TOWARDS A DESIGN PHILOSOPHY FOR EVERYDAY COMPUTATIONAL THINGS

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1 Introduction

Everyday things are the things we live with. They are the building blocks of our lifeworlds. Many everyday things are not specifically for work or leisure, as they transcend the borders of many activities. Consider, for instance, the use of telephones: we use them at work to coordinate and communicate, but we also use them to talk to friends and familiy. In the case of mobile phones, this is even more evident as we carry the very same device with us, independent of whether we are working, spending time with friends, travelling, etc. As the mobile phone has entered our everyday life, it has also become a personal object that we use to express who we are, our lifestyle, etc. (cf. [50, 79, 82]).

The mobile phone is just one example of how computational things increasingly pervade everyday life. Computers are embedded in all sorts of existing kinds of things, such as cameras, cars and watches, transforming and amplifying their original appearances and functionalities. Computational technology is also used to realise a plethora of new kinds of devices such as video games, PDAs (Personal Digital Assistants), and musical instruments, the list being made longer each day. As computers pervade everyday life, they too will become everyday things.

What an everyday computational thing is, can not be captured by reference to distinctions such as office applications (e.g. word-processors) vs. games, or productive work vs. passive consumption, since such distinctions fail to acknowledge the complexities and subtleties of everyday life. Further, as use of information and communication technology increases and the importance of colocation in space and time for collaboration and communication is reduced, divisions between work and spare time based on locations in space (e.g., offices) and time (e.g., business hours) are undermined. Instead of thinking about computer use in terms of work or play, the development towards a ubiquity of computational things in everyday life urges us to revisit the basic question of what computational things are in respect to how we are going to *live* with them. This question is the topic of this thesis.

Traditionally, human-computer interaction research tended to focus on how to effectively support people in accomplishing, primarily work-related, tasks, and therefore the notion of usability was central. As computational things become everyday things, what we design for can not be restricted to how to enable people to become more productive. Thus, there is a need for complementary design philosophies. The ambition of this thesis is to support the development of such new design philosophies and perspectives.

This thesis is an investigation of the design space of everyday computational things starting from the question of how to design such things so that they can become integral parts of everyday environments. Using experimental design, I have investigated how to design computational things for meaningful presence in everyday life, how to work with time as a central design variable, how to combine computational technology with traditional materials used in interior design. I have worked with how to design for different aspects of use, especially the aesthetics of things in use. The specific results from this investigation are the design examples described in the seven papers included in the thesis. These design examples illustrate a set of parameters, and design opportunities, of this design space, and they can be said to act as a kind of "landmarks". The more general results of this investigation are formulated as a design philosophy for everyday computational things. This design philosophy is described towards the end of this paper.

In the following, I will introduce the thesis by first describing its background in relation to two different lines of critique of present-day human-computer interaction. The first critique concerns the design of the human-computer interface itself and how computational technology can be integrated with everyday environments. The other concerns problematic consequences of a strict focus on usability, and what other values and aspects of use we have to acknowledge when designing for everyday life.

2 Background

The development of computer use can be described as a development towards ubiquity. First, very few computers existed and many people shared each one. Over time, this condition has changed and today, one user frequently confronts many computers and may even regularly use a collection of more or less specialised computational devices such as stationary and mobile PCs (Personal Computers), PDAs (Personal Digital Assistants), digital cameras and video games.

The design of how computational things appear *in use* has been centred on the notion of a human-computer interface, an interactive "surface" through which the user controls the computer and the results of the computations are displayed. As new areas of computer use have developed, new human-computer interfaces have been created to meet new demands (cf. [36]). Over time, new disciplines and research areas related to human-computer interaction (HCI) have emerged, e.g., *interaction design* as a response to new design challenges (cf. [89]) and *Computer-Supported Cooperative Work* (CSCW) as a response to the focus on single users within HCI in settings where the social and organisational context of computer use have become increasingly important (cf. [11]).

The human-computer interface is frequently referred to as the “user interface”, the reason being that it was just yet another interface between components of the system that had to be designed [37]. As we leave an engineering perspective and focus on people and their use of computers, this terminology is, however, no longer adequate. Grudin states that “Ironically, “user interface” is a technology-centered term. /…/ The computer is assumed, the user must be specified /…/ *The term “user” retains and reenforces an engineering perspective*” [37, p. 270].

Given the development of information technology during the last decade it is remarkable that little has changed since Grudin made his analysis over ten years ago. Not only is the term “user interface” still in use, but so is the perspective it reinforces, as can be seen in this quote from *User and Task Analysis for Interface Design* by Hackos and Redish:

> It is from work in cognitive psychology over the last several decades that we have come to appreciate that we cannot just impose designs on users. People are active parts of the system, and because they are much less predictable and less well understood than the computers and other technological parts of the system, they require even greater study and understanding. [38, p. 15].

Intitially, computers were a scarce resource and users literally had to come to the machine. The situation we face today is, however, quite different. It is important that we do not continue to regard the user as yet another part of some technical system, but instead consider computational things to be part of a larger context, in this case everyday life. This means that we have to revisit issues in both the design of computational things and how they will be used.

2.1 Ubiquitous Computing

> The significant universal tool of computer culture is the electronic screen. The screen is the pet of computer culture – at home as well as in the office. The television screen has developed into the universal communication medium of the information age, the screen is the paper of the Gutenberg age. Its applications are more or less unlimited. *Leopoldseder* [51, p. 69].

As screen-based interaction with computers still dominates, this statement is probably as relevant today as when it was made by Leopoldseder fifteen years ago. Comparisons between literacy technologies and computers have, however, also been used to illustrate the shortcomings of present human-computer interaction. Weiser comments that:

> Not only do books, magazines and newspapers convey written information, but so do street signs, billboards, shop signs and even graffiti. Candy wrappers are covered in writing. /…/ Silicon-based information technology, in contrast, is far from having become part of the environment. /…/ The state of the art is perhaps analogous to the period when scribes had to know as much about making ink or baking clay as they did about writing. The arcane aura that surrounds personal computers is not just a "user interface" problem. [83, p. 933].

What makes literacy technology so different from computational technology is, according to Weiser, how little effort it takes to use it: it is just there as a part of everyday things and environments, without demanding our attention [83]. In the case of literacy technology, the technology itself has "disappeared". (One should, however, not forget that it took us many years of hard training to develop these skills.) Making computers disappear, however, implies a reconsideration of many aspects of their design: "Getting the computer out of the way is not easy. This is not a graphical user interface (GUI) problem, but is a property of the whole context of usage of the machine and the attributes of its physical properties: the keyboard, the weight and desktop position of screens, and so on." [84, p. 76]. Similar views have been developed elsewhere, especially within the areas of *augmented reality* [88], *tangible user interfaces* [46] and more recently in the notion of *information appliances* [67].

A program for how to make computing an integral, invisible part of people's lives, called *ubiquitous computing,* was developed by Weiser and colleagues at Xerox PARC in the late 1980s [83, 87]. One of their hypotheses was that to effectively become part of the environment, computers have to be sensitive to where they are located, who is using them and similar issues related to context [cf. 80]. The first devices that came out of the ubiquitous computing experiments were the *tabs*, *pads* and *boards* [80, 83, 84]. They correspond to different sizes of commonsense objects: objects that fit in the hand (tabs), objects that can be carried around, e.g., about the size of scratchpad or a book (pads); and objects that are stationary resources, such as wall-mounted boards (boards).

The tabs, pads and boards were designed for different forms of reading and writing information: the tabs for easy information retrieval and writing short messages while on the move; the pads for, e.g., desktop use: the user would have several pads around, just like we are used to work with several paper documents, books, scratchpads, etc., simultaneously; and the boards, finally, as counterparts to bulletin boards, white boards and other similar surfaces that we use for public information distribution and collaboration.

