Form and Movement in Domestic Networked Systems

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Abstract. It is increasingly desirable for electronic artefacts in the home to be grouped as sets, sharing data and properties across a network. A range of strategies can be used by a designer to explore the value and use of the systems for users, in particular through the properties of form and dynamic behaviours, including visual output and movement. This paper focuses on a range recent work which exploits rich behaviour and novel forms to highlight opportunities for user engagement in the home.

Keywords: Movement, ubiquitous computing, distributed form, appropriation.

1. Introduction

“They [microprocessors] will be found in the alarm clocks, the microwave oven, the TV remote controls, the stereo and TV system, the kid's toys, etc. These do not yet qualify as UC for two reasons: they are mostly used one at a time, and they are still masquerading as old-style devices like toasters and clocks. But network them together and they are an enabling technology for UC. Tie them to the Internet, and now you have connected together millions of information sources with hundreds of information delivery systems in your house.”[1]

Weiser and Brown’s vision of a proliferation of embedded processors in discrete objects throughout the home raises a number of questions for interaction design, including the design of the form and behaviour and system. In our work, we have been exploring the possibilities for networked devices in the home with a variety of projects. In this paper, we use several examples in order to discuss some of the fundamental questions raised by the notion of ‘ubiquitous computing’.

Weiser and Brown (1996) use Natalie Jeremijenko’s dangling string as an exemplar of new ubiquitous computing systems. In this piece, the rate of flow of data across an ethernet network is mapped to the level of agitation exhibited by a length of string linked to a motor. In ways such as this, networks can provide opportunities for sharing information across physical objects within the domestic landscape so that the behavioural characteristics of these objects becomes pooled, and can be selectively used, or linked to one another. There is a potential for orchestrating or synchronising be-
haviours across space, mediated by electronic interconnections. The question is: How can we design such systems so the people encountering them can apprehend these links? What is a form design for systems of distributed devices?

In Jeremijenko's piece the physical world becomes a richer version of a task-based GUI, where "The string, in part because it is actually in the physical world, has a better impedance match with our brain's peripheral nerve centers"[2]. From this perspective, peripherally sensed behaviours are a feature of a spatial GUI, where the effectiveness of performing tasks is enhanced by distributing the interface through space. We believe it is also useful to consider how computational features can be used to augment our experience of what we do in our homes. Our aim is not to harness the things around us to perform computation tasks, but to use computational aspects to enhance what people are already doing in their homes. What are appropriate roles for distributed systems in everyday life?

Traditionally, technologies are designed to convey information and possibilities for interaction clearly and unambiguously to people. This assumed relationship underlies much thinking about form semantics, ease of use, and interaction design more generally. Even non-traditional interfaces, such as Jeremijenko's dangling string, are assumed to have an appropriate interpretation (in terms of network traffic, say). But if technologies are viewed as extensions of normal user-defined activities in the home, rather than as a form of extended GUI, this assumption may need to be questioned. How can we design for users to appropriate the operation and even meaning of distributed devices?

In this paper, we describe four systems we have developed over the past few years that have a bearing on these questions. None were built to address these questions directly, so the answers they offer are often implicit in their larger story. Nonetheless, we believe that through the development of these systems, we have established some tentative approaches to these issues.

2. The Key Table and Picture Frame

The Key Table is a small table for an entrance hall, and the picture frame could hang on a living room wall. Individually, the table and frame are recognisable pieces of household furniture that perform familiar functions. The design augments these expected functions by providing the table with a load-sensing capability, and giving the picture frame mechanical movement. In addition, the objects are wirelessly linked, so when objects are placed onto the surface of the table, the picture frame swings out of alignment. The more forcefully objects are placed on the table, the more pronounced the swing of the frame.

The Key Table and Picture Frame were developed as part of the Equator IRC. Partners at Lancaster University had been exploring weight-sensing technologies, and this inspired a range of furniture which made use of surfaces that sense objects, via shifts
in their weight. We considered the ways that furniture could be made responsive to people, and could emphasise existing behaviour to promote reflection or disruption. During the design process, the pieces of furniture acquired its own behaviour, becoming semi-autonomous agents which act as thresholds into virtual or real spaces.

