Interactive Infrastructures
Distributed Interfaces for the Built Environment

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Abstract
An interactive infrastructure allows users to have access to the parameters of an electronic environment in real time, potentially leading to an increased productivity, lowering of energy and material consumption, and generally greater user satisfaction and experience. The aims of this research are to investigate and design new ways for interacting with the infrastructure of buildings, and to research and develop the basis for an interactive infrastructure communication language which enables the distributed elements of the infrastructure to communicate with each other and with the users. The effectiveness of infrastructure in buildings can be significantly improved with this approach[1].

Imagine walking into a room, and being able to control the lights, temperature, and other environmental parameters with your own ***personal physical interface*** *(or your smartphone). The room presents itself by its parameters, which can be linked to the physical controls of the interface (sliders, knobs, switches, motion sensors, touch screens). The level of access offered depends on whether the visitor is the owner, an invited guest, or a burglar, and is individualised also in the physical appearance offering accessibility for people with special needs. If there is a history of interaction, these mappings are already known to the room and taken as a starting point. The environment can present itself in a dynamic way, based on behaviours and memories. The visitor can feel immediately at home and control relevant parameters such as temperature and light levels. Taking the interface around the house, further interactions can be facilitated, such as engaging with audiovisual content, setting individual room temperatures, lighting behaviours…. a personalised infrastructure.*

Background
The importance and presence of infrastructures in the built environment has increased over the years. Infrastructures provide access and control of electricity, data networks, light, water, air-conditioning etc. It is an essential part of the architectural structure because it directly relates to its inhabitants. The infrastructure is the part of the technological environment that the inhabitants interact with. However, the interaction possibilities are often severely limited due to inadequate user interfaces.
The design of infrastructures is often not regarded as an essential part of architectural or building engineering practices, while it is important for the way the building operates. An increased awareness of the importance of sustainability and preserving our natural environment has led to an increase in attention for the design of the infrastructure, part of an emphasis on more holistic, integrated and inclusive design approaches. For an extended parametric design approach, which includes the real-time behaviours and interaction as part of the actual building, it is essential to include attention for the infrastructure design as part of the whole architectural design practice. In order to do this a structured interaction language and protocol is needed, facilitating the reuse and incremental development of interaction modules. Based on the layers of solid technical

[1] This working document is extended from a recent publication [Bongers, Eggen and Oosterhuis, 2014].

developments and protocols (described in detail below), this proposed language is firmly based on real world parameters and human factors. The first steps towards the development of this language are presented in this paper, supported by theoretical frameworks and practical approaches, and illustrated with examples.

The Electronic Ecology

As electronic technology has become increasingly miniaturised (disappearing from presence) and at the same time more interconnected (networked), it becomes more invisible and yet more omnipresent. These are opposing trends, where the most powerful technology is at the same time the least visible. This is a threat, as well as an opportunity - we can focus the design efforts on the interactive aspects and the interface of the technology. Because the underlying technology has less physical presence, the interface can be designed to better fit the human, both physically as well as mentally.

This approach can be seen in the fields of Ubiquitous Computing (or Ubicomp) [Weiser, 1991], Pervasive Computing (as IBM calls it), the Internet of Things (MIT) [Gershenfeld, 1999, Gershenfeld et al, 2004], Sentient Computing (AT&T's term) or Ambient Intelligence (the term used by consumer electronics company Philips) [Aarts and Marzano, 2003, Aarts et al, 2003]. This can also be called the electronic ecology or *e*-cology [Bongers, 2004a], a term which is inspired by the importance of natural ecosystems and also referring to J. J. Gibson's ecological approach to perception [1979], to emphasise the *interaction* as the central area of design efforts. The greatest possibilities of the *e*-cology or ubicomp lie in the potential for de-centralised systems, such as the Internet, and there are examples from other fields such as governance, and permacultural approaches.

In the recent years we have seen a number of technologies and techniques from avant-garde research labs becoming mainstream, in commercial products such as Apple's iPhone and iPad, Google Glass, and Nintendo Wii and Microsoft Kinect game controllers. These products often have changed the way people do things with computers, liberating the technology from the desktop or even laptop and bringing it in the social realm with many consequences and usages beyond what was originally envisioned in the scenarios of use.

