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AMBIENT INFORMATION VISUALIZATION

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Ambient Information Visualization

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Abstract

This thesis investigates the concept of *ambient information visualization*. It has its background in the research fields of *ubiquitous computing* and *information visualization*, where the former investigates how computers move off our desktops and instead come to permeate our everyday environments, and the latter looks into how computers can be used to convey complex information in ways that makes it easier to process for the human mind.

The term ambient information visualization distinguishes an area where these two research fields merge, and can be defined as the use of visual representations of digital data to enhance a physical location. These visualizations are typically displayed using flat-panel displays or projectors and ideally act both as information displays and decorative elements in the interiors where they are placed.

The thesis describes a suite of design examples, where the first ones explicitly address the issue of creating a decorative surface by using the styles of famous artists as inspiration for the appearance of the visualizations, creating so-called *informative art*. Subsequent designs are developed under the superordinate term ambient information visualization and strive to find generic, inherent properties of peripheral information displays and how these properties come to affect design requirements.

As a way of informing the design process, visualizations have continually been tested with users in different environments, including exhibition settings with large amounts of visitors as well as long-term studies of use in office settings with smaller user groups.

The knowledge gained from the design and study of these examples is analyzed and the results highlight issues that are of central importance when designing a visualization. These issues are divided into three categories that concern the *information source*, the *mapping* from data to visual structures and the *use* of the visualization.

Keywords: *information visualization, ubiquitous computing, ambient displays, ambient information visualization.*

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Contents

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1 Introduction

During the last 50 years, computers have gone from being room-sized machines specialized at performing advanced mathematical calculations to being smaller, more general information processing devices which we use for both work and leisure. Computers are also increasingly becoming embedded into artefacts in our surroundings.

In some respects, this development can be seen as a movement toward something resembling the *ubiquitous computing* scenario envisioned by Mark Weiser and colleagues at Xerox PARC, which foresaw a future where computation would be available everywhere (Weiser, 1991). Their vision was not primarily focused on the embedding of computers into everything, however, but rather on how the *use* of computers would evolve into a state where it became effortless and transparent, allowing the user to focus on the task at hand.

In order for us to be able to benefit from the computational power we embed into our environments, the computers will have to communicate, or output, the results of their computations to us somehow. The medium used by personal computers is primarily visual, possibly in combination with sound. However, as the number of computers increases, and they become embedded into our environments, the need for new ways to output information arises. As Weiser and Brown states in their paper on *Calm Technology* (Weiser & Brown, 1996):

> *if computers are everywhere they'd better stay out of the way.*

The authors stress the importance of that computer use, in addition to the focused interaction computers demand today, also should be able to take a more peripheral role in the user's attention span. Rather than using a personal computer screen, placed on a desktop, as its only medium of communication, computer output should be available to the user where and when she needs it, in the same way as other, non-digital information presentation appear where it is needed.

Consider, for example, a train station; regardless of where you are in the building, a clock is likely to be somewhere within sight. This is no coincidence, but rather a conscious decision by the architect. Since most people visiting the sta-

Figure 1: Shinjuku district, Tokyo, Japan

tion building are either going somewhere with a departing train or are picking someone up at an arriving train, information about what time it is in relation to the scheduled arrival and departure times is of inherent interest to the people inhabiting the building.

Having computer displays everywhere, communicating information and seeking people's attention, could easily become overburdening. Think of places like New York's Times Square, Tokyo's Shinjuku (see Figure 1) or The Strip in Las Vegas: in all of these places, people are bombarded with commercial messages from a multitude of huge information displays, all competing for attention with flashing lights, blasting sound and their massive scale. They are all extreme examples of commercial centres created by the market economy, and as such extreme examples of information displays, but they still serve as a contrasting example to the more subtle display of time at the train station.

If information displays are to blend into their surroundings, they have to be carefully designed, taking into consideration factors like *what kind* of information is displayed, the *placement* of the display and *who the users are*. Furthermore, placing the presentation in an architectural context is likely to make the *aesthetics* of the presentation more important for how it is perceived.

The information presentation should be designed to accommodate the situation of use, which means that a peripheral placement of the display has different requirements than a desktop presentation where the user has her focused attention directed at it.

The use situation for a peripheral, public information display is likely to be subject to more distracting elements than its desktop counterpart, and a public display should accommodate this situation by providing a presentation that is as effortless as possible to read. Norman (1993) distinguishes two modes of cognition: *experiential* and *reflective* cognition, where the first is fast and effortless and the latter is slow and cumbersome, requiring the help of external support such as writing or books. Reflection requires concentration and, to quote Norman, "is best done in a quiet environment". A task that at first requires reflection can, however, become an experiential one, given enough practice. Revisiting the example of the clock, using it to tell the time is most certainly a reflective task for a beginner, but with practice the task becomes less difficult and eventually experiential. Adopting Norman's vocabulary, the display of information should be such that it makes use of experiential rather than reflective cognition.

How to present information graphically has been studied for a long time within the fields of graphic design and visualization. Norman says "*The power of the unaided mind is highly overrated.*" (Norman, 1993, p.43), and gives examples of how various problems become easier to solve when presented graphically. The external, graphical representation helps relieve the human mind of the effort to keep abstract things in memory and thus the problem becomes easier to solve.

The research field of visualization is devoted to the exploration of how graphics can be used as a means to exploit the special properties of visual perception in order to augment the human cognitive system. This is done by presenting data in ways that reveals hidden patterns or show relations that are not obvious to the unaided mind (Card et al, 1999). Computers, with their powerful number processing skills and capability to display interactive graphics, are very well suited for this purpose, and research within *information visualization* has during the last two decades explored ways of using computers to create interactive visual representations of abstract data. This rich knowledge of how to create efficient computer-based information presentation should be of great help when designing peripheral information displays that meet the needs of the ubiquitous computing scenario, like invisibility in use.

Applying the knowledge from information visualization to off-the-desktop information presentation is not always straightforward, however. For example, the move from the personal computing paradigm may limit the user's ability to interact with the data, which restricts the ways data can be presented. This new application area is likely to have a big impact on the requirements for information visualization, but fundamental principles on how to map data to visual structures should still apply.

1.1 Contribution

This thesis is an exploration of how the requirements for computer based information presentation change as it moves off the desktop and into the user's surroundings. The exploration is to a large extent carried out within the framework of *informative art*, which is a term denoting visualizations that use art and other decorative artifacts as a source of inspiration, both for the design of their appearance and for their role in the user's life. The assumption behind this design approach is that works of art—and 'art' here incorporates everything from paintings and sketches to posters and photographs—are frequently used as ornaments in our surroundings. These artworks are used to create a certain atmosphere or ambience at places where we spend our time. The purpose of informative art is to take the role art plays when it is used as ornament, and use it for the display of information.

The thesis also introduces the concept of *Ambient Information Visualization* (or ambient infovis, for short), which is a more generic term describing information visualizations that are explicitly designed to be displayed in the users surroundings rather than on a desktop screen. The move off the desktop and into the environment has a big impact on the design requirements of a visualization. The design space of ambient infovis can be mapped to a model describing its role in the

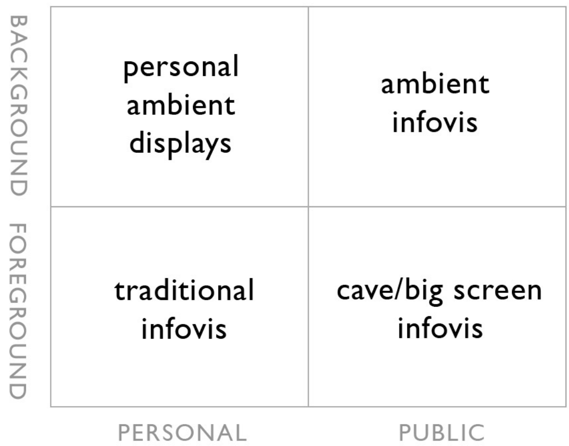

Figure 2: The design space of ambient information visualization.

individual user's *attention* span contrasted against how it is *accessed* in the environment. Using the access-attention-model seen in Figure 2, we see that ambient infovis resides in the background of the users' attention, since it takes place in the periphery; it is also public rather than personal. This places the design space in the upper-left quadrant of the model, whereas traditional infovis, which requires the focused attention of a single user, is placed in the lower-left quadrant. The Public/Foreground quadrant is occupied by visualizations that are design for focused, collaborative use—typically visualizations designed for large screens or so-called CAVES (Computer Animation and Visualization Environment). The last quadrant, Background/Personal, contain ambient and peripheral displays aimed at personal use, e.g. *InfoCanvas* (Miller and Stasko, 2002).

The access-attention model will be revisited at a later stage, when the design space of ambient infovis is defined more thoroughly and positioned against a background of related work within ubiquitous computing and information visualization. This definition is the topic of this thesis, which also answers the question:

> *What issues are of central importance when designing ambient information visualization?*

1.2 Thesis Structure

Section 2 describes the fields of ubiquitous computing ad information visualization and how they form the background for ambient information visualization. Section 3 lists the six papers that, together with this cover paper, constitute this thesis. Section 4 describes the research method. The results are summarized in section 5 and finally section 6 provides a discussion and a conclusion.

2 Background

Informative art is a concept that stands on two legs: ubiquitous computing and information visualization. They constitute the research background against which the work here should be seen. In the sections below, I will give a historical review of these three fields in order to position the project.

2.1 Ubiquitous Computing

In the early 1990s, Mark Weiser and his colleagues at Xerox PARC, devised a new computing paradigm called *Ubiquitous Computing* (or *Ubicomp* for short). This paradigm entails that in the future, computers will be everywhere and that computing access will permeate everyday life (Weiser, 1991). Inspired by the ideas of Suchman and other social scientists, who suggested that people work in a world of shared situations and that no action is isolated from its context (Suchman, 1987), the researchers argued that if computers are to truly become fundamentally integrated with our everyday lives and practices, they have to become effectively invisible in use—i.e., when you use a computer, you do not think of that you are actually using a computer but are fully focused on the task at hand.

The PARC researchers envisioned computers of the future to come in different shapes and sizes to accommodate the different needs that arise in the diverse usage situations that arise when the machines take the step off the desktop and into our everyday environments. They distinguished three different scales in which the computers of the future would be incarnated:

The smallest of these scales is the inch. Computers of this scale are called *tabs*, and are the computational correspondence to things like post-it notes, titles on book spines, or clocks—i.e. something that is specialized to solve one task.

Next comes the foot scale, where computers are called *pads* and correspond to things like sheets of paper, notebooks or magazines and are supposed to lay around wherever you may need them, like artifacts made of paper do today. Pads are used in ways similar to how we use paper—to sketch on, to read from etc.

The last and largest scale is the yard scale, with computers called *boards*. These computers work like boards; interactive bulletin boards or blackboards, but also as video screens.

Depending on what environment you are in, these devices appear in different quantities, but typically there are 100 or more tabs, 10-20 pads and one or two boards in any given room. Furthermore, all these devices should be able to communicate with each other and be aware of their location, e.g. know in what room they are in and what other computational devices are around them.

Weiser identifies three crucial technologies that are needed to realize the ubiquitous computing vision: cheap, low-power computers that include convenient display, a network that ties them together, and software systems implementing ubiquitous applications.

The work on Ubicomp at Xerox PARC continued throughout the 1990s, and spawned projects realizing parts of the vision, such as *PARCTAB*, *ParcPad* and *Liveboard*, which served as test bed devices for computers of different scales. The Tab was probably the most influential of the prototyping devices, bearing much resemblance to the cell phones and handheld computers of today. The devices were intended as technological explorations of how the ubicomp vision could be realized with available technology.

2.1.1 Design for Everyday Environments/Use

Much of the early research within *human-computer interaction* (henceforth abbreviated *HCI*) sprung from *human factors*, a discipline that had its origins in the industrial revolution. Industrial psychologists recognized that in order to reduce the probability of human error when handling machinery, the design of the interfaces needed to be dictated by how the human mind, rather than the machinery, worked. When applied within HCI. human factors came to deal with optimizing the design of computer interfaces in order to minimize human error, reduce ambiguity and increase the efficiency of use. This is a very task-oriented approach to interfaces, where computers are reduces to tools that are used to solve some task as efficiently as possible. As computers move off the desktop and into our everyday environments, however, the need for new perspectives arises.

Within the Ubicomp field, an increasing amount of attention has been spent on studying the way in which computers will come to permeate our lives. In the paper *At Home with UC: Seven challenges* (Edwards & Ginter, 2001), issues regarding the technical, social and pragmatic domains that have to be overcome in order for the "smart home" to become a reality.

Based on field studies of domestic life, Tolmie et al. published a paper called *Unremarkable Computing*, (Tolmie et al., 2002) in which they identify issues that are crucial when designing technology that is "invisible in use". They shed light on phenomena like activities that become invisible by virtue of having become routine—they are observable and identifiable, but to the people involved they are routine and hence carried out without reflection or thought on the activity itself. They stress the importance of not confusing invisibility in use with perceptual invisibility: ubicomp technologies of the future may well be *seen*, but they should have inherent qualities that enable them to become routine, and gain "invisibility status" that way. Important aspects to consider for designers involved in the creation of the future ubiquitous computing environments have been discussed by (Rodden and Benford, 2003) and concepts like *Everyday computing* (Abowd & Mynatt, 2000) also relate to similar issues. These approaches all have in common an approach where the designer studies the life and activities of people and let this ethnographic data inform the design of computational devices that support these activities.

Originating from a critique of the human factors-centered view of design that reigns within HCI, a range of alternative approaches to design has appeared on the research scene in the last few years. The assumption behind these approaches is that a lot of aspects that are crucial to the way we perceive computers will be overlooked if we adopt a strict human factors perspective for the design process. This will be especially unfortunate for the computational devices that are intended for our everyday environments, and these alternative design methods have to a large extent dealt with how to design for everyday environments.

An alternative method for gathering data about domestic life with the intent to influence design is to deploy so-called *cultural probes* in domestic environments. People use the probes to document different aspects of their life. The returned probes are then used as a source of inspiration for the design of new domestic devices. One such example is *the Drift Table* (Gaver et al., 2004) – a computationally enhanced sofa table that in addition to functioning as an ordinary sofa table also is equipped with a viewport through which you can watch aerial photography of England and Wales. The table surface is load sensing, so depending on how items are placed on the table, the aerial view will drift slowly in direction of where the load is heaviest. This drift table explores the concept of design for *ludic engagement*, where people are seen as playful creatures, or *Homo Ludens*.

When spending time in our homes, many of the activities we engage in are of a leisurely nature: they make us feel relaxed or engaged, or they simply allow us to dream away for awhile, depending on what we are in the mood for. These are aspects that are in focus when designing for ludic engagement, rather than more work-related aspects that usually direct the development within HCI.

> *"What if computing helped us pursue our lives, not just our work?"*

The drift table is one of many examples of design for domestic environments coming from the Royal College of Art. Another one is the *Placebo* project, where the designers placed experimental designs in domestic environments for some period of time and then came back to interview the people who had been living with the designs. Transcripts of the interviews are published, in unedited form, and without any attempt of interpretation from the authors, in (Dunne & Raby, 2001). The work is based on previous work like (Dunne, 1999), that describes a design methodology called *critical design*, which, in Dunne's own words strives to:

> *"explore fundamental issues about how we live amongst electronic objects. The most important elements of this approach are: going beyond optimization to explore critical and aesthetic roles for electronic products; using estrangement to open the space between people and electronic products; raising awareness of the electromagnetic qualities of our environment: and developing forms of engagement that avoid being didactic and utopian."*

Related to Dunne's critical design approach, is the concept of *Slow Technology* - technology that is explicitly designed to promote reflection and mental rest, rather than efficiency (Hallnäs and Redström, 2001). The authors argue that this focus is essential if we really want the use of computers to become integrated into our everyday lives. They foresee a movement "from use to presence" of computers, meaning that in the future computational devices will not be something that we *use* as much as something we *live with* (Hallnäs & Redström, 2002).

Continuing their work, the authors draw a parallel to design and architecture, where the birth of new materials or technologies have a way of affecting the way we design things. See for example how the use of reinforced concrete affected the way architects build things like houses and bridges. The same holds for the design of everyday things, where techniques such as bentwood and materials like plastic greatly affected the design of, for example, our furniture. The ubiquitous computing paradigm entails building computers into things, amplifying them and complementing their original functionality with new, interactive capabilities. Hallnäs & Redstöm consider computation as a material for design, and ask what properties it has, and in which way it will affect the everyday computational things of tomorrow (Redström, 2001).

2.1.2 Ambient Information Displays

In 1996, an new view on how to design interfaces for ubiquitous computers was presented in the paper *The Coming Age of Calm Technology* (Weiser and Brown, 1996), which described visions of how computers of the future would be able to "stay out of the way". Calm technology was described as technology that "engages both the center and the periphery of our attention, and in fact moves back and forth between the two". The authors argued that since humans only can focus their attention on a limited number of things at a time, and traditional computer interfaces require such focused attention from its users, a constant increase in the amount of computers requiring your attention will eventually become overburdening. The authors also argued, however, that humans have the ability to stay *attuned* to a lot of simultaneous information sources that reside in the periphery of our attention. By making use of this ability when creating computer interfaces, and explicitly design for the periphery of the human attention, we can accomplish the Ubicomp vision, where computer use becomes truly invisible.

In their paper on calm technology, Weiser and Brown states that

> *"Unlike virtual reality, ubiquitous computing endeavors to integrate information displays into the everyday physical world."*

The paper describes one such integrated information display, called *The Dangling String*. This was an art piece created by the artist in residence Natalie Jeremijenko, originally called *LiveWire*. The piece consisted of a plastic string, attached to a motor that would move according to the amount of traffic in the local area network, thus taking otherwise invisible information and giving it a physical manifestation in the room.

In the late 1980s and early 1990s, research on so-called media spaces was popular within HCI. The typical media space consists of a direct audio and video connection between two remote locations, intended to support collaboration between people in these locations. By keeping two (or more) spaces connected with a live video feed, even when it is not used for meetings or other work-related activities, an opportunity for keeping aware of the goings-on in other locations is created. This was explored in systems like *Portholes* (Dourish and Bly, 1992), which enables people to stay aware of the activities in several places; both public ones like lunch rooms or commons and the offices of friends and co-workers.

The *AROMA* system described in (Rønby Pedersen and Sokoler, 1997), provides the same kind of awareness information used in Portholes, but instead of displaying video images in a window on a screen, AROMA presents information using a set of more abstract output devices. The idea is both to make the information more peripheral by taking it off the desktop and placing it in the environment, and, by using abstract display methods, to provide just "enough" information and at the same time shield the privacy of the people being monitored. The system uses a camera and a microphone as input units and for output any of the four following: *speakers* playing wave sounds, a *Peltier element* changing temperature, a *merry-go-round* changing speed or a wall-mounted *monitor*, where clouds drift by at a speed depending on the amount of activity detected in the input data.

This way of presenting information in the users' environment, using modalities other than just vision has since been explored within the field of *ambient displays*. The term *ambient media* was coined in a paper from the Tangible Media Group at the MIT Media Lab that described the *ambientROOM* – a room that had a range of information displays integrated into its architectural structure. For example, the activity of someone close to you could be displayed as water ripples in the ceiling, the amount of e-mail in you inbox could be expressed as the sound of rain in the room (the heavier the rain, the more e-mail you have). They also describe displays that are not integrated in a specific room, but could be placed anywhere. These displays were called ambient fixtures and the examples described in the paper are called *WaterLamp*, which displays information by illuminating a tray of water from beneath and depending on some source of information, solenoids tap the water surface, creating patterns of water ripples in the ceiling. The second example is called *Pinwheels* and consists of an array of computer-controlled pinwheels mounted in the ceiling that spin according to some source of information, e.g. network traffic.

Another example of display design that strives to make use of out peripheral attention is the *Information Percolator* (Heiner et al, 1998), an ambient display that consist of 32 transparent, water-filled plastic tubes, each with an aquarium air pump mounted at the bottom. By releasing a short burst of air in a tube, a "pixel" is created that travels up the tube. The display is thus able to show any pixelated image of a resolution of approximately 32x25 pixels. The display was used for several applications, including a movement awareness display and a reminder clock.

With the goal to create general mechanisms for integrating ambient media with digital information, *the Ambient Media System* was developed at TeCo in Karlsruhe, Germany (Gellersen et al., 1999). The system connects hits on web pages to ambient devices in the environment, such as lamps, table fountains and a humidifier; thus integrating web awareness into the environment.

At Berkeley, the Group for User Interface Research has created a generalized mobile interface where six objects can be hung in strings from a "staging area" and, depending on some information, be lowered up to three feet. This interface has been used to create different ambient mobiles like the *Weather Mobile* and the *Bus Mobile*, which present weather and bus traffic information, respectively.

The *InfoCanvas* is a personalized peripheral display where the user can select the information she wants to monitor (e.g. stock portfolio information, weather, traffic data, news headlines, etc.) via a web-based interface and map it to a pictorial representation on the display (Miller and Stasko, 2002). A collage of such pictorial representations is then displayed on a peripheral display in the users surrounding, e.g. on the wall in an office, where it provides her with information "in a calm, unobtrusive manner".

The *Hello.Wall* is an ambient display consisting of LED-clusters forming light patterns that convey information. The display has three different modes and activation areas, one of which is ambient (Prante et al, 2003). Hello.Wall also has features connecting to the to the research on media spaces and awareness from the 1990's, where it is used to connect "commons" in two geographically dispersed offices by displaying abstract activity information.

On the consumer market, Boston based company *Ambient Devices* (www.ambientdevices.com) have commercialized the idea of ambient displays, and sells a set of different displays, including *Ambient Orb* and *Weather Forecast Beacon* The Orb can display a information ranging from stock market to weather to someone's presence on instant messenger whereas the Beacon only shows weather information for some location.

2.2 Information Presentation

The second "leg" of the foundation for ambient information visualization deals with information presentation. Humans have explored technologies for conveying information for a very long time—at least since the earliest findings of rock art, and probably even longer. In this section I give a brief account for the development of information presentation, with a specific focus on visual presentations, the ones that in modern day has become known as *visualization*, and with the advent of computers; *information visualization*. The research field of visualization is not new, but in order to understand its development, let us look at the definition of the term (from Merriam-Webster Medical Dictionary):

visualization - formation of mental visual images

The scientific field of visualization (which I, for brevity, use to encompass diverse areas like cartography, graphic representations etc.) has been devoted to studying the creation of visual means of *aiding human cognition*. The power of the human mind is enhanced greatly when provided with suitable tools (Card et al., 1999, p.1-2). Giving a thorough account for the development of tools for aiding human cognition is beyond the scope of this thesis; hence I will only visit a few milestones in the history of the field up until the present day.

Pictorial "languages" in the form of pictographs (rock paintings) and petroglyphs (rock carvings) from various cultures around the world are the earliest preserved examples of the way humans tried to record and convey information. This kind of rock art predates all written language and was commonly used to tell stories of hunting. Later cultures, like the Egyptian, developed these kinds of rock art into a proper pictographic language called *hieroglyphs*. The closest thing to a pictorial language that is still in use today is Chinese writing, whose logographic symbols have a pictorial background.

Around 1350 Nicole Oresme presented some graphical ways of visualizing theoretical functions and logical relations between tabulating values and so created the foundation for the bar-graphs of today. The scientific application of visualization began to develop more rapidly in the 1600's, with inventions like the Cartesian coordinate system and became gradually more advanced alongside the development within statistics, economics, etc. William Playfair is known for introducing the pie chart as well as the modern bar chart in the late 1700s and the 19^{th} century saw a virtual explosion in the development and use of different charts and graphs. This development slowed off in the early 20^{th} century which instead was a time for consolidation, with standards forming for when and how to apply different techniques.

During the second half of the 20th century came the computers, which with their innate number-crunching skills were very well apt to dealing with numerical data. Computer graphics has from its beginning been used for the visualization of scientific data. The rapid development of computers caused another creative explosion within the visualization field. As computers became more powerful they were able to process larger amounts of data of increasing complexity, and the enhanced graphics capabilities allowed for more advanced visualization techniques. This development gave rise to the field of *information visualization*. Information visualization has been defined by Card et al. (1999) as:

> *"The use of computer-supported, interactive, visual representations of abstract data to amplify cognition"*

This definition more or less presupposes the use of a desktop computer that allows for interaction with the information, changing point of view, rotating, restricting it etc. Building on the definition of visualization above, together with the definition of information as being "interpreted data", one could easily imagine a definition of information visualization that has nothing to do with computers, or even graphics. However, since the above definition by Card et al is commonly accepted within the field, I will adopt it for the discussion here.

2.2.1 Reference Model for Information Visualization

Card et al present a reference model for visualization (redrawn in Figure 3), which is a schematic view of how visualization is created by structuring of *Raw Data* into *Data Tables*, which then are mapped to *Visual Structures* which in turn can be explored from different *Views*. The core of this model is the mapping from Data Tables to Visual Structures, since that constitutes the move from Data to Visual Form, which obviously is a crucial step in the process of amplifying cognition.

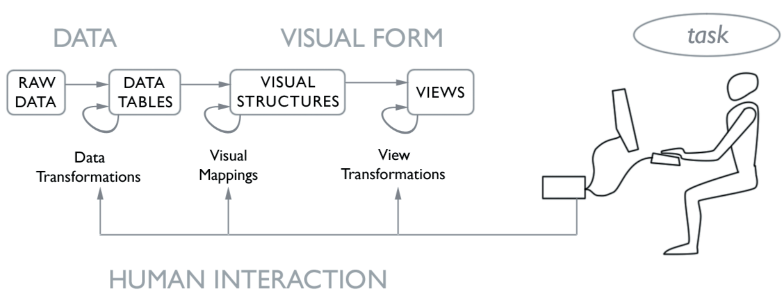

Figure 3: Reference model for Visualization, redrawn from Card et al (1999).

	Spatial	Q	O	N	Object	Q	O	N
Extent	(position)	●	●	●	grayscale	◑	●	○
	size	●	●	●				
Differential	orientation	◑	◑	◑	color	◑	◑	●
					texture	◑	◑	●
					shape	○	○	●

● good ◑ marginally effective ○ poor

Table 1: Efficiency of retinal properties for encoding of data, redrawn from Card et al (1999).

There are different types of data and Card et al adopts the division of data from (Mackinlay, 1986) into *Nominal* (unordered data such as {cat, dog, bird}), *Ordinal* (ordered data <small, medium, large>) and *Quantitative* (numerical data [0,10]).

Visual structures are defined to consist of *spatial substrate* (i.e., the visualization surface, onto which graphical elements are mapped), *marks* (i.e., graphical elements like points, lines, areas or volumes), and the *marks' retinal properties* (i.e., position, color, size, etc.). Not all visual structures are equally suitable to display different kinds of data. Table 1 shows a summary of how well suited different retinal properties (e.g. color, size or postition) of marks are to decode data.

2.2.2 Artistic InfoVis

The very first examples of information presentation like the rock art hunting stories mentioned above, were decoration as much as they were carriers of knowledge, and throughout the development of visualization as a field, aesthetics have been more or less an issue. If you consider examples from Edward Tufte's books *The Display of Quantitative Information* (Tufte, 2001) or *Envisioning Information* (Tufte, 1990)—they both provide a plethora of examples of how the most efficient visualizations have a quite aesthetic quality to them, even though they are not (necessarily) sprung from an artistic statement.

The visual appearance of the early visualizations of the computer age were limited by the graphics capabilities of the machines, but as computer graphics developed, these limitations gradually faded and indeed the new possibilities sometimes led to people getting carried away which resulted in effects such as careless use of colors, as noted in (Tufte, 1990, p.88).

As the discipline matured, however, the aesthetic appeal of visualizations gradually has gained renewed attention, e.g. in John Maeda's *Aesthetics and Computation Group* at the MIT Media Lab (the group has now changed names to *Physical Language Workshop*, but their focus on the aesthetics of computation remains. See also (Maeda, 2000)), and the Department of Art at Carnergie Mellon University gives a class on *Information Visualization as Artistic Practice*, which recognizes the aesthetic qualities that well-designed visualizations can have.

2.3 Ambient Information Visualization

The two fields of ubiquitous computing and information visualization form the background for the design space of *ambient information visualization*, which deals with the design of screen-based information displays that take peripheral roles in their users' environment. In other words, it is information visualization for ubiquitous computing environments.

This thesis explores how the knowledge gained within these two fields can be employed to create information visualization for everyday environments that have the necessary qualities to become integrated in the life and activities of its user.

2.3.1 Definition

The term Ambient Information Visualization is meant to encapsulate the role of the visualization in its surroundings. Let us revisit the definition of the word 'ambient' used in (Wisneski et al, 1998):

> *ambient* \Am"bi*ent\, a. Surrounding, encircling, encompassing and environing. (Oxford English Dictionary)

Arguably, the term 'peripheral' could have been used, which in some regards might have been more descriptive of the display's role in the user's environment, but since 'peripheral' word also has the negative connotation of referring to something of lesser importance, 'ambient' was considered more appropriate. Additionally, this includes the notion of the display contributing to the ambience of its location.

