensate people for the noise of passing air traffic, but we also thought it might encourage a felt appreciation of the home's connections with far off locations through the aircraft passing overhead. The design also seemed of potential relevance to other groups – plane spotters, for instance, or people worried about the environmental impact of flying. Like many of our designs, it seemed to create a richly evocative situation that could be approached at a number of levels and from a number of perspectives.

Origins and Development

The initial idea for the Plane Tracker came about six years before we built the device. It took the form of a sketch proposal, one of about fifty we produced in an early stage of the large-scale project of which this work is part, suggesting that passing traffic (airplanes, trains) might compensate households within hearing by transmitting unspecified data to them. We didn't develop this notion at the time, and instead pursued other ideas.

About three years later, however, the proposal chimed with a story (quite possibly an urban myth) about exotic plants growing nearby international airports, supposedly from seeds caught in aircraft undercarriages. We began to develop the notion of an electronic window box that would show images of flowers from countries that passing aircraft had visited (as well as a more local version reflecting national train journeys). After a number of design mockups, however, we gave up this direction. It seemed too difficult to generate enough flower images to indicate any possible location in the world, and unlikely that people would be motivated enough to learn the mapping from plants to locations if we did.

After another break, the concept was reinvigorated when one of the design team started to experiment with GoogleEarth. It soon became clear that by using its programming interface, we could recreate the flight of a particular aircraft across the globe, and thus take advantage of the huge amount of content GoogleEarth offers.

Implementation

To determine the origins and destinations of passing flights, we purchased a basic scanner radio and aerial, tuned to pick up aircraft registration transmissions (called ACARS; see en.wikipedia.org/wiki/ACARS), We decoded these using open source software called ACARSD (www.acarsd.org). These transmissions include information including the unique aircraft registration number and its current flight number, but not the origin and destination airports. To find these, the ACARSD system has to query, over the internet, amateur plane spotter website databases to retrieve the

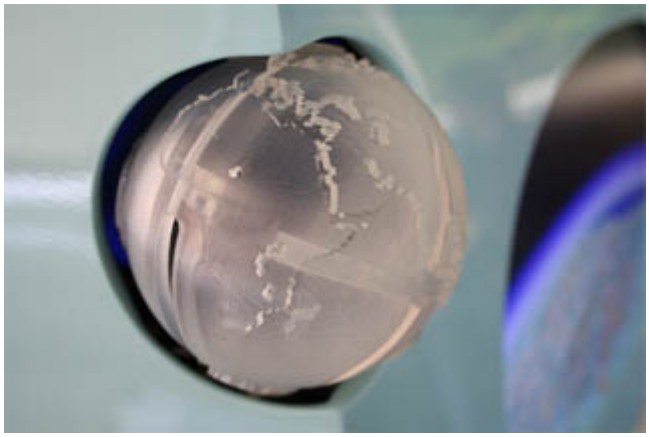

Figure 4. The Globe location indicator

airport codes (www.planespotting.net). All this information is appended to a log file stored by the ACARSD system.

We wrote a program called GENav to read the ACARSD file and use the information to control GoogleEarth. GENav translates airport codes to geographic locations, and adds information about their height above sea level and the direction of the runway. This is done by querying a file that we compiled from DAFIFT data taken before October 2006 from the US military's National Geospatial-Intelligence Agency (www.nga.mil/portal/sie/nga01) and data compiled by Arash Partow for his Global Airport Database (www.partow.net/miscellaneous/airportdatabase/). GENav interfaces with GoogleEarth to create straight-line approximations from these origin and destination locations, gradually rising and falling in apparent height with the view slowly turning to align with the relevant runways. The view travels at a fixed speed, so the duration of the journeys depends on the distance travelled, lasting between about two to ten minutes.

The Aerial, the Globe, and the Object Language

As we developed the system, we realised that the aerial we were using had problems detecting ACARS signals from indoors. We could have designed the Plane Tracker to use an outdoor aerial, but this would pose cabling problems. Moreover, we believed that having the aerial as a visible component of the device might help remind people that the imagery they saw onscreen was controlled by real aircraft passing nearby. Then we discovered an article in *Wired* magazine about NASA scientists using genetic algorithms to design extremely sensitive aerials for satellites [4]. We contacted the scientists, and to our surprise and delight they agreed to design an aerial specialised for picking up signals at 131.725 Mhz (the transmission frequency for ACARS).

The aerial they designed for us was unexpectedly large and complicated, and we worried it might be too fragile to stand up. We sent the design to Arup, the engineering firm, for structural analysis. They reported that the aerial would have to be supported at three specific points, and it would then settle into the correct shape under its own weight.