The tabs, pads and boards used different forms of GUIs, but over time other approaches to interface design, such as *Calm Technology* [85, 86], were developed. Central to the notion of calm technology is the idea of periphery and peripheral attention. A characteristic property of peripheral information sources is that we can move our attention to them when needed in a seamless, and to some extent even unconscious, fashion (cf. also [12]). With calm technology, this vision of ubiquitous computing involved considerations on all levels of design ranging from hardware to the aesthetics of computational things in use.

Ubiquitous computing as a term was, at least initially, associated with these projects at PARC, but it is increasingly used as a general term for the research field that these ideas generated (cf. [35]). Other related terms are, for instance, *pervasive computing* [3], *sentient computing* [44], *invisible computing*[67], and *disappearing computing*[1]. The ubiquitous computing experiment at Xerox PARC represents one of the first reconsiderations of what computational things are and how to go about designing them, but there have also been other approaches to design for "ubiquitous computing" in the broad sense of the word.

Augmented-reality starts from a view similar to that of Weiser's vision of ubiquitous computing: instead of bringing people to the computers, be it a desktop computer or a VR (Virtual Reality) system, we should integrate computational technology with existing things and environments [88]. One common approach is to use overlay technology, such as see-through head-worn displays, to superimpose graphical information on the physical objects the user looks at (cf. [30, 71], also *wearable computing* [60]). In this way, physical objects can appear to have new (visual) properties, virtual objects can be added, etc. We might say that since the computer is only used as augmentation, it will not be a part of the real-world, but rather as a layer between people and the rest of the environment (cf. [29]). When used in the right context, the possibility of not having to change the properties of the real-world objects can be a way of introducing computational support into a practice by means of augmenting existing tools rather than replacing them. This strategy have been used

1. In 2000, a research agenda called *The Disappearing Computer* was initiated within the European Union research framework for Future and Emerging Technologies. For more information see "The Disappearing Computer, Information Document, IST Call for proposals, February 2000" (http://www.cordis.lu/ist/fetdc.htm).

in the development of computer support for work practices that have little room for error and breakdowns, such as air traffic control [59], where the so-called "flight strips" used for keeping track of aeroplanes where augmented rather than replaced with digital counterparts.

Besides giving computers access to rudimentary information about where they are located, who are using them, etc. the idea with *context-aware* (cf. [80]) computing is to make it possible for computing systems to infer what the user is doing so that he or she does not have to attend to the machine at all times commanding it what to do next (cf. [52]). Rekimoto and Nagao argue that:

> GUIs can reduce the cognitive overload of computer operations, but do not reduce the volume of the operations themselves. /…/ The user's focus of interest is not the human-computer interactions, but the human-real world interactions. /…/ Consequently, the reduction of the amount of computer manipulation will become an issue rather than simply how to make existing manipulations easier and more understandable. [71, p. 29].

To address this problem, they propose an interaction style called "Augmented Interaction" that "aims to reduce computer manipulations by using environmental information as implicit input." [71, p. 30]. Such implicit input will be gained by using various sensor technologies, such as camera vision, to infer what the user is currently doing. Such use of sensors is also central in the related areas of *intelligent* [13], *reactive* [15] and *responsive environments* [27].

The notion of *tangible user interfaces* represents another critique of GUIs and the personal computer (cf. [78]). Early examples include work on *graspable interfaces* [31] and experiments with tangible user interfaces at Interval [14]. Ishii and Ullmer present a design program for "tangible bits" [46] that states that "Ultimately, we are seeking ways to turn each state of physical matter – not only solid matter, but also liquids and gases – within everyday architectural spaces into "interfaces" between people and digital information." [46, p. 235]. Thus, tangible interfaces aims to literally turn the physical world into an interface, and to make computational resources available in a way that enables us to use the skills we have developed for manipulating ordinary physical objects. We also find the notion of foreground and background in this design program for tangible bits: with tangible interfaces we will be able to grasp & manipulate "foreground bits" coupled to physical objects, and to be aware of "background bits" through *ambient media* [46 p. 235] (cf. also [91]).

The concept of *information appliances* [67] is closely related to the idea of replacing the computer with a number of highly interconnected specialised devices in the ubiquitous computing scenario above. Norman argues that what makes the personal computer so complex and difficult to use is that it aims to do too many things for too many different users. By replacing the universal computer with information appliances optimised for a single task or activity, we can overcome many (if not most) of the usability problems associated with computers [67]. To get more complex functionality, users should be able to combine the functionality of several appliances, hence the need for communication between them. Given the difficulties associated with programming and managing our existing electronic appliances, such as video recorders, television sets and mobile phones, this solution might not be as simple to implement as it might first seem. Nevertheless, if we move beyond usability considerations, the concept of information appliances can be an interesting basis for reconsidering what computational things might be like (cf. [34]).

The approaches described above are all examples of how the personal computer and present interaction design have been challenged, and how computers instead can be made part of everyday environments. Designing everyday computational things is, however, not only a matter of making the interface reach out into the world, but also a matter of what we consider computer use to be about.

2.2 Use and Usability

When we describe or denote an everyday thing, we often do this on the basis of its practical functionality, e.g., a sail-boat, or a rain-coat. Even extreme designs of utility things with very limited practical functionality in actual use, are still defined by their "functionality" and it is this "functionality" that is the basis for the design. Part of the ambition in experimental design is to stretch the notion of what a given kind of thing, e.g., a house, is by exposing certain aspects of what we think it is and see how far one can go before the designed thing is no longer considered such a thing but something else. While practical use is a useful way to point out a place or a role of an artefact, it does not imply that practical functionality is all that matters.

Paulsson & Paulsson discuss three forms of use of utility things that the designer has to acknowledge: i) *practical* use; ii) *social* use; and iii) *aesthetic* use [68]. Practical use is for instance when we use a hammer to drive a nail, or when we use a car to take us somewhere. Unlike most hammers, cars also have strong symbolic values in social use. Social use concerns the roles things play in our social life, their symbolic values in social contexts[2], as when we choose to wear certain clothes for a particular occasion, e.g., at a wedding. Finally, aesthetic use concerns reflective use, e.g., when we observe a thing for its beauty. Aesthetic qualities cuts across both practical and social use as it concerns how we turn to a thing and reflect upon its expressions. These distinctions do not have to be made in terms of use; we can also distinguish between functional, symbolic and aesthetic *qualities* in use (cf. [20]).

Another way of describing similar aspects of the design of a utility thing, is to use the notions of product and meta-product. According to Monö, a meta-product is the result of "all the interpretations and ideas

2. This notion of symbolic properties should not, however, be confused with product semiotics, where semiotics is used in design to analyse how a certain design is perceived and understood (cf. [63]).

‘behind’ the physical product, such as prejudices, status, nostalgia, group affiliation and so on.” [63, p.20]. In our culture, the meta-product is made increasingly important, e.g., when we pay more for a certain brand [63, p. 20]. In Monö’s description of semiotic design, aesthetics is said to be “*the study of the effect of product gestalt on human sensations*./.../ the way in which parts are made into a whole with the desired effect on human sensations. As a result, the aesthetics of design also comprises the study of the way in which human beings read and understand how to interpret the parts and the whole of a visual gestalt.” [63, p. 27]. Here, aesthetics is one of the factors that determine the consistency of the appearance of a thing.

In his analysis of design as rhetoric, and the designed object as argument, Buchanan discusses three aspects of the design argument: *logos*, *ethos*, and *pathos* [8]. Logos is technological reasoning, “the way the designer manipulates materials and processes to solve practical problems of human activity.” [8, p. 96]. For instance, most hammers are based on the basic premise of a lever supporting a head, made in a size fitting comfortably in a person’s hand. Ethos is the character of the designed product, as it reflects its maker: “part of the art of design is the control of such character in order to persuade potential users that a product has credibility in their lives” [8, p. 101]. Pathos, finally, concerns emotional persuasion and can be considered the connection between design and fine arts. Emotional persuasion is often in focus when we think about “form”, e.g., persuasion in terms of “beautiful” or “artful” design (cf. [8, p. 103]).

Although these three perspectives on design have their origins in such diverse design philosophies as the *Scandinavian Modern* design [68], *semiotic* design [63] and contemporary design theory [8], they all acknowledge a basic set of functional, social and aesthetic qualities of an artefact. We can now compare this to how design is approached in human-computer interaction.