The other part of the term—information visualization—has been defined as :

> *"Use of interactive visual representations of abstract, nonphysically based data to amplify cognition"* (Card et al, 1999)

The combination of these two terms into the compound term *ambient information visualization*, should encompass the relevant aspects of both definitions and any possible synergy that might arise. A tentative definition may be:

Use of visual representations of abstract data to enhance a physical location with digital information

This tentative definition will serve as background to the papers described in the following two sections. We will return to this definition in section five to discuss how well it suits the work presented in the thesis.

3 Thesis

This thesis consists of six papers, plus this cover paper. In the following section I will present these six papers briefly, stating their main contributions and role in the thesis.

3.1 The Papers

I Informative Art: Using Amplified Artworks as Information Displays.
Redström, J., Skog, T. and Hallnäs, L. (2000)
Published in Proceedings of Designing Augmented Reality Environments (DARE) 2000.

II Informative Art: Information Visualization in Everyday Environments.
Holmquist, L.E. and Skog, T. (2003)
Published in Proceedings of Conference on Computer Graphics and Interactive Techniques in Australasia and South East Asia (GRAPHITE) 2003.

III From Usable to Enjoyable Information Displays
Ljungblad, S., Skog, T. and Holmquist, L.E. (2003)
Published as a chapter in the book: Funology: From Usability to Enjoyment. The paper in the thesis is an extended version of the book chapter.

IV Between Aesthetics and Utility: Designing Ambient Information Visualizations
Skog, T., Ljungblad, S. and Holmquist, L.E. (2003)
Published in Proceedings of the IEEE Symposium on Information Visualization (InfoVis) 2003.

V Subject to Change: Issues with Long-term Evaluation of Ambient Displays.
Skog, T., Ljungblad, S. and Holmquist L.E. (2005)
Unpublished.

VI Activity Wallpaper: Ambient Visualization of Activity Information
Skog, T. (2004)
Published (as poster) in Proceedings of Designing Interactive Systems (DIS) 2004.

Paper I introduces the concept of *informative art* - public information displays that use the language and role of art to communicate information. The concept is twofold and stands in part on the concept of Calm Technology, presented by Weiser and Brown, by moving the display of information off the desktop in order to peripheralize the interface. Another aspect of informative art is tied to the concept of *slow technology*, which strives to complement the reigning view of computer technology as tools, with the option that computational artifacts also can promote reflection and concentration. By gathering information from the environment and displaying it—in some processed form—an amplification of the both the art and the environment in which it is placed, is achieved.

Paper II describes four instances of informative art that were exhibited at SIGGRAPH Emerging Technologies 2001. The first example is called *Weather Composition* and presents weather information for six cities in the world in the style of a Mondrian composition. *Motion Painting* takes inspiration from op-artists like Bridget Riley in a visualization of activity information. *Stone Garden* visualizes earthquake information with what looks like a photograph of landscape art. *Soup Clock*, finally, is an abstract egg timer in the guise of an Andy Warhol silk screen print or painting of Campbell's soup cans. The main focus of the paper is the exploration of what makes successful visualizations for everyday environments through the design of a suite of examples. These examples serve to illuminate different crucial aspects of visualization design; the speed of animation, how the user ability to read a display changes over time, suitable balance between detailed information and overview, and aesthetic concerns.

Paper III was initially published as a chapter in the book *Funology: From Usability to Enjoyment* (Blythe et al., 2003). The version included in this thesis is extended with a section on related work and a detailed description of implementation and installation not included in the original book chapter. The paper describes the design and preliminary study of an "enjoyable" information display carried out in a university setting. The paper discusses the differences in requirements that arise when you are designing information displays that are supposed to be enjoyable rather than just efficient. The paper also provides an overview of the users' opinions on the display in general and how well it fits in as a part of their everyday environment.

Paper IV introduces the term *ambient information visualization*, as a superordinate term to describe the class of visualizations to which informative art belongs. With three previous Mondrian-esque visualizations as starting point, the paper describes the development of a fourth example, this time visualizing bus traffic information. The visualization is designed in an iterative process involving potential users, and the resulting display is subject to a brief evaluation in a university setting (c.f. Paper III). The results from that and previous evaluations, as well as exhibition installations are generalized to form four *lessons learned*, that serve as a summary of the experiences with designing ambient information visualizations.

Paper V describes a long-term evaluation of the display presented in Paper IV. As background, a number of previous attempts to evaluate ambient displays a re discussed, as well as possible, but yet to be explored, evaluation methods. We argue that, since ambient displays are integrated parts of the architectural surroundings in which they are placed, they have to be studied and evaluated *in situ*. The paper describes installations of the display and how the perception and use of the display varies with the physical location and the user group. The results highlight issues that could not have been unveiled in lab studies of the display, and that stresses the influence that the context has on the use of a display, and how use may change with the habits of the users.

Finally, paper VI describes the design of a new ambient visualization called *Activity Wallpaper*, which serves as an electronic "memory" for a place, by using sensors that collect activity data from the place – in this case an analysis of audio information – and then visualizing that information back into the space. The visualization is projected on a wall, which is the underlying reason for using wallpaper patterns as inspiration for the visualization. The paper included in the thesis is an extended version of the published one and describes a new activity analysis model that makes use of more sensors, which allows for a more diverse analysis of the activity or ambiance at the place that is being monitored.

4 Method

The six papers in this thesis describe the path from the initial experimenting with artistically influenced visualizations to an emerging framework for ambient information visualization. The work on which the papers are based was carried out at the PLAY studio at the Interactive Institute between the fall of 1999 and the summer of 2002, and from then on in the Future Applications Lab at the Viktoria Institute in Göteborg, Sweden.

The work on which the papers are based began with the idea of using art as inspiration for the design of information displays by employing its role as a decorative element in peoples' surroundings. The term we chose to denote such displays was *informative art*, which later was to be extended into *ambient information visualization* in order to encompass all peripheral visualizations, and not only those that build on an explicit artistic model.

The design space of ambient information visualization has been explored by the iterative creation of design examples (cf. Redström, 2001) with the purpose to shed light on what constitutes successful ambient infovis. The procedure has been to implement different mappings from information to "aesthetical" graphical structures, to test or evaluate these implementations, primarily by subjecting them to the scrutiny of users trying them out in different settings, and in that way gain knowledge about what constitutes viable mapping strategies and also to spawn ideas for new mappings. In addition to the exploration of mapping strategies, an important part of the work in this thesis is the study of ambient infovis *in use*. As the visualizations are designed to be a part of the user's environment, the context is likely to affect how the display is used. Hence we have conducted studies focused on how the displays fit into peoples everyday lives and how the use of the displays develop over time.

The design method used for developing the examples is a mix of methods from several disciplines. Some of the design examples has gone through what resembles the iterative refining of prototypes that is common within software engineering. Boehm, for example, introduced a so-called *spiral model*, in which each development cycle produces something that can be evaluated (Boehm, 1988). "Evaluation" within software engineering does usually not involve users, however, and Boehm's spiral model is not directly applicable within HCI. The model has, however, inspired other spiral methods that involve user testing and the spiral model is a straightforward way of breaking down a design process into different phases.

A crude description of the process traveling through a spiral model would be to divide it into four phases where the first consist of the design of a prototype, the second is some kind of user test to collect feedback, and the third step is to analyze the feedback to gain new knowledge about the prototype. Finally, the newly-found knowledge is used to infuse the development of a new prototype that—hopefully—is better than the first one. When this happens you have gone "full circle", but since the prototype is more refined, you have reached a higher level and hence the iteration of this process builds a spiral, and creates a spiral model. An alternative take on a spiral model, that in some respects is a better way of describing the research process used here is Verplank's spiral (see Figure 4). The model is described in (Holmquist, 2000) and shows how the development process moves from a "*hunch*" of something that might be interesting to explore, and as a first way of testing the hunch you do a *hack*, and then you *try it*. From this trial you form an *idea*, which can be used to sketch one or more *designs*, which can be developed into a *prototype*, this in turn can *tested* with users. Results from this (or these) test(s) are used to develop *principles* which develop into *plans* and finally *production* of something that goes on the *market*. As noted by Holmquist, the final two steps paradigms and industries are steps that are only applicable to a few, truly ground breaking inventions (e.g. the telephone or the car.) and thus I have chosen to adopt his use of the model, where the last arrow is dotted.

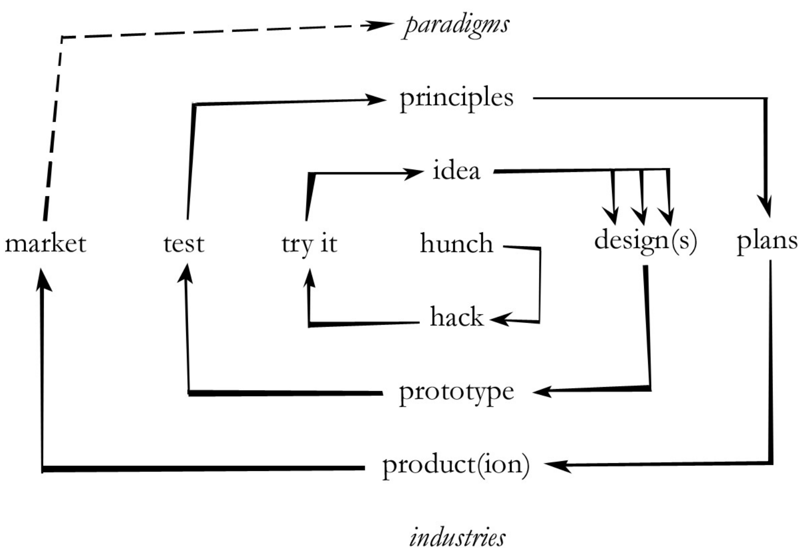

Figure 4: Verplank's spiral. Redrawn from Holmquist (2000).

The aim with the design of the examples and the evaluations has not been to create an exhaustive list of guidelines for how to design ambient information visualization, but rather to unveil aspects and issues of that are of crucial importance for how a visualization is used and perceived. Thus the examples serve as probes into the design space and are not part of a systematic exploration of all possible mappings in search of the best one according to some measure of efficiency.

4.1 Research

The idea for the informative art project was spawned by the Master's thesis *WebAware: Continuous Visualization of Web Site Traffic* (Siverbo and Skog, 1999), which also was published as a student poster at CHI 2000 (Skog and Holmquist, 2000). WebAware is a dynamic visualization of web site traffic, intended to provide people working in the company (or any workplace with an affiliated web site) a sense for what areas of the web site got the most traffic. In the visualization, each web page is represented by a dot, laid out using a visualization technique called Cyber Geo Maps (Holmquist et al, 1998) that distributes a tree structure in circles around the root, which made the entire web site look somewhat like a galaxy (see Figure 5). Whenever a web page was visited, the corresponding dot in the visualization would be highlighted. This highlight would then gradually fade away

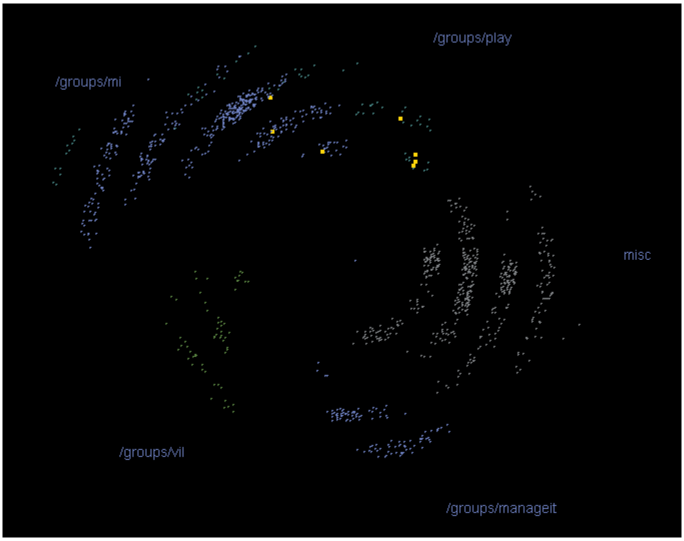

Figure 5: A Screenshot of WebAware, displaying six highlighted pages in the `/groups/mi` and `/groups/play` areas of the site.

(unless the page was visited again, in which case it would be highlighted again). The resulting visualization thus provide users with a dynamic picture of the web site traffic. We let people at our lab try the visualization and many of them found it aesthetically pleasing, so we experimented with different ways of displaying it in public areas of the office using a projector and plasma screen.

Having an aesthetic information presentation available in our everyday environments spawned the idea of actively employing items that we use for decoration as inspiration for information presentation. This chain of thought led us to art, and the idea of designing visualizations using well-known paintings as a visualization template, and thus the concept of informative art was born.

4.1.1 From Hunch to Hack

The first examples, or *hacks*, of informative art were developed in the winter of 1999-2000. The compositions of Dutch artist Piet Mondrian were used as inspiration for the first piece that was developed. The simple but characteristic graphic style seemed like a suitable template on to which information could be mapped in a fairly straightforward manner. The visualization we designed was of e-mail traffic (see Paper I) where quantitative information (the number of e-mails) was mapped to the size of colored fields. The color of the field was mapped to the time since a person last sent or received an e-mail. Making use of the same three primary colors as Mondrian, i.e. *blue*, *yellow* and *red*, a person could be "cool", "neutral" or "hot" respectively, depending on how recently he or she was involved in any e-mail correspondence.

The paper also describes an example that explores a simple mapping from information to the color of a field. The example is a clock contrasting objective and subjective time, where the subjective time is defined as some activity, e.g. the amount people passing through a door, so that the more people that would pass through the door, the faster the time would go (see Paper I). These early examples of informative art were running on wall-mounted flat-panel displays in a meeting room in our office (see Paper I, Figure 1).

4.1.2 Trying It & Getting Ideas

As a way of getting feedback on our designs—or, to use Verplank's term, to *try it*— we arranged a one-day exhibition at the Borås Art Museum in May 2000, on their yearly night of culture. We exhibited, among other designs (see Redström, 2001, p. 31) an altered version of the Mondrian visualization where the size of the colored squares were not controlled by the amount of e-mail traffic for some office worker, but from the amount of light let into the drawers of the *Chest of Drawers*

Figure 6: Three pieces of informative art at the Borås exhibition.

(described in Hallnäs et al, 2001; Redström, 2001). We also exhibited the clock of objective/subjective time, together with a new piece visualizing the amount of visitors to the exhibition (see Paper VI) as a pattern of colored fields where the color was determined by the amount of people entering or leaving the exhibition during one minute (see Figure 5).

These early examples yielded promising results in terms of how they were received, both by exhibition visitors and people at our lab, where we had examples running on wall-mounted flat-panel displays. Feedback from users, both at the lab and at the exhibition suggested that the mappings from data to supposedly aesthetical visual structures were comprehensible which indicated that the visualization could function both as information providers and decorative elements. The examples were not quite as exhaustive as we wanted them to be, however, and we also wanted to further explore the design space, both in terms of possible information sources and new visual structures.

This further exploration of the concept of informative art, was conducted through the development of a suite of new design examples for the Emerging Techtnologies exhibition at SIGGRAPH 2001. The examples explore new possible information sources, as well as the inherent possibilities of employing an artistic "template" for the display of information. Thus we designed four new examples, with four different sources of information, mapped to four different artistic templates. We chose to work with information that the exhibition visitors could relate to, and thus would be of interest to them. The examples, which all are described in greater detail in Paper II, were:

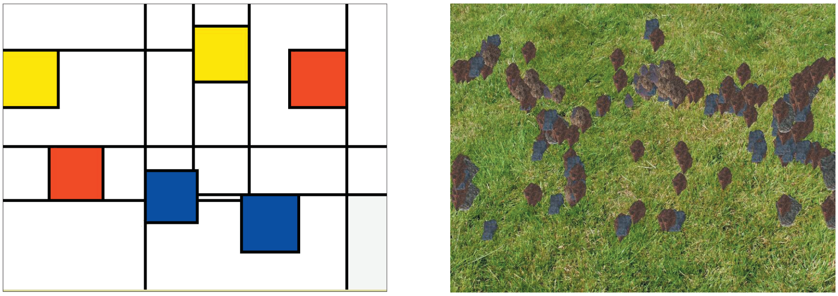

Figure 7 a & b: Weather Composition and Stone Garden

- *Weather Composition* (Figure 7a), which displayed weather information for six cities in the world using a Mondrian template. Information is mapped to the size and color of squares, which are laid out based on a world map. The motivation for the choice of information source was that weather is something everyone can relate to, and by choosing to represent cities from different continents, we got information that international conference visitors could relate to.
- *Stone Garden* (Figure 7b), which displayed earthquake data in a visualization resembling a picture of landscape art in the style of e.g. Richard Long. Information is mapped to the size of symbolic graphical elements and to the location of these elements form on the screen. Subsequently, as the number of symbols on the screen increases, they will form patterns that carry information in themselves. The choice of seismic activity as information source was based on the assumption that it was a topic of constant interest in Los Angeles, where the exhibition was held.
- *Motion Painting* (Figure 8a), which took inspiration from op-artists like Bridget Riley and abstract painters like Mark Rothko to visualize the activity in a room. Information is mapped to color of graphical elements (lines or dots, depending on the configuration of the visualization—which in turn highly affected the look of the display) and spatial mapping is determined by time which makes the visualization create activity patterns over time, where fluctuations in the activity can be seen. The information source here has an obvious connection to the place where the visualization is installed.

Figure 8 a & b: Motion Painting and Soup Clock

- *Soup Clock* (Figure 8b), which was an abstract egg-timer inspired by Andy Warhol's silk screen prints and paintings of Campbell's soup cans. The visualization counts down time until some pre-set deadline. Information is mapped to a pseudo random pattern of symbolic pictures (soup cans). At the exhibition, the soup clock was used to count down the time until the exhibition closed every night at 6 PM, and thus, like the motion painting, had an obvious connection to the setting.

The four pieces were exhibited for one week at the Los Angeles Convention Center in August 2001, to an international crowd, quite diverse in terms of background. We wanted to create a homely feeling to the exhibition and thus we chose not to use computer screens for the visualizations, but projected them onto hanging fabric (cf. Redström, 2001 p. 31). We also placed a couch, two comfortable chairs and a sofa table in our display space in order to create a kind of lounge space, where visitors could sit down for a while and see the project (Figure 9).

Figure 9: Picture from the exhibition setup at SIGGRAPH2001.

At this point, informative art had been exhibited in two different settings, to two different audiences, and although the concept had been well received, we felt the need to take the next step. Since the original inspiration for the project came from the art people use to decorate their surroundings, rather than art seen in museum and exhibition settings (although the two sometimes converge), we wanted to design an example that would let us explore how informative art worked in everyday use, where people had continuous access to a visualization.

Hence we adapted the Weather Composition exhibited at SIGGRAPH, so that instead of displaying the weather for six different cities, it displayed the current weather condition and a four day weather forecast for the Gothenburg region. A one-week study of this display was carried out at a local university, where we installed and ran the visualization on a wall-mounted 50-inch plasma display. The reception of the visualization was mostly positive, although the general consensus among the students seemed to be that a weather forecast was too static an information source to create an interesting display. When going from the spatial layout of the weather composition that was based on a world map, to the more arbitrary mapping used in this example, user's seemed to have greater difficulty comprehending the mapping—it was not as easy to find a mnemonic to remember the mapping.

4.1.3 Making Designs & Developing a Prototype

The suite of design examples in combination with the feedback from the user trials was a solid enough basis to start a serious reflection on what constitutes successful informative art visualization. It seemed reasonable that the results did not only apply to our artistically influenced visualizations, but also to the more generic class consisting of all visualizations aimed to take a peripheral role in the users' everyday lives. We chose to call this class of information visualizations *ambient information visualization* (ambient infovis, for short), to reflect their role as something blending into the surroundings, rather than something that requires the user's focused attention, like regular visualizations do. The foundations for ambient infovis are outlined in Paper IV.

The development of informative art continued through the design of a new display, again aimed at the university used for the study described above. The new visualization showed bus traffic information and was based on the Mondrian template, but this time we involved groups of potential users (i.e. university students, see Figure 10) in the design process, allowing them to give feedback on an initial design, which we then revised before the installation (see Figure 11 a&b). The visualization was running for two weeks on a 50-inch display at the university, dur-

Figure 10: Conducting a pre-study of the bus visualization.

ing which we conducted brief interviews with students spending time in the area around the display. The results from the study showed that the students in many cases were able to read the display, but that its placement sometimes hindered the use, since it was not always within sight when you were getting ready to leave, and hence was of no help.

The study helped us identify four *lessons learned* that serve as a summary of generic knowledge that we gained from our design examples and stress the importance of paying attention to issues regarding the *information source*, and *visual coding*. We found that the scope of the information source affects the relevance to the users (e.g. world weather has a much greater scope than e-mail traffic, and hence affects how the display works in different settings). The dynamics of the information source is another issue of great importance, where a balance must

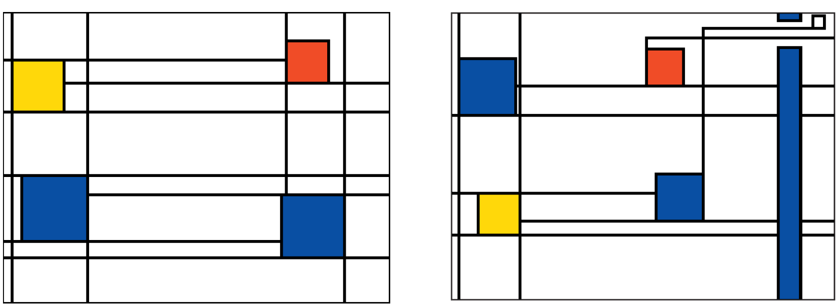

Figure 11 a & b: Intial design and redesign of the bus traffic visualization.

be struck in order to find the right amount of animation of the display (e.g. it has to change often enough for users to notice a change over time, but it should not be too animated or it will run the risk of distracting people). Regarding the visual coding, we found that using an artistic template for a visualization is not a hindrance for the comprehension of the display, and that letting some aspect of the information source (e.g. geographical features) affect the spatial layout of the visualization can be a helpful mnemonic for the mapping.

4.1.4 Testing the Prototype

Along the lines of many others, (e.g. Suchman, 1987; Dourish, 2000), we argue that the use of technology is inseparable from the context in which it is placed, both in terms of physical, architectural structures and the social structures and practices governing the use situation. When considering ambient and peripheral displays, which are explicitly designed to take their place as integrated parts of the users' surroundings, the context of use becomes even more crucial. So, in order to truly evaluate the concept of informative art, we needed to get usage data from real-life installations of a display.

Considering the results from the study of the bus display at the university, which did not see as much use as expected, we wanted to test it in another, less dynamic, setting, where people would have continuous access to the information, in order to find out how that would affect the use of the display. We also wanted to the test to run for an extended period of time to see how the use would change.

The second installation, was done in an office setting at a company with about ten users sitting close to the display (see Figure 12). The study lasted for a year, and to collect data from the users we started with on-site observations at the time around the installation and followed up these observations with iterative questionnaires that were e-mailed to the user group. We concluded the study with a final on-site observation and interview with our contact person, to see how the setting had changed during the installation. The display in the office setting saw much use during the initial stages of the study, but unfortunately the usage level dropped off significantly over time. This was mostly due to a general change of commuting habits of the users.

We also installed the display in our own lab, where it, at the time of writing, is still running. Data collection at the lab consisted of informal day-to-day observation of display use, completed with a questionnaire of a similar kind to the ones used in the company setting. This installation saw stable level of use from four users during the six months, an occasional use from one more sporadic bus traveler.

Figure 12: The bus display in an office setting (marked by white circle).

4.1.5 Principles & New Design

The lessons learned described above and the knowledge gained from studying the use of the bus display, now began to form *principles* for the design of ambient infovis. The last design example in the thesis, the *activity wallpaper*, addresses the important issue of working with information that is relevant to the prospective users. Another aspect that was in focus during the design was to work with information that maintains a strong connection to the place in which the display is situated, since our previous results had indicated that such a connection can strengthen the situatedness of the display, making it feel more as an electronic amplification or enhancement of the surroundings.

The visualization displays activity data, like in the previous examples *Exhibition Activity Monitor* from the exhibition at the Borås art museum and *Motion Painting*, from the SIGGRAPH exhibition. The visualization is inspired by wallpaper patterns and designed to be projected on a wall, so people spending time in the room can see a history of the activity in the room, reflected in the wallpaper pattern (see Figure 13).

The visualization also connects to fundamental mapping principles from information visualization in an attempt to adopt a reversed approach where the mapping is based on empirical results of how to map different data to the spatial layout and the retinal properties of the marks. The focus on aesthetics and integration is still retained with the influence of wallpaper patterns on the appearance of the visualization and color choices.

Figure 13: The Activity Wallpaper.

4.2 Discussion

In the previous section we have seen how the design examples maps onto Verplank's spiral, moving from the initial *hunch* to map information to artistic templates to the *hacks* that were the first examples of informative art. They were *tried out* at the Borås exhibition. The feedback helped the development of the *idea* of informative art, and the *designs* exhibited at SIGGRAPH. The *design* and *prototype* steps were iterated with the forecast composition and then the bus composition, and the latter was also the subject of a long-term user *test*.

This test and the aggregated knowledge from the earlier designed are summed up as *principles* for the design of ambient infovis that become manifest in the last example, the activity wallpaper, and that are further developed in this thesis.

The model is initially intended to describe the development of commercial products and for researchers, going further than the principles stage is hardly fruitful, although, as Holmquist remarks, some other part may pick up the thread and continue through the spiral.

In summary, the design examples and the evaluations describe the way from the initial hunch of combining information displays and art, to the concept of ambient information visualization. In the section below I will discuss the implications of the results presented in the papers.

5 Results

When designing ambient infovis the focus cannot be only on the input side of things, nor on polishing the output until it fits perfectly into a specific environment. The designer must take a holistic perspective from the very beginning and consider the interplay between the input and the output of the display and make sure that it is harmonious in order for the display to be regarded as an enjoyable part of the surroundings. Furthermore, a holistic perspective on the display itself is not enough: the holistic perspective must also be adopted on the display's role in the ongoing activities where it is situated. It can never become fully integrated in peoples' everyday lives unless it has the necessary properties that allow it to become *embodied* in the physical environment, as well as in peoples' lives and practices (Dourish, 1999).

The initial assumption, or hunch, to use Verplank's term, of this thesis was that the role of art as ornament or decoration in our everyday environments would be suitable for computational amplification, and this was also the reason for choosing the name *informative art*. The main motivation for the introduction of the term a*mbient information visualization* was to broaden the concept and not presuppose the use of an artistic template for the visualizations. Any developer of screen-based, peripheral information displays should be able to benefit from the findings. It was from these premises we arrived at the definition of ambient information visualization, given in section 2.3.1:

> *Use of visual representations of abstract data to enhance a physical location with digital information*

In the sections below, this definition will be scrutinized in the light of the results presented in the papers of this thesis.

5.1 Traditional Infovis vs. Ambient Infovis

The reference model for visualization described in (Card et al, 1999, p. 17; adapted here in Figure 1) describes how *Raw Data* is transformed into *Data Tables* which then are mapped to *Visual Structures*, which in turn can be presented in different *Views*. A central part of the model is the *Human Interaction* where the user can interact with the visualization to change any (depending on the visualization design) of the last three steps in order to ease the comprehension of the visualization.

With ambient infovis, however, the user cannot interact directly with the visualization, and thus has no way of manipulating the data or visual form, which means that how these parameters should change over time has to be defined ex-

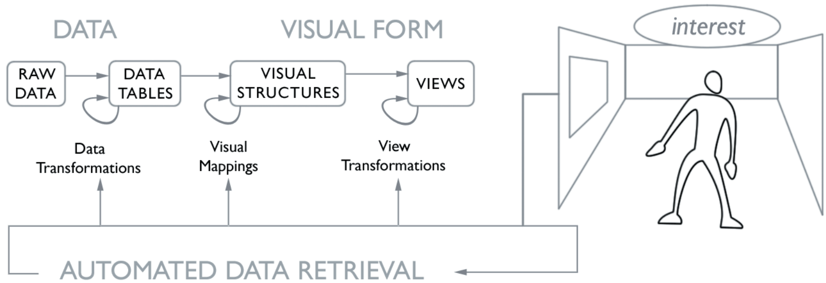

Figure 14: Reference Model for Ambient Information Visualization

plicitly by the designer. Furthermore, the use of ambient infovis is not necessarily task-driven but rather stems from an 'interest' in the information source. This is due to the fact that ambient infovis is not an application that is used as a tool to solve some task on a desktop computer, but rather a way of integrating information in the surroundings. To create a reference model for ambient infovis, these two parts of the infovis model will have to be changed.

5.1.1 Human Interaction vs. Automated Information Retrieval

Traditional infovis usually is a tool for looking at, and manipulating views of, a fixed data set, whereas ambient infovis is a means of presenting and overview of and providing awareness of dynamic changes in a data set or information source. This has fundamental implications for the design of the visualization and in the reference model for ambient infovis, seen in Figure 14, the 'human interaction' is replaced with a box labeled 'Automated Data Retrieval', indicating that any change in the appearance of the visualization is initiated by an automatic, iterative retrieval of data. How the data retrieval should be designed depends on several factors, like how often the information changes and how animated the final visualization should be (cf Lesson 2 from Paper III: *Rate of Change and Update Rate*).