2.1. Form and movement

A strategy of unfamiliarity was used to make the table and frame stand out and appear somewhat alien in the home; also bright colours, diagrammatic forms and basic build quality made the objects feel more prototypes. This aesthetic was chosen to make them appear part of an experiment, as if they had been produced in a science lab for the purpose of a trial. We could have customised ready-made pieces, or used furniture that was already a part of the participant’s home, but we decided that this approach could desensitise a user from the purpose of the investigation.

Fig. 1. The Key Table and Picture Frame.

Rather than operating as one half of a pairing, the moving picture frame was originally conceived as an independent interaction. This piece was devised for the whimsical notion of relieving people of the burden of straightening their picture frames. Titled ‘Self-Levelling Picture Frame’, the device used sensors and motors to constantly correct and balance itself. Developing the behaviour of the frame so that it tipped sideways played with some symbolic associations. Modifying the Picture Frame to move mechanically off balance suggests many cultural idiosyncrasies: a skewed picture indicates neglect, subsidence, burglary or simply something wrong. Prolonging
the skew for a period after the event highlights the disruption, perhaps annoying (or even entertaining) the home's occupants.

The frame therefore acts as an alert system, displaying a state of calm or varying degrees of drama. This dramatisation is extended by linking the table to the frame, demonstrating the flow of a behaviour throughout the home. Much like the theatre of a slammed door, the paired system broadcasts events, perhaps to warn other inhabitants to tread carefully, or even to indicate a grand entrance. These linked objects can be seen as networks for reflection and emotional signalling between members of the home.

The Key Table and Picture Frame are not designed to be configured by the user. The two devices have a fixed interaction, calibrated and designed before the prototype are installed. Its subtlety lies in the ability to reflect variations in the behaviour of the people who share the home. The next project that we discuss offers a variation of this model by drawing upon a suite of input measurements, offering a range of output devices with mechanical behaviours, and providing a degree of configuration between the elements for the user.

3. Weather Watchers

Weather Watchers was a one-year research project based in the Interaction Design Research Studio at the Royal College of Art[3]. A field study of home meteorology was initiated to drive the development of a prototype system, in an effort to find an existing domestic context in which to explore the familial aspects of the ubiquitous computing era.

Home meteorologists are fascinated by the development and deployment of new objects and interfaces. They are curious about the underlying sciences, and possess a high level of technical knowledge. Home weather observation stations are built to record individual meteorological elements including barometric pressure, rainfall, humidity, etc. A range of sensors are used to capture the data, and can be bought individually and combined in weather stations. It is common practice to use electronic logging equipment to read these measurements periodically, and to pass the data to a computer for storage.

Weather observation is an example of an existing household practice that captures many of the features of domestic ubiquitous computing. It involves a number of distributed devices that are both linked together and linked to wider networks of information. These devices are scattered within and nearby the home, and people must make senses of their interconnections and the way information flows among them. The devices are utilitarian from one perspective, but one can also argue that they support a form of intellectual aesthetic perception of the patterns of weather, and so will fit or disrupt the aesthetics of the home more generally. In order to explore these is-
sues further, we investigated a particular weather watcher and developed new devices for his context of use.

3.1. Existing Behaviour

We met Bernard Butler through the Climatological Observers Link. An active contributor to the journal, Bernard had retired from the Meteorological Office, but maintained a strong interest in meteorology. He kept a range of recording instruments in and around his home in Wokingham, and also took regular readings from a local weather observation station.

A spare bedroom served as the main repository of measurement devices and collected weather data. Along with traditional analogue instruments, the room contained three computers, each with a particular role. The first linked to, and controlled, a satellite receiver mounted on the roof of the house, capturing data transmitted from weather satellites. The second computer allowed Bernard to process this data, which contained high resolution images of the Earth’s surface, recorded by the satellite as it passed overhead. These images were archived, and also uploaded to Bernard’s website. The third computer acted as a display for temperature and humidity readings, which were provided by a home-made sensor in the front garden. Once a minute, this data was transferred to the computer, which then plotted a graph of changing conditions throughout the day.

Also of interest was the distribution of related objects throughout the rest of the home. Barometers were mounted to the wall by the front door and near a bookcase in the living room. There were antennae mounted to the roof, an anemometer within reach of a window in the loft, to measure wind speed and direction, and homemade sensors built with PVC tubing and tinfoil in the gardens. Huge amounts of data were generated and filed, and these files spilled out of the study to fill bookshelves on the upstairs hallway. Thus the surfaces of the home became supplemented by tool type objects; utility existed alongside ornament and decoration. Whereas the framed photos and pictures were static, the flickering screens were updated to show new readings. These devices sat strangely among the expected furnishings.