There is an interesting relation between ubicomp and *integrated design* which is a design approach that takes the broader context and all relating factors in the wider sense into consideration, rather than designing an object or building in isolation. Integrated design looks at how a design might be used, how it influences and interacts with people's behaviours, how it relates to other designs, etc. Integrated design aims to deal with the full complexity of the real world. When designing for a specific situation it takes into account all the stakeholders, elements, activities, goals, agendas, scenarios of use, and all aspects of a widely dispersed network of interrelationships.

Essential for this approach however is that not only the technology and functionality is distributed and networked, but also the interface structure is distributed as an ecosystem facilitating interaction. The projects of our teams and earlier research follow a modular approach, resulting in Interaction Appliances which replace the (disappeared or dissolved) devices and their interfaces.

The shift away from actual devices has been accelerated not only by networks, but also by the increased miniaturisation (the computer disappears [Norman, 1998], [Denning 2002]). Seemingly, all that is left is the interface, through which the technology manifests itself (its displays and controls). But even this is under pressure, the interface often shrinks and starts to disappear also. This is aggravated by another tendency, which is the increase in functionality in almost any technological artefact or entity.

The thinking of devices and their interfaces is still present in many technologies around us - one needs only to look at the many remote controls in the average household to see the symptoms. Moreover, there are many parameters of the functionality of our increasingly dynamic environment that are *not* made accessible to the people, at least not easily and intuitively. The proposed interface ecosystems aim to open up this unexplored potential.

Interactive Architecture

Inspired and informed by collaborations with Dutch architects Lars Spuybroek and Kas Oosterhuis, (Water Pavilion [Schwartz, 1997], Transports [Zellner, 1999], [Mandrelli, 2000], Muscle projects [Oosterhuis and Biloria 2008]), and Barcelona collective Metapolis (Media House project [Guallart, 2005]) it was realised that architecture could be approached as a dynamic, interactive structure rather than a static and fixed one. In traditional architecture there are many dynamic elements; windows and doors open and close, lifts and escalators move up and down, and of course the whole infrastructure (concerning with the indoor climate, flows of water, electricity and light) is dynamic and potentially interactive. Further extending Le Corbusier's famous notion of 'a house as a machine to live in' as well as Marshall McLuhans envisioning media as 'the extensions of man', these interactive infrastructures enable inhabitants to profoundly control and unite with the built environment.

The Metapolis Media House project was used as the first architectural testing environment for the Internet of Things, with the participation of Neil Gershenfeld [Guallart, 2005].

The work of Kas Oosterhuis, considered as an advanced proponent of dynamic and non-standard architecture, pioneers the use of parametric design [Jormakka, 2002], [Oosterhuis 2003, 2011] [Burry 2011] in which all the parameters of the 3D model of an architectural structure come under real-time control. Oosterhuis' work unites an exceptionally free flowing *form* with structural *function*. This has led to several architectural pioneering projects such as the Muscle range of interactive and kinetic architectural structures. In addition to this work, in a collaborative research project at Hyperbody at the faculty of Architecture at the TU Delft several new interfaces and modular interaction appliances were developed for Protospace [Bongers, 2012] as shown in Fig. 1.

Fig. 1 Interaction Appliances in Protospace

Individual Interfaces

In addition to the ability customise an interface through software, recent developments in 3D printing have made it much easier also to individualise the *shape* of a product. The recent trend in the field of industrial design is known as 'mass customisation' [Heskett, 2002], as a response to the 20th century mass-production.