5.1.2 Task-based vs. Interest-driven Use

In some instances it can be argued that ambient infovis is used as a tool; consider for example the Bus Composition, whose use can be quite tool-like. This kind of use is not inherent to the concept of ambient infovis, however, and if we consider examples like the Weather Composition or the Motion Painting, they serve more as enhancers of the users' awareness of some source of information, than as tools for some task. This "trait" of ambient infovis, acting first and foremost as awareness provider, led to the second change in the model; the change of from "task" to "interest" in the user's motivation for using the visualization in question.

5.2 Issues of Central Importance

There are some issues that, according to the results presented in the papers, stand out as being of vital importance in order for a visualization to fit the definition of ambient infovis. These issues concern *information source*, *mapping* and *use*.

5.2.1 Information Source

Issues regarding the information source are of obvious importance when designing ambient infovis. Not all information sources are suitable for this kind of presentation, for different reasons, as can be seen below.

Dynamics

In Paper IV, the importance of finding the "right" amount of dynamics for a visualization is stressed. A balance has to be struck between static and animation, where the visualization has to change often enough to be interesting but not so often that the display becomes distracting for people spending time around it. Finding an exact measure for what amount of dynamics is right is hard, or even impossible, since it is likely to change with the location of the display, the information source and the visual appearance of the display.

For example, the *Motion Painting* was running at a much higher update rate when displayed in an exhibition setting than what we found suitable for our lab, since the settings differed in terms of usage (one-time visitors at the exhibition vs. long-term regular users at the lab). Furthermore, the *Weather Forecast Composition*, was found to be too static, since the forecast information did not change more than a couple of times a day at most, which meant that the only thing in the visualization that was visibly changing during the day was information about the current weather.

Exact Information vs. Overview

One of the strengths of ambient infovis is that it can provide users with a quick overview of one or more, potentially quite complex, information sources. In Paper V, the most positive feature of the bus visualization turned out to be that the information was quick and effortless to read. The ability to convey information in an easily accessible way is an important step towards achieving the experiential cognition discussed in section 1.

Information Retrieval

How often the automatic information retrieval should be invoked depends on the dynamics of the information source. The visualization should retrieve data often enough to reveal any relevant changes in the information source. What constitutes a 'relevant change' in the information source depends, of course, on the source. In a less dynamic information source, that changes with intervals of a couple of minutes or more, all changes can be considered relevant. On the other hand, if the information source is highly dynamic as can be the case for the *Motion Painting* or *Activity Wallpaper*, may have to be toned down, in order for the visualization not to become overly animated.

5.2.2 Mapping

The mapping of information to graphical structures is crucial when designing ambient infovis. As noted in the introduction, the presentation should be such that it allows for experiential cognition. Even though quite complex tasks can become experiential given enough training, the mapping between information and visual form should ideally be simple and straightforward enough for the users to be able to remember it after a brief explanation.

Information and Aesthetics

Informative art had the explicit goal to work on two levels: first and foremost as information provider, but also as decorative element in the environment in which it is placed. To some extent this is true also for ambient infovis: even if the aesthetic aspect is toned down in the definition of the concept, the visualizations still will be placed in a certain architectural context, and the aesthetic appeal of the display is likely to affect how it is received by people spending time there. Except for the *Objective/Subjective Clock* and the *Exhibition Activity Monitor* all of the examples in this thesis use some kind of aesthetic inspiration for the visual design.

Graphical Properties of the Marks

In information visualization, much effort have been spent on finding suitable mappings between data and the graphical properties of the marks. Since the suitability of these mappings pertain to the human visual perception system, they hold true for ambient infovis as well even if it in some cases can be motivated to disregard the optimal mapping, e.g. in order to follow an artistic "template".

What should be in focus is that the resulting visualization is easy enough to read so that the most important information is available with a single glance at the visualization. The *Bus Traffic Composition*, for example, adheres to the infovis "rules" for mapping and maps the most important data in the hierarchy to the most powerful graphical property of the mark (cf Table 1): the *position* of the mark differentiates the buses, the *color* indicates the "catch status" for a bus and the *size* indicates the exact amount of time until the bus leaves (cf Card et al, 1999).

Graceful Degradation

Modern information technology has its limitations, and from time to time some link in the chain between the raw data and the user is likely to malfunction. As a designer of ambient infovis, it is important to acknowledge this, and design for these events. A visualization must have a way of indicating when it does not function properly, or users may lose their trust in the display (cf Paper V).

For example, should the visualization not be able to retrieve information from its source, this should be made visible in the appearance of the visualization. If it "freezes" and displays the last information that was in fact retrieved, or if it crashes all together, displaying error messages from the operating system, this is likely to affect the long term trust that users have in the display. For example, in Paper V, one user claimed to have lost trust and interest in the display after technical difficulties in the period following the installation of the display.

5.2.3 Use

In the beginning of this section I stressed the importance of adopting a holistic perspective on the design of ambient information visualization. Our studies of the use of the visualization show that there are aspects of the use that need to be considered during the early stages of the design process. These aspects include the interests of the prospective users, the size of the user group, and the placement of the display in the users' environment.

Relevance to Prospective Users

In order for people to want to use a display it has to display information that is relevant to them. For traditional infovis, or any desktop computer application for that matter, the designer can assume that the user have an interest in the information presented, or she would not have launched the application in the first place. Ambient infovis is placed in the users' environment and as designer, one cannot assume that everybody has an interest in the information. This has (at least) two major implications: firstly, not all information sources are suitable, and the designer should try and choose information that is relevant to as many users as possible in the location; and secondly, the visualization should be designed in a way that allows people who are not interested to ignore it; i.e. it should blend into the environment, and not alert the users attention.

The best way we have found to achieve this so far is to design displays that have a connection to the place in which they are placed, either by enhancing that place by making visible some, otherwise inaccessible, information (cf e-mail composition, activity wallpaper), or by relating information from that place with other places (weather composition).

Moreover, what information is relevant is something that is susceptible to change with the users' habits. Paper V describes how changes in the users' commuting habits had a big negative effect on the use of the bus visualization. The volatile nature of relevance is an issue that has to be acknowledged by designers of ambient displays if a stable level of use is desirable.

Placement & User Group Size

The study presented in Paper V, where the bus display is studied in different settings, shows that the placement of the display is crucial. If the visualization is not accessible to the user when she has a need for the information, she will not go out of her way to read the display, nor should she have to.

The study of the Bus Traffic Composition from Paper V shows that the visualization did not see much use in the university setting, mostly because of its placement in a semi-public area where people only occasionally spent time, and therefore did not have continuous access to the information. The same display saw significantly more use in the office and lab settings, where it was constantly accessible to a smaller group of users.

5.3 Summary

In this section I have presented what I believe to be the most important requirements for ambient infovis. A comparison with traditional infovis shows that moving visualizations off the desktop and removing the ability to directly manipulate and interact with the data set greatly affects how a visualization can be designed. The issues concern *Information Source*, *Mapping* and *Use*, which all affect the use and perception of a visualization in different ways, and hence must be regarded during the design process.

6 Conclusion

In this thesis, I have presented the design space of ambient information visualization, visualizations that are designed as a way of integrating information into everyday environments. The design space has been outlined in the intersection between the research fields of ubiquitous computing and information visualization.

The design space has been filled with a suite of design examples, whose design and evaluation have highlighted issues that are crucial to the successful design of ambient information visualization.

Our everyday environments are infinitely diverse and will thus all pose different constraints on how information presentations can be designed. A setting like a bedroom would call for extreme subtlety in the presentation whereas settings like Shinjuku, Times Square or The Strip mentioned in the introduction would require brute force and enormous size for the presentation not to drown in the surrounding noise. In between these extremes are settings that have other characteristics and peculiarities that have to be addressed by display designers. The issues of central importance presented in thesis should be general enough to be valid for the design of the vast majority of displays, and thus help to lay the foundation for a framework of ambient information visualization.

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INFORMATIVE ART: USING AMPLIFIED ARTWORKS AS INFORMATION DISPLAYS

Johan Redström, Tobias Skog & Lars Hallnäs

Informative art is computer augmented, or amplified, works of art that not only are aesthetical objects but also information displays, in as much as they dynamically reflect information about their environment. Informative art can be seen as a kind of *slow technology*, i.e. a technology that promotes moments of concentration and reflection. Our aim is to present the design space of informative art. We do so by discussing its properties and possibilities in relation to work on information visualisation, novel information display strategies, as well as art. A number of examples based on different kinds of mapping relations between information and the properties of the composition of an artwork are described.

Keywords

Art, design, augmented and amplified reality, information visualisation, ubiquitous computing.

Introduction

In hotel rooms, offices and other public spaces, as well as in our homes, pictures, posters, textiles etc. often can be seen as part of a designed environment rather than as solitary art objects. Although the distinction between design/decoration and artworks is subtle, it is clear that the pictures, posters etc. in these cases are integrated parts of a given environment.

An artwork is also a part of the environment in the sense that it can act as an information carrier giving hints about different properties of the place where they are located. The pictures, posters and other artworks in an office or in someone's home can give a visitor information about the local office culture or its owner's aesthetical preferences. Having a certain poster clearly visible to everyone entering an office, can be a way of making a statement.

In this paper we describe how other kinds of information can be mapped onto the design surface as well, making pieces of art more explicitly reflect aspects of its environment. Our aim is to present the design space of *informative art*, by discussing its properties and possibilities primarily in relation to work on interaction and information design. We will also illustrate what informative art might be like in practice, using a number of examples.

Background

There are at least two reasons for complementing the desktop PC display with other techniques of providing information from the digital realm. First, the screen estate of an ordinary display is limited and already crowded with more information than most users can gain overview of. Second, since users are not always located at their desks, and since what information is relevant is highly dependent on where and when a person is doing something, users need other ways of obtaining the desired information. The concept of ubiquitous computing [28] was introduced as a way of achieving both of these aims. As computers become available anywhere anytime, they might become a less intrusive part of our lives that poses fewer constraints on how we structure our activities, compared to the present situation. That is, if the problems associated with having information technology available everywhere all the time can be solved. It seems that much of the design strategies developed for the ordinary PC will not hold for ubiquitous computing.

One of the reasons is that the PC is designed to be one of the most important ”things” to its user, being in focus and continuously attended to when in use. This might work when we have one or maybe a few devices around, but if our environment would be full of computers – as the ubiquitous computing scenario implies – constantly calling for our attention, it soon would become intolerable. Thus, it has been argued that in order to achieve the benefits of ubiquitous computing novel ways of designing information technology that can reside in the periphery of our attention, will have to be developed [29].

Information displays of various sizes placed at a variety of locations have been a part of the ubiquitous computing paradigm since the very start [27]. More recently, other media and display strategies have been explored that are more radically different from how information is presented on an ordinary PC, e.g., the *ambient displays* created by Wisneski et al [30] and Rodenstein [22], *TouchCounters* [31], *Information Percolator* [10], and abstract information displays such as [18]. With

Figure 1: Picture showing three pieces of informative art on display at our lab.

ambient media the goal has been to integrate information displays with architectural space, often in the form of more or less ”tangible” presentations [12].

This research constitutes an important part of the background of the work presented here. However, while the work exemplified above has resulted in novel artefacts that act as displays, our aim has been to augment a traditional notion of art objects, turning the given type of design surface into an abstract information display. Aesthetics and design methods are in focus, not the development of new display techniques (cf. [3,4]).

Informative Art

With *informative art*, we refer to pieces of art that dynamically reflect, and therefore in some ways represent, information. Since this might describe almost any piece of art, given a suitable definition of 'information', it needs to be made more precise. The concept of informative art rests on a combination of the idea of using artworks to convey information, the way this was described in the introduction, with that of exploring how various objects and surfaces in physical space can be used to represent digital information.

Informative art focuses on how traditional art objects, like paintings and posters, can be augmented, or *amplified* [7], and made to display information. These amplified art objects will act as abstract information displays in the sense that the relationship between information and display surface will be a mapping between design structure and information structure rather than a effective presentation of information content. Adding a layer of information representation to an artwork can be made in several different ways. The strategy employed most commonly in the examples presented here is to map parts or properties of the composition to different sources of information, and have the composition changed over time according to the dynamics of the information.

Besides the fact that pieces of art already are used to convey information about different aspects of an environment, other properties such as placement make them suitable as information displays. The kind of artworks we are interested in amplifying, usually reside in the public spaces of an office or elsewhere where people passing by easily can take a look at them. Information displays placed at such locations have the advantage of not competing for attention with other applications, as would have been the case with yet another window on the personal computer display. Further, the information presented in informative art as described here, is not usually related to a specific person, but to a group of people or to a place. This makes it less relevant to have the information accessible on a personal computer, but more so in places where people move around in order to get a sense of what is going on. Below, we discuss some of the properties of informative art in relation to other work.

Information Visualisation

The purpose of informative art stands in contrast to using concepts and techniques developed in art to, for instance, improve application usability [2], to make more dense information visualisations possible by means of using many different layers of ”brushstrokes” [14], or the seemingly more accidental pieces of art that might be the results of various visualisation techniques, such as *TreeMaps* [13].

While these and other information visualisation techniques certainly can be said to have aesthetical values, they address the problem of how to use visualisation to create an efficient and useful tool for information exploration. Informative art, on the other hand, is more about how layers of information can be added to a certain structure or composition. This is also the reason for calling it ”informative *art*”, and not ”artistic or decorative information”. Given the importance of aesthetical considerations, informative art is related to the use of computational media in design and fine arts [16,23] (see also research groups such as [1]).

Awareness

A number of applications have been developed that support people's 'awareness' about different aspects of their environment. Especially support for spontaneous or "informal" communication among the members of a geographically distributed group by means of providing information about "what is going on" or "who is around" have been explored (cf. [5]). The rationale for such systems is that when people are co-located, physical space provides them with a number of cues, such as the sounds of people moving around or the light coming out of an office window, that seem to be of importance when engaging in spontaneous conversations. Systems more similar to the prototypes described here include for instance: *VisualWho* [6], which visualises the actions of communities on the www; *Chat Circles* [26], a system designed to enrich the virtual environment of online chat; and *AROMA* [18], a system that supports awareness of presence in a more abstract fashion.

Instead of making information about events taking place in physical space available in a virtual counterpart or by other means trying to build a richer context in a virtual social space, our aim has been to make otherwise invisible information available in the physical environment. Unlike conversations in the corridor, communication by means of for instance e-mail, documents, web pages etc., is invisible to everyone but the sender and receiver. By presenting cues about the such communication taking place at an office, we aim to provide a complement to the information already available (cf. the *Dangling String* [29]). The main purpose with the work presented here is not, however, to support informal communication, but to make the environment present information about the events taking place in it.

Designing for the Periphery

In many of the systems and displays discussed above, there has been a conscious effort in designing for the "periphery", i.e., to make the systems provide background information that does not continuously force the user to actively attend to it. In this project, we have also aimed at making the surface of the display objects non-obtrusive. This has partly been done by placing the display objects at locations where they do not interfere with too many other sources of information. However, the technology involved is also "calm" in the sense of a traditional art object: it is something we intentionally look at for moments of reflection; something we concentrate on for moments of mental rest.

The notion of peripheral attention can also be problematic. In the case of

Muzak™ [17] ”art” is used as a background technology to manipulate and affect people in certain ways, e.g., to move faster or slower through a certain area, by presenting information designed to be perceived unconsciously. This is not the purpose with the work presented here. Information is ”hidden” in the sense that it is embedded in pieces of art, but not in the sense that it is designed to be unconsciously (or *subliminally*) perceived. For instance, the changes of a certain shape in a picture might reflect changes in outdoor temperature, but this is a fact about the dynamics of the artwork that people may or may not pay any attention to, even if they find the picture as such interesting. Further, the aim with the prototypes described here is not to reduce cognitive load in terms of less demanding or more peripherally perceived displays, the way it has been argued that for instance ambient displays might help reduce information overload [30].

Amplifying Reality

With *amplified reality* we mean the enhancement of expression or functionality of artefacts using technology [7]. The canonical example is how audio technology such as microphones, amplifiers and loudspeakers are used to amplify the expression (e.g. loudness), or functionality (e.g. the use of feedback and distortion), of musical instruments. The use of, for instance, the electric guitar in rock music clearly illustrates how such amplification can increase the possibilities of expression.

In contrast to some *augmented reality* systems that use personal technologies such as goggles or headphones to superimpose digital information onto the real world, amplified reality is about the *public* presence of the physical artefacts themselves. In other words, if a personal wearable VR-system made up of head-up displays, earphones etc. enhances the *impressions* of the real world by adding graphics, sound etc., amplified reality is about enhancing the *expressions* of the real-world objects themselves using primarily embedded technology.

Amplified Artworks

The project described in this paper is an instance of amplified reality in as much as it is an attempt to make otherwise invisible information visible using amplified ”art” objects as abstract information displays. Thus we attempt to pick up hidden information, like information about local digital communication, amplify it and present it through a public media.

By an amplified art object we simply mean a technological strengthening of a traditional notion of an art object, like a painting etc., and not an enhancement of the aesthetical expression *per se*. It might be argued that this is in fact the opposite of a strengthening, at least from an aesthetical point of view, but it is a technological strengthening of the surface in the sense that we, for instance, may work with a dynamical composition that changes its appearance over time. It is clear that this mainly is a conceptual matter since the work methods are completely different from traditional painting.

The conceptual reference to a traditional notion of an art object is of basic importance here since this reference determines the intended functionality of the amplified art objects, i.e., as objects in the given environment, they are nothing but "paintings" functioning as a kind of information display. Obviously there are clear connections here with a long tradition of investigating form and material in experimental art and design (cf. [16,23]). Curiously enough the systematic aesthetics of information technology design seem until recently, e.g. [8,9], to have been rather neglected area.

Examples

In order to explore the concept of informative art, we have developed a number of prototypes that use different kinds of mappings between the dynamics of the *information* to be reflected and the composition of an artwork.

Information

The examples described in this paper are all, more or less, based on information stemming from digital communication. There are, however, a number of other sources of information that might be of interest as well. For instance, the structure of many buildings makes it quite difficult to get an overview of the activities taking place. If there are large open spaces one might see where people are moving, but otherwise information such as that many people seem to be heading for a certain lecture hall thus indicating an upcoming talk or session, is hard to obtain. Information about such more or less visible events in physical space might therefore be as relevant to the design of informative art as the occurrence of digital communication, given the purpose of amplifying otherwise unavailable information.

One possible source of information would be to use photocells placed adjacent to "important" doors connecting different areas, e.g., the door to an office corridor, in order to obtain information about approximately how many people are passing by. Such an information source would still be rather abstract since no information about whom, why, or even in what direction people are moving, will be available. Still it would be an indication of activity at that location. Another example would be to use a technology similar to the ones we have used in order to support local interaction (i.e., short-range radio transceivers that enable devices to ”know” what other devices are in the vicinity [20]) in order to make it possible for a work of informative art to obtain information about how many people are present in its near surroundings and change its composition accordingly. Such a mapping would also be a kind of abstract representation of activity at the location of the artwork.

Further, in some of the examples described above, time is used as a variable that is mapped to the composition. Other such general sources that might be or relevance includes light sensors to obtain the amount of daylight outside, thermometers for indoor and outdoor temperature etc. Thus, as there are a vast range of information sources that can be used in informative art, and since it is the different ways of mapping information to a composition that are the main focus in this paper, the information in the example below should be seen as illustrations that can be substituted rather easily for other kinds of information.

E-mail and Website Traffic

Every time an e-mail passes through a mail server, information about the mail is stored in the system log. What kind information is stored varies between different kinds of mail servers, but typically each row in the log file at least contains information about sender/receiver, what time the mail passed through the server, and the size of the mail. Similar to the e-mail servers, most web servers store their traffic in a log file. The information on each row in such a log file usually consists of what document was requested, when it was requested and who (i.e. what IP-number) requested it. To obtain the parts of this information that are required by the applications that perform the visualisations, we implemented a server application in Java, that parses the content of the log files, extracts the relevant information and finally sends it to the client(s) connected to it.

Compositions Using Colour Fields

Since many compositions make use of elements or objects with properties such as size, shape and colour, they present a number of possibilities of mapping external information onto the composition.

De Stijlistic Dynamics

Looking for inspiration for the visualisations we soon came to think of the compositions of the Dutch artist Piet Mondrian, which are based on rectangular colour fields together with black lines. Mapping information into such a composi-

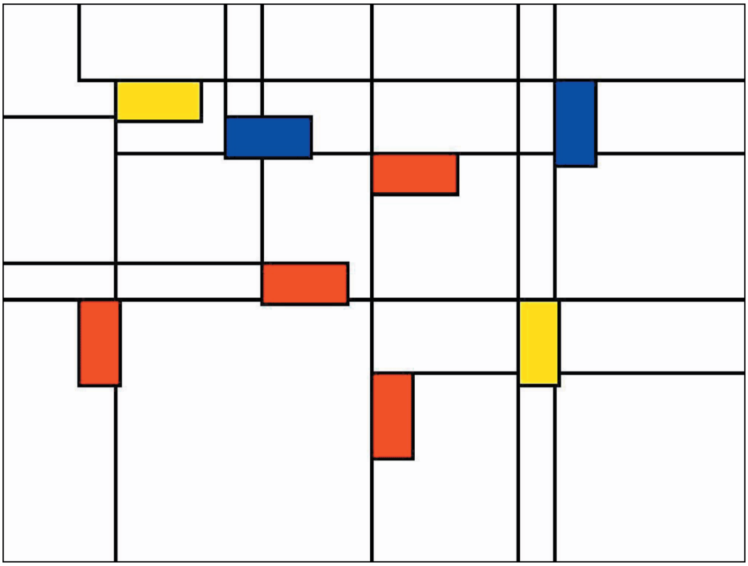

Figure 2: A Mondrianesque composition when initiated.

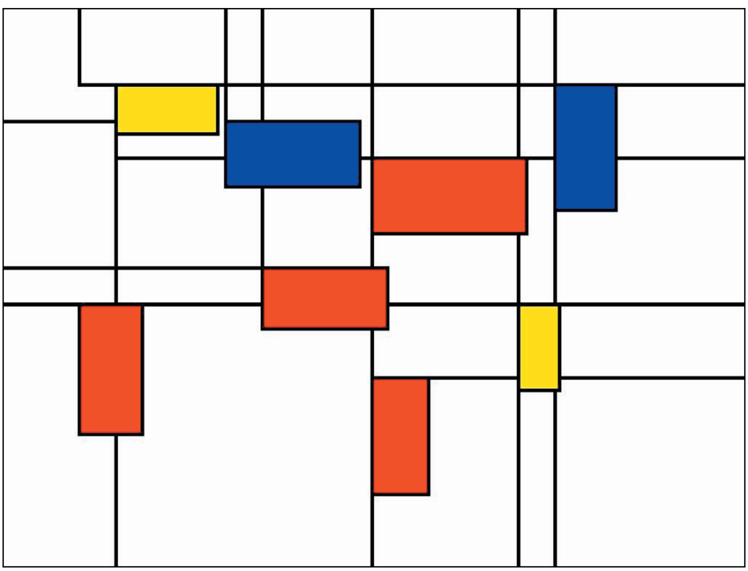

Figure 3: The same composition (fig. 2) when changed according to the e-mail traffic.

tion can be done in dozens of ways. We have chosen to do a fairly straightforward mapping, where each colour field represents the e-mail traffic associated with one person (fig. 2). Whenever a person sends or receives an e-mail, the area of the field she is represented by is increased. Conversely, if someone is not involved in any e-mail communication for a period of time, the area of her field is decreased (cf. fig. 2and fig. 3)

Every time the system starts up, a new "painting" is generated. To keep a certain structure of the compositions, each field is placed in the same place every time. The appearance of the fields, however, can vary in both shape and colour.

There are three possible shapes for the fields: quadratic, standing rectangular and lying rectangular. We have chosen to use the same colours as Mondrian did for his compositions, namely red, blue, yellow and black.

Other features of the composition, such as shape and colour of the fields, or even the lines between the fields, could also be employed for mapping information into the visualisation. In order to make the visualisations as "Mondrianesque" as possible, we have chosen not to employ other colours than the ones he normally used, since varying these too much would probably steer the overall impression away from Mondrian. However, the compositions generated only have a superficial relationship to Mondrians paintings. This was also our intention, since the aim only is to make spectators associate the composition with Mondrians paintings.

A Klein Clock

The inspiration in this example comes from the *monochromes* created by the french artist Yves Klein. A monochrome is a painting using one colour – like the blue colour in Klein's late monochromes, referred to as International Klein Blue.

Let (a,b,c) be the RGB code for a given colour, i.e. the colour of a "monochrome". We will think of the three coordinates as abstract representations of the information properties "mass", "growth" and "flow". As an example, one interpretation of these properties might be: "mass" as number of e-mail, "growth" as a ratio between the number of e-mail at a short late period of the given period and the number of e-mail at an initial period of the given period, and "flow" as a ratio between the number of incoming and outgoing e-mail.

If we measure the e-mail traffic over a period of time – say the morning hours one day – with respect to some concrete interpretation of mass, growth and flow we obtain an objective information measure that can, using a suitable coding schema, be numerically coded as the RGB code of a sort of reference monochrome (a,b,c). We may now use this reference monochrome (a,b,c) as the basis for a

Figure 4: A Klein Clock Example

structure of abstract colour symmetries in the sense that: (a_1,b_1,c_1) and (a_2,b_2,c_2) are symmetrical relative to (a,b,c) in case

$$(a_1,b_1,c_1) + (a_2,b_2,c_2) = (a_1+a_2,b_1+b_2,c_1+c_2) = (a,b,c)$$

Starting off with this, we can let the clock tick by adding RGB-codes modulo (a,b,c):

$$(a_3,b_3,c_3)=(a_1+a_2 \bmod(a),b_1+b_2 \bmod(b), c_1+c_2 \bmod(c)),$$

on the basis of given initial codes (a_1,b_1,c_1) and (a_2,b_2,c_2).

These initial colour codes can be chosen as predictions, as descriptions of an ideal state of affairs or as measures of past information activities. In this way distinctions like objective-subjective and presence-past etc. can be introduced.

The clock is divided in two fields (fig. 4). In the left field the colour of the objectivity/presence measure is present as a static reference and the structure generated by the two initial subjectivity/past colours is ticking in the right field. Each code (a_n,b_n,c_n) for a colour that is displayed in the right field is the sum – modulo (a,b,c) – of two preceding codes $(a_{n-1},b_{n-1},c_{n-1})$ and $(a_{n-2},b_{n-2},c_{n-2})$. The rate of ticking, that is the time each colour is displayed in the right field of the clock, is a function of the two immediate preceding codes, e.g.: $(C + 10 * (x + y + z))$, where C is a constant and (x,y,z) is the colour to be displayed in the right field. Each coordinate will have its own rate of ticking.

Intuitively the clock is ticking towards an ideal situation when the colour displayed in the left and right fields coincide. On its way towards this ideal state the clock will display different time structures of colours such as various cycles of repetitions etc. These structures are completely determined from a mathematical point of view given the initial codes, but can from a perceptual point of view look random at first. Gradually we can learn to read the structures and get an abstract feeling for the kind of information that generated the structure and initiated the particular time structure that ticks towards its reference monochrome. If the given information structure is simple, say extremely low activity in e-mail traffic, it is rather easy to read the colour structures displayed by the clock. But if the information is more complex it will take time to figure out what is going on. The difference in structure between different initial colours is also essential. So starting with what at first looks like random noise the viewer will gradually discover a predicable structure that can be very rich. The basic ticking algorithm discussed here can of course be varied in many ways to obtain other types of time structures.

A Clock Displaying Objective and Subjective Time

This clock is built upon the relation between the notion of ”objective” and ”subjective” time, represented by two colour fields (fig. 5). To represent the ”objective” time we have mapped the time to the colour of the outer surrounding field. At midnight it is black, then the colour slowly gets brighter as time goes by, and by noon it is white. It then starts to change back into black during the second half of the day. This effect is achieved by slightly changing the colour of the field once a minute. The nuance is changed according to an hour-long scheme that starts out by increasing (or, during the second half of the day, decreasing) the R value in the RGB-code by one every minute during 20 minutes, repeating this procedure with the G and B values. Thus, every hour, on the hour, the R, G and B values will be the same, making the colour of the composition a nuance of grey. In this way the darkness of the field will show what time of day it is, and the nuance (i.e., slightly red, blue or green) of the field will show how much of the hour has passed. While the very slow changes in colour and abstract code of a RGB-value will prevent most people from perceiving it, this is in fact a real clock that displays exactly what hour and what minute it is.

The notion of ”subjective” time is represented by making the colour of the center field reflect the number of ”events” that have passed, e.g., the amount of digital communication or the number of visitors to the office accumulated during the day. The colour of this field is updated in the same way as the other one, except that it is updated whenever an event takes place, and not when a certain time has elapsed.

