Physical Computing

Using everyday objects as Communication tools

Panagis Papadimatos

The Bartlett School of Graduate Studies
University College London

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Abstract

Physical Computing is a new research field in which our world of everyday objects and places becomes infused and augmented with information processing and exchange. The advocates of this notion demonstrate that physical objects have a sensory richness of meaning that screen-based elements do not. When we see, hear and feel real-world objects we are enabled to train both cognitive and perceptual skills in combination. Such objects can help us create interfaces that are easier and more fun to use.

In this paper I clarify the notion of Physical Computing in relation to previous paradigms in order to investigate the sequence of the evolution that lead this development. After outlining the criteria I believe are essential for such a system and building an experimental prototype that combines these criteria, I explore if indeed the people's experience by those artefacts is coherent and engaging.

These experiments suggest that Physical Computing applications have a great impact not only on people but also on the surrounding space. Malcolm McCullough's concept of how these systems are overlapping with architecture provides a useful framework for interpreting these results.

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1 Introduction

The human-computer interaction is a relatively recent phenomenon. Back in the 70s when computer hardware was terribly expensive, all programming efforts went towards optimizing the use of limited computation, and the few specialists were sufficiently motivated to learn tedious but machine-efficient operations. As hardware became more powerful and less expensive (which it continues to do at an astonishing rate) designs could evolve away from convenience for computers towards convenience for people. When the technology became practical for casual work by versatile people who demanded and could suggest still more intuitive methods, interaction design emerged as a substantive discipline. [McCullough, 1996 – p.115]

Fig. 1 Apple II, advert. from 1975 [source: www.1000bit.net/ adverts.asp]

Steve Jobs, when he founded Apple Computer, set out to build “computers for the rest of us”. The idea was to enable people who were not computer experts – like artists, educators and children – to take advantage of the power of computing. The graphical user interface (GUI) popularized by Apple was widely successful, widely copied, and is now the standard interface of almost all personal computers. Thanks to this interface, people from all walks of life use computers.

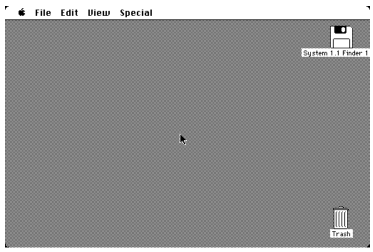

Fig. 2 The Mac OS System 1.1 Graphical User Interface [source: http://www.guidebookgallery.org]

Parallel to the GUI development, computers expanded their roles from business automation into personal communication and visual arts, and as the internet connected so many of us into an extraordinary ecology of “voices” the notion of virtual space was created. On the one hand the Net eliminated the traditional dimension of civic legibility, you cannot say where it is or describe its shape [Mitchell, 1995 – p.10] and on the other hand the architectural space as we knew it from physical environments was supplemented by the virtual space. [Schmitt, 1999 – p.67]. A common critique of that new development was that personal relations would suffer with the emergence of the information age, but contrary to that view the information infrastructure was more an improvement for the physical infrastructure than a threat. It actually helps us to stay in touch with our distant friends or enable us to pay our bills without leaving our houses.

Since the early 2000s a new design challenge appears to be in play. Interface design has become interaction design, and interaction design has come into alliance with architecture [McCullough, 2004]. New terms have emerged like “ubiquity”, “pervasive”, “tangible”, “spatial or physical computing”. All the above new trends share the same notion; “Now that computation’s denial of physicality has gone as far as it can, it is time for the reclamation of space as a computation medium” [Greenwold, 2003 – p.8]. All these variety of terms have been used to encompass different activities being carried out, but in order to avoid any confusion I will use the term “Physical Computing” as an umbrella term.

Simon Greenwold [2003] defines physical computing as human interaction with a machine in which the machine retains and manipulates referents to real objects and spaces. The advocates of this notion demonstrate that physical objects have a sensory richness of meaning that screen-based elements do not. When we see, hear and feel real-world objects we are enabled to train both cognitive and perceptual skills in combination. Such objects can help us create interfaces that are easier, more beautiful and more fun to use [Øritsland et al, 2000].

Taking into consideration the fact that previous paradigms of cyberspace threatened to degrade the physical infrastructure [Schmitt, 1999], by moving the play into the virtual realm, physical computing suggests a defense of our physical world. Malcolm McCullough [2004] believes that architects and those in related disciplines of the physical environment need to become aware of the challenges and opportunities raised by this new state. They need to understand where technology is going and what it has to do with architecture.

1.1 Research objectives

As we witness this paradigm shift from the machine space into the physical space, physical computing emerges and integrates with our surroundings. Initial objective of this dissertation is to investigate the sequence of this evolution. I believe that there is a clear step by step development from the Virtual Reality to Mixed Reality and finally to Physical Computing. This development followed not only the evolution of computers but also the evolution of the way we perceive computation in relation to space.
After clarifying the notion of physical computing the aim of this paper is to present the results of an experimental prototype, in this case a table lamp. After some modifications applied to its circuit in order to embed some sort of computation it is tested as an alternative way of communication. The Purpose of this experiment is to demonstrate the power of embodiment that Physical Computing provides.

1.2 Overview

This paper is organized into four parts.

The first part identifies and clarifies the features of Physical Computing
The second part presents related work that inspired this project
The third part gives a thorough description of my prototype along with the findings of my experiments.
And the fourth part evaluates the findings of my results and gives also some views of future development.

2 Framework

In this chapter I will present the framework of Physical Computing. I believe that there is a clear step by step development from Virtual Reality to Mixed Reality and finally to Physical Computing. Under no circumstances do I want to imply that physical computing is the ultimate solution to every need. Even though it is more tempting due to the fact that it is more attached to our physicality, it doesn't mean that all the previous notions have ceased to serve their purpose. It is just that Physical Computing presents itself as another option.

Fig. 3 *A Virtual Reality Head Mounted Display[Source:http://www.vr.ucl.ac.uk/img/headset.jpg]*

2.1 The abandoned "virtuality"

Since the 90s the use of computers for architectural applications follows a number of main lines; Virtual Reality[1] (VR) represents one development, which for a number of reasons, has continued to be of academic rather than practical interest [Penn et al, 2004]. One of the main reasons is that VR applications are based on immersive equipment, and due to their cost are affordable only to specific institutions. But even with the best equipment the problematic depiction of reality never ceased to be a drawback; even by using the most advanced rendering methods the final outcome (with few exceptions) is rather naïve simply because the unreality of virtual spaces is their over perfection. It's true, however that VR still serves psychological experiments and simulations and general applications investigating non-aesthetic factors very well.

Fig. 4 *A Virtual Reality CAVE (Cave Automatic Virtual Environment)* *[source:http://www_ivri.me.uic.edu/ivrI/contamination/vr.JPG]*

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*[1] **Virtual reality** (abbreviated **VR**) describes an environment that is simulated by a computer. Most virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced and experimental systems have included limited tactile feedback.*
Users can often interactively manipulate a VR environment, either through standard input devices like a keyboard, or through specially designed devices like a cyberglove. The simulated environment can be similar to the real world—for example, in simulations for pilot or combat training—or it can differ significantly from reality, as in VR games.In practice, it is very difficult to create a convincing virtual reality experience, due largely to technical limitations on processing power and image resolution. [source: Wikipedia http://en.wikipedia.org/wiki/Virtual_reality]

The above reasons made the luminous digital worlds displayed in CAVEs (Cave Automatic Virtual Environments) and Head Mounted Displays lose their appeal and that is why during the 90s there was a growing interest in techniques for combining real with virtual environments to create “Mixed Realities” – spatial environments where the participant can interact with physical and digital information in an integrated way [Milgram, 1994].

Fig. 5 See through head mounted display. [source:http://www.columbia.edu/cu/gsapp/BT RESEARCH/VR-CONST/vr-gear.jpg]

A whole new family of terms came into play, such as *Augmented Reality* and T*angible Bits*.
Augmented Reality involves overlaying and registering digital information (e.g. text and graphics) onto a real world scene in such a way that the digital information appears to be attached to physical objects, even as they move about. The physical scene might be the local environment, with the digital information being introduced via a see-through head mounted display. Alternatively, it might be remote, being viewed on a video display that is then enhanced with digital information.

Fig. 6 *ARTHUR, An Augmented Reality Application. [source:http://idwonline.de/pages/de/newsimage16073.jpg]*

The approach of Tangible Bits [Ishii, 1997] involves the use of graspable physical objects called *phicons*[2] interacting with digital information, for example moving physical models across a table top in order to access a digital map that is projected onto it.

A number of claims have been made about the benefits of these different kinds of Mixed Realities including enriching the user experience, enhancing learning and improving collaborative working and planning. However one main thesis that has been proposed is that manipulating familiar physical artefacts (e.g. toy bricks) or acting in physical spaces, when interacting with digital information, provides greater embodiment for the user compared with interacting with more abstract representations [Dourish, 2001]. In other words the kinds of interactions experienced in Mixed Reality environments fit more

Fig. 7 A Tangible Bits Application with the use of phicons [source: http://tangible.media . mit.edu/projects/tangibleviewpoints/]

2 **The word phicon is a portmanteau based on physical and icon.**

naturally with the way we interact with the physical world, especially when they take advantage of our well-learned repertoire of physical actions (e.g. grasping, pushing, and lifting) [Rogers et al, 2002].

2.2 The Fourth Machine Age

Kaj Grønback and Peter Krogh [2001] from the Centre of Pervasive Computing (CfPC) in Denmark are trying to identify the elements of the new state; they refer to the article “The End of the Mechanical Age” by Ezio Manzini. Manzini argues that the premise of mechanization has come to an end, and that is because it is no longer adequate to simplify and clarify complex phenomena, especially if in such systems the observer is always regarded as external to the system observed. The article concludes with the idea that we are no longer confronted with a given taxonomy of materials and techniques, but with a continuum of possibilities. Grønback and Krogh focus on this continuum that has triggered a significant increase of the integration of physical artefacts with computation. And even though “Mixed Reality” is usually used to describe such cases they prefer notions like “pervasive” and “ubiquitous”[Weiser,1993], because such notions are better for describing what is actually happening. “The notion of MR is an abstract idea of what information technologies enhancement of physical objects does to our perception of reality”.

Following their argument they relate Ezio Manzini’s article to Reyner Banham’s [1960] “Theory and Design in the first Machine Age”. They assume that we are on the border of the fourth machine age. The first machine age was characterized by large and heroic machines like cars, airplanes and heavy industry. The second utilized the mechanics of the first to invent small and pervasive mechanics like the refrigerator, the vacuum cleaner and other household machines. The third machine age is characterized by the emergence of the computer originally designed for specialized use in work settings. Today the

computer seems to be utilized as to what happened to mechanics in the second machine age, they become ordinary and penetrate into every object of our daily lives.
They present as an example the “furby” toy, a cute small teddy stuffed with sensors. Simple Artificial Intelligence (AI) software enables the furby to learn up to 1000 English words and sentences. It is also capable of mediating a sort of feelings in response to a hug or a tickle. With the appearance of the furby, independent web sites emerged informing how to hack it and extend it with new software. By this example Grønback & Krogh demonstrate that the cultural and the aesthetic premises of design has changed especially when objects of design can no longer be regarded as solitary entities but as artefacts which are comprised with activities mediated by networks and direct human manipulation.

