Pin & Play: An Overview

Kristof Van Laerhoven, Albrecht Schmidt and Hans-Werner Gellersen

Ubicomp Group, Department of Computing, Lancaster University,
LA1 4YR Lancaster, United Kingdom
{kristof, albrecht, hwg}@comp.lancs.ac.uk

Abstract. *The classic obstacles in the digital augmentation of everyday objects and appliances are usually situated around batteries, communication, size, and weight. Wired communication is often not possible, changing or charging batteries is generally considered a nuisance, and augmenting an appliance is usually not worth it if it means increasing its size or weight. We make fully use of a subclass of devices that are typically attached to the wall to overcome this problem. We present several implementations where low-cost wallpaper, consisting of insulated conductive layers, provides both power and a networking bus to common devices like pins on a notice board, wall switches, lights, and thermostats. They can be placed and replaced at will in any orientation, while the attachment to the wall supplies power and networking as a bonus. Moreover, our prototypes show that this doesn't affect familiarity of the objects, which makes interaction with them a breeze. This paper describes the architecture and principles of this method, dubbed Pin&Play, and gives several implemented examples to make the objective clearer.*

1 Introduction

Appliances that are large in size because of their functionality, like refrigerators, TV sets, dishwashers, vending machines, etc. usually remain on the same spot for long periods. It is both easy and worthwhile to provide a wall socket for them. A lot of objects that we use in our daily lives are, however, used in different locations. Many of those are furthermore small in size, and their form-factor doesn't allow them to be plugged in a wall socket or have a network connector.

Placing electronics in these objects or augmenting them with networking capabilities therefore becomes difficult. Build-in batteries might provide a solution in some cases, but this often means an unacceptable increase in size and weight of the appliance in the worst case, or a tedious changing or recharging of batteries in the best case. So-called cradles provide a means of networking devices like mobile phones, personal digital assistants (PDAs), digital cameras, or laptop computers, but these are different for each device and need to be thoroughly distributed.

This paper presents current research that focuses on a certain class of objects that is typically attached to the wall. These objects could be devices we are already familiar with, such as wall-mounted clocks, wall switches, wall lights, posters, thermometers, pushpins, etc. or they could be completely new. A visual characteristic of these objects is that they have a pin-connector. The fastening to the wall not only provides placement and physical support, but additionally *power* and *network connection*. Introducing these devices to a power and networking source is therefore as straightforward as pinning them to the wall, hence the project's name: Pin&Play.

Vertical surfaces such as walls and notice boards are one of the most common supporting structures for the display and exchange of information. They support the meaningful arrangement of many kinds of objects in everyday environments, for example clocks, calendars, lights, controls, pictures, notes, and posters. Many objects may be attached long-term on a surface while others may be replaced or relocated very frequently. Obviously, the easier an object can be attached to a surface, the more control users have over their environment. In this paper we propose a new type of network that seeks to build on the role of surfaces in everyday environments, and that aspires to particular ease of user control. We call our concept Pin&Play as it foresees the ad hoc connection of objects by literally pinning them to a networked surface.

The technology design of Pin&Play is driven by the general aim to facilitate everyday environments with computing in ways that do not break with accustomed uses but instead exploit existing affordances. This relates to ideas of calm computing as expressed by Weiser [10] and to other human-centered interpretations of the ubiquitous computing vision as, for example pursued in Europe's research initiative The Disappearing Computer [11]. However, our work has also received some inspiration from other technology proposals, in particular from the Networked Surface [5] and Pushpin Computing [3]. The relationship of Pin&Play to these works will be further explored below.

The purpose of Pin&Play is to network objects in everyday environments, and it is important to view the technology in relation to networking trends in ubiquitous computing. In contrast to networks for conventional distributed computer systems, networks for ubiquitous computing are typically less concerned with bandwidth optimization and widest possible reach, and instead aimed at high density and integration of large numbers of nodes per volume [Weiser93]. Another important trend is the integration into everyday environments and especially homes [ref on home networking?]. Work in this direction includes home network provision of consumer electronics (e.g. IEEE 1394 "Firewire"), the use of existing infrastructure (e.g. powerline and phoneline), and the deployment of wireless solutions (e.g. 802.11 and Bluetooth). Pin&Play is not challenging any of these developments but proposed as complementary technology, addressing a design space between wired and wireless technologies. It is distinguished by enabling particularly dense networks of surface-attached objects, by exploitation of existing and powerful affordances in physical spaces, and by the simplicity of use and control.

