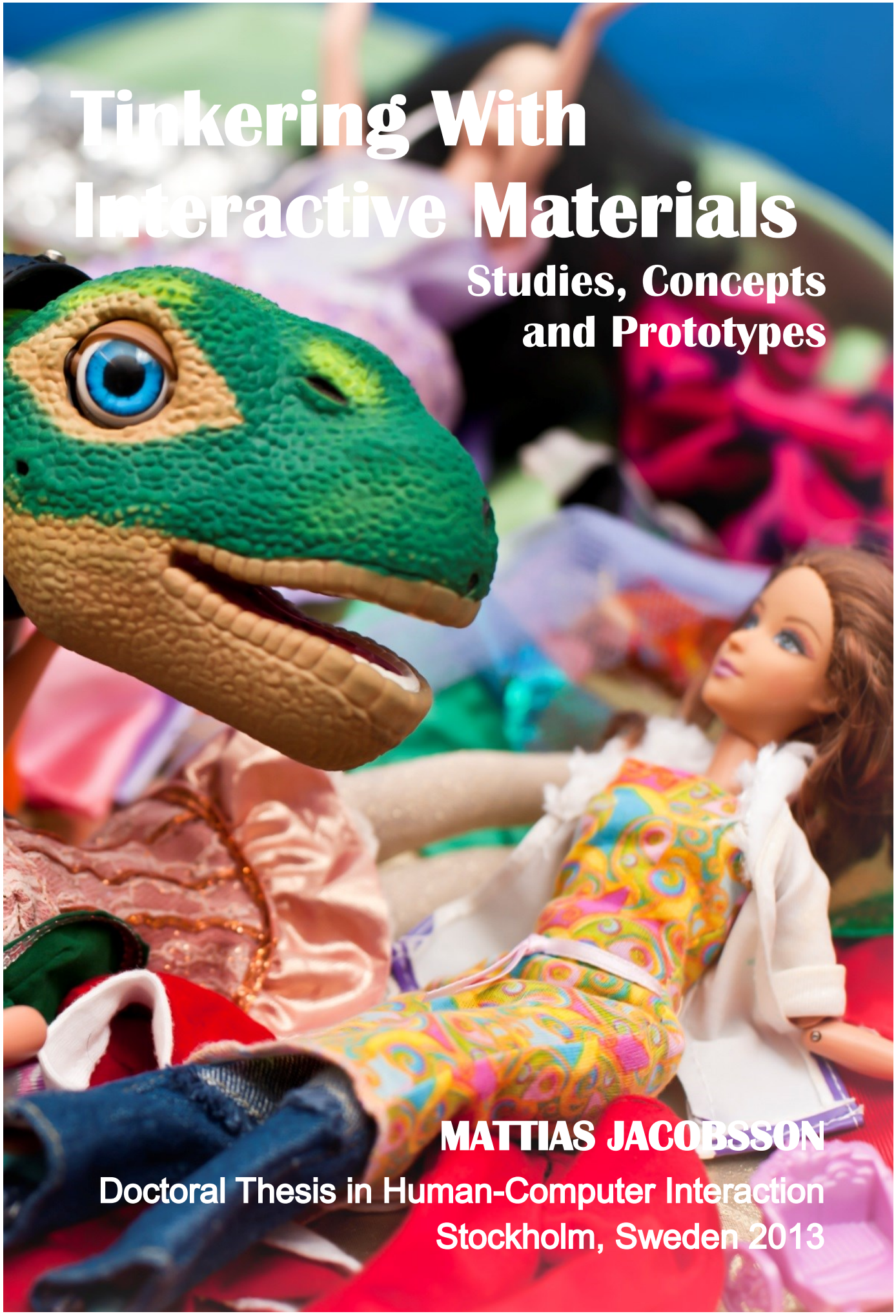

Tinkering With
Interactive Materials
Studies, Concepts
and Prototypes
MATTIAS JACOBSSON
Doctoral Thesis in Human-Computer Interaction
Stockholm, Sweden 2013

TRITA-CSC-A 2013:12
ISRN-KTH/CSC/A--13/12-SE
ISSN-1653-5723
ISBN-978-91-7501-962-8





KTH Computer Science
and Communication

Tinkering with Interactive Materials
Studies, Concepts and Prototypes

Mattias Jacobsson

Doctoral Thesis in Human-Computer Interaction,
Stockholm, Sweden 2013



Mattias Jacobsson, Royal Institute of Technology 2013

KTH School of Computer Science and Communication
TRITA-CSC-A 2013:12
ISRN KTH/CSC/A--13/12-SE
ISSN 1653-5723
ISBN 978-91-7501-962-8

Swedish Institute of Computer Science
ISRN SICS-D--65—SE
ISSN 1101-1335
SICS Dissertation Series 65

Printed in Sweden by Universitetsservice US AB, Stockholm 2013
Distributor: KTH School of Computer Science and Communication

Cover Photo: John Paul Bichard

Abstract

The concept of *tinkering* is a central practice within research in the field of Human Computer Interaction, dealing with new interactive forms and technologies. In this thesis, tinkering is discussed not only as a practice for interaction design in general, but as an attitude that calls for a deeper reflection over research practices, knowledge generation and the recent movements in the direction of materials and materiality within the field. The presented research exemplifies practices and studies in relation to interactive technology through a number of projects, all revolving around the design and interaction with physical interactive artifacts. In particular, nearly all projects are focused around robotic artifacts for consumer settings. Three main contributions are presented in terms of studies, prototypes and concepts, together with a conceptual discussion around tinkering framed as an attitude within interaction design. The results from this research revolve around how grounding is achieved, partly through studies of existing interaction and partly through how tinkering-oriented activities generates knowledge in relation to design concepts, built prototypes and real world interaction.

Acknowledgements

The research presented in this thesis is truly the product of many people working, crafting, programming and writing together, shoulder to shoulder. Honor towards colleagues, collaborators, friends and family is in many ways reflected in this thesis, big and small. If you dear colleague of friend happen to read something in this thesis that speaks to your heart, there is a very good chance that your influence had something to do with it.

When we moved our Future Applications Lab to Kista and Mobile Life in 2008 I ended up in a small room that was impossible to furnish according to modern office standards. This intriguing interior design problem and our futile attempts to address it, is how I got introduced to my main supervisor Ylva Fernaeus. Since then we have not only shared office space when possible, but also everything else that comes with a long lasting friendship that without doubt was put to the test by the process of writing and handling this very thesis. Thank you Ylva for always being there for me – you are simply the best!

Already in 2004, after receiving a rather suspicious looking offer in my e-mail, I put on my sun glasses and travelled across town to learn a bit about what researchers between academia and industry do for a living. That's how I got introduced to my first main supervisor Lars Erik Holmquist. Through the years since, we have done an amazing journey together driven by part passion, part joy for gadgets and doing state of the art research. Thank you Lars Erik for being the best visionary, tour-guide and making this amazing journey within research possible!

I would also like to take this opportunity to thank Kia Höök who on more than a few occasions has been there for me. Your person, energy, love and passion for what you do always have a great positive influence on me, and I often find myself awed about how you pull it all off. Thank You Kia for always inspiring me!

As with any large family and arguably for the sake of symmetry, I towards the end reached out my hand to Barry Brown to come aboard as my co-supervisor. Being witty, clever and deadly serious at the same time, Barry has the ability to deliver hard facts in a clear and precise way that makes it easy to focus and keep up motivation. Thank you Barry!

In fact, there are many more people that ought to be mentioned next than would possibly fit in these two pages of text. A majority of these are colleagues and friends with whom I have shared office space over the years.

One group of people in particular have been with me from the very beginning of my Ph.D studies doing this journey together. A warm thank you to Sara Ljungblad, Maria Håkansson, Lalya Gaye and Mattias Rost for all the amazing travels together, your support and friendship over the years.

I would like to thank all my former colleagues at Viktoria, and in particular Ann Andreasson, Jonas Landgren, Dick Stenmark, Magnus Andersson and Johan Bodin for all the good and memorable times that we have shared. Thank you also John Sosoka and Gerry Ens for letting me briefly be a part of your amazing team back at Ugobe. Furthermore I would like to thank all my colleagues, both former and present, at Mobile Life and SICS. A few in particular that either directly or indirectly have influenced my work with this thesis – Stina Nylander, Pedro Ferreira, Anna Stål, Elsa Vaara, Annika Waern, Oskar Juhlin, Maria Holm, Henriette Cramer, Jakob Tholander, Maria Normark, Alex Taylor, Karin Fohlstedt, Thomas Ringström, Lotta Jörsäter, Markus Bylund, Jarmo Laaksolahti, Arvid Engström, Celia Yanqing Zhang, Pedro Sanches, Jon Back, Elin Önnevall, Alexandra Weilenmann, Nicolas Belloni, Elena Márquez Segura, Kim Nevelsteen, Syed Naseh, Staffan Rosenberg, Vicki Knopf, John Paul Bichard, Jin Moen, Johanna Mercurio, Jordi Solsona, Mudassir Ahmad Mughal, Tina Bin Zhu, Vygandas Simbelis, Anders Lundström, Vasiliki Tsaknaki, Jinyi Wang, Moira McGregor, Jirina Kotrbova, Tom Homewood, Lucian Leahu, Goranka Zoric, Vincent Lewandowski, Donny McMillan, Martin Murer and Petra Sundström – Thank you all!

A special thanks to all my students and interns who have contributed in big and small ways within projects!

I would like to mention and show my gratitude towards SSF and Wireless@KTH for partly funding two of my projects, as well as the departments of Informatics at GU, DSV at SU and MID/CSC at KTH for all the academic support throughout the years. In particular, thank you Jonas Löwgren, Ann Lantz and Cristian Bogdan for all the support towards the end.

To my parents Mamma Inga-Lill, Pappa Kjell, my brothers Jonny and Dennis, farmor Ann-Marie, close friends Johan and Jan, and parents-in-law Lasse and Ann-Chatrin, with families – Thank you all for your unconditional love, support and patience throughout the years! Unfortunately I may just have realized that an educational endeavour might never really come to an end ;)

And last but not least, to my dear wife and daughter for pulling me back into reality with a hug when drifting too far away into the deep unknown. From the bottom of my heart, thank you Pernilla and Elin for addressing my stubbornness with kind words, hugs and kisses!

Stockholm, October 2013
Mattias Jacobsson

Contents

Abstract ..... **iii**

Acknowledgements ..... **v**

Contents ..... **vii**

Introduction **1**

1.1 Research Questions *4*

1.2 Structure of Thesis *5*
1.2.1 Contributions Overview 5

1.3 Context of Research *6*
1.3.1 General Work Process 9

1.4 Summary of Publications *9*

Background and Related Work **15**

2.1 Robotic Artifacts and Materials *16*
2.1.1 Materials, Materiality and Media 18
2.1.2 Robotic Materials 21
2.1.3 Interaction Design and Embodied Interaction 22

2.2 Tinkering *25*
2.2.1 Attitude versus Practice 25
2.2.2 DIY, MAKE Culture and Crafting 27
2.2.3 A Corporeal Turn 30

2.3 Research and Articulation *31*
2.3.1 Strong Concepts 33
2.3.2 Grounding it in the Wild 34
2.3.3 Prototypes as Grounding through Tinkering 36

Studying Existing Interactions **39**

3.1 Reflection on Methods *40*
3.1.1 Transfer Scenarios 41

3.2 Studies of Existing Human Robot Interaction *42*
3.2.1 Narratives within an Online Blogging Community 43
3.2.2 Families Adopting a Toy Robot 46
3.2.3 Persistent Interaction 49

3.3 Contrasting Methods *53*

Tinkering in Interaction Design **57**

4.1 Examples of Tinkering *58*

4.1.1 Interactive Communication 58
4.1.2 Movement and Accessorizing 61
4.1.3 Hacking Interaction 65
4.1.4 Studying an Robotic Arts Community 66

4.2 Characterizing Tinkering 67
4.2.1 Prototyping and Sketching in Hardware 70
4.2.2 Hacking and Reverse Engineering 71

4.3 Towards User Empowerment 73

Research Contributions 75

5.1 Articulation of Tinkering as part of IxD Research 75

5.2 Using Studies to Inform a Tinkering Oriented Design Process 79
5.2.1 Owners of Unusual Pets 79
5.2.2 Adopting a Robot 80
5.2.3 Always On 81

5.3 Tinkering as a Foundation for Developing Stronger Design Concepts 82

Discussion 85

6.1 Tinkering and Crafting Articulations 86
6.1.1 A Lesson Learned About Robotic Artifacts 89

Conclusions 91

7.1 Tinkering a Future of Robotic Artifacts 93

Bibliography 95

Part 1

The Thesis

1

Introduction

The concept of tinkering is nowadays used rather vernacularly, or in other words commonly without any more specific meaning. According to the Oxford English online dictionary, Merriam Webster dictionary and Wikipedia, tinkering appears to originate from around the 14th century where the "professional" tinkerer was a travelling mender of e.g. household utensils. The technical and metallurgical practice of using tin and tools to fix and mend utensils correlates beautifully with how for instance electronic components are soldered manually onto prototyping perfboard's or PCB's (printed circuit boards). Bending and sticking thin metallic legs into narrow holes, applying flux, while simultaneously applying molten tin, can be quite tricky, not to mention doing the reverse process that requires tools for heating, de-solder braids, suction and lifting the component – often all at once. A feeling for temperature is important as too warm may damage components and too cold may cause so called "cold solder" joints that makes circuits misbehave. Moreover, the heat from the soldering iron causes flux, solder and components to have a scent, a useful and underrated resource when considered from a corporeal and practical perspective.

Relating to how the earliest personal computers' (e.g. Apple I), pointing devices, mobile phones, etc. were invented, researched and put together, it is clear that these manual practices of instrumental tool use and fiddling with components is nearly identical to how it is done today when new interactive artifacts are to be invented and designed. The major difference of course lies in scale and there are exponentially more components and tools and they have better quality, steadily gets faster, become cheaper and have increased precision. In fact, innovations in miniaturization and automation in the early 90's resulted in multi-layered circuit boards and surface mounted components so flat and small that monocular glasses and surgically steady hands were needed to tamper with it. This development

has over the past five years been broadened to also incorporate electronics printed onto and into both thin and flexible materials which is one of the main reasons why we today have super flat and light laptops, mobile phones, e-book readers and tablets, and that emerging consumer product demonstrators are flexible and yet credit-card thin.

Academic research on the other hand is commonly understood as the trade of producing knowledge by advancing that which is already known. Donald A. Schön argued that this view is not enough and pointed out that skills and attitudes are other important factors that relate to this practice of knowledge production [Schön 1984]. More importantly, he suggested that reflection-*in*-action and knowing-*in*-action is closer to reality for how professionals turn over knowledge. Extending that argument, in this thesis I will reason about the concept of *tinkering,* and attempt to position it as an essential attitude for interaction design research. In 2008, Mizuko Ito et al introduced the idea of *tinkering* as being central to knowledge production when conducting and analysing ethnographic studies of school children in the US and Japan [Ito et al. 2009]. Notably, later that year John Seely Brown further re-popularized the term through his online published talk entitled *"Tinkering as a Mode of Knowledge Production in a Digital Age"*. Within the research field of Human Computer Interaction (HCI) we are interested in the broader notion of human activity and more specifically its relation to computation. In other words we will often talk about interfaces, communication, interaction, users, experience and context when we try to describe what we do. The question is: how do we as researchers reflect upon our own practices with respect to what might be central for our own knowledge production? Fortunately, writing a thesis is one of those processes suitable for addressing such questions.

Traces of the tinkering concept in HCI specifically can be tied to metaphorical discussions regarding the practice of *bricolage* where a person would explore and put together e.g. an outfit or software program [Papert 1993; Blackwell 2006; Resnick and Silverman 2005], or *pottering* where a person casually and without any particular plan keeps things tidy [Taylor et al. 2008]. In this case we will use tinkering in terms of a more pragmatic attitude to explore what it could offer researchers within HCI and more specifically Interaction Design (IxD) research – a subfield focused around the shaping of digital artifacts from a user- and experience-centred perspective. Furthermore, because of its technical connotation, we argue that tinkering is a suitable candidate for contrasting the perspectives of crafting related to design and engineering, something that today falls under the notion of *prototyping* [Koskinen et al. 2011]. Although tinkering may be thought of as a constructive

process, it is at the same time as much of a tearing down approach as a way of gaining knowledge or reverting to a previous state. As such we will argue that it shares similar if not the very same fundamental attitude with practices such as e.g. *hacking* and *reverse engineering* [Erickson 2008; Rosner and Bean 2009; Kadavy 2011].

In this thesis we will take a closer look at what tinkering would mean conceptually in terms of a more corporeal practice-oriented activity in an overall design process. In order to illustrate this perspective we will use both studies and designs of *robotic artifacts* as a sort of lens through which we can build up an understanding of what *tinkering* conceptually can offer in terms of an interaction design research process. Throughout the thesis I will present a number of research contributions such as results from studies, design concepts, sketches, demonstrators and developed methods. More specifically the work has covered studies of people's relationships with unusual pets, studies regarding a robotic toy dinosaur, the use of clothes and accessories as a way of programming robots and smartphones, crafting and presenting research demonstrators e.g. a swarm of blinking and communicating robots, and finally critical reflections about what the 'wild' actually means when the study objects concerns robotic artifacts or prototypes. These activities have contributed to both the understanding and contrasting of tinkering and how it relates to more established concepts within interaction design such as e.g. prototyping and sketching in hardware. By focusing on robotic artifacts I will discuss how a broader view of embodied interaction may resonate with the tinkering process.

In the latter part of the discussion chapter, I will attempt to outline and position tinkering as an essential attitude that is part of an overall design process in interaction design research. The more critical agenda is to push for terms for consolidation under the interaction design research umbrella where design processes often appear to cause friction when incorporating engineering oriented practices. In essence, we will argue that tinkering together with sketching and inquiry are three complementary attitudes that produce well-articulated research. The primary target audiences for this thesis are students, researchers and academics in the fields of HCI, HRI (Human-Robot Interaction) and interaction design.

My research motivations are based on the assumption that robotic artifacts may highlight many of the difficult issues and problems that have emerged in HCI and Interaction Design over recent years. Robots are notoriously embodied, move about, highly situated, technologically complex, and can be quite messy in terms of interaction. Not the least,

they are *designed* and thus *crafted* with an *agenda* that depends on relationships towards stake holders and intended audiences. This thesis will touch upon this point over and over and also attempt to tie it back to fundamental concepts from philosophy regarding how articulations are formed. By viewing physical artifacts or objects as articulations I will then reconnect it to an overall design process with tinkering being one of the central components.

Before pressing on with the research questions, let's have a look at what such an agenda could look like from a research perspective. There are a number of reasons why I find this crafting oriented agenda to be an important topic for investigation, e.g. crafting as a way of exploring a research question, designing probes with the intent to elicit data, as art or objects to think with, as a manifestation of a concept or knowledge carrier, as a intended product designed towards consumers and finally as an incremental contribution for improving upon an existing artifact. These rationales are not by any means exclusive and may be used in any combination as well as on their own. This thesis aims to cover a number of the points stated above, but in particular focusing on the ones related to tinkering, design and inquiry as *attitudes* in the HCI-research practice. Attitude in this case means a collective of activities that directs and emphasizes our work in terms of processes and practice. In particular, this thesis argues that *tinkering* as a *corporeal* research practice provides articulations of emerging interaction design aspects related to the materiality and envisioning of interactive artifacts within HCI. Envisioning in this case has to do with how interactive artifacts are crafted, designed, experienced, used and reflected upon as part of an explorative research attitude that literally involves hands on work. The notion of the corporeal attempts to emphasize that interactive artifacts consisting of interactive materials are both crafted and experienced by means of profound entanglement with respect of the human body.

1.1 Research Questions

There are three overarching research questions that I would like to address with this thesis.

1. How does tinkering manifest itself as a practice when conducting research on interactive technology?
2. How can studies of real world interaction with robotic artifacts inform tinkering practices with interactive materials?
3. How does the tinkering attitude relate to studies and design in HCI and interaction design research?

The first two questions will be addressed through the outline of contributions and aims to motivate the third question which is more to the point of making a general contribution to HCI research. These contributions have the character of an on-going research dialogue rather than explicit findings since the more hands on part of the work is outlined in the general contributions.

1.2 Structure of Thesis

This thesis is structured as a compilation of peer-reviewed publications backed up by this cover paper (or "Kappa") stitching together the articles by lifting up an overarching theme of research. The first part of the thesis consists of this cover paper while the second part consists of selected peer reviewed publications, which when necessary have been reformatted layout-wise (not content wise) to make them more coherent with the general layout of the thesis.