Fig. 8 A “Furby toy [source:http://xenia.media.mit.edu/~kelly/Furby/anatomy/THE_FURBY_HQ.htm]

Although Grønback & Krogh prefer the notion pervasive in my opinion they are talking more about Physical Computing. Their argument is about the utilized computer that penetrates into everyday objects. Talking about the “furby” they refer to an autonomous physical artefact that can be extended with new software. It’s about computation that moves beyond the traditional confines of the desk and attempts to incorporate itself into our experience of the physical world.

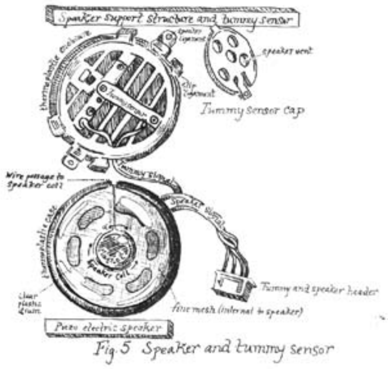

Fig. 9 Furby’s speaker and tummy sensor [source: ibid]

At this point I would like to underline the difference between Physical Computing and Mixed Reality. By definition MR is about the integration of digital information onto a real world scene in such a way that digital information appears to be attached to physical objects. If one wants to experience an MR application, he/she must use either a see-through head display or a video display in order to achieve this integration of the real with the physical.
Physical Computing is about the distribution of computation across tangible physical artefacts that are spread throughout the physical environment. For one to experience a physical computing application

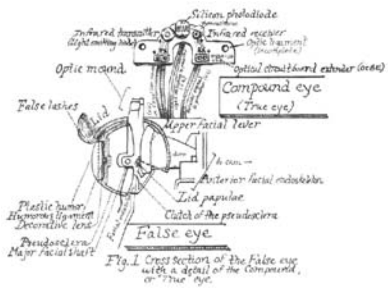

Fig. 10 Cross section of the Furby’s eye [source: ibid]

there is only a need for his/her senses. It’s about computational activity in which we interact with directly. MR might give an integrated view of digital information but Physical Computing gives physical form to it.
So, if we consider that VR needs immersive technology to be displayed and MR needs technology that integrates the digital and the physical, what does physical computing need? The answer to that question is embedded information processing which will be explained in the next section.

2.3 The Embedded Information Processing Revolution

Today less than a quarter of chips produced by Intel, the largest manufacturer, are put into desktop or laptop computer motherboards. The rest are embedded into things that we use, carry, drive or wear. Since 1994, microprocessors have outnumbered humans on the Earth. As of 2002, for each person in the United States, there existed a Microelectromechanical System (MEMS) chip, which is an essential component in physical-digital interfaces. Technology visionary Mark Weiser [1993] defined ubiquitous computing as “hundreds of computers per person”. When the Association for Computing Machinery (ACM), the world’s largest membership organization of information technology researchers, launched a general-readership publication named Ubiquity, and called its plenary conference “After Cyberspace”, the paradigm-shift become more or less official. [McCullough, 2004 – p.5]

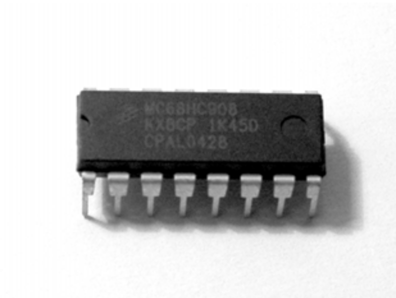

Fig. 11 *A microcontroller [source: http://n1vg.net/opentracker/images/chip-large.jpg]*

Steve Sanghi [1996] the president of Microchip Technology Inc. mentions the embedded information processing revolution and he wants us to keep in mind that embedded means hidden, or buried. The above revolution is hidden inside the products we use every day; such as a car security system that immobilizes a car when an unauthorized entry happens.

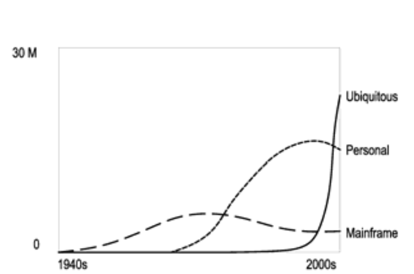

Fig. 12 *Major trends in computing (after Mark Weiser) [source: McCullough,2004]*

Such intelligence can be found in five broad markets. The first is the consumer segment, which includes home appliances and entertainment equipment. The second is automotive, where a modern car has nearly 50 microcontrollers providing intelligence and control, like keyless entry, antilock braking, and air bags. The third market is office automation, which includes PCs, keyboards, copiers and printers. The fourth market is telecommunications, which includes mobile phones, networks and answering machines. And the fifth market encompasses industrial products, such as door locks for hotels and industrial machinery.

The revolution in embedded intelligence is driven by microcontrollers. We use more than 30 times as many microcontrollers each year. Looking at the average western adult we can tell that there is one microprocessor in his laptop but he is using at least 12 to 14 microcontrollers every day. We have one in our mobile phone, watch and calculator. Microcontrollers are in a laptop computer's mouse, keyboard, modem, sound card and battery charger. In our homes we might not find many microprocessors, but there are several microcontrollers in the alarm clocks, thermostats, air conditioners, TV remote, hair dryer, VCR and of course the refrigerator.

There is an explosion in the application of microcontrollers, and they all deliver embedded intelligence. Today, almost any end product, if there is power applied to it, will use a microcontroller. The microprocessor-based information revolution is above the surface and very visible. However, the embedded information processing revolution is much larger and happens beneath the surface. [Sanghi,1996]

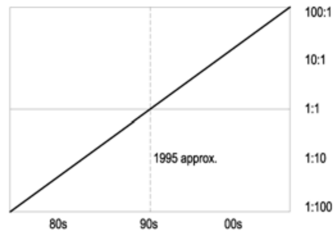

Fig. 13 *Ratio of microchips to humans on Earth [source: ibid]*

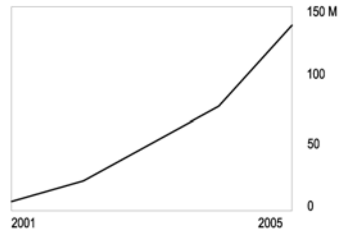

Fig. 14 *Five- year market forecast for number of MEMS chips produced for microelectronics [source: ibid]*

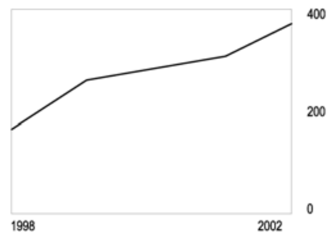

Fig.15 *Five year trend: number of stories in the New York Times including the world "sensors" [source: ibid]*

2.4 The Disappearing Computer

Another fact that needs to be underlined is that contrary to the previous notions, by which I mean VR and MR that actually use the computer as a tool, Physical Computing suggests a new approach.

This new approach takes a thorough look into the Computer itself, and develops a more tight connection with it which works vice-versa.

Hiroshi Ishii [1997] from the Tangible Media Group of the MIT Media Lab claims that the interaction with Graphical User Interfaces (GUI) is separated from the ordinary physical environment within which we live and interact.
Indeed the interaction between people and the machine is now largely confined to traditional GUI – screens based on desks with computers that have evolved in an office environment in which we sit on chairs, move our fingers, entering and receiving information censored by our conscious minds. Physical Computing pours out beyond the screen, into our places, under our laws of physics, embedded in our devices - everywhere. [McCullough, 2004]

Under this trend information technology contexts are no longer valued for immersiveness so much as for "periphery". Interface design experts emphasize the term locus[3] of attention. Unfortunately our attention ability remains finite while the number and complexity of tools continues to increase and to overload our screen's workspace.
In response, most agendas of physical computing share a belief in "periphery". As defined by Mark Weiser and John Seeley Brown [1996], from the open research centre Xerox PARC, "periphery is background that is outside focal attention but which can quickly be given that attention when necessary." This is one way to deal with information overload. Trying to keep too much in the locus of attention tends to be stressful. We find it more natural to use our considerable powers of sensing the surroundings, and then to experience more capacity and resolution where our attention is focused. Thus as Weiser and Brown [1996] have observed, bringing something back from the periphery to the centre of attention is a fundamentally engaging and calming process.

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[3] A centre or focus of great activity or intense concentration [source: http://dictionary.com/]

Physical computing takes this approach beyond the information context to include physical architecture. GUIs have long been built on principles of shifting focus – picking up a tool, opening and closing a window, etc – but they still leave us staring at a cluttered screen. Portable and embedded systems take the information processing into the physical realm, where the capacity for periphery is deeper and the act of bringing things to the centre is more intuitive. Principles of periphery can of course help reduce contention on a screen, but they also suggest a larger shift in our goals for natural interactions. [McCullough, 2004]

As a response to this relatively new research field "The Disappearing Computer" (DC) is one of the most forward looking and experimental research areas of the Fifth Framework Programme (1998-2002), an EU initiative to support research and development in Europe. The Disappearing Computer initiative belongs to the Future and Emerging Technologies (FET) activity of the Fifth Framework's Information Societies Technologies (IST) research programme. It would be very interesting to take a look at the mission of the initiative:

> *"Mission Statement*
> *To see how information technology can be diffused into everyday objects and settings, and to see how this can lead to new ways of supporting and enhancing people's lives that go above and beyond what is possible with the computer today. Specifically, the initiative looks at how to make 'information artefacts' based on new software and hardware architectures that are integrated into everyday objects .It looks at how collections of artefacts can act together, so as to produce new behaviour and new functionality. It investigates the new approaches for designing for collections of artefacts in everyday settings, and how to ensure that people's experience in these new environments is coherent and engaging."*

[http://www.disappearing-computer.net/mission.html]accessed July 05

***Fig. 16** The Disappearing Computer [source: http://www.disappearing-computer.net/]*

The Disappearing Computer initiative has a clear vision of the Future. A vision in which our world of everyday objects and places becomes infused and augmented with information processing and exchange.
In this vision, the technology providing these capabilities is merged with real world objects and places, so that in a sense it disappears into the background.
As a consequence, human-centred notions, such as real objects and everyday settings, can come into foreground, rather than the computer-centric ones which have determined the evolution of the computer-as-we-know it.
Artefacts will be able to adapt and change, not just in a random fashion but based on how people use and interact with them. Together, new functionalities and new forms of use will emerge that will enrich everyday life, resulting in an everyday world that is more 'alive' and 'deeply interconnected' that our current day understanding.

Since 2003 the Disappearing Computer (DC) has passed into its second phase which is Disappearing Computer II. And it continues to fund projects based on the original initiative throughout Europe.