The notion of individual products is a significant shift in the field of industrial design, a shift towards the rather unexplored territory between *craft* (highly skilled individual labour, production of single pieces) and *industrial production* (mass made by machines). Since the transition from craft to industrialisation as the main means of manufacturing during the industrial revolution, and the reorientation (as one could call it) of the role of craft through the Arts & Craft movement, Bauhaus and subsequent developments, each found its own part of the field of production. It could be described as meta-craft. In the last decades there have been significant developments in CAD / CAM (Computer Aided Design and Manufacturing) which are now becoming mainstream and increasingly available to smaller studios and even individuals [Hague et al, 2003]. This has led to many new practices, techniques and approaches, and the opportunity to design individualised physical interfaces. In a recent special report in The Economist this was described as 'the third industrial revolution' [Markillie, 2012], a claim that provides insight into the impact 3D printing technology will have on the way physical products are manufactured. This article refers to an industry standard report by Wohlers Associates, Inc., an independent consulting firm that provides technical and strategic consulting on the new developments and trends in rapid product development, additive manufacturing, and 3D printing. Although 3D was traditionally used as a method to make one-off prototypes, Wohlers estimates that currently around 28% of the money spent on 3D printing things is for final products. They predict that this will rise to just over 50% by 2016 and to more than 80% by 2020 [Wohlers and Caffrey, 2013].

The possibilities of design (CAD) were always ahead of what was possible in manufacturing (CAM). The field of architectural design seemed to have been much further in developing parametric modelling, and linking CAD to CAM in the "file-to-factory" approaches enabled architectural designs to rely on individually specified components rather than being limited to the use of standardised elements. This has led to the notion of non-standard architecture and the recent buildings of Kas Oosterhuis have extensively developed and applied this method [Oosterhuis 2003, 2011]. Product Design is now increasingly engaging with the possibilities, which we are using in the design of individual interfaces, using CAM to create the final product.

This approach of mass-customisation resonates well with our desire to make individual products to suit the needs of individual users and practices. It is very different from mass production, and it influences the whole design process. It offers new possibilities for including the users and clients in the design process, delivering not a final product with fixed parameters but an open design with specified ranges of parameters to be determined by the user. This leads to the design approach in which a meta-craft designer needs to develop 'product envelopes'. In one of our recent projects in the Interactivation Studio we have develop a modular sensor floor systems, where each pressure sensitive module is part of a prototype interaction infrastructure of sensor and actuator modules (wireless displays) [Bongers et al, 2014]. The floor is currently used to physical rehabilitation exercises, and can be applied on a wider scale in the home. The core of the tiles are 3D printed (in polyamide with laser sintering techniques by the printing-on-demand company Shapeways), designed to be strong yet light to keep costs to a minimum. But most importantly, this approach has the potential for parametric design and the floor tiles can be produced individually in any size.

Moving away from traditional industrial design, there is a need for a different design approach and further advanced design tools when dealing with individual products and manufacturing, than when designing for mass production. It influences all stages of a design process, not just the final ones. When designing for individual products, we design not just one product (or not even multiple products) but a range of products, through an envelope set by the encompassed parameters and their limits. Part of our research aims to establish the heuristics, approaches and guidelines that drive and guide these design processes.

Interaction Appliances

As stated above, rather than the traditional notion of devices and their interfaces, in a Ubicomp paradigm the computer / devices have disappeared and their only remaining physical presence is through the interaction elements (sensors, input controls, actuators, displays etc.). It makes sense therefore to focus on the functionality, and design interfaces directly related to the functions. This approach has had an impact on the field of HCI, and is particularly addressed in sub-disciplines which are represented in publications and conferences such as Ubicomp, Mobile HCI, and wearable computing. A modular approach to interface design is often key. Our own developments are for example the Video-Organ modular instrument for the live performance of audiovisual material [Bongers & Harris, 2002], and the Interaction modules for the Protospace multi-user architectural design environment of the Hyperbody research group at the TU Delft [Bongers & Van der Veer, 2007] [Bongers, 2012]. Both projects were used to develop and apply design spaces for physical interfaces and multimodal interaction, respectively. The term Interaction Appliances was introduced as a working title, inspired by the notion of Information Appliances as pioneered by Jeff Raskin [Norman 1998]. Interaction Appliances are interface modules that facilitate a two-way interaction (input and output, through multiple modalities). In their most expansive form the modules consist of hardware (sensors and actuators, interfacing), firmware, and software. Each module is networked (wired or wireless) and ideally all elements in the system can talk to each other and configure the total interaction. This implies that an Interaction Appliance has no fixed settings, it can be reconfigured on the fly according to the context. An extreme application of this principle is demonstrated in the Hyperbody spin-off Hive Systems, which is a system for reconfigurable distributed architecture.
In order to achieve this flexibility, every IA module has a small computer built in (a PIC microcontroller, containing the firmware). An important element of the IA concept is the software part of each module. In the software the ‘raw’ sensor signals can be conditioned (smoothing, filtering), scaled, and curves applied (eg. linear or logarithmic). The data is then ready to be mapped to system functions in a meaningful way. This meaningful data is the data that should be distributed over the system, so that mapping can take place dynamically and can be context-dependent. This proposal differs from many existing proposals and projects, which exchange data in more ‘raw’ form and the meaning is established at other layers [Baalman et al, 2009], [Luyten & Coninx, 2005].