Usability

Considering the use of computers as approached in HCI, the notion of *usability* is central. Definitions of usability vary, but the following five attributes can be considered typical [65, p. 26]:

- Learnability
- Efficiency
- Memorability
- Errors
- Subjective Satisfaction

Here, learnability means that a system should be easy to learn and that the learning curve should be appropriate, i.e., that novice users quickly can begin to work with the system and that the learning curve is smooth and does not pose large steps that are hard to overcome. Efficiency is about maintaining a high degree of productivity once the system has been learned. Memorability is about how easy it is to remember how to use the system once learned. For instance, systems that are only used a few times a year must be easy enough to memorise so that the user does not have to learn everything over again every time the system is going to be used. Further, the system should be designed in a way that minimises the number of errors users make, and in case an error occurs, recovery should be quick and easy. Finally, the system has to be satisfying to use; the user should like to use it.

As a comparison, we can consider the ISO 9241-11 definition of usability in the "ergonomic requirements for office work with visual display terminals" ([47], adopted from [32]):

- *Effectiveness*: the accuracy and completeness with which users achieve certain goals;
- *Efficiency*: the relation between effectiveness (as defined above) and the resources expanded in achieving them;
- *Satisfaction*: the user's comfort with and positive attitudes towards the use of the system.

In the actual practice of interaction design, usability is not necessarily restricted to these attributes and so neither list should be seen as exhaustive. However, it gives a general idea of how computer use is approached, what criteria are used to determine the quality of a design and that the underlying premise is how to make people more productive. Hackos and Redish state that “good design is important. It makes users happy and productive, increasing customer satisfaction, one of the major goals for most companies. It increases efficiency and decreases support calls, thus making and saving money for companies.” [38, p. 1]. Here, usability as a way of evaluating a design is clearly related to productivity.

Computer Use Revisited

It is obvious that the usability approach to design leaves out aspects of use that are acknowledged in other areas of design for everyday life. In fact, the basic premise of technology use as a way of increasing productivity, is in many respects incompatible with everyday life. Djajadiningrat et al. argues that “While usability is often a laudable goal, it isn’t enough. Focusing on ease of use tends to encourage a narrow view of what ‘use’ is with respect to technology, emphasising efficiency and productivity over exploration or curiosity. With a correspondingly narrow range of models for usability, interaction tends to be self-similar, mundane, and ultimately boring.” [22, p. 66]. The importance of “subjective satisfaction” in usability studies also indicates the relevance of a broader view on use. Hassenzahl et al. [39] report findings that indicate that “hedonic qualities”, such as novelty and originality, can be as important as ergonomic qualities, such as simplicity, in determining a software’s appeal to the user.

In *The Design of Everyday Things* Norman states that: ”If everyday design were ruled by aesthetics, life might be more pleasing to the eye but less comfortable; if ruled by usability, it might be more comfortable but uglier. If cost or ease of manufacture dominated, products might not be attractive, functional, or durable. Clearly, each consideration has its place. Trouble occurs when one dominates all the others." [66, p. 151]. Norman's remark suggests a very simplified notion of what design is about, and especially what aesthetics is about. In comparison, Borgmann argues that:

> /.../ design as a practice has divided into an engineering branch and an aesthetic branch. Engineering devises the ingenious underlying structures that disburden us from the demands of exertion and the exercise of skills and leave us with the opaque and glamorous commodities that we enjoy in consumption. Aesthetic design inevitably is confined to smoothing the interfaces and stylizing the surfaces of technological devices. Aesthetic design becomes shallow, not because it is aesthetic, but because it has become superficial. It has been divorced from the powerful shaping of the material culture. Engineering has taken over the latter task. But it in turn conceals the power of its shapes under discreet and pleasant surfaces. If we are concerned to revive engagment, we must try to recover the depth of design, that is, the kind of design that once more fuses engineering and aesthetics and provides a material setting that provokes and rewards engagement. [7, pp. 15f].

Part of the problem with the role of aesthetics in technology development is that aesthetics is often reduced to a matter of how a given thing "looks" on the surface. If we are interested in designing consistent and convincing things, things that have "depth" [7], we must consider aesthetics to be something much more profound. Zaccai argues that: "the original meaning of aesthetics must be rediscovered. We need to understand that aesthetics is not simply a visual exercise, but rather the appropriate and harmonious balancing of all user needs and wants within technical and social constraints." [93, p. 6], and further that "At a certain point the seemingly divergent requirements of technical rationalism, emotional content, and sensory perception converge and complete a sphere. It is that sphere which defines the true nature of aesthetics" [93, p. 9]. Crampton Smith and Tabor present a related perspective on the role of aesthetics in design:

> Aesthetics, moreover, are concerned with more than visual appearance. There is a delight in a program that is rigorously consistent, elegantly clear and lean, where sound and vision are perfectly at one, or where the representation chosen neatly fits the ways that users think about what they are doing. These qualities cannot be added on at the end: They are integral to the design and engineering of the product. [16, p. 45].

Aesthetics is not a matter of how to create a stylish surface of some artefact – it is one of the foundations for design. Design of computational things can, therefore, not be reduced to a matter of aesthetics vs. usability. We can not develop computational things with focus on practical functionality only and then add aesthetic, social, emotional etc. qualities afterwords – such dimensions of everyday things have to be made integral parts of our design approach from the start.

Despite the problematic lack of attention to aspects of use of everyday things that fall outside practical functionality and usability, this does not seem to be something that the HCI research community is going to reconsider in the near future. In *Strategic Directions in Human-Computer Interaction* [64], based on the results of the Human-Computer Interaction Working Group of the ACM Workshop on Strategic Directions in Computing Research, the field of HCI including future strategic themes are outlined. The strategic themes presented are: i) universal access to large and complex distributed information; ii) education and lifelong learning; iii) electronic commerce; iv) end-user programming; v) information visualisation; and vi) computer-mediated communication [64, pp. 800-802].

One of the technological trends identified is new forms of computational devices and ubiquitous computing. Among the HCI problems in ubiquitous computing presented, we find issues such as how to address "the tension between the design of interfaces appropriate to the device in question [size and resolution of display, stance of the user, e.g., sitting, standing, etc.] and the need to offer a uniform interface for an application across a range of devices. [e.g., to quickly learn to use a familiar application on a new device]" [64, p. 803]. With the possible exception of electronic commerce – as it is said to involve social issues such as trust and privacy – only the practical functionality and usability of computational things are considered. In the concluding section of the report, the authors state that: "We now have a solid foundation of principles and results to teach in courses and from which to base today's user interface design and tomorrow's research. As computing systems become increasingly central to our society, HCI research will continue to grow in importance." [64, p. 806]. While this design philosophy has been highly successful in some areas of computer use, this does not imply that it is universal.

This narrow perspective on the use of computational artefacts that, presumably, will be designed to be a part of people's everyday lives, is, unfortunately, also evident in the agendas of novel approaches such as ubiquitous computing. For example, in *Charting Past, Present, and Future Research in Ubiquitous Computing* by Abowd and Mynatt [1], the concept of "everyday computing" is presented and we learn that the following features of informal and daily activities will have to be addressed in future research: that i) they rarely have a clear beginning or end; ii) interruption is expected; iii) multiple activities operate concurrently; iv) time is an important discriminator; v) associative models of information are needed [1, pp. 42-44]. Among the future research directions that the authors think are needed, we find: how to vi) design a continuously present computer interface; vii) presenting information at different levels of the periphery of human attention; ix) connecting events in the physical and virtual worlds; x) modifying traditional HCI methods to support designing for informal, peripheral, and opportunistic behaviour [1, pp. 45-46].

While these issues all can be considered relevant, this agenda is also an illustration of the difficulty of turning away from a productivity oriented perspective on computer use. Abowd and Mynatt consider social issues in ubiquitous computing important, but their concern seem to be limited to aspects such as security, visibility, control and privacy in an environment where computers use sensors and automatic capture to become “context-aware”. Although the authors aim to introduce the notion of “everyday computing”, aspects of use that are crucial in other areas of design for everyday life are missing in this agenda.