This introduction is the first chapter and gives an overview of the thesis as well as introduces the general agenda and the research questions. Chapter 2 sets out to give a basic theoretical orientation for why the research questions are relevant for interaction design and ties tinkering to a number of concepts as well as a handful of related white spots where issues in HCI is currently being debated. Chapter 3 goes into discussing methods as well as giving details on studies that have been used to understand interaction with robotic artifacts in the wild. Furthermore it discusses a bit on what is meant by "the wild" by reflecting on three distinct approaches for studying one and the same robotic artifact. Chapter 4 goes deeper into what we mean by tinkering and in a similar way discusses methods and approaches as well as bringing in examples from my own research in terms of up-front self-reflections. Chapter 5 brings together the contributions as outlined in the previous section in order to see how they fit together with the posed research questions. Chapter 6 is a discussion around the implications of the research and what it means for the governing design process. Chapter 7 concludes this thesis by summarizing the research in view of the posed questions.

1.2.1 Contributions Overview

The contributions offered in this thesis range from sketches, research prototypes, design insights, and concepts to methods related to studies of interaction with robotic artifacts. These will be outlined more specifically in the research contributions (Chapter 5). Next, the main characteristics

of the contributions will be briefly introduced in order to get a sense for the background, theory (Chapter 2) and methodology that are presented in the intermediate chapters (Chapter 3 and 4). The final chapters will conclude with a few words on the overall structure and meta-level reflection of these contributions (Chapter 6 and 7). My main contributions are based on the following activities:

1. Crafting and hacking together research prototypes while discussing the benefits of demonstrations as articulations
2. Field studies of people's interaction with existing technology to support tinkering in the design process.
3. Development of strong design concepts as a result of articulating a tinkering attitude in interaction design

Sketches and scenarios have in this thesis been used as envisioned uses of a technology and can be seen as detailed carriers for ideas and concepts situated in a context. Hardware sketches are mock-ups or tangible representations where most of the technical capabilities are left unimplemented but still belong to its detailed usage/experience scenario. Research prototypes are rough implementations of ideas and concepts with a clear manifestation and representation but that still lacks e.g. the touch of a finished product, vital accompanying technology or business model. Design concepts in this case are detailed governing structures for how one could think about interaction design and bridge the gaps between context, user and technology. A method in this case, is a detailed procedure or process e.g. for setting up and conducting an open ended field-study based on interviews and simple rules for conduct. The overall contribution is a meta-level reflection regarding tinkering as an attitude within interaction design.

1.3 Context of Research

The main bulk of research work captured in this thesis spans over two European projects, Embodied and Communicating Agents (EC-Agents) and Living With Robots and Interactive Companions (LIREC), both part of the Future and Emergent Technologies program for advancing ICT research (FP6 and FP7 respectively). Thus in terms of core funding it should be stressed that this thesis is indeed a product of the European research community. Between these two projects I applied for and received a personal grant from SSF to conduct research together with Ugobe – an American start-up developing and making robotic toys.

In the EC-Agents project our role was to conduct research about potential applications and to create demonstrators representative for the more theoretically oriented work. Examples of such work includes theories and models about the emergence of language, emergent group coordination, studies of biological systems exhibiting rudimentary forms of communication, language games etc. Examples of systems we explored, designed, built and studied together in this project are Push!Music - autonomous sharing of media agents, Digital Flowerwall - autonomous wallpaper agents as well as my own project of focus (included in this thesis) about a swarm of small communicating robotic artifacts called GlowBots.

In the LIREC project (Just about completed at the time of writing this thesis) our main role was to conduct studies of so called companionship technologies, e.g. robotic pets, both already existing and being developed within the project, out in realistic and naturalistic environments. We often refer to such environments where users would live their ordinary life together with the technology as *'In the Wild'*. Furthermore we were also responsible for lifting to notice and exploring ethical concerns that would be related to robots and companionship technology. In the final part of this project we have provided a set of high-level guidelines or framework for the design of companionship-technology *grounded* in studies found in this thesis, other studies that we conducted and related work done by LIREC-project partners.

My research presented in this thesis has mainly been conducted within the Future Applications Lab, led by Lars Erik Holmquist. Together with Maria Håkansson, Mattias Rost, Sara Ljungblad, Ylva Fernaeus, Nicolas Belloni, Zeynep Ahmet, Henriette Cramer, Lalya Gayle, Johan Sanneblad and Tobias Skog, I have collaborated shoulder to shoulder in terms of everyday work. In more recent years this lab merged into the Interaction Design and Innovation lab (IDI) led by Kia Höök and Petra Sundström. More recent colleagues in this context include (amongst others) Stina Nylander, Jakob Tholander, Maria Normark, Pedro Ferreira, Carolina Johansson, Anna Stål, Johanna Mercurio, Jordi Solsona, Elsa Vaara, Jarmo Laaksolahti, Bin Zhu and Elena Márquez Segura. Our interdisciplinary group(s) has conducted state-of-the-art research at both the Viktoria Institute in Göteborg and, in more recent years, since 2008, at the Mobile Life Centre in Kista/Stockholm. At the Viktoria Institute our group had a close academic relationship with the IT-University, a shared institution between Chalmers and University of Gothenburg. In Stockholm we have had a corresponding relationship with DSV, a shared

institution[1] between KTH and Stockholm University and finally with the MID-department as part of the CSC school at KTH.

The Mobile Life Centre is a so called Vinnova Excellence Centre, a ten-year joint venture between SICS (Swedish Institute of Computer Science, author's current employer), Stockholm University through DSV, KTH and finally a number of high-profile industrial partners and organisations e.g. Microsoft Research, Ericsson, Sony Ericsson, IKEA, ABB, Telia Sonera, Nokia and The Municipality of Stockholm[2]. SICS in turn is part of a larger national organisation that represents world leading research - called Swedish ICT (Information and Communication Technology). In the later stages of the research more and more ties were made with KTH and the MID department where this work came to be academically hosted upon completion.

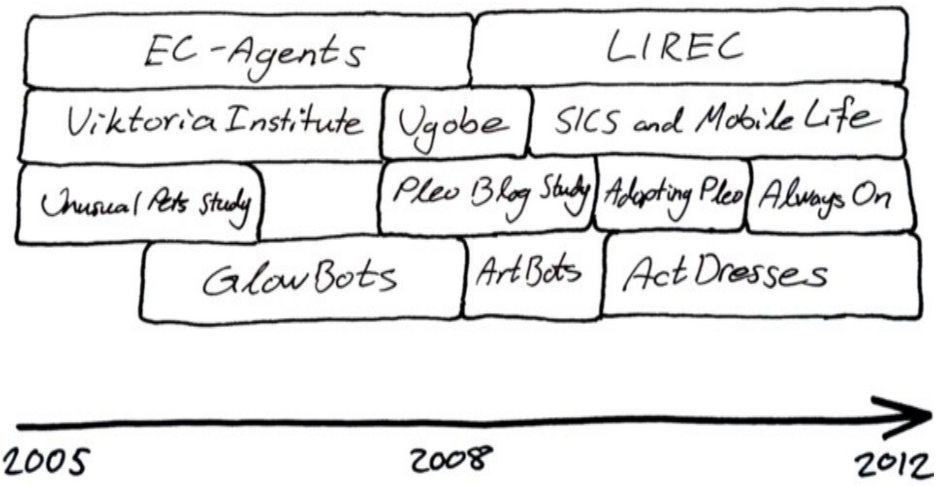


Figure 1: Overview graph showing progression of research from top line to bottom: Projects and funding, Location, Studies, Governing design activity/project

In summary, Figure 1 above illustrates the actual work included in this thesis and how it relates to these different contexts, in terms of where, when and what. Apart from this work, there are a number of projects that have run in parallel but will not explicitly be discussed in this thesis, e.g.

[1] From 2012 the DSV department belongs solely to Stockholm University.
[2] The industrial partners have varied slightly over the years, e.g. Sony Ericson left the venture as part of their reorganisation with Sony, and there are also a number of smaller but significant partners, e.g. Company P, Moveinto Fun, Kista Science City and STING.

Push!Music, Push!Photo, Autonomous Wallpaper, The RobCab Study, EcoFriends and Internet of Sports.

1.3.1 General Work Process

The character of my research follows an explorative research attitude. The aim for such research process is not products for the consumer market, but rather to engage in a continuous research dialogue and *interaction design interventions*. This dialogue is in one way the "traditional" one of publish, review and present – as well as "less formal" practices. That is to say there are these more non-formal, but not less important, research occurrences such as everyday meetings, discussions during the coffee breaks, seminars, social media, smaller informal presentations, tinkering & hacking sessions, workshops together with various industrial partners and small talk over some newly acquired gadget at a colleague's desk. Thus, the overall work presented in this thesis does not adhere strictly to any idealized cyclic or linear process, although in parts one may find traces of steps that move between sketching, prototyping and studies. Arguably the most sincere way to frame this process is that the research can be mapped out as a loosely connected network of interventions and this thesis ties them together through a more meta-level analysis and argument.

1.4 Summary of Publications

Below is a short summary of the peer-reviewed papers included in this thesis (Part 2: The Papers) together with statements about individual contribution and division of labour. More details about the contributions and how they contribute to the overall theme of this thesis will be covered in Chapter 5.

Paper I: GlowBots - Designing and Implementing Engaging Human Robot Interaction

Jacobsson, M., Fernaeus, Y., and Holmquist, L.E. GlowBots: Designing and Implementing Engaging Human Robot Interaction. Journal of Physical Agents, 2 (2), pp. 51-60, 2008.

This journal paper has a generous format offering enough space to carefully include a more comprehensive overview of the GlowBots project, which over time had grown quite large in terms of material. It captures a nearly complete chronological description starting from early studies of people's relationship with less common pets - like snakes,

spiders or lizards. Based on this data we constructed personas using affinity diagrams with these marginal practices as input. In the next phase we enter a design process starting from one of the resulting personas. In this process we dig into the rich technical details about all the possible materials that we wanted to explore. The result is a demonstrator called GlowBots which is the resulting physical manifestation of the description from that particular persona. In the last phase, we demonstrated the result and conducted studies – both at exhibitions and in 'the wild'. (expand this) The first part is also covered in (Ljungblad, 2006). Moreover, the construction of the additional hardware piece called see-Puck is covered in more depth in a CHI note (Jacobsson et.al, 2008).

My part was to lead this project, take part of analyzing the data from the first study about marginal practices, aquire and learn the e-puck platform, explore interaction modalities and the available robotic materials, participate in hardware design of the see-puck, sketch interaction scenarios for the robot and program the main behaviour. Furthermore I organized the two big dissemination events for the prototype (SIGGRAPH and Wired NextFest) as well as present it at the final review for the ECAgents project. I also planned and analysed the data in the final evaluation study. Through working with the GlowBots I would like to highlight the following lessons:

- For humans to be part of a dialogue between machines it has to be (i) situated and (ii) afforded by the involved materials. Thus our tinkering attitude opened up and allowed us to understand communication from an interaction design perspective.
- Swarm of homogenous units work well in terms of demonstrator robustness, we even had the opportunity to tweak and tinker in situ while the demonstrator was running. What it actually means to be "demo-ready".

Paper II: Play, Belief and Stories about Robots: A Case Study of a Pleo Blogging Community

Jacobsson, M. Play, Belief and Stories about Robots: A Case Study of a Pleo Blogging Community. Proceedings of RO-MAN 2009, Toyama, Japan, 27 Sept - 2 Oct 2009.

This paper describes an ethnographic study of how people express their interaction and relationship with the robotic toy Pleo in online blogs. The method used is inspired by virtual ethnography and the data set consists

of blog-posts from a period of three months capturing early adopters and their experience mediated through this medium. Being a qualitative study, it gives hints towards experiences, issues, social and ethical considerations expressed by the bloggers. The results are a set of emerging themes, social aspects and particular qualities related to the conveyed interaction.

This study was conducted as a part of my internship at Ugobe Inc funded by a Personal grant from Stiftelsen för Strategisk Forskning (SSF). Although this is mainly my own research, supervision by Ylva Fernaeus and discussions in writer's workshops with colleagues in Mobile Life helped in shaping the analysis and discussion. The main highlights from this study are:

- We found a number of categories that describe how people blog about their relationship with Pleo, one example being how they tinker and do DIY surgery on the robot.
- People seem to enjoy personalization and the unfolding stories that are triggered implicitly by the robotic artifact.
- The study revealed and highlighted accessorizing as a practice which led us towards developing the concept of ActDresses.

Paper III: Crafting Against Robotic Fakelore: On the Critical Practice of ArtBot Artists

Jacobsson, M., Fernaeus, Y., Cramer, H., and Ljungblad, S. Crafting Against Robotic Fakelore: On the Critical Practice of ArtBot Artists. Proceedings of CHI 2013, Paris, France, ACM.

This paper summarizes two studies regarding robotic art practitioners that took place during two separate ArtBots events. The initial goal was to investigate the artists take on crafting robotic artifacts as well as how the audience reflected upon the works. We frame this discussion around what we call robotic fakelore in terms of how the artists are able to both advance robotics while at the same time subtly criticize it from within with respect to how robots are portrayed in popular media. Furthermore we conclude with arguing for how to better include arts research within HCI.

I took an active part in the first study where we planned, interviewed and gathered data from the event during three days. I have also been actively involved with the analysis and structuring of the data, something that has

evolved over time in order to get a balance in its critical framing. A main lesson from the study:

- Critiques were delivered in the same language as that they are implicitly criticizing – as artifacts consisting of robotic materials. ArtBots as a curated venue create this unique space of expression.

Paper IV: Comics, Robots, Fashion and Programming: outlining the concept of ActDresses

Fernaeus, Y., and Jacobsson, M. Comics, Robots, Fashion and Programming: outlining the concept of ActDresses. Proceedings of TEI'09, Cambridge, UK, ACM.

ActDresses is one of the main interaction design explorations of this thesis, and tries to articulate the development of a novel concept for embodied interaction with technology. This paper describes the design process behind the concept as well as main variables that the interaction designer would use to craft artifacts based on this idea. It is important to understand that this work was grounded in the practices that were observed in the Blog Study about how people used accessories to personalize their robotic toys.

My role in this project was to identify and advocate the core concept of using clothes and accessories as a way of both conveying and affecting behaviour of robotic artifacts. The following conceptual work as well as the first round of sketching, tinkering and prototyping was a shared effort done together with Ylva Fernaeus. At the later stages I would further push on with the sketching and tinkering aspects of the work. Main lesson from this paper:

- Sketching out an idea conceptually helps in framing the other required parts e.g. (field studies and tinkering) for a stronger interaction design concept.

Paper V: The Look, The Feel and The Action: Making Sets of ActDresses for Robotic Movement

Jacobsson, M., Fernaeus, Y., and Tieben, R. The Look, The Feel and The Action: Making Sets of ActDresses for Robotic Movement. Proceedings of DIS 2010, Aarhus, Denmark, August 17-20, 2010.

In this final paper we use the concept of ActDresses to sketch out and develop robotic artifacts that can be controlled using clothes and accessories. In a way this is a type of evaluation, which shows that the concept can indeed be successfully implemented over and over. It also implies that it is not bound to robotic artifacts and hints towards other areas where this behaviour exist e.g. mobile devices.

My contribution in this work was in part to supervise our intern Rob Tieben and our two bachelor students Victor Luque and Johan Sundin who built two of the three reported prototype systems. The other part was to write about the overall process and detail the development of these demonstrators in relation to the ActDresses concept. Lessons and highlights:

- With the Roomba and SquareDance prototypes we showed that we could combine high and low-level behaviours in interesting ways.

Other related publications that are not explicitly included as part of this thesis:

Ljungblad, S., Walter, K., Jacobsson, M., and Holmquist, L.E. Designing Personal Embodied Agents with Personas. In Proceedings of RO-MAN 06, The 15th IEEE International Symposium on Robot and Human Interactive Communication, Hatfield, United Kingdom. (Full paper)

Jacobsson, M., Bodin, J., and Holmquist, L.E. The see-Puck: A Platform for Exploring Human-Robot Relationships. In Proceedings of CHI 2008, Florence, Italy, April 10-15, 2008. (Short Paper)

Jacobsson, M., Ljungblad, S., Bodin, J., Knurek, J., and Holmquist, L.E. GlowBots: Robots That Evolve Relationships. In Adjunct Proceedings of SIGGRAPH 2007, San Diego, USA, August 5-9, 2007. (Abstract)

Fernaeus, Y., Jacobsson, M., Ljungblad, S., and Holmquist, L. E. Are we living in a robot cargo cult?. In Proceedings of the 4th ACM/IEEE international Conference on HRI '09. ACM, New York, NY. (Short Paper)

Fernaeus, Y., Ljungblad, S., Jacobsson, M., and Taylor, A. 2009. Where third wave HCI meets HRI: Report from a workshop on user-centred design of robots. In Proceedings of the 4th ACM/IEEE international Conference on HRI '09. ACM, New York, NY. (Short Paper)

Fernaeus, Y., Jacobsson, M., Ljungblad, S., Håkansson, M., and Holmquist, L. E. (2009) *Contrasting Perspectives on Robots: a study among artists, researchers and the general public.* In Proceedings of HRI 2009, 9-13 March 2009, La Jolla, California, USA. (Short Paper)

Fernaeus, Y., Håkansson, M., Jacobsson, M., and Ljungblad, S. (2010). How do you play with a robotic toy animal? A long-term study of Pleo. In Proceedings of IDC'10. (Full Paper)

Ljungblad, S., Kotrbova, J., Jacobsson, M., Cramer, H., and Niechwiadowicz K. 2012. Hospital robot at work: something alien or an intelligent colleague?. In Proceedings of CSCW '12. ACM, New York, NY. (Full Paper)

2

Background and Related Work

This chapter introduces a brief background and related work that aims to frame a few selected white spots or touching points where tinkering can be pulled to the foreground with respect to research in HCI. Here a more practical stance of HCI will be presented where researchers are to be considered as crafters using their own set of materials and how it connects to today's emerging maker movement and Do-It-Yourself (DIY) practices in society at large.

My own understanding of what has unfolded in more recent years is a development in mainly three directions – the first being the extending of the concept of embodied interaction [Dourish 2004] into an even more critical take influenced by e.g. feminist theory and philosophy of the corporeal [Butler 2006; Sheets-Johnstone 2009]. Secondly, design has emerged as a way to talk about how HCI as a field to a large part has everything to do with actually crafting interactive artifacts using physical-digital materials [Zimmerman et al. 2007; Löwgren and Stolterman 2007; Buxton 2007; Holmquist 2012; Sundström 2010]. Thirdly, there has been a development that deals with studying things "in the wild", where the wild is based on everyday and real world use in its broadest sense [Rogers 2012; Brown et al. 2011; Weilenmann and Juhlin 2011]. As will be argued for through this overview, the research field of HCI is currently moving in a direction that revisits crafting practices with respect to interactive materials and even starts to question the role of design beyond what can be captured in the notion of "design" [Frens and Hengeveld 2013].

2.1 Robotic Artifacts and Materials

In this thesis robots are considered to be physically manifested artifacts that are crafted through a design process. Interaction design, when applied to more engineering-oriented fields like robotics, takes a broader view and strives to make technology that supports rather than supress interaction. Artificial intelligence is generally seen as closely connected to robotic agents and thus an integral part of any type of human robot interaction. Alex Taylor has argued for an interactionist take on intelligence that states that some artifacts exhibit behaviour that we may be ready to treat as intelligent [Taylor 2009]. This means that it is possible to view intelligence as something that is not fixed, but open for interpretation as we go along and interact with artifacts. This is clearly a break from traditional ways of viewing artificial intelligence as something given and at the same time indicates that HCI and interaction design are in a sweet-spot for treating intelligence as an available resource in the design process. Carl Di Salvo makes the following visionary commentary on robots viewed from the perspective of interaction design:

"Robots are hyperboles of the products contemporary designers are challenged with. That is, they are an exaggeration of the contemporary products because "robots are everything all at once": complex embodied technological artifacts that require significant design knowledge of industrial, communication, interaction, service design, potent cultural icons, and, too, the most mundane of gadgets." [Saffer 2009, pp.202]

In part, this is the same argument that this thesis is founded on, but taken a bit further in the direction of viewing robotic artifacts as something that is made up by physical and digital materials that can be crafted together. The following examples will describe two research-related examples of



Figure 2: The Hug, a plush pillow that is designed to provide an experience reminiscent of hugging developed by Gemperle et.al at Carnegie Mellon University.

robotic artifacts that illustrate this perspective and that have been inspirational to my work. The first example is *The Hug*, a robotic artifact that communicated remote hugging activities or that in another version simply "hugged back" when being hugged [Gemperle et al. 2003]. Design wise it had many basic qualities of a pillow, and the space the research group investigated were intimate social communication together with physical communication. One of the primary intended user groups for this technology were senior citizens, and the idea was to bring family members separated by distances, closer together by more physical means of communicating. As such this project thereby sometimes falls under the category of assistive technologies, but the design could as easily also be imagined for a more general user group with regards to self-affective measures, e.g. a comforting pillow or a pillow for watching horror movies. Just as the authors conclude, a hug addresses a very basic human need and is perceived in interesting ways when performed by a technical artifact.