While it is true that some people advocate change based on new possibilities, others actively resist it. Even if the majority accepts new technology, only a minority truly adopts new practices. And we can see this today as far as computer ownership does not guarantee computer literacy. According to McCullough [1996], there is no better example of circumstantial knowledge than the way some people perceive the computer as its input and output devices alone - as if the screen is actually the computer. This is an indication that physical devices are the only tangible elements of the technology.

Physical Computing takes advantage of the above indication and uses it as a tool to engage people. It unites the space and the computer into one entity.

Throughout this chapter I outlined the notion of physical computing in relation to the notions of Virtual Reality and Mixed reality. Subsequently I will present some related work that helped me to identify the features of physical computing in many scales, from the paradigm of the use of the building as a physical background, to the augmentation of everyday objects with new properties and qualities.

3 Related work

We are heading towards new means of presenting visual information; means that demonstrate the embodiment of IT into architectural elements or objects. These realizations explore the probability of context with various levels of abstraction, giving alternative ways for visual communication. In this chapter I will present some examples from various scales, starting from a building’s scale and gradually reducing in scale.

3.1 Ambient Displays

“Four years ago, Frank G. Zarb, chief executive of the NASDAQ stock market's parent company, decided to take the role of visionary leader to a new level: he would commission a Times Square sign so big and bright that it would make all the others blur into the background.”[Blair, 2000]

The result of that endeavour is the eight-story cylindrical sign that wraps around the Condé Nast Building, at Broadway and 43rd Street. The screen wraps 27 metres around the Condé Nast Building and takes up about the same space as three basketball courts. It is 45 centimetres thick and its surface is more than 3,000 square metres. From a control room in the Condé Nast Building, operators and managers run the screen, which displays advertisements and stock information from companies listed on the NASDAQ market — anything from simple text to full-motion movies.

Fig. 17 *The NASDAQ sign [Source: http://www.adventurist.net/trips/nyc_07-2003/gallery--times_square/]*

Beneath the sign's skin are 18 million Light Emitting Diodes[4] (LEDs), attached to minicircuits called pixels. Within each pixel are eight small light-emitting diodes; two blue in the middle with two green and a red on one side and two red and a green on the other (LED Cluster). The flickering lights that they produce are translated by the human brain as true colours and images.

Fig. 18 *LED clusters*
[Source: Electronix Express]

The density of the pixels allows for bright and vivid colours that can be viewed easily in direct sunlight. The LEDs are also less prone to damage from temperature change or blowouts than light bulbs, and are supposed to last 100 times longer — a total of 100,000 hours.

Many people think of large-format displays in terms of the year the NASDAQ sign went up. This outdoor installation demonstrated that besides size, another factor important to ubiquitous display is its ruggedness. A display that can be left out in the rain opens a very different realm for imagination.

3.2 KPN Telecom building

However, the NASDAQ sign has no interactive features; it actually provides a passive one way visual communication. It displays only advertisements and stock information. On the other hand, during the same period, that is 2000, Renzo Piano completed the headquarters of KPN Telecom Corporation in Rotterdam.

Fig. 19 *KPN Telecom Building, Rotterdam [source:http://www.galinsky.com/buildings /kpntelecom/]*

The building is located at the end of the Erasmus Bridge, which is an icon for the city of Rotterdam. It is a relatively tall tower in the Netherlands since most of the country does not have high rises. The

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4 A light-emitting diode (LED) is a semiconductor device that emits incoherent narrow-spectrum light when electrically biased in the forward direction. This effect is a form of electroluminescence. The color of the emitted light depends on the chemical composition of the semiconducting material used, and can be near-ultraviolet, visible or infrared. Nick Holonyak Jr. (born 1928) of the University of Illinois at Urbana-Champaign developed the first practical visible-spectrum LED in 1962. [source; http://en.wikipedia.org/wiki/LED]

building looks as if it is divided into three vertical sections. One section faces the rest of the pier while another faces the city, sandwiching a skinny section in the middle. The one facing the rest of the pier is very simple in design, having a rectangular facade with window openings evenly distributed. The section that faces the city and the Erasmus Bridge is the most interesting portion of the building. The facade is clad with a green curtain wall system that is complemented by green lights distributed evenly over the glass facade. The lights work as a giant billboard and the patterns they create are easiest to see at night time or on an overcast day. These patterns change and move throughout the day.

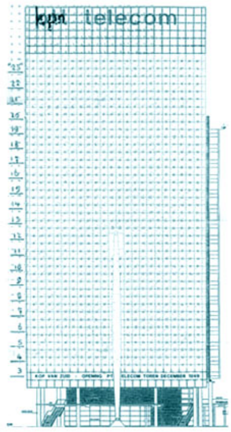

Fig. 20 *KPN Telecom Building, Rotterdam [source:http://greenlightdistrict.initworks.nl/#4]*

The facade is equipped with a monochrome, 2922 square metres screen consisting of 896 square lamps in a 22x41 grid creating a 37.8m x 72m image or animation. Obviously, design possibilities are limited. At the moment the .BMP (Bitmap) file format is used to trigger the screen. This means that in order to display an image, the system needs a black and white bitmapped image of 22x41 pixels. Any black pixel will turn on the corresponding square green osram lamp. Displaying animations requires a 41 pixel high bitmap of which the width depends on the amount of frames: an 18 frame loop results in an 18x22=396 pixel wide image.

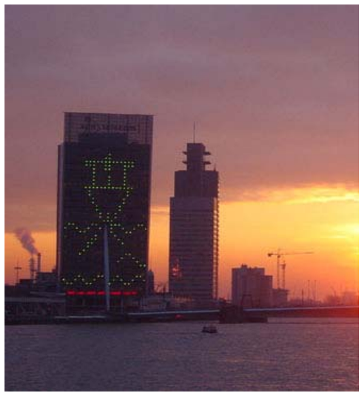

Fig. 21 *KPN Telecom Building, Rotterdam [source:ibid]*

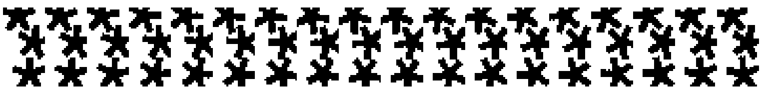

Fig. 22 *An 18 frame bitmap image [source: http://greenlightdistrict.initworks.nl/#start]*

Virtually anyone's design can be part of the skyline in Rotterdam. Through a web site everyone can submit a design for the KPN screen. This screen represents the idea of a two way visual communication. Unlike the NASDAQ screen the KPN screen allows the viewer to be a part of it.

3.3 Levels of abstraction

The KPN screen demonstrates a case of displaying context with limited detail capacities; if we consider that the NASDAQ sign has 18 million pixels the KPN has only 902. However, this fact detracts nothing from its impact on the landscape of Rotterdam [Schieck, 2005]. Exploring this case and focusing on the emotional impact from limited levels of information I would like to present the work of the artist Jim Campbell.

Jim Campbell's "Ambiguous Icons" were one of the standouts in the Whitney Museum's "Bitstreams" exhibition. These pieces rendered videos of walking human figures on a grid of LED lights. Campbell records his subjects in digital video, converting live action to millions of pixels. Then he reduces the number of pixels and uses them to drive the LED grid so that each LED fades and flashes in various luminosities.

By this method the artist succeeds in transferring the reduced figures to a dynamic shadow in a field of glowing red dots. "Ambiguous Icons draw their strength from the tension between an abstract surface and the recognizable image this surface implies, literally bringing questions of representation to light." [Kurtz, 2002]

The force of these human silhouettes emerges once the viewers decipher the image. The rendered shadows are rendered barely within the limits of our perception, based on our innate ability to perceive human movement.

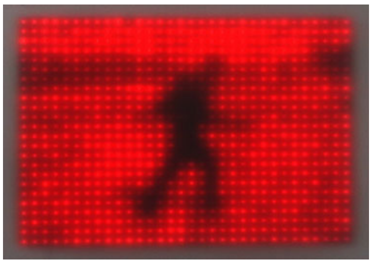

Fig. 23 *Ambiguous Icon #5 (Running, Falling), 2000*
Custom electronics, 768 LEDs, 28" x 22"
[source: http://www.jimcampbell.tv/]

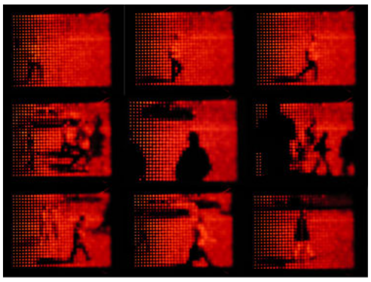

Fig. 24 *Ambiguous Icons*
Church On Fifth Avenue, 2001
Custom electronics
[source:ibid]

3.4 Hotpants/LittleVision device

The next example, partially inspired by the work of Jim Campbell, is a device made by Simon Greenwold [2003]. Hotpants/LittleVision is a standalone pocket device for the recording and showing of short video

Fig. 25 *Hotpants/LittleVision*
[source: Greenwold,2003]

segments, it consists of a simple circuit which uses a PIC[5] microcontroller to drive a matrix of 10X14 red LEDs. These LEDs can be set to display at full brightness, half, or off. The board exposes a set of programming pins, which are used to connect the board to a PC for the downloading of new frames. The board stores about 300 frames and plays them back at 12 per second, for a total of 25 seconds of video that loops. A second board with a camera can alternatively be attached to the LittleVision, which can be used to record movies directly to the device without the use of a PC.

Fig. 26 *A workshop participant and his Hotpants [source: ibid]*

Greenwold, as a member of a team that helped teach an undergraduate class in microcontroller design in the MIT Media Lab, had the opportunity to run several workshops in which participants build their boards the first day and make movies the second day.
The resolution capacity of the above device is very limited indeed, and complex scenes are not recognizable. However, according to the developer the participants grew an instant connection with the scenes they were filming.

“it was a very different experience that it would have been to see themselves on a television screen, or even on the LCD panel of a handheld video camera” [Greenwold,2003 – p.78].

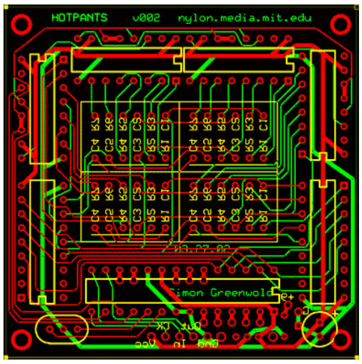

Fig. 27 *The Hotpants circuit [source: ibid]*

On his evaluation Greenwold believes, and so do I, that the power of the device is its physicality. It is a tangible entity to be handled and manipulated. Because each pixel is visible, it is impossible for one to forget its physicality and focus only on the image surface.