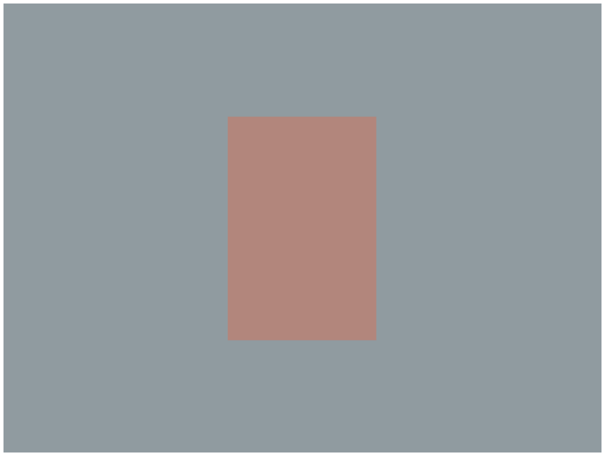

Figure 5: A clock displaying the flow of ”objective” and ”subjective” time.

Compositions Using Generative Grammars

We also wanted to use more abstract properties, such as complexity or density, of a composition to reflect information. The main problem for such a strategy is how to find a consistent way of creating different versions of a given composition. Searching for a suitable strategy, we found the techniques used in *artificial life* promising [cf. 15].

The possibility of generating increasingly complex patterns using generative grammars have raised great interest among those trying to model how complex patterns with holistic properties can arise in natural systems. So-called *Lindenmeyer systems* were developed for, and have mostly been used for, modelling the visual patterns of flowers, structural properties of plants and trees and other similar phenomena [19]. In contrast, we have used such systems to create abstract patterns, in which the repetition of shapes and structures are used to create a series of patterns which are logically related to each other.

A Lindenmeyer system is defined by a start condition, a number of production rules and a description of how to interpret them, i.e. a generative grammar which expressions are interpreted as instructions for drawing a figure or a pattern. Iterations of the rules can then be used to generate different versions of the pattern, usually of increased complexity as the number of iterations grow. Although a number of different kinds of generative grammars are employed in Lindenmeyer systems, we have only used context free grammars.

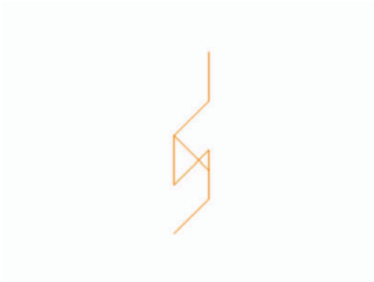

Figure 6: #7 after 4 iterations

Figure 7: #7 after 6 iterations

Figure 8: #7 after 8 iterations

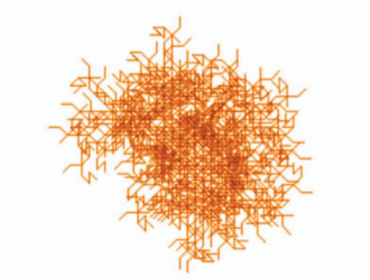

Figure 9: #7 after 13 iterations

Figure 10: #6 after 7 iterations

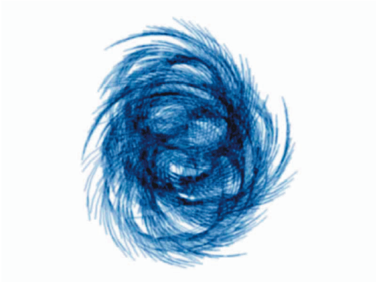

Figure 10: #6 after 14 iterations

Example

The possibilities with using context free generative grammars are perhaps best described by an example. This is the definition of the pattern used in #7 (fig. 6-fig. 9).

Axiom: X (start condition)

Rules: X: X+Y, Y: Y++[X]

Y is interpreted as "draw a straight line of length l", + as "turn 45° counterclockwise" and [...] creates a branch (i.e., [pushes current state on top of stack, and] pops current state from top of stack). X is not given any interpretation in terms of a drawing instruction.

Iterations, *i*, are generated by substituting X and Y with their respective expressions. Thus, we obtain the following instructions for generating a figure:

i=0: X

i=1: X+Y

i=2: X+Y+Y++[X]

i=4: X+Y+Y++[X]+Y++[X]++[X+Y]+Y++[X]++
[X+Y]++[X+Y+Y++[X]] (fig. 6)

We have mapped information about the frequency of communication over e-mail as well as website traffic to the number of iterations. Beside the production rules, the choice of other variables, such as turning angle, also plays an important role to the visual appearance of a pattern (as can be seen in #6 (fig. 10 & fig. 11) in which the turning angle is much smaller, 4°, than in #7, the only other difference being the second production rule where one turn has been eliminated (Y: Y+[X])). Such variables could, of course, also be used for mapping to external information sources.

WebAware - An Example Based on Spatial Layout

Applications that make use of the "spatial" properties of information (e.g., how different parts are related to each other) are an important area of research on information visualisation. *Web Aware* [24] (fig. 12) is a system that dynamically visualises the traffic on a web site and displays this visualisation in a public place. The purpose of it is to make people in a workplace aware of what is going on on their web site. WebAware falls somewhere between a more traditional information visualisation application and informative art. In being a visualisation on display in

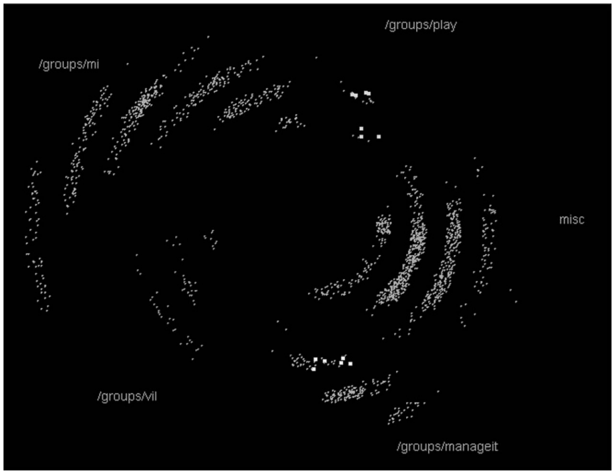

Figure 12: A screenshot of WebAware.

Figure 13: An installation of the ChatterBox using a computerprojector and a sheet of paper hanging from the ceiling in our kitchen.

a public space, bringing electronic information into the environment, WebAware can be used as an illustration of informative art.

As a basis for the visualisation, a site map based on the external structure of the site is used. The map reflects the hierarchical directory structure of the documents on the server, i.e. documents that are situated close to each other on the server are close to each other on the screen. In this way the map can be said to reflect the ”spatial” features of the tree structure.

In the map, each document is represented by a dot. When a web page is requested from the web server, the corresponding dot on the map is highlighted, and then, as the time lapsed since the download grows larger, will fade back to its original colour. In this way, information about the status of the current web site traffic is mapped to the colour of certain parts of the map, making them stand out from the rest of the map.

ChatterBox - An Example Based on Content

We have also experimented with informative art based on the content of e-mails and webpages. With *the ChatterBox* (fig. 13*)* we wanted to create an entertaining and inspiring information resource based on the e-mails sent around at an office, that also could convey information about on-going activities and projects [21]. When the ChatterBox receives e-mail (in the present version only e-mails explicitly sent to it due to privacy issues), it analyses their content and stores the sentences along with some information about what grammatical relations occur in them, in a database. In parallel to this ”listening”, it also ”talks” continuously in the sense that it generates new sentences based on the material in the database. Finally, the generated sentences are presented on a public display.

We have experimented with a number of different ways of generating sentences. The first prototype employed a technique similar to the ”cut-up” method of William S. Burroughs [25], i.e., to recombine words at random. While this strategy certainly generated new ”sentences”, the presentation was too difficult to make sense of given the aim to convey information about ongoing activities and projects. This led us to develop more sophisticated methods for analysing the original material and generating sentences that keep more of the original context, e.g., only substitutes parts of sentences with material from other sources. Still, the ChatterBox is capable of delivering quite unpredictable ”statements” about the work at an office.

Discussion

Below, we discuss some of the properties of informative art that might be of importance to future work, as well as when evaluating its relevance for information and interaction design.

Privacy Issues

Whenever information about people's activities is made available, privacy issues have to be addressed. In the case of informative art, certain examples might be perceived as surveillance tools. We think, however, that there are a number of reasons for believing that this will not be the case. First, the examples are symmetrical in the sense that everyone contribute with and have access to the same amount and kind of information. This is a property usually not associated with surveillance where observers usually know much more about the ones they observe, than the observed ones know about the observers.

Second, the information presented in the examples above is abstract. For instance, in the Mondrian-style examples where each coloured field represents one person it is hardly possible to see how many mails she has received and information about to or from whom the mail was sent is not available at all. In addition to that, people watching the display do not know what field represents which person. Further, the information used in the examples presented here is already available to anyone who knows how to obtain it.

This is not, however, to say that privacy is not an issue in informative art, but just to point to a few possible countermeasures for protecting the privacy of the people using it (cf. [11]).

Evaluation

If one wants to evaluate a piece of informative art, what are the relevant questions to ask? In the case of an information display, issues like readability and efficiency of presentation are important criteria when evaluating a design. In the case of an artwork, evaluations in this sense are not relevant at all. Instead reflection and critical analyses are of interest. Since informative art falls somewhere in between these two categories of design, evaluating pieces of informative art might be a quite complex issue.

For instance, evaluations of the ChatterBox have shown that it can be entertaining and that its output can serve as incitements for spontaneous conversations. However, it was also clear that its usefulness as an awareness support is rather limited, since some people found the recombination of material as more of a degradation of information than as something that could inspire to new ways of looking at the original. This was especially obvious in usage contexts such as at offices, where people seemed to be focused on usefulness and efficiency, properties which the ChatterBox in many respects lack. This illustrates the difference between designing something that have information presentation as its main purpose, and informative art that is designed with other considerations in mind as well, since this might lead to less efficient information presentation. Being clear about the intended purpose with the display, i.e., whether it is an ordinary information display or a "piece of art", is obviously of great importance and one has to choose methods for evaluation accordingly. In the end, the main purpose with any evaluation is to gain knowledge about and insights into a certain domain, often in order to be able to explore it further or to improve existing designs. In the case of informative art, evaluations are likely to contain elements from empirical user studies, as well as the kind of reflection and critical analyses normally associated with art rather than information technology.

Slow Technology

Informative art is not very suited to present important or transient information, i.e., information that has to be distributed and attended to within a short timespan. A piece of informative art should not demand continuous attention in order to see if anything interesting has happened. As mentioned above, the difference between a pice of informative art and a more traditional information display might be a matter of degrees and in order to get the most out of the former we believe one has to acknowledge the properties of ordinary pieces of art, posters, pictures etc. Good design for user interfaces of standard applications, like search engines, should promote fast learning, easy understanding, simplicity of use, consistency etc. It is design of fast and efficient technology, of artefacts that are tools, designed for certain specific and well defined purposes.

This type of design goals and its associated guidelines and design methods are not completely obvious when it comes to interaction design as *environmental* design, as room and space design. *Calm technology* [29] is an example of a different type of approach that comes out of the needs of environmental design

In informative art we would like to add a *slowness* factor. If an object of informative art should be of some interest as an object of reflection it can not be too fast and immediate.

There must be something to reflect on, something to understand that has an interest in its own right. The objects can not just act as tools for fast access to information. Thus there is a need for *slow technology* here, a technology that promotes concentration and reflection.

Information Representation

Compared to work on information visualisation and ambient displays, informative art will be more about how information can be reflected in a structure designed with other criteria than information representation in focus. Thus, it is more about adding a layer of information to an existing structure, than creating a structure that will carry the information from scratch. This might be an important strategy when designing computer augmented, or amplified, environments. If a seamless integration of digital and physical should be possible, the inherent properties of existing objects have to be explored and acknowledged.

We have elaborated on a number of different ways of adding a layer of information to a composition. Properties such as the size, shape and colour of objects, as well more abstract ones, such as complexity and density of a composition, have been employed. These are only samples of possible relationships between artworks and information, and it is easy to imagine a number of other variants and combination of relations as well. For instance, in the compositions using generative grammars only one variable, the number of iterations, was mapped to an external information source. Using the content of the information to control or generate the production rules themselves, as well as mapping information to other variables, e.g., the turning angle, would open up even more possibilities in creating a close relationship between composition and information. Thus, creating the artwork would be much like creating a relation between some information and a certain presentation. The mapping of information structure and design structure of the object surface is clearly of basic importance for an informative art object. This is first of all a matter of intrinsically aesthetical properties of the art object as such. In a piece of informative art the adequacy of information "presentation" should be a mere consequence of the fact that fundamental aesthetical problems are solved in a satisfactory manner. The art object will in this case not present information as directly as a time table at the railway station, but as inherent in the composition itself. We can for instance classify the examples presented above in terms of the type of information structure mapping involved:

Mondrian - information maps to the size of local surfaces in the composition

The Klein Clock - information maps to colour codes which completely defines an instance of the clock

The compositions based on generative grammars - information maps to the iteration of the constructing rules for the system

Web Aware - information maps to the spatial layout and colour of the composition.

ChatterBox - explicit information maps in a distorted manner directly on to the surface of the art object

Now if a viewer does not know anything of the background of these things, what would she understand by just watching them for a while? Maybe it would be fun to watch the Mondrian-style display behaving a bit strange, changing the size of local surfaces etc, but if somebody told the observer that this object presents the e-mail traffic at the office, would that make her understand? Our intention is that the objects should function just like art objects, so 'understanding' here just means that one gets a clue to what to look for. The object will mediate between hidden information and presence in the environment. If the structure mapping gives a satisfactory solution to given aesthetical problems, then people watching it will gradually feel a clear presence of information about e-mail traffic when passing by the object or when stopping by for a moment of reflection. This knowledge about e-mail traffic will always be abstract in a certain manner, but this is also one of the main properties of the design space of informative art.

We will not argue that informative art will imply less cognitive load than traditional information displays. On the contrary, the abstract and intricate relations between properties of a composition and some source of information might sometimes be hard to perceive instantly. The benefits of informative art therefore have to be something else. We believe that one of the most interesting properties of informative art is that it opens up a design space where information presentation can be explored from a different point of view.

Conclusions

We have presented the concept of informative art and described its design space in relation to work on information and interaction design. Besides giving a more theoretical account of how the design of informative art differs from the design of other information displays, we have presented a number of examples. The examples were also used to illustrate some of the many different possibilities of mapping information onto a certain structure or composition.

One of the most interesting issues in the design of informative art is the fact that information representation has to be achieved according to quite different criteria compared to more traditional information visualisation. In information visualisation, the structure or composition that carries the information is optimised with regards to the information in question. In informative art, on the other hand, the visualisation has to comply to criteria such as that the overall composition should be motivated from an aesthetical point of view and that the design should be able to fill the role or niche of an art object in a certain space.

Finally, informative art can be seen as a kind of *slow technology* that encourages moments of reflection and concentration in order to understand it. Thus, it stands in contrast to other information displays that are designed with readability and efficiency in mind. Informative art is not about reducing cognitive load, but about inspiring and providing food, rather than fast food, for thought.

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INFORMATIVE ART: INFORMATION VISUALIZATION IN EVERYDAY ENVIRONMENTS

Lars Erik Holmquist & Tobias Skog

Thanks to advances in display technologies, it will soon be possible to have electronic information displays virtually everywhere. We have developed the concept of *Informative Art* as a way to integrate information visualization in the everyday human environment. Informative Art combines a dynamically updated information display with the decorative role of visual art, such as posters and paintings. We present four examples of Informative Art, where we borrowed the styles of various modern artists to show different kinds of information. For instance, a composition similar to the style of an abstract painter, Piet Mondriaan, showed the current weather in six different cities, while a piece of "landscape art" in the style of Richard Long gave a view of the last 30 days of global earthquake activity. We discuss how designing information visualizations for everyday environment introduces requirement that are different from those of graphical user interfaces for desktop computers.

CR Categories:

I.3.8 [Computing Methodologies] Computer Graphics – Applications; I.3.6 [Methodologies and Techniques] – Interaction Techniques; J.5 [Arts and Humanities] – Fine art; B.4.2 [Input/Output and Data Communications] Input/Output Devices – Image display

Keywords:

Informative Art, information visualization, ubiquitous computing

1 Introduction

Electronic information displays are seemingly ubiquitous. We meet them not only the screens of the desktop computers we stare into at work and in our homes, but there are displays on mobile phones, on hand-held computers and video games, on VCRs and watches, and so on. Yet we may actually only have seen the start of their influence on everyday life.

Display technologies are becoming more affordable and unobtrusive every year, and soon there should be no need to limit advanced displays to professional use. Flat-panel LCD displays are falling quickly in price and can soon match CRT screens in affordability, yet offer much more flexibility in placement and use.

Data projectors are becoming smaller and less noisy, with increasing brightness. Even more exciting is the prospect of alternative display technologies that have yet to make it to the consumer market.

”Electronic inks” of different varieties promise to combine the readability of printed paper with the dynamics of computer graphics, for instance by allowing a seemingly ordinary newspaper or book to download new content on-the-fly [Jacobson et al. 1997]. For other purposes, a display screen can now be woven directly from electro-luminescent materials, creating a flexible, thin, high resolution display with no size restrictions [Visson 2002]. Yet another type of textile-based display may be created with photochromically coated threads, which change color dynamically when subjected to ultra-violet light [Holmquist and Melin 2001].

In the near future, we should be able to hang an affordable highresolution display on a wall in the same way as if it was a poster or a painting. Further down the line, with the help of other technologies currently in development, it should be possible to display computer graphics on almost any surface – imagine wall-paper, curtains, windows, tables, even clothing with dynamically updated computer graphics! But what happens when the computer application designer also becomes an interior decorator or a fashion designer? When creating computer graphics applications for everyday environments, we will discover that they have requirements that are very different from those we are already familiar with from designing user interfaces for traditional desktop computers.

2 Informative Art

Informative Art is a type of computer applications which borrow their appearance from well-known artistic styles to visualize dynamically updated information [Redström et al. 2000]. At first look, an Informative Art application might appear to be a static image, but its appearance will actually change continuously to reflect

Figure 1. An experimental environment with three flat-panel screens showing Informative Art.

some source of information. Informative Art is designed with the intention to be displayed in the same places where we normally encounter art or pictures in our homes, such as the kitchen or the living-room, as well as in public spaces or in the workplace. Currently, it is most convenient to use projectors and flat-panel screens to display Informative Art, but in the near future we expect other, more suitable display technologies to become available.

For the sake of illustration, imagine that Figure 1 depicts a living room or workspace in the near future. There are what appears to be three different paintings on the wall. These ”paintings” are in fact wall-mounted displays, each of which is connected to a computer that runs a different Informative Art application. One of these applications might create an abstract composition of several black lines and colored fields, reminiscent of the famous abstract paintings by Dutch painter Piet Mondriaan. However, each of the fields in this ”painting” in fact represents a person, e.g. a member of a family or a workgroup. The size of each field represents the size of the person's e-mail queue, so that the more unread e-mail there is, the larger the corresponding field will be. Thus, the ”painting” will change its appearance depending on the situation – for instance, if it is a busy day with many e-mails being left unread, the image will be dominated by large colored fields. Individual variations will also become apparent. If for instance someone is away for several days without reading mail, the field representing that person might grow much larger than the others. It is possible to imagine many other mappings between various types of information and the image: the color of a field might change depending on the person's location (at home, at work, etc.), or the size and placement of the fields might change to reflect relevant if a person is in a meeting or talking on the phone, and so on.

It should be pointed out that an Informative Art application does not necessarily provide exact information – for instance, one cannot tell the exact number of unread e-mails each person has in the above example, but only if there are ”a lot” or ”very few”. Also, the display will change quite slowly, so that changes will usually not be noticeable unless one looks at the display for an extended period of time, or if there are long intervals between each time it is viewed. These are conscious design decisions that have been made to make the applications function more like a visually pleasing artwork, and less like animated computer graphics.

3 Related Work

Ever since computers with graphical output became available, there have been attempts to automatically create artistic images using computer algorithms, sometimes with results that mimic the style of human artists. In pioneering work beginning in 1962, A.Michael Noll created a number of computer-generated black-andwhite artworks [Noll 1995]. Of particular interest to our work are Noll's ”Computer Composition With Lines”, in the style of Piet Mondriaan's ”Composition With Lines”, and ”Ninety Parallel Sinusoids With Linearly Increasing Period” which closely paralleled Bridget Riley's ”Current” (both 1965). In our Informative Art applications we have used inspiration from other images created by the same artists, but we used different algorithms to create our images. Following on Noll's works, many other automatic computer art systems have been created. However, such research is mostly outside the scope of this paper, since our focus has been on the use of art as an information medium in the everyday environment, rather than on computer generation of visual art for its own sake.

The notion of distributing information displays in the everyday environment originally grew out of the concept of ubiquitous computing, where computing resources are distributed in the everyday environment rather than being confined to a desktop workstation [Weiser 1991]. In a development of ubiquitous computing the term Calm Technology was coined to describe technology that is ”encalming”, and reduces information overload by engaging both the center and the periphery of our attention [Weiser and Brown1995]. An example of Calm Technology is the Dangling String. This was piece of cable hanging from the ceiling and connected to a small motor, which in turn was affected by the amount of traffic in the local ethernet. The more traffic there was in the network, the more the cable would shake, thus giving an inexact but very evocative indication of the activity in the network.

Another closely related concept that of Ambient Media [Ishii and Ullmer 1997]. Ambient Media are information displays that are designed to reside in the periphery of the user's attention, relying on the human capability for ”background processing” of information. For instance, light from a lamp was directed through a water tank that in turn was affected by a motor, so that water ripples could be created, which would then be reflected in the ceiling. This motor could then be connected to an information source, so that for instance the level of activity in the local network would be reflected by intensity of the water ripples reflected in the ceiling.

Slow Technology is an area that grew out of earlier work in Informative Art [Hallnäs and Redström 2001]. The philosophy of Slow Technology is quite different from that of Ambient Media or Calm Technology, since it does not directly try to make human information processing more efficient. Instead, Slow Technology is was created to encourage reflection on the design and aesthetics of computational artefacts. A user interface based on such principles is the opposite of an intuitive interface, because it is explicitly designed so that it will ”take time” to learn what it is and how to use it. This is reflected in some of our Informative Art applications, since users will need an explicit explanation to fully understand their function.

Some other recent projects where information displays have been developed with the intention to be integrated with everyday environments include the Information Percolator, where a decorative information display was created using a system of liquid-filled tubes and air pumps [Heiner et al. 1999]; Digital Family Portraits, where the border of a digital image was employed to convey information about the health status of a person in a remote place [Mynatt et al. 2001]; and Information Collages, where informational images were automatically generated from an aesthetic template based on paintings by artists such as Kandinsky [Fogarty et al. 2001].

Informative Art differs from previous work in the way it relies on inspiration from both the appearance and the function of traditional art. While other projects have played on familiar metaphors and natural phenomena (ethernet cables, water ripples, etc.) they have for the most part not attempted to supplant existing

Figure 2. We strived to create a home-like environment in which to exhibit Informative Art applications

decorative artefacts. On the other hand, projects such as Digital Family Portraits, InfoCanvas [Miller and Stasko 2001] and LumiTouch [Chang et al. 2001] use the physical form of paintings or photo frames, but the content is not designed with any obvious aesthetic considerations. Information Collages has used a similar motivation as our work, but did not elaborate on the practical implications of deploying information visualization in everyday environments.

4 An Informative Art Installation

We have created an installation containing a number of Informative Art applications, which was first exhibited at SIGGRAPH 2001 Emerging Technologies [Skog et al. 2001]. The applications were all written in Java to run on laptop PCs. The graphics were projected using standard data projectors. However, rather than using ordinary projection screens we decided to project the images onto large pieces of white textile. This choice was made to illustrate how Informative Art should be considered more as a decorative wall-hanging or a drapery, rather than a computer application. In combination with carefully selected furniture, this arrangement gave our installation a considerably more ”home-like” appearance than a typical computer technology showcase (see Figure 2).

Each of the applications was inspired by the work of established 20th-century artists. When developing the applications we took inspiration from many printed reference sources on modern artists and styles (e.g. [Britt 1989; Hughes 1991]). It is illustrative to compare our results with their artistic inspiration, but for copyright reasons we can not reproduce any artworks in this paper. In the appendix we supply Internet addresses where examples of these works can be seen.

To illustrate how Informative Art is a general concept which can be used to visualize different types of information, we used a variety of information sources. These included global information that is readily available on the Internet, such as the current weather; and local information, such as the activity in the environment as perceived by a camera.

4.1 Weather Composition (Figure 3)

This application was inspired by the abstract compositions created by Dutch artist Piet Mondriaan in the 1920's, where he used the primary colors red, yellow and blue combined with black or grey lines on a white background. These works were part of the larger art movement ”de Stijl”, which produced many other similar works by Mondriaan's contemporaries. We took inspiration from this style to create an applications which displays the current weather in six different cities around the world.

The image consists of six colored squares, on a background of black lines forming an irregular grid. Each square is mapped to a particular city in the world. The placement is roughly based on a world map with the Greenwich meridian in the center, so that the position of each square corresponds to the ‘ approximate position of the corresponding city on the map. We chose a range of cities from countries around the world, which would have different temperatures and conditions. The upper row represents from left to right Los Angeles, USA; Gothenburg, Sweden; and Tokyo, Japan. On the lower row is Rio de Janeiro, Brazil; Cape Town, South Africa; and Sydney, Australia.

The position of the squares is fixed, but the current weather in the corresponding city affects the appearance of each square in two ways. The size of the square changes with the temperature in the city, so that the hotter it is, the bigger the square will get. The color of the square is determined by the weather conditions in the city. We took the same primary colors that Mondriaan used – red, yellow and blue – and mapped these to weather conditions. Yellow means clear weather, blue

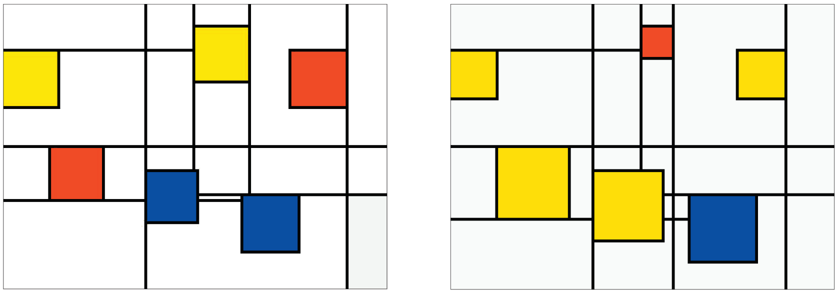

Figure 3. A weather display showing the weather in six international cities, inspired by Piet Mondriaan. The left image was generated in June 2001, the image to the right in December 2001, illustrating the differences in temperature between summer and winter on the north and south hemispheres.

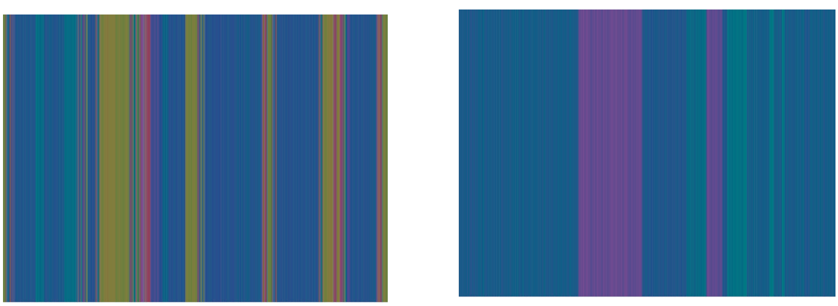

Figure 4. A reflection of the activity in a space over time, inspired by Bridget Riley's "Op-art". The image to the left shows several instances of high activity, whereas the right image reflects a periods dominated by low activity.

represents some kind of downfall (rain or snow), and red means cloudy weather. We reasoned that yellow would be associated with sun, and blue with water – the remaining color, which was red, then came to mean cloudy conditions.

The weather data was downloaded from the Yahoo! Weather service (weather.yahoo.com). A dedicated server application ran on a separate computer, continuously downloading and parsing the weather information. The server sent data to the client approximately once per minute, which made adjustments to the visuals accordingly. The position of the squares and lines was hard-coded into the application; the size and color was then adjusted according to the incoming data.

4.2 Motion Painting (Figure 4)

Here, our main sources of inspiration were the bright and colourful "Op-art" patterns created by British artist Bridget Riley in the 1970's and 80's. The application relies on information about the movements in a room, as registered by a digital camera. Over time, the application will create an image that reflects the level of activity in the area visible to the camera.

The application works by continuously painting thin, parallel vertical lines in shifting colors from left to right. When the far-right side of the image is reached, the painting starts over on the left, covering the entire image in about 30 minutes. The color of each line is determined by the amount of motion in the area overlooked by the camera. On start-up, the camera is calibrated to the current level of activity in the room, and a base color is selected by the user. During painting, each line differs more or less from the hue of the base color depending on the amount of activity, so that if the activity level is similar to when the camera was calibrated, the lines are very close to the base color, but if the activity is different, their hue differs more or less radically from that of the base color.

The application captured images from a standard Web cam, using Sun's Java Media Framework (available at java.sun.com/jmf). The level of activity was measured by capturing an image from the camera and comparing it to a previously captured image. A numerical value of the difference was created by subtracting all the pixel values of the two images – the higher difference, the more activity would have taken place between the two captures. The value was then normalized by dividing it with the number that was derived when calibrating the application, so that when the activity level was similar to that during calibration, the resulting number was close to 1. The resulting numerical value was then used to determine the hue of the currently painted color, by multiplying it with the hue of the base color, so that the more the number differed from 1, the more different would the painted color be from the base color.