Bernard’s home – at once unusual and mundane – served as a focus for our design in this project.
3.2. A System of Movement

The distribution of weather measurement devices throughout Bernard's home, and his fascination with meteorology inspired a prototype system of movement for the home. This was a distributed set of linked electro-mechanical objects, whose physical behaviours were driven by weather change.

One device might represent barometric pressure, another to levels of solar radiation. These objects exhibit richer movements and different scales of actuation than traditional weather watching tools - vibrations, compression, spinning, jolts. The scale and speed of the movements are calibrated by algorithmic transformations of raw weather measurement data. The processed data is transmitted as control messages to influence the motors and LEDs. Despite the physical separation of each prototype, the message sending is co-ordinated, so that each device moves simultaneously. Thus there is a
sense of rhythm throughout the home. There need be no intervention from the weather observer, as Tabor suggested; these electronic objects seem to have a life of their own[4].

Fig. 3. A model of the system with hardware and software components.

The prototypes have a utilitarian aesthetic – it is evident that they are capable of movement, and the range and limit of the movement is clear. They look like tools for measurement. In addition they are designed to attach to and make use of familiar features in the home, by sitting on a shelf, attaching to a window, clamping to a light fitting and plugging into the computer. Like Bernard’s incongruous instrumentation, they exist amongst familiar things and are parasitically integrated into the domestic landscape.

Initial designs for a suite of objects are shown below, followed by a short description of their function.
• Weather station
The weather station is designed to be set up outside. Every 15 seconds a set of meteorological sensors sample the wind speed and direction, barometric pressure, temperature and humidity. Changes in these conditions create ambient movement in the output devices.

In addition, historic weather data can be retrieved from the Met Office archive. A location and a date can be selected, and the objects become playback devices for that particular data-set. This might be extreme weather, or data from a day with personal significance.

These two modes provide different types of engagement. The former is the default state. The behaviour is always on, like a clock. It provides a rhythm, which reflects the world outside. The later provides a more direct interaction

• Shadow caster
This device is designed to clamp to the flex of a ceiling light. It has a blade that sits above the light bulb and moves in a circular motion. The blade casts a shadow onto the ceiling. It was imagined that the movement of the blade would be linked to changes in wind direction.

The novel, mechanical behaviour of the Shadow caster extends the function of the light by providing an awareness of what’s happening outside.

• Window blind
The object attaches to the inside of a window using suction cups. It uses a vertical movement to open and close a paper sail, which folds like a fan when it is compressed. By taking input from barometric pressure, this object acts as a shield between the home and outside when the weather becomes stormy.

Fig. 4. Prototypes of Shadow caster and Window blind.
Weather watchers draws on home meteorology to provide an example of how the behaviour of a distributed system can respond to the interests of the user. These interests become represented autonomously and spatially by being embedded in the home through the appropriation of existing surfaces and appliances. For our research, this is perhaps the beginnings of a exploration of how a language of movement and resource sharing across objects might supplement the primary, functional properties of a discrete object, so that the broader beliefs and imaginative worlds which attend, but are unacknowledged by the primary interaction, can be addressed.

In the research project which follows, we tried to move on from the illustrative quality of Weather Watchers – where the system was a characterisation of a specific interest – by designing a system that was not functionally or aesthetically determined by a particular type of data, but which was an open system that invited appropriation by any user for potentially any input.

4. Media Mediators

The Media Mediators were a set of networked objects capable of simple movements, with embedded electronics receiving and interpreting instructions broadcast from a computer [5]. Like the previous prototypes, the movement they performed determined their forms and mechanical structures. The context within which they would perform the movement was left open, and they had a purer form aesthetic to suggest this neutrality. They did not sit upon or attach to existing surfaces or appliances, but occupied their own space.

They were designed to invite the user to create a system of movement – something appropriate to their own interests, or to an activity within the home. In this sense they were envisioned as being descriptors for flows of domestic data, which would again be afforded by a linked and distributed system, and where a particular set of data could be replaced by another set, then a third data set, so the model of resource sharing could become foregrounded.
4.1. Mediators as Media Playback

We began with an initial scenario in order to demonstrate how these blank, movement capable objects might be used. The system was deployed as a platform to enhance the experience of digital media play back. This would allow the experience of the media – be it a film, an animation, some music or a set of slides – to be extended through the home, instead of being confined to a screen and speakers. One source of inspiration for this scenario was Physical Markup Language (PML), a standard proposed by Philips[6] which has more recently become manifest as amBX[7].