A Musical Parallel

In the mid 1980s in the electronic music world the MIDI standard was introduced. This Musical Instrument Digital Interface was developed by a consortium of the electronic musical instrument industry as well as academic researchers in electronic music studios and musicologists, and musicians and composers. The result was a universally adopted and implemented standard, which although it had some limitations (in bandwidth, its keyboard-based nature, and a few other quirks) it was powerful and flexible enough to accommodate many new possibilities. The universal availability of MIDI brought about a whole new electronic musical instrument paradigm. A plethora of new instruments came about [Paradiso, 1997], [Bongers, 2007]. It was possible to develop personal physical instruments (controllers) which would translate the players movements (gross and fine) into MIDI commands which received by a synthesizer or sampler would result in sonic output. The MIDI standard is still unique in its omnipresence, and indeed has been used in scientific research, medical applications and in interactive architecture [Bongers, 2004b]
The absence of a similar standard for the general HCI field, particularly in UbiComp and pervasive computing, is surprising. Considering the history of MIDI as a musical example and the paradigm

shift it has enabled, it is in a sense remarkable that the ubicomp field has gotten this far without a standard. Imagine where it will go once we have developed this standard….

Example Application – Lighting Interface

Traditionally, light control in home and office environments takes place through switches (on/off), dials and sliders (dimmers), and sometimes motion sensors. These controls can be incorporated in the built environment such as walls, or be attached to lights that people place themselves (desk lamps, bed side lights). This often leads to a jumble of controls each with their own location, interaction style, and focus.

There is a need for a unified and integrated control system, however the light interaction should be intuitive, clear, and allow for profound control over all lighting parameters (location, direction, intensity, colour etc) yet be easy to use. On top of the technical infrastructure we need to design interfaces that allow people to influence their lighting environment. In our project since 2011, using a spatial gestural interface based on a laser pointer and sensors with multimodal feedback (light, sound and touch) an intuitive and engaging interaction style has been designed, as a first exploration of a the development of a interaction infrastructure for lighting control (see Fig. 2). We looked at other gestural interfaces [Pan et al, 2010], [Seifried et al, 2009] and laser pointer based controls [Myers et al, 2002, Myers, 2002], [Bongers and van der Veer, 2007], and focused our design on fine-tuning the elaborate multileveled and multimodal feedback. This work was presented as a demo at OzCHI 2011, and at the Interactive Lighting workshop at DIS 2012 organised by the team at the TU Eindhoven that works on the development of interactive lighting infrastructures (Offermans et al, 2014). In 2012 an extensive user interaction study has been carried out and a journal publication is in preparation. In these projects DMX based systems are used, and the Philips Hue system, as well as products from the Siemens spin-off EnOcean, which makes interfaces (wireless light switches, impact sensors) that use energy harvested from the environment such as light and movement (the impact of the switch generates enough energy to send the radio control signal to the receiving light, a technology which is also applied in the Philips Hue Tap wireless switch).