It is obvious that technological development is ahead of the understanding of technology use. This is not too surprising given the history of technology-centred development. What is intriguing, however, is that a research discipline devoted to developing human-centred systems has paid so little attention to aspects of use that falls outside a concern for increased productivity. While the desktop computing paradigm has been challenged in a multitude of ways, we see little development in the understanding of what it means to have computational things present in our everyday lives. There are, however, examples of how to break away from this perspective on computer use.

Dunne argues that “The result [of the Human Factors approach to design], as the computer industry merges with other industries, is that the optimisation of the psychological fit between people and electronic technology, for which the industry strives, is spreading beyond the work environment to areas such as the home which have so far acted as a counterpoint to the harsh functionality of the workplace.” [23, p. 18]. According to Dunne, this is due to uncritical acceptance of the “American Ideology” and the idea that all problems are “technical” problems and subject to rational solution through the accumulation of objective knowledge with a general ambition of maximising society’s productivity and making the most economic use of its resources (cf. [23, p. 17]). To open up for new perspectives on electronic products and reduce this tight “psychological fit”, Dunne has explored the notion of “parafunctionality”, a kind of “functional estrangement” by means of creating a “poetic distance” towards the object [23, 75].

Another set of examples of new possibilities in the design space of everyday computational things are the conceptual information appliances presented in [34]. Here, Gaver and Martin criticise present design of everyday computational things: “Suggestions for how digital technologies might be employed in everyday settings tend to represent a narrow range of cultural possibilities, reinforcing a simple dichotomy between work and play. Many devices import values from the workplace into the home, emphasising the requirements of “domestic work” by allowing chores to be done more efficiently or productively. Others emphasise the desirability of taking “time off”, allowing people to play unproductive games or access new forms of broadcast media. Other values seem rarely to be addressed at all.” [34, p. 209]. The information appliances presented are instead designed to uncover new places for technology in everyday life by exploring different values, emotions and desires. Examples include the *(De)tour Guide*:

> The Guide would permit a variety of functions, from leading users to a designated location to encouraging them to become totally lost in unfamiliar districts. [34, p. 210].

Another proposal is the *Dawn Chorus*:

> It is pleasant to be awakened by the sound of local songbirds, but how much more enjoyable it would be if they knew our favourite music. This could be made possible by an artificially intelligent birdfeeder. Joining a microphone, speaker, pitch-tracker, and software, it would use behaviourist principles to teach the birds new songs, /.../ individuals could be taught to take different harmonic roles. The process could take months, but in the end a polyphonic dawn chorus might be achieved. [34, p. 210].

Clearly, these proposals challenge traditional assumptions about computer use and support development of new possibilities for the design of everyday computational things.

We can also consider the research programs that introduced novel approaches such as ubiquitous computing and tangible media, as they tend to use both artworks and experimental design objects as illustrations. For instance, one of the primary examples of calm technology – the *Dangling String* – is made by an artist, Jeremijenko [86]. Bishop's *Marble Answering Machine* is presented as a source of inspiration in tangible media [46]. Further, experimental design by Dunne and Raby on *Fields and Thresholds* has served as inspiration for work on interfaces that act in the periphery [24, 46]. What is inspiring with these examples is not their practical functionality nor their technology, but how they differ from more traditional human-computer interfaces.

When we turn to everyday life in general, we have to extend our notion of use to encompass aspects such as social and aesthetic qualities as well, and therefore, a strict focus on usability is not sufficient. Given the expected impact of computational technology on everyday life, it might even be the case that usability *per se* is problematic. Dunne argues against a tight psychological fit between people and technology [23], and Meurer presents a related argument:

> By introducing microprocessors at all levels of our everyday lives, we have altered our understanding of use and the way in which we use things. /.../ The social, cultural, and ecological problems unleashed by these developments reveal how necessary it is to rethink our concept of use and ease. The easier something is to use, the less we think about how we are using it and the "side effects" of such use. The more perfectly a product has been designed, the less we are tempted to consider any problems posed by it or its use. [61, pp. 46f].

It is probably not the case that usability is something to be avoided, but we cannot simply assume that technology that is easy to use, or technology that is invisible, is "good" technology (cf. also [7, quote on page 14]).

The development towards ubiquity of computational technology in everyday life urges us to rethink what a computational thing is in respect to how we are going to live with these things. To broaden our understanding of the design space of everyday computational things, we have to revisit basic issues in human-computer interaction. New theoretical frameworks for design for different qualities in use and roles in everyday life, can help us gain new perspectives. We can use experimental and critical design to create examples of what everyday computational things might be, and get a richer basis for discussion and reflection.

3 Thesis

The design space of everyday computational things include both what we normally call "computers", and various everyday artefacts being computerised. Agendas such as ubiquitous computing, augmented reality and tangible user interfaces have provided examples of how desktop computers can be replaced with solutions that are integrated with things and environments in various ways. The transformation of various everyday things by means of embedded computational technology illustrate the powers of computing in things we would not even consider to be "computers". Thus, there is a significant amount of possibilities for using computational technology when designing things for everyday life.

The topic of this thesis is how to design for *living with*, rather than just *using*, computational technology. To design for everyday life involves much more than supporting people to accomplish certain tasks more effectively, and therefore, design for usability and practical functionality is not sufficient. Since the concern here is how to design things, it is, however, not enough to criticise existing approaches to interaction design by pointing out their limitations outside their original domain; for such critique to be meaningful, it has to be accompanied with practical examples of alternative approaches to the given problems. To support discussion of, and reaction upon, how to design everyday computational things, we therefore need new design philosophies and examples of how such philosophies can guide design.

The ambition with this thesis is, therefore, not to answer a specific question regarding human-computer interaction, but to develop a more general design philosophy for how to design computational things for *presence* in everyday life. Such a design philosophy does not have to be a replacement for existing approaches; rather, it should be a critical contribution to the discussion and analysis of information technology development.

To develop such a design philosophy, we have used experimental design to make investigations into the design space of everyday computational things. By creating a collection of design examples of how such things can become integral parts of everyday environments, we can get both knowledge about the design space itself, as well as a basis for discussion and reflection. Our starting points for this investigation have been:

- amplification of everyday things and environments using computational technology
- forms of information presentation
- time as a central design variable
- use of everyday materials in the design of computational things
- the aesthetics of computational things in use

The details of these investigations are reported in the seven papers included in the thesis. They are:[3]

1. Redström, J., Dahlberg, P., Ljungstrand, P. & Holmquist, L. E. (1999). Designing for Local Interaction. In: Nixon, P., Lacey, G. & Dobson, S. (Eds.); *Managing Interactions in Smart Environments*, pp. 227-238. Springer-Verlag.

3. Below, the papers are also referred to as [P1] – [P7].

2. Holmquist, L. E., Redström, J. & Ljungstrand, P. (1999). Token-Based Access to Digital Information. In: Gellersen, H.-W. (Ed.); *Handheld and Ubiquitous Computing*, Lecture Notes in Computer Science No. 1707, pp. 234 - 245. Springer-Verlag.
3. Redström, J., Ljungstrand, P. & Jaksetic, P. (2000). The ChatterBox: Using Text Manipulation in an Entertaining Information Display. In: Fels, S. S. & Poulin, P. (Eds.); *Proceedings of Graphics Interface 2000*, pp. 111-118. Canadian Information Processing Society.
4. Redström, J. Skog, T. & Hallnäs, L. (2000). Informative Art: Using Amplified Artworks as Information Displays. In: Mackay, W. (ed.); *Proceedings of DARE 2000 (Designing Augmented Reality Environments)*, pp. 103-114. ACM Press.
5. Hallnäs, L. & Redström, J. Slow Technology; Designing for Reflection. Accepted for publication in: *Personal and Ubiquitous Computing*. Springer, London, U.K.
6. Hallnäs, L., Jaksetic, P., Ljungstrand, P., Redström, J., & Skog, T. (2001): Expressions; Towards a Design Practice of Slow Technology. Accepted for publication in: *Proceedings of Interact 2001*, IFIP TC.13 Conference on Human-Computer Interaction, July 9-13, Tokyo, Japan.
7. Hallnäs, L. & Redström, J. From Use to Presence: On the Expressions and Aesthetics of Everyday Computational Things. Submitted for publication.