2 Related Work

There is a broad spectrum of work that in a wider sense is related to ours, for instance research into ubiquitous computing networks, on interactions in smart environments, and also on how people interact with physical space. For the sake of space and in the interest of focus we will here only discuss other work that is particularly close to ours.

Lifton and Paradiso have proposed Pushpin Computing [3]. They use a similar infrastructure with pushpins and layered conductive sheets, but in different ways. The pushpins communicate through capacitive coupling or Infra-Red and use the direct contact to the conductive layers in the board only to obtain ground and power. The network is not based on a bus like in our approach but truly decentralized since pushpins communicate only with neighbouring pushpins in a close (~10 centimeters) range, and no central backbone is present. In this concept, pushpins feature as explicit computational elements to create a new type of computing architecture. Pushpin Computing is not concerned with facilitation of everyday objects and environment, which makes their approach very different from Pin&Play in both philosophy and envisioned use.

The Networked Surface is a new type of network investigated at Cambridge University [5]. It is very similar to Pin&Play in that builds on surfaces in everyday environments, however with focus on horizontal surfaces such as desks and tables. In contrast to Pin&Play the created network is primarily aimed at connection of higher-end computational devices that are placed on top of it, such as handheld and mobile computers. Instead of using layers, the Networked Surface is composed of cleverly placed tiles, such that there is a connection to power, ground, and communication channels at all times. Objects can be connected to the surface through circular pads designed to map with connection points onto the tiles. These pads are considerably larger than Pin&Play connectors and not well usable with very small objects. Interesting though is that the Networked Surface also provides information about position and orientation of objects, to be derived from the internal surface structure. A drawback of this structure is the complexity: the network has to manage a large number of tiles in the surface and to negotiate connection points with object adaptors. Wrensch et al. describe the rototack, a pushpin-like device with embedded computation and actuator [4]. The Rototack exhibits Pin&Play behaviour in that it begins to "play", i.e. execute pre-programmed actions, when it is pinned to a common surface, in this case a corkboard. The project though is not concerned with networking or power provision through a surface.

3 Characteristics of Pin & Play

Pin&Play is based on the vision that walls and other common surfaces can be used as ad hoc bus network for objects that become attached to them. This is a vision that requires a novel network composition, and that is concerned with qualities not typically considered in networking, e.g. facilitation of everyday environment and exploitation of design affordances for ease of use.

2.1. Pin&Play Components

Surface. The purpose of the Pin&Play physical network medium is to provide both network connectivity and power to attached objects. It is based on conductive sheets rather than on wires as the objective is to facilitate entire surfaces as two-dimensional network. As solid sheets would leave holes when pushpin connectors are inserted and later removed, fiber sheets are used instead. Pin&Play Surfaces are composed of multiple layers of such sheets embedded in common surfaces. An anticipated challenge with the use of sheets rather than wires is that the resistance and the capacitance can be expected to increase faster over short distance, as surfaces get larger. However, a range of conductive materials are available that are optimized for low resistance. In general, the surface design is aimed at simplicity and low-cost, for example avoiding subdivision into tiles, to hold up our vision of deployment in everyday environments. Deployment of the surface material could for instance be envisioned in the form of smart lining under standard wall paper in the home, to enable entire walls as shared medium for objects that are attached to them.

Connectors. The design of Pin&Play connectors is aimed to support two very different functionalities in a single mechanism. First, they obviously have to support physical connection of Pin&Play network nodes to the surfaces (they would be the plugs if the network were not socket-less). Secondly, they should support attachment of objects based on existing and familiar practices. The connector design is therefore based on pushpins that can be stuck into Surfaces, and that can be removed as easily, thus employing a truly ubiquitous device that is commonplace in home and work environments. The connector design is further aimed at flexible augmentation of objects and hence conceived as adapter rather than built-in physical interface.