The second example is *Tabby*, a pulsating, breathing, furry lamp that gives life-like artifacts a whole new dimension [Ueki et al. 2007]. While having the practical functionality of an ordinary desk lamp, it features an air-pump that inflates and deflates a thin rubber-balloon-like cover made of a furry fabric. This results in a calm breathing that has an aesthetics to it that is reminiscent to having a pet-cat that sleeps on a chair or table. The purring sound from the fan can in this way actually complement the experience rather than be annoying as it often turns out when e.g. an



Figure 3: Tabby, the furry, "breathing", light emitting artifact from Keio University

otherwise static computer-rack turns robotic by being equipped with little else than wheels and a few sensors. Its spherical posture conveys a sense of integrity that speaks of *"Hey I am here, and this is my space"*. Thus, paying attention to governing details when composing an artifact, making sure that materials go well together in an overall aesthetics, is a primary challenge seen from an interaction design perspective. These two examples emphasize that the emerging role of everyday robotics is far from fixed regarding the visions portrayed through popular media (more on this topic in Paper III). There is also a distinct physical "softness" to these examples that speaks for a more corporeal – body to body, non-verbal type of interaction. Further explorations in this area have been made by e.g. Thecla Schiphorst [Schiphorst 2009], by looking at aspects of embodied soft figures and how this notion of softness can be regarded a kind of design material that encourages more bodily interaction.

At the point where this research started, there were several studies of human-robot interaction in existence (e.g. studies of Roomba and Aibo), but when it came to designing robotic artifacts or exploring the design-space for such artifacts there were still much research to be done. Nowadays, robotic artifacts are generally built using the very same materials used to craft interactive technologies, something that we may refer to as simply physical-digital materials [Sundström et al. 2011; Fuchsberger et al. 2013] or even robotic materials. As robotic artifacts, they highlight many of the practices and activities involved when crafting with these materials. For example the "live" aspect becomes particularly important from an interaction design point of view since a "living" non-static artifact implies crafting with materials that both act and "talk back" in a more literal way than traditional materials (e.g. [Schön 1984; Tholander et al. 2012]). Research around robots and robotic artifacts is a relatively narrow genre within interaction design research, and in particular the research that explores its specific materiality and craftsmanship aspects have not really taken off yet. However, as detailed in Paper III, there exist practitioners and knowledge of working with these materials e.g. in the ArtBots community. What robotic artifacts then provide is a kind of lens through which certain crafting practices in interaction design become even more visible by studying these communities and at the same time reflecting upon our own work.

2.1.1 Materials, Materiality and Media

A more recent move within interaction design and HCI research is the discussion regarding materials, materiality and media. One fundamental question in these discussions concerns how we as researchers can extend

our conception of the materials that are used in interaction design as being different from traditional materials. Fernaeus and Sundström suggest that, there is right now an emerging need for highlighting more distinctive material properties within HCI [Fernaeus and Sundström DIS 2012]. This then becomes central to the HCI-field as researchers and practitioners put together and explore these materials using a range of skill sets, hands on crafting and material knowledge [Redström 2001]. Through the years there has been a development from considering these materials that make up interactive technology as "without properties" to being computational composites to being physical-digital materials that actually do have properties [Löwgren and Stolterman 2007; Vallgårda and Sokoler 2009; Sundström et al. 2011]. In this thesis the notion of physical-digital materials as well as interactive materials are used interchangeably and sometimes more specifically robotic materials depending on if the context is more related to designing interactive artifacts or robotic artifacts.

I participated in the 2012 workshop on materials and materiality at the annual CHI conference, and this year (2013) a number of papers brought out various aspects on this topic. For instance, one by Fuchsberger et.al [Fuchsberger et al. 2013] highlights the connection between materiality and media in HCI analyzed through Latour's Actor Network Theory (ANT) and McLuhan's media analysis framework, by considering the *active role of materials*. Firstly, what they underline in their work is a detailed argument for how physical-digital materials are profoundly different given their richness as both media and material properties. Secondly, while discussing how they applied the ANT framework they infer an elaborate definition of how *tinkering* can be viewed as the very associations that make up the emerging networks:

"A network consists of associations which have to be established. These associations define the relatedness of the actors within the network, and can be described in terms of collaboration, clash, addition, tension, exclusion, inclusion, etc. Associations are also sometimes called tinkering, emphasizing the step-by-step activities performed by the actors" [Fuchsberger et al. 2013]

Thus, it is precisely these activities framed as an *intentional collective* and their relationship with physical-digital materials that is the main focus of this thesis. From a practitioner's perspective, the primary advantage of viewing something as a material is that it becomes immediately available, its properties and qualities can be teased out and literally put at one's fingertips ready to be crafted with.

Framing the space between media and materials through the levels of interaction, dynamics and software/hardware (digital/physical) integration gives an overview of the relationship between these as if they were to be considered physical-digital materials. In Figure 4, smartphone and tablet PC represents the media and the experience it conveys rather than the devices in themselves.

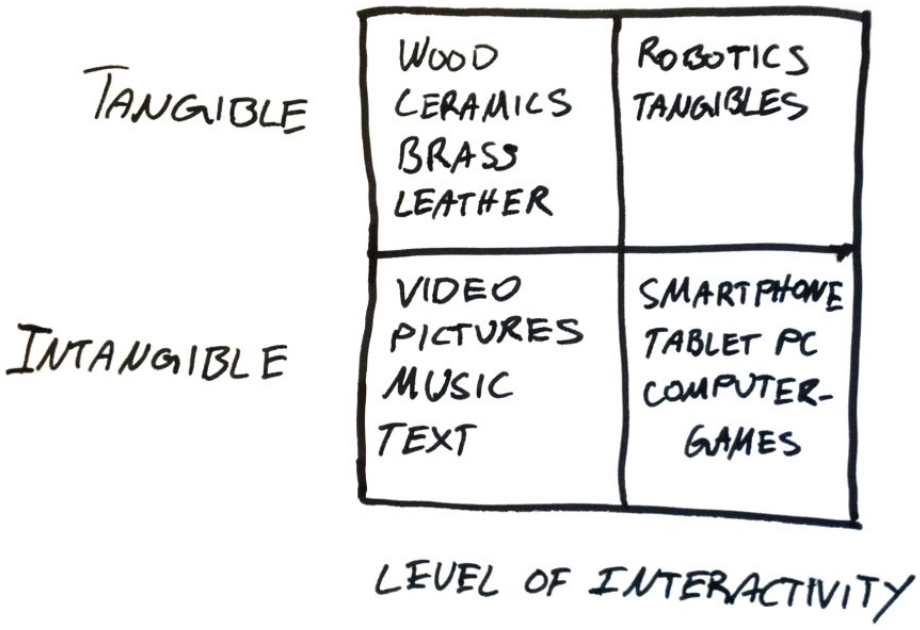


Figure 4: Attempt at positioning robotic materials from an interaction design point of view.

All these materials (or forms of media) will require material knowledge such as what it means to craft and work with them. Since tinkering implies working more directly with materials it also means working directly with materials that come to "live" which is articulated when working with robotic artifacts or other dynamic materials. This is different from e.g. sketching, in that it means working with representations on the conceptual level while still working hands on with the very materials of an artifact.

To summarize, detailing aspects of the craftsmanship with interactive materials is something of an on-going meta-level project within HCI, which several researchers currently are trying to articulate. Tinkering offers a term to describe some of the hands-on aspects of doing research with physical-digital materials in this research domain. As an attitude it

relates to a number of established practices such as prototyping, sketching in hardware and reverse engineering, but from the perspective of an intentional collective of activities or *attitude*.

2.1.2 Robotic Materials

With design comes a tradition of working with various materials and acquiring what we call material knowledge, a kind of encompassing knowledge about materials; their properties and qualities, how one can craft and build with them and how they might fit together with other materials [Cross 2010; Löwgren and Stolterman 2007]. This type of knowledge has proven to be relatively difficult to define, communicate and externalize, even when working with simpler, well defined and well behaved materials. In fact, a common insight is that it is seldom possible to copy or imitate the practices of dealing with classical materials like clay, wood and paper straight off for interaction design purposes. Robotic materials as a subset of interactive materials, bring out other practices and skill sets, e.g. component knowledge – how parts fits together with other parts, system knowledge – how functionality works from a systems perspective, interaction knowledge – how systems works with people in the loop, and computer knowledge – how it is programmed to produce the wanted behaviour – digital as well as physical. Not only does this group of interactive materials incorporate already existing practices (programming, sketching in hardware, prototyping, reverse engineering, hacking, etc) but as I argue in this thesis it also hints of a signifying attitude that complements design, engineering and field studies.

The specific field of Human Robot Interaction (HRI) initially emerged out of cognitive science, and engineering practices further emphasises the use of physical-digital materials. However, HRI has in a way not yet incorporated a design-oriented philosophical tradition as in the broader field of HCI and interaction design. These materials are emphasising a strong physical "in the real world" presence as well as tapping into every aspect of traditional interaction design. Robots and interactive companions are thus not only traditional devices but should be regarded as dynamic actors within our everyday contexts. Such contexts span over both physical and social domains, e.g. we will not only touch them, we will even relate to them through social media [Cramer and Büttner 2011].

Moreover, technology can be seen as something akin to bodies, and link to the philosophical meaning of the fact that motion appears to somehow articulate embodiment [Taylor 2009]. For instance, Alex Taylor explores the more rough sides of technology where e.g. where robots would be

viewed as “dirty” in the sense of having biological compounds. It is thus an interesting paradox that we in academic writing often refer to the human body as the user that is at all times ready to use, or simply just not worth emphasizing beyond the interaction it provides. Just as we as people may unreflectively “wash our hands”, we are often unable to grasp the sheer complexity of our body interacting with the soap, thus reducing it to a bland concept. Maxine Sheets-Johnstone summarizes the issue at hand in one clear sentence:

"More broadly, the hard problem is to see ourselves and all forms of life as intact organisms, living bodies, rather than as brains or machines."

Similarly to when Hutchins emphasizes that context matters [Hutchins 1996], our bodily involvement in our work and practice plays a significant role both in interaction design and HCI as a whole [Klemmer et al. 2006]. Although it is somewhat of a reflection on the side, Sheets-Johnstone points out what her overall argument about corporeal might imply for robotic artifacts more specifically:

"Robots are not forms of life to whom emotions happen but remote-controlled puppets to which signals are sent; they are not moved to move, but are programmed to move."

All these apprehensions are vital for when designing robotic artifacts as they too are expressions for when technology is both *in movement* and *in corpus*. Pfeifer and Bongard came to a similar conclusion but from the direction of artificial intelligence stating that *“intelligence requires a body”*. More importantly, they build and craft prototypes and systems in order to better understand the role of embodiment, but from a view that tries to emphasize that artifacts are embodied [Pfeifer and Bongard 2007]. At the end they do express a desire for design, but in the sense that engineers often talk about design which is in far more functional terms and abundant of interaction and studies thereof. This reflection brings us back to Schön’s argument about the separation between knowledge and practice in academia and as research practitioners and academics we might have to ask ourselves if we are actually once again are abstracting away the researcher as a craftsperson by not seeing the practices for what they are.

2.1.3 Interaction Design and Embodied Interaction

Who is a designer in interaction design? For me personally this is one of the more problematic questions, which is probably due to what I regard

as conflicting attitudes. Zimmerman provides an interesting reflection, in particular highlighting just how problematic it has become to talk about design [Zimmerman et al. 2007]. In some cases design speaks of professionalism, where the designer is a practitioner who produces the specifications for an artifact [Cross 2010, pp.33]. But will the rest of us then be disqualified to talk about our practices as design? Fällman argues for having a *design attitude*, which in a way is a more inclusive term that does not exclude the interdisciplinary researcher who has a non-designer background [Fällman 2003]. Furthermore the concept of design appears to be somewhat affected by a cultural divide where the meaning ranges from "everything that is crafted" to "representational sketches" to much more specifically "giving form".

In one textbook on interaction design, Löwgren and Stolterman [Löwgren and Stolterman 2007] presents an overview of what it takes to be an interaction design practitioner. The general design process is described as moving from vision to specification and it brings up a discussion by Christopher Alexander in the 1970's, concerning how modern architecture emerged as a result from the professional division between labour and responsibility due to increased complexity. At the same time Löwgren and Stolterman suggest that there has always existed a movement of craft within HCI and interaction design as outlined by Wroblewski in his text "The Construction of Human-Computer Interfaces Considered as a Craft" from 1991. This is particularly relevant to this thesis as Wroblewski suggested that we may regard a researcher within interaction design as an *articulate craftsman* who tinkers with tools and materials that have both physical and digital properties [Wroblewski 1991].

In his book "Where the Action is – The Foundations of Embodied Interaction", Paul Dourish [Dourish 2004] presents a perspective of interaction design based on phenomenology. Dourish delivered an argument that spans several evolutions of interactive manipulation modalities, e.g. electrical, symbolic, textual and graphical. This main argument suggested that the experiences of computation spanning these modalities while seen from either a social or a tangible perspective could be seen as drawing from phenomenology as its philosophical foundation. Furthermore Dourish gave an overview of the involved practices that govern interaction design research in terms of designing, building and studying (although not taking it as far as a circular revolving process). Towards the end, he summarizes his case by identifying a particular attitude and program among the research that he looks at [Dourish 2004]. Rather than elaborating more broadly about these attitudes, he

summarizes that embodiment is the one unifying perspective that brings these practices of interaction design research together.

However, this notion of embodied interaction is not the only way to talk about embodiment in HCI. Since my focus to a large part deals with robotic artifacts, I would like to comment on what it might mean for a piece of interactive technology to be *embodied*. In the domain of tangible and robotic interfaces, embodied sometimes refer to interactive devices that it is *self-contained* and that interaction somehow unfolds through its physical presence and appearance. As such it may acquire a state of agency or *character* that is tightly bound to physical, social and cultural aspects of interaction [Laurel 1993]. I am however aware that this is a different interpretation of embodiment, one that diverges from Dourish's notion of embodied interaction which is about how interaction is coupled to the human body as the centre for social action in relation to the sense-making process involving the use of artifacts [Dourish 2004, pp.189]. Thus, at this level, I will have to take an inclusive stance and treat both humans and artifacts as agents or actors which are to be seen as equal in terms of having embodiment, i.e. a physical body.

In the vision for ubiquitous computing [Weiser 1991], computers as we know them disappear into the fabric of everyday things while computation at the same time bleeds into everyday activities. As a contrast the mainstream vision of robots is nearly the exact opposite in that physically manifested robots are foretold to be increasingly present and articulated throughout our environments. As a way of articulating this physical aspect of interactive robotic artifacts, Fernaeus suggests that we may view technology as resources for human action and experience [Fernaeus 2009]. This is an attempt at studying embodied interactive entities from a user-centred rather than a data/AI-centric perspective that otherwise is still common within the HRI community. The model as such takes a stance in tangible interaction and outlines four dimensions for how a physical artifact works as a resource for human action:

- Physical manipulation
- Contextually oriented action
- Digitally mediated action
- Perception and sensory experience

These dimensions are then addressed through a set of guiding questions to reflect upon when studying or designing the artifacts. For instance, when looking into physical manipulation the designer might ask what kind of physical manipulations can be supported by the device. The

corresponding guiding question for a user study would be to inquire about how people physically handle or manipulate the device out "in the wild" [Fernaeus 2009].

2.2 Tinkering

The goal of this thesis is not to push for a brand new concept, but rather to articulate what is already going on through focused observation and reflection based on my own research experiences in the field of interaction design. As I will detail in this chapter, there are areas in HCI and interaction design that are being discussed right now that relate to a governing term describing a class of activities related to crafting. The French term *bricolage* was introduced by Levis Strauss as a concept that captured the use of materials at hand to create new things [Lévi-Strauss 1966]. This concept is in many ways identical to "tinkering" in its original interpretation [Lévi-Strauss 1966], and has been brought up in e.g. design studies [Louridas 1999]. However, although bricolage has previously been introduced in HCI [Blackwell 2006], it has over the years been coupled with practices connected more closely to software and programming. For instance my colleagues and I have ourselves used the term in our own work to talk about how people may dress up robots as a way of doing end-user programming [Jacobsson et al. 2010]. But tracing back to its original meaning, the concept of bricolage appears interchangeable with respect to the nowadays notion of tinkering. A final argument for why I prefer to use the term tinkering is that it may appear more coherent in style when writing in English. In Chapter 4, I will present a brief account of tinkering as a concept and tie it to my own experiences with hands-on work and corporeal aspects of crafting with robotic materials.

2.2.1 Attitude versus Practice

Through the previous overview of some of the ongoing discussions around materiality in HCI there is something of an *intentional collective of activities* that are related to its crafting practices [Fuchsberger et al. 2013]. One approach is to consider this collective of activities as an attitude that directs and acknowledges our work in terms of processes and practice.

In Donald Schön's book "The Reflective Practitioner", readers are being immersed into a discussion about knowledge production (anno 1984) and its relation to professional practices [Schön 1984]. What makes it typical for its time is related to the debate about the normative effect that

professionalism has and the separation between "knowing" and "doing" [Frayling 2011]. By looking at a number of professions, Schön outlined what he referred to as knowing-in-practice and suggested that the lion part of this knowledge is so called *tacit knowledge*. This involves the delicate networked bulk of small and peculiar ways of knowing or having hunches related to practices that are inherently hard to put into definition [Crawford 2011]. In a way, tinkering as a part of interaction design (in terms of its practices) cannot disregard this issue, and the purpose with this section is to be explicit about this matter. This is for instance why reading e.g. this dissertation will not in an easy way translate to the corporeal knowledge acquired through actual tinkering practice.

While referring to Schön, I would like to highlight a particular passage regarding attitudes, a theme that he only briefly touches upon almost in passing. In one section he quotes Edgar Schein, and summarises Schein's three main components of professional knowledge [Schön 1984, pp.24]:

1. An underlying discipline or *basic science* component upon which the practice rests or from which it is developed.
2. An applied science or *"engineering"* component from which many of the day to day diagnostic procedures and problem solutions are derived.
3. A skills and *attitudinal* component that concerns the actual performance of services to the client, using the underlying basic and applied knowledge.

Here, Schön asks us to pay attention to this structure as it tries to convey a kind of norm hidden in the structural notion of how "applied science" rests on the shoulders of "basic science". Another way to put it is to be sensitive towards the implication of giving certain schools of thought higher status. Keeping this in mind while focusing on the third point, highlights something quite intricate as it infers a second separation between practice and attitude in terms of knowledge production for an applied science. While Schön chose to focus on the practice exerted by working professionals, in this thesis I will take another route and dwell a bit more on what it means to have an *attitude* or *stance*. Thus in my interpretation, it would appear that an attitudinal component would offer a different foundation to relate to, contrast and complement other attitudes and practices within HCI and interaction design research.

That said, Schön is seemingly well before his time; and while struggling with making his case about the locus of knowledge, the perhaps best framed paragraph for an HCI audience is the following:

Both older and newer schools have "nearly abdicated responsibility for training in the core professional skill", in large part because such training would have to be grounded in a science of design which does yet not exist. [Schön 1984, pp.47]

Today however, is a different time with other problems and we could actually state that we in our research community have an established and strong presence of design within HCI, although perhaps not necessarily the same notion of design as Schön and others have hinted at. In more recent years a number of people, e.g. Cross, Stolterman, Löwgren, Fällman and Zimmerman have further developed the idea of having a design oriented philosophy while at the same time mapping out relevant practices and methods. A tell that our field are in fact advancing would be that our research community as a whole now tackles other emerging issues, e.g. how to better include and make use of the arts within our research community (See e.g. Paper III) [Candy et al. 2012; Gaver et al. 2003].

Sketching or "fiddling" with materials is what we today are looking at in HCI in terms of material knowledge [Fernaeus and Sundström 2012]. In the early seventies, John Chris Jones discussed how design activity (primarily regarding architecture) from mainly three perspectives: as a black box, as a fully transparent process and as a self-organizing system [Jones 1992]. Jones showed that how a design activity was carried out depended on if it was solution, exploration or problem oriented. In my view is tinkering not explicitly just design nor is tinkering only engineering. It is reasonable to claim that it should be located somewhere in between where it could be properly grounded in its own values through practices like sketching or "fiddling" e.g. being playful, creative and explorative. To me, this is where the main difference in attitudes lies. Still, and as I will argue in this thesis, we as researchers in this field are by no means done yet with shaping the understanding of these involved attitudes, and even less so how to fully make the most out of them.