Below, the papers are shortly introduced.

In *Designing for Local Interaction* [P1], limited communication range between devices was used as a basis for design rather than as problem to solve. By focusing on the notion of proximity as a criterion for information relevance, we aimed to investigate questions such as: how users can create a computational environment in an ad-hoc fashion; how aspects of activities such as local mobility can be used as a basis for information filtering: how information technology can support group awareness when travelling together; and similar issues regarding proximity and local interaction.

Token-Based Access to Digital Information [P2] is about how everyday objects can be used as representations for digital information and be incorporated as parts of the interaction. The paper is based on an analysis of a set of tangible user interfaces and experiences from the *WebStickers* project [54]. The focus is on the distinction between *tokens*, *tools*, and *containers* and in what ways they represent and manifest digital information.

The *ChatterBox* [P3] is an experimental information display based on a combination of text analysis, generation and presentation. Its basic function is to collect and analyse texts produced at a given place, e.g., an office, store them and then continuously generate new texts based on the analysed material. Finally, the resulting texts are presented in a public place, such as a corridor. The paper describes the design of the ChatterBox as well as use experiences.

Informative Art [P4] is a design program for exploring new appearances for information displays. Informative art is designed to look like ordinary (but electronic) pictures, posters or paintings. Over time, however, their dynamics are revealed as they are continuously modified according to changes in the information source they represent. The ambition was not to create art *per se*, but just to use the notion of an art object as a starting point for creating prototypes. The paper describes a series of examples that illustrate different relations between the display surface and source(s) of information, such as mapping information to a single colour using the RGB-code as representation, mapping information to the size and placement of objects, and mapping information to the generation of visual structures using generative grammars.

The fifth paper describes a design program called *Slow Technology* [P5]. Slow Technology is an agenda for experimental design of technology made for moments of reflection and mental rest with focus on the aesthetics of things in use rather than their practical functionality.

Expressions [P6] describes examples of how the design program of Slow Technology has been realised. By interpreting acts in everyday life as acts of reading and writing information using information technology, we investigated different expressions of computational things in use with focus on aesthetics.

The seventh and final paper entitled *From Use to Presence* [P7] describes the development of the theoretical framework of Slow Technology. Here, we revisit the question of what a computational thing is and discuss how design for presence with focus on expressions and aesthetics of computational things in use can help us move beyond design for practical functionality and usability.

4 Method

4.1 General Methodological Framework

The theoretical framework of this thesis is the *new informatics* as described by Dahlbom [18]. The new informatics is a design oriented research discipline directed towards information technology *use*. The new informatics is engaged in design work, creating new technology use. The focus on information technology use means that it is not technology *per se* that is the subject matter, but its potential roles in our lives, our organisations, our societies, etc.

On a more general level, the new informatics can be considered an artificial science [18]. Simon remarked that the modern world is an artificial world, i.e., a world of artefacts [77], and proposed a science of the artificial as a theoretical foundation for design. While Simon's framework is concentrated on design as problem-solving by means of rational search in a given space of possibilities, Dahlbom's call for a new science of the artificial is focused on the normative, social and political aspects of technology use and development [19]. Unlike nature, the man-made world is created and it can be changed [17, 19]. The collection of artefacts that surround us represent more or less conscious choices and decisions people have made regarding what technology to develop, how to design it, what goals to pursue, what qualities in use to aim for, etc. Clearly, most of these decisions could have been made differently and in some cases other decisions would have resulted in better technology. When we study artefacts, we therefore do not only face the question of what already is, but more importantly, the question of what could be.

When we introduce something new in everyday life, we also change what was there before. To use Borgmann's example: by introducing the television set we do not only alter our home environment, we also, to some extent, transform the question of what to do in the evening to a question of what TV-show to watch [6, p. 112]. Television introduces a new role for technology in life, but it does so at the expense of other things. In this way, our lifeworlds are formed by the things that we – more or less consciously and willingly – choose to have around and therefore, these choices represent "moral decisions" [6] that we make regarding how we lead our lives. Ideally, we should not make such decisions on behalf of other people. However, since we are developing new forms of technology use, we do make decisions as we choose to create certain things but not others. Still, we can expose these questions in critical design by not hiding the technology behind a smooth and seductive surface, by not making the technology itself invisible, etc., but instead maintain a distance, or friction, between people and technology to encourage reflection and discussion (cf. [23]).

The research process begins with formulating a design program based on a set of initial conjectures about the design space and how to investigate it. The investigation undertaken in this thesis is not about refining and optimising existing artefacts, but rather on the development of a collection of examples that illustrate different possibilities within this design space (cf. [33]). Thus, this is not a well-defined problem that lends itself to a rationalistic search for an optimal solution. Instead, we use experimental design as a way of finding a path into a problem that is poorly understood at the outset. A design program serves as a starting point and a framework for such investigation.

The next step is to formulate more specific design ideas and working hypotheses that can be addressed in practical work, i.e., by working with designing, implementing, testing and evaluating prototypes. In all of these steps, new experiences are gained and new design opportunities are discovered; the implementation of a specific prototype can expose new design opportunities, as can results from a field study of some specific situation or setting. Of central importance is to be attentive to what happens during this process of realising the ideas from the design program, since just working through the steps to arrive at a final solution will not in itself result in the knowledge we are after. The experience gained and the new design opportunities discovered lead to a new set of working hypotheses, usually directed towards a more specific part of the design space, and finally to reformulation of the design program or the development of a new design program. Thus, we have a process of:

- i) formulating a design program;
- ii) realising the program by designing, implementing and evaluating design examples;
- iii) reflection and formulation of results, e.g., reporting on the experiences gained, formulating new working hypotheses, reformulating the design program.

This process is in part similar to methods for iterative prototyping and stepwise refinement in systems development, where one moves from the more abstract towards the more concrete in iterative steps (cf. [5, 21]). An important difference, however, is that the method employed here is not primarily designed to lead to increasingly more advanced or "better" prototypes. Instead, it is the development of the questions asked and the hypotheses posed that are in focus: we move from the more general to the more specific as our understanding of the design space deepens and we are able to formulate new and more detailed hypotheses. Thus, the prototypes themselves are not necessarily more advanced in later steps of this process, which in turn is one reason for referring to them as design examples instead.

Part of the design philosophy developed at the PLAY research group (cf. [42]) – in which this work has been done – is to work with inexpensive technology. While this was originally due to the financial situation of our group, it has also become a statement against the expensiveness and complexity of much information technology. Working with limited technology can also inspire new perspectives and when it comes to developing computational things for everyday life, the cost involved in producing a design is an important aspect in evaluating its feasibility.

Below, the application of this general methodological framework in the thesis work is described in more detail.

4.2 Research Process

Designing for Local Interaction [P1] is based on a series of projects concerning local interaction and communication that were proposed as a part of the *Intelligent Environments* project [40]. Following a first prototype – the *Hummingbird* [43] – which implemented the very basic ideas, and the results obtained from evaluations of it [43, 81], we developed its functionality further in the so-called *Generalised*

Hummingbirds. This slightly more advanced device in turn opened up for new perspectives of what could be done with limited communication range between computational devices, and with additional inspiration from a field study of news journalists made by our colleagues (cf. [28]), the *NewsPilot* system was designed. With the NewsPilot, we were coming close to the scenarios of the original project proposal and so the experiences gained were analysed and reported in the paper included here. More recently, a start-up company called *Wunderkind*[4] was formed around a new device based on ideas and results from these projects. Thus, we have a process of moving from a general project program to commercial products via a number of prototypes, much in line with the research approach described in Holmquist [41].