Pin&Play Objects. The very idea of Pin&Play is to provide networking to objects that are commonly attached to surfaces, rather than to conventional computing devices. In general, we consider two different types of object. First, we envision that any kind of object that people would attach to vertical surfaces can be "upgraded" to a networked object while also retaining its original appearance, purpose and use. This would apply for example for picture frames, artwork, wall calendars, clocks, light controls, and so on. Secondly, we envision objects that succeed today's mundane and ubiquitous connectors and fasteners, for example "Smart Pushpins" that can be used to attach notes to boards but that in addition provide new functionality on the basis of being digital and networked. Obviously, both types of objects require unobtrusive embedding of computation and network interface. In this context it has to be noted that Pin&Play objects do not require their own power supply unless they are required to be "on" in detached mode.

Pin&Play Network. Objects become powered up when they are attached to a surface. It is the task of the network to discover newly attached objects and to maintain network state. The network further has to provide the communication protocols for the connected nodes. A primary optimization target for the network is to support large-scale surfaces, high density of nodes, and ad hoc integration of previously unknown objects, while bandwidth is of lesser concern.

2.2. Properties of Pin&Play

The design of Pin&Play differs substantially from other conventional computer networks and other networks proposed specifically for ubiquitous computing.

Networking Properties. Pin&Play addresses a design space between wired and wireless technologies. On an imaginary scale of ubiquity of network access, it goes beyond one-dimensional wired structures in providing network access across 2D surfaces, while of course not going as far as offering connection throughout 3D volumes. However, we consider it likely that overall higher density of nodes per room can be achieved if the enclosing walls were networked, in comparison to the state of the art in wireless technologies. A main advantage of Pin&Play over wireless technologies is that it provides power to connected objects, and thus supports the integration of objects that have no batteries or other power supply. The approach is very similar to that of a PDA-cradle or a laptop docking station, but with minimal constraints concerning where and how to connect the object, and with more direct interconnection possibilities.

Use-Related Properties. We already stressed that the Pin&Play concept is firmly built on common structures. It addresses important user values such as familiarity of the concepts used, better observability of network configuration, and straightforward control in the sense of minimal-effort attachment and detachment of objects. Pushpin-like connectors provide a strong affordance, and the user act of connecting an object to the network becomes embedded in the act of attaching it to the wall or other surface. Another important property is the free placement of objects on a Pin&Play Surface. People use surfaces for meaningful spatial arrangement of objects and therefore it is valuable that surface augmentation does not constrain such use.

Deployment Vision. Pin&Play is at this stage of our investigation a highly speculative technology, however its design is clearly targeted at real deployment in everyday environments. The components underlying Pin&Play, in particular the layered conductive fiber sheets and the pushpin-like connectors, require careful design but do not involve sophisticated or expensive technology. If a satisfactory design is achieved, production at low-cost would certainly be realistic.

2.3. Actual Implementation of Pin&Play

The surface. The physical augmentation of the corkboard to a network bus was achieved by adding two conductive layers to a corkboard, using the cork as insulator. The conductive fiber sheets [4], which are traditionally manufactured for shielding applications, are not only straightforward to apply; they also leave no holes once the pins have been removed which ensures it can be used longer than solid conductive sheets. The fabric is usually silver (Ag) or nickel-copper (Ni-Cu) plated nylon and has a typical thickness of 0.1 millimeters (0.005 inches).

Figure 1. Left: the Pin&Play enabled notice board, with various woven samples of conductive fabric in the background. Right: the notice board being used.

We opted for assigning the ground layer in front and the data layer in the back of the corkboard, because the data layer is more protected, while the ground layer could stay on top of the board, requiring no additional covering. Furthermore, when working with very large surfaces, it might be necessary to tile several boards next to each other (Figure 2), all using the same ground layer. In that case a common ground layer in front would be desirable for both mechanical and esthetical reasons.