The Plane Tracker's unusual form reflects the requirement of supporting the aerial and also indicating its extent (to avoid people bumping into it accidentally). Beyond this, its form and colour are designed to evoke the 'jet age', around 1958. Two designers were particularly influential at this time, Charles Eames and Piet Hein. The Tracker directly references a piece by each designer: Eame's La Chaise (see www.vitra.com) and Hein's maths for Fritz Hansen's Superellipse Table (www.fritzhansen.com). Not only is the super ellipse used for the screen shape reminiscent of airplane windows, but visually it appears to enhance and harmonise with the flow of GoogleEarth imagery.

Watching simulated flights over the earth on GoogleEarth, we realised it was easy to lose one's bearings and decided to give some indication of the imaginary location. We rejected using the system's screen labels as breaking the illusion of looking down on the earth, and in any case felt that being too precise would distract from the onscreen experience. We experimented with various forms of instrumentation, from a digital readout of longitude and latitude to a graphical representation of a globe to be shown on a secondary display. Eventually, inspired by aircraft instrumentation, we devised a mechanical globe. Basically a sphere with an extruded landmass, this semi-translucent device (which we built using a rapid prototyping stereolithography machine) is mounted on the corner of the case and controlled by two servomotors so that the current location is always on the side facing out from the device (see Figure 4).

The Field Trial

P and G are a married couple in the fifties who live in a Victorian terraced house in Isleworth in West London. They share this house with their son, T, who is a recent university graduate in his early twenties, and a dog. P is a technical manager within a UK Central Government department and G works part time in a local school. T works at a local supermarket. The family have lived in their house for over twenty years. It is located under one of the flight paths taken by planes landing at Heathrow airport. Indeed, arriving planes typically take a route which seems to follow the length of the street enabling a good view of planes approaching and flying over.

The Plane Tracker was sited in the bay window in the house's sitting room, a room at the front of the ground floor normally used by the family for relaxation, reading and TV watching, among other activities. As with the Local Barometers, the Plane Tracker was in the volunteer household for a four-week period and observed in situ by an ethnographer throughout this time. Again, in excess of 30 hours field observation were conducted.

Following Flights

The Plane Tracker engaged the household in the activity of following flights to and from distant destinations as they unfolded on screen. This was an activity sometimes engaged in by single household members, other times as a group when opinions about flights and locations would be shared and occasionally debated. The household's interest in the Plane Tracker persisted throughout the trial period. To give a more detailed impression of how the household engaged with the Plane Tracker, consider the following episode from one early evening.

A plane flies overhead and is noted by P. Less than a minute later, the globe on the side of the Plane Tracker whirrs and the view on screen jumps to a new location. P (to me): "Is that the Caspian Sea? There's Cyprus." <pointing to screen>. G enters. P (to G): "It took off from something like an island near a land mass." P gets an atlas. P: "If it took off from near the Caspian then it might have come from Baku or Krasnovodsk." The Plane Tracker view returns to London. P: "You wouldn't think a plane would have flown to Heathrow from Krasnovodsk… unless that's the Gulf <pointing to what was previously identified as the Caspian Sea> and it'd be Bahrain. That looks like a desert and it was sandy when it took off from that island… <checks atlas> Yes, definitely Bahrain." P looks at the atlas and marks out the route over Cyprus inscribing a line from Bahrain towards Heathrow with his finger.

This example contains a number of interesting and typical features of how the Plane Tracker was used to identify and follow routes. It is typically difficult to identify a location associated with a flight immediately upon the view switching to show it. Features around the distant airport might be taken in (P: "When it went to Dubai you could just about see the palms.") but that is rarely sufficient to enable the location to be identified. As the view pulls out and the flight is recreated, notable shapes are attended to and, if other people are present, often pointed out or queried. Some shapes are familiar (the shape of Cyrpus, the "boot" of Italy, the configuration of blue that is the Great Lakes of North America), others are less recognisable from the view provided ("Is that the Caspian Sea?"). If a preliminary conjecture has been made, an atlas (or the world map that is on wall of the household's entrance hall) may be looked at for further detail. This can give rise to further hypotheses as to the flight's identity (Baku or Krasnovodsk) or suggest other things to look out for as the flight unfolds on screen. In the case noted, P thought it unlikely that a plane would

Figure 5. Discussing the Plane Tracker's view.

have flown to Heathrow from Krasnovodsk (the only large enough settlement on the eastern shores of the Caspian to reasonably support an international airport) so he then wondered whether his initial supposition that the sea adjoining the airport was the Caspian was false ("…unless it's the Gulf"). This led him to immediately suggest that the airport the flight took off from was in fact Bahrain. Other details now became intelligible (the sand around the airport) and, on tracing the route from Bahrain to London, yes indeed, it would pass over Cyprus.