Token-Based Access to Digital Information [P2] has a similar background in the Intelligent Environments project [40]. Unlike [P1], which was almost exclusively based on our own experiences, [P2] is based on an analysis of a number of tangible user interfaces with focus on how they address association between physical representation and digital information. The *Webstickers* system [54], which uses barcodes, is used to illustrate design opportunities regarding how everyday objects can be used as tokens for digital information. Webstickers was developed using iterative prototyping: an early version was presented in [53] and after evaluation, the system was re-designed and once again evaluated in a user study. This final system was presented in [54].

In many ways, [P1] and [P2] represent the background against which the later projects should be seen: they represent our first endeavours into areas such as ubiquitous computing and tangible interfaces, and they are also rather typical to design oriented human-computer interaction in terms of research approach. The interplay between design phases and evaluations such as user studies of various kinds to support reflection and formulation of results, also fits into frameworks for HCI research such as [58] (cf. also [4]).

4. Cf. www.wunderkind.se

With the ChatterBox [P3], we set out to explore a sub-field of ubiquitous computing and tangible media called ambient media, i.e., new kinds of information displays that are integrated with the physical environment. The notion of designing for the periphery of attention, inspired us to consider different forms of use. However, while most ambient displays explored new forms of information presentation to reduce cognitive load, we were interested in transforming information for other purposes than just to "inform", such as to entertain, inspire or even confuse.

At the beginning of the project, we continued to use a similar combination of design phases and user studies. First, a simple prototype to test the basic ideas was created [70]. Results from preliminary evaluations revealed problems in the initial design, which was based on pure random recombinations of words collected in a database, and so a second, more advanced system was designed and implemented. We performed several studies of this prototype in a range of settings. First, it was installed at two offices during two weeks. At the end of the test , we evaluated the ChatterBox using both fill-in forms and on-site interviews. In addition, the ChatterBox was used at a few reception parties.

During these evaluations it became evident that our basic method for evaluation would not work properly. Originally, we had the idea of creating something that could serve as a source of inspiration and thus it seemed reasonable to ask questions concerning its qualities as such. To do a proper user study, one needs a precise definition of intended use on which to base evaluation criteria. Further, one needs a way to map the results back to the design choices made. "To inspire" or "to entertain" are, however, not very precise notions of use. Given the difficulties with defining even the narrow notion of use in usability studies, and evaluating it properly (cf. [32]), it is not clear what functionality in use we actually evaluated by performing these interviews. Even if we had found out to what extent the ChatterBox had inspired people, it is not clear how these results could be mapped back to the specific design choices made, such as to what analysis, transformation and generation techniques were used. From this point, the question of forms of evaluation and alternatives to traditional user studies to support reflection and formulation of results became an important part of developing our research method.

The primary quality of the ChatterBox is not whether it actually increases creativity at an office, or if it is entertaining to this or that degree. Its values lies in what new ways of thinking about information technology use it can provoke. From the evaluations we learned that we had neglected the importance of the expressions and aesthetics of this kind of technology. Not in the sense that it was not properly "styled" to fill its intended role, but that it should be seen as an experiment with expressions of information technology rather than as an application with some specific functionality. This became especially evident when we later exhibited it together with some pieces of Informative Art at an art museum. At the exhibition, different people "used" it in very different ways: a group of teenagers used it as a kind of message board, others wrote messages to find out how the text transformations worked, still others just watched it, etc. In this case, no explicit descriptions of the ChatterBox intended functionality were given and so its "use" was open for the "users" to decide [5].

The work with Informative Art [P4] represents the first steps towards a new working method based on more explicitly formulating a design program and then creating a number of design examples based on that program to investigate and learn more about the design space in question. Previously, we had concentrated on working with one or two lines of prototypes gaining experience and understanding of the initial problem by improvement and development of these. This strategy is also evident in the work with the ChatterBox. In comparison,

5. The experiences from the art museum exhibition is not reported in the ChatterBox paper (since the exhibition took place after the paper had been published), but the traces of this re-valuation of how to look at it as a design example, can be seen in the series of texts describing it: from the early prototype in [70], in [P3], in [P4] and finally in [P5].

Informative Art is a step towards working with a collection of examples, each representing some aspects of a possible solution to the posed problem.

When working with Informative Art, we began to formulate a more detailed design program for investigating the expressions and aesthetics of information technology. The design program of Slow Technology [P5] was directed towards investigating computational technology as a design material.[6] Here, the method of formulating a design program is more explicit and the design program itself is given more attention in both the design practice and in the papers written.

The first attempts to realise the design program were made for an art museum exhibition held at the Borås Art Museum in May, 2000. The exhibition was a one-day event and took place during the city's yearly "night of culture". The exhibition included the ChatterBox, several examples of Informative Art using both traditional displays and projections on various materials, as well as the *Fan House*, the *Sail House* and *Chest of Drawers* described in [P6]. At the exhibition, we did not attempt to make any "user studies", but the group which had been working together producing the exhibition were all present, talking to visitors, discussing the designs, etc. The many hours of discussions with visitors gave valuable input for further work and helped us focus on what seemed to be critical issues.

One of the things we found out was the importance of what combinations of materials were used. This was first indicated in the early work with the ChatterBox but was accentuated at the exhibition. For instance, there was a great difference between traditional LCD-displays and projections on fabric: to many visitors, even the neutral design of the LCD-displays dominated the overall expression – something which was not the case with projections on fabric. When developing the next generation of design examples (described in [P6]),

6. Later, we found that movements such as "slow food" (cf. www.slowfood.com) and even "slow cities" have been under development for several years (cf. [1]).

we therefore concentrated on using materials traditionally used in interior design, such as fabric, wood, and paper. These examples were mainly built using material found lying around at our homes and at the office, as well as things bought at, e.g., the large Swedish furniture store IKEA. Thus, the design examples in [P6] are literally based on various everyday things and materials.

The examples described in *Expressions; Towards a Design Practice of Slow Technology* [P6] were based on various interpretations of what it might be like to read and write information in everyday life using computational technology. It represents a return to working with the explicit use of computational things but with a different perspective: instead of working with functionality in use, we concentrated on the aesthetics of use. Thus, [P6] is a point of closure where the initial experiments with various objects and materials in Webstickers [54] and [P2] are revisited, as is the idea of creating a computationally amplified environment from [P1]. Still, the perspective on both computational technology as material for design, and its relation to other materials, the rest of the interior, etc. has changed significantly.

From Use to Presence: On the Expressions and Aesthetics of Everyday Computational Things [P7] is a theoretical paper based on the experiences gained during the work originating with the ChatterBox – when we first began to question how we approached "use"– and onwards, but takes a more general look on what it means for a computational thing to be present in everyday life, or in someone's lifeworld. In relation to the design practice, the aim of this paper is twofold: i) to reflect upon and report the more general experiences gained, and ii) to develop a theoretical framework on which future design experiments can rest. This corresponds to the last step in the general method described above.

4.3 Discussion of Method

The new informatics stresses engagement in design [18], and that artefacts are designed rather than documented [17, p. 70]. A basic problem in design research is that there is no settled tradition of what design research is and exactly how it is to be carried out (cf. [72]). Buchanan states that: "No one seems to be sure what design research means. Should design research follow the model of traditional academic disciplines, or should it seek a new model, based on the intimate connection among theory, practice, and production that is the hallmark of design?" [10, quoted in 72]. Central to the difficulties with defining design research is the interplay between theory and practice in working with design problems, and that the design problem is a question of instantiation rather than generalisation;

Research in human-computer interaction frequently uses psychology as its basis. Shneiderman states that "Each experiment has two parents: (1) the practical problems facing designers, and (2) the fundamental theories based on psychological principles of human behavior." [76, p. 32]. By formulating hypotheses that can be addressed by the methods of experimental psychology, data can be gathered, analyzed and finally new design solutions can be recommended. While experimental psychology is suitable for investigating aspects such as usability, it is not necessarily a useful way to uncover new roles, values and places for computational things in everyday life. If we instead consider computational technology a social, cultural and aesthetical phenomenon, psychology is just one out of many possible ways to ground and inspire experiments. Depending on the research questions at hand, we will have to substitute psychology for sociology, cultural studies, aesthetics, philosophy of technology, etc., or some combination of these. This also means that we need a more general framework for the design of computational things.