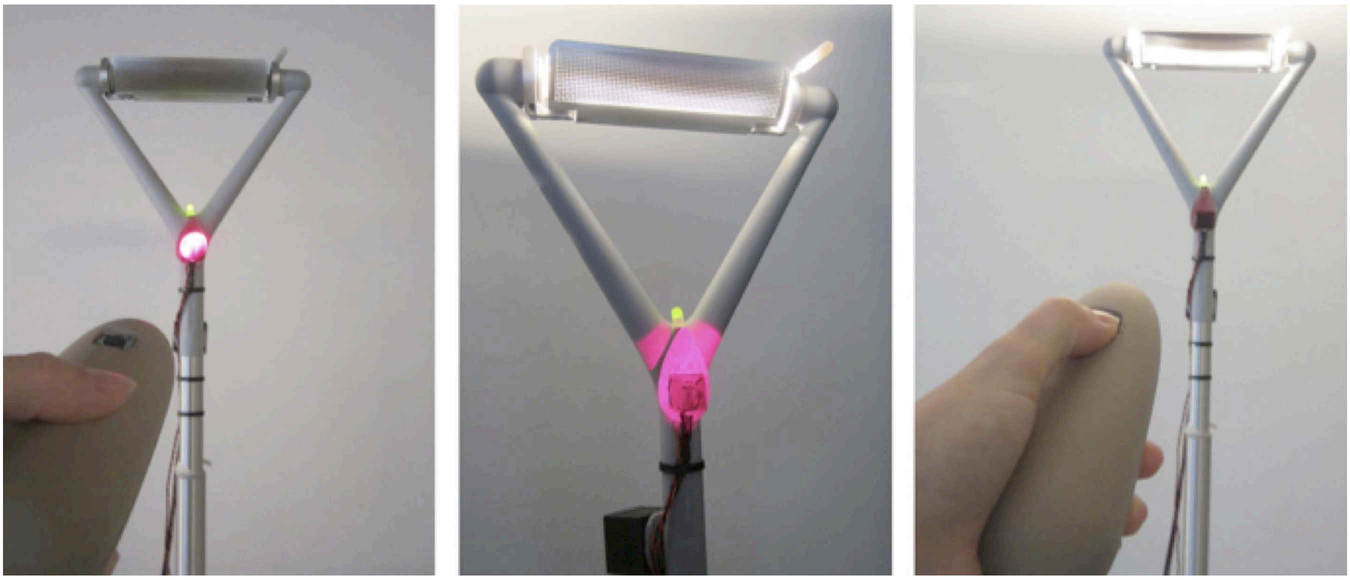

Fig. 2 The Light Pointer (image by Marigo Heijboer)

An Approach to Interactivating Infrastructures

The research presented in this paper is about distributed interfaces, with an emphasis on physical interaction. This work aims to develop the preliminary specification of an interaction protocol, through which the modules (Interaction Appliances) can communicate throughout the system including the (dynamic) mapping to system parameters. The goal of this work is to introduce the ideas as a starting point for further development, inviting the academic and design communities and the industries to be involved in advancing and implementing such a language.
In the sections below the approach is presented, as well as the design frameworks that are used as basis for the developments.

Multimodal Interaction Space

Development of interaction can be guided by the multimodal interaction space (MIS) [Bongers and van der Veer, 2007]. The framework is related to other multimodal interaction frameworks in HCI [Schomaker et al, 1995], [Bernsen, 1993], [Eggen et al, 1996], [Wensveen et al, 2004], and consists of *modes*, *modalities* and *levels*.
Modes are primarily concerned with how information is coded, and in MIS there are the three main modes of information (re)presentation: symbolic, iconic, and the thing itself. This leads to the main modes of interaction, symbolic (eg. text), iconic (mimicking that which is represented) and manipulation (with the actual object or physical presence). These representational interaction modes are linked to theories of human development of kinetic / enactive, iconic / mimetic, and symbolic / abstract (respectively) in the work of Jean Piaget, Jerome Bruner and Lev Vygotsky [Wood, 1998]. This research on human learning and development formed the basis of the now widespread graphical user interface (GUI) paradigm through the research at Xerox PARC in the early 1970s [Kay, 1990]. Other modes of interaction are relevant too, particularly the important notion of implicit interaction (as opposed to explicit), intentional or accidental presentation, peripheral (as opposed to focal) interaction, etc. [Bakker et al, 2012]
Modalities refer to the human perceptual channels such the visual, auditory and the tactual. In our approach there is an emphasis on the sense of touch and movement as well as sound (focal and peripheral), as the visual channel is already well covered in the current situation. Tactual perception is the general term encompassing the sub-modalities of tactile, kinaesthetic and haptic perception [Loomis and Leederman, 1986], and the essential difference between active (self-moving) or passive (imposed movement) situations [Gibson, 1962, 1966].
Levels of interaction are another part of the framework, analysing the layers in the interaction. Interactions often are compound not only in modes and modalities but also with different actions occurring over time and with different purposes. Studying the time-based nature of interactions, from the bird's eye view to the microscopic, requires zooming in and out in time, and can unravel the multiple interactions. The levels are related to layered models from HCI, where interactions virtually take place at different levels, for instance in the work from the late 1980s of Jakob Nielsen's Virtual Protocol Model [1986], Donald Norman's Theory of Action [1986], and most sophisticatedly Martin Taylor's Layered Protocol [1988, 1991]. Layering is commonly applied in HCI in the Hierarchical Task Analysis (HTA) method. Each of the levels of interaction requires its own specific feedback characteristics, which is one of the key areas of research and development in the Interactivation Studio.