2.2.2 DIY, MAKE Culture and Crafting

Do-It-Yourself (DIY) and the so called "maker movement" describe everyday practices that almost anyone can engage in using off the shelf tools and materials together with online instructions etc [Tanenbaum et al. 2013]. These communities of "practice" have recently become popular to both study, support and engage in within HCI; and looking at recent activities we see diverse examples such as traditional book-binding and

restoration using leather [Rosner and Taylor 2011], gadgeteering in Steam Punk communities [Tanenbaum et al. 2012], various toolkits and adaptations such as Arduino Lilipad [Buechley et al. 2008] (Figure 5), Raspberry Pi, etc. Practices in DIY, MAKE Culture and Crafting communities thus have a special relationship with interaction design that can be studied practiced and learned about. For instance, most interaction designers would arguably be engaged in at least some crafting practice, either professionally or on a more amateur basis. Currently, I am sitting next to research colleagues who sew, knit, blacksmith, cut, fix and carve, although these practices usually expresses a simpler and more mundane aspect of a skill or practice that stands in contrast to its established profession e.g. tailor, smith or shoemaker.



Figure 5: Example of artwork made with Arduino Lilipad as presented at the TEI'12 demo session.

In particular the tangible, embedded and embodied interaction (TEI) conference is partially formed around crafting practices, but also UIST, UbiComp and the main SIG-CHI conference expresses a strong interest in this direction with their demonstration and interactivity tracks. What is interesting in relation to this thesis is the collaborative aspect around tinkering. Crafting together shoulder to shoulder, while having that tinkering attitude we previously characterized, would in a good way facilitate knowledge transfer between people. It is implied that such crafting is practice-oriented and that things break down due to experimentation and that some parts are more difficult or easier than others. Examples of this can be seen in John Seely Brown's vision of a learning environment as well as the maker's fairs, in good old fashion knitting workshops and Crawford's description of motorcycle repair shops [Crawford 2011].

In the discussion on constructionism, Seymour Papert advocates his position that there are two styles of solving problems [Papert 1993]. As a contrast to the analytical style of solving problems he describes bricolage

as a way to learn and solve problems by trying, testing, playing around. We have previously argued that bricolage and tinkering are more or less identical concepts in terms of an attitude perspective. What is suggested here then is that tinkering in a similar way offers a mode for problem solving from a constructivist perspective.

"For planners, mistakes are steps in the wrong direction; bricoleurs navigate through midcourse corrections. Bricoleurs approach problem-solving by entering into a conversation with their work materials that has more the flavour of a conversation than a monologue. " – Papert & Turkle

The maker movement is a good example of how the tinkering attitude is spreading and the sense of demands it sets out on products. For something to be open means everything and it poses new requirements for how to frame the design of artifacts (Figure 6). From a "makers" (or tinkering) perspective; eye-catching, neat or closed designs are not favored by this group since they are regarded as un-democratic.



Figure 6: The maker's bill of rights is a manifest that advocates a certain kind of democratized openness that is at the heart of the maker culture.

A number of companies even make it one of their core ideas to open up for tinkering, e.g. Lego, Adafruit, etc. while others focus on serving a

broad assortment of sub-level components e.g. Radio Shack. In HCI we are seeing an increase of interest for studying how crafting and hacking relates to corporations [Rosner and Bean 2009]. Moreover, living in a consumer oriented society means having access to an extensive amount of "off the shelf"-equipment. In the field of HCI, we must finally come to realize that interaction design researchers are also sometimes makers.

2.2.3 A Corporeal Turn

This section reasons mainly about the very locus of tacit knowledge within our human bodies, and what it means for bodies to move in terms of implications for discussing robotic artifacts and its materials. In terms of phenomenology, Merleau-Ponty argues for *corporeity of consciousness*, meaning that our perception of reality inevitably happens through our bodies. Sheets-Johnstone has extended this argument by including lines of thought from evolutionary philosophy. She argues that thinking is tightly connected to movement, and builds her understanding on the evolutionary grounded idea that movement precedes thought:

"Precisely by thinking in movement, infants are gaining knowledge of 'objects, motion, space and causality' ..." [Sheets Johnstone, The Corporeal Turn, pp.44]

At the same time it is remarkable to what lengths researchers in interaction design take to avoid talking about, struggle to objectify and transform the apparent nature of human bodies. On the other hand we as researchers tend to at the same time make the most extensive descriptions and accounts regarding technical details and procedures. To counterweight this the HCI community talk about experiences and emotions, but not so much directly about peoples' actual physical bodies. However, on-going discussions in HCI indicate that the topic is slowly progressing as can be seen in the programs from last decades SIG-CHI publications, with examples regarding from bodily-experiences to somatic explorations and even intimate design [Sundström et al. 2005; Schiphorst 2009; Bardzell and Bardzell 2011]. One of the keynotes by philosopher Richard Schusterman from CHI 2012 introduced the body from the angle of what he refers to as *somaesthetics*, which advocates a program for increased intra-personal bodily-awareness [Shusterman 2008].

This is interesting, not only because of the phenomenological connection, but rather because of our own corporeal practices as researchers, and how we can get more profoundly involved with our own work. Not only does

knowledge exist in someone's "mind" or in the "wild" [Hutchins 1996], but it also resides in our flesh and bones [Sheets-Johnstone 2009]. Rather than being a philosophical pastime, it is not yet clear how our research culture must become more self-reflective of its own practices when it comes to designing with interactive materials.

2.3 Research and Articulation

In the book "The Postmodern Condition" by Loytard in 1984 [Lyotard 1984], narratives and in particular stories of how science unfolds were severely scrutinized, resulting in a rather confused state where scientists must come to terms with that research and ultimately researchers are merely human. As researchers we have wishes, dreams, drives, flaws and desires just like everyone else. Latour raised a critical voice towards established research practices by taking a social constructionist view of how academic research works [Latour 1988]. He studied researchers in laboratory environments and how they communicated their research through scientific arguments. Besides a number of observations about academic publishing culture, the overall emphasis in his work stressed that researchers in technical domains ought to approach the actual state of affairs (getting outside of their labs) which at the time implied a change in methods, approaches and in not least attitudes.

What we mean by articulation today originates from how *rhetorics,* i.e. the practice of making an argument, emerged in philosophy [Wood 2005]. Part of the design tradition in HCI is about how to make such articulations both through written text and crafting physical objects such as prototypes and demonstrators in order to illustrate or make an argument even clearer [Redström 2001]. Tying back to Latours argument, these results and contributions can take many forms since they are no longer as strictly bounded by traditions in research practices e.g. ones that emphasize a strictly unified representation e.g. written text. On the other hand what is considered *good* research may still be contestable, but what is clear is that such an articulation – in any form – is a sound and *well-crafted* argument that is *original, grounded* and *relevant* [Löwgren and Stolterman 2007, pp.2]

Practices that govern knowledge generation in HCI at large have evolved over time resulting from a constant influx of adopted methodologies such as e.g. methods from ethnography and design. Depending on stakeholders, visions and societal motivation such practices have been captured in models of governing research processes as a way of theorizing across traditional field domains. One of the very earliest

models in HCI that is relevant to the topic of tinkering and interaction design is the so called Verplank's spiral (Figure 7) which captures one idea of what an overall design oriented research process is about. William Verplank, a former Xerox PARC veteran introduced the term *Interaction Design* together with William Moggridge in the mid 80's, some ten years before the term would emerge in HCI as part of the general move towards design theory [Moggridge 2007].

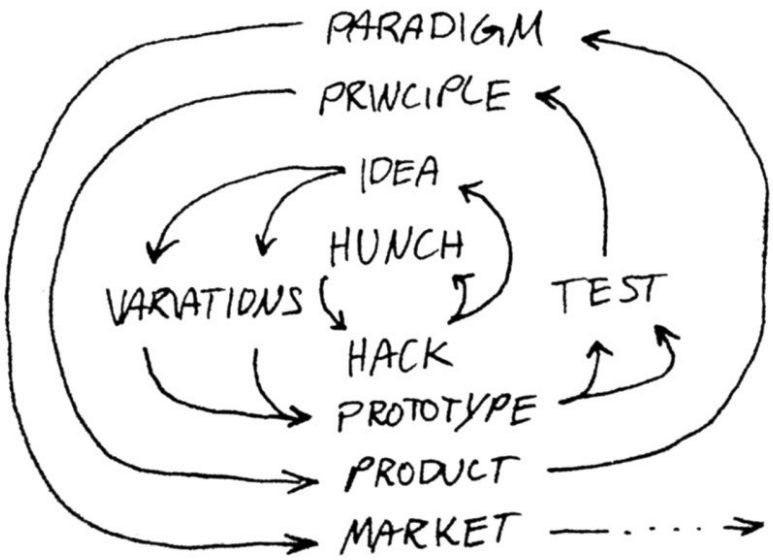


Figure 7: The classical Verplank hack and hunch spiral model of an interaction design research process.

This model captures the research process in a number of conceptualizations (top), states (bottom) and hands on practices in the middle. According to this model, interaction design appears to revolve around a kind of kernel that is not yet named, but that involves hack, hunch, variations and test. In my view this kernel is clearly related to a whole range of crafting practices and methods for grounding hunches, that more coherently may be described by a governing attitude within the interaction design umbrella.

From Verplank let us move on to Zimmerman and his colleagues notion of research *through* design from a HCI practitioner's perspective (not necessarily a researcher) [Zimmerman et al. 2007]. In their view the interaction designer attempts to do the *right thing* – that is changing the world from a known state into a preferred state as suggested by Herbert Simon [Simon 1996]. More importantly Zimmerman et.al purposefully

map out what the role of interaction designers is in relation to engineers, behavioral and social scientists. In this description the role of interaction design specialists is central in the production of knowledge produced by the HCI research community, intended to be transferred towards HCI practitioners. Furthermore, such knowledge is at large based on research artifacts that represent "what ought to be". Examples of such artifacts range all the way from design patterns to research prototypes and are different from how HCI and design practitioners work in the sense that the latter focus on commercially oriented products. Here it must be emphasized that the notion of design as used within research not automatically translates into e.g. form-giving, industrial or product design [Zimmerman et al. 2007].

2.3.1 Strong Concepts

Conceptualization in design is about the sort of intermediate knowledge that resides between implementations and theory. The governing method is *research through design* as outlined and practiced by Zimmerman, Fällman, Löwgren, Höök, Holmquist and others [Zimmerman et al. 2007]. Examples of such intermediate bodies of knowledge are patterns, guidelines, frameworks, methods and tools, approaches, etc. Recently Höök and Löwgren [Höök and Löwgren 2012] introduced the notion of so called strong concepts, a sort of ecological and epistemological take on concepts that emphasizes a format suitable for interaction design. Along with the definition they present instructions for both how to assemble and disseminate them academically, an interesting approach for positioning them within research. Höök and Löwgren describe strong concepts in the following way:

"Strong concepts are generative pieces of knowledge, in the sense that they help generate new solutions for a particular design situation. When an interaction designer or researcher has appropriated a particular strong concept, it comes into play during ideation by suggesting specific directions and guiding the design towards particular operative images that can be further elaborated and detailed." [Höök and Löwgren 2012, p.5]

Notably, Höök and Löwgren highlight an additional *generative* condition linked to their notion of strong concepts. That is to say that the research results, in particular within interaction design oriented HCI, should also generate and inspire new artifacts or concepts [Höök and Löwgren 2012]. In a way this broadens our perspective of what constitutes as verifiable – a concept that produces "offspring" survives thus verifies its reproductive

integrity, to put it in evolutionary terms. Creating a strong concept in interaction design could be seen as to unfold over two phases. Firstly, it is articulated through its relation and relevance relative to other concepts and secondly, it gets defined by its applications and uptake. These two phases correlate to its theoretical grounding (other concepts and theory) and real world grounding (results from conducting studies). In addition, the uptake hinges around its ability of being generative and relevant, thus producing instances or artifacts that actually embody and become proponents of the concept. Ways in which a concept would fail could for instance be that another competing concept challenge it, that it isn't strong enough for survival, too vernacular or that it arrives too early and therefore become old fashioned when its generative qualities kick in.

In my work I have adopted this notion of strong concepts by having an attitude where I allow myself to get familiar with the materials at hand while at the same time articulating and grounding my work in studies, hands-on practices and theory. The one project in this thesis that perhaps best correlates to this methodological approach is ActDresses (see Paper IV and Paper V). By combining theoretical grounding (visiting theories), real world grounding (conducting studies) and crafting instances (building demonstrators), these three together form a foundation for how one can develop novel concepts within HCI. However, to succeed as a concept in research it must still be properly published and disseminated in order to generate and ensure uptake [Latour 1988]. That said, strong concepts are in my view not separable from the prototypes, mock-ups and sketches that helped in shaping them. In fact, it may very well be these very artifacts and the real-world embodied interaction with them that make the concepts "strong" (i.e. sharable and understandable).

2.3.2 Grounding it in the Wild

The concept of *grounding* is based on *Grounded Theory* (GT) outlined in the mid 60's by Glaser and Strauss as a methodological approach in sociology for turning data into theory [Glaser and Strauss 1967]. Before, theory was (in most cases) regarded as hypothesises to be tested and verified through statistical means, whereas in grounded theory a hypothesis was the result of an in-depth analysis of collected data through studies conducted in the real world. The main argument suggested by the theory is that something observable "that what is" resides in the world that can be captured conceptually through a bottom-up approach. Thus, theoretical concepts or hypothesises cannot simply be made up *a priori*, but based on what is observed or in this case studied. GT has since its

first publication been rigorously developed into a detailed framework and methodology.

In HCI, GT has been viewed as an inductive approach that not only serves to generate well-grounded theories from ethnographic studies [Lazar et al. 2010] but also grounds design concepts [Ljungblad and Holmquist 2007]. This also relates to the concept of "in the wild" in the sense that grounding hinges around data about unfolding interactions in everyday contexts. The basis for approaching GT generally consists of four stages [Lazar et al. 2010, p.284]:

- Open Coding
- Concept Development
- Categorization of Concepts
- Theory Formation

Regarding studies of products, Lucy Suchman studied how people engaged with printers in the early 80's. Inspired by Geertz and others, she took on the task of questioning the cognitivist approach by pointing out how important contextual and social factors were in terms of affordances and resources for action [Suchman 1987]. The key point can be summarized in this quote from her book:

"The emergent properties of action means that it is not predetermined, but neither is it random. A basic research goal for studies of situated action, therefore, is to explicate the relationship between structures of action and social circumstances." [Suchman, 1987, pp.179]

This means that the situated and social contexts frame the interaction and should not be separated through lab-studies or strict measures of efficiency. Yvonne Rogers gives a more recent account for how HCI views this turn to the wild and gives further arguments to why it is important [Rogers 2012]. For one it marks the difference between usability and experience as the latter is intimately connected to the setting. Rogers exemplifies this by discussing the broader experience of buying a product, for instance browsing through a supermarket, looking for known brands, judging the attractiveness of the packaging, carrying home the product in a bag, enjoying the feeling of unboxing, the smell of something new, quality, ignoring the manual, and so forth. In the chapter regarding studies of interaction (Chapter 3) I will continue to reflect upon what constitutes as "the wild", and in particular how it relates to my own overall research process.

It is reasonable to assume that the "real thing" is something researchers in our field need to have a healthy relationship with. This is where grounding in reality becomes essential and why studies of people in the everyday, wild, real, marginal, and so forth, matters not only as evaluations, but as grounding those other practices of making. As researchers in HCI we may at this point start to question whether the physical-digital artifacts we craft are to be evaluated as designs (instances of concepts), or as artifacts that are put through a number of more grounded trials with the overall goal to produce strong(er) concepts with a capability to generate multiple instances.

2.3.3 Prototypes as Grounding through Tinkering

In a design oriented HCI it is implied that prototypes or artifacts composed of various materials are crafted as part of a research practice [Löwgren and Stolterman 2007; Zimmerman et al. 2007]. Materials are used in a quite generic sense here, and can mean everything ranging from specific functionality e.g. wireless connectivity to certain properties e.g. elasticity as well as to descriptive representation e.g. wooden. In short, different materials can be seen as having distinctive affordances and properties that can be recombined into artifacts. One way of looking at research prototypes is that they emerge when stretching a research question into materials that have certain functionality (but not necessarily form). There are a number of motivations that come to mind for adopting this this perspective e.g.:

- Building and crafting as a way of exploring a research question
- Constructing (physical) probes or provocations ("probocation", "provotypes") for eliciting and capturing data
- As to conduct deliberate design interventions
- Aiming for product design towards consumers
- As art or "objects to think with"
- As a manifestation of a concept, knowledge carrier
- As a modification of an existing artifact for incremental improvement

One example of a metaphor for when something is not grounded and thus out of touch with reality is the Cargo Cult discussion, coined by Richard Feynman in his 1974 speech to Caltech students regarding scientific practice. In this talk Feynman expressed a worry for a kind of scientific activity that shallowly engages in honest experimentation [Feynman 1974]. In HCI and interaction design, the term has been used to express an unavoidable division between representation and what is real

[Holmquist 2005]. Holmquist realized this issue and argued about what is grounded, represented and assumed in the practices found in interaction design. For instance, *mock-ups* are artifacts that have the appearance but not the functionality of the *real thing*. Similarly a *prototype* would have the functionality but not the appearance of the *real thing*. In other words, artifacts produced in interaction design research should be treated as vehicles of various degrees of knowledge, representation and grounding rather than finished products.

A related term is demonstrator, which means that the focus is shifted towards how the object is made ready for interaction and ready to be experienced. In "Technology as Experience", McCarthy and Wright suggest that ethnographic practices are particularly suited for capturing accounts of experiences enabled by technology [McCarthy and Wright 2004]. However, the first hands-on experience of an interactive object can in my view happen precisely when technology is being crafted or even as part of a process when a technical yet unfamiliar artifact is being taken apart. Going from this very first glimpse of an experience to the experience handed through a demonstrator is quite a leap, and it may be worth the effort of using such ethnographic practices earlier on in the design process.

Looking at a couple of classic examples, Douglas Engelbart and William English demonstrated their famous first prototype of a computer mouse back in 1963. While Engelbart has been credited to be the designer behind the mouse concept, it seems that it was in fact English who actually crafted and put together the prototype [English et al. 1967]. Similarly, while Steve Jobs had the role of a visionary and entrepreneur, it was his companion Steve Wozniak who pretty much single handily crafted together the prototype of the Apple I personal computer in 1976 (greatly inspired by e.g. Alan Kay and Adele Goldberg's work at Xerox PARC) [Wozniak 2007; Isaacson 2011]. Today Apple has become something of a branded definition of what excellent design would be and how it is supposed to be experienced. This highlights an issue with design in that it sometimes might conceal other types of more hands-on craftsmanship.

One way of looking at prototypes is from the other direction – that material exploration through a tinkering process spawn a prototype that at the same time becomes a new and novel concept. To give an example – Topobo, developed by Raffle and Parkes at MIT Media Lab, is a conceptually related system where lego-like pieces are put together, some of which are joints capable of repeatedly playing back on the fly recorded

motions [Raffle et al. 2004]. The resulting artifacts can be ‘programmed’ to move about, using movement as input. Furthermore, from a conceptual point of view, these examples show how tightly connected the descriptive and concrete parts are. In a way, these concepts and their corresponding demonstrators complement and become inseparable from each other.

3

Studying Existing Interactions

This chapter discusses how tinkering activities can be grounded and guided by real use through studies of existing practices and products, and in what way those study methods may offer grounding in a governing design process. The methodological exploration presented in this chapter is based on three studies of a commercial robotic toy dinosaur named Pleo. Compared to most other toys, Pleo is technically very sophisticated, and after its release in late 2007 it gained interest by several research groups in the area of HCI [Segura et al. 2012; Ryokai et al. 2009; Paepcke and Takayama 2010]. Reasons for using an existing commercial artifact for these studies, rather than a research prototype or design of our own, were to shed light on methodological issues regarding what it means to ground research in the wild rather than bringing a narrow focus to the design process.

Studying an artifact while under construction can lack fundamental aspects of real world use e.g. the absence of developed practice, as discussed by Crabtree [Crabtree et al. 2006]. Furthermore, it has been pointed out that even trials of new technology as such suffer from a "absence of practice" in that novel technology is supposed to support a practice that has not yet emerged [Brown et al. 2011; Crabtree 2004]. Studies on an existing product eliminate some of these methodological challenges in regards to the often inherent fragility of research prototypes, and the potential bias associated with the parts of the interaction that are broken or simply not there yet. Studying mass produced commercial artifacts not only helps in approaching the idea of realistic use, it also helps setting up parallel studies with more or less identical exemplars of the same artifact, using the methodological setup as the differentiating parameter. Finally, studying existing products on the mass market provides opportunities for identifying design challenges that may not arise from studies of research prototypes only. In this

chapter, I approach this matter by providing examples of studies I have made, relating them to other relevant work while explaining in what way they complement one another and how they fitted into my tinkering oriented research process. The meta-level work around *contrasting* in this chapter is in part an ongoing project that has been developed together with my colleagues Ylva Fernaeus and Sara Ljungblad.