The notion of a science of the artificial, first proposed by Simon [77], provides a general framework for what design research can be. Simon's account of design research has, however, also received much criticism. Following Rittel, Buchanan argues that design problems constitute a specific kind of problems that are "wicked" in nature [9] and inherently indetermined, i.e., that the conditions for solving the problem are not possible to capture completely, which in turn makes a rationalistic search for a solution impossible. Rittel has argued that wicked problems have no definitive solution, and that no formulation or solution of a wicked problem has a definitive test [Rittel quoted in 9]. Even if design problems are not inherently indeterminate, the complex context of most non-trivial design problems make them near indeterminate in practice.

Instead of trying to reduce the design problem to a matter of logic, several different frameworks describing the nature of design as an interplay between theory and practice have been proposed. Winograd and Flores based their framework for design on phenomenology, mainly (some interpretation of) Heidegger, and describe how practices are interrupted by breakdowns that open up for reflection and discovery of new design opportunities [90]. Other philosophical strategies such as language-games have also been used to describe the nature of design problems and practices (cf. [25]). It has also been suggested that design can be seen as *bricolage* (cf. [17, 55]).

Schön used the notion of "reflection-in-action" to describe the interplay between practice and reflection as a way of developing an understanding of the problem itself and possible solutions that could not be formulated at the start [73, 74]. For instance, Schön uses the term "seeing-as" to describe how designers approach new situations by reflecting upon perceived similarities between previous experience and the new problem at hand. According to Schön, the strategies for dealing with complex problems found in design practices are also evident in scientific investigation:

> /.../ experiment aimed at testing a particular hypothesis or achieving a particular technological effect repeatedly produces unexpected phenomena which trigger new hypotheses, goals, and questions. Experiment functions at the same time to test technological moves, discriminate

> among plausible scientific hypotheses, and explore puzzling phenomena. /.../ the "science" in question is not after the fact presentation of knowledge of the sort usually found in the scientific journals but before the fact, apparently disorderly research of the kind sometimes described as "the art of scientific investigation". [73, p. 177].

The general method used in this thesis is closely related to these views on the nature of design problems, and on the importance of a combination of reflection and action in addressing them. We might say that design problems are developed, rather than solved, within a design practice (cf. [56]). Common to these frameworks, is that they stress the importance of what happens during the design (and research) process: as understanding deepens, breakdowns occur and design opportunities are revealed, new phenomena appear, etc., we continuously discover new possibilities. By reflecting upon the experience gained during the design process, we can proceed and stipulate new working hypotheses, change working method, etc. Attentiveness to what happens during the process, and not just during evaluations, is something that the method used here was devised to support.

The inspiration for working with a design program and example collections came from other areas of design, such as architecture, graphical and industrial design, where designers and artists work with creating a set of examples exploring different properties of a material to develop an understanding of it. An understanding of what can be done with oil painting, wood sculpturing, etc., can perhaps only be achieved by working with the material in question in practice. An investigation of an area or design space by means of building a collection is not restricted to material properties, as can be seen in e.g., [34] where a similar approach is used to uncover new parts of the design space of information appliances, primarily in terms of emotional and social values.

Prototypes are frequently used as demonstrators of feasibility. Prototypes also make various evaluations and user studies possible. In the approach employed here, however, the design examples also become arguments (in material form) in themselves. The design examples are created to support critical reflection upon the design of computational things and thus the design choices represent some interpretation of, and relation to, the questions addressed. Just as working with the design problem is a combination of theory and practice, its "solution" is present in both the theoretical reflections and in the physical artefact itself. In this sense, the design examples are integral parts of the arguments made (cf. [75]).

When we think about design in terms of change and how to change the state of the world of artefacts, it is clear that this is not only a matter of problem-solving but a matter of constructing the world we live in (cf. [19, 61]). Technologies are not neutral; rather, they are intimately interwoven with human practices (cf. [6, 45]). While Simon seemingly aims to reduce the distance between natural and artificial science by introducing a framework that would support a more formalised and objective description and design of artefacts, Dahlbom calls for an artificial science that emphasizes the differences:

> /.../ [taking an artificial science approach] means that rather than stressing such natural science values as careful documentation and reasoning, methodological acumen, knowledge of the field, the quest for abstract, fundamental principles, universal truths, the scientific community will begin to stress problem relevance, human interest, imaginative scenario building, and good ideas. /.../ It means that there will be a growing framework for future archeological explorations of the socio-technical possibility space". [19, p. 13].

In this manifesto, the central ambition becomes how to improve the world of artefacts to better support what we believe to be the good life.

The importance of a critical dimension in design research is in part a consequence of the fact that the artificial is created rather than discovered. Dahlbom argues in favour of an artificial science that is value oriented, normative and engaged rather than neutral, descriptive and detached [17, 19]. Ehn stresses the social and political dimensions of design [25], and that there is a need for critical development of information technology that unite art, science and technology [26]. Buchanan makes the following remark in his discussion of design as rhetoric: "The point, however, is not simply that technology is distinct from science. More important, it is that technology is fundamentally concerned with a form of persuasion and, as with traditional rhetoric, speaks from no special authority about the good life. It provides only resources that are used to support a variety of arguments about practical living, reflecting different ideas and viewpoints on social life. /.../ Design is an art of thought directed to practical action through the persuasiveness of objects and, therefore, design involves the vivid expression of competing ideas about social life." [8, p. 94]. Critical design, therefore, is an important way of exposing issues in technology use and development.

5 A Design Philosophy for Everyday Computational Things

The specific results from this investigation into the design space of everyday computational things are the design examples presented in the individual papers. This collection of examples illustrates a set of parameters, and design opportunities, in this design space. The general results of this investigation are described as a design philosophy for how to design computational things for meaningful presence in everyday life.

The design philosophy is based on a set of premises, or design *leitmotifs*. While these basic premises can be considered general results from the experiments, they are also used to declare a position I take in relation to the questions investigated. Thus, this design philosophy is normative, and its value depends on the extent to which it supports further investigation and development of everyday computational things; its basic premises are not "universal truths" but suggestions for how to approach the design of everyday computational things based on the work reported here. The design philosophy rests on the following four premises:

(1) Computational technology is a design material

(2) Time is the central design variable

(3) Presence precedes use

(4) Aesthetics is the basis for design

The theme of this design philosophy is design for *presence*. To consider computational technology a *design material* means that one does not think about computers as the means for implementing a certain functionality. Instead, one works with it as just another material for design, with certain properties and expressions as such. To consider *time as the central design variable* means that one starts with the temporal structures that arise from computation and how to manifest these in space, and not from how to make three-dimensional objects dynamic using computational processes. That *presence precedes use* means that computational things are considered to primarily have *meaningful presence* in someone's life and only secondarily as having a certain practical functionality. This design philosophy also states that *aesthetics*, and not psychology, sociology, etc., is the basis for design. Below, I discuss how these premises are related to the specific results of this thesis.

Computational Technology is a Design Material

When we no longer start from the practical functionality of computational things, the notion of computational technology as simply the means for implementing such functionality becomes unsatisfactory. Instead, computational technology has to be seen as a design material, with – like any other material used in design – certain properties as such (cf. [57]).

In what sense is computational technology a design material? Form and material are what build the appearance of a thing. The term "computational thing" refers to that such things receive their characteristic appearance by means of computations, by the execution of programs. We can say that computational things depend on computational technology as material for building their appearance.

Computational technology as design material is not simply a matter of computer hardware, but about all the things it takes to make something "computational": it takes programs to be executed, mechanisms for executing the programs, interfaces for controlling the programs and "displays" and other interactive surfaces for manifesting the results. Here, we can distinguish two main form elements: i) the temporal structures that are generated by the execution of programs; and ii) the spatial structures that manifest these temporal structures. Thus, the appearance of a computational thing is a combination of temporal and spatial gestalt.