The Plane Tracker, then, incited *investigative work* on the part of those interested in it (see Figure 5). Initial conjectures might be formulated, shared, tested, revised. This might guide the use of *further sense making resources* to work out what the flight was and what the screen was showing. The participant's own *knowledge and intuitions* about air travel and world geography might well play a role in this. Below we discuss this in more detail.

Juxtaposing and Coordinating

The above examples show how the Plane Tracker was used characteristically in juxtaposition with other informative resources. The household commonly used a world atlas to decipher and follow routes, but it was variable in its level of detail (e.g. summary views of Africa) and the divisions from page to page sometimes interfered with following the route as it unfolded on screen. The atlas did give enough detail of the coastline near Karachi to enable its identification as a destination (and rule out Bombay which, on the occasion in question, G had speculated was the flight's destination). A large river visible arching around a city destination enabled identification of Zagreb and the River Sara. Grosser geographical features could be identified from the key map in the atlas or by consulting a Peters projection world map in the hallway. Flights from Toronto and Chicago were distinguished from each other by checking their relative location around the Great Lakes on the world map. As the Plane Tracker was located in the same room as the household's TV, it was possible to obtain (limited) flight information from teletext and check this against conjectures about the route the Plane Tracker was recreating. However, this proved to be of limited usefulness as the available teletext pages only showed flight arrivals.

The motorised globe on the Plane Tracker was another element in the assembly of resources people could bring to bear on identifying locations and following flights. The globe did not enable an exact fix on geographical location. The face that it showed to the viewer of the Plane Tracker was sometimes enough, however, to confirm or rule out some initial hypotheses, e.g. if a suggested location would require the globe to be oriented the other way around. More commonly, the globe was attended to as an alert that a new replay of a route was about to commence as it made a characteristic whirring sound when starting a new journey.

The Home and The World

Some of what the Plane Tracker showed could be deciphered by means of geographical knowledge that the members of the household already had. The shape of the Great Lakes, the location of the Caspian Sea, the Gulf and so forth were recognisable from the screen of the Plane Tracker, if not immediately, then after the image moved enough to show the feature in the context of others. Some of the knowledge the household had was interestingly specific. For example, when the Plane Tracker was initially installed the route depicted was from Tenerife to London, and while it was clear to G that this was an island in the Atlantic, she couldn't be sure which one. However, T immediately recognised Tenerife when he returned home, pointing out several places on the island he was familiar with as a result of a geology field trip when he was an undergraduate student.

The appearance of a location on the Plane Tracker and the activity of following flights occasioned the sharing of existing geographical knowledge or the discovery of new things. The name of the river that loops around Zagreb was previously unknown to the household. In identifying Karachi, some noticeable brown bands on the landscape were pointed out and associated with terrain markings in the atlas: the Makran Range. One location in India was persistently tricky to identify. In the repeated consultations of the atlas, a number of geographical features of India were incidentally discussed: the location of Delhi, the course of the Ganges, the relationship of India to Pakistan.

Through all this activity, the household, at least for the moment, enlarged its acquaintance with the rest of the world and its connection to Heathrow. Interestingly, it was precisely because the Plane Tracker did not directly reveal the identity of flights and locations that people had to engage in investigations which enabled them to deploy and develop their geographical knowledge. If anything, this made the connections between *their* home, *that* plane and the rest of the world all the more vivid – because they have worked out the connections for themselves.

Pacing and Repetition

Throughout the first week the Plane Tracker was deployed, the wind was blowing in a north-easterly direction, causing planes to be redirected with substantially less traffic coming over the house – only five planes during one half-day visit, as opposed to the usual rate of one every minute or two. This had a large impact on the behaviour of the Plane Tracker. The Tracker (re)plays the route of the last flight it has detected. This means that when planes are frequent, a new flight tends to be played as soon as the last one is finished, but if planes are rare, a single route may be repeated continually. Thus on the first day of deployment the route from Tenerife to Heathrow was replayed for at least six hours, and, on the day following, Toronto was revisited continually during a period of at least four hours.

Even when it was appreciated that the small number of flights going overhead was giving rise to this behaviour, the repetition of routes on screen was a source of annoyance. G: "Last night I thought I'd go crazy if we went to Tenerife again." A young teenage cousin visiting the household, B.,

after seeing the cross-Atlantic route from Toronto to London replayed multiple times, said: "If I see Toronto again, I'll smash it." Fortunately, immediately after this the route being displayed changed. With this degree of repetition and rarity of new flights being replayed, G said "it is difficult to be enthusiastic. [The globe] goes whoosh and oh it's Canada again."