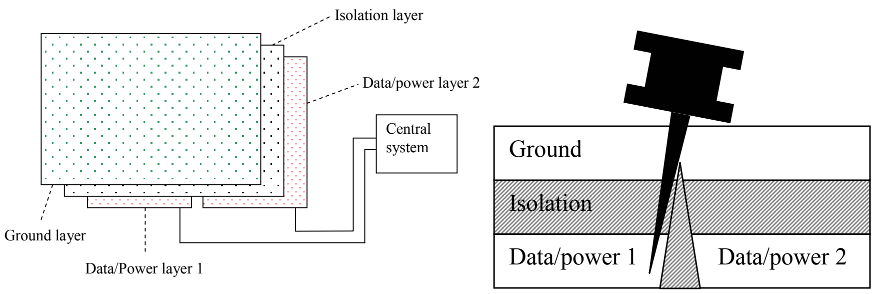

Figure 2. Tiling several boards into one is an option if the communication for large surfaces becomes flawed.

The network. To facilitate implementation of the network protocol, the Dallas MicroLAN [1] was chosen as the base communication layer, as it is an inexpensive and flexible networking standard, only requiring a single wire plus a ground reference. A large variety of network components is available and range in application from simple identification devices, read/write memories, to sensors and switches.

MicroLAN makes it is perfectly possible to build huge networks with many components that can be dynamically added or removed, it supports interrupting and requires a pull-up voltage between 2.8 and 6 Volts. This scalability and flexibility comes with a price though: the maximum communication bandwidth is only 16300 bits per second. The structure of the MicroLAN is furthermore a master-slave architecture, where the master could be seen as just another pin, accessing both layers to provide the essential power and communication to the board. Although implementing the network controller embedded like this is not unimaginable, a MicroLAN to serial interface is used at the moment to let a regular PC control the network. The aim of the network master's software is to find out what pins are plugged in, what components they contain and what they expect from the network.

The Pin connectors. Our current prototype has two isolated pins to get into the front and back layer of the corkboard, much like that of the Pushpin Computing approach [3]. This connector design, with the larger pin partly covered with a transparent insulator has the disadvantage of being fixed in orientation once it has been plugged in, and being more vulnerable to short-circuits since the tips of both pins are more accessible (Figure 3).

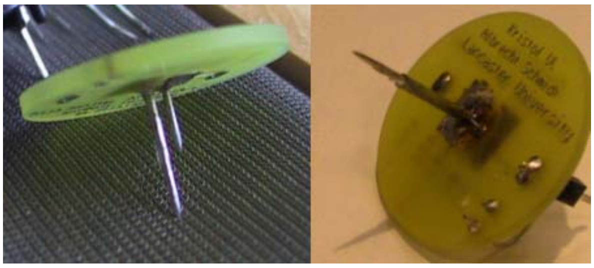

Figure 3. The two connectors. Left: the current two-pin arrangement, right: the prototype with one pin.

Additionally, the two-pin configuration is slightly harder to plug in, and alienates the Pin&Play pin from traditional pins. It does however already illustrate the ease of pinning an object into the surface to provide it power and networking capabilities. As an alternative, we consider a single-pin design. Figure 2, right, shows the initial implementation, made from an industrial stainless steel nozzle (inner diameter: 0.58 mms), as an outer cylinder containing a needle inside, both separated by contact glue.

2 Examples

3.1. Notice Board Pins

In order to stress Pin&Play's focus on small and ordinary objects, the illustration in this section will be set around the ordinary corkboard and pins one can find in most home or office environments. The pins will be augmented to networked nodes that have the ability to notify the user(s) if the item which they pin to the board loses its validity. In addition, each pin has a priority value to put emphasis on interaction amongst the nodes in the network: only the pushpin with the highest priority will be able to alert the user.

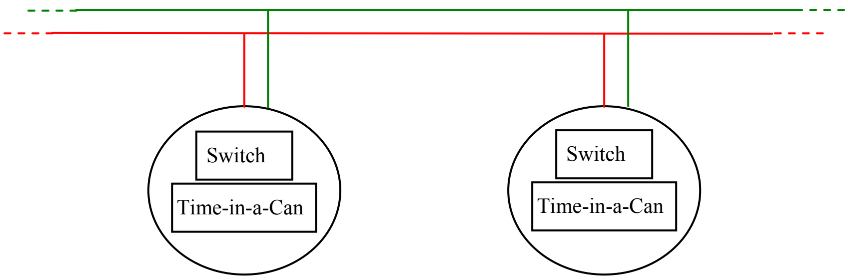

Figure 4. Network representation of two pins, resulting in 4 networked devices. Each device in the network needs one connection to a common ground layer, and one to a data/power layer.