In anticipation of how a user might modify their media in a simple video editing application, a QuickTime movie was augmented with a set of instructions. During playback of the movie on a PC – within a QuickTime based application developed by Murat Konar – the instructions would be sent to, and broadcast by a USB peripheral. This broadcast is received by the mediator prototypes, which interpreted the instructions and moved accordingly. This instruction channel was embedded alongside the sound and video streams using as an invisible, time-coded subtitle. The instruction contained three commands for each stepper motor (a finely calibrated motor capable of precise positioning) in each object, denoting the speed, direction and number of steps to perform.

Fig. 5. Media Mediator prototypes installed at the Royal College of Art, designed with Andy Law.
In this application, the shared properties of the networked devices (in our case this was exclusively the mediator prototypes, though it could of course be any property of any appliance in any home) become appropriated and synchronised as a physical home theatre. Rather than imagining enhanced DVD’s or enriched adverts, we were motivated by providing creative opportunities for the user to act as an author and publisher of the content, so these pooled properties become a set of resources for the user as a director, taking control of the technological landscape that surrounds them.

4.2. Inviting appropriation

To explore other uses for the mediators, we worked with volunteers who would adopt the prototypes and find ways of using them within their own homes. These were fairly technical users: T was a PhD student with a particular interest in the semantic web and D was a sound technician with an interest in robots. The aim was to work with users who might develop a high level of technical knowledge about the prototypes and be able to exploit the openness of the prototypes design to such an extent that they might modify the original functions and properties.

T thought about the system he would build with the prototypes, and provided examples of the data he planned to cause movement in the objects. Online services like instant messaging would hook into the prototypes, where they could become peripherals that expressed the presence or mood of his friends. This was extended into an appli-
cation that translated a variety of written sources, including literature and news, into a range of movements in the prototypes, which echoed semantic qualities of the source text.

Fig. 7. A diagram made by T to depict a range of data inputs for his system of movement.

T compared two prototypes on the basis of his ability to precisely control the motion of the objects, where real world behaviour was a “direct correlation to the input parameters”. Whereas one was suited to applications that needed a degree of accuracy, the movement of the other was less predictable exhibiting “different qualities which are interesting as well” and with a “slightly random, pet like” behaviour.

While our original aspirations for the system was the openness of the data they might link to, T’s suggested that he might want to gradually narrow down this choice, and eventually link to a fixed data set. Despite this he was excited by the scope of options that were available to him at the development stage, and the range of potential data sources he could test. In this respect, there was a sense that the openness and adaptability of the objects would lead to a period of testing in which the prototypes would not have a stable role, followed by a period of verifying specific roles.

While we had explicitly set out not to give the objects anthropomorphic features, like T, D was fascinated by the tension between the objects as entities and as signals. D had recently begun experimenting with simple robots, and showed us a development
kit he had bought for a microprocessor-controlled crawler. After a discussion of his ideas about applications for these robots, we asked him why the media mediators might be different. A portion of the conversation is quoted verbatim here as, it contains some interesting details about the personification of objects:

researcher: Would you like to live with the cake [one of the prototypes] or would you like to have lots of little robots crawling about your house?
D: [referring to a prototype] It’s a little more abstract, I guess, and a little more subtle. It would be easier to live with than a robot, but then people live with pets though, they assume their own personality just like these would do eventually.
researcher: How do you think an object acquires a personality?
D: It a very good question, I don’t know, the same reason a car assumes a personality, or a push bike, you know if you interact with it, which you will be doing with these, it’s like the ghost in the machine.

D also spoke about his interest in using the mediators to transform data into physical characteristics; "They're objects and I think it’s fun that they’re powered by data". He described a more visible and tangible role for data, in contrast to his experience of using a PC interface where "you don’t see the data that goes behind it and what works that, and this is one of the interesting things, that these [the mediators] show data in a different way, what you can sort of facilitate with it, as objects, like a knife and a fork you can cut with it".