4.3 Stone Garden (Figure 5)

This piece was inspired by ”landscape” artists, such as England’s Richard Long, who create art from natural elements, for instance by placing patterns of stones on grass lawns. We appropriated this style to visualize a very ”earthly” type of information, namely global earthquake data.

Similar to the Weather Composition, the lawn corresponds to a world map, with the Greenwich meridian in the center. Whenever an earthquake occurs, an image of a stone is placed on the lawn. There are 10 different stones, and the size of the current stone corresponds to the magnitude of the earthquake on the 10-graded Richter scale. The position of the stone directly corresponds to the latitude and longitude of the earthquake. The application has access to information about the last 30 days of earthquakes, thus giving a comprehensive view of recent earthquake activity. Clusters of stones will be formed in areas where there is high activity, making it possible to discern geographical areas with high geological activity, such as Japan and the Californian coast.

A dedicated server application downloaded and parsed earthquake information from the home page of IRIS, the Incorporated Research Institutions for Seismology (www.iris.edu). The client, running on a separate laptop, queried the server for data and updated the display accordingly. The visualization was updated every minute, so that when a new earthquake was detected, it would show up almost immediately. The graphical elements that made up the image – the lawn and 10 stones of different sizes, one for each number on the Richter scale – were based on digital photographs taken by the authors.

4.4 Soup Clock (Figure 6)

This piece was inspired by the early 1960’s works of American ”Pop” artist Andy Warhol, where images from advertising and popular culture were repeated over and over with small variations. We took the iconic image of a Campbell soup can, as used in many of Warhol’s works, and created a form of clock or ”egg-timer”. This application would show the passing of time by gradually replacing the image of one kind of soup with another.

The image consists of 55 soup cans of two distinct flavours and colors: asparagus soup (yellow), and tomato soup (red). When the countdown starts, there will only be asparagus soup cans, and the dominating color is yellow. As time passes, one by one the asparagus cans will be replaced by tomato soup, so that at the final moment when the countdown is over, there will only be red soup cans left. The clock can be set to start and end at any time, for instance to keep track of a lunch

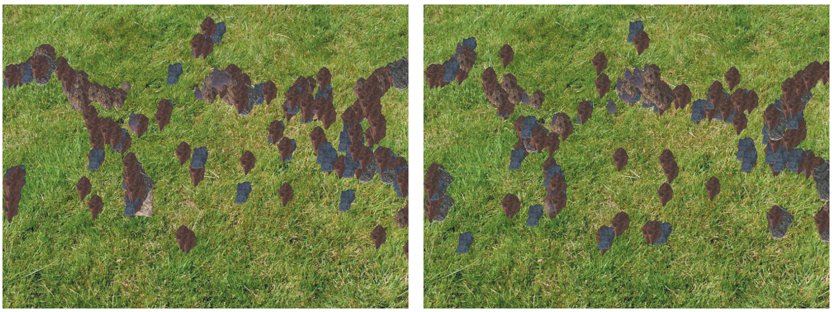

Figure 5. 30 days of global earthquake activity displayed as "landscape art", inspired by Richard Long. The left image was generated in June 2001; the image on the right is from December 2001. Earthquake-prone areas such as the Californian coast are clearly visible.

Figure 6. A count-down clock or "egg-timer" inspired by Andy Warhol's paintings of Campbell soup cans. In the left image, only a little time has passed; at the right, most of the time has passed.

break or the time it takes to cook an egg.

The application relied on the computer's internal clock to tell the time, with starting and ending times supplied as parameters on startup. The placement of the tomato soup cans was based on a pseudo-random algorithm, so that each new can would be added at a random place, but since the random seed was always the same, the same pattern of placement would be repeated every time the application was run. The graphical elements were based on touched-up digital photographs of actual Campbell brand soup cans, taken by the authors.

5 Discussion: Designing Information Visualizations for Everyday Environments

Informative Art illustrates some important ways in which the requirements for computer applications for everyday environments are different than those on a desktop screen.

5.1 Movement and Animation

Informative Art occupies a place somewhere in between an animation and a static image. They are not static, because the images do change depending on the information source; but they can hardly be called animations either, since changes usually take place very slowly. It is actually not uncommon that uninformed viewers mistake Informative Art for static images, because unlike with most computer applications, ”nothing happens” to show that the applications is running.

This ”slowness” represents a conscious design decision. As is well known from research on human perception, quick movements and animations in the periphery of human vision will attract a person's attention [Sekuler and Blake 1994]. If an Informative Art application incorporated too much movement, it would continually draw attention to itself, much like a switched-on TV set. Several times in our own work, we have been forced to tone down the animation in an application, for instance by letting only a small portion of the image change at a time rather than the whole picture. This means that even if a dynamic visualization works well on a desktop screen, the same visualization might be so distracting in an everyday environment that it is practically unusable.

5.2 Interpreting Information Over Time

For an uninformed viewer, it is difficult or even impossible to figure out what kind of information is shown in a piece of Informative Art. To be useful, each of them will require an explanation. Wecould have made the applications in our examples easier to understand at first sight, for instance by providing captions which identified each city on the Weather Composition. However, we believe that not only would this have made the images less attractive and detract from the clean artistic styles we were striving for – it would in fact be unnecessary.

A piece of Informative Art is designed to be present in the user's everyday environment for an extended period of time, and therefore, instant comprehension is not crucial. If someone installs a piece of Informative Art in her home, she will make sure that it fits her interests as well as her taste, and will thus probably be well informed of its functions from the outset. Similarly, if a piece is installed in a public place, there should be some kind of explanation available (e.g. a caption) but one should trust users to be able to find out the details over time. If the piece is well designed, users will then have no problems explaining it to others, and the information will spread. At the SIGGRAPH exhibition, we observed how visitors were first puzzled, but after having been given an explanation of the installation, they were immediately able to explain it to other visitors. Informative Art thus represents a different approach than the traditional one user / one application philosophy of personal computing. We are currently performing preliminary experiments in public places to explore how this kind of ”mouth-to-mouth” information spreading works over time.

5.3 Exact Information vs. Overview

Informative Art will generally not provide the viewer with exact information. For instance, in the Weather Composition, it is not possible to see exactly what the temperature is in Tokyo, but only e.g. if it is ”warmer than in Sydney” or ”very cold”. In the same way, the Warhol Clock does not give the exact time, but gives a ”sense” of how much time has passed. We believe that the information provided in these cases is quite sufficient for everyday use, and for detailed information it is always possible to turn to newspapers, Web sites, etc. It is actually possible that users in time will learn to ”read” the visualizations in such detail that they might eventually be able to get just as detailed information from Informative Art as from a list of numbers.

However, Informative Art provides something which other mediums do not provide: a continuously updated overview of a complex information source. While the current weather is available (and in more detail) from other sources, to get the same information as the Weather Composition it would be necessary to visit 6 different web pages once per minute. Similarly, information like the global earthquake activity shown in the Stone Garden is also available on the Web, but only in a format that is difficult to interpret for most users. This means that in reality, users have no easy way to access the information provided by our applications. Thus, Informative Art provides a possibility to ”reveal” information that is otherwise hidden or hard to interpret, and make it available in everyday settings. We believe that there are many types of information that would be suitable for this kind of visualization. For instance, the financial or organizational state of a company might be displayed publicly on the company’s premises using Informative Art, to give employees a continuously updated view of the situation.

5.4 Aesthetic Concerns

Everybody decorates their personal space to make it more ”livable”, and the configuration of furniture, plants, photos, posters, etc. directly reflects and influences the personality of the inhabitants. Informative Art must be able to fill the same role. Since the concept is based on the idea that Informative Art should occupy the same kind of places that paintings and posters currently do, it was crucial to make our applications visually appealing. However, the authors are not artists and have no formal training in the visual arts. Instead we chose to ”borrow” inspiration from famous works in the history of visual art. Many of the original artworks we used for inspiration are available as poster reproductions, bearing out their popularity as decoration in everyday spaces.

But ultimately the choices we made, and the choices that everyone else will have to make in the design of computer applications for everyday environments, must be based on aesthetic concerns. This is an area that still remains largely unexplored in user interface research, although it is starting to gain attention. In particular, it has been suggested that when computers start to permeate everyday spaces, our attitude towards them will have to shift from one of ”use” to one of ”presence”, as is already the case in areas such as furniture design and architecture [Hallnäs and Redström 2002].

6 Future Work

Our work in Informative Art is still at an early stage. We believe it is an area that gives rise to many important questions. We also believe that it is rife with possibilities not only in user interface design, but also in related areas including computer graphics and display technology.

6.1 Long-term Evaluations

We will need to study more closely how Informative Art can be incorporated into the everyday human environment, in particular for long-term use. The effects of Informative Art can not be easily evaluated using laboratory studies in a limited environment, but should instead be studied in real-life settings. This will require advances in the robustness of our applications, ideally so that they can run for several months with no need for supervision. It also puts demand on the physical environment and installation of display equipment. Initially, we plan to install Informative Art in public places that people spend time in and often return to, e.g. cafés or the lobby of a company, and study the effects using qualitative methods such as interviews and ethnographic studies. We are also working with display manufacturers to develop displays than are suitable for displaying Informative Art in everyday environments.

6.2 Display technology

We have been using mainly data projectors and flat-panel LCD or plasma displays. These technologies have problems that need to be addressed before they become a viable option for use in everyday environments. Many issues that are not a problem when a display is used professionally may become a serious concern in everyday use. Fan noise from projectors that is acceptable during a presentation will not be tolerated in a living room. Excessive heat is another problem, especially with many displays in the same room. Current displays (particularly LCD-based screens and projectors) are often sensitive to burn-in when an image is displayed for a long time. Finally, power consumption and the associated costs must be considered, especially if a display is to be running at all times.

All of these problems might be solved in future technologies such as electronic ink and electro-luminescent fabrics. However, we believe that traditional display technologies could also become suited for everyday use, if they were designed from the start with such use in mind. Electronics manufacturers have already introduced products such as electronic picture frames to which an image can be downloaded from the Internet, but much research still remains before a computer display can be laced in a home with the same ease as a painting or a drapery.

6.3 Application of Computer Graphics Techniques

There are several areas of computer graphics which would be suitable to apply in Informative Art. In particular, in the field of painterly rendering, many rendering techniques have been developed that imitate the styles of individual artists or even entire artistic movements (c.f. e.g. [Hertzman 1999]). By using these, it would be possible to create works of Informative Art that closely mimic the work of human artists. For instance, it would be possible to create images that look like they had been painted with water color, but which dynamically change their appearance according to an information source.

One might also use generative techniques such as L-systems, cellular automata, etc., could be utilized in informative art, since the output of such systems is often visually appealing. These techniques have already been used extensively for the realistic rendering of plants [Prusinkiewicz and Lindenmayer 1990], and such botanical images have recently been applied to the visualization of complex information [Kleiberg et al. 2001]. In Informative Art applications which incorporate natural phenomena, such our Stone Garden, generative computer graphics techniques should offer many possibilities.

6.4 End-user Customization

Some of the mappings between data and visualization in our examples may seem arbitrary, and would not represent a natural choice for many users. For instance, people would sometimes interpret the colors in the Weather Composition differently. Some associated blue with blue skies, i.e. clear weather; others though that blue meant cold and red meant warm. The reason for this is that our current applications were designed completely by us, with no input from prospective users. However, we believe that future Informative Art applications would benefit from end-user customization, so that prospective users might change the mappings according to their tastes. Similarly, the types or instances of information should also be possible to change. In the weather display, most users would probably want to change the application to show cities that were of direct interest to them, rather than those chosen by us. Similarly, rather than seeing the current weather, they might want to see the weather forecast, or perhaps some completely different information, like the traffic congestion on a nearby highway.

This type of end-user customization will require an amount of modularity and generality that our current applications do not have. Ideally, a user should be able to connect any information source to any visualization, so that for instance the activity in a room might be visualized using an Andy Warhol motif, or the weather forecast shown in the style of Bridget Riley. It should also be possible to combine Informative Art applications provided by different authors or companies. Providing this kind of flexibility will provide a challenge in many areas including software engineering, information visualization and user interface design.

7 But Is It Art?

The final issue that must be addressed is Informative Art's relationship to ”real” art, as created by professional or amateur artists. The authors' position is clear: Our Informative Art examples are not art. The purpose with this work has been to explore new ways of introducing information displays in the everyday environment. We do not consider ourselves artists and do not have any artistic intentions or training. However, from the outset it was clear to us that our applications would benefit from the aesthetic sensibilities that an artist could provide. Therefore, we ”appropriated” what we considered good visual art that we believed would be suitable to display in an everyday environment. This can be likened to how musicians ”sample” sounds and melodies to create a new work.

The work also raises the question of copyright, and the relation of our applications to the specific artworks that served as inspiration. We have in no case used copyrighted materials in our applications, but instead we paraphrased a general style or visual appearance. Perhaps some of the artists would have been dismayed to see how we used their work as influence. For instance, whereas Mondriaan painstakingly composed each of his images, our paraphrases are much less carefully constructed and would probably not stand comparison with any of the works produced at the height of De Stijl. On the other hand, Warhol's interest in pop culture and repetition should have been well served by today's computer technology. Therefore, we believe that having artists as collaborators will be beneficial in the future design of Informative Art, and we plan to work with artists and designers in forthcoming projects.

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FROM USABLE TO ENJOYABLE INFORMATION DISPLAYS

Sara Ljungblad, Tobias Skog & Lars Erik Holmquist

1. Introduction

When computer screens are used as public information displays, the information presentation is usually designed to be as efficient as possible. This is appropriate considering the traditional view of usability, where you wish to achieve optimal readability. Think of timetables for buses and trains, lists of arrivals and departures at airports, parking meters, clocks, etc. They are all efficient in the sense that they successfully communicate the information they are supposed to, but they rarely feel exciting or aesthetically pleasing (see Figure 1). At the same time, in the same places, you will find various forms of adornments, placed there with the intention to entertain and stimulate the people spending time in these places. In a similar way, in our private lives, we decorate our homes and offices with posters, paintings and other decorative objects to create an environment that appeals to our senses.

If people like to surround themselves with decorative objects like posters and paintings and at the same time there is a need for public information presentation in their surroundings, why not incorporate the enjoyment factor into the design of information displays?

The urge to try and beautify information displays is an issue that has been recognized by others as well, and attempts are sometimes made to make existing information displays more enjoyable, integrated parts of the surroundings. For example, at the central train station in Göteborg, Sweden, a small wooden tower holds a computer screen listing current arrival and departure times (see Figure 2). Despite the designer's effort to make the display more enjoyable by incorporating it in a decorative object, the dull appearance of what is presented on the screen makes it stick out rather than blend in. A more sensible way of designing a decorative information display might be to use people's aesthetic preferences as a starting point when developing information displays that are intended to be enjoyable rather than just usable. Imagine, for example, a weather forecast presented in the

Figure 1: Electronic timetables for public transportation are seldom attractive, designed to be usable rather than enjoyable.

style of a painting of a well-known artist such as Piet Mondrian, displayed on a flat panel screen on your living room wall.

This is a scenario that is more feasible than one may think. Plasma and LCD screens are already advertised as being suitable for hanging on the wall like paintings [6]. They were initially developed as, and intended for viewing TV, video and DVD, but could also become part of spaces where we socialize, read and relax, e.g. displaying a decorative picture. In this case, the computer screen works fairly well as an adornment, but the possibilities that advanced technology offers are much greater. This is especially obvious if you consider that in a near future, things like curtains, walls, lamps and tables could be augmented to present real-time information. Computer technologies are becoming more affordable and less obtrusive every year and new technologies such as "electronic inks" and electro-luminescent materials may soon allow flexible materials such as paper and fabrics to become computer displays. If people are to have various objects in their everyday environments constantly presenting information, it is necessary to make the presentation blend into the surroundings, or the amount of information calling for attention will be overwhelming.

Figure 2: At the Central Station in Göteborg a computer screen is built into a tower to make the display more aesthetically pleasing.

Pictures of various kinds are commonly used as decoration, in the form of paintings and drawings as well as photographs but also, since the birth of computer graphics, in the form of computer generated imagery. Anyone familiar with the field of information visualization is aware that a picture that presents complex information can be beautiful, and at the same time a very effective way to describe, explore and summarize a set of numbers [7]. Information visualization uses the possibilities given by computers to present overviews and manipulate large data sets or complex data. In this way, pictures make it possible to show information that would otherwise be hidden or hard to interpret [1]. Furthermore, advances in computer graphics are making it possible to dynamically transform pictures, e.g. with painterly rendering and color transformations, such as those found in Adobe Photoshop filters.

Informative Art is a playful combination of these traditional wall decorations, such as paintings, and dynamic computer displays [2]. At first glance, an informative art visualization looks like a piece of abstract art, but instead of merely presenting a static image, its visual appearance is continuously updated to reflect some dynamically changing information. The resulting visualization is then

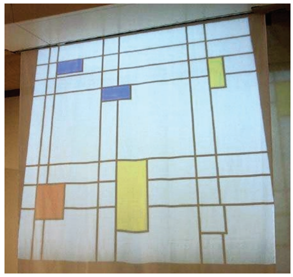

Figure 3: Informative Art: A visualization of e-mail traffic inspired by the dutch artist Piet Mondrian.

shown on a wall-mounted display to give the impression of an ordinary painting. Installations of informative art have previously been displayed in conference settings, such as SIGGRAPH Emerging Technologies [3].

1.1 An Example of Informative Art

To illustrate the concept of informative art, we will now describe the display seen in figure 3. The projected image is reminiscent of a Mondrian painting and visualizes e-mail traffic for a group of people working in an office. The visualization has six colored fields, each of them reflecting the e-mail traffic that one person has been involved in during the last 24 hours. The more e-mail a person sends and receives the larger the field representing that person gets.

The colors of the fields indicate how much time has passed since a person last sent an e-mail. A field can be of any of the three primary colors Mondrian used for his compositions, i.e. *red*, *yellow* and *blue*. In our visualization, red indicates that a person is "hot", i.e. that she recently sent an e-mail. As time passes without this person sending an e-mail, the color "cools down" to yellow and finally, if the person has not sent an e-mail in a long time, the field turns blue.

The result is a "calm" information display – inspired by Mark Weiser's idea of ubiquitous computing [8] – running in an office environment, constantly providing a group of people working there with updated information on their e-mail traffic.

1.2 Related Work

Examples of computational technology that is designed to inspire and entertain, rather than just to be efficient tools to accomplish some task, have become more frequent during the last decade of HCI research. There have, for example, been several efforts to amplify everyday objects with computational power and repurpose them into information appliances, not unlike what we have done with the informative art visualizations.

One such example is [Ishii], where glass bottles are used as a "transparent" interface to a computer, as envisioned by Mark Weiser in his Ubicomp scenario. The bottles were designed to "provide easy and aesthetically pleasing access to digital information". The digital information is contained within the bottles, and can be released by uncorking them. For example, three bottles can form a "jazz trio" where each bottle contain one instrument, and by uncorking them, you can hear the instuments play a piece of music, etiher by themselves or in ensemble, depending on which bottles you uncork.

At the Royal College of Art in London, Bill Gaver and colleagues are exploring design for ludic aspects of everyday life. In [Drift Table] it is stated that when designing for ludic purposes, one should even de-emphasize the pursuit of external goals, since: *"Ludic activities are, by definition, non-utilitarian. If a system can easily be used to achieve practical tasks, this will distract from the possibilities it offers for more playful engagement."*

As an example of design for ludic purposes, they present the *Drift Table*, a table with a built-in viewport through which you can see aerial photography of England and Wales drifting by. You can navigate the map by placing various items on the table surface, which is load-sensing, so if you for example place a heavy book on one side of the table, you will make the map view move in that direction (unless, of course, the book is counter-balanced by another, heavier item on the opposite side of the table). The photography is in high resolution (the map data is approximately 0.8 terabyte) and the "top speed" with which the view of the landscape can move is approximately 50 kph, which means that moving through the landscape is something that takes hours and days rather than seconds or minutes.

Although our purposes with informative art are not entirely in line with the ones Gaver et al. state above—our displays sometimes *do* have a utilitarian purpose—we argue that a more "artistic" way of displaying information, recognizing the need for incorporating ludic values into HCI, still can encourage exploration and reflection.

2 A Case Study of Informative Art

In what sense would a piece of informative art be enjoyable? Would people actually be able to read it? To find out, we decided to conduct a study of everyday use of informative art. The ambition was to get perceptions and opinions from as many people as possible, to explore if our visualizations would work in an everyday setting.

2.1 Setting and Preparations

The fall of 2001, the IT University in Göteborg, Sweden, started its first semester with about 150 students, distributed over five Master programs. We considered the university to be a suitable setting for trying out our display, since the university students constituted a fairly large, yet naturally limited, group of prospective users.

Before starting to design a visualization, we conducted a pre-study, involving 31 students, with the aim to get suggestions for suitable information sources that would be of interest for the students. How we intended to present the information was not brought up in detail in this pre-study, only that the presentation would use graphical shapes rather than text. We got several suggestions, including timetables for public transportations, available lecture rooms, current news headlines, etc. One of the most common suggestions was weather forecasts and since we previously had worked with visualizations of weather [3] and this was information that was readily available online, we chose to design a local weather forecast for the Göteborg area.

2.2 Weather Composition

Our previous weather visualization was part of the SIGGRAPH exhibition mentioned above, as one out of four pieces of informative art [6]. It was called *Weather Composition* and was based on a Mondrian template similar to that used for the e-mail visualization described above. It mapped weather information for cities around the world to the size and color of six squares.

In the visualization, each square represents a city in the world. The cities are scattered over six continents; North America, South America, Europe, Africa, Asia and Australia. To make the mapping easy to remember, the spatial layout of the squares are based on a world map, so the squares form two rows where the squares in the top row, from left to right, represent Los Angeles, USA; Göteborg, Sweden and Tokyo, Japan. The bottom row, from right to left, is Rio de Janeiro, Brazil; Cape Town, South Africa and Sydney Australia. The size of the fields represent the

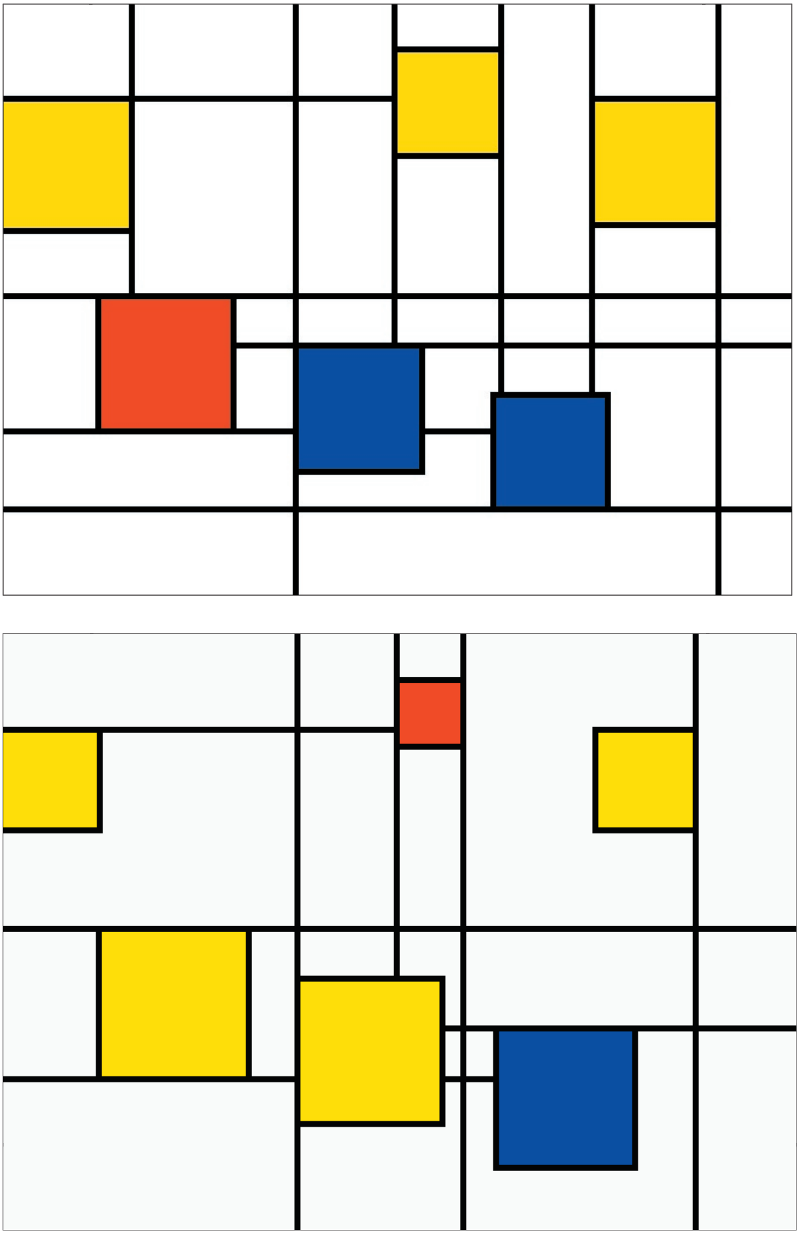

Figure 4: Two screen shots of the Weather Composition. Captured in August and December of 2001.

current temperature in the city, so the hotter it is the larger the squares get. The colors are mapped to generalized weather conditions, where yellow means sunny, blue means rainy and red means cloudy. Figure 4 shows two screen shot of the visualization taken in August and December of 2001. The first screen shot shows no big differences in the temperature in the cities, but the weather conditions do differ a bit. In the latter screenshot you can clearly see the big differences between the cold Swedish winter and the hot summer days in the southern hemisphere. The visualization was popular among the exhibition visitors and proved to be easy for people to read when they were provided with a brief explanation. Easy enough, in fact, for returning exhibition visitors to be able to explain the mapping to other visitors who saw it for the first time!

We chose to build the new visualization on the same code base as the Weather Composition, adapted to display a weather forecast of the Göteborg region.

2.3 Implementation Details

The visualization is implemented as a Java application on a standard PC running Windows (see Figure 5 for a schematic view). The application consists of two main parts: an information retrieval and extraction part and a visualization part. The information retrieval is invoked every five minutes to reflect any changes in the weather dynamically. It downloads the weather information from the Yahoo!® Weather service (`http://weather.yahoo.com`), parses the HTML code and extracts the text. Next, the document is searched for the relevant information, i.e. the current temperature and weather condition plus the forecast for the next four days. The visualization differentiates three different weather conditions:

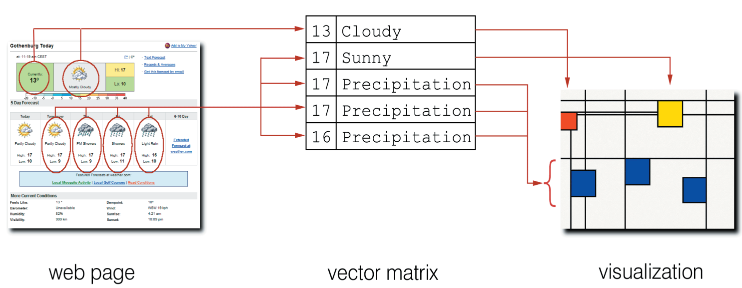

Figure 5: Schematic view of the implementation. On the left, the Yahoo! weather web page, from which the weather data is taken, an put in the Vector matrix seen in the middle. From the values in the matrix, the visualization on the right is created.

Weather/Color	Yahoo! Weather Categories
Clear (Yellow)	Sunny, Clear, Fair, Haze, Hazy, Widespread Dust, Windy, Mostly Sunny, Partly Cloudy
Cloudy (Red)	Mostly Cloudy, Cloudy, Fog, Foggy, Smoke, Showers in the Vicinity
Precipitation (Blue)	Light Drizzle, Drizzle, Scattered showers, Showers, Light Rain, Rain, Freezing Rain, Mixed Rain And Snow, Blowing Snow, Scattered Snow Showers, Snow Showers, Heavy Snow Shower, Wintry, Wintry Mix, Flurries, Light Snow, Snow, Thunderstorms

Table 1: The Yahoo! weather conditions and their interpretations.

clear, *cloudy* and *precipitation*, and since the weather information retrieved from Yahoo! is far more detailed than that simple distinction (it has 33 different weather conditions), we had to make an interpretation of the Yahoo! weather condition categories. This interpretation can be seen in Table 1.

The temperature and weather condition values are stored in a 5x2 `Vector` matrix. When the information is retrieved, the values from the Vector matrix are used to change the appearance of the visualization accordingly.

The resulting piece is similar to the Weather Composition, but here each colored square on the display represents the weather for one day, rather than the current weather in a city (See Figure 6). The display is read western style, left-to-right, top-to-bottom. The first square (top-left) represents today's weather, the next one represents tomorrow and the three in the bottom row represent the following three days. The weather is mapped in the same way as in the weather compostition, so the five squares in present a four-day weather forecast (plus the current weather) in the following way: The size of a square reflects the temperature for that day. The hotter it is, the larger the square becomes. The colors of a square show the weather condition of that day: yellow represents a clear weather, blue represents precipitation and the remaining primary color; red, represents cloudy weather.