While we can separate these two elements when we consider what builds the appearance of a computational thing, it does not mean that we can separate the design of what a computational thing looks like from the design of how it behaves. On the contrary, it means that creating a consistent overall appearance is a matter of balancing both temporal and spatial form elements. Designing a computational thing for everyday life is not a matter of replacing the traditional beige exterior with a more colourful shell.

The notion of a combination of spatial and temporal gestalt has a number of implications for how we design and think about computational things. The perhaps most important design implication of this is that, in principle, we are free to use any material, e.g., textiles, wood, paper and other traditional materials, in building the spatial appearance of computational things [P6]. Once we realise this, we can work with many different combinations of materials and see how this affects the overall appearance.

We can now formulate a more general answer to how computational technology as design material is related to other materials in building the appearance of computational things. Computational technology is primarily used for building temporal structures by means of executing programs. Thus, its main form element is time and temporal gestalt. To build a computational thing, this material is combined with other materials that are used to build the interactive surfaces and displays that manifest these temporal structures. In practice, this perspective opens up for the use of almost any material in the design of everyday computational things.

Time is the Central Design Parameter

How to design in time will be one of the central issues in an aesthetics of computational technology. Having temporal structures as central form elements makes computational technology different from most traditional design materials and makes the aesthetics developed within practices based on e.g., design-by-drawing, inappropriate. Instead, we can turn to areas such as music, film and drama for inspiration and knowledge of how to craft, or compose, temporal gestalt (cf. Jones' notion of *intangible design* [49, 62, see also quote on page 165]).

Too often in human-computer interaction, time is a parameter that one simply wants to reduce, e.g., when one continuously tries to reduce the time it takes to perform a certain task. This means that we neglect the temporal form element of computational things and its contribution to their "character" (cf. [48]). If we instead want to focus on time as a central design variable, we can use approaches such as Slow Technology to investigate the aesthetics of computational technology [P5]. By slowing things down, we can expose the temporal form element in both design and use. When designing slow technology, special attention is given to how to form temporal structures. When in use, slow technology will more or less force its "users" to pay attention to temporal gestalts.

Presence Precedes Use

The idea of designing for meaningful presence rests on the notion of everyday things as existentially defined building blocks of someone's lifeworld. At some point, the thing has been allowed to enter this person's life and as this happened, it received a certain place or role and became a meaningful object. For instance, the sofa in my living room is not just any sofa that happens to be placed there – it is a particular sofa that gradually has become something that I take for granted as part of my life. We will not capture these aspects of everyday things by a reference to some general notion of use and instrumental functionality, and in this sense, presence precedes use [P7].

Many computer applications have preference settings, bookmarks, macros, etc. that enable users to customize and adapt them to personal habits (cf. the notion of *end-user programming* [64]). The first two papers of the thesis illustrate how an interface can be even further opened up for the user to define and how arbitrary everyday things can be used in this process. We can compare this with how people furnish their homes and other places with furniture, and other objects. Ideally, they should be able to do the same thing with computational things.

In [P1] we found that also very limited propagation of information can be highly useful as much information has relevance only at a certain location or in the vicinity of a certain person. The limited communication range allowed us to use a decentralised approach that means that the users do not have to think about managing an overhead system or infrastructure. In [P2], we used Webstickers [54] as an example of how physical tokens can be used as bookmarks for webpages. The possibility to use any object by attaching a barcode sticker to it, opens up for the creation of personal milieus of physical representations for digital media. It also illustrates how the properties of tokens can be used to represent properties of the associated digital information.

Another possibility is to work with more implicit forms of use. The experiments with the ChatterBox [P3] and Informative Art [P4] are examples of such an approach. These systems are not designed to be explicitly used in the way tools are, but instead to be parts of a given environment similar to how decorative objects are used to furnish homes, public places, offices, etc. However, they also paved the way for the examples presented in [P6], and how we can design for presence by focusing on the expressions of things instead of their functionality. In [P6], the use of computational things was further elaborated upon using designs based on re-interpretations of various acts in everyday life. Here, acts such as what walking into and out of a room, pushing and pulling drawers, throwing paper in the wastebasket, etc., were interpreted as acts of reading and writing information using computational technology.

Aesthetics is the Basis for Design

It is clear that we can not design everyday computational things with focus only on practical functionality. It is also clear that computational technology cannot only be considered the technical means for implementing a certain functionality. When we think about computational technology as a material for design, we have to ask the same questions about its properties as we ask about any other design material. When a new material becomes available, it soon challenges present ideas about design, aesthetics, manufacturing, etc., as it opens up new possibilities. Consider for instance the role of materials such as steel and reinforced concrete in architecture or chromium-plated steel and plywood in furniture design in the development of the Modernist movement (cf. [69, 92]). While reinforced concrete initially was just another way to realise certain architectural structures, it soon began to influence the (development of) aesthetics of architecture. Correspondingly, we have to consider the aesthetics of computational technology as a material and the aesthetics of computational things in use.

The expressions and aesthetics of computational things are not only important when we want to understand how to craft a new design material – they are also central when we aim to design for meaningful presence, rather than efficient use, of everyday things. If we think about the acts, or processes, of acceptance when a thing enters someone's lifeworld, we find that before, and in-between, we explicitly use things, they are just there: they are *present*, presenting themselves to us in various ways. A thing presents itself through its expressions. As these expressions become central, aesthetics, as a kind of logic of expressions, becomes the basis for design for presence [P7].

When we design tools, the idea, or image, we have of what it is we are designing is based on some specific use. When thinking about how to design a hammer, we think about what it is to drive a nail. If we are going to design for presence with focus on the expressions of computational things, what such "images" can guide our design? To support thinking about the expressions of computational things, we have developed a number of design leitmotifs. One such leitmotif is to think about computational things as "displays", i.e., as things displaying the execution of programs ([P6], [P7]). To think of a given thing as a display, we can then ask questions such as in what ways and in what sense it expresses the execution of a program, what determines what to be displayed, what initiates the programs, etc.[7]

The perspective on computational things as displays can also be used to get a new perspective on existing things, such as various everyday things that have been computerised. Equipped with questions such as the ones above, we can analyse a given computational thing in regards to its expressions as a display. Imagine, for instance, analysing a modern car, with its computer-controlled engine, anti-lock brakes, anti-spin systems and automatic gearbox, in terms of being a display and not a car. This leitmotif does not only encourage reflections upon the expressions of computational things, it is also a non-technical account of what a computational thing is that can help us uncover new design opportunities for everyday computational things.

6 Concluding remarks

This thesis reports on the development of a design philosophy for everyday computational things. This design philosophy differs from traditional human-computer interaction design in that it focuses on the presence of computational things, instead of their use; their meaningfulness instead of their practical functionality and usability. It differs in that it regards aesthetics, rather than psychology, as the basis for

7. To consider computational things as "displays" is just one design leitmotif that can help us focus on the expressions of computational things in use. Other leitmotifs will help us expose different issues and in many ways, the notions of *amplified reality* [29] and slow technology have served similar functions in the work presented here.

design. It emphasises that time is a central design parameter and that computational technology is not only the means for implementing a certain functionality, but a design material with certain expressions as such. This design philosophy does not support increased productivity; it is a design philosophy aimed at supporting a more general philosophy of technology by providing a collection of examples to encourage reflection and discussion.

This is not to say that the design philosophies behind the personal computer, design for usability, etc., are wrong. The design philosophy presented here simply has a different purpose, different ambitions. Just as we have a plethora of computational things, we have to have a variety of ways of approaching their design. Problems occur when we consider a single design approach to have universal legitimity – everyday life is not a homogenous fabric. As most design philosophies are formed in relation to problems with previous approaches, we also have to remember that their life-spans are limited. Only by continuously questioning, evaluating, reformulating and inventing approaches to the design of computational things, we will have a chance not only to keep up with the pace of technological development, but to actually shape it.

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