Media Mediators explores how a user can employ authoring processes to enrich digital content, and how this content could influence a system of mechanical movement, exhibited co-operatively across multiple appliances. There is also scope to extend this sharing with resources other than movement, and to connect to appliances additional to the specialised prototypes described here. In contrast to this distributed system, which is carefully constructed by the user, the project described next serendipitous influence from data sets that are generated from social activity taking place in local neighbourhood.

5. The Local Barometer

The Local Barometer seeks to provide people with a sense of the sociocultural texture around their homes: cleaners advertising in newagent windows, nosey neighbours and pub gossip, conversations in Post Office queues, fridges or cars for sale in a local paper. A wind vane mounted on the outside of the home senses wind speed and direction, and this data is then passed to software which determines down-wind postcodes.

The software uses these postcodes as a search term to retrieve content from the web, returning classified-ads, news items, or images associated with the down-wind area. This content is transmitted to a network of small displays distributed throughout the
Home, where it scrolls across the screen in a direction also determined by wind speed and direction. The system suggests the imaginary flow of local information through the home, and works to encourage reflection on the local environment.

The Local Barometer explores many of the issues we raised at the beginning of this paper. First, it involves information passed among a number of devices in the home, which raises the challenge of designing so that the interconnections are apparent. Second, it is not meant to serve as a kind of augmented GUI, allowing people to search local information, but instead to augment existing awareness of the neighbourhood. Finally, it is left open what this information might be for – it is up to the users to make sense of it.

5.1. Set alongside the familiar

Local Barometer consists of multiple small screen displays that are situated throughout the home. Each display has a unique form and is designed to suggest potential locations: sitting on a mantle piece, wedged between books on a shelf, plugged into kitchen sockets, hiding under stairs or hanging by a hook from a door handle.

Fig. 8. The output displays of the Local Barometer.

It is imagined that each unit will sit near existing touch points of information such as book spines or telephones in order to reinforce the idea of external events mixing with the domestic landscape.

5.2. Passive engagement

The notion of passive engagement comes from idea that these systems are not exactly interactive in the traditional sense. The data is streamed into the home much like that of a television or radio broadcast – not by a director, producer or presenter but by a
series of automated systems that are responding to changes and events in the local environment.

The output on these displays is not entertainment but a series of structured snippets of information that are designed to be compelling and provoke curiosity, even voyeurism. These displays are small and become foregrounded or peripheral throughout the home, allowing the user to dip in and out of active engagement with the content.

5.3. Curious Content

The data is rendered to the displays with a scrolling motion, so that text or images gradually appear and disappear over the course of a minute or so. As each item appears only once, flows of data through the home are emphasised as transient.

A range of strategies has been used to encourage reflection, particularly with the textual content. The format of adverts from classified-ad site is specific and rigidly formatted, featuring a price, a contact number or email address. These details are removed from the data, leaving just the descriptive body, resulting in a more curious form. The texts become defamiliarised, making the information unclear and creating a certain power and ambiguity. This is emphasised with the addition of a few carefully chosen line breaks:

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Challen
piano
upright
circa 1950
1 careful lady
owner
good condition
all singing all
dancing
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The line breaks create moments of surprise, when meanings not intended in the original advert suddenly surface as equally valid readings of the text. The less familiar the content appears to be, the more context the readers have to provide themselves in order to make sense of the messages.

The same tactic of decontextualisation is applied when images are displayed on the Local Barometer. Stripped of their associated text, images of objects, people and places float by provoking curiosity and surprise. For instance, is the washing machine
for sale or in the wanted section? Is that a picture of a lost kitten? Why is an image of the park on display?

The approach of removing some context from the web gathered data allows users to produce their own meanings from what they see. All the information displayed on the Local Barometer is rooted in the local environment, but it is not designed as a search tool or a recommender system for showing people what the system thinks they want to see. Rather, it provides a rich source of content for users to inhabit and layer meaning upon.

6. Conclusions

6.1. Distributed Form

William Buxton[8] describes how interactions with digital systems can have different modes of involvement. Unlike telephone conversations, which have beginnings and ends and a sustained level of involvement, his proposal is for a communication medium more like a continual broadcast, with occasions of focused dialogue between other users of the system. A similar model can be used to think about how we interact with digital appliances in the home. We can imagine interface elements - the screens, buttons, and beeps that help us relate to an object – moving intuitively between the foreground and the periphery of a user’s attention.