The application requires the components to be small, sturdy and cheap in order to be successful in real-world settings, which is a harsh but important prerequisite for many ordinary objects, as pointed out explicitly in the introduction. The development and implementation of each component in the Pin&Play concept will be discussed and evaluated to these requirements in the remainder of this section.The physical augmentation of the corkboard to a network bus was achieved by adding two conductive layers, using the cork as insulator. The conductive fiber sheets [7], which are traditionally manufactured for shielding applications, are not only straightforward to apply; they also leave no holes once the pins have been removed which ensures it can be used longer than solid conductive sheets. They do have a higher restistivity than plain network wires with a surface resistance of maximally 0.09 Ohms, or 0.05 Ohms on average per square, which will affect scaling up the board size.

To facilitate implementation of all components, the Dallas MicroLAN [1] was chosen as the base communication layer, as it is an inexpensive and flexible networking standard, only requiring a single wire plus a ground reference. The reference manual of its starter kit [2] mentions it being able to support networks with a length of more than 300 meters without any repeater or signal regenerator. A large variety of network components is available and range in application from simple identification devices, read/write memories, to sensors and switches. MicroLAN makes it is perfectly possible to build huge tree-structured networks with many components that can be dynamically added or removed, it supports interrupting and requires a pull-up voltage between 2.8 and 6 Volts. This scalability and flexibility comes with a price though: the maximum communication bandwidth is only 16300 bits per second. The structure of the MicroLAN is a master-slave architecture, only allowing multiple masters using special notification methods.

Figure 5. Some of our bigger Pin&Play surfaces. Pins can be moved from one board to another without loss of data, time or calendar, even when the two boards are not connected via a network.

Our current prototype has two isolated pins to get into the front and back layer of the corkboard, much like that of the Pushpin Computing approach [3]. However, in the next version we envision using a single pin, either consisting of two isolated conductive parts or one solid partially coated version, to gain a higher robustness for the pushpin and ease its handling.

At the heart of the pushpin is the Time-in-a-Can iButton by Dallas Semiconductors [6]. It is a self-sufficient component, containing its own battery (3V Lithium: with 10+ years data retention!), oscillator (32768 Hz), memory (4096 bits), internal real-time calendar and clock (precision: 2 minutes/month), programmable alarms, and full MicroLAN communications support. The pushpin furthermore contains an LED that can be switched by a 1-Wire MicroLAN-compatible switch. Connecting a single pushpin hence introduces two devices into the network that are just *physically* bound in the same package. Both switch and Time-in-a-Can have internal memory, where they have stored their partner's unique address, so they can be bound together in virtual space as well. The Pin&Play pushpin is, just like its traditional counterpart, completely independent of the corkboard since it stores and updates all necessary information locally and is self-sufficient. It will work on another corkboard as well, provided it is Pin&Play-enabled.

The pushpin (Fig. 6) is, in contrast to other miniature devices from similar research projects, reasonably cheap and robust. The total sum of required components for one pushpin is less than 10 US dollars at a thousand pieces, using the current retail prices. Additionally, the rigid structure of the main component (i.e. an iButton, embodied in stainless steel) ensures reliability and a long life time despite it being a prototype. The tiny dimensions of especially the Time-in-a-Can iButton (1.6 cm diameter, 0.6 cm height) produce a total size of a Pin&Play pushpin that is close to its traditional equivalent.