3.1 Reflection on Methods

In general, setting up and conducting studies of user interactions is about collecting and analyzing data. The overall goal of conducting such studies before designing or prototyping is related to the concept of *grounding* in sociology, where existing practices, what people actually do and express, will form hypothesizes and theories from the ground up, emerging from the data [Glaser and Strauss 1967]. The core of this idea gives qualitative work a sense of scientific legitimacy that previously sometimes were considered as reserved for more quantitative approaches [Silverman 2000]. This becomes essential to this thesis in the sense that a qualitative approach can guide the crafting-oriented design process regarding research prototypes. By conducting studies with people and looking at interactions that are grounded in what people actually do, it is possible to acquire information that can guide the development and formation of physical artifacts, for instance:

- General and particular accounts of practices and experiences
- Experiential qualities – sensual, relational, emotional, social
- Common and odd issues and pitfalls
- Influence of context

Such knowledge follows from looking at examples from the HCI field, literature and not the least hands on practice. Looking back a decade, several researchers have suggested that an important part in the interaction with technology is the felt and lived experience e.g. [McCarthy and Wright 2004]. At the same time more recent research has emphasized the inherent difficulty of making such accounts. Grounded in the unfolding practice by using technological artifacts McCarthy & Wright do suggest a pragmatist approach to the problem. This approach is summarized in four *experiential* threads that intend to articulate an experience and its involved qualities. At this point it is worth to point out that the concept of the everyday is used to characterize a preferred context, but that the accompanying example cases from around 2004 are built around work situations and the desktop computer. Today the concept of the everyday has a rather different meaning that incorporates

for instance our *mobile life*, where the line between work and leisure generally has become blurred.

3.1.1 Transfer Scenarios

One method that has inspired this work is *Transfer Scenarios*, which highlights a connection between making studies on more marginal existing interactions beforehand and then start a design process, rather than using user studies to study and evaluate one's own designs. The method of *Transfer Scenarios* was conceptualized by my colleagues Sara Ljungblad and Lars Erik Holmquist in an effort to ground technological explorations in existing but marginalized practices [Ljungblad and Holmquist 2007]. In this thesis I have practiced this method in conjunction with the GlowBots project described in Paper I, but it also made me reflect on the grounding of user-centred studies as a way of informing the tinkering process by looking at existing practices and products. Although I was not involved in the formal development of Transfer Scenarios, I did participate in part through study analysis sessions and subsequent implementation efforts and from a close distance watched it coming together (see Chapter 3). Transfer Scenarios outlines a structured approach that begins with identifying target qualities within an existing observed community of practice and moves towards implementations of prototypes by making detailed descriptions of use through scenarios and personas grounded in those qualities [Ljungblad and Holmquist 2007]. A related approach is called *associative design,* which starts with ethnographic studies of one particular practice and then tries to see what technologies and common attributes that may be applicable to another completely different domain of practice [Esbjörnsson et al. 2004].

One of the first activities to get started with transfer scenarios was to map out values and qualities that were considered important. Such target qualities could for instance be e.g. agency, autonomy, emergence, etc. The next step, and in many ways the most difficult one, was to identify and find an existing "marginal practice" where these values exist and in some sense even are articulated. The two cases our lab used to exemplify such communities were *lomographers* and people having "non-standard" pets such as snakes, spiders, etc.

Once the existing marginal practice was identified we began planning the qualitative study. In our projects we used semi-structured interviews, either single interviewees or group-sessions as a basis for collecting data. One benefit of doing these more in depth interviews was that the

questions discussed may be directed towards getting empirical data about respondents' experiences, and in particular experiences entangled with the sought values.

In our case we used a commonly known approach of structuring data by means of *Affinity Diagrams*. Such diagrams are topological emerging "islands" that are formed by clustering streams of data, in this case excerpts or sentences of text that have been cut out from the transcribed interviews. The result of this process was clusters of excerpts that illustrated the contrasting values. The next step was to turn each cluster into a persona and more detailed scenario by using "glue" data that tie the excerpts together. The result was scenarios that blended fiction and reality using familiar terms to express something unfamiliar.

Through a final step the actual transfer was done by replacing certain words, like in our case "Pet" with "Agent". This action effectively injected the desired design domain into the scenarios. The result helped in shaping governing scenarios that can guide the design and development of new artifacts through tinkering-oriented activities. More details on such activities are presented in the next chapter, which in part focuses on one of my own tinkering sessions that started precisely when these scenarios had been created (Chapter 4).

3.2 Studies of Existing Human Robot Interaction

In this section I will outline three studies on Pleo – a robotic toy product. The first study is detailed in Paper II while the other two complementary studies on Pleo have been published as [Fernaeus et al. 2010] and [Jacobsson and Nylander 2012]. To exemplify how we have tried to get a realistic understanding of how people actually interact with a robotic artifact we started out by looking at how people told stories about their experience through online media such as blogs. The second study was a longitudinal study conducted in order to find out if and how more long-term interactions would form and how issues would manifest themselves in this longer perspective (between 3 to 6 months). The final study was based on an approach where the general idea is to look at short term, but more continuous interaction (over a few days). By looking at these three approaches we will end this chapter with a meta-level analysis of these studies and what it means to conduct user studies of existing products in the context of this thesis.

3.2.1 Narratives within an Online Blogging Community

The first study that I will discuss here (Paper II in this thesis) was based on user-generated blog posts available on the online blogging community at *www.pleoworld.com*, during spring 2008. This study was inspired by the recent practices within the HCI community of using cultural commentaries [Gaver 2007] and blogs written by enthusiasts [Nardi et al. 2004] as methods for getting insightful and articulated reflections regarding a specific form of technology. These practices are related to the research method of virtual ethnography [Hine 2000], where social practices within online communities are studied by analysing their published material, discussions and comments. The main methodological arguments for conducting these types of studies is that they make use of active and unbiased reflections of real users, avoiding many of the problems associated with e.g. interviews. Our motivations for this approach was that it specifically acknowledges virtual ethnography as a way to reflect upon users, practices and deployed designs while at the same time regarding information technology as a communication medium in its own right. Additionally we used the data and analysis as a source of inspiration for our more conceptual design work.

The study was carried out on the blog corpus of all the Pleo owners that had registered with the US site and on forum posts as well as videos that were directly linked from within the blogs. At the time of the study the product had not yet been introduced outside the US, thus other communities had yet to take off. With that said and because of the cross-linking we also ended up including a handful of early adopters from the UK and Canada. The data was collected during April 2008 when Pleo had been on the market since mid-December 2007. At this point there were approximately 20 000 Pleo's out on the market and we used all 520 blogs available at the time.

All data was collected and handled manually, names were anonymized (when necessary), printed out and structured based on richness and topical similarities. A majority of the blogs contained only one or two posts, which were categorized as greeting and welcoming messages. In our analysis of the remaining corpus we picked up on four descriptive themes that would span over the different experiential stages that the relationship transcends: *arrival and appropriation*, *when technology breaks down*, *Pleo as a resource for social engagement* and *playing with Pleo*.

The kind of data that this study captured showed a surprisingly large variation in interaction, situations and use contexts. We also received

materials in a variety of media forms, including not only text but also video and pictures. However, our main data in this study took the form of snippets of text published on the blogs. Examples of settings accounted for included descriptions of how Pleo was being used as an ice-breaker at a hotel reception desk, as a toy played with by children, or step-by-step instructions for how to perform advanced DIY "surgery" on the device:

"Yesterday Pleo had a broken neck. I contacted customer support, and they told me that I could send him back, and get a new one. But, I didn't like the idea of exchanging something I have gotten so attached too. So my mom made a small cut in the top of his neck. This had voided the warranty. She found out that the problem was the cable that lifted his head etc, had broken. Surprisingly she fixed this. She put the cable under a screw. We weren't sure this would work, but it did! Now Pleo is able to lift his head up and down, and do everything he was able to do before! The only problem is he has a small cut on the top of his neck. But I'm okay with this, because its not really a big deal. It can be fixed, I just don't know what to fix it with! We love Pleo, and this doesn't bother us. We're just glad to have our little guy working again!" [Blogger X]

This excerpt shows just how curious, adventurous and experimental people can be, even with this rather complex product and by voiding the warranty. As another selected representative, the following example illustrates what kind of format most users in this community used in their descriptions of interacting with pleo:

"Today my friend and I were in the car playing with Pleo. But He was soooo tired. He sat down and started cooing. Then Pleo got scared and started crying because of the movement of the car." [Blogger Y]

In this example the user presents a narrative where they have chosen to share their report of a specific situation stating that Pleo was tired and disliked the experience of being in a car. Additionally we get a hint of a technical design gimmick through a behavioural observation stating that Pleo reacts quite vocally when being shaken.

In this early stage of Pleo as a commercial product, a significant amount of the blogging practice appeared to bring up issues related to the product and to negotiate policies with the community. For instance, a few users reflected on the wear and tear of the rubber skin. In one case it was suggested that such markings only add to its personality similar to an old worn teddy bear while others discussed preventive solutions using e.g. baby-powder to cover up the problem. One blog even expressed

existential concerns about returning their broken Pleo since they felt insecure about whether they would get *their* Pleo back or a *replacement*.

In a final representative example, and one that inspired the upcoming design exploration most, users express their use of various types of accessories:

"Today I'm beading a crystal necklace for Pleo, and adding a fossil charm! His crocheted wardrobe will consist of a 'floppy hat', walking boots, cape and of course, sunglasses, for our walks and sidewalk surf days! He will be styling!" [Blogger Z]

This study was important to us because it provides an *unedited* view of what people think, say, and how they reflect on their device. Unedited in this respect, mean that it is without the intervention of researchers, and that all words, terms and viewpoints are the participants' own from the perspective of consumers of a product – also including all the narratives about its marketing material, instructions for use, and their personal social motivations and contexts of use.

However, as a result of this study we observed how people both staged situations and played along with them according to a product narrative that allowed people to handle aspects of the interaction that broke down. Similar to what is commonly noted in game studies, this could be read as accounts of *performed belief*, rather than reports on what the devices are actually doing "for real". This distinction is important since the information that people reveal on blogs have the characteristics of small subjective stories that are crafted to be shared and reacted upon. Furthermore, a potential bias of the medium of blog posts would account for the extent to which we observed personalization and accessorizing of their robotic toys, potentially as a way to design pictures that looked interesting for others in the community (Figure 8). This is worth stressing since we did not notice such practices to any extent near this in the other studies that we conducted. This study played an important role in the shaping the concept of ActDresses, presented in Paper IV and V and also detailed in the next chapter as an example related to tinkering.

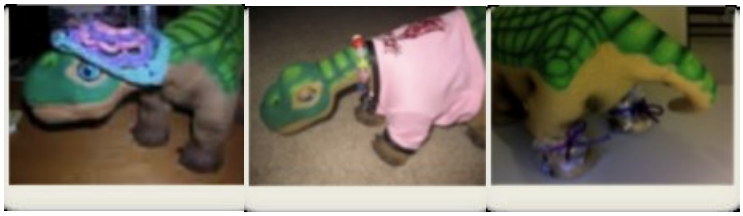


Figure 8: Pictures from blogs showing different types of clothes and accessories put on Pleo and pictured in blog posts.

3.2.2 Families Adopting a Toy Robot

In our second study, we placed a Pleo robot in the homes of different families for several months, and thereafter interviewed them regarding their practices and reflections on their experiences. The motivation for this study setup was to explore how Pleo was used and played with casually, as well as how it became adopted in families in their homes over a prolonged period of time, ranging from 2 to 10 months. This study is presented in more detail in [Fernaeus et al. 2010].

The study started out with a recruitment process by putting post-cards in different places, e.g. the reception desk at our research institute and at a culture centre in the city in order to get in contact with interested families. Six families were then selected based on their interest, number of children and their ages, pets and reasonable travel distance from our research centre. Together with a Pleo robot (fully charged but wrapped in its original box), each family was equipped with a video camera and a web-based self-reporting tool to share personal accounts with us. They were invited to film anything of interest to them, and in particular play sessions with Pleo. The families were told not to open the boxes until the researchers had left, and thereafter they would be allowed to interact with Pleo as they pleased.

Each family was interviewed at least once and most of them twice about their time with Pleo in their homes (Figure 9). In one case we asked the parents to interview their own children as a supplement, as we found it problematic to interview such young children. The semi-structured interviews were video recorded and lasted between 20-45 minutes. The first set of interviews occurred after the families have had Pleo for two-three months, and the second time after roughly six months. Since the families participated for different lengths of time, we had to be flexible about when to interview them the second time. This also had to do with fitting home interviews into busy family lives.

A main finding from this study again concerned a tension between approaching the robot as a toy while also expecting it to act more like a real pet animal. This affected how participants played with the robot; how they reflected on its use over a prolonged period of time; and the sometimes surprisingly hard work of maintaining the robot. For example, when the interviewer asks a boy in one of the families to try to elaborate a little more on how he had played with Pleo, he answers:

"*I have mostly petted it… I really don't know how to play with it. [giggles] It really doesn't work to throw a ball.* ***That*** *doesn't work…*

[…]I usually take it slow because it doesn't do much, maybe if I put something in its mouth…"

The boy's comment captures how most of our participants spoke about interacting with Pleo after the first excitement had worn off. They generally described it as too limited for what they had expected or wished to do, which seemed to be for more physical, active and varied play. The interviews further raised a number of issues regarding how Pleo might fit in children's play patterns. As the parents in Family 1, 3 and 4 suggested, there is a *life cycle of toys*, which is likely to apply to Pleo as well. This not only means that children change interests as they grow older, but also that they frequently attend to different toys or themes of toys, and that they shift between which ones are their favourite toys. We saw this as a highly relevant observation from the perspective of designing advanced, and expensive, toys. The parents' role in this setting could be looked upon as "backstage technicians" for their children's play. When reflecting further upon this, one parent commented:

"you want some value for your money, right, otherwise it just sits there and collects dust".

From these and similar statements from other parents, it seemed that the parents felt a responsibility to engage in the maintenance of Pleo, perhaps because they knew it was a relatively expensive product (even though they did not have to pay for it in this case).



Figure 9: Picture taken at one of the interview sessions with one of the families keeping Pleo in their home.

The fact that Pleo allowed only one hour of play but required four hours to recharge frustrated adults and children alike, making recharging of batteries a time consuming activity. Compared to e.g. Paro where the charging of batteries is a carefully designed part of playing, by 'feeding' the toy through a cabled pacifier inserted in its mouth, this robot had a removable battery that had to be recharged at a separate station. It was also a nuisance that there was no way of telling when the robot was going to run out of battery. When reflecting upon this, several parents compared Pleo with regular home appliances and how even a simple electronic toothbrush can recharge itself without the need of removing the battery. During interviews we got many suggestions about how this aspect could be improved and more carefully integrated into playing with Pleo. For instance, recharging could be done simply by putting it in a special bed, similarly to how Roomba has a docking station for recharging. We found that while the Pleo initially was found to be very attractive, it did not manage to keep this attraction over a longer period, and failed to meet the expectations of the participants. We concluded this study by proposing challenges for designers of similar kinds of artifacts in order to maintain interest and engagement over time.

A related topic was that users, mainly from one of the families, reported that inserting new behaviors through using the SD-card became central in their interaction. In a way this relates to the central role of tinkering from the end user perspective that other robotic toys and play kits such as the LEGO Mindstorms, Topobo [Raffle et al. 2004], and the Sony AIBO have. For instance, the AIBO was developed as a very high-end toy targeting children, but its main actual uses was for engineering students as a standard platform for the annual RoboCup championships (http://www.robocup.org/). In this project we found that there might be some inherent expectations on robotic toys regarding tinkering, i.e. that one should be able not only to play with them as they are, but also to access and modify their behaviors on many different levels. This is an aspect of robotic toys that has not been sufficiently highlighted in previous user studies of electronic toy animals and so called "companionship technology", and that could have implications for other technologies as well.

This study was valuable to us because it showed how interaction unfolds during an extended period of time, and gave a complementary picture of real obstacles in comparison to the previous study on blog posts. Although this may imply that parts of what could be learned from the previous study were visible here as well, it also showed how the relationship and interaction with the device changed over time, and

interestingly in this case towards a less intense one. Since the study was performed in homes with more than one person, it also captured aspects of the social interaction around the device, such as development of different roles for playing and maintenance. Perhaps most importantly, this study highlights in parts a need expressed from end users to be able to get more profoundly involved with the robotic artifact on many different levels. This observation strengthened my hunch that concepts such as accessorizing interactive artifacts may play an important role in shaping tomorrows technology if and only if they at the same time elevate these types of involvement.

3.2.3 Persistent Interaction

In our third and final study of interactions with Pleo, participants were given the challenging and somewhat artificial task of bringing the robot with them at all times and continuously switched on during a few days. This aimed to furthering our understandings of social negotiations that would occur when a "live" robotic toy artifact would be deployed in in-between contextual situations. This study has been discussed in [Jacobsson and Nylander 2012].

Our general motivation for this study was to trigger situations that did not seem to normally occur when keeping the robot at home and playing with it now and then, or casually blogging about it. By triggering such situations, we hoped that participants would reflect on the robotic artifact in regards to a more varied set of everyday situations. Since we previously had looked at long-term casual interaction, we were in this case interested in how interaction would play out in a multitude of real situations, including what we denote as *in-between-contexts* and contexts that might be inaccessible to an external observer. In this case we created a setup where participants were given two basic rules to follow regarding the robotic artifact:

1. Keep it with you at all time, no less than three feet away.
2. Whenever people are around, make sure to keep it switched on as much as possible.

We anticipated that this setup would require much work from the persons participating in this study, and we therefore actively searched for participants who would accept to take part in this, being outgoing, social and willing to engage in the study with full commitment. We ended up recruiting five participants, three females, one in her early thirties (F1),

one in her early twenties (F2), one in her late twenties (F3), one ten year old boy (M1) and a male in his forties (M2).

The participants were briefed beforehand about the study, then instructed and equipped with a Pleo. Together we discussed and agreed on an initial period of three days for the study. After that we were going to have a quick debriefing and decide whether to end or continue the study. F1 proceeded with the study for three days while F2 continued for a total of ten days. F3 spent three days, M1 spent four days and M2 spent a bit over two days. The participants were handed two batteries in total rather than the factory default of one, this to allow keeping Pleo switched on for longer periods. The interviews with F1, F3 and M2 took place at an office and the ones with F2 and M1 at cafés. Each interview was audio-recorded and later also transcribed.

As a result of the study setup, all participants told similar stories about bringing along Pleo on commuter trains, busses or on the subway. Most were also concerned with the practical issues involved in carrying the robot around (see Figure 10), and finding ways of charging the battery during the day. Another repeated observation was the knowledge about the functioning of Pleo that the participants developed during the short time of this trial. The setup seemed to help participants in quickly developing a deeper proficiency of using the device than by only bringing it to their homes and then using it on rare occasions, as seemed to be the standard case in the other two study setups. Also, without explicitly addressing it, several issues brought up in the previous studies also came up as discussion points in this study, like for example issues around battery use. Moreover, the participants were able to speak of interesting but unusual use scenarios, and functionality of the device that were not observed in any of the other studies, but that still could be considered relevant for realistic use situations. None of the other participants for instance reached the point of experiencing what happened if the device was left untouched for a longer period of time, which was here observed to trigger a certain set of behaviours in the robot. Thus, it seems that the always-on setup worked as a lightweight approach for gaining more explicit experiential accounts of a technology together with otherwise very open-ended instructions for use.



Figure 10: Participant F1 showed how she had prepared a special bag for carrying around her Pleo.

Most reflections were concerned with how the robot affected interaction with other people in the public space. People around did generally seem interested in what was going on, but would usually appear to just observe from a distance. On the other hand being in the immediate context like sitting next to or in front of strangers in the public, there were two reported stances that would occur – either the person engaged, asking polite questions or interacted briefly with our participants, or they tried to ignore the situation. In the following comment F2 reports on one such episode:

"She [An old Lady on the subway] looked at me - sort of with an evil outlook... As with a "Shut that thing [The Pleo] off!" And I - Ok, Ok, Ok... I'm not particularly - like I'm not easily embarrassed or usually care much, but OK, shit then, I will turn it off then so she [The old Lady] doesn't turn crazy or something..."

In particular our participants reported that Pleo became an *object for display* and also the centre of attention in most reported situations. Far from all situations were considered negative (situations that required this social re-negotiation of policies), and in other similar situations Pleo would in fact become an "ice-breaker" for starting more casual conversations with strangers. In most situations a stranger would out of curiosity pop the question of *"what is that?"* or just comment *"How cute!"*. In a particular situation reported by M2 the context is a cinema where people are hanging around waiting just before entering the salon. A stranger carefully observes for several minutes how M2 handles the

robotic dinosaur, and then suddenly approaches and very kindly asks *"What IS this thing??"*. On a related theme F3 reported that when she met up with her friends at an airport they showed signs of being in a bit of an awkward situation where they at first did not dare to ask about it. On the other hand F3 commented that she got much more reactions from people than she had first anticipated. While F1 and F3 were more casual in their interaction, F2 took the opportunity to be more explorative in her approach. For instance, while F1 would take it with her to go out for coffee or eat with friends, F2 would pretend (or actually try) to feed it with real food; or style it by putting make-up or baby-clothes on:

"I tried to put make-up on it once, but it did not stick so well..."