The Design Space for Physical Interfaces

In engineering literature [Sinclair, 1988], but also to an extent in HCI [Hinckley and Wigdor, 2012], [Wilson, 2012] it is common to describe and categorise sensors and actuators by their physical working principle, such as light, ultrasound, or magnetism. For the purpose of analysis of interaction and design of interfaces it is more appropriate however to categorise in terms of human factors. For instance, a human movement can be tracked through infrared light sensor or a

ultrasound sensor, and although there are subtle differences associated with each sensing technique what is important in HCI is the human movement rather than the technology.
Based on experiences in designing interfaces ranging from electronic musical instruments, interactive architecture, live video performances and installations, a framework was developed for physical interface design using the terms *range*, *precision* and *haptic feedback*, in relation to each Degree-of-Freedom of movement. This framework has been applied in the design of physical interfaces, but can also be used in the analysis of existing interfaces. It enables the comparison between interfaces and interface elements in quantitative measures [Bongers and Harris, 2002].
The design space is related to the issue of mapping, which is about the relationships between the computer's input, behaviours and parameters of its processes, and output. The importance of mapping can not be emphasised enough in design, and when applied with sophistication this is the most crucial area of the craft of designing for interaction.

Interaction Infrastructures Protocol

Following from the discussion on Ubicomp and the electronic ecology, the need for a unifying interaction language is identified. Such a language or protocol will enable all the elements in what we call an interaction infrastructure to communicate with each other. Most distributed computing and Internet of Things projects have some form of language but this is usually based on merely technical descriptions and ad-hoc devised languages. It is proposed to develop a language based on real-world parameters and the other dimensions of the physical interfaces design space (PIDS) as presented in the previous section.
An example of a scenario of use in such an environment is when a new element is introduced by a user carrying a generic controller, the environment and controller can exchange information and enable appropriate mappings to be made on the fly.
In order to be relevant and applicable, this language primarily needs to be firmly based on human factors, movement parameters, and other physical measures of the environment. With this level of meaningful description, the other levels of connection and protocol can be filled in. It is proposed that the protocol operates independently of the new or existing technical layers, conform the multilayered OSI model. There is a range of hardware/software standards (USB, Firewire, Ethernet, WiFi, Bluetooth, Zigbee etc. generally accredited by the IEEE) that can form the lower layers.
There are a number of languages, including those related to the performance arts, that in a way sit between this top level (human factors) language level and in some cases include low level software and hardware protocols. Examples are DMX (theatre lighting), X10 (home automation), CAN (automotive), I2C, Dali (lighting), CBus, IrDA (infrared remote controls), CoAP (and other web based protocols including XML), MQTT (telemetry), OSC (real time performance data) and of course MIDI.
With such a protocol in place, manufacturers have an incentive to join this open standard. For instance, the Fitbit products of health and movement trackers use a proprietary protocol and Fitbit actually stores the user's bio-data on their own servers, which the user can only have access to through a paid service. The Philips Hue lighting system is an example of Internet of Things thinking with an open communications standard, using an Ethernet based bridge and Zigbee based wireless communication to the individual lights. As a result, there are over 50 iPhone apps for controlling the Hue system, as opposed to only a handful of apps for the Fitbit (which has been on the market for a much longer time). Each appliance comes with its own app, at present if controlling a lighting system consisting of Philips Hue lamps and Belkin WeMo units one would need to switch between two apps. The IFTTT (if this than that) app is a very rudimentary attempt to unification, it can only switch appliances based on a Boolean condition. But IFTTT enables appliances to be controlled with social media events, which is a good example of what is possible with an interaction language standard.