While persistent repetition of routes could be excessive, playing a route more than once did support the kind of investigative activity noted above. A location seen before, or one where a very familiar geographical feature is instantly recognisable, might be identified soon after the globe whirred afresh. More commonly though, some features local to the destination would be noticed first time, and some features of the route identified, with conjecture about the identities of places and flights being tested out on subsequent repetitions. For example, P was only able to surmise that a flight had originated from the Philippines when he had seen the view fly over the very large landmass that is Asia. Once a firm opinion had been settled on, the route might be traced from start to finish with a finger on the atlas, with glances up to the screen to note features as they fly by. The first days of extended repetition thus served as a serendipitous training period for using the device. Still, it quickly became clear that once a route was identified further repetition was annoying, and everybody was relieved when the wind reverted to normal for the last three weeks of the trial.

Appreciating the Plane Tracker through Engaging with it

The Plane Tracker was appreciated for the quality of its design, construction and image quality, though a flat panel display was suggested as more appropriate for a longer-term stay with the household. The household also had other suggestions for enhancing the design of the Plane Tracker including making it easier to use the globe with precision, giving more low level detail when close to destinations, and perhaps linking in to live arrivals and departures information from Heathrow. Broadly though the design quality of the Plane Tracker was strongly appreciated.

The Plane Tracker engaged the interest of the household throughout its stay with them. As we have discussed, the household followed flights on the Plane Tracker and, through this, came to discuss and know various parts of the world that have a connection with Heathrow and the air above their house. The Plane Tracker was a conversation piece: how it works, how it could be developed, what it shows and what it means about the home and its location. The display of particular destinations might suggest topics for talk of personal significance: the dessication of the Aral Sea, Guantanamo Bay, a daughter living in Australia, the environmental impacts of air travel, the lure of exotic locations, the effects of air traffic on their quality of life.

Summary

The Plane Tracker was designed as a threshold device linking the home to air traffic passing overhead and, through presenting animations of the routes planes take, to various destinations around the world. Our volunteer household notably engaged with the Plane Tracker to decipher and follow routes, juxtaposing the picture from the Plane Tracker with an atlas and other sources of geographical knowledge available to them (including what they themselves know). The Plane Tracker's tendency to repeat the most recently identified flight helped observers work out destinations and routes. However, when plane traffic was minimal, the continual 'looping' of routes was found tedious, even though, in another respect, this does make clear the sensitivity of plane traffic to local weather conditions. The form design and aesthetic quality of the Plane Tracker was strongly regarded by our volunteer household, and the device's ability to identify planes passing overhead and though that connect the home to far off lands was appreciated as a unique quality.

DISCUSSION AND CONCLUSIONS

Overall, the field trials of the Local Barometer and Plane Tracker supported our belief that people would find appeal in new ways of looking out from their homes. In both case studies, the participants engaged with the systems, both individually and in groups, over the course of the month-long trials. They often spent surprising (to us) amounts of time exploring what the systems were presenting and how to interpret this in terms of its larger context as well as in its personal implications. In doing this, they drew both on personal knowledge and external resources. These results support the potential of threshold devices as a new genre of domestic ubiquitous computing.

We pursued our field trials from an ethnographic tradition, producing lengthy observations and 'thick descriptions' of a small number of participants. We believe this approach gives richer and more valid data for understanding how people might engage with new designs than a larger number of shorter trials would, not least because it allows the 'trajectory of appreciation' [4] that characterises people's engagement with new artefacts to be studied over time. Note that we are not claiming our data comes from a representative spectrum of the population, as one might do if evaluating a commercial market for the prototypes. Instead, we have focused on describing volunteers' experiences with the prototypes as a kind of existence proof that such (positive) experiences might be had, and on articulating some of the factors those experiences highlight.

In the following, we discuss some of the features of the devices we believe are important to their appeal and which could be capitalised upon in future design work.

Open to Interpretation

Both the Local Barometer and Plane Tracker were designed to present a situation to people without advocating an appropriate interpretation. As we have found in previous work, e.g., [3], designing in this way allowed various interpretations of the pieces – as revealing sociocultural texture or as advertising devices, as seduction to exotic travel or as warning against environmental degradation – to be made at different times and by different people. This

openness has two advantages, we believe: first, it allows us as designers to highlight situations and raise issues without dictating their interpretation; second, it allows the same devices to be appreciated in multiple ways by multiple people, potentially extending their appeal.