[5] PIC, is a family of «Reduced Instruction Set Computing» microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by *General Instrument's* Microelectronics Division. It is generally regarded that PIC stands for Peripheral Interface Controller, although General Instruments' original acronym for the PIC1650 was "Programmable Intelligent Computer". [source: Wikipedia]

3.5 Web are you?

"Web are you?" is a networked emoticon[6] device by Mauricio Melo [2005]. You log onto it through the Internet and let your significant other at home know if something at work or at school has made you happy, sad, upset, etc.

Ideally there are two devices even though it can work even if there is only one. The one can be plugged to your home network, somewhere that can be seen by any of the family members. The other can be set at your office and be plugged to the office LAN[7]. At any given time during the day, if any of the device's icons are pressed the device will reflect your current mood state sharing it with your significant other or a family member. If there is only one home device, it can be accessed through a regular webpage or cell phone.

The devices are connected to the Internet through an Xport controlled by a Microchip that handles the basic communications. A series of switches reciprocally activate four LEDs that light the transparent emoticons. Either device is accessible on the web through its proprietary IP[8] address.

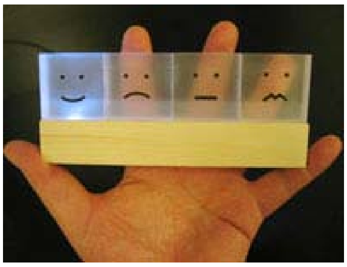

Fig. 28 Web are you? [source:http://www.mauriciomelo.com/contents/interact05.htm]

Fig. 29 Web are you? [source: ibid]

According to Mauricio Melo [2005], some times we would like to know how our partner is doing during the day and vice versa, especially if we spend most of our day at our workspace. The main

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6 An emoticon, also called a smiley, is a sequence of printable characters such as :), or :(or a small image that is intended to represent a human facial expression and convey an emotion. Emoticons are a form of paralanguage commonly used in email messages, in online bulletin boards, or in chat rooms. The word emoticon is a portmanteau based on emotion and icon. [source:Wikipedia]

7 A Local Area Network (LAN) is a computer network covering a local area, like a home, office or small group of buildings such as a college. [source::ibid]

8 An IP address (Internet Protocol address) is a unique number, similar in concept to a telephone number, used by machines (usually computers) to refer to each other when sending information through the Internet. This allows machines passing the information onwards on behalf of the sender to know where to send it next, and for the machine receiving the information to know that it is the intended destination.[source:ibid]

idea is to use a communication channel that doesn't require an immediate response from the other part. Web are you? Is more of a company or presence; communication is there but in a very subtle way. It's a reminder once in a while during the day of each other's mood state. Like a snapshot that shows a smiling or frowning family member.

3.6 Hypothesis

Following the investigation of the systems described in the above section, I have outlined the criteria I believe are necessary for physical systems. Even though I presented examples from various scales I want to underline the essence of these examples.

Physical Properties
A device that is rugged enough so that it can be handled and manipulated by the user without the possibility of ruining it. Having also the size and the materials that emphasize its physical / tangible entity.

Function
A device that creates a conversation between the physical world and the digital world of the computer. That works as a transducer or a converter of one form of energy into another, by which I mean the electrical energy of the computer into the physical energy of a tangible device.

Communication - Emotion
A device that enables users to pass a message or an emotion to others. I strongly believe that the emotional factor is essential for intelligent machines. Donald A. Norman [2004] adds that the objects in our lives are more than mere material possessions. A favourite object actually is a symbol, setting up a positive frame in our minds, a reminder of a pleasant memory, or an expression of one's self. There is something

that ties us personally to such objects and that is the emotion that they convey to our minds.
Jim Campbell, an expert in conveying emotions though physical installations, has answered that the real interactivity that takes place in “interactive” works is between the viewer and himself and not between the viewer and the object. [Whittaker, 1998]. So in order for an interactive device to be successful it must stimulate the user’s mind, in order for his/her mind to build a mental representation of an emotion, a memory or an actual person.

Based on the criteria that were covered the following hypothesis was formulated.
Combining the features of KPN to display and transmit simple visual messages together with Hotpants/LittleVision idea of tangibility and finally with Web are you? feature to create emotional attachments within distant spaces. I intent to build a physical system that would combine the above factors. I believe that such a system would have an impact on its viewers and that it would suggest a way of enriching their surrounding space together with giving them the option to communicate if they feel like it. Such an experience with this kind of device would be beneficial and enriching for its users.

4 HackHAL the prototype

This section describes the prototype I built to investigate the principles outlined in the previous section. The objective of this system was to explore the idea that users of physical computing objects develop an emotional attachment to such objects.

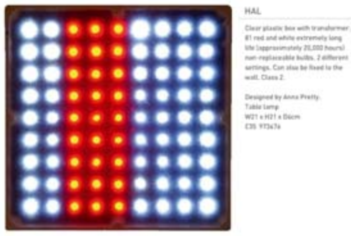

Fig. 30*: HAL Table Lamp as displayed in Habitat's web site [http://www.habitat.net]*

4.1 HAL Table Lamp

The idea for this project came unexpectedly while browsing in the home ware store "Habitat". The HAL Table Lamp originally designed by Anna Pretty, was the starting point of the project. It is a clear plastic square box that consists of a 9X9 array of 81 red and white LEDs. HAL has 2 different settings. In the first setting all the LEDs are lit and in the second, three different groups of equal in number LEDs, progress sequentially. Although there is not any trace of intelligence in the sequential setting, HAL gives the impression that progress randomly. The viewer needs to observe for at least a couple of minutes to realize that what gives that impression of "randomness" is just a sequence of just three sets of LEDs.

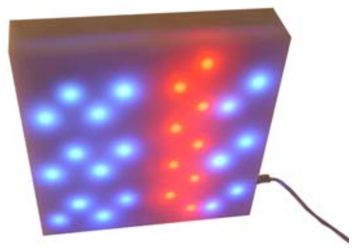

Fig. 31*: HAL in action*

The observation of such a lighting device raised the issue of what potential such an apparatus could have if one was able to manipulate the function of each LED individually. Such realization was motivating and lead to the investigation of the Physical Computing sector. The next stage was to obtain a HAL Table Lamp and decompose it in order to investigate the ways that one could control such a device

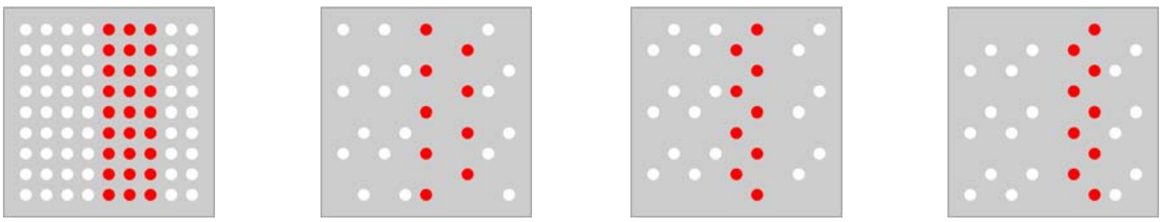

Fig. 33 *The two setting of HAL,(from right to left) when all LEDs are lit, and when the three different sets progress sequentially.*

Contrary to expectations for a microcontroller, the dismantling of the device revealed a simple switch that could only dim between three states. At that stage, the challenge was to produce a prototype that would offer the opportunity to an average PC user to handle.

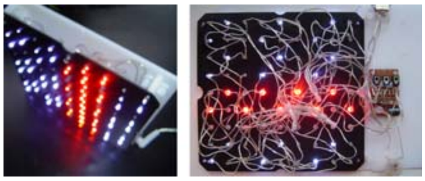

Fig. 34 *HAL autopsy*

4.2 The storyboard

From the initial stages of my quest, I tried to set some restrictions on the possible uses of my system. In the best case I would be able to drive a LED matrix that would have an infinite, or at least wide, range of capabilities. Design seldom benefits from infinite possibilities and it is more likely to be beneficial and appreciated when its variations occur on a few appropriate themes.
A specific application would also be useful for the evaluation and the testing of the prototype.

The next stage was to draw a storyboard that would clarify and display the concept of the prototype and present a scenario for its application based on it. Based on the criteria that I have outlined from the previous chapter, I had to work with a tangible, rugged device that would work as a transducer or a converter of the electrical energy of the computer into the physical energy of a device, which would also be used to pass a message or an emotion to others.

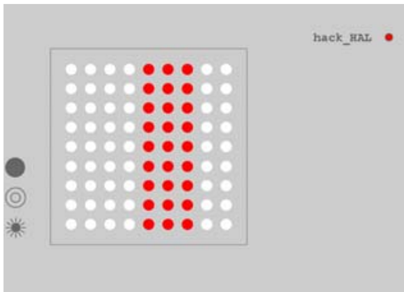

Fig. 35 *Storyboard scene 1*
Hal in its original state

The working scenario for HackHAL is that one is able to control it through his/her PC and upload to it any program he/she wants in order to transit his/her emotional state in any place at any time providing that there is a second device that can receive such messages of mood variations. Such a scenario contains all the criteria the thesis intends to investigate for a physical computing project. The choice of an already existing end-product as a starting point allows the exclusion of any aesthetic issues because it takes the device as a tested artefact.

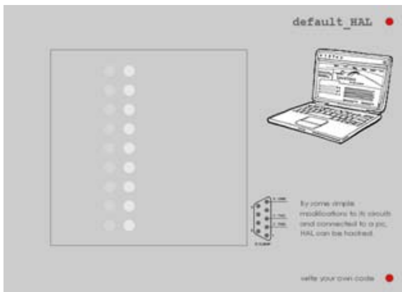

Fig. 36 *Storyboard scene 2*
A PC is connected with HAL and a new program is uploaded

Considering the limited time for the completion of this project, a number of stages had to be identified. The first stage would be to modify HAL in order to have individual access to every LED. The second to connect HAL with a PC through a Serial port and upload to it a new pattern program, and the final stage to use ad-hoc[9] communication in order to be able to send programs to a distant HAL through a network or to connect two HALs together. The division of the stages would ensure that even if I got only to the second stage, I will still be able to test the prototype and get feedback from the users.

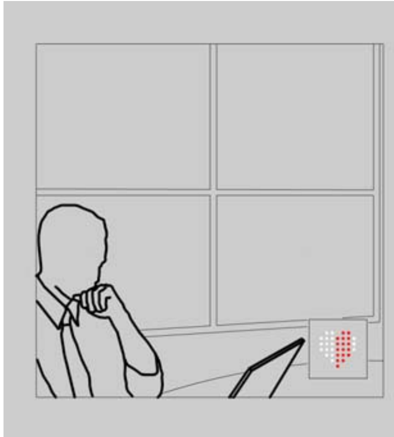

Fig. 37 *Storyboard scene 3*
Hal can be an object of one's ambient environment, the user any time he chooses he can send a message to one having a similar HAL

4.3 Technical Details

I then focused my research on the potential driving system that would allow me to control 81 LEDs. Prototyping with physical computing is not a very easy task; it integrates activities like computer programming, basic electronics and supportive software and hardware tools.
The first thing I had to learn was how to deal with a microcontroller.