The squares positions in the visualization are fixed, with the upper left corner as "anchor point", which means that they will grow down and to the right as they get bigger. The black lines in the composition carry no information, they only move with the size of the squares.

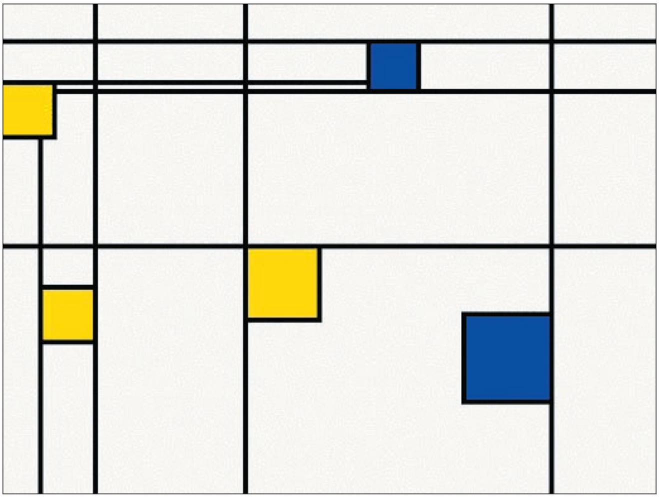

Figure 6: A weather forecast of the Göteborg Area.

3 The Study

We installed the visualization on a laptop computer that we hooked up to a 50-inch flat-panel plasma screen. The screen was one of several displays that were part of the infra structure at the university and was mounted on a wall in an open public space, usually referred to as "square 2". Surrounding the square on three sides are offices, lecture rooms and a design studio (see Figure 7). The square was furnished with about ten groups of tables and chairs where the students often worked when not attending lectures or working in the design studio. We kept the display running 24 hours a day during the test period, which lasted for a week.

During this test period, we conducted two studies, one of which was preceded by a brief tutorial, given to a group of students, on how to interpret the visualization. During the tutorial, the about 30 students were given an introduction to the overall concept of informative art and then taught how to read the information.

To collect feedback from the students, we used questionnaires that were handed out to randomly selected students who were spending time in the square. The questions were designed to establish the user's comprehension of the display and their opinion of it, with special focus on its role in the environment, and also their overall opinion on the usefulness of peripheral information display. We handed out the questionnaires in two passes, one after three days of use and another after a week. The two studies yielded a total of 40 questionnaires, 15 of which came from students who had attended the briefing.

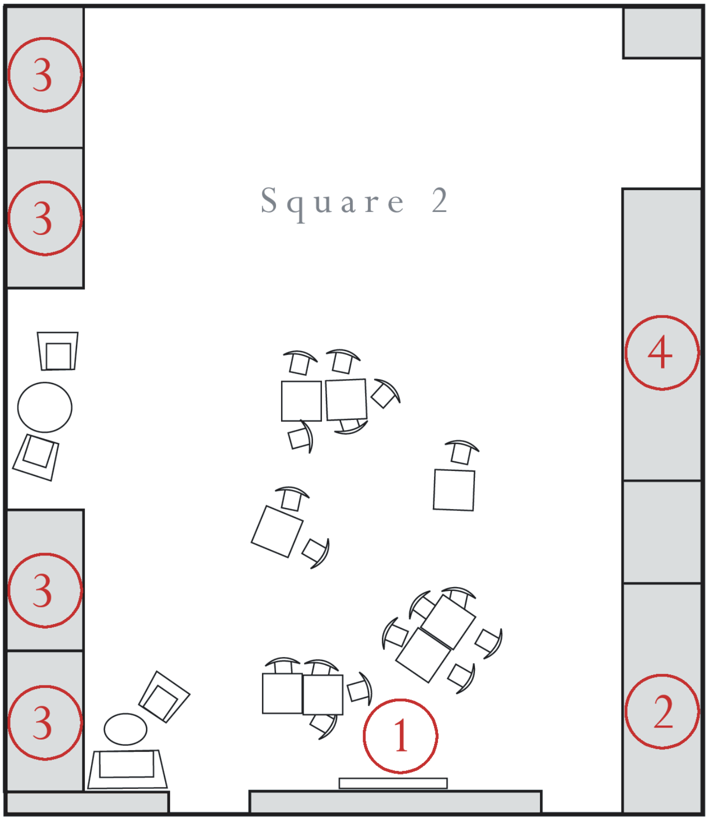

Figure 7: Map of square 2. 1: the display, 2: design studio 3: offices, 4: lecture room

3.1 Students Who Attended the Tutorial

When provided with a brief introduction, a majority of the students indicated that they could read the visualization, that they enjoyed it, and that it naturally blended into the background. Two students made the following comments:

> *"I think it is good because the information is transmitted in a simple way. I don't find the display annoying either, which is positive."*

> *"Very good. Easy to learn and it immediately blended into the background and consciousness. Actually, I don't want it to be taken away."*

Figure 8: The Local weather forecast presented as informative art at the IT University in Göteborg.

However, it turned out that misinterpretations and misreadings did occur, even for students who had been to the briefing. One person made the following comment:

> *"An interesting and different way to show an uninteresting weather forecast. The question is how interesting it is to show a forecast with graphics. It would be more informative if it was the actual weather that was being presented."*

In fact the piece was designed so that the interpretation of the coming four days temperature would be guided by the current weather, which together with its representation on the display, would serve as a frame of reference. Other people also seemed to have mistaken the display for showing a weather forecast for the coming five days, rather than today's weather and the coming four days.

One student suggested that blue could be associated with a blue sky rather than rain. Another subject found it hard to map the days to the position of the squares as they had different sizes and did not follow a line. This person also mentioned that she associated blue with cold and red with heat.

As we wanted a decorative image to become an information display, we suspected that some might find it hard to read. Considering this, we also expected that people would be skeptical about this way of presenting information. Despite our fears, the comments were generally positive as the majority actually said that they liked it. One person appeared to be excited by the novelty and surprise introduced by the concept, commenting that it was:

> *"Fun and sensational!"*

3.2 Students Who Did Not Attend the Tutorial

Those who did not attend the tutorial were usually not aware that the piece was a weather display, let alone how to read it. As the piece only rarely changed its visual appearance, some students believed that it was a static image. One person made the following comment, indicating what she thought about using a plasma screen to display an image:

> *"…this is fairly useless as a painting. The machine is meant for animated images, right?"*

This was not the only person who seemed to believe that the display showed desktop wallpaper or a temporary image rather than information:

> *"I don't know what it is but it looks like art."*

> *"A bad paraphrase of a painting made by Piet Mondrian"*

> *"Some digital art"*

When we designed the piece we did not want it to be annoying or attention grabbing. Thus, instead of having gradual transitions or animations that would attract attention, the changes appeared instantly. Many who did not know that it visualized information commented that they had not noticed any changes. The fact that they did not perceive changes might have been affected by the fact that they neither expected it to reveal information, nor to change its visual appearance.

Some people clearly sensed that it probably was displaying some information, without knowing exactly what:

> *"It is hard to see if the pattern has changed. Whatever it shows is hard to read"*

> *"I don't understand the content, but with some information about the context…"*

Without any given context, it seems very hard, if not impossible to know that informative art visualizes information, regardless of what it is.

Some students had their very own suggestion on what was visualized. For instance, one student believed that the piece was a map, showing cold and warm fronts. Another student had a more peculiar explanation (especially considering the University was located in Göteborg!):

> *"It is a network visualization, part of the subway in Stockholm."*

Those who did not understand the information could still appreciate the piece as a decorative item, which some seemed to do, considering the following comments on the piece:

> *"Inspiring!"*

> *"Pretty, however I think that it may be different (the attitude) depending on what kind of art you like."*

3.3 Discussion

Based on the results gathered from the students who had not attended the tutorial, we see that it is hard if not impossible to figure out what the information is without an explanation. The fact that "we see things through the eyes, but we understand things with the mind" [5] is literally inevitable with informative art. Whereas many information displays provide the context along with the information, with informative art you need to know what to look for, in order to interpret it correctly. Thus, you will only be able to read the information if you know how to "decode" the visualization.

The majority of the students who had attended the tutorial expressed in their answers that they liked the piece; some indicated that the display was both enjoyable and readable:

> *"It is a nice and easy way to get weather information"*

> *"I got an explanation right away, and then I understood what it visualized, I thought it was nice."*

Perhaps an even more important result that this particular piece was readable by some and enjoyable was a comment that went beyond the current application. A student emphasized that not only did she find it inspiring, but also that the piece raised ideas on how other information could be presented.

4. Conclusion

Informative art is not designed to display information in the most efficient way, but rather in a fashion that appeals to people's sense of aesthetics. In general, it does not provide the viewer with exact information, but instead gives an overview or summary of some data, e.g. that the temperature will rise in the coming days, or an overview of the e-mail activity in a group.

It is possible, however, that people could eventually learn how to extract more detailed information from a piece of informative art so that in some cases, it could replace a numerically precise presentation. For instance, in the case of the Mondrian weather display, people might after some time learn to associate the size of a square with a certain temperature, rather than just get a sense of whether it will be colder or hotter in the next few days.

People who are not aware of the informative content of a piece are likely to perceive informative art as pure decoration. Without an explanation it is extremely hard, perhaps even impossible, to know what a certain piece visualizes. This suggest the possibility to show private information in a place where other people also spend time. For example, a piece of informative art could be placed in someone's office to give a daily update about her stock portfolio, or show the time elapsed in different projects. Visitors would look at the decoration, but not be able to read the information.

Is informative art the solution for getting rid of the boring information screens displaying arrivals and departures at airports, parking meters etc. in public places? Probably not; these information displays are designed with efficiency and readability as the most important design criteria. As they display information that has a need for exactness, this field of application is probably not the best one for something that has as a primary aim to be enjoyable. If the same information is presented for a group of people who read the timetables everyday, the time left until the next bus could indeed be presented with informative art.

In the future, informative art could give us a continuously updated overview of complex information and provide opportunities to expose and visualize information that is otherwise hidden or hard to interpret. For instance, context-related information, such as the amount of people in a building or the activity in a workplace could be visualized with graphical shapes and patterns. Such displays would be constantly running in the background in everyday environments, and could ultimately provide a form of natural or "calm" technology, combining an informative function with the aesthetic and visual appeal of traditional art.

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BETWEEN AESTHETICS AND UTILITY: DESIGNING AMBIENT INFORMATION VISUALIZATIONS

Tobias Skog, Sara Ljungblad and Lars Erik Holmquist

Unlike traditional information visualization, ambient information visualizations reside in the environment of the user rather than on the screen of a desktop computer. Currently, most dynamic information that is displayed in public places consists of text and numbers. We argue that information visualization can be employed to make such dynamic data more useful and appealing. However, visualizations intended for non-desktop spaces will have to both provide valuable information and present an attractive addition to the environment – they must strike a balance between aesthetical appeal and usefulness. To explore this, we designed a real-time visualization of bus departure times and deployed it in a public space, with about 300 potential users. To make the presentation more visually appealing, we took inspiration from a modern abstract artist. The visualization was designed in two passes. First, we did a preliminary version that was presented to and discussed with prospective users. Based on their input, we did a final design. We discuss the lessons learned in designing this and previous ambient information visualizations, including how visual art can be used as a design constraint, and how the choice of information and the placement of the display affect the visualization.

CR Categories: B.4.2 [Input/Output and Data Communications] Input/Output Devices – Image display; H.5.1 [Information Interfaces and Presentations]: Multimedia Information Systems; H.5.1 [Information Interfaces and Presentations]: Evaluation / methodology – Screen design; I.3.8 [Computing Methodologies] Computer Graphics – Applications

Keywords: Ambient information visualization, informative art, ambient displays, calm technology

Figure 1: An example of ambient information visualization: a visualization of bus departure times, inspired by the artist Piet Mondrian

1 Introduction

Information visualization can augment human cognition in many ways, and has proved useful in professional application areas such as scientific visualization and business management. But what are the potentials of information visualization in everyday life? Could infovis techniques be used to support “mundane” activities, such as catching a bus or finding out what the weather will be tomorrow? There are many places where there is no immediate access to a computer, but where information visualization might be used to provide time-critical, localized, or otherwise important information. In this paper, we explore how ambient information visualization can take infovis out of the desktop computer screen and into the real world.

Designing information visualizations for off-the-desktop use is different from designing for other electronic media, such as interactive software or web sites. One cannot simply put up a computer screen in a living room or a train station and run some standard visualization software. First of all, we cannot expect potential users to be immediately familiar with the visualization techniques involved. Thus, even more than with ordinary information visualization, it will be necessary to carefully design the mappings in the visualization so that they can be grasped quickly and are easy to read, even from a distance. Second,ly aesthetic concerns become a major issue when a visualization is integrated with a larger environment. It will be necessary to design visualizations that not only provide useful information efficiently, but also blend in with the surroundings and are appealing to look at. Furthermore, ambient infovis should contain only a minimum of animation, since the human eye has a tendency to automatically be drawn to moving images, which could prove to be a major distraction [Sekuler and Blake 1994]. These two conflicting concerns – aesthetics and utility – must be reconciled to create truly useful ambient information visualizations.

In previous work, we have been drawing inspiration from famous artists when designing information visualization, creating so-called informative art [Redström et al. 2000, Holmquist & Skog 2003]. By basing our visualizations on well-known artistic styles, we hope to create ambient information visualizations that literally look "good enough to hang on the wall", while still providing useful information. In this paper we will describe the iterative design of our most recent example, a dynamic visualization of bus departure information inspired by the Dutch artist Piet Mondrian. The visualization was designed in collaboration with prospective users and deployed at a local university (see Figure 1). Based on this experience, we outline important criteria for the successful design of ambient information visualizations, and how their design relates to that of traditional infovis applications.

2 Ambient Information Visualization

Information visualization is commonly defined as "the use of computer-supported, interactive, visual representations of abstract data to amplify cognition" [Card et al. 1999, p. 7]. By ambient information visualization, we mean information visualization applications that do not reside on the screen of a desktop computer, but in the environment or periphery of the user. Using ambient information visualization, dynamically updated data sources can be presented in new environments, where a traditional computer display may not be suitable.

Using the physical environment to present information has been explored previously, in particular in ambient media [Ishii et al, 1997]. In ambient media, information displays are designed to present information in the periphery of the user's attention. For example, the authors introduced a lamp that uses different intensity to indicate variations in an information source. Closely related to this is the term calm technology, which was coined to define technology that moves between the periphery and the centre of the user's attention [Weiser and Brown, 1995]. When correctly designed, calm technology should become a natural part of the user's everyday surroundings. An example of calm technology was the dangling string, an installation where a hanging piece of wire would shake more or less depending on the traffic in the local network.

Many ambient displays have been based on physical constructions, but this puts limitations on the flexibility of the display and the complexity of the information that can be shown. A natural choice would therefore be to use computer graphics for ambient displays, but the cost, size and capabilities of computer screens has been a hindering factor. However, display technologies are rapidly advancing and becoming more affordable, and therefore it should soon be possible to hang a high-resolution display on a wall as if it was a poster or a painting. In the future, technologies such as electronic ink and color-changing textiles may make it possible to display computer graphics on almost any surface, even wallpapers or curtains [Jacobson et al. 1997, Holmquist and Melin 2001].

Several peripheral displays using computer graphics have been presented recently. A common approach seems to be to take information from traditional wall-hung art to inform the design and use of such displays. InfoCanvas are specialized computer displays that provide awareness of some source of information using images, creating a form of "virtual paintings" [Miller and Stasko 2002]. Information collages are automatically generated, aesthetic collages in the style of certain artists that reflect dynamic information [Fogarty et al. 2001]. Digital family portraits mimic the appearance and function of a picture frame, placing updated information about the health of an elderly family member in the border of the photo [Mynatt et al. 2000]. Our own related work in informative art will be further discussed in section 3.

Ambient information visualizations present new challenges to the application of established infovis techniques and evaluation methods. For example, an important criterion for information visualization in science and technology is display effectiveness, where time, accuracy and cognitive workload are measured [Nowell 1997]. Such a measure of effectiveness is relevant when applied to systems that are designed to perform work-related tasks. Ambient information visualizations, on the other hand, will be lived with rather than used, which means that traditional measures of effectiveness may not necessarily be the most relevant [Hallnäs and Redström 2002]. More specifically this suggests that factors such as calmness and appearance might be just as important issues for an everyday application as effectiveness is for professional tasks. This in turn means that new evaluation criteria, based on long-term usage studies rather than lab experiments, may need to be developed.

3 Informative Art

Informative art is a subset of ambient information visualization, in that it is situated in an everyday environment rather than on a computer screen. In the design of informative art we were inspired by the appearance and function of paintings, posters and other objects that people use to decorate their living spaces [Redström et al. 2000]. Previously, we have created several examples of informative art, inspired by artists ranging from Andy Warhol's pop-art, Bridget Riley's op-art and Richard Long's landscape art [Holmquist and Skog 2003]. Data sources that were visualized included the passage of time, the movements of people in a room, and world-wide earthquake activity.

The most fruitful template for informative art so far has proved to be the Dutch artist Piet Mondrian, who did a number of recognizable works in an artistic movement called "De Stijl" (literally, "the style"). In the section below we will describe three previous generations of informative art, all inspired by Mondrian.

3.1 Previous Mondrian Designs

Within De Stijl, Mondrian created a characteristic and immediately recognizable style of painting. His most famous compositions consisted of arrangements of colored fields and black lines over a white background. In these works, he used only three primary colors, namely red, yellow and blue. This style is immediately recognizable, and its surface characteristics are easily reproduced with computer algorithms (in fact, some of the earliest experiments in computer graphics-based art mimicked some of Mondrian's black and white compositions [Noll 1995]).
We found the characteristic look of Mondrian's compositions to be a good basis for an abstract information visualization. The use of three easily distinguishable colors together with geometrical shapes seemed ideal for our purposes. We have so far used Mondrian's style to visualize dynamic data concerning e-mail traffic, current weather, weather forecasts, and most recently bus departure times. Typically, data has been mapped to the size, position, and color of the fields in a composition, giving us three possible dimensions to use for visualization, although not all were used in all examples.

3.1.1 E-mail

The first example of informative art can be seen in Figure 2. It is a dynamic display of e-mail traffic, designed to be situated in an office [Redström et al. 2000]. Each of the colored fields in the visualization represents the e-mail traffic for one person. The size of a field is mapped to the amount of e-mail sent and received by that person during the last 24 hours. The color of the fields carries no information, but is randomly appointed at start-up. Every field has the same position every time, so by time it may be possible to differentiate between the different persons in the office. However, in this case we were more concerned with the overall impression of activity in an office, rather than that of individual users, which is why there is no immediate way of determining which field represents which person.

3.1.2 World Weather

A second example of a Mondrian-inspired visualization was one of four pieces exhibited at the Emerging Technologies section of SIGGRAPH 2001 [Skog et al. 2001]. Here, we displayed current weather information for six cities around the world, which was taken in real-time from a web page. Each city is represented by a colored square, whose size is mapped to the current temperature in the city. The higher the temperature is, the larger square gets. The color of the square is mapped to weather conditions, where yellow means sunny or clear, blue means downfall, i.e. rain or snow, and red means overcast.

The distribution of the squares is loosely based on a world map metaphor. Each square's position in the visualization roughly corresponds to that city's placement on a world map, with Europe in the center. The cities shown here are, in the top row, from left to right: Los Angeles, Gothenburg (in Sweden) and Tokyo. The bottom row shows Rio de Janeiro, Cape Town and Sydney. This mapping turned out to be quite easy to learn for visitors at the exhibition, and we felt that the visualization gives a good overall view of the weather situation in the selected cities.

3.1.3 Local Weather Forecast

This visualization is an altered version of the one described in section 3.1.2. This visualization was adapted to show a weather forecast for the local Gothenburg region, taken from a web page [Skog et al. 2002]. Each square represents the weather of one day. The size and color are mapped to temperature and weather respectively, as in the example above. The position, however, does no longer give geographical information, but indicates what day the weather forecast is for. The left-most square in the upper row shows the current weather condition and the right-most shows the forecast for the next day. The forecast for the following three days is shown, from left to right, by the squares in the bottom row.

This prototype was installed for evaluation purposes on a large plasma screen at a university in Gothenburg (Figure 4). We first asked students what sources of information would be interesting to have visualized by informative art, and weather information was one of the most common suggestions. The visualization

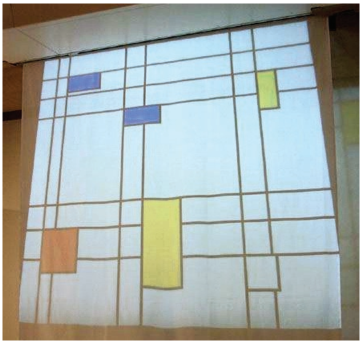

Figure 2: A Mondrian-inspired visualization of e-mail traffic.

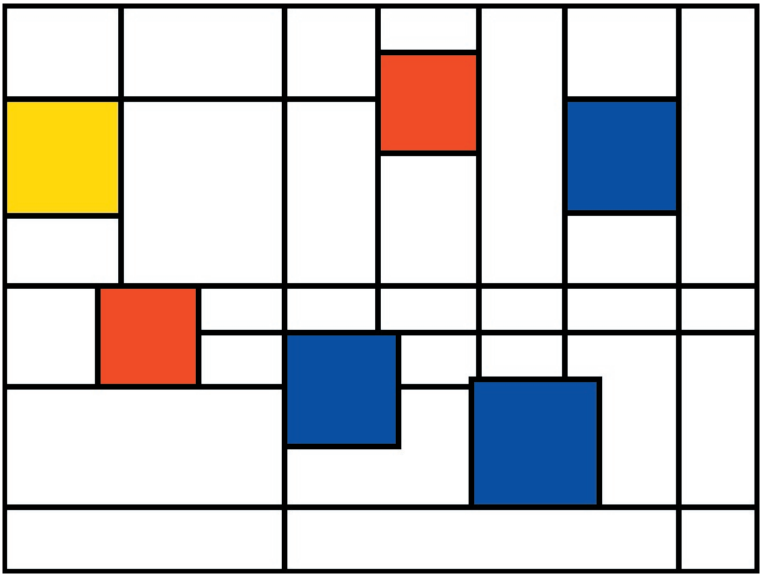

Figure 3: A visualization of the current weather in six cities around the world

Figure 4: Informative Art visualization of a local weather forecast, running in a university setting.

was then created and we had it running at the university for an evaluation period of one week. We found that students were able to learn to use the visualization after a brief introduction, but we also identified several problematic issues in the design. For more information, see [Ljungblad et al. 2003].

4 Designing an Ambient Information Visualization of Bus Departure Times

During the design of the weather forecast visualization (above), another of the most frequently requested data sets was public transportation information. At the time, there was no source providing reliable data of this kind. Timetables could have been used, but since a timetable does not provide actual real-time data, and since the buses to and from the university often were delayed due to passenger overload, we decided not to use this data for the visualization.

In early 2003, however, the local transit authority started providing a new web-based service keeping track of buses and trams in the public transportation network. This service uses the transit authority's sensor system, installed to keep track of buses and trams in the city. This information is available for commuters at larger bus stops, in the form of large text-based LED-displays, indicating how many minutes remain before the next bus or tram arrives (see Figure 5). The web site has a page for each bus/tram stop in the network. In turn, each page contains traffic information for all bus/tram lines trafficking that stop, showing when the next two buses/trams are due to arrive at that stop.

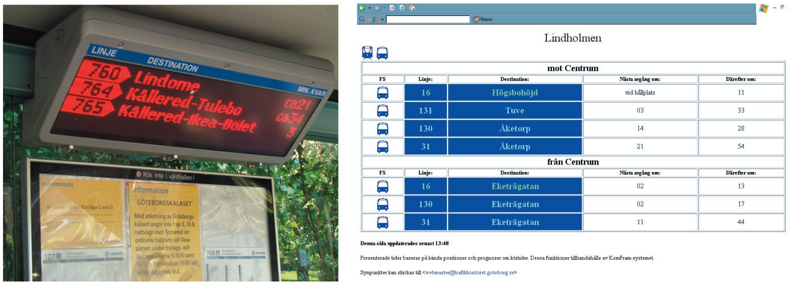

Figure 5: LED-display showing bus & tram traffic information (left),

When this information was made available on the web page (Figure 5) we saw this as an excellent opportunity to create a new visualization for the students at the university. Almost at the same time, a new bus line was added (line 16), connecting the university and the central parts of the city. Many of the students have started to depend on this particular bus for their commute to and from the university. With over 300 students and teachers regularly spending time in two main open areas, we considered the departure times of this bus line to be a suitable source of information to visualize in this space.

4.1 Preliminary Visualization

We created a visualization that shows the departure times of the buses on line 16, two in each direction. Several ambient displays of local transport data have previously been presented, e.g. in the form of a hand-held display that the user could bring along while going to the tram stop [Lunde and Larsen 2001] or a physical "mobile" where numerical indicators attached to strings would move up and down to show bus departure times [Mankoff et al. 2003]. For our visualization, we again chose to use Mondrian as inspiration to create an informative art installation.

We let each bus be represented by a colored square. The size of the square shows the amount of time before the bus leaves the university bus stop, so that the less time remains, the smaller the square is. The color is used to shows intervals of time it would take to catch the bus from the position of the display. The timing used for these mapping were based on our own experiments of walking from the university to the station. Again we mapped information to Mondrian's three primary colors, where:

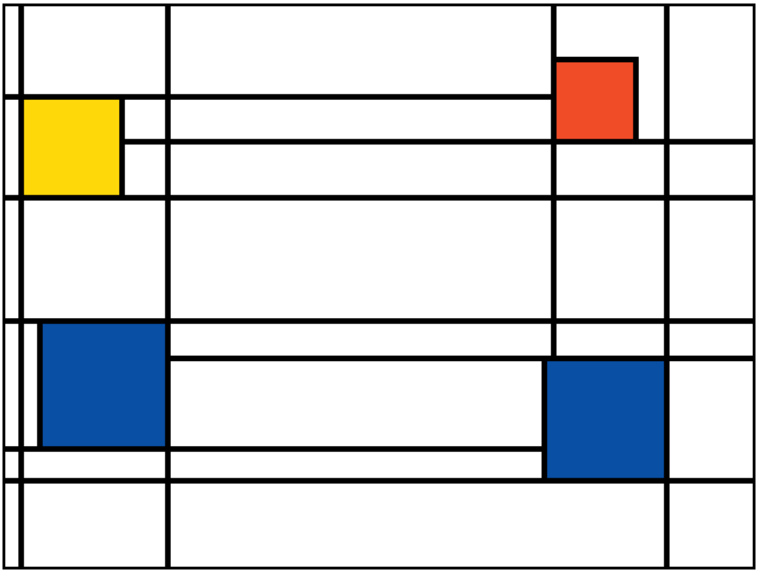

Figure 6: Preliminary visualization of bus traffic

- Blue means you have plenty of time before the bus leaves.
- Yellow means it is time to pack your stuff and start walking to the bus stop.
- Red means you're in a hurry. You may have to run to catch the bus.

We used the position of each square to indicate where the bus is headed. The squares are laid out so that the two squares on the right hand side represent buses traveling towards the city center whereas the squares on the left hand side represents buses traveling from the city center.

4.2 Feedback from Users

In order to get feedback on the preliminary visualization we interviewed three groups of students (a total of eight studets; five male, and four female) who all used the bus for their commute to the university. We ran the visualization on a laptop, using real, online data. The use of size and colors to indicate departure times seemed intuitive and the students understood it quickly. They also seemed enthusiastic about having this type of visualization available. They were aware of the web page containing the same information, but rarely used it.

The students helped us identify a number of problems with the proposed visualization. The most important issues were:

- Direction: The students found it hard to identify what buses were traveling in which direction. It seemed our use of position to indicate direction was not intuitive.
- Connection to the physical world: During the interviews, we noted that the students used the visualization as an abstract map of the bus stop, in order to make some sense of which bus was heading in which direction. They asked on what wall the display would be situated, using the physical surroundings as a point of reference. Since we had not taken this into consideration when designing the visualization, the readings turned out to be ambiguous and arbitrary.
- End stop: During rush hour traffic, an extra bus is used to offload the regular bus service. This extra bus runs as a shuttle between the university and the central station. Students traveling past the central station stop wanted a way to differentiate the two lines, so that they did not risk ending up on the wrong bus.
- Relevance: Two of the students pointed out that there was no need to show buses that when it is too late to catch them.

4.3 Redesigning the Visualization

Based on the input from the students, we chose to change the visualization in a number of ways. The resulting final visualization can be seen in Figure 7.

We chose to adapt the map-like connection to the physical world suggested by how the students tried to read the preliminary visualization. In the redesigned version, we added a blue line in the right hand side of image, to represent the river running through Gothenburg. The area to the left of the blue line acts as an abstract map of the bus stop. The two squares on the left now represent the buses traveling from the city center and the ones on the right represent buses traveling to the city center. In contrast to the first version, the squares are also arranged vertically according to the direction of the bus, so that for the squares on the left the, closest bus is represented by the square at the bottom, whereas the reverse is true for the right-hand side. The resulting visualization was intended to give a more intuitive impression of buses running in both directions along the river.