New forms for technology

In order to create the situations we wanted with the Local Barometer and Plane Tracker, a significant amount of work focused on the form designs for each prototype. We believe the results make a substantial contribution in their own right. The Local Barometer demonstrates the potential of multiple, wirelessly connected, small-screen devices in the home. These can be appreciated in a wide variety of contexts – while walking down the hall, say, or glancing up from doing the dishes – in which computational devices are seldom encountered. Moreover, our implementation in the form of hacked mobile phones opens new possibilities for a family of 'immobile mobiles' that we believe has significant potential beyond the current application. Similarly, the Plane Tracker reinvigorates notions of 'information appliances' [11, 8] that are specialised for particular applications. Its appearance as an aesthetically crafted object meant to be the centre of some attention was both welcomed by the participants, and indicative of the potential for alternatives to more typical appliances such as televisions or sound systems. If nothing else, our field trials demonstrate the possibility and appeal of designing ubiquitous computing prototypes that work not only technically, but aesthetically as well.

Our prototypes are not ambient interfaces as described by, e.g., [5]. They are not meant to be experienced primarily at the periphery of attention (we use 'threshold' as in '…of a house' not '…of attention'). Instead, they reward varied attention and interactivity in ways that many ambient devices do not. Most ambient devices are defined around a medium chosen for its aesthetic effect (e.g. glowing orbs, rippling water, spinning pinwheels), which is mapped in an arbitrary way to a stream of data. Our prototypes, in contrast, are designed around the information they are to convey. We see our devices simply as computational artefacts designed for domestic use, a setting in which attention to aesthetics is clearly important.

Using ready-made information

Crucial to both the Local Barometer and the Plane Tracker is their use of information and influences that come from without the local confines of the technologies. The Local Barometer depends both on current wind conditions and on content found on a third-party website. The Plane Tracker depends on an intricate combination of radio signals and online information, including GoogleEarth as well as databases maintained by amateur plane-spotters. Both systems can be seen as a form of 'mash-up', in which diverse sources of online information are combined to create new experiences. Importantly, however, both the Local Barometer and Plane Tracker connect online information with physical events around the home, helping to localise and situate it in ways we discuss below.

Relying on ready-made information has both advantages and disadvantages, as our case studies illustrated. Using sources such as advertising databases and GoogleEarth provided access to a content that did not have to be authored or stored within the system itself, content which is continually updated and changing. This promotes openness to interpretation as the meaning of the content is steered not by us, but by multiple voices and perspectives providing relatively direct evidence about environments of interest. One of the effects of this is to provide a requisite level of surprise that made the systems engaging and novel over relatively long periods of time. On the other hand, relying on outside information could pose problems when, e.g., there was little wind (no messages would appear) or the wind was blowing the wrong way (no flights would pass nearby). The overall effect is to reduce control over the content that would appear on the systems. The resulting lack of predictability can be frustrating, but equally, it can be the source of continual richness.

Looking out from the home

Not only did the Local Barometer and Plane Tracker use ready-made information, but this was accessed and presented relative to the home's location. Our work responds to the call for the situatedness of use [13] in a particular sense and in a vivid way. It is precisely the situation of *this* device in *this* house near *these* for sale items or under *this* passing aeroplane that enters into how people make sense of them. The Local Barometer found text and images from locations in certain directions and distances from the home. The Plane Tracker recreated only those flights that passed close enough for their transponder signals to be picked up. Both provided new sorts of view from the home, much as the Video Window discussed at the outset does. This was important to how participants engaged with the pieces. R reasoned about the text and images he saw with respect to his existing understanding of the areas they represented, routinely gesturing in the direction of the relevant neighbourhoods as he discussed their natures. G, P and T regularly used their understanding of the particular flights going in and out of Heathrow to interpret the Plane Tracker's display, referring to travelling with the device to and from their current location. In each case, the way the devices situated the content they provided with respect to the home's particular location added notably to their interpretability and personal import.

Beyond supporting access to and appreciation of information about the home's environment, the Local Barometer and Plane Tracker seemed to support an appreciation of participants' surroundings as related to their own circumstances and orientations. For instance, the Plane Tracker evoked a sense of wanderlust for P, but one of environmental responsibility for G. Because Threshold Devices provide views from one's own home, the things they show tend to have personal impact. And because the views they give are framed and filtered and defamiliarised [1], they may sometimes be greeted not only as relevant to immediate activities, but as reflecting and impacting upon

one's longer-term situation and its moral and emotional implications. In short, Threshold Devices seem to support perception not only of what is *out there*, but what is *in here*. We plan to explore this further in future work.

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