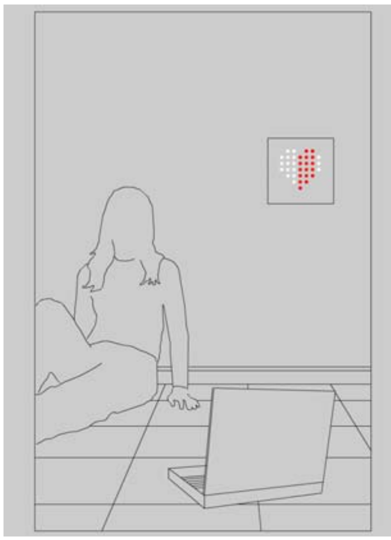

Fig. 38 *Storyboard scene 4*
The message reaches the other HAL

Hernando Barragán [2004] in his thesis "Wiring – Prototyping Physical interaction Design" of the Masters Program in Interaction Design Institute Ivrea, identified and outlined the basic features of a microcontroller.

[9] In computer networking, ad-hoc is a connection method for wireless LANs that requires no base station — devices discover others within range to form a network for those computers. Devices may search for target nodes that are out of range by flooding the network with broadcasts that are forwarded by each node. Connections are possible over multiple nodes (multihop ad-hoc network). Routing protocols then provide stable connections even if nodes are moving around randomly .[source:Wikipedia]

4.3.1 Microcontroller’s basics

A microcontroller is an electronic device with a set of Input and Output pins. These pins may look like real pins, or can just be connectors that allow the microcontroller to be plugged into other devices. You can find microcontrollers that are single units and others that are complete electronic boards with access to the pins through connectors.

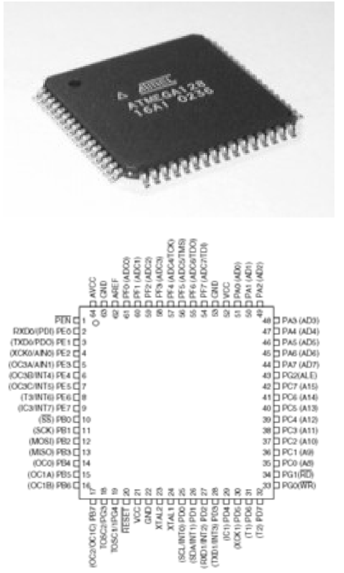

Fig.39 *The AVR atmega 128 Microcontroller from ATMEL and its pin configuration*
[source: http://www.atmel.com/]

4.3.2 Input/ Output – Analogue/ Digital

Depending on the microcontroller, the pins can be inputs or outputs, so they can be used to receive and send signals. These signals can be either digital or analogue. A digital signal is discrete which means that it can have only two possible states, either logical 0 (LOW) or logical 1 (HIGH). These values (HIGH or LOW) are reflected in changes in voltage. So LOW is 0 volts and HIGH is 5 volts. When a continuous range of multiple values is considered then we need analogue signals. Many physical phenomena manifest in this way, like measuring light intensity, temperature, sound. In this case a pin in a microcontroller can be used as an analogue input getting values from a light sensor, or as analogue output dimming a lamp.

4.3.3 Timing and communication abilities.

Microcontrollers also have timing abilities that can be used in different ways to measure time lapses or to trigger time events. Microcontrollers have communication capabilities usually with serial ports, the same kind of serial ports that are available in most computers. In this way they can communicate with other devices using the well known serial protocols. In many cases the serial ports are used for both programming the microcontroller and for communication purposes.

4.3.4 Programming a Microcontroller

Programming a microcontroller is a process with two components. One happens in a PC or host computer, and the other in the microcontroller itself. On the PC there is what is called a programming development environment, which generally includes an editor for the user to type its programs, and include the functionality to compile and generate the necessary files that are understandable by the microcontroller and written to what is known as object binary file. This binary file can be downloaded to the microcontroller and then executed by it. To download the file to the microcontroller, a special setup is needed, usually done through a serial port. Once the program is downloaded to the microcontroller it can be disconnected from the host computer. The program will stay in the microcontroller's memory and will be executed every time the microcontroller is turned on.
The programming languages available to program microcontrollers range from native versions of assemblers, C and BASIC, but there are others that can be programmed in most popular programming languages like Java and Logo.

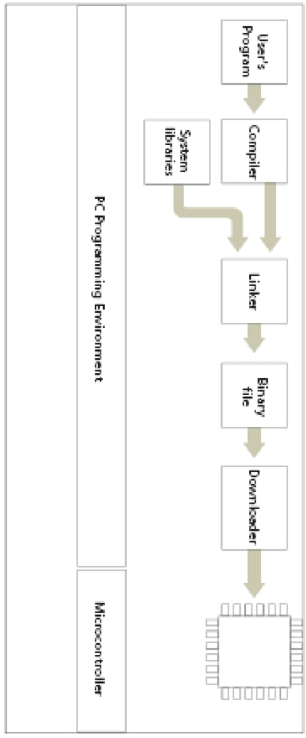

Fig. 40 *Microcontroller's programming process [source: Barragan,2004]*

Nowadays there is a wide range of popular, powerful, and relatively inexpensive microcontrollers available on the market for commercial, educational, hobbyist and entertainment applications.
The microcontroller's functionality varies from basic logic control up to fully functioning computers with wireless internet or network access, Bluetooth, GPS capabilities and more complex systems. Many companies like Motorola, Microchip, Parallax, Texas Instruments, Rabbit Semiconductors, and ATMEL etc. have a vast selection of programmable devices. [Barragán, 2004]

4.3.5 Available Kits

There are many companies that have targeted their products to intermediate's and beginner's lever users. They have developed educational material as well as support.

My initial choice was the Parallax BasicStamp, which is a very popular microcontroller. There is a vast source of information, code, examples, experiments, support, user groups and material available. It is sold as part of a basic kit for beginners or as a stand alone product for advanced users. The kit includes a board, microcontrollers, compiler and a companion book to develop experiments. BasicStamp is programmed in variations of the BASIC programming language which nowadays is not widely used. The most persistent drawback of the BasicStamp that actually made me reject it, is the fact that it has only 22 usable pins. 22 pins would not be sufficient to drive an 81 LED matrix, and an additional circuit similar to the one that Simon Greenwold used for the Hotpants/LittleVision would have to be manufactured. Greenwold had the same problem which he managed to solve by the use of shift registers. Shift registers turn serial outputs parallel by piping clocked values to their output pins on a specific signal. With the addition of 4 shift registers Greenwold got 32 extra outputs controlled by 3 pins on the microcontroller (data, clock, and value). Building an additional circuit for this project would be time consuming, so another microcontroller kit with more output pins was selected.

Fig. 41 Parallax BasicStamp BS2sx as a starter kit - Includes BS2SX-IC, Board of Education programming board, Serial Cable, BASIC Stamp Manual v2.0, and cd-rom.
[source: http://www.parallax.com/]

Fig. 42 Parallax BasicStamp2 as a stand alone product [source: ibid]

4.4 The Wiring software

Wiring is an open project initiated by Hernando Barragán (University of Los Andes | Architecture and Design School). Wiring started at the Interaction Design Institute Ivrea and it is currently developed at the University of Los Andes

Wiring is a programming environment and electronics I/O board for exploring the electronic arts, tangible media, teaching and learning computer programming and prototyping with electronics. It illustrates the concept of programming with electronics and the physical realm of hardware control which are necessary to explore physical interaction design and tangible media aspects [Barragán, 2005].

Fig. 43 The Wiring environment

The Wiring software is currently in a pre-released stage, and it is free for everybody to download and test. The pre-released stage is under development and unfortunately has a number of bugs. However, the web site provides a discourse section where everybody is free to post any question or problem about Wiring.

4.4.1 Wiring / Processing

Wiring builds on Processing, an open project initiated by Ben Fry (Broad Institute) and Casey Reas (UCLA Design | Media Arts). Processing evolved from ideas explored in the Aesthetics and Computation Group at the MIT Media Lab.

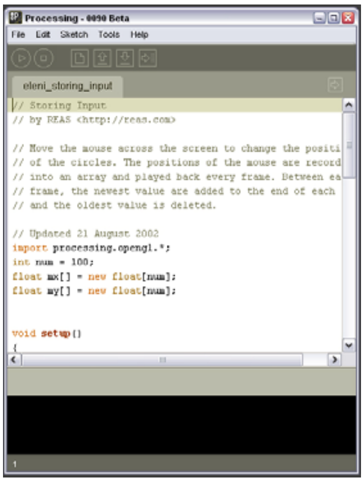

Fig. 44 The Processing environment

Processing is an open source programming language and environment for people who want to program images, animation, and sound. It is used by students, artists, designers, architects, researchers, and hobbyists for learning, prototyping, and production. It is created to teach fundamentals of computer programming within a visual context and to serve as a software sketchbook and professional production tool. Processing is developed by artists and designers as an alternative to commercial software tools in the same domain. [Fry and Reas, 2005]

The Processing environment is written in Java. Programs written in Processing are also translated to Java and then run as Java programs. Programs written in Java and Processing usually run faster than programs based on scripting languages like ActionScript and Lingo, which is important for many graphics applications.

Large distinctions between Processing and Java are the Processing graphics library and a simplified programming style that doesn't require users to understand more advanced concepts like classes, objects, or animation and double-buffering (while still making them accessible for advanced users). Such technical details must be specifically programmed in Java, but are integrated into Processing, making programs shorter and easier to read.

With Processing there is a large worldwide community of artists, designers and programmers, as well a group of educators, using Processing in their teaching curriculums in art and design schools. A large number of workshops that have been taught around the globe together with the collected feedback for the Application Programming Interface (API), are allowing the development team to refine the software by releasing better versions.
Hernando Barragán builds on this work and attempts by linking Wiring with Processing to extend this experience to hardware programming and prototyping with electronics.

4.4.2 The Wiring I/O Board

The Wiring electronics I/O board is based on the Atmel AVR atmega 128, which is a powerful and cost effective microcontroller. The board has 40 Digital pins that can be configured as Inputs/Outputs from the Wiring language in the Wiring programming environment.
Some other features of the board are:

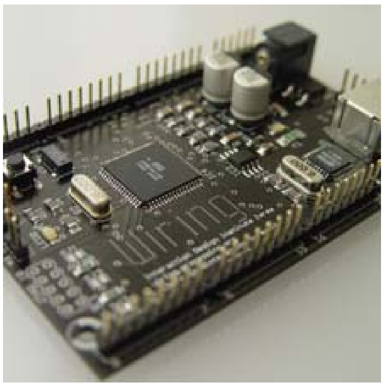

Fig. 45 The Wiring I/O Board [source: http://wiring.org.co]

8 Analogue Inputs capable of reading voltages between 0-5V. These inputs can be used to measure continuous quantities like light intensity, temperature, position etc.

6 Analogue Outputs (PWM), which can switch something ON and OFF thousands of times per second, allowing effects like dimming a light or control the speed of a motor.