Conclusion

In this paper we have outlined the need and opportunities for interactive infrastructures. We are currently aiming to bringing together partners from technical R&D, human sciences, design research, and industry together in joint projects to investigate these issues further and explore the opportunities. In the three design labs of the three contributors several projects have been developed and further work is planned, following the approaches as presented in this paper. The aim of this publication is to encourage further collaborative research, assessing the proposed approaches and develop further insights and practical applications.

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Scenarios

<u>*Distributed interaction and flow of information*</u>
A good example of distributed interaction (through the use of mesh networking) could be imagined in a public transport infrastructure and information display. The common approach is one that is centralised, for instance all buses equipped with GPS communicate wirelessly their position to a central control station which can disseminate this information to potential users. In a Ubicomp approach, creating an electronic ecology of interconnected nodes of buses, bus stops and users could create a decentralised, information spreading network. Each bus would 'radiate' its location in real-time to the next node (usually another bus) and eventually to a bus stop, where it can be received by the potential user. Of course the information could still be collected centrally to present in apps or web sites, but in effect it is a self-organising network topology which is flexible, robust, and requiring very little energy to propagate. A user roaming around in the streets of the city can tune into the nearest bus stop, and pick up the relevant information (and only that) of the approaching buses. The information available can help the user to make their decisions on whether to walk (more healthy), take a taxi (note that the taxi companies will be a strong force against the possibilities of this scenario, if they can), take the car (the purpose of this scenario is to get people out of their cars) or indeed… take the bus.

<u>*The Tabula Rasa House (Casa Rasa)*</u>
Coming home, you'll find your house as a large, empty space. The space is a tabula rasa. You start by pulling up a chair where you need it, perhaps to get a good view of the sunset through the window that you made appear on the west side of the house, or to sit at a table you pulled up from the floor so that you can do some work. Images of the work at hand get projected on the table top surface, while playing music from parabolic loudspeakers aimed at your location. Cooking a meal involves pulling out the kitchen bench top, ingredients from your shopping bag and a fridge and storage cabinets that appeared, possibly guided by an augmented overlay of a projected recipe or suggestions while improvising with ingredients, and wine suggestions. After enjoying the meal and the wine at the table, the space appropriately lit by a combination of LED lights (controlled by the personal interface) and candles (lit by a match), and having done the dishes using the sink that was pulled out of the wall, you go for an evening stroll and admire the moon and the scents of the evening flowers.

<u>*The guided robot cleaner*</u>
For a long time only imagined in the realm of science fiction literature, robot vacuum cleaners are currently readily available in the shops. Only now we find new nuisances and problems of use, such as the story of the robot cleaner that went for the dog droppings (it considered this an alien substance) and spread them out all over the white carpet.
Years ago a student project proposed a remote controlled cleaning robot, to be operated by the youngsters in the household as a kind of computer game, interacting with the real world. Maybe a dinner guest can entertain himself by directing the housecleaning robot around the house while enjoying the hors d'oevre, using their personal interface which allows access to these parameters of the house. A whole new discussion about etiquette is needed, is it actually ok to involve in these activities as a guest? What about privacy issues?

<u>*Setting up the apartment*</u>
Having just received the keys of my newly built apartment, I enter the place with an assembly of items to finalise the design of the place. Not only will I put the lights in places where I like them, connecting to an omnipresent grid of low voltage power infrastructure, I am also able to put the light switches and analogue controls where they are most appropriate. All this is not fixed, I can

change this over time as I get more experienced in the particularities of this apartment, or as my needs and patterns of use change. Most time I spent finetuning the mappings, between the palette of physical input controls that I have at my disposal, and the parameters of the building. Redundancy is embraced in the ongoing design process. For instance, for the situation when my hands are occupied or dirty I can use my voice to control certain parameters. However, finding myself in a situation where my cleverly designed voice control would be totally inappropriate (for instance, the children are just about to fall asleep, or I am engaged in verbal conversation with others) I am glad I can also use the physical controls.