Furthermore, in order to differentiate the rush hour extra buses from the regular buses, we decided to add a black line, indicating the final destination of

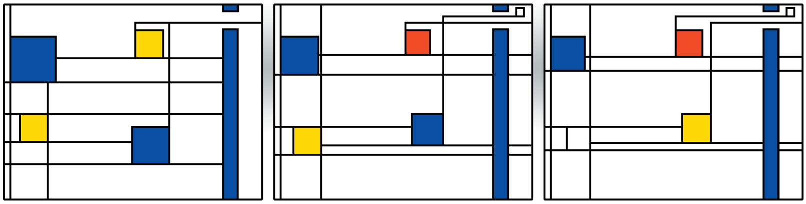

Figure 7: Three screen-shots (A,B & C) from the revised version of the bus traffic visualization. A shows the "regular" mode, where both buses heading towards the city centre (the two squares on the right) have the same final destination. B & C shows the visualization when one of these two squares represent a shuttle bus, which runs between the university area and the central station (represented by the small white square in the upper right corner).

the buses traveling towards the city center. As can be seen in figure 7, the bottom square has a line that starts in the upper right corner, and ends up in a small white square that represents the central station. The top square has a line that starts in the upper left corner and that ends up at the edge of the screen, indicating that it continues past the central station bus stop. None of the remaining lines in the visualization carry any information.

In order to deal with the problem with the visualization showing buses that it is too late to catch, we decided to represent such buses with white squares. This means that the squares are still there, but they are less visible than squares of other colors. The reason for not removing squares representing these buses altogether was that it would be too disruptive to the visualization as a whole.

A final modification was introduced soon after we started running the visualization at the university. The database server running the application at the transit authority turned out to have a lot of down time, and we realized that we had to add some kind of mechanism to indicate breakdowns. We did this by changing all the squares' colors to black whenever the server went down. The black squares would then indicate that there was no reliable data available for the application.

5 Preliminary Evaluation

The visualization of bus departure times is currently running at the university, on a plasma screens in a public area close to the main exit (as seen in Figure 1). The over 300 teachers and students at this department of the University will pass the display every day. Our plan is to let the application run for an extended period of time, to get long-term usage data. When we did our first study, it had been installed for 15 days, but effectively running only for about 10 days, due to server breakdown at the public transportation network and other technical problems.

There have been comparatively few evaluations performed of ambient displays in use, although some heuristics have been developed to influence the design of such displays [Mankoff et al. 2003]. We believe that it is difficult to capture the value of an ambient information visualization using traditional usability measures, and in particular that they have to be studied in situ and in actual use rather than in a lab environment. Therefore our approach has been to conduct on-site interviews to see if and how the visualization is taken up and used by the people in the area. We have tried to provide open-ended ways for people to use the visualization, so that the usage is natural rather than forced for the sake of evaluation. The authors themselves do not belong to this department of the university and are not regular visitors to the area where the display is installed, and should thus have minimal influence on the use of the visualization.

When we first set up the visualization, a caption with instructions for how to interpret the information was placed next to the screen. Unlike for our previous evaluation (the weather forecast, above), we did not arrange any public presentations. Instead, about 30 handouts with instructions were placed on a shelf immediately beside the display. Furthermore, the IT University added a news item on their homepage about informative art which included instruction on how to read the visualization. Thus, while noone was directly instructed or asked to use the display, information on how to use it was readily available for those who wished to do so.

We conducted our interviews during the afternoon on an ordinary weekday. Seven people were asked for an interview, when passing by or staying in the area of the display, three men and four women. Out of these, one woman was not interviewed, since she only made sporadic visits to the University. We wanted to involve only those who were constantly spending time in the area.

5.1 Results

5.1.1 Comprehension

When trying to assess the comprehension of our ambient information visualization, we used the broad framework of a three-step scale, where each step is a prerequisite for the next:

- *That* something is visualized – does the subject know that the display is an information visualization and not simply decoration?

- *What* is visualized – can the subject tell us what data the visualization reflects?
- *How* the data is visualized – can the subject read and interpret the visualization correctly?

Only when reaching the third step does a person have enough understanding to actually use an ambient information visualization.

Out of the six persons who were interviewed, one person did not know that some data was visualized on the display. This person did not travel with the bus line in question. The reminding five people knew that the display visualized dynamic data, and also what was visualized, i.e. departure times for bus line 16. All of these five subjects traveled with this line with some regularity.

Two people knew what was visualized, but did not know how to read it. However, both of them could explain that the colors on the "buses" represented something like "hurry", "leave now" and "there is time left". One of the two pointed out one square and suggested that it represented a bus that probably went to the town, which was correct. Therefore, although they did not have sufficient understanding for practical use of the visualization, they had still picked up some of the essentials.

Out of the five, three people knew how to read the visualization. One of the three first claimed that she was unable to read it, but in fact, when asked to explain the visualization, she could read it correctly.

5.1.2 Use

Two of the three persons that knew how read the visualization, had also used it to catch the bus. One of them had used it three times and the other once. Both of them said that they planned to continue using the display, providing it would continue to provide reliable information. One of them commented that it was great to get "information at a glance" and that it was particularly good in this place.

The person who could read the visualization, even though she thought that she could not, said that she was on her way to use it once. At the time she did not have the "energy" to get herself into it, and because she already had her outdoor clothes on, she simply left for the bus instead. She said that she would like to use the display, mainly if she was going home. If she was planning to continue the trip, she would rather use the website provided by the public transportation, where more detailed information could be found.

The two people who knew what was visualized, but did not know how to read it, believed that they would not use the display in the future. Both of them usually did not look at any timetables, unless they were staying late, something they had not been doing lately. One of them preferred more exact, number-based information, and suggested that people might need different amount of time to get to the bus, which he thought the current visualization did not support.

6 Designing Ambient Information Visualizations: Lessons Learned

In this section we will briefly discuss some of the lessons we have learned from designing several generations of ambient information visualizations. A summary of the development and features of our Mondrian-inspired informative art can be seen in Table 1 and Table 2.

6.1 Table 1: Information Source

The choice of what information to visualize is obviously important when designing ambient information visualizations, as it would be in any infovis application. But unlike ordinary infovis, where users can be expected to actively seek information, ambient information visualization provides users with this information in their everyday environment – whether they ask for it or not. This means that whereas we can rely on users of desktop infovis applications to actively work with an application, and to be prepared to give it their full attention for some amount of time, this is not always the case for ambient infovis applications. In particular we found that information used in ambient infovis has to have a relevant scope and a suitable rate of change.

6.1.1 Information Scope and Relevance to Users

The scope of the information used in our examples of informative art range from covering an office (e-mail traffic visualization), to encompassing the entire world in (world weather visualization). The bus visualization, which spans a local bus stop, was somewhere in between: it goes outside the user's immediate surroundings, yet it concerns something that potential users are very likely to be familiar with. We feel that ambient information visualizations must be designed so that the scope of the information is clearly linked to the placement and possible users of the display.

World weather has relevance to users from all over the globe (or at the very least in the six cities being visualized). This made it suitable in an exhibition situation, were visitors were likely to come from many different countries. The e-mail example, on the other hand, was really only relevant to the people working in the particular group whose e-mail was being visualized. Both of these examples there-

Visualization	Scope	Rate of Change	Display Update
E-mail	office	variable	once/minute
World Weather	world wide	hours	once/minute
Local Weather Forecast	city	days	once/minute
Bus Traffic	nearest bus stop	~every 30 seconds	every 15 seconds
Bus Traffic revised	nearest bus stop	~every 30 seconds	every 15 seconds

Table 1: Overview of the information sources used for our examples

fore worked well as illustrations of the concept of ambient infovis, but neither was compelling enough for it to see continued real-world use.

The bus visualization, on the other hand, is relevant to a place, in this case the area around the university bus stop. This means that all visitors to the place where the visualization was situated were potential users of the display. To a similar extent this was true for the weather forecast, which was relevant to the local city area. But the bus visualization has proven to be by far the most compelling of our designs so far, which is probably related to the fact that it also helps in carrying out a certain activity (catching the bus) which is not so much the case for the weather visualization.

Lesson 1: By finding information that is relevant to the place where the ambient display is located, every person spending time at that place becomes a potential user.

6.1.2 Rate of Change and Update Rate

All our ambient infovis examples have been based on dynamic data, but update rates have varied. We found that the selected information source should have a suitable rate of change – so that on the one hand, the display changes often enough that users perceive it to be dynamic, but on the other hand, not so often that it becomes a source of distraction.

On the worldwide weather display, even though the update was based on real-time weather data, hours could pass between perceivable changes. The weather forecast could be perceived as static, since it only changed a few times per day, when the new forecast became available. People would thus sometimes believe that the visualization was "broken", since there was no perceivable change. Also, because of the low rate of change, there was no "urgency" to the information, and in the case of the weather forecast it was actually sufficient to look at it once per day to get all information it had to offer.

The bus visualization, on the other hand, was based on real-time data that changes quite often. Furthermore it provides time-critical information that directly helps the users with an everyday activity. However, since the buses run very frequently during the daytime, many users would simply not bother checking when a bus was due – they would just go to the bus stop, expecting a bus to come. This situation changes during the evening and our impression is that the visualization will see more use when the buses are less frequent.

Although the rate of change in the information source is something that cannot be changed, the update rate of the display is under the control of the developer. Our experience indicates that it would be fruitful to include some minimal amount of animation to the display of data that changes with a low frequency, to make the users aware that the application has not frozen. This might have promoted the impression that the weather displays were showing real-time dynamic data. On the other hand, for information that has a very high rate of change, e.g. a stock market index, it can be necessary to slow down the update rate so that the viewer is not distracted by continuous fluctuations in the visualization.

Lesson 2: The rate of change in the information should be frequent enough to promote relevance, but the developer can affect the visual appearance by slowing down the changes or adding a small amount of animation.

6.2 Table 2: Visual Encoding

When designing informative art, it may be necessary to make trade-offs between the aesthetical template and the visual encoding. There is no question that in some sense, adhering to a visual template that has been determined without concern to the information that is to be visualized can be restrictive. At the same time, this approach has the advantage of making the designer of the visualization "see through the eyes of an artist", which might be a good way for even a person with little visual design training construct a visualization that has aesthetic appeal. In our experience, using an artistic template does not necessary make the visualization less useful.

6.2.1 Using an Artistic Template to Visualize Information

As can be seen from the table we have been able to visualize a quite diverse data set using the style provided by Mondrian. In practically all of these examples we have used a mapping from some quantitative data to the size of colored fields. This mapping has worked quite well, even though it is not ideal for temperature, since the centigrade value for the freezing point is zero, and there is no simple way of making the area of a square indicate a negative value.

Visualization	Size	Color	Position	Geographical Metaphor
E-mail	amount of e-mail	-	-	-
World Weather	temperature	weather condition	location of city	world map
Local Weather Forecast	temperature	weather condition	day of week	-
Bus Traffic	time until bus leaves	time intervals	direction of bus	-
Bus Traffic revised	time until bus leaves	time intervals + breakdowns	direction of bus	city landmarks + bus stop

Table 2: Overview of the visual encodings used in our examples

Nowell [1997] suggest that no more than five or six colors should be used in coding a display and that color-coding should only be used for the information that is most directly relevant. We used the three primary colors that are a characteristic of Mondrian's compositions as important information carriers in our visualizations. The colors were used to indicate discrete data classes, such as types of weather conditions and, in the latest example, specified time intervals. This has worked quite well, although occasional users expressed a dissonance between their own associations to colors and our mapping (e.g. in our weather visualization blue means "rain" whereas many users associated it with "blue skies" [Ljungblad et al. 2003]).

But most interestingly, a side-effect of using Mondrian as a template has been that all our examples use bold and easy-to-read encodings to visualize a limited amount of information. We have been forced to carefully design the mappings to fit with the limited template. This has led to simplified visualizations, which once learned can be read very quickly, and at some distance from the display, even in busy environments. This might not have been the case if we had started from scratch, and without the visual template we could have been tempted to cram too much information into the display.

Lesson 3: Basing a visualization on an artistic style need not hinder – and might even support – the readability and comprehension of an ambient infovis installation.

6.2.2 Using the Spatial Layout as a Mnemonic

In our Mondrian examples we have used different strategies for the spatial layout of the colored squares. The arbitrary spatial mappings used in the e-mail and local weather forecast visualizations (described in section 3.1.1 and 3.1.3, respectively) tended to be harder to remember than the ones where we used a geographical metaphor as a basis for the spatial layout of the graphical components.

The first example that used a geographical mapping was the world weather visualization described in section 3.1.2. Although no visual cues to the mapping were given, we found that the spatial mapping in that example was of great assistance for viewers to help them remember the mapping. The users would of course need to learn which six cities were represented, but once this had been done it worked both ways, since the visualization also act as a mnemonic to indicate in which areas of the world the cities were located.

The latest example, where we let actual geographical landmarks be represented in the visualization, has rendered the best results so far. With the representation of the river as a point of reference, the viewers could easily derive which bus was which. The visualization became a sort of abstract map of the bus stop, without breaking the adherence to the visual style of Mondrian. This builds somewhat on lesson 1, where we found the relationship to a specific place to be useful.

Lesson 4: Letting features of the information source affect the visual encoding, thus providing a mnemonic to remember the mapping, is a good way to support the comprehension of the display.

7 Conclusions and Future Work

In information visualization, aesthetics can almost be considered an added bonus, or at least a bi-product when striving for readability and effectiveness. In ambient information visualization, on the other hand, aesthetics is considered a primary property, both in the design and during use. When designing ambient infovis, it may even be necessary to go against established infovis guidelines in order to adhere to an artistic template. For instance, the bus visualization is not entirely consistent in its coding, since the representation of the river has the same blue color as the squares representing buses. Additionally, some of the black lines carry information, whereas others do not. However, we did not find this inconsistency to be a problem in our user studies, and the design was still considered intuitive.

Graceful degradation is an important issue for ambient information displays. Since an ambient information visualization is usually not interactive, it is crucial that applications have a way of indicating when they are not functioning, or have trouble retrieving data, so that users can rely on the display as a source of accurate information. In our bus example we let black squares indicate that the server was down, and that no reliable data was available. It is particularly worth noting that this consisted a noticeable break with the artistic template, something that should make it easier for users to conclude that something is wrong with the application.

It is also important to make the most crucial information available at a glance. The bus visualization uses redundant coding – both color and size – to represent time to departure. From our preliminary study it seems that people tend to use the color, rather than size, to determine the time to departure. One reason for this might be that color is said to yield faster result than e.g. shape, when used redundantly with other encodings [Nowell, 1997]. The size of the squares, on the other hand, in principle gives a more exact indication, but in practice, it is very difficult to translate the visual size into an accurate measure of departure times. In forthcoming studies it will be interesting to see if people will be able to use the size of the squares to better estimate time, and thus getting a more precise reading of the display.

Our ambient information visualization of bus departure times is currently running at the university, and we plan to conduct a long-term study of the uptake and use of this application. We are concerned with issues such as how the understanding of the display changes over time, and how it takes its place in everyday life. One measure would be to determine how likely knowledge of the interpretation is to be lost over time – i.e., once a person has gone "up" a step on our three-step scale (that – what – how) how likely is she to go "back" and forget this knowledge? The design of the mappings must be intuitive to be both easy to learn and easy to remember, and this will probably have a noticeable effect on the uptake and comprehension of the visualization. Therefore, it would be interesting to study and contrast the use of two different ambient information visualizations that show the same data but use different mappings and artistic styles.

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SUBJECT TO CHANGE: ISSUES WITH LONG-TERM EVALUATION OF AMBIENT DISPLAYS

Tobias Skog, Sara Ljungblad & Lars Erik Holmquist

Abstract. "Off-the-desktop" systems that present information in the users' everyday environments, so called ambient or peripheral displays, are a popular research topic within HCI. Many designs of such displays have been presented but evaluations of them are rare. To gain knowledge about the use of ambient displays we have installed and surveyed the use of an ambient visualization of bus departure times during 12 months. Based on the empirical findings from this study and a nine-month internal evaluation, we discuss aspects of ambient displays that relate to their role as integrated parts of an environment and the impact it has on their evaluation. Our empirical findings suggest that the users' habits, attitudes and physical context all affect the use and perception of a display, and we highlight issues that may affect long-term use and therefore should be considered when designing an ambient display.

1 Introduction

The design of systems that support awareness in the user's surroundings has been a topic of research within HCI since the early nineties, and it remains an active field. One popular way of presenting awareness information is via *ambient displays*, i.e. displays that present (non-critical) information in a nonverbal way, often in the periphery of the user's attention. An early example of an ambient display was the *Dangling String*, presented in [20]. Originally an art installation called *Livewire*, created by Natalie Jeremijenko, the piece consisted of an Ethernet cable attached to a motor that would move more or less depending on the traffic in the local network at an office, providing the office workers with subtle information about network activity. In later research, ambient displays have used media like sound, light, movement or smell to present information in a subtle way, that makes them blend into the architectural surroundings [4, 6, 16, 21]. There is also a class of screen-based ambient displays that have explored how images can be used to convey peripheral information. Health status, activity and the stock market are examples of information sources that have been visualized in displays like a photo frame [10], iconic representations in images [9,13,19] or more art-like pictures [1,2].

A critical aspect of the design of any interactive system, especially in the HCI community, is evaluation. Despite this, evaluations of ambient displays are rare. As pointed out by Mankoff et al. [6], this may depend on the fact that ambient displays are difficult to define in measurable terms and thus difficult to evaluate. Most published studies of ambient displays have been focused on issues like perception [22], information recall [14] or heuristics for the design of ambient displays [6].

We argue that finding out what makes ambient displays successful requires longitudinal studies of their use in real-life settings. In this paper, we describe a study of an ambient visualization of bus departure times in two different settings, lasting 12 and nine months, respectively. The study yielded results about how display use changes over time, in concert with changes in its context – results that could not have been reached from short-term studies or lab tests. Based on these results we highlight issues that may affect the long-term use of an ambient display and thus should be considered by designers of new displays.

2 Designing for the Periphery

Ambient displays are often referred to as peripheral displays, in order to reflect their peripheral role in the users' environment. Much of the periphery discussion stems from Weiser & Brown's work [20], in which they coin the term *calm technology*; and define it as technology that engages both the center and the periphery of our attention, by being able to move back and forth between the two. This clearly is a desirable goal for ambient displays, since they are supposed to seamlessly blend into our everyday environments and at the same time be able to convey information in an intelligible way. However, the question of how ambient displays, or any technology for that matter, can be designed to be 'calm' still needs to be explored further.

The notion of calm technology and development of ambient displays have spawned research within perceptual psychology, where researchers have been studying how this way of displaying information affect the human attention [3,5,7]. Some designers imply that their displays make use of the psychological phenomenon called *subliminal perception* [21, 16], but this phenomenon is not yet fully understood, and psychologists are still trying to understand the workings of it [8]. Hence, it will be difficult for a designer to create a peripheral display, or any interactive system, that makes real use of it. Instead, we argue that the focus when designing ambient displays should be on exploring actual designs that allow the user to shift her attention easily back and forth. Putting the user in control of when to retrieve information should help make the display more peripheral.

We envision the role of ambient displays to be similar to that of a wall clock. The wall clock is an institutionalized peripheral display that is ubiquitous, at least in western society, where it is fundamentally integrated into everyday life. When we read it, it's with a single glance and we usually do not think about the fact that we're using a clock. Also, it never demands our attention, but we rely upon it to be there, constantly telling the time, and we choose exactly when we want to read it and thus it fades into the background.

3 Evaluation Approaches

The idea of evaluating ambient displays is not new, and in the late nineties Wisneski [22] performed experiments on several displays including the *Water Lamp* [21]. The study is focused on how the people in a lab setting perceived changes in the display, and does not uncover whether the participants actually could make sense of, or use, the display. *The Digital Family Portrait* [10] is a picture frame display that reflects the wellbeing of the person in the picture, and was evaluated through "Wizard of Oz" field trials in a natural setting with a grandmother and her grandchildren. During the tests the prototypes were updated daily based on telephone interviews. The motivation for conducting a field test was that the display was designed as a social system, meant to be part of people's everyday life. However, since the display was not fully implemented, this method required much intervention from the researcher.

Some ambient displays have also been studied in exhibition settings, e.g. *Pinwheels* [21] and *informative art* [2]. Exhibitions are a good way of getting preliminary feedback, but since the typical "user" at an exhibition only visits once, it is difficult to get any reliable usage data. Also, in such a setting, possible novelty effects cannot be eliminated and are even likely to bias the results quite significantly. Informative art has also been the subject of a one-week study in a "real-life" setting at a university [18], but the short-term nature of the study makes it resemble an exhibition setting in the sense that it did not unveil any interesting usage patterns.

Mankoff et al [6] introduced a modified heuristic evaluation that focuses on usability issues of ambient displays. This kind of evaluation aims to highlight potential problems with the display, during the design phase, without having to involve the users. Design guidance is certainly useful for avoiding well-known design traps, but there are still many contextual factors, that will change between settings and that will affect how a display is perceived.

Plaue et al [14] describes a comparative, quantitative study of information recall between a user-customizable "information awareness display" called *InfoCanvas*, a web portal display and a text-based display. A qualitative study of the InfoCanvas is described in [19], where four people used displays that were customized to their wishes, for two months. To get data about the use and the opinions about the display, the users were interviewed before, during and after the study.

We argue that people's habits as well as the physical and social context of an ambient display all affect the perception of it, and that these aspects have to be regarded in its evaluation. The highly situated nature of ambient displays and their intimate connection to the environment can give rise to unexpected problems that cannot be found without actually studying them *in situ*.

The fields of ethnography and ethnomethodology have inspired a range of HCI-related qualitative studies of technology in use and how technology affects the (work) practices that evolve in everyday life, e.g. [12]. These studies can provide valuable insights about how people interact with technology, both individually and in terms of the interplay between social structures and technology. Most of these methods build upon observations of user behavior, however, and the case of ambient displays becomes troublesome, since the observable behavior is reduced to a glance at an object, possibly followed by a response that may be observable or not (i.e. the user may not react in an observable way to the information she reads from the display). Another drawback to ethnography is that a properly conducted study can be highly time-consuming, both in terms of data collection and analysis, which makes it less suitable for studying the installation of a display over extended periods of time.

However, there are methods for collecting qualitative data that are viable for the purpose of evaluating ambient displays, e.g., interviews that commonly are used for gathering data on how users perceive and use a technology or technological artifact.

4 Designing an Ambient Display

The empirical data in this paper is gathered from studies of installations of a display that shows continually updated bus traffic information, originally described in [18]. For clarity, we give a brief description of the design here as well. The visualization shows traffic information for a bus line in {City, Country}, that connects large residential areas and the city centre with a rapidly developing area with schools and office buildings. The display was initially designed for students at a university in this area who depend on this bus for their commute, although the information content is equally relevant for anyone in the area who rides that bus. The real-time traffic data is provided by the local transit authority, via a web interface. The look of the display is inspired by the style of the Dutch artist Piet Mondrian, who has provided inspiration for several earlier examples of informative art, e.g. [2, 15].

In the visualization (see Figure 1), each colored square represents one bus and indicates when it leaves by changing size and color. The size of a square decreases with the time that remains before the bus leaves. The colors (blue, yellow, red & white) are used to denote the status of that bus, where:

- *Blue* means you have plenty of time before the bus leaves.
- *Yellow* means it is time to pack your stuff and start walking to the bus stop.
- *Red* means you're in a hurry. You have to hurry to catch the bus.
- *White* means that it is too late to catch the bus.

There is also a feature indicating breakdowns. Should no data be available (e.g. due to network problems), all of the squares will turn *black*. The positions of the squares indicate the direction of the bus, and are mapped to the actual locations

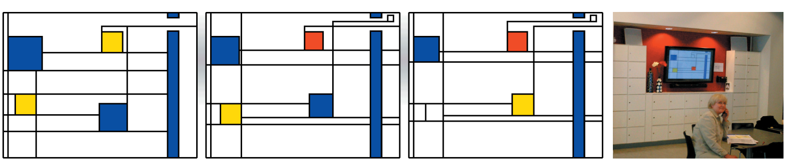

Figure 1. Three screenshots of the visualization, and its installation at the university

of the buses on the bus stop. The two squares on the right side represent buses headed for the city center, whereas the two on the left represent buses headed for the university. The blue line in the right side of the visualization is a representation of a river running through the city, acting as a mnemonic to how the buses are mapped to the colored squares.

During rush hour traffic, extra shuttle buses run between the university and the central station in order to offload the regular buses. To separate them we added information about the final destinations for buses traveling to the city center. In the middle screen shot of Figure 1, the bottom right square has a black line starting at the top, ending up in a small loop in the upper right corner of the visualization. The loop represents the central station and thus this bus is a rush hour shuttle. The line starting from the top of the upper left square ends at the right edge of the screen, indicating that this is a regular bus. The remaining lines do not carry any information.

4.1 Study at the University

The display was subject to a brief study at the university, where it ran for two weeks on a 50-inch plasma display. To get usage data from the user group, which mainly consisted of students at the university, we used semi-structured interviews. We did six such interviews with students spending time in the area around the display.

The results showed that five of the interviewees took the bus daily and that three of these had used the display to figure out when to leave. The main issue indicated by the answers regarded the placement of the display, which was in a place where the user group did not have constant access to it and hence could not use it when they needed the information.

5 Long-term Internal Study

At the time of writing, we have had the same bus visualization running in our lab for about nine months (April 2004 to January 2005). In the room where the display is placed, four out of six people use the bus regularly for their commute. Of the remaining two, one uses the bus sporadically and one commutes by car. The visualization is running on a wall-mounted 15" flat panel display placed near the exit.

Since the visualization was developed at the lab, all of the people there were already familiar with it at the time of installation. To collect data about the use of the display, we have used questionnaires and informal observations.

5.1 Results

The four people that commuted by bus also were regular users of the display. Three of them claimed to use the display every time they took the bus and the fourth said: *"almost every day"*. The fifth person, who used the bus sporadically, claimed to have used the display about 50 times since it was installed.

The consensus among the five people who had used the display was that the placement of the display was good, as exemplified by these comments:

> *"it is close to my desk and I can quickly look at it when I feel it's time to leave. It's also right by the exit, that's good"*

> *"I see it from my desk & when I'm on my way out"*

Furthermore, three users said that the display made have a less stressful relationship to catching the bus, e.g. *"I feel that I, when it comes to taking the bus, have a more relaxed attitude towards time /…/"*

The questionnaire answers together with informal observations suggested that the usage had remained relatively stable over time. A slight drop in use was noted during the summer months since people were more prone to taking the bike to work when the weather was better, but the use picked up again during the fall. All in all, the display has turned out to be quite useful and is now a well integrated part of the daily life at the lab.

6 Long-term Study in an Office Setting

The results from the study at the university indicated that the display use was limited by the fact that people did not spend enough time around it. Hence we wanted to find a setting for a new study, where the users would have practically constant access to the display, making the information available as a natural part of their everyday surroundings. In particular we wanted the study to illuminate how the setting affects the use of a display, and if the use would change over time.

We installed the display in an open office environment at a company located in the same area as the university (see Figure 2 & 3). The visualization was identical to the one at the university and internal setting, but adapted for the bus stop closest to the office building. It ran on a wall-mounted 15-inch LCD display, inside a wooden frame that was added to make it feel less like a traditional computer screen. We used the same caption with reading instructions as in the university setting, and placed it next to the display. Four or five people watched the installation and were given brief oral reading instructions. At installation time, a group

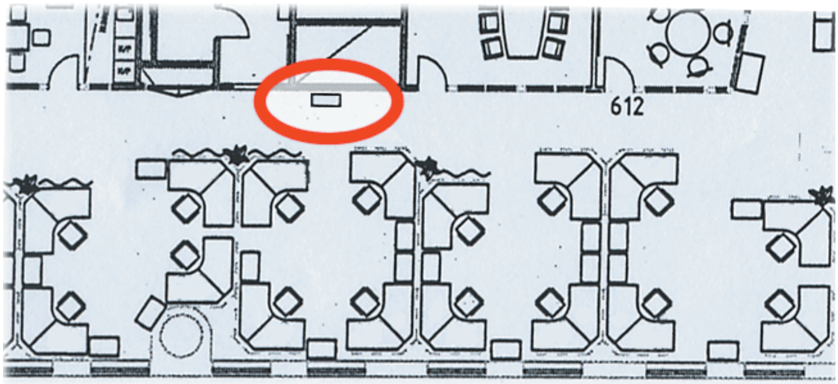

Fig. 2. Space plan of the office setting. The ellipse marks the display

of about ten people had the display close enough to read it from their desk. The majority of these people used the bus for their commute, either every day or more sporadically. The group consisted of a mix of men and women (about ¾ men) in the approximate age range of 25-35.

The display was installed in the office for almost exactly one year (from mid September 2003 to early September 2004), and except for minor technical glitches during the first two weeks, it ran around the clock. The physical setting remained largely the same during the 12-month period of evaluation, apart from minor changes such as 90-degree rotations of occasional desks. The display was kept hanging in the same place for the entire evaluation period.

6.1 Method for Gathering Data

In order to acquire data about the use of the display and how that use developed over time, we had to find a suitable method of probing the users opinions about the display.