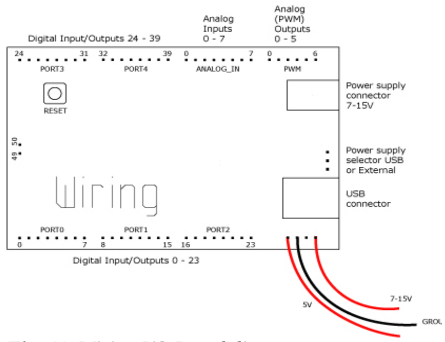

Fig. 46 Wiring I/O Board diagram [source: ibid]

And 2 hardware serial ports. One of them is used to communicate to the computer via the USB. It also provides ISP[10] and i2c[11] Interfaces, so it's possible to connect i2c sensors which are becoming very popular or create a network of devices. [Barragán, 2005]

The fact that the Wiring I/O board has 40 Digital pins was essential. With these pins I could at least drive a 6x6 LED matrix without the use of any additional circuit. The next step was to start dealing with electronics.

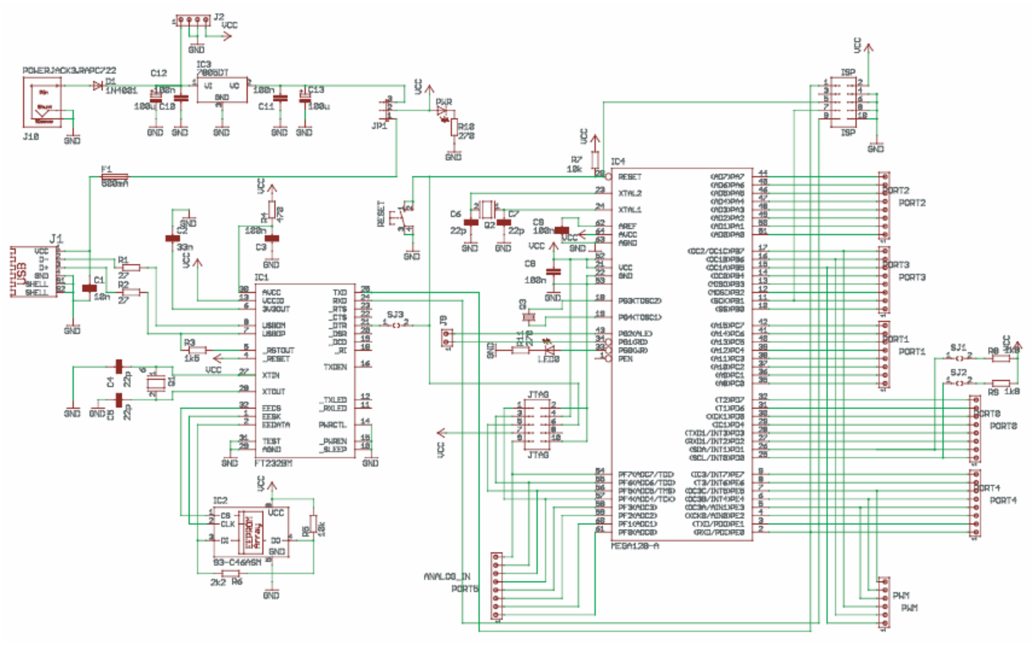

***Fig. 47** Wiring I/O Board circuit schematics [source: ibid]*

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10 In-System Programming, a way to configure programmable logic devices while they are installed in a larger system [sourse: Wikipedia].

11 I²C (for Inter-Integrated Circuit, pronounced I-squared-C) is a serial computer bus invented by Philips. The original system was created in the early 1980s as a simple internal bus system for building control electronics with various Philips chips. Today it is used to connect low-speed peripherals in an embedded system or motherboard. [sourse: ibid].

4.5 Building the prototype

HAL consists of two parts: the cell and the inner part. Both parts are made from a white semi transparent plastic surface, which provides an interesting diffused effect when the LEDs, attached to the inner part, are lit.

Although the initial intention was to modify the existing circuit, the fact that I had to work with 40 Digital pins forced me to rebuild the inner part of the lamp. I had to evenly distribute 36 LEDs in a 6x6 array.

In other words, every LED would form a circuit that would be connected to the Wiring board, which would be programmed to connect and disconnect each LED circuit’s power. LED must have a resistor in series to limit the current to a safe value, if not they are destroyed almost instantly because too much current passes through and burns them out. In order for one to calculate the value of resistance he must refer to the *Ohm’s Law.* According to that law, Resistance = Voltage / Current.

Finally the components used are 5volts 3mm Super Bright Red LEDs with 330 Ohms Resistors.

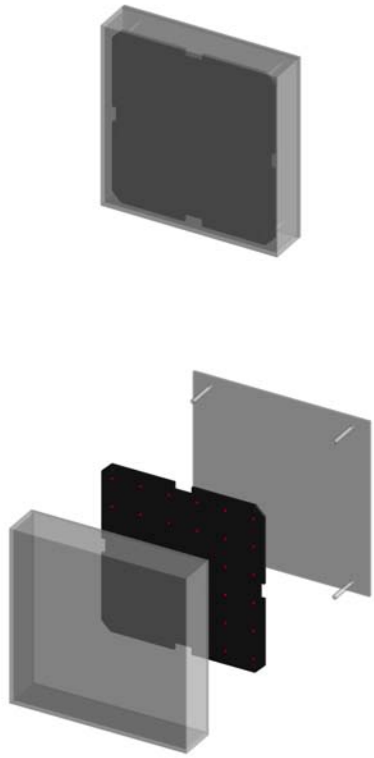

Fig. 48 HAL assembled and disassembled

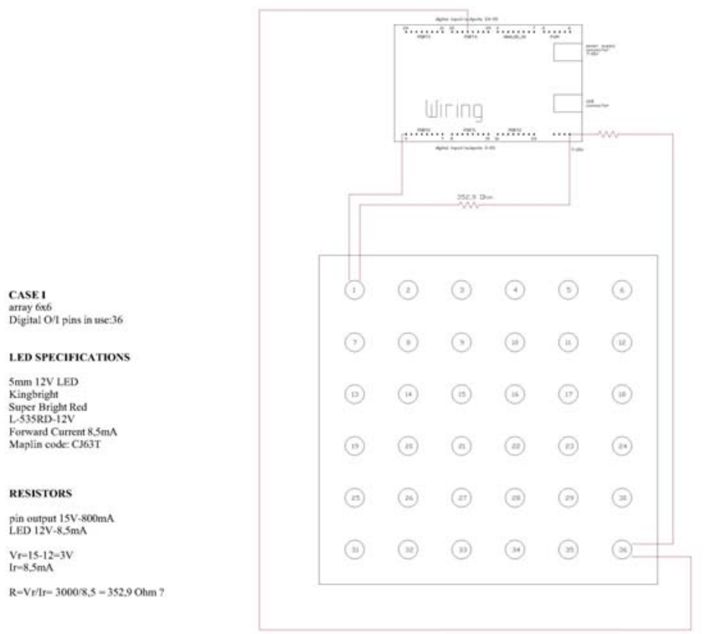

Fig. 49 *Circuit diagram indicating how the first and the last LED is connected to the Wiring I/O Board. Having also the calculations for the appropriate resistors.*

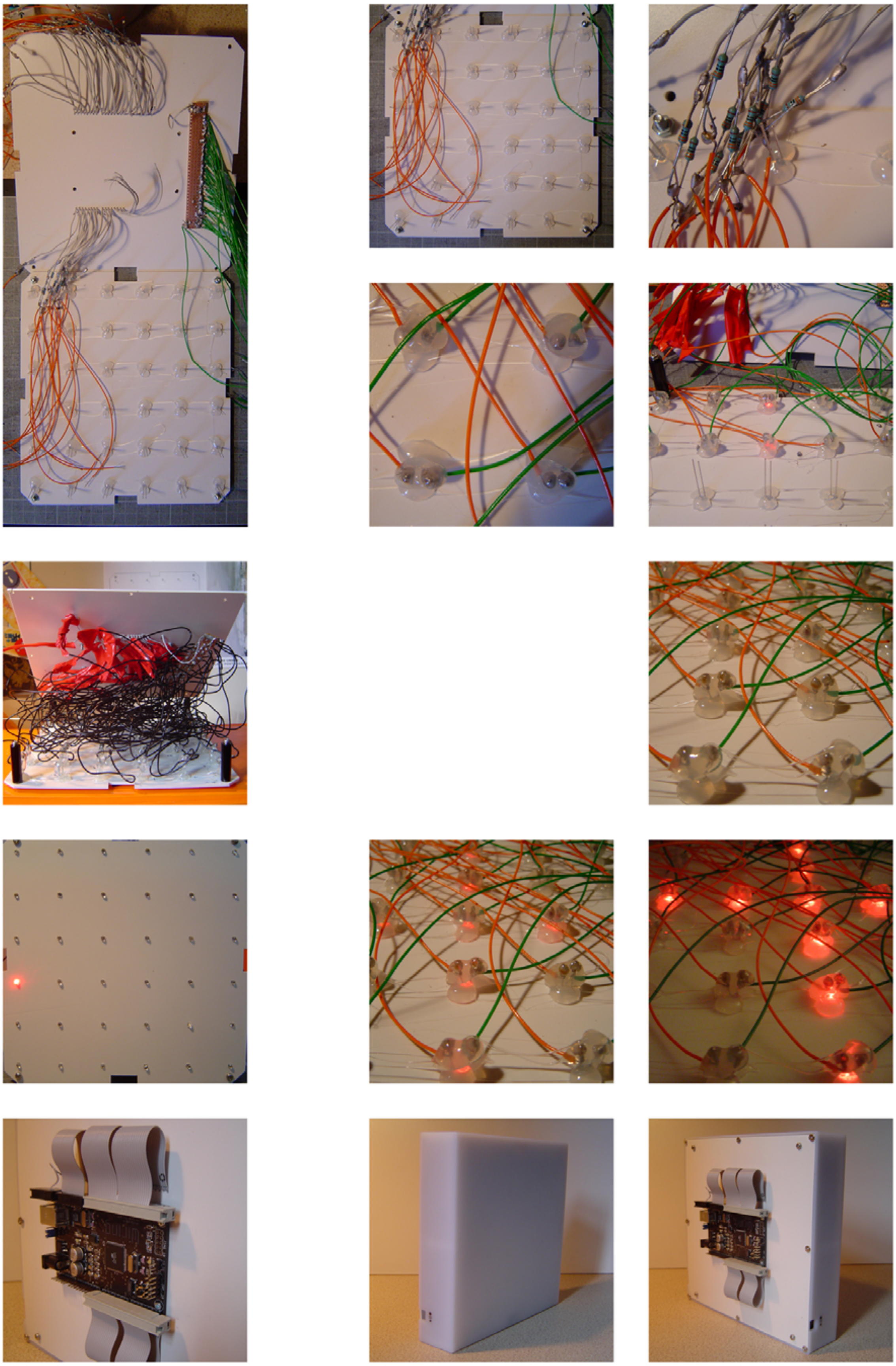

Fig. 50 Building the prototype, at the bottom we can see the prototype with the Wiring I/0 Board attached at its back.