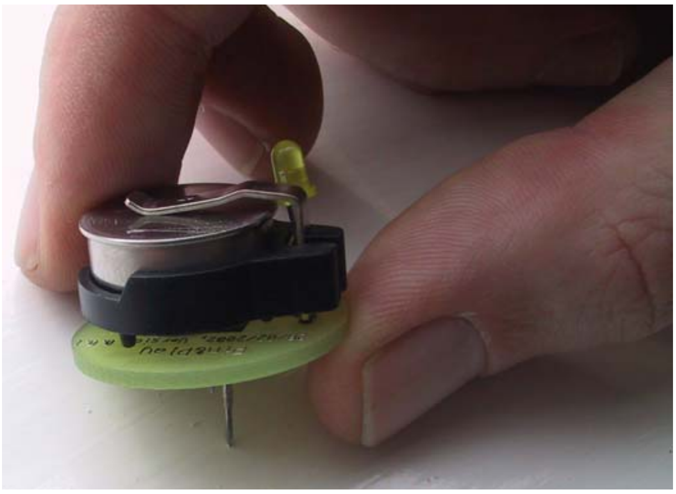

Figure 6. Close-up of an assembled pin. The current model has two isolated pins for accessing both layers. The one-wire switch is hidden behind the i-Button's connector.

The aim of the corkboard's embedded software is to find out what pins are plugged in, what pins are expired, and what pins that are expired have the highest priority. Using this information, it can allow the pins with an alarm flag set to activate their LEDs. The MicroLAN is used as the low-level base layer of communication. When a pushpin is plugged into the board, its switch and Time-in-a-Can get powered and provide the MicroLAN's network master with unique identity codes and descriptions for both components. The associated components' unique identity codes are read from the addresses in the RAM memories of all components. This enables the reliably linking of the Time-in-a-Can iButtons and the switches that are packaged into the same pushpin, and avoids conflicts if two or more pins get attached in approximately the same time-window. After this initialization process, information or tasks in the iButtons' memories could be read and executed, and the switches can be controlled.

3.2. Dynamic Wall Switches and Lights

To illustrate that any wall-mounted object can be augmented in the same fashion as in the previous example, we focused our attention to one of the most common objects found on a wall: wall switches that control the lights in a room. Instead of the electrician deciding for you where these switches belong, one can put the Pin&Play three-layered surface as wallpaper on the wall and use an augmented switch.

Figure 7 shows the front and internals of a Pin&Play enabled switch. It can report to the network master when the device is being switched, after which the appropriate light can be switched on or off. Developing more elaborate appliances such as dimmers or 'smarter' switches is very straightforward. Moreover, the network master can keep logs, automatically activate lights, or monitor light activity by just modifying the software.

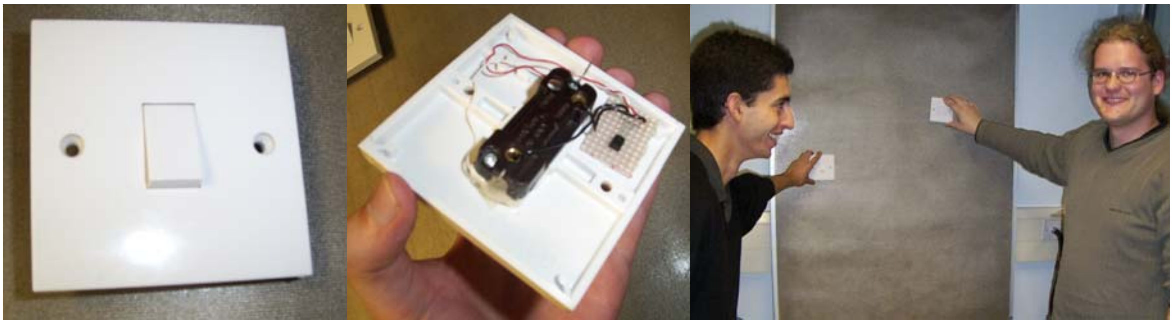

Figure 7. The front (left), internals (middle), and placement (right) of a Pin&Play wall switch.

The user will benefit from the dynamic placement of the switch: if the user desires the wall switch to be located in a different place or orientation, all that is required is pulling it out of the wallpaper and re-attaching it where preferred. Spotlights or wall-mounted lights can be attached and re-attached in the same fashion.

The insulating material used in this implementation is a flexible rubber sheet material with an adhesive side, to make it easier to glue the conductive fabric on. One could really imagine this process to be automation-friendly, enabling the production of flexible, layered wallpaper, which can be installed at low cost in both office and home environments.