Participant F2 furthermore reported that she had purposely avoided some ordinary situations like the school class and pursued other for her more adventurous activities like visiting a church. Thus, the rules in 'always on' encouraged the participants to explore situations out of curiosity as well as to reflect on everyday contexts.

The younger subject M1, basically reported on similar experiences to the others, but with another set of contexts such as football-games, play sessions with friends, his little brother and grandparents. What we did not anticipate in this case was the effective social barrier that the family around a 10-year old offers. Even if the settings are similar, they are obviously experienced very differently through the eyes of a very young person, for whom bringing a toy with them is not anything unexpected. In general, there were very few problematic issues occurring (except battery related ones) when doing this type of study with M1. In this case the robotic dinosaur worked excellently as a toy prop and while generating interest, the only types of reported cases of social awkwardness would be similar to when someone is a bit too attached to a toy in general and simply cannot let go of it (which actually was one of the imposed rules). In terms of companionship technology this type of behaviour is on the other hand quite common, in particular when we look at how mobile phones are used today.

Thus, the study quickly confirmed that the robotic dinosaur would alter the personal space by becoming an object for display that attracts attention. F1, F3 and M2 expressed it as being awkward in certain social situations, but not necessarily a bad experience. This is related to Steve Benford's work on uncomfortable interactions, where something may be awkward in the very moment but after some time transforms into the better narrative [Benford et al. 2012]. On the other hand all participants

expressed their interactions in a way that would appear be closer to having a real pet compared to the participants in the second study. For instance they talked about their experience in terms describing how they experienced things together rather than talking about it as an external object in their environment.

Although being a study with only five participants, with the shortest study period and with the most artificial setup, we were surprised to see that this study gave us rich and interesting insights into aspects of what could become relevant use qualities of interaction with robotic companions in the wild. In particular the use of explicit rules for participation and interaction generated a social narrative – similar to the cultural narrative in the first study. Furthermore the participants appeared to get a realistic apprehension of Pleo's capabilities, both technical and social.

3.3 Contrasting Methods

Here I will present a meta-level reflection of the three presented studies about interaction with Pleo, each performed in settings that in different ways could be considered "in the wild". The three studies were all performed on the same commercial product, and thereby *outside* the design process of that particular product. Instead the studies were intended as formative to new designs of next generations of this type of artifact, and more broadly also contributing to the design and setup of studies.

The three studies were based on *content analysis of user-generated blog posts* (Study 1), *interviews about long-term domestic use* (Study 2) and the method that we here refer to as *always on* (Study 3). As illustrated in Table 1, the presented methods each resulted in different and complementing insights of what it means to look after and play with a robotic toy such as Pleo. This allowed us to see which findings that were overlapping in all three studies, and which that only occur in one of them, and especially the potential aspects of bias and authentic use derived from the three setups respectively. Thus, our ambition was not primarily to confirm specific findings about Pleo, but also to learn how different methods work towards understanding interaction with new kinds of devices. There are of course many other methods that also attempt to capture interactions in the wild, e.g. cultural probes, controlled studies in more formal settings (e.g. educational), and auto-ethnographic methods, which would each also bring their own picture of what the natural use

	Study 1	Study 2	Study 3
Method	Content analysis of user-generated blog posts	Interviews of families having the device in their homes	Interviews with participants volunteering to have the device on and active during several days
Participants	520 anonymous bloggers	6 families (29 people)	4 volunteering adults and one 10 year old child
Study period	Blog corpus generated during a 4 months period	3-9 months	Between 2 and 10 days
Strength	Unedited and without researcher intervention Unscripted use	Access to realistic play settings from a longitudinal perspective	Produces data in short time Triggers interactions in public Quickly developing competence of using Pleo
Potential bias	Blogging as performed belief Practice shaped by what fits blogging format Blogging not typical for Pleo owners	Not real owners Performing to researchers "By invitation situation"	Enforced, conditioned interaction Performance of being in a "research study"
Main takeaways	Dressing, naming and storytelling Real questions of buying, owning, repairing, adoration, common practices, etc.	Fit in ecosystem of toys Maintenance Tinkering Comparison Pet vs. Toy Real play challenges, battery life etc.	Technology as identity marker Realistic real world contexts, persistent use Broader functionality was explored

Table 1. Overview of the three studies.

setting would imply, what interactions it would involve, and how the technology is appreciated and understood.

Here I will reason about what these studies provide in terms of what *design input* they generated, what is meant by realistic interactions with novel robotic artifacts, and finally how the three methods worked to investigate aspects that are central to the concept of *interactive companions*. On a methodological meta-level, I regard properties of "the wild" as framed within each of the different study setups, and argue that

these are versatile tools for acquiring data that can steer us towards more firmly grounded design and tinkering processes. As has been discussed also elsewhere (e.g. [Rogers 2012]) the concept of "the wild" suggests a nearly ideal use setting, one that is untouched and inherently natural. However studying the wild with a technology that is new and potentially *strange* can never be a study of people in their everyday context without requiring them to perform, or have a conditioned relationship with the study setup as such.

Similar to a lab study; attempting to eliminate bias completely, inevitably leads to new biases when studying new interactive technology. The three studies presented here might even come across interactions that are *biased* as a result of "being in the wild". Still, the findings will be fundamentally different from those found in a lab environment, and this is exactly the reason to start the messy work of approaching the wild in the first place. For instance, in the second and third studies the participants knew that Pleo was not designed by us, thereby the risk of participants being overly positive to the design was reduced and they came to openly discuss qualities and suggestions for improvements, as well as sometimes giving quite negative comments on aspects of the design that did not work well for them. Had we done the same study on a product of our own design, we might have received less elaborate suggestions on these matters.

For us as researchers in this field, "the wild" usually implies an idea that *real* usage and experience are reserved for those environments where the narrative suggested by a certain design unfolds spontaneously. But what is real could also be understood as a multitude of environments and settings together with particular aspects that we are interested in from a research standpoint. The question we needed to ask ourselves was if we really believe that a single shot approach – one study or rather one methodology could be enough.

Several authors [Brown et al. 2011; Hornecker 2012] have recently discussed the challenges of demand characteristics in user study setups, i.e. the implicit roles of participants as active performers towards the research team, to which they have been invited, and thereby sense a pressure to generate useful and interesting data. The nature of my first study naturally excluded this issue, while it was impossible to neglect that in the second study the participating families took it as their job to orient their practice towards helping us in evaluating potential qualities and shortcomings of Pleo, sensing a responsibility for making sure their children would play with it while also taking care of this expensive

device so that it would not break etc. Some of the parents in our second study clearly showed some characteristics of "lead participants" [Brown et.al 2011], helping their children re-charge the device and in other ways making sure the robot was played with enough to satisfy our research investigation with "good data". Although, we do not know any details of how the exact social situations took form in the actual play settings, some of the interviews made it clear that the parents sometimes were heavily engaged in helping their children, and that this required efforts beyond what they would otherwise invest in their children's playing with toys. The third study was in this sense perhaps more honest in that "unscripted and spontaneously unfolding use" was never even implicitly called for, making the participants active engagement as co-investigators an issue that they openly reflected about in the interviews.

Furthermore by viewing the studies from a performance perspective, real usage is rather what a variety of contexts pulls out in terms of interaction. By presenting three studies using different methods, we thus illustrate how the design space of study setups is fundamentally intertwined with what would be defined as realistic use. Ultimately what is at stake here is how our research field frames and relates to terms such as long-term, open-ended, realistic and useful in terms of generating knowledge about interaction in socially expanded use settings.

Through this procedure of contrasting methods we were able to assess and validate what parts of each study that could be regarded as strong, potentially biased and articulated as natural interactions that we could take inspiration from when developing new design concepts. In the end, what we strive for in interaction design research are ways of making our concepts more firmly grounded, where one part is having informed tinkering activities in the design processes.

4

Tinkering in Interaction Design

In this chapter I will outline what tinkering means generally as well as in the more specific context of interaction design practice and how it relates to other concepts and activities within the design oriented HCI discipline through a survey of concepts such as prototyping, crafting, MAKE/DIY, bricolage, and hacking. This is to position tinkering as a more distinctive term that captures what I see as the essential attitude and practice of these concepts and at the other end lets us grasp how it may fit within the interaction design research paradigm. The distinction between attitude and activity is deliberate, and aims to put emphasis on intent rather than on ontological framing.

From the perspective of this thesis, tinkering is regarded as an attitude and not a very detailed process as that would go against both its vernacular use and its main objective of being open and inclusive. Everyone may engage in tinkering, not only some particular group of trained professionals e.g. educated engineers or designers. It would in some sense be similar to having a design-oriented attitude [Fällman 2003], but arguably easier in the sense that interdisciplinary people would feel more comfortable using this term as opposed to conforming to more specific roles e.g. designers, engineers or humanists. With that said, it is however relatively easy to find "grand masters of tinkering". My personal experience is that we all are likely to have a sense of the persons who enjoy tinkering in our social networks and what they can offer. Furthermore, since they are practitioners in environments filled with tools, gadgets and materials they are easy to spot, sometimes towards the extreme end leaning towards hoarding. Such an environment is orchestrated in that tools and materials are set up to be ready to engage with [Schön 1984; Crawford 2011].

Why then can tinkering be regarded as an attitude? When someone says "I will tinker with this for a while …" it implies an explorative endeavor about to happen rather than labeling a process of something that has already been made. It puts an emphasis on having tools available as part of the environment where the tinkering is taking place. Just as any car or motorcycle workshop is set up to handle just about any type of repair, fix or adjustment – the modern interaction design research lab needs to be set up in such a way that the researcher can craft research prototypes. Although tools and setting are not enough; training, practice, and even more practice are indeed required to become proficient [Crawford 2011]. This embodied knowledge cannot be acquired through merely reading text, although it is often a complement or scaffolding for the training activity. Just as learning clinical surgery requires years of careful watching and practice, and learning what a car *is* by tearing apart, replacing and putting it together again, interaction designers similarly explore their materials as part of their practice. Framed in this way - tinkering is *thinking by doing*.

4.1 Examples of Tinkering

I will now present three accounts in terms of my personal involvement through hands on experience of tinkering in interaction design research. To me this is where the presence of a tinkering attitude is the strongest, in the actual situation of crafting and having a dialogue with the materials. As it is my own reflections about my own work – in a sense autobiographical – I will expose my inner voice and dialogue in an attempt to reflect the certain 'crudeness' of the tinkering attitude.

4.1.1 Interactive Communication

The Glowbots project (Paper I) came about as a natural continuation of actually implementing one of the systems that had come out from the transfer scenarios approach. The scenario on which this project is based is grounded in a persona named 'Nadim' who would engage with robotic artifacts to 'breed' patterns. We found a suitable candidate platform to support this scenario through one of our partners in the European Project, the EPFL-group in Lausanne. They had just released a robotic platform called the e-Puck, a round coffee cup sized robot specifically developed for doing swarm robotics and communication experiments. As implied by our role in this European project it was very much expected of our group (through tasks set up in so called deliverables) to build demonstrators that showed emergent behaviour through communication. Additionally, in these integrated European projects it is very important to find common

points to collaborate around, and the e-Puck thus naturally became one of these. Here I will focus on a couple of my own explorations that revolve around communication, visibility and user-interaction.

When the e-Pucks a couple of months later finally arrived, we were good to go. At the time being a truly remarkable piece of technology – I started with getting acquainted with the platform, what hardware it had and how to use the software API to program it. Within the EC-Agents project we often discussed both theoretical and practical foundations for communication, e.g. the language game [Steels 1999], insects trails of pheromones [Floreano et al. 2007], brain-like models capable of learning language [Szathmáry et al. 2007], communication in social networks [Baronchelli et al. 2005], etc. Many of the discussions were at a fairly abstract level and often the major outcomes were to be models – mathematical descriptions about communication rather than specific technical challenges. Being in this group of researchers, we started out with considering ways for implementing some sort of very simple language game. In short the language game should be about connecting utterances (initially usually random) to things within their shared context by means of looking and pointing. It is simple in theory and easy to model, but hard to implement in real robotic setings using speakers, microphones and cameras, given our noisy world. In many of the experiments that were set up by the other groups, either quite sophisticated robots or workarounds were used to demonstrate the feasibility of these models. All experiments were carried out in laboratory settings.

I started to reflect on what it meant for an interactive artifact to be *truly embodied*. Watching presentations of these experiments, it became obvious they were all highly specific and not at all that general and adaptive. Furthermore, the way that the e-Puck was set up it was suggested that communication between them should happen through their Bluetooth interface. Anyone that has ever dealt with Bluetooth probably knows about the issues around pairing multiple devices to another. Then imagine having two options – either pairing each and every one of the twenty devices individually to each other or re-routing through a dedicated server computer on the side. Such a dedicated server would remove a vital part of what it means to be self-contained since parts of the functionality would be off-loaded to a second entity. Furthermore, we discovered a limiting maximum of eight connections per robot, meaning we had no other option than having to do some kind of routing in order to facilitate communication between all twenty devices. Plus, Bluetooth was at this point not that energy efficient, at least not this version of it (v2.0).

This is a very frustrating position to be in where technology appears to match rather poorly with fundamental concepts in the design brief and at the same time appear to be the imperative.

At this point I had come to read two heavily influential books related to complex systems research, one about emergence by Steven Johnson [Johnson 2001] and one called SYNC by Steven Strogatz [Strogatz 2003]. Emergence is an interesting concept that revolves around the idea of acquiring something that is bigger than the sum of its parts. And having communication emerging in a swarm of robots just through carefully setting up one single program seemed like a conceptual match. Strogatz gave many examples about observations in nature where oscillating entities through subtle influences becomes synchronized. For instance hand-clapping at an arena where the hand claps suddenly get into sync, forming a powerful chorus. Another example is how a specific group of cells work together in order to induce the electrical pulse that makes the heartbeat. In our case these two concepts combined – emergence and paired oscillations seemed like an interesting concept to explore further.

Holding the e-Puck in ones hands and carefully exploring its capabilities revealed a few interesting things. It appeared possible to use the front-facing camera together with LEDs to signal and interpret information sent visually. On the other hand that would require image recognition to be carried out in software, plus the communication would have to take place within the robot's field of view. It also had speakers and three microphones, so in principle they could make and receive sounds. This together with signal processing in software would also be feasible, but apart from a large software effort also a quite noisy approach. Another solution I could see involved bootstrapping the infrared proximity sensors as communication interfaces. Their 'normal' operation was to send out infrared light-flashes from an LED and if an object is nearby the flash would be reflected and sensed by an adjacent IR detector. The sensed light intensity is roughly inversely proportional to the distance. The detection range is around 10-15cm. For a coffee-cup sized robot that seems like a narrow enough distance for users to perceive that the communication is actually situated. Compare that to Bluetooth which implies that any single robot in the swarm could potentially talk to any other robot since distance would not be a factor in the interaction.

In the first test run the robots had a fixed period of about two seconds where they would blink all LEDs including the infrared. Between the blinks they would sense with the IR-sensors. If something was sensed

then they would randomly adjust their period slightly. This small random 'kick' is the trick that makes periodically oscillating things to get into sync. It is a bit surprising to watch blinking lights suddenly appearing in chorus like that. At this point we finally had a seed of something that could be regarded as situated yet emergent communication among a swarm of robots.

4.1.2 Movement and Accessorizing

Sometime before the ActDresses concept came into existence, we only had a vague and rough idea about what interaction concerning clothes, costumes and accessories would be like. The earliest formulation was that *"the robot should be able to show a behaviour that depends on what it wears"*. We started out by fleshing out the concept of ActDresses through a series of scenarios and mock-ups. This is presented in Paper IV, and partly covered in Chapter 3, where the study of a Pleo Blogging community triggered me to explore this path.

For our very first mock-up we used Pleo as a platform, and also tapping into the inspiration that we got from reading the blog posts. In particular we looked at scenarios like using a pyjama to enable sleep mode or a studded leather watchdog neck bracelet to enable its watch-dog mode (Figure 11). It was at this time possible to trigger behaviours by sending commands through its USB-port, and the hack consisted of having an RFID-reader close to its skin that could read off tags embedded in the clothes. The RFID-reader was connected to an adjacent laptop that translated the read tags into commands that were sent back to the Pleo robot. This showed that the principle worked, but it looked and felt rather bulky with lots wires and equipment strapped on the outside of the robot. Putting the robot under the knife did just not make sense since it was impossible to imagine how to properly hide the reader, a small computer and the cables under its rubber skin without significantly altering its



Figure 11: First hack of Pleo never got under its skin.

appearance. So while succeeding with the conceptual principle, we failed in imagining how to make it truly self-contained and thus decided to try something different.



Figure 12: Early sketching using a cake bundt cake pan and magnetic signs.

We continued with other platforms and exploring other combinations of known and unknown materials that were readily available. In this early scenario we re-imagined a typical situation with a vacuum cleaner and how to augment the interaction using accessories such as labels inspired by comics for action and activity. As a representative shape of a robot vacuum cleaner we picked a bundt cake pan (Figure 12), and the signs were created out of stickers put on a magnetic rubber laminate.

The resulting artifact allowed us to feel and reflect upon how cartoon-inspired stickers could be used to put the robot in a certain behavioural state, visualize what state it is in, and finally show what state to expect. In the second hardware sketch we used the familiar e-Puck platform together with a ring of lower level instruction tokens put on the head of pins, such as “move forward”, “rotate left”, “stop”, “flash lights”, etc.

In the third set of prototyping sessions we decided to continue with the previous mock-up using the familiar and readily available e-Puck platform (Figure 13). The general idea in this case is to have small round symbolic tokens that can be attached to the robot in order to program it on the fly.



Figure 13: Using the GlowBots prototype as a mock-up for the ActDresses concept.

From the Glowbots project I had at this point acquired experience and platform specific practical know-how so crafting a rough and quick mock-up did not seem like it would be too challenging. Of course I got stuck almost immediately as I tried to figure out how to read out various types of accessories. I thought about using one-wire technology such as iButtons, and after two weeks of getting acquainted with technical specifications and elaborate circuitry interfacing the one wire bus with an RS232 serial, I had nowhere near reached a point where we could actually switch and plug in the button-like identity markers. At one point where I thought that it just ought to work, I managed to send a string of bytes to the e-Puck over the serial bus and received nonsense. If the nonsense would at least change as we switched identity markers it would still be ok, but what I then received in byte-stream did not correlate to any of my efforts. I had arrived at a dead end and had to start over. It is worth noting that the acquired hands-on knowledge with these iButtons would become relevant at a later point in a related exploration with the Roomba Create platform (Paper V), where it worked as expected.

Meanwhile I started considering alternative and less sophisticated options. I knew that the proximity sensors positioned in a ring around the e-Puck could be used to detect nearby objects. It would thus be possible to obscure the sensors with a flexible paper, plastic or cardboard-"skirt" that through a certain pattern obscured sensors. A far less sophisticated solution would be to use the switch knob on the top of the e-Puck. It was already part of the standard software API, which meant that the programming part would be straight forward. After all I wasn't reaching for a sophisticated technology demonstrator or near product design. I was aiming for a simple prototype that would demonstrate a novel user

interface using accessories. The problem was thus reduced to switching a knob, slightly off-centre located at the very top of the e-Puck. Cutting off a cylindrical slice from a plastic pen together with a piece of Lego transformed the knob into a "handle" where accessories could be mounted on top using the Lego-mechanics as part of the interface.

The challenge was to find a way of positioning each accessory in one distinct way. Although the knob has twelve distinct positions, four would be sufficient as a trade-off between precision and just enough for demonstration purposes. In practice that meant that I could define a 'direction' as composited by three adjacent knob positions. Thus I decided to have four different directions, a neutral one and the other three directions bridging between accessories and behaviours. This meant that a user would start from the neutral direction and then have the placed accessory to tell in which direction to put it. Since the knob was slightly off-centre I cut out round pieces of cardboard of the same diameter as the e-Puck to explore how a Lego piece could be mounted so as to tell the user how to turn it. As it turns out – if a Lego brick is positioned in a certain way on the round cardboard the user only has one option as to turn the whole piece so that the cardboard would be centred perfectly on top of the robot. Missing at this point were two things, some behaviour routines and what exactly the accessories would be. Being at the top rather than around the robot the first accessory that came to our minds was hats. The most important aspect for the software routines was that they too were to be distinct enough as to reflect a certain characteristic implied by the hat. Code-wise this corresponds to crafting three distinct enough patterns of motion. The people observing it would then be able to connect the performed behaviour to its costume.

Through small scale demonstrations at open-houses and internal events, informal feedback revealed that this prototype worked really well to explain the ActDresses concept. It is elegant and simple enough so that just about anyone can understand it through instructions and hands on interaction. Although the mechanical nature of the prototype makes it a bit brittle, its simplistic setup yet sketchy appearance also implies a certain distinct character (Figure 14).



Figure 14: The Hat-Trick prototype using the e-Puck platform and a physical knob-controlling mechanism with the looks of a hat.