The interfaces of such objects have been described as ambient[9], where there is an aspect to their behaviour that is independent from the user. They may have a degree of agency, of behavioural autonomy[10] They may also behave as signals, using indicators of a change that we can either attend to or ignore. However, movement is a powerful attractor. Our gaze is pulled from thing to thing, and there is potential for our concentration to be attracted through these modalities rather than determining our own course of action.

We might imagine interactions with objects in the domestic interior in this way - a series of foreground and peripheral actions. For individuals undertaking private tasks there are moments of contemplation, pauses, and a sense of drifting to and from action. Throughout these modalities is the common thread of the self. This is the open-ended nature of our experience; tasks are small islands of engagement within a haze of being.

This connection between the user and outside world can be seen as the result of the organisational freedom the home affords. The interior is scattered with stuff, which represents the user’s role, their interests, passions and values. It is within this landscape that we can think of the media which pushes into these electronic objects not as anonymous data, flows of abstracted binary packets, but as sensory data, rich information which fuels the behaviour of the possessions, which in turn go some way towards defining us.
6.2. Serving the Home

Let us now return to Wieser and Brown’s computational model. This suggests that the proliferation of digital resources had been propelled by a migration from factory to home. So in addition to responding to the technological functions of newly emerging software and hardware, we have explored the cultural and psychological themes that attend this domestic technology usage. This has been clearly articulated by Bill Gaver’s Equator Group[11], where a case is presented for research that looks away from the legacy of HCI’s roots in work, to activity that is less clearly task based:

The home is also a setting, however, for many activities that are less clearly utilitarian. People browse through books, pursue idle speculation, play word games with one another, and admire the garden. They engage in ludic activities, acting as ‘Homo Ludens’—people as playful creatures. Such activities are not a simple matter of entertainment, or wasting time. On the contrary, they can be a mechanism for developing new values and goals, for learning new things, and for achieving new understandings.[12]

In the four projects described here, we have suggested how distributed and linked systems could support these types of activity. The Key Table and Picture Frame provides an emotional signal between occupants, leading to speculation rather than providing a fixed meaning. The prototypes built for the Weather Watchers and Data Barometers project respond to open and unending flows of information, which support the user’s interests and curiosity about phenomena outside of the home. Media Mediators provide an open system that can be personalised by the user, so that appliances are transformed into characterisations of the user’s curiosities and interests. Rather than becoming overcrowded by unwanted technological functionality, the home becomes reinvigorated by a sense of the occupant’s identity.

6.3. Finding Meaning

We have considered the domestic environment as a stage for a complex choreography of rich behaviours across multiple linked objects. We have also made a distinction between foregrounded and peripheral behaviours, which might depend on the duration or the role of a particular instance of this choreography. A third important feature of rich, linked behaviour is sensitivity to a tension between the habits of the user and the ambition of the designer.

With the Media Mediators we saw a system that was intended to be customised by the user. The behaviours are designed, but the affect of those behaviours, and the interconnection of multiple influences to create a choreographic chain is open. This is in contrast to the Key Table and Picture Frame, where the interaction is fixed. There is a narrative proposition about the interaction, even though this might not be made clear
to the user – as the keys get thrown on to the table, the sudden tilt of the frame sends a warning to others.

As complexity and chaining of objects in real space is built up, it becomes harder to sustain the narrative ambition of the designer. With complexity comes indeterminacy, and the lives of the user floats freely from the inferences of the technology once it has moved from the context of the GUI to a real landscape. It becomes more desirable to provide the user with the ability to create affective links between the behaviours of discrete objects.

Resource sharing across distributed systems creates an opportunity for designers to provide rich and sensitive interactions for the user to experience. From these initial research directions it seems crucial to balance the ambition of the designer to pre-structure this experience with potential for customisation and authoring by the user, so that the interrelation of the system is clear enough for the user to creatively navigate but not overbearing so that the user feels they have lost control of their home to the digital beasts described by Tabor.

References

2. ibid.
3. The research was jointly funded by the Helen Hamlyn Research Centre and Philips Design.
5. Again, jointly funded by the Helen Hamlyn Research Centre and Philips Design.
7. More recently PML has matured into amBX see http://www.ambx.com/ for some details.
11. Equator is a six-year Interdisciplinary Research Collaboration funded by the EPSRC, Gaver’s group is based at the Interaction Research Studio at Goldsmiths.