4.6 The first programmes

Having the prototype ready and able to be connected with a PC, I started to write the first programs. A set of small prototypical examples are already developed in order to illustrate the basics of the media and the available commands of the language. These examples are available in the Wiring Examples sketchbook distributed with the application and from the Wiring web site in the Reference section.

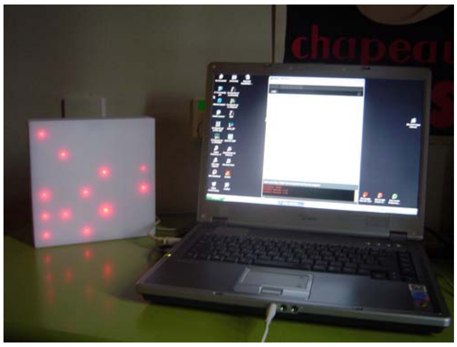

Fig. 51 *The first programs*

The syntax is quite simple, and easy to learn. First the user must initialize the mode of the pins to be either output or input.

```
void setup()
{
  int i;
  for(i=0; i<35; i++)// initializes pins 0 to 35 as
outputs
  {
    pinMode(i, OUTPUT);
  }
}
```

And then in the loop function all one needs to do, is give the number of the particular LED you want to be lit (HIGH) and the duration (delay).

```
void loop()
{
  digitalWrite(1, HIGH);   // sets on the num 1
  delay(200);           // waits for 200 milli seconds
  digitalWrite(1, LOW);  // turns the num 1 off
}
```

The above example makes a LED to blink every 200 milli seconds.

A variety of different programmes was used as a means of testing the abilities of the wiring software as well as the prototype's . Through such experimentations one comes across a number of bugs in the software, such as the random() function which does not work properly.

The next attempt was to design a simple application through Processing. An application that would enable someone to draw patterns displayed onto the prototype in real time. If I was going to use HAL as a communication tool, I had to find an easy way for one to draw patterns or at least to try them.
For this case I had to upload a program to HAL that enables the board to accept real-time values through the serial port. Then I had to run another program in processing that draws a graphical interface of HAL. By pressing any button with the mouse, I could see the corresponding LED lit in the actual HAL.

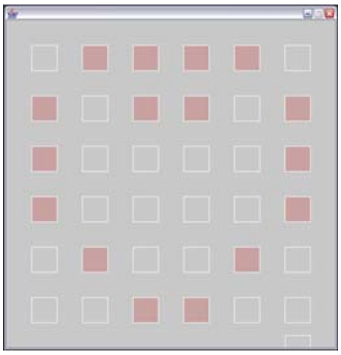

Fig. 52 The Processing applet that enables users to test a light pattern

The drawback of this attempt was that the board can only read one signal at a time, when it receives more than one value, simultaneously, the board is confused. Unfortunately this was a hardware problem that couldn't be solved.

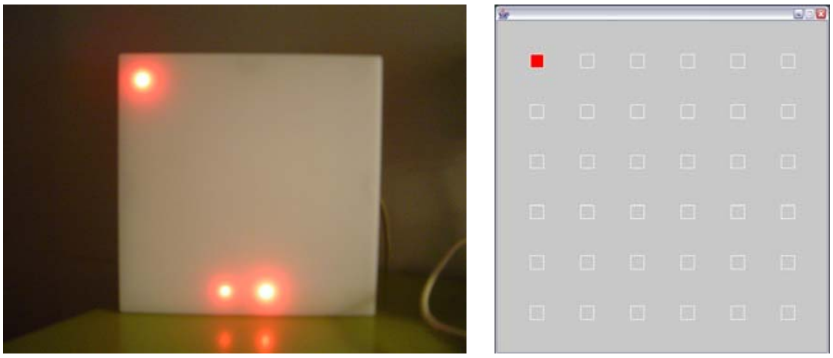

Fig. 53 The Processing applet that enables the user to control HAL in real time through a graphic interface. The two LEDs that are lit at the bottom is an indication that HAL is waiting for serial signals

4.7 Testing it

After building a second prototype I started to test my device with 3 different subjects. The subject keeps one HAL in his/her room or his/her workplace and receives e-mails from me. The e-mails contain a code that the subject uploads to HAL. The subject is free to write his/her own code and send it back to me in response. After the test the user returns the device with feedback about his/her experience

The type of messages that we exchanged were related to the situation we were in at the particular moment of communication. For instance, one morning while I was having my coffee, I sent a message displaying a steaming cup of coffee. Or on a rainy day I sent a cloud. Due to the fact that the displaying abilities of the 6X6 array are rather limiting, I also sent a sequence of letters forming a word as an explanation of the icon that was displayed. For example the steaming coffee was looping for one minute and was then followed by the word COFFEE, and the cloud was followed by the word RAIN.

The subjects that participated in the experiments were from various backgrounds. The first and second were a psychologist and a neurologist respectively, completely unfamiliar with programming, who kept HAL in their rooms. The third was an architect/ researcher, familiar with programming who kept HAL in her office environment.

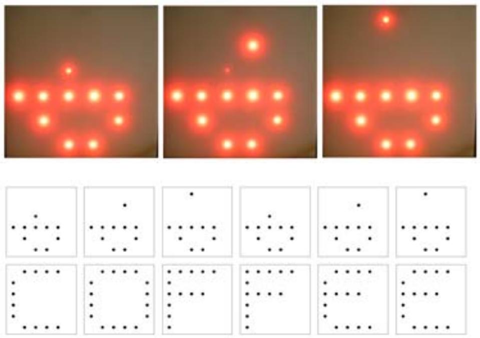

Fig. 54 The steaming cup of coffee pattern

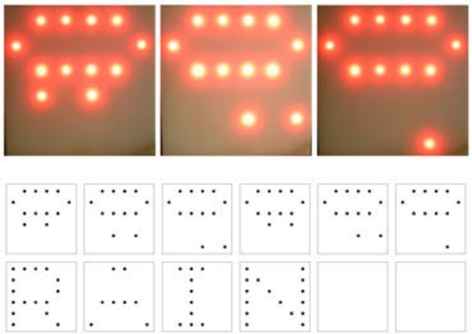

Fig. 55 The rainy cloud pattern

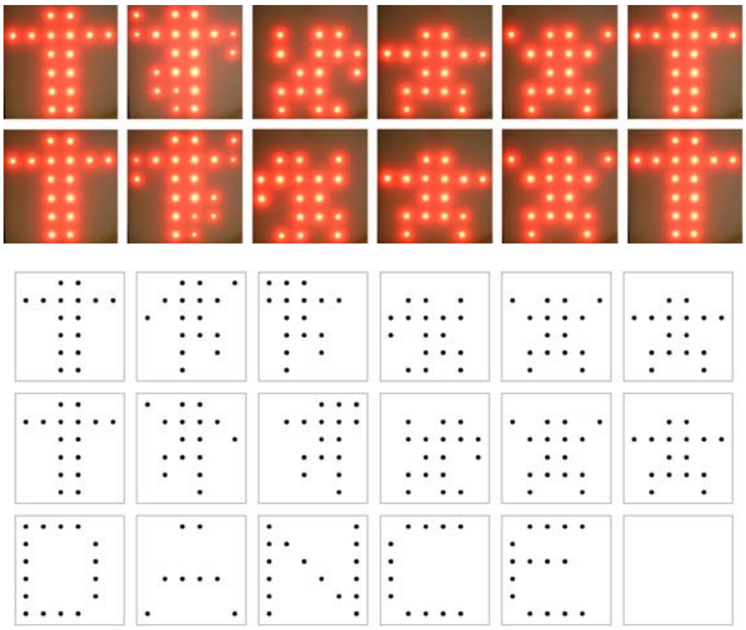

Fig. 56 A dancing man pattern

4.8 Evaluation

The evaluation of HAL was of an informal nature, more qualitative than quantitave. There were no detailed questionnaires or any strict theme about the exchanged messages. The experiments were investigating if HAL could be an alternative way of communication embedded in one's ambient environment.

4.8.1 Testing HAL in a room environment

The two subjects unfamiliar with programming found HAL engaging and interesting. They were intrigued by the idea of receiving "machine" code, which was not at all understood and hat to be uploaded to HAL for its comprehension. Although the interface was not considered to be very helpful by the participants, they tried to modify the original code and sent it in response to the initial message. In order to allow the users to handle the messages, some ready-made functions were added to the code. For instance 25 functions that were corresponding to every letter of the English alphabet.

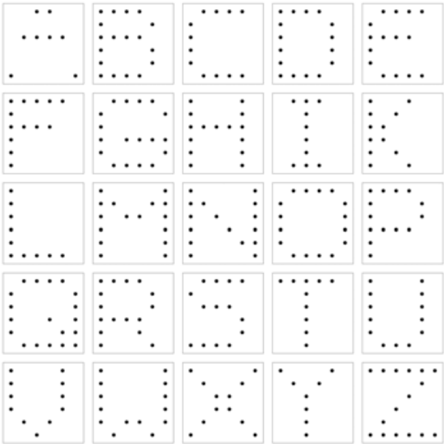

Fig. 57 25 functions that correspond to every letter of the English alphabet

```
void A()
{
  digitalWrite(led+2, HIGH);
  digitalWrite(led+3, HIGH);
  digitalWrite(led+19,HIGH);
  digitalWrite(led+20, HIGH);
  digitalWrite(led+21, HIGH);
  digitalWrite(led+22, HIGH);
  digitalWrite(led+30,HIGH);
  digitalWrite(led+35, HIGH);
}
```

This is a function that sets up the letter A, all the subject had to do was type:

```
A();
delay(1000);
```

for the HAL to display the letter "A" for one second.

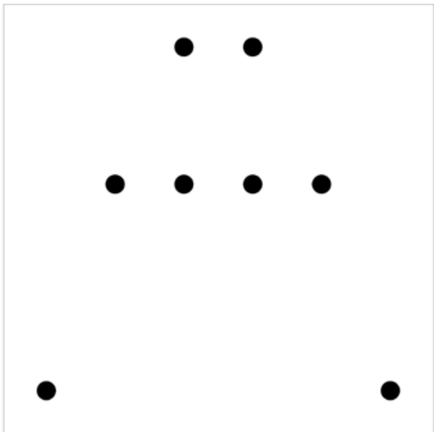

Fig. 58 The function A();

Following such a principle, I could have already set up a number of ready-made icons, such as a smile or a sad frown etc, that they would choose by just typing them to the compiler.

I don't want to imply that a completely unfamiliar user can actually learn Java in 5 minutes and I have to admit that I had already explained the basic parts of the program to them and showed them exactly which parts they were allowed to modify. The interesting fact of their attempt is that HAL actually provoked them to deal with the idea of programming that in any other case they probably would not.