As noted above, we do not consider methods like field observations and video analysis to be the most appropriate for this kind of study, since the observability of ambient display use is questionable. In addition to this, our access to the office was restricted due to the security policy at the company, which meant we couldn't come and go as we wanted. This was another factor that made the use of traditional observational methods unsuitable.

We still wanted to use qualitative methods to collect the users' experiences

Fig. 3. Photo of the display installation in the office setting. The white circle marks the display

with and perception of the display and not just obtain usage data in the form of "raw" numbers. We chose to use questionnaires with open-ended questions as our primary means of gathering data. We considered it to be a fair trade-off, since questionnaires are a low-cost way of getting qualitative data about the use of the display, albeit not as much as would a full-out ethnographic study. We did three iterations with questionnaires: after three weeks, three months and nine months. We concluded the study by conducting an on-site unstructured interview and observation of the setting after 12 months. In the sections below we will summarize the results from the three questionnaires (henceforth referred to as Q1, Q2 and Q3) and the concluding interviews.

6.2 Q1: 3 Weeks of Use

The first questionnaire consisted of 12 questions that were designed to get information about things like the users' bus traveling habits, their thoughts on ambient information presentation in general, the placement of our display and their understanding of it. The questionnaires were e-mailed to 11 people that had their workspaces in the vicinity of the display. 10 of these questionnaires were completed and returned to us within two weeks. Problems with the configuration of proxy servers and firewalls had occasionally caused difficulties retrieving information from the web interface (indicated by black squares as described above). At the time Q1 was carried out, the display had been functioning properly for approximately 70% of the time.

Nine out of ten subjects commuted by bus. Eight out of nine expressed an interest in using the display to find out when the bus leaves. Our results show that seven people had tried to use the display and two of these also were planning to use the display on the day of the study. The remaining three had not tried to use the display, for various reasons. The first was riding his bicycle to work, and was not interested in information about bus traffic. The second said that the display had been broken, which made it impossible to use. The third did take the bus, but usually just headed for the bus stop without checking the timetable or the visualization.

A Conversation Piece

All participants knew what information the display was presenting. Four of them had attended the brief presentation when the display was installed and the remaining six had either gotten an oral explanation by a colleague or overheard colleagues talking about it. Thus, it seems that information was spread efficiently through informal communication; the display had become a "conversation piece" that everybody was aware of. This process was clearly facilitated by the fact that the users were a much smaller, tightly-knit group than the large, loosely defined, user group consisting of students and staff at the university.

Ability to Read the Display

In the questionnaires, the users was asked to estimate their own ability to read the display. These results were then compared with their actual ability to read the display. None of the participants said that they were unable to read the display. Six claimed that they could read it partly and three claimed that they could read it entirely. Four people could read the display correctly. Two persons claimed that they had to read the caption to fully understand the display. Three people could read it partly, but not enough to be able to use it.

Abstraction The fact that the display presents an overview rather than exact, numerical information, was commented on by several people. Two users claimed that the lack of exactness affected their trust of the display. This comment on disadvantages with the display, exemplifies one of the concerns:

> *"You don't get an exact image. Hard to trust the information to 100%. I would not trust it if it was for example train departures (that leaves more rarely). Quickly forgets how to interpret it when you haven't used it in a while."*

One user meant that the abstraction was a good thing:

> *"Quickly available – can with a quick glance estimate how much in a hurry I am: exact time is not necessary - it is enough with an estimate. It becomes information overload to have to keep times in memory and look at the watch to calculate what bus to take. Have other things to think of."*

Placement

One question asked for the users' opinions about the placement of the display and when comparing the answers to this question, we found that people were not only concerned about their own access to the information, but also about their colleagues. For example, some thought the display was in a good place since it was accessible to them, whereas some thought that it was badly placed because others could not see it. People who liked the placement made the following comments on why they thought so: *"You pass it by"*, *"I see it perfectly"* and *"It is simple just to give it a glance"*, whereas the ones who did not like the placement thought that: *"More people should see it"*, and *"It is probably better by the door so that more people can see it"*.

6.3 Q2: 3 Months of Use

The second questionnaire was distributed when the display had been installed for about three months. A big difference from Q1 was the comparatively low number of replies. This time, only five out of ten people returned the questionnaire, one of which didn't actually answer the questions, with the motivation that she now commuted by car. Of the remaining four, two said that they used the display and two said they didn't. One of the non-users used other means of public transport (ferry) and the other left several reasons for not using the display:

> *"Don't know how much time the colors correspond to, the painting seems to work only when it wants to, easy to check with [local bus company] when you're at the computer anyway, and the bus leaves often enough for you to be able to just go out and wait."*

With the exception for this respondent, the opinions about the display were mostly positive, but even this skeptical person seemed to like this way of presenting information:

> *"Fun idea, anyway. Would work better at home where your computer's not on as often, if you could fine-tune the times/colors yourself."*

The overall impression from this second questionnaire was that only people who either used the display, or at least liked the concept, bothered to answer the questionnaire. The remaining people did not respond at all, even after an e-mail reminder about two weeks after the initial e-mail with the questionnaire.

Integration & Placement

The responses indicated that the users liked having the display as a part of their environment, and they wanted it to stay: *"Want to keep it. Fun gizmo. The customers like it. Suits our department."* All of the respondents were happy with the placement of the display, but one complaint regarded the integration in the surroundings as indicated by this comment: *"Yes, it sits where it's clearly visible and it doesn't disturb anything else. The frame doesn't fit in very well in the surrounding environment."*

6.4 Q3: 9 Months of Use

When the display had been running in the office for about nine months, we e-mailed a third and final questionnaire. Unfortunately, the response rate continued to drop and this time we got only three replies. One of them was from a regular user of the display, one was from an occasional user and one was from a former regular user of the display who, when asked if he had used the display, answered: *"Always when I was sitting by it /.../"*. On the question "Would you rather see that the display was placed somewhere else?" he wrote yes, with the motivation: *"where I can see it"*. This indicates that he probably would have continued to use the display, if he still had been sitting where he could see it.

Furthermore, there were some contradictory statements regarding the suitability of the placement of the display: *"Easy to see from my place"* versus *"I don't think that many can use it."* The latter person, who seemed concerned about others not being able to see the display clearly, was a regular user of the display, and not concerned for his own sake.

6.5 Concluding Interview and Observation: 12 months

After almost 12 months of use, we paid a visit to the office to get some final feedback from users, and see how the setting had changed over the course of the last year. The major reason for doing this was the dropping response rate for the questionnaires, which made us feel the need to do an on-site observation of the setting to establish possible reasons for the lacking response from the user group.

We also did an unstructured interview with our contact at the company about how the setting had changed in terms of the composition of the user group and their (commuting) habits.

Changes in the Setting and User Group For the first ten months of use, the user group was virtually static, except for a couple of master's students leaving and one or two people switching places (as indicated by the answers from one person in Q3). The last two months were more turbulent, due to a restructuring of the work groups, vacation times and new master's students coming in.

Changes in Commuting Habits The major change in the setting during the evaluation period up until Q3 was that many of the people who traveled by bus when the display was installed had switched to commuting by car, and in a couple of cases by ferry, leaving only 2-3 regular bus travelers. It seemed like most of the commute-switches were made about 2-3 months into the study, i.e. in November-December of 2003, perhaps due to bad weather.

This change in the commuting habits serves as one probable explanation for the gradual drop in the number of responses for the questionnaires—if people are not traveling by bus, the display lacks relevance for them and will not be used.

7 Discussion

In the introduction we argued that ambient displays should be evaluated in context, due to their role as integrated parts of our everyday environments. What constitutes a good display is likely to be an interrelation between its design and the setting in which it is placed and thus it is hard to determine how well it will work beforehand. Our studies have revealed issues that affect the long-term use of a display, and in the sections below, we will highlight these issues using empirical data and give some generic guidelines to how these issues can be addressed when designing a display.

7.1 Evaluation Method

Performing long-term studies of ambient display use is not a trivial task. A study should not be overly time-consuming, but at the same time you want to reach as profound knowledge as possible about the use an thus a balance need to be struck between the cost and effect. We found that using questionnaires in combination with brief on-site observation and interviews gave good results. The drawback was the declining response rate for the questionnaires that was seen in the office setting. Although this lack of responses can be considered a result in its own right, future studies could consider complementing questionnaires with on-site interviews at an earlier stage if lack of responses turns out to be a major problem. In our case, the lack of responses turned out to have a natural cause, as can be seen below.

7.2 How Users' Habits Affect Use

Looking at the diagram in Figure 3, there is a clear pattern that reveals the declining interest in the display from Q1 to Q2 to Q3.

In Q1, after three weeks, it was obvious from the answers that the display had been a frequent conversation topic at the office. Considering this, the novelty effect may have contributed to the relatively high number of users at that time.

In Q2, after three months, the use had declined considerably and it is reasonable to assume that the novelty effect of the display had worn off. There had also been some changes in the commuting habits, which caused some of the formerly enthusiastic respondents to lose interest and stop using the display.

In Q3, after nine months, the usage was relatively stable and not much had changed from Q2. There were a couple of devoted display users, whereas the others in the setting had become used to having the display around but did not pay much attention to it.

At the final, supplementary interview and observation, many of our suspicions regarding the usage drop were confirmed. People lost interest in the display mostly because the information lacked relevance to them when they did not use the bus.

One problem with our visualization was that for any given installation site, only people that used the bus would be prospective users. Hence, it was problematic for us to find a setting where a group of people could have constant access to the display, and where a sufficiently high ratio of the people in that group commuted by bus. The office was such a setting at installation time, as the users' commuting habits changed over time, the number of display users consequently plummeted (see Figure 3).

When designing the display, we assumed that the group of bus commuters was relatively stable over time, but in the office setting it turned out to be much more prone to change than we would have ever expected. On the other hand, in the lab setting, no permanent drop in usage has been observed. Our results show that a majority of the people continues to use the display as long as the information is relevant to them (i.e. as long as they commute by bus), but when circumstances regarding the relevance change, so does the display use.

In [19] a "lesson learned" regarding the relevance of ambient visualizations states that: *"By finding information that is relevant to the place where the ambient display is located, every person spending time at that place becomes a potential user."*

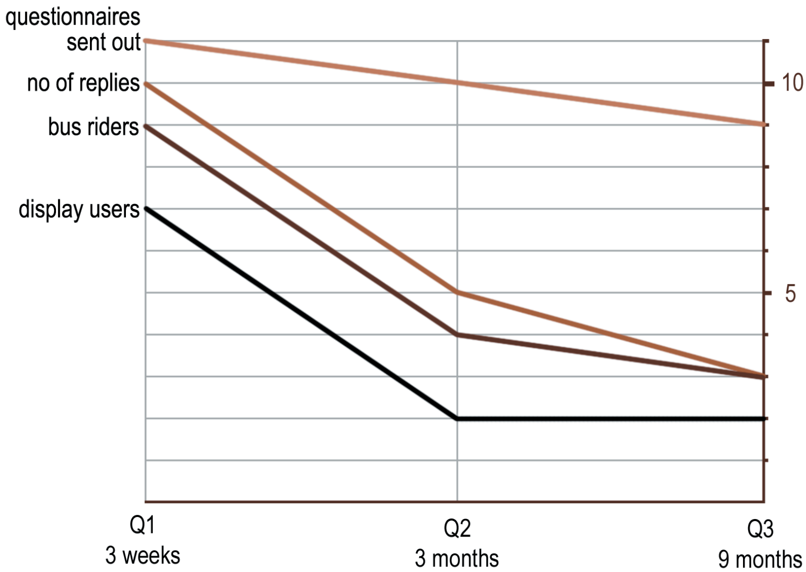

Fig. 3. Diagram of how display use, bus traveling and questionnaire replies changed between Q1, Q2 and Q3

Considering the results from our study here, we would like to add that designers of ambient displays should also consider how prone to change the user group is in terms of behavior that would affect their display use. If the information conveyed by a display is one whose relevance changes over time then so will the use of the display, something that in the long run may cause the potential users to lose interest in it.

7.3 Placement

A perhaps obvious advantage of studying ambient displays in situ is that you unveil issues about the placement of the display. In both the office setting and at our lab the display is constantly available for the people around it. At the university a larger group of people would pass by the display, but no one had continuous access to the display. This also meant that people were not necessarily close to the display when planning to go home and thus could not use it to figure out when to leave.

There have been user speculations regarding the display placement, with people suggesting both that the best thing would be to pass by the display on the way out (i.e. to have it placed nearby the exit) and others being quite happy with having it placed near their desk. Our findings from the university suggest that when people are already on their way to the bus, they will not stop to read the display, so we argue that placing the display by the door is not a good idea, unless the users are sitting so that they can read it from where they are working. Even if the information is related to the activity of leaving the office, users obviously need this information when they make the decision to leave and not when they are already on their way.

In the office setting most comments regarding placement were positive but suggestions that it should be moved next to the exit did occur. There were also some concerns that not everybody could read the display.

In the lab setting, where the display is placed near the exit, but still within view for all users, we got only positive feedback regarding placement, which suggests that it was successful in terms of being accessible and perhaps also conceptually, as the information relates to leaving the place.

8 Conclusions

Our empirical results indicate that the context greatly affects the use of an ambient display and cannot be ignored when it comes to evaluation. The display and its context, in terms of the both the physical setting and social structures, interplay to form complex patterns of use. Great effort can be spent to reach deeper understanding of this interplay, and ideally full-out ethnographic studies should be conducted if the objective is to collect the richest possible data. That kind of studies, however, can be highly time-consuming and they are not always a viable way to conduct an evaluation. In this paper, we have presented the use of questionnaires, interviews and informal observations as a low-cost alternative for gathering qualitative data about the long-term use of an ambient visualization.

In addition to issues considering the evaluation method, we have highlighted two main issues that affect the use and perception of a display: placement, and how the changes in the users' habits cause the relevance of the display to change.

Regarding placement, the display has to be placed in such a way that the users have access to it when they are in need of the information or it will never become a naturally integrated part of the surroundings. The use of a display has to be effortless in order to weave itself into the fabric of the users' everyday lives.

Regarding how the behavior and habits of the users affect the relevance of a display, this is clearly an issue that is important to consider for designers of ambient displays. In order to accomplish a level of use that remains stable over time, the relevance of the display has to be assured, or users may lose interest.

Finally, we believe that time has a central role to play in the evaluation of ambient displays. In order to speak intelligently about the relation between the use of ambient displays and how it is affected by the lives of their users, evaluations will have to be carried out over long periods of time, and in real life settings.

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ACTIVITY WALLPAPER: AMBIENT VISUALIZATION OF ACTIVITY INFORMATION

Tobias Skog

Abstract

We present Activity Wallpaper, an ambient visualization of activity information, based on an analysis of audio data. The design of the visualization is used as example in a discussion about the requirements of information presentation for public spaces.

ACM Classification: H.5.2 [Information Interfaces and Presentation]: User Interfaces

Keywords: Ambient information visualization

Introduction

When architects design a public space, one aspect they consider carefully is the choice of materials. For example, they may choose to use materials that wear with time, in order to give a space a "memory" of how people have inhabited it [1]. This wear and tear, however, is very slow and may take decades in becoming noticeable. Computer technology enables us to provide a space with an electronically amplified memory, e.g. by using sensors that capture data about people's activity and presenting an overview of this data in the space. Ideas along these lines have been explored within HCI research, e.g. in [4] where The Sound Mirror and other instances of Soniture are discussed; and in Palimpsest [8], an installation that allows people to interact with projected video clips of people that have spent time in that space at some earlier point in time.

Today, public spaces are increasingly invaded by computer technology, predominantly in the form of public information displays. Despite this, little effort is spent on finding ways of integrating these displays in the architectural settings

Figure 1: A Projection of the Activity Wallpaper.

in which they are placed. We have proposed the concept of ambient information visualization (ambient infovis, for short), visualizations designed to provide subtle information persentation in public places [10]. In this paper, we present the Activity Wallpaper, an ambient visualization of activity information based on an anlysis of audio data.

Visualizations Of Activity

Several examples of presentations of activity have come out of the HCI field; in one early example of ambient display design [13], awareness of human activity through the use of ambient displays is discussed. Numerous examples of screen-based activity visualizations also exist, some of which are described below.

Related Work

Visualizations of activity are fairly common, but the majority of them concern activity in terms of computer use. This includes activities such as online chat conversations [2], navigation on the world wide web [12] and an inspirational visualization of texts created at an office [9].

Visualizations of human activity in the real, physical world are less common, but they do exist: The AROMA system [7], for example, provides mutual awareness information about the activity in between people who are geographically dispersed. It displays visible and audible activity information as subtle changes in an active painting on the wall. Other examples are Shop Activity [3], which visualizes the activity in a workshop at MIT Media Lab, and Presence Era [11], an interactive installation which allows users to browse through an activity history for the gallery in which it is placed. The latter two uses web cameras as only input, whereas AROMA also has the ability to handle input from microphones, and potentially various sensors.

Ambient Infovis & Local Activity

Our own previous work contains two examples of visualizations of physical activity, which we will describe in greater detail in the two sections below. The Exhibition Activity Monitor (Figure 2) visualization was created for an exhibition at an art museum. It measuresthe amount of people that passes in or out through a door by using a photo cell mounted in the door. The visualization consists of 60 rectangular fields in different shades of gray, each representing a time span of one minute; the whole screen thus covering a time span of one hour. If no one passes the door during a minute, the field representing that minute will be black. The more people that pass, the lighter shade of gray the square will be, and if as many as 30 or more people pass during one minute, the square will become white. It starts by filling the field in the upper left corner and then moves from left to right, until the first row is filled. It then starts over at the left end of the second

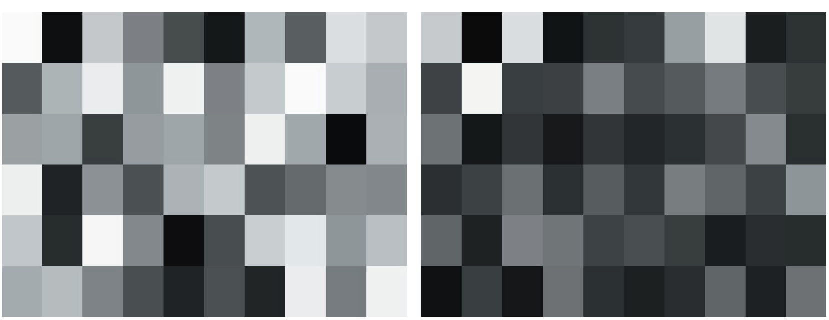

Figure 2: Exhibition Activity Monitor

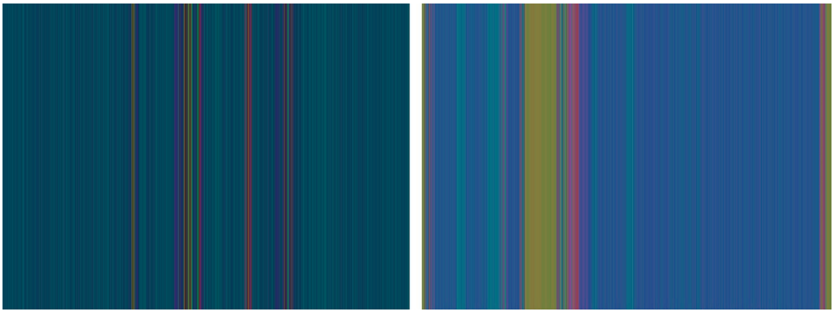

Figure 3: The Motion Painting

row and so on until the whole screen is filled. When the entire screen is filled, the visualization starts over in the upper left corner, overwriting the information from one hour earlier.

The Motion Painting (Figure 3) is another activity monitor, created especially for exhibition at SIGGRAPH 2001 [5].The visualization paints thin, vertical lines in different colors from left to right on the screen. It uses a web camera to determine the activity level in a room (or whatever area theweb camera is aimed towards). Zero activity is mapped to a "base color" of choice, and the more activity it is in the room, the more the color differs from this base color. The speed with which the lines are painted is set at startup. At the exhibition it was set to a high update rate, in order to make the visualization more interactive. It then took about half an hour to fill the screen with lines. When running in our lab, however, it was usually set at a slower pace, taking an entire day to fill the screen with lines. We found this tobe a nicer use of the visualization since it constantly providedan activity history over the latest 24 hours, which is more interesting when you see the display every day.

Capturing Activity Data

Since we were designing for a public place, we wanted to find a place outside the lab to use as a test bed. We believe that use in dynamic, everyday environments has the potential to give us more valuable feedback on our ideas. We decided to design the visualization for a local café, which is good example of the kind of setting that we were looking for. Activity data can be captured in a multitude of ways, e.g. by using cameras, micophones and photo cells, as seen above. We decided to use microphones, mainly for two reasons. Firstly, a microphone can easily be concealed in the room, and secondly, microphones are cheap, readily available and plug-and-play. This enabled us to start prototyping right away, which wouldn't have been the case had we chosen to use a custom built sensor.

Using Amplitude

As an initial stage in developing the audio analysis, we simply used the amplitude of the audio signal as a means of measuring the activity, well aware of that it was a crude tool. It proved to be useful in the early stages of experimenting, but we soon realized that this "naïve" method of measuring activity would not suffice for our purposes. In order to create an interesting and useful display, we needed a more advanced model that would give us a richer output.

Advanced Audio Analysis

We developed an analysis model in MATLAB (http://www.mathworks.com) on a standard PC, running Windows. For privacy reasons, none of the audio data thatis captured by the microphone is stored, but is passed on directly to the analysis. The program records for ten seconds, performs the calculations and then outputs the analysis (at a rate of approximately four times per minute) to a Java program drawing the visualization, described later.

The MATLAB program consists of four different modules that analyzes the sound signal and tries to detect different characteristics that are significant for the perceived activity level at the café. The four modules are invoked sequentially and each outputs a normalized value in the range [0-1]. A full documentation of the model can be found in [6]. The four modules are:

- *Center of Gravity Fluctuation Strength* (CGFS): The center of gravity is a parameter describing if the signal energy of the sample window is predominantly high or low frequency. The CGFS then, measures fluctuations in this parameter over time.
- *Mean Level Fluctuation Strength* (MLFS): Similar to CGFS, MLFS measures the fluctuation strength over time in the signal, but for amplitude rather than frequency. Speech will generate a low MLFS value, whereas a smooth signal, like a sinusoid will generate a high value.
- *Speech Interference Level* (SIL): Indicates the amount of background noise in the signal. This could be people moving chairs or silverware against china, but also speech from people situated at some distance from the microphone.

- *Low Frequency Modulation* (LFM): Measures the speech rhythm of captured voices. This parameter gives the best results for single speakers, without background noise, but still gives a hint about the general speech rhythm of the people in the room.

Given this, what assumptions can be made about the activity level at the café? We found the three most interesting features to be MLFS, SIL and LFM. The MLFS parameter provides a rough measure of the amount of speech in the audio signal, suggesting how crowded the café is. SIL measures the background noise, which can be caused by background speech or just general hubbub from people moving around. LFM indicates how animated the discussions in the area around the microphone are.

Designing the Visualization

When designing the visualization, there was a number of issues to consider, such as what information to display, how much historical data to incorporate, what display technology to use, etc. These issues are discussed below.

Making Use of the Analysis Model

We chose to use two of the parameters from ouput by the analysis model: MLFS and SIL, which we found to be two good parameters. Contrasted against each other they form an interesting "activity space" where the values from the parameters meet. The MLFS parameter indicates whether or not the café is crowded and the SIL parameter reflects how calm or noisy it is. Contrasting these values against each other gives us four "states" in between which statistical data will move, as can be seen in Figure 4. The reason for discarding the third parameter that we initially found interesting, LFM, was that this parameter works better for input signals with one single or a few speakers. This condition is not representative of the café environment, thus we chose not to include it.

Displaying Activity History

Simply visualizing the current activity level at a location is not very relevant, since if you are located in a place you can determine the current activity level there by yourself. Hence we need to record a history of the activity to make the display interesting and allow for people to relate the current activity level to other points in time such as "this time yesterday" or "Tuesday morning".

We decided to let the display show a week of historical data, based on the hy-

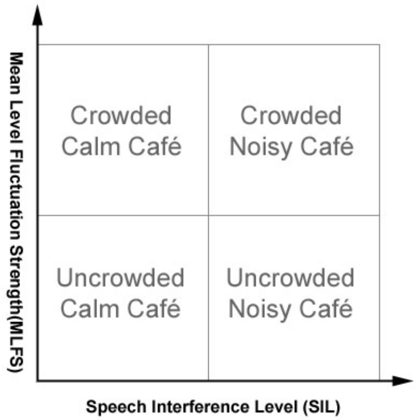

Figure 4: The four "states" in between which the output from the analysis model will move.

pothesis that "a week" is a time frame that people in our society are likely to have their everyday lives structured by, in some sense. We wanted the layout of the display to be structured in a way that would allow the users to intuitively grasp this structure. We chose to structure the time along two axes where one represent the day of week and the other the time of day. The display has eight columns, one for each day in the past week, and each column is divided into 30 rows, each corresponding to 1/30 of the time the café is open (Figure 5 A). The café doesn't open the same time every day (8 AM on week days, 10 AM on weekends), so the rows are aligned to make each row correspond to the same time of day for all days. This means that on the weekends, when the café opens later, the first few rows won't display any activity, simply since the café is not open at that hour.

Display Technology

When we first started developing the visualization, we intended to run it on a LCD-screen, mounted on a wall. The large size of the room in the café where we wanted to display the visualization discouraged us from this solution, since we feared that display would disappear rather than blend in. Using a larger screen did not seem appealing either, since that would be more of an intrusive element in the environment. Hence we chose to use a projector, which allowed us to enlarge the visualization, while still keeping it an integrated part of the room.

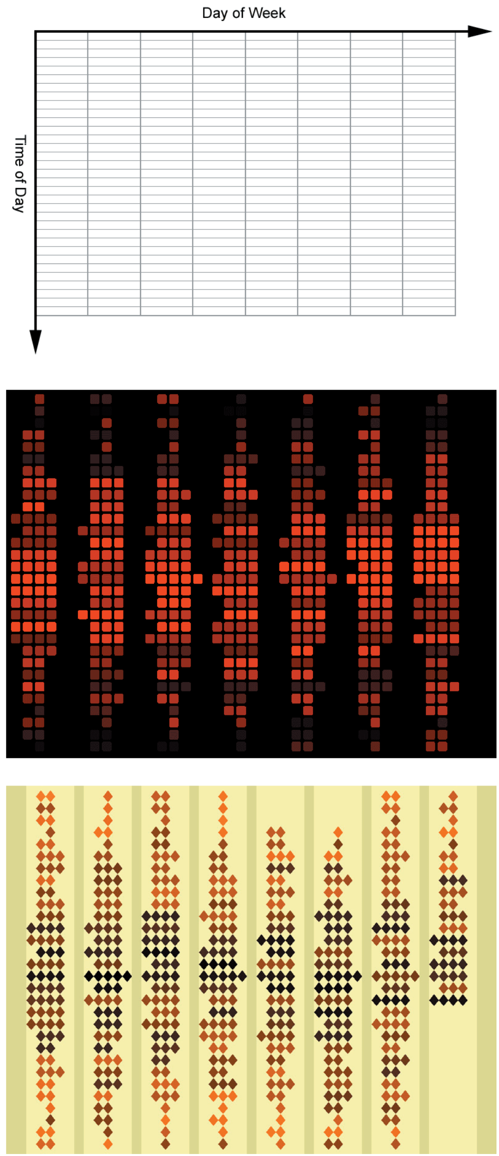

Figure 5: Development of the visualization (A, B & C). A shows how time is mapped, B shows a visualization sketch and C shows the visualization after modifications for use with a projector.

Appearance

The choice of a projector as a display method somewhat affected the way we could design the visualization, e.g. in terms of color choices, since visualizations with dark backgrounds tend to be hard to read when projected. This caused the change of appearance from Figure 5 B, to the one in Figure 5 C, which is inspired by patterns from wallpapers and tapestries. This choice was made since we wanted the projection to be an integrated part of the wall, much in the same way as a wallpaper or mural.

Current data is written in the rightmost column, from top to bottom, as the day passes. The history of the seven preceding days are read from right to left, so that the leftmost column represent the activity from a week ago. Also note the "blank" space at the beginning of two of the columns, indicating that there was no activity.

The color is determined by the noise level, as indicated by the SIL parameter. The more the color diverts from the Figure 4: The four "states" in between which the outbackground, the noisier the café is. The number of "dots" (0-5) in each row represents the crowd (indicated by the MLFS parameter), so that the more dots, the bigger the crowd was at that point. By looking at the resulting visualization, patrons can see how the activity level at the café has fluctuated over the last week, revealing phenomena like lunch hour peaks or quiet weekend mornings.

Discussion

Previous activity visualizations have for the most part consisted of mappings from fairly simple, uninterpreted sensor data to some output. We argue that more advanced analyses of activity, like the one used here, have the potential of revealing more aspects of activity and how these aspects interrelate. This opens up for analyses and interpretations of activity, which hopefully will yield even more interesting displays.

Here, we have presented the Activity Wallpaper, an ambient visualization of activity that is intended to act as an amplified memory for a public place; in this case a café. By making the activity history visible in the café, we hope to enhance its aura and give the patrons a feel for how the place is inhabited.

A projection of the visualization can be seen in Figure 1.

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