4.1.3 Hacking Interaction

Having defined the concept of ActDresses theoretically (Paper IV), we sensed that it could be general enough to be applicable to other types of technological artifacts where accessorizing as a practice is already common. Working at Mobile Life, one obvious platform that would fit that description is of course the mobile phone. Together with Wireless@KTH, I and my collaborator Ylva Fernaeus applied for, received and started a short three month project (stretched out over six months) to develop such a concept and implement a demonstrator for the ActDresses concept on a mobile phone.

In this case we considered at a number of different technological possibilities for attaching accessories such as phone-shells, stickers, jewellery, etc. At the time when we started this project in 2010, we were aware that mobile phones featuring NFC existed, but only for one or two Nokia phones using Symbian OS. It was not until late 2011 that this technology would become generally available on more modern smartphones using e.g. Android as a system. To our mind NFC seemed perfect in every way, but further exploration would soon widen our perspective. In the end we would make a list of all the sensors available and then playfully tease out what they reacted upon that could be used as input. This exercise goes a bit like the following:

"The accelerometer reacts to motion – what may induce motion? Vibrators, tapping with fingers, etc. The camera can recognize contours, colours, brightness, etc. How can we make these? The phone-jack can detect if the hands-free is plugged in and whether it has a microphone or not. Here we might have something… The compass/magnetometer reacts

to the earth's magnetic field. Perhaps it will react to other magnetic things. Aha!"

This reflection resulted in a simple but elegant hack using the magnetometer of a smart phone (Sony Ericsson Experia X10) as input. By duck-taping small yet strong NeoDym magnets onto the shells at various positions, their relative influence on the sensor given by the absolute distance became their ID. This exploration then exposes something fundamental, namely that the interaction now depends on a



Figure 15: Mobile ActDresses with custom shells for controlling the behaviour of a smartphone

fixed position or in other words socketed accessories. Sockets bootstrap what and where accessories can be put. This works well for phone shells since they already are socketed mechanically and thus only fit one at a time and in one place (Figure 15). NFC or any other radio based technology works somewhat differently by allowing non-socketed item placement as long as it is within reach signal wise. In reality, the specific functionality of simultaneously reading multiple NFC-tags is not enabled on mass market phones.

4.1.4 Studying an Robotic Arts Community

In addition to my own reflections on building prototypes and demonstrators for research, I have been part of a project with the goal of studying practitioners in the robotic arts community. The main outcomes of this project are detailed in Paper III as part of this thesis. Here I will

exemplify and try to articulate how the artists relate to each regarding the touching points related to tinkering in Chapter 2.

The first point is about corporeal practices and how that was manifested throughout the artists' work. In the article the discussion is focused around the theme of robotic fakelore. The argument is that the artists collectively deliver a kind of critique that is in contrast to robotic products and how robots are depicted in our contemporary society. In their practice the artists expressed a range of values that emphasised bodily interaction, for instance one piece was partly human (a person sitting inside of the art piece) and the audience was encouraged to touch the person's skin as part of the interaction. Other pieces encouraged skin-close interaction by being designed as hand-held devices that would move in the hands of the user. Furthermore the way the artists talked about their work, it is obvious that a significant amount of work went into sculpting and crafting their pieces.

The second point is related to the observation that they make use of so called robotic materials. These materials are similar to what we use in interaction design research, materials that are physical, electrical and computational, but with an emphasis on dynamics as they exert motion in space. The artists actively explore their materials by crafting works that are interactive and *live* and thus are able to talk back through motion in the crafting process. Furthermore, the artists know what it means to be demo-ready and they often seek to engage actively with the public to have a discussion around the art pieces. There is no back-up plan, so the art pieces have to be robust enough to simply work and there is often a rich story or a political message for visitors to take home about how the art pieces came about.

4.2 Characterizing Tinkering

As an attitude, we will relate tinkering to a number of core values and an intentional collective set of activities that can aid in guiding the actual crafting practice. The primary ones are the *playful* and *curious stances* which help to create a bit of distance to any cultural preconception. Playfully pretending or having that *"what would happen if..."* curious urge is often enough – as a relaxed yet excited way of getting started. Just about everything is acceptable at this point, but at the same time being open for both criticism and appropriation. Commonly, the first thing that happens rather spontaneously is the sheer "fooling around" with technology and tools. After a while, the materials at hand start to talk back, resonate with ideas and act as catalysts, like for instance *"what if*

we just could carve out the shape of this display to be round?" rather than the traditional rectangular configuration that is typical for screens. There is no right and no wrong and in a way we are allowed, if only just briefly, to be free from the constraints of imposed norms. Many if not most ideas like these are killed prematurely before even conceived as physical manifestations. Still, we should keep in mind that materials certainly contain their own set of values, for instance anthropomorphic (human looking), zoomorphic (animal looking) or technomorphic (technically looking) materials may look innocent enough on its own may become powerful cultural signifiers when combined. For example putting a camera onto a robot comes with a truck-load of expectations around human oriented conceptions of vision e.g. seeing, being seen, crying, blinking, staring, avoiding, looking and so forth. This is somewhat related to a discussion about the so called Media Equation by Reeves and Nass, where technology and media are treated similar to actual social beings [Reeves and Nass 2003].

Paper as a material has many properties that have been well explored in HCI and elsewhere. It was central in the development of the desktop metaphor [Johnson et al. 1989], the way people used post-its in coordinating their work environment [Bentley et al. 1992], for sketching out ideas onto cardboard [Buxton 2007] and even folding artifacts ranging from simple airplanes to extremely complex origami creatures [Gardiner and Gardiner 2012]. We also need to be aware that values exist in a cultural context, in the very architecture of the crafting space itself. When artifacts are created in fun environments with playful attitudes, those cultures and attitudes have a reasonably good chance of being reflected in the crafted artifacts themselves, just as the opposite of having strict, closed and concealed values would hold true.

Another core value is *openness* where artifacts and details can still be deliberately hidden as in encapsulating, but not hidden in the sense of being deliberately difficult to open up. In fact, this modular approach and sincere honesty is a shared core value in the same manner as open software where code is meant to be shared and used by others. This paves a way for assessment and appropriation similar to how free speech works. Furthermore this core value suggests an inherent modularity where each module is made so as to be readily available. With this modularity the process of tinkering becomes *traversable* and by using generally available tools (screw drivers, pliars, etc) it becomes easy to rapidly build, tear down, rebuild, undo, change, redo, remove, add, put together and so forth. By traversable I mean the ability to go back and forth within the process, to assemble and take apart. This is at the very core of the

tinkering attitude and it is easy to see how it is both similar and different to a sketching session. One mainly deals with representations towards final designs where the other mainly deals with a *live corporeal dialogue* directly concerning the real final materials rather than the final design. Ingold makes a much related case for the embodiment of skills and its relation to tools and appropriation [Ingold 2006]:

"No object considered purely in and for itself, in terms of its intrinsic attributes alone, can be a tool. To describe a thing as a tool is to place it in relation to other things within a field of activity in which it can exert a certain effect. Indeed, we tend to name our tools by the activities in which they are characteristically or normatively engaged, or by the effects they have in them. Thus to call an object a saw is to position it within the context of a story such as the one I have just told, of cutting a plank."

Comparing Lego (socketed by friction) to welding or some other more terminal process also highlights that there exists an active choice for where and when to forge clear modular boundaries. Each step where modularity is achieved can be framed as a success, and in practice it means that the space of possibilities just got *defined* yet *multiplied*. Defined in the sense that we now have a distinct *module* and multiplied in the sense that we can explore how to recombine it with other modules. Such modules or components can be reused, retrofitted, polished or even discarded altogether, but the point is that it has a sense of openness to it that shines through and although we may have moved through many layers of abstraction it is also possible to hand on this sense of openness to other practitioners and users. Those people are now empowered in the sense that they with the same tinkering attitude are allowed to hack, tear apart, and reverse engineer and thus acquire knowledge about the involved materials and corporeal practice. This is intimately related to how Cross frames knowledge as something that resides both in the artifacts and in the design process [Cross 2010]. Furthermore, one way to look upon it is that this reversed design process reveals details and knowledge about usage and intent connected to form and function similar to how reverse engineering reveals more technical inner workings. Such knowledge can be thought of as *component knowledge* that contains details about properties, contexts of use and inner components residing in other layers of abstraction. Moreover, as our bodies get used to incorporating components into various practices and situation, we develop a deep sense of the knowledge. As this knowledge gets harder and harder to describe adequately we end up with what is considered to be *tacit knowledge*.

Taking a step back, it should be added that tinkering as such is not to be taken for an ideal but that the process can be chosen to be guided by sketches, visions and concepts as well as be completely open-ended. In the following sections we will look at related approaches such as sketching in hardware, DIY and Crafting, and Hacking and Reverse Engineering. As we will see, in particular in these latter sections, tinkering resonates to a large extent with ideals and practices related to software. Since tinkering is an attitude I it is reasonable to assume that it is not limited to hardware since working in software hinges around the very same core principles. The difference lies mainly in the question about corporeal interaction versus symbolic manipulation, something that will be more thoroughly investigated in the section on hacking and reverse engineering.

4.2.1 Prototyping and Sketching in Hardware

This section aims to describe how prototyping and sketching in hardware relates to tinkering. As I briefly mentioned in the introduction, sketches together with scenarios generally form envisioned uses of a technology and can be seen as detailed carriers for ideas and concepts situated in a specified context detailed by a given scenario. Hardware sketches are physical mock-ups or tangible representations where most of the more detailed technical capabilities are left unimplemented but still belong to its detailed usage/experience scenario. As a concept, sketching in hardware has gained some traction in interaction design research to bridge the gap between mockups – physical models and the use of electronics and digital material in a sketching process [Holmquist 2006][Sundström et al. 2011]. Today there exist many kits for quickly doing hardware sketches e.g. general purpose kits such as Arduino, Gadgeteer, BASIC Stamp, u-parts and in terms of more specific kits for different areas e.g. in robotics we have e-Puck, LEGO Mindstorms, iRobot Create, etc.

Prototyping as described in interaction design literature leaves quite a bit to wish for in terms of the kind of craftsmanship outlined by e.g. Schön [See e.g. Buxton 2007; Koskinen et al. 2011]. Often the term simply refers to the general practice of *designing* prototypes, that is artifacts with a clear idea of manifestation and functionality that resides in-between a mockup and a demonstrator. An even more general use of prototyping implies that most of its knowledge is kept tacit and that the crafting practice as such may be kept at a distance from the scientific discourse. This is alarming since it effectively suppresses a large part of the thinking

and knowledge production, which in my opinion often primes many essential "discoveries" in interaction design.

Tinkering as an attitude offers a mode of conduct for exploring concealed or hidden properties (like magnetism, wifi, IR, etc) in addition to using known functionality which is the general goal with sketches. A good example about exploring physical-digital properties like these is presented in Petra Sundström et.al's work on inspirational bits [Sundström et al. 2011]. In this project they have created and given examples of simple units of technology that can be used in hardware sketching sessions for interaction designers to explore how digital technology resonates with real world usage rather than idealized technical specifications. Notably this example is part of a deliberate turn towards materiality in HCI where the goal is to emphasize physical-digital materials and how they can be used in interaction design. Tinkering is a way of continuing this material move [Fernaeus and Sundström 2012] by providing a mode of conduct or attitude that seeks to include, and emphasize practices around crafting with interactive materials.

Within HCI and interaction design, tinkering allows us to work directly with prototypes, demonstrators as well as end products, and thus does not distinguish between how "finished" different artifacts are. It is not a perfectly linear process, and as an attitude it does not even need to have that aspiration. We may at any time switch between tinkering and any other governing attitude such as design, inquiry, etc, but the point is that while research text books tend to highlight processes that are rather linear, the tinkerer is free to pick and mash-up any existing products for prototyping or hardware sketching. However, grounding tinkering practices in studies of actual interaction does impose structure in a similar sense to how a landscape helps the architect design a building.

4.2.2 Hacking and Reverse Engineering

With hacking it is possible to consider both computer hacking and hacking together physical artifacts as ways of applying shortcuts as well as clever and thoughtful quick fixes. Furthermore, a hacker attitude can be characterized by *knowledge* and *determination*. In Jon Ericson's view hacking from a software perspective is about "the art of creative problem solving", by means of "finding an unconventional solution to a difficult problem" or "exploiting holes in sloppy programming" [Erickson 2008]. He essentially talks about the professional hacker as in that merely a few people actually have the strong technical competence required to really find and exploit weaknesses in software. From this perspective, errors,

mistakes and exploits can be considered to exhibit a certain kind of attractiveness in the way that they provide a door into uncharted or unknown territory. As with any other difficult challenge there is likely a strong connection between effort and reward. Steven Levy gives a much in depth account of hacking and how the term gained traction at the MIT campus in the late 50's [Levy 2010]. He states that *"while someone might call a clever connection between relays a 'mere hack', it would be understood that, to qualify as a hack, the feat must be imbued with innovation, style, and technical virtuosity"*. One important realization is that this original notion of hacking involved a great deal of interaction with physical materials like punch-cards and radio-tubes. Similarly, traces of this type of interaction related to the early 19th century jacquard loom have recently been brought up in HCI as an example of practices that more fully involves the body [Fernaeus et al. 2012]. It is thus reasonable to believe that the word 'hacking' is a fairly recent conceptualization of far older practices and values. Nowadays, hardware hacking in particular has acquired a somewhat broader meaning in that it could mean anything from just plain and simple crafting to finding shortcuts or clever and thoughtful quick fixes even in more mundane materials.

Even in our field of interaction design, the term hacking stems from both this general use and the more strict reading reflected in traditional computer science. For instance, in Verplank's model, hacking means a rough first simplest and quickest implementation of core functionality [Buxton 2007]. This is often the step in the process that takes place just before moving on with sketching in hardware or prototyping, but its arbitrary use may suggest that it is used interchangeably in between the two. It is interesting to see that hacking in this context is still not bounded to either software or hardware, but rather sees them as a whole – a material that is seen as an interactive material rather than having distinct physical and digital properties.

Reverse Engineering is another important concept that begins with an artifact, of more or less unknown content, that through careful and structured disassembly unfolds and details any knowledge contained within [Kadavy 2011]. This could theoretically be done at any layer of abstraction:

- Assembly details
- Component details
- Schematics
- Functionality

Reverse engineering is, strictly put, a process of close examination and thus does not allow for any type of modification. The result is often documentation covering the component knowledge, plus the more tacit knowledge bound to the disassembling person or the group of people participating. Nowadays it is popular to also document a disassembly process on video, which is then uploaded by people and can be found on online video services such as YouTube. This method and set of principles are not limited to merely hardware since the observed effects often are a result of the interplay between hardware *and* software when it comes to physical-digital artifacts.

Viewing this practice from another angle, there is a quite clear connection to an explorative attitude, as the whole method is about exploring not only the artifact, but also procedures themselves, tools and "bodily know how" for how to actually do reverse engineering. From this perspective it fits rather well with the theme of tinkering since they both share an explorative agenda as well as the taking apart and examination practices.

4.3 Towards User Empowerment

Tinkering as an attitude is very sensitive when it comes to values, and we should be critically attentive when making connections such as cultural stereotypes of household labour division and the traditionally male dominated engineering practice that might make it appear skewed in terms of gender. Moving beyond gender we should instead reason about *tinkering* in a very *corporeal* sense since it is a highly embodied self-reflective process [Schön 1984]. By corporeal we mean skin-close engagement, breathing on glass components while polishing with cloth, smelling that puff of molten tin and flux, feeling the frictional forces when using a finger-nail to separate a plastic cover, and so on. Although our bodies are from one perspective similar they also represent the fullest diversity, a resource too often overlooked in the name of objectivity, norms and rationalization. No matter how detailed a procedure, it is a body that puts it into practice and thus reveals the fuller extent of it [Ingold 2006]. It is in that perspective, as an attitude and intentional collective of practices, that tinkering can finally be framed as "thinking" with materials, knowledge bound to artifacts resulting from embodied interaction.

It is also worth stressing that one must not become too naïve and interpret thinking in this sense as disconnected to 'normal' thinking. Corporeal in this case implies using the whole body, brain included and in a very real

sense substantially richer than merely symbolic manipulation. Some may recall that phenomenology, indeed, refuses any such separation [Dourish 2004, pp.21]. This leads to the question regarding what attitude we as researchers and practitioners have towards ourselves – our own bodies and technology. Would it be possible that tinkering actually mirrors or imbues interaction, even in its making? This implies that making or crafting something is not a separate thing from interaction, it's a continuum where tinkering and interaction overlap. This is in a way similar to how Höök e.al. views interactional empowerment as an integral part of the whole affective space rather than something that can be separated out [Höök et al. 2008]. Thus, by keeping this attitude throughout the process, even intentionally, we may in fact end up with artifacts that the receiving end i.e. *users* may pick up and feel empowered by. The character of this empowerment would then correspond to the enabling powers embodied within the artifact, which are the very same attitudes and values that helped shape it in the first place.

As a summary of the main practices regarding the tinkering attitude we emphasize the traversing process of building and tearing. Crafting or making are the constructive parts while reverse engineering exactly corresponds to this notion of tearing in a strict form. Hacking in light of its double meaning, one more generally closer to crafting and the other more software oriented, has in common a sense of critical exploration and hunger for knowledge through finding and making use of exploits. However, it is wise to take into consideration that artifacts are not self-sustained similarly to how a written text would be a bit lost without its actual socio-cultural context. Thus, acquiring any specific intended meaning by just picking up an artifact can never be taken for granted. This is central within the arts and for instance Dewey discusses this in depth [Dewey 1934]. On the other hand, to interpret something in a new context is of course to discover something new, to get a small reward for being curious. To hold something that has this open modular structure and to be able to access its knowledge, purpose and use through tinkering, to my mind, means being truly empowered as it does not try to limit options on purpose.

5

Research Contributions

The contributions presented in this chapter are at large represented throughout the thesis papers. Here the contributions will be revisited and structured in order to shape the overall argument that will help in supporting and properly addressing the posed research questions. The contributions aid to outline my governing research practice in interaction design concerning three attitudes – studies, design and tinkering. As an overview these three sections will be presented as applied, field studies, and conceptual contributions.

Each contribution will be introduced with a brief overview and with pointers to its respective publication as included in this thesis. In particular we will look at how the contributions relate to the overall research agenda of conducting studies and tinkering as a deliberate attitude and practice. This is done by providing examples of on the one hand sketching in hardware, hacking, reverse engineering, bricolage, etc. and on the other hand grounding through studies of real world observed interactions. Finally I will explicate what the research contribution consists of in terms of sketches and scenarios, implications for design, design concepts, prototypes and studies.

5.1 Articulation of Tinkering as part of IxD Research

In this contributions section I present three research prototypes, the GlowBots, the Hat-Trick and Mobile ActDresses. These are at the same time the resulting demonstrators of the corresponding given examples of tinkering (Paper I, Paper V and [Jacobsson et al. 2012]).

At one point Nicolas Negroponte at MIT media Lab proposed that their mantra should be “Demo or Die!” as a response to the older academic

saying “Publish or Perish” [Brand 1988]. This is a tradition that we have kept close to heart within our Future Application Lab as well as at the Mobile Life Centre. The main difference arguably lies in that we also ground our work by making studies in order to better understand existing needs, desires and problems. However, more than just for the sake of showing off new novel technology, there is a deeper and more profound reason for offering hands on experience using the technology that we develop. Just as reading a text or a sketch may convey a concept, a prototype in its physical form is capable of transmitting concepts and ideas by hands on experience. However, what cannot be transmitted are sketches and things that did not go into the demonstrator. Furthermore every embodied experience with an interactive artifact is unique and personal, just as any interpretation, symbolic or otherwise, would be.

Throughout this thesis I have created a number of demonstrators, thus it is natural to reflect a bit on the curatorial aspects of showcasing a piece of technology. Assuming that the tinkering attitude is rather ubiquitous and that it also holds the key to acquire knowledge, tacit or not, contained within the artifact it seems interesting to consider how this is done in practice. There are a number of situations where demonstrations can occur, and just to give but a few examples from our own experience:

- Informally giving demos to colleagues
- Showing demos to other research labs
- Showing prototypes to visitors of our lab
- Curated exhibitions or science fairs, e.g. CeBit, ArtBots, Wired NextFest
- Showing demos at review, lab or board meetings
- Giving demos to media, potential partners or investors

Some of these occasions are in fact peer-reviewed, which is in itself a process of knowledge transfer as well as assessment. Another important aspect from a research perspective concerns how to preserve the state and ensure lasting functionality of the research prototype. It should preferably be ready to show to other researchers, industrial partners, at various exhibitions, for media dissemination etc. as a way of communicating this knowledge. For that reason we think of demonstrators as rather finished research prototypes that are packaged in such a way that it is quick and easy to pick it up and do the “demo performance” (Figure 16). Within our lab at Moblie Life we have casually referred to this concept as being *“demo ready!”*.