4 Conclusions

The Pin&Play idea proposes to enable walls in everyday environments as network media, using pins as physical connectors to provide network connection, power and physical attachment, with the freedom of being plugged in in any place or orientation.

Technologically, it consists of three main components: a multi-layered network medium to be realized as large surface, pushpin-like physical connectors for objects to allow socket-less attachment to the surface, and embedded network adapter technology required for objects to become Pin&Play-enabled. The Pin&Play-enabled objects may be augmented objects that people would normally attach to vertical surfaces, or objects that succeed today's mundane and ubiquitous connectors and fasteners.

The use of off-the-shelf components and the MicroLAN network protocol result in robust and small prototypes that are cheap, easy to (re)produce and yet more than powerful enough for the applications we envision. The network can handle hundreds of devices in a small (though two dimensional) space, which is especially attractive in the augmentation of small and mobile appliances.

We demonstrated feasibility of the concept by augmenting both a conventional corkboard and pushpins with computing and networking capabilities, using the MicroLAN network standard and compatible objects. The pushpins are capable of alerting users when the note they attach is expired and they can resolve amongst each other who has the highest priority to actually signal the user first. Both pushpin and board are cheap and easy to construct, as it is founded on established off-the-shelf network technology components. Furthermore, wall-mounted switches and lights were implemented as an indication of typical examples for the Pin&Play concept. Future goals of the project will encompass the implementation of more such examples.

The main strength of Pin&Play is that it relates to the fact that people use surfaces such as walls and boards to design their personal and shared areas, to spatially arrange artefacts, and to organise information. It combines the embedding of information technology in the fabric of everyday life with user-friendliness through the use of familiar concepts.

Acknowledgements

The Pin&Play assessment project is funded by the European Commission's IST (contract code IST-2001-37007), and is a collaboration between Viktoria Institute (Sweden) and Lancaster University (UK). Kristof Van Laerhoven is furthermore funded by the Equator IRC, supported by EPSRC.

References

1. Dallas MicroLAN http://www.dalsemi.com/
2. “Dallas Reference Manual MicroLAN Starter Kit” http://www.dalsemi.com/
3. Lifton, J., Paradiso, J. http://www.media.mit.edu/resenv/PushPin/ and http://www.media.mit.edu/~lifton/thesis/
4. Wrensch, T., Blauvelt, G. and Eisenberg, M. "The Rototack: Designing a Computationally-Enhanced Craft Item." In Proceedings of DARE 2000, Designing Augmented Reality Environments, Elsinore, Denmark, April 2000.
5. Scott, F. Hoffmann, G. Mapp, M. Addlesee, A. Hopper. Networked Surfaces: A New Concept in Mobile Networking. In Proc. of WMCSA 2000, December 2000, Monterey, California, IEEE Press.
6. “Time-in-a-Can”, DS1994 4-Kbit Plus Time Memory iButton datasheet. http://pdfserv.maxim-ic.com/arpdf/DS1992-DS1994.pdf
7. Shieldex Conductive woven sheets: http://www.shieldex.com
8. K. Van Laerhoven, A. Schmidt and H.-W. Gellersen. "Pin&Play: Networking Objects through Pins". In Proceedings of Ubicomp 2002, G. Boriello and L.E. Holmquist (Eds). Lecture Notes in Computer Science; Vol. 2498, ISBN 3-540-44267-7; Springer Verlag, Göteborg, Sweden. September 2002, pp.219 - 229.
9. K. Van Laerhoven, N. Villar, M. Håkansson, and H.-W. Gellersen. "Pin & Play: Bringing Power and Networking to Wall-Mounted Appliances". In Proceedings of the 5th IEE International Workshop on Networked Appliances, Liverpool, UK. 2002.
10. Weiser, M. “Some Computer Science Problems in Ubiquitous Computing”. In Communications of the ACM, July 1993.
11. the Disappearing Computer: http://www.dissappearing-computer.net/
12. Technical Brief: 1-Wire Net Design Guide: http://www.maxim-ic.com/1st_pages/tb1.htm