During the course of the experiment , I sent to one of the subjects that was about to leave for one month holiday in Tai Pei,a message displaying an aeroplane taking off with the text "HAPPY HOLIDAY". The subject within half an hour had responded with a message displaying an ice cream with the text "SUMMER" in order to express her holiday mood. The interesting fact that I want to underline is the feedback she sent me about her experience.

> *"I have very limited knowledge and experience in computer program design.. Panayiotis kindly gave me a chance to write up a program and to design a code to test if we could communicate through the device he designed.*
> *At first, he showed me how to operate the device, including installing the program and basic operation of the lights and writing up of the program. For a beginner, it took me about 10 minutes to get familiar and operate independently without difficulties. It took me another 15 minutes to design a picture/signal and to write up the program for the signal. I was so proud that I was able to make my first "communicative" signal with lights and sent it back to him. He successfully figured out my message.*
> *Through this test, Panayiotis demonstrated an interesting way to communicate and stimulate our feelings."*

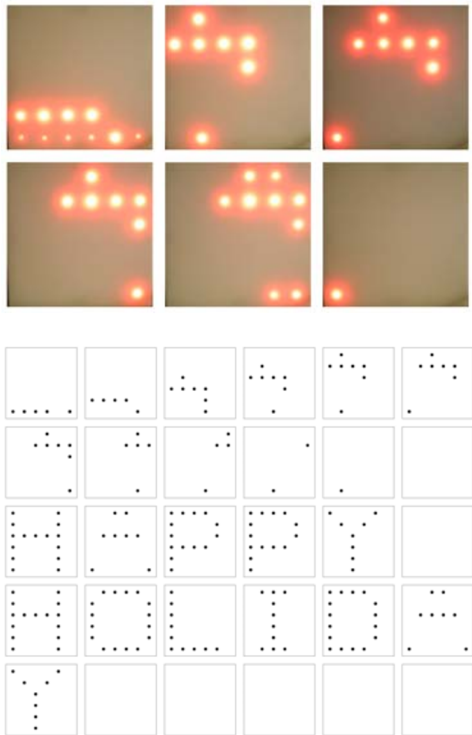

Fig. 59 *The message with the taking off aeroplane*

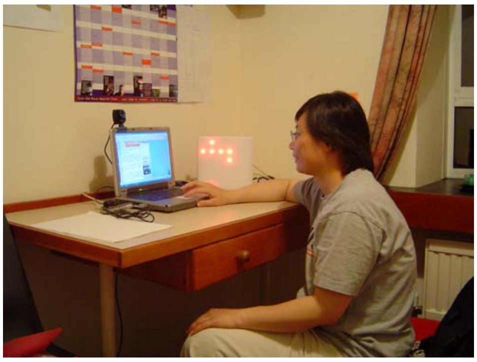

Fig. 60 *The subject in her room*

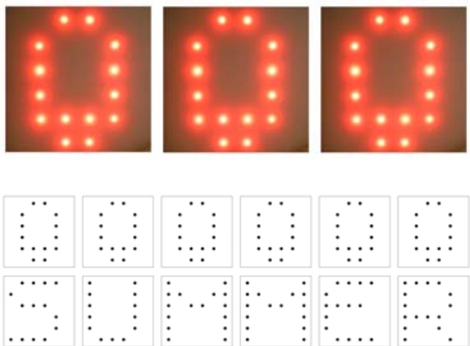

Fig. 61 *The subject's reply*

The underlined phrases of the subject's feedback indicate, in my opinion, two strong points.
Completely unfamiliar with programming, the subject felt proud for being able to modify the program and make it work according to the message she wanted to reply. That means that she gained something through this process.
Secondly, by mentioning that the device demonstrated an interesting way to communicate and "stimulate our feelings", one could claim that HAL indeed evoked a sort of emotion to her, that probably wouldn't have been achieved by an e-mail saying "happy holiday in Tai Pei".

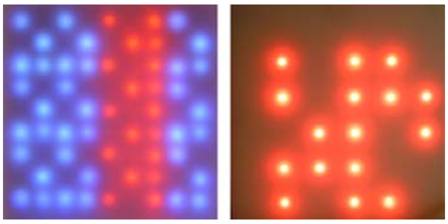

Fig. 62 *HAL original and HAL modified*

In my question if they prefer the modified HAL to the original one they all answered that they find the original one boring, compared to the modified. They also liked the idea of a standalone device in their ambient environment that has the ability to render a message in a visual way.

4.8.2 Testing HAL in an office environment

The third subject is a researcher architect who works in an office environment with a number of other colleagues. HAL was placed above the subject's desk in a place to be seen by everyone. The interesting outcome of the experiment is that HAL created an event in the space. Everybody was curious to know about that strange lamp that was displaying patterns. The colleagues as well as the subject ended up taking part in the game of trying to guess the meaning of the symbols I was sending, which they were expecting with great anticipation. In general they could quite easily figure out what the symbols meant, but the letters were confirming their guesses. Probably the subject was the only one conceiving HAL as communication device with me, contrary to the colleagues that conceived it more as a device that was testing their cognitive perception.

Fig. 63 *HAL in the subject's office*

In this chapter I have given an account of the research I did on how to build my prototype and the components I employed. I also presented the informal experiments I made testing HAL with 3 subjects.

5 Discussion

In this chapter I will compare the initial statements of my Hypothesis with the evaluation of my experiments. I want to discuss if indeed a conversation between the physical word and the digital word of the computer has an impact on users. Another key factor of my quest is the extent of the emotional stimulation that this conversion had to the user.

5.1 Physical Computing and impact

HAL is indeed an example that demonstrates the embodiment of Physical Computing. As I mentioned before, the subjects were intrigued with the idea that they were receiving “machine” code, which they couldn’t understand at all and they had to upload to HAL in order to figure out what it was about. By this process they could realize the conversion of one form of energy into another. It’s about computation that moves beyond the traditional confines of the screen and attempts to incorporate itself into our experience of the physical word, into HAL. This conversion was taking place right in front of their eyes.

One could say that this happens everyday, especially when we connect an external device to our PC, for instance a second monitor or a projector. I believe that most of us cannot understand, even If we read, how a computer screen converts the digital signals into images. I think the power of HAL lies in its physical properties. It’s not a high-tech screen, but a tangible and understandable device that lets the user manipulate its functions.
The user, having this option, is confronted with a continuum of possibilities. Probably this could be the idea of the real interaction, meaning the fact to interact with an open-system rather than a set-system. Throughout this process the user can have a pleasant

experience. If we follow McCullough's [1996] claim, about the way some people perceive the computer as its input and output devices alone - as if the screen is actually the computer, we could assume that what the user can actually learn and understand through a physical computing device are some basic features of computation.

As mentioned before one of the subjects felt proud, being able to reply to the message I had sent her. This fact can be related to what Jim Campbell says about the "real interactivity" that takes place between the viewer and himself and not between the viewer and the interactive work. HAL enabled the subjects to attach feelings to its flashing LEDs. I think to the subject's mind, and probably mine too, LEDs never cease to be just "lamps". The feature that they were able to manipulate those lamps to whatever they wanted is the key to their experience.

5.2 Emotion

The availability and the ease of the new means of communication such as, the electronic mail, text messages or MSN messenger[12] have showed that they are often used just to transfer emotional states between friends, family members etc. Probably that's why the use of emoticons in these kinds of messages is so popular. Emoticons are based on the inclusion of sensory information for the meaning to become something more than the apparent words or symbols.
The use of HAL as a medium of communication is actually based on this phenomenon; the viewers decipher the light signals and convey them into emotions. However, the physical nature of HAL actually augments these messages and makes them background information in one's ambient environment.

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[12] MSN Messenger is Microsoft's instant messaging client for Windows computers aimed toward the home user. Among its users it is often referred to as MSN, for example, "I'll send it to you over MSN."[source: Wikipedia].

5.3 Events in space

Taking into consideration the event that was created by HAL in the experiment in the office environment we are coming into alliance with Malcolm McCullough's views about this newer field of information technology.

"Interaction becomes a defence of architecture. In contrast to earlier stages of interface design aimed at building attention-saturating worlds, this new paradigm in information technology turns to building physical backgrounds. The more those principles of locality, embodiment, and environmental perception underlie pervasive computing, the more it all seem like architecture" [McCullough, 2004- p.63]

According to McCullough, Architecture in its very long history, was a social frame first and became operable equipment only later. Computing has been the opposite. In its relatively short history, it was operable equipment first and social organization technology only later. As computation acquires even more spatial layers, it conceives schematic identities ever more independent of their technical execution. One word for these identities is architecture.

"The word Architecture has been appropriated to describe all manner of technological designs that are infrastructural and that cast everyday activity in a particular way. Information technology becomes a remedy for architecture that needs to rejuvenate itself" [McCullough,2004- p.63]

Physical Computing is becoming more and more sophisticated about environmental perception. It takes advantage of physical contexts as frames for social functions. It shifts focus from technological novelty to more enduring cultural frameworks.

McCullough believes that these shifts suggest more emphasis on quiet architecture, simply because physical architecture is relieved from its struggle to be at the fashionable centre of attention, and a return to what it does better that is the enduring formation of periphery.

Even though Physical Computing enables us to create events in space it doesn't mean that we have found the ultimate solution to every need. It's just that architects seem to have another tool at their disposal. As design participation broadens in digital technology, architects should awaken to these issues. It's about time to start seeing things as overlapping subjects which are causing social consequences.

5.4 Future developments

HAL did not reach its final stage. This would be the use of ad-hoc[13] communication in order for a user to be able to send programs directly to a distant HAL through a network or to connect two HALs together. This task would be a goal for a future development that will probably give new feedback to the objectives.

Another essential aspect is the development of the interface that will allow users to program HAL without machine code but through a simple graphical representation that will automatically create the program. However, the experiments with HAL in this more manual version showed that play comprises a lot of learning, especially when it comes to software data structures.

Another future development would also be the addition of a secondary circuit that will extend the resolution of HAL beyond the restrictive 6X6 array.

[13] In computer networking, ad-hoc is a connection method for wireless LANs that requires no base station — devices discover others within range to form a network for those computers. Devices may search for target nodes that are out of range by flooding the network with broadcasts that are forwarded by each node. Connections are possible over multiple nodes (multihop ad-hoc network). Routing protocols then provide stable connections even if nodes are moving around randomly .[source:Wikipedia]

6 Conclusion

Through this project I had the opportunity to be exposed to a wide range of information and techniques. Even though I faced many obstacles partially due to my lack of knowledge in this field, that forced me to step back and try different approaches, I am very excited and challenged with the work done.

Having looked at the results of my experiments it is evident that such systems can create objects that are more fun and engaging to use. Physical computing suggests a new approach that is likely to affect the way we see things. It actually opens the “continuum of possibilities” that will enable artefacts to adapt and change according to our preferences. Probably the Fourth Machine age would be a more human-centric one, in which the objects will adjust to our life and needs rather us to adapt to them.

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