Specifically Paper III regarding the study of ArtBot-artists highlights what it actually means to craft with physical-digital materials and put them out there on display for a general public to consume. The aspect of performance is implicit and the artists has to account for and make sure that the piece will withstand three days of (in most cases) constant running and interaction. This is not something that happens suddenly but something that comes with these materials being machines and/or computers that are active and in some sense increasingly reactive. This is not the same thing as working with clay or paint since the materials are capable of talking back in a whole new range of modalities.



Figure 16: A case of GlowBots and a box of Mobile ActDresses ready to pick up and demo.

Among potential issues we find that the demonstrators we produce often are associated to one or at best a couple of researchers. It is not always that obvious when picking up a device created a few years back to guess its original intent as a demonstrator. Well-crafted documentation is important, open source helps a great deal and open specifications opens up for quickly making copies, but an overall experience unfolds from actual interaction with the artifact as we engage with it through our bodies.

In my work I have actively used venues such as SIGGRAPH Emerging Technologies, Ubicomp, TEI, CHI and other scientific venues as peer-feedback occasions for assessment of the kind of knowledge that comes with interacting with a demonstrator. It is similar to interacting with a product, but offers a first-hand and possibly unique interactive experience that is potentially relevant for broader use in our society. What the product has on the other hand is a market, a carefully developed strategy and a more self-motivated place in the ecology of products. In that perspective the demonstrator is still an idea represented as an artifact, which does not automatically translate to the market's collective demand of a consumer product.

So what else is it that we want to achieve with demonstrations? Beside knowledge assessment, we use the visibility of our prototypes and demonstrators as a way to shape references between our works. For instance, if I had merely watched a video of interaction with Tabby [Ueki et al. 2007], I would not have gotten nearly the same appreciation as I got by physically interacting with the breathing, furry, warmly glowing, life-full artifact. Using scientific venues helps in reaching out to and connecting with industry, although I must admit that as a researcher I often tend to think of the artifacts we create as rafts for concepts rather than seeds for products. What is missing then is perhaps the attitude of entrepreneurship that in a better way can bridge the gap between demonstrators and products.

The GlowBots project (Figure 17) is described in Paper I and has been outlined in further detail as an example of how I have used a tinkering oriented attitude to craft and design a robotic artifact capable of interactive communication. Furthermore I have used GlowBots as *probes* to elicit field data, as *vehicles* of knowledge to influence and inspire research and practices within the field and as an on-going *material dialogue* that remains open for tinkering.



Figure 17: GlowBots demonstrated at Wired NextFest 2008.

The Hat-Trick demonstrator is a demonstrator that conveys the main message of the ActDresses concept. It is not made as a product prototype or intended for end users, it is simply an articulation in physical form of what it could mean to accessorize technology in terms of end user programming. Secondly, the implementation serves as an example of a quick and *less sophisticated* hack that speaks of the tinkering attitude

rather than deign or engineering. In other words, I had to engage with the materials in a corporeal hands-on dialogue to tackle a particular problem, just to discover and eventually accept that the real problem could be framed differently. I had thus moved from a technically oriented formulation of the problem to a problem formulation posed by being profoundly involved with the artifact and its materials as mix between craftsman and a first-hand user.

5.2 Using Studies to Inform a Tinkering Oriented Design Process

In this section we will have a look at qualitative studies made with respect to particular user groups, developed prototypes or existing products. A key theme has been to at the same time critically challenge our own research agendas to get a sense of how interaction unfolds out in the messy everyday world. The research approach suggests that these studies are interventions or explorative in nature seeking to map out emerging themes informed by what is observed. For this reason the studies are rarely oriented towards evaluations or feeding back, but seek to inform an advancing interaction design research practice that explicitly includes also a tinkering attitude. That is not to say that evaluation is not important, but it is to take a more pragmatic perspective on the incentive for doing studies in the first place. The notion of 'wild' is often very much determined by the method or the study setup. One way around the problem would be to acknowledge that there exist many 'wilds' and that the larger picture can be captured by using several contrasting methods and approaches as discussed in Chapter 3. The following three studies serve as examples for where the outcome has inspired tinkering processes like the ones outlined in Chapter 4. For instance the study called "owners of unusual pets" is an integral part of the GlowBots project, while the Pleo Blog Study and "Adopt a Robot" study together set the stage for exploring designs and the concept of ActDresses. Finally, the "Always On" study doubles as a study and a methodological exploration that informs projects and prototypes currently under development.

5.2.1 Owners of Unusual Pets

Back in 2005 my colleagues and I began to consider the role of "in the wild"-contexts and designerly ways of getting inspired by various more peculiar activities that takes place there, activities that refer to as *marginal practices*. Such practices have a limited and often secluded community that clearly is a contrast to what could be attributed to a general sense of norm. One example of such a marginal practice would

be lomographers and how their particular take on photography could be used to inform a design process focused on developing an innovative photography application [Ljungblad 2008; Håkansson et al. 2006]. By then studying marginal practices, in this case owners of unusual pets such as snakes, spiders and lizards, we have developed a methodology to motivate and articulate involved user qualities as a way to inform new designs [Ljungblad et al. 2006].

The overall idea was to create a number of different personas representing contrasting relations regarding their pet-relationships. The process began by first cutting up the printed out transcripts from the study into a pile of quotes. Then we pick quotes from this shuffled pile and put them together into an affinity diagram. Each emerging section then corresponds to a persona. There is no real authority in this process other than the shared assumption that personas should be representative for how our users related to their pets in a constructed yet grounded sense. At this point all notions of various pets (e.g. spiders, snakes, lizards) were generalized into just 'pets'. The emerging clusters were then written together into a more coherent description of the persona using general fictive "glue data". The result at this stage was four personas – each representing a distinct relationship towards their 'pet'. To make the personas more alive we gave them realistic (fictive) names and avatars. This is a very powerful trick for aiding the construction of a mental image around a concept. The next step was to make a clear transition into the target domain by replacing all notions of 'pets' by 'agents'. This shift turns the personas into governing design descriptions for building artificial agents e.g. robotic artifacts. The main contributions in this study are:

- The contribution to the Transfer Scenarios approach as such
- Here we got the chance to familiarize ourselves with the notion of *grounding*, a theme that has become rather central in our group over the years, and particularly for me reflecting on the ways that reality resonates with interaction design.
- The specific persona called 'Nadim' that worked as design guideline for the GlowBots project

5.2.2 Adopting a Robot

This study is not explicitly included as a paper in this thesis, but is partly outlined as the second example study in Chapter 3. In this study we wanted to explore long term effects of people having a robotic toy dinosaur to care for [Fernaeus et al. 2010]. In particular we were

interested in the kind of relationships that would form in terms of companionship as well as particular accounts of actually living with the technology in general over an extensive period. In a way this study did not deliver as much data as we originally anticipated. Perhaps this was due to that we somehow inaccurately expected that long term studies implied more data. On the other hand we saw this as a good thing, given that the data we did get gave us a sufficient understanding of both general and particular experiences from analysing the data. Main takeaways:

- A main finding from this study concerns a tension between approaching the robot as a toy while also expecting it to act more like a real pet animal. At the centre of this is the maintenance issue
- The robotic toy was expected to fit into an established eco-system of play and toys.
- Parents (in this case mostly fathers) expected to in their own way be able to tinker or play with the artifact, e.g. program it or script their own behaviours.

5.2.3 Always On

In this project we developed an approach for doing in the wild inquiry using guidance rules that emphasized a more persistent interaction [Jacobsson and Nylander 2012]. This is the third of the given example studies that was introduced in Chapter 3. In our rather pragmatic approach we have worked on this in two ways. First we created an a-typical scenario case, where we broadly imagine a user together with a robotic artifact moving about in the wild. Learning from previous experience with studying how users interact with this technology we identified three major issues that we wanted to pursue:

1. The companionship aspect, where a piece of technology would accompany the user to a greater extent
2. The battery issue, how do users plan their power consumption and recharging
3. The context issue, there is no incentive to bring the artifact into a variety of social settings

Reflecting upon these three challenges we started to get a feeling for the things we wanted to capture by designing a new method. We were particularly interested in uncovering so called *in-between contexts* – everyday settings that are rich with uncertainty but also contain a trove of social norms and rules for engagement. A few example contexts are in a

subway, in a bus, in a mall, in a pizzeria, at a cinema, etc. In other words contexts that are transitional or that change greatly over time with respect to e.g. the presence other people. Based on previous experiences, we decided on a qualitative approach with semi-structured interviews in combination with taking inspiration from HCI-probes [Hutchinson et al. 2003; Gaver et al. 1999]. For instance, in the always-on studies, participants were instructed and encouraged to gather pictures, video as well as any other kind of media that would help them to reflect upon their experience, in a semi-structured interview debriefing session. Furthermore, these sessions were scheduled right after ending each individual study while the participants' memories were still fresh. The main takeaways from this study can be summarized as follows:

- Handling energy and charging batteries, trying to keep the artifacts alive when it matters, and the planning that follows.
- Pleo became an *object for display* and also the centre of attention in most reported situations, non-regarding of the experience (e.g. situations that required social re-negotiation of policies).
- The "ice-breaker" effect for starting more casual conversations with strangers. This was revealed in the blog study (Paper II).

5.3 Tinkering as a Foundation for Developing Stronger Design Concepts

ActDresses is a concept that originated from the study in Paper II, reflecting on how people portrayed and talked about their interaction with the robotic toy Pleo in online blogs. One theme that stood out in that study was descriptions of accessorizing, DIY and other similar engaging practices that appeared to be meaningful to these users. At about the same time, this behaviour was being reported in related studies on Roomba – the robotic vacuum cleaner [Sung et al. 2007]. My hunch that resulted from observing these practices was to bootstrap them for not only changing the physical appearance but also to connect it to any digitally augmented appearance. For dressing up a robotic toy this implied that a costume or accessory would affect its behaviour at some level in the software.

At this point a first sketch of the concept was drafted, which was given the name ActDresses with the intention to emphasize the social enactment related to a costume or dress. Furthermore we reviewed related work on the role of costumes and uniforms in society and their signifying relationship with respect to roles. For instance, it is common in theatre to visually signify roles and aesthetical expressions by using costumes. The

concept of ActDresses is presented in Paper IV and V, while a kind of validation of the concept that confirms its generative capabilities has been presented as a demonstrator e.g. at CHI'2012 Interactivity [Jacobsson et al. 2012]. This demonstrator is called Mobile ActDresses and shows one way in which the concept could manifest itself on mobile phones, another consumer oriented device where practices of accessorizing already exists through e.g. exchangeable phone-shells.

6

Discussion

The main topic for this discussion will be how to carefully put together and construct the overarching argument about tinkering and position it in the interaction design research process. Up to this point I have characterized tinkering in terms of attitudes and practices and also provided a bit of general theoretical orientation, approaches and methods as well as an overview of my research contributions. Throughout the discussion I will attempt to draw on this work and start to rebuild our argumentation in order to support our research questions. Moreover I will articulate how I have crafted and used robotic artifacts to explore the nature of embodiment and corporeal interaction in interaction design. I do this by looking at how research through design consists of practices dealing with artifacts from an embodied perspective. As researchers in interaction design we design, we tinker, we engineer and we do studies as a way of shaping our arguments and articulations – using instrumental attitudes for improving our world one artifact at a time.

Let us now have a look at what could be emphasized with this separation between attitudes and practice (Table 2). If an idea or concept is the point, an attitude marks the sense of directionality. Having a tinkering attitude thus means to playfully explore what options there are given by the materials in order to turn a concept or idea into physical form. There is no real controversy here; the main point is that tinkering offers another mode of knowledge processing that ties closer to embodied practices and where we as researchers are allowed to have a direct dialogue with interactive materials and their functionality.

Where is the dialogue in each of the other two discussed attitudes, and what part of interaction is it bound to? As has been suggested, in field studies dialogue resides in the observation of practices that occur in the wild. In design the dialogue is between conceptualisations,

	Field Studies	Design	Tinkering
Attitude	Exploring what people are already doing	Exploring what people would like to do, feel or experience	Exploring materials and how they can be used or recombined
Practice	Interviews, Observations, Surveys, Analysis	Sketching, Brainstorming, Conceptualizing, Critiquing	Examining, Crafting, Prototyping, Debugging, Testing
Result	Accounts of what is real and exists, Implications for Design or Tinkering	Mock-ups, Sketches, Form but not necessarily Function	Prototypes, Demonstrators, Function but not necessarily Form

Table 2: Overview of how tinkering relates to other main attitudes and practices within interaction design.

representations and the format [Stolterman 1999]. It is important to stress that new influences, new ideas and new takes on existing practices in interaction design might open up for additional or alternative attitudes and practices. In fact, it may be inevitable if our field of HCI is to expand and adapt to future challenges. For now, my work in this thesis suggests that we need to be open for something other than design: it is the knowledge and practical skills of a craftsman combined with studies of what people actually do.

6.1 Tinkering and Crafting Articulations

I propose that tinkering framed as an attitude together with looking at robotic artifacts may aid in getting a perspective on practices in interaction design research where we as a field aspire to build novel and more complex interactive systems. This understanding of the role that tinkering has appears to resonate with Buchanan's description of how design in general relates to *Logos, Ethos* and *Pathos* [Boyarski and Buchanan 1994]. From a historical point of view it is worth noting that these concepts originate from how *rhetorics,* i.e. the practice of making an argument, emerged in philosophy [Wood 2005]. My understanding is that this is still at the core of today's research practice where we make such articulations both through written text and through crafting physical artifacts [Redström 2001].

With tinkering we thus put emphasis on the functional element that corresponds to Logos, but that does not in any way mean that it is separable from or even unrelated to either Ethos or Pathos. Logos roughly

corresponds to the inner workings of an artifact and how the involved technology and materials relate to each other as well as the structure and surface that hold them together. The same line of reasoning applies for studies and grounding in existing everyday practices and how that relates to Ethos. With Ethos we seek to frame what is real and the inherent responsibility for creating the artifact in the first place by making sure that it stays *grounded* and thus in a very precise sense – not to lose track of or weaken the research question along the way. This is one aspect of how research that involves physical artifacts and interfaces, simply put, may account for a degree of credibility. Thus, the most common approach to improve credibility is through making studies, evaluative or precursory, and by that making sure that an artifact is *right*, justified and actually deserves a place in our society. Finally, Pathos can be seen as the process around considering the receiving end's perspective of what would be considered attractive and aesthetically relevant. This is in a rather similar manner approachable through practices regarding design and form giving.

What my studies suggests then, is to consider these concepts on an equal level in the sense that all three are *necessary* to make a strong articulation. They can all three be regarded as attitudes, distinct by their individual orientations around a number of core values. That is not to say that some values cannot be shared, but rather that the attitudes themselves may be governed by different sets of practices and knowledge domains. In my own engagement with the practices of creating research prototypes, and studies of ArtBot artists reflections, I have come to learn the following lesson that addresses the first research question:

Put faith in that the tinkering attitude and a dialogue through active involvement with interactive materials will let the materials to talk back and reveal a path forward.

However, we must also be aware that it may take time since it involves engaging, struggling and fighting with the materials as we could see in Chapter 4. Looking back at Verplank's model of interaction design, we can see this revolving central core of "hunch and hack" as directly corresponding to this notion of tinkering. Moreover, Sundström reasons about what it means when finding oneself in a situation of fighting the materials, and in a way this could be what happens when simply applying the wrong attitude [Sundström 2010].

What more would then be required than the right attitude and how did my studies inform the tinkering activities and specifically the part that is not

so much about design? It is important to realize that while the whole process is a design process, any particular approach or attitude within that process is not necessarily design oriented. For instance the GlowBots project started with a study around unusual pets that revealed that the patterns on the lizards' skins were an important part of our users' relationship with those pets. While the design challenge was to build a group of autonomous communicating agents with a known form factor that exerted some visual impression, the tinkering challenge revolved around hacking together a round screen that could talk to the e-Puck robot platform and experimenting on how the communication connects to the patterns via infrared to produce an emergent behavior. This required guiding inspiration from the scenario as well as dealing with both hardware and software in an intricate process of active material dialogs that had less to do with the form and shape. In the end this push for tinkering resulted in a better solution that the very first one that came out from the initial design brief. From ActDresses we learned that a design brief does not always imply a specific technical solution. By going back and forth in the tinkering process we arrived at a point where the concept not only worked, but at the same time revealed its generative aspects by being applicable to other artifacts that share similar use scenarios.

As a partial answer to the discussion I would like to stress the importance of engaging in "studies in the wild" to get a firm grounding and to equip the body with the *proper set of receptors* that bootstraps the tinkering process. In a way this is what makes it an informed or more skilful process that elegantly traverses the landscape of possibilities rather than a crude trial and error process. In other words, the other main pathway to failure is when it is not properly grounded in some kind of reality. In my perspective this is without doubt the ethically correct thing to do. This second form of reality check can be summarized as the following lesson which also addresses the second research question:

It is wise to ground tinkering in field studies of existing products before attempting to create artifacts, not the other way around as is often implied by the evaluation paradigm.

I see these lessons as comments to the on-going discourse of failure in HCI, where rather than being a taboo we must realize its broader potential in terms of knowledge contribution [Gaver et al. 2009]. As researchers, we should instead strive to be openly critical and strive to do the 'right' thing based on what we observe through our field studies. This is even such an essential lesson that we teach it to our students in their very first HCI-course.

Tinkering offers a broader view of product development in that it advocates another sense of openness. It is hard to shake off the feeling that robotic consumer products (such as Pleo) appear to have an agenda of imposing too much of a pre-defined narrative. Rather than experiences that emerge, surprise and change depending on context there has been a trend towards specific experiences – that the products are designed to deliver a defined set of emotions [McCarthy and Wright 2004]. This seems to be in conflict with customers or end-users wishes to play, tinker and use imagination for self-empowerment. Keeping things open thus implies purposefully leaving room for things that are playful, implicit, serendipitous, a bit broken, self-reflective and to be interpreted in a variety of contexts [Höök et al. 2008][Tholander and Jacobsson 2013].

All of this must be seen in contrast to the design tradition of HCI, and the process needed to advance this work. In this context the tinkering attitude will never be able to stand on its own, independent from other attitudes. It should be challenged and worked through in a similar fashion as design was, which over the years highlighted many prominent concepts within design like for instance ambiguity, experience and sustainability [Gaver et al. 2003; McCarthy and Wright 2004; Blevis 2007].

6.1.1 A Lesson Learned About Robotic Artifacts

In my view robotic artifacts highlight many of the difficult problems in interaction design. Furthermore, I have come to realize that my argument goes in the opposite direction as interaction design suggests that many of the difficult problems related to how interactive robots come into existence may be approached design wise. At the same time the tangible and physical nature of robots implies that they consist of materials that one can have a dialogue with, beyond just the digital aspects. This can be seen in the ArtBots-study where I and my colleagues looked at how artists expressed themselves through these materials. At this point I realized how different the artists take on robotics were compared to the engineering approach that many of our collaborators had in the European projects and at the human robot interaction conferences (Paper III).

Related to robotic materials is the aspect of a narrative. We saw this in how GlowBots appears to tickle the children's imagination compared to how Pleo was supposed to be played with as the shape of Pleo's comes with a kind of embodied narrative that implies playing with a dinosaur-puppy. Furthermore, using Pleo in the Always-On study seemed to shift the played out narrative closer to what interaction design really is about.

To our surprise, many of the unfolding events with strangers followed similar social protocols that would accompany any ordinary pet. In the end, the users somehow seemed to enjoy this aspect.

One of these material considerations that have been discussed in this thesis was revealed by, simply put, tinkering with communication between a small swarm of robotic artifacts and observing and reflecting upon communication conceptually. Tinkering in interaction design highlights how important it is to realize that communication, as in a social setting involving people, is something very different than wireless communication technology. The bottom line is that it is important to make the communication perceivable as well as responsive without being constrained by any given technology. From an interaction design perspective – just being able to perceive and take part in an on-going discussion could be very interesting, pleasant and joyful as the experience unfolds, and when we get it right, we will be able to discover and expand our own communicative capabilities. This hints of a certain openness or ambiguity, and it is in that sense the opposite to command driven interaction as the one we see in e.g. Google Voice Search or Apples Siri today. As we learned through our experimentation, using Bluetooth or any wireless outside our own range of perceivable communication would result in closed or broken communication. The lesson that we learned was that situated close range communication like using IR made it both perceivable and responsive since the communicative range more closely matched the robotic artifacts' range of physical interaction with one and another.

7

Conclusions

In this thesis I have reviewed and reflected upon my own research in order to build up an argument for how to conduct research in today's HCI landscape by making and using research prototypes in an explorative agenda. The procedure has been to flesh out what a tinkering attitude could offer and more importantly what it means in terms of interaction design. I have showed that tinkering is about exploring possibilities given by materials and affordances in a playful way. To make this argument, the thesis brings up different aspects of what constitutes as knowledge. By doing a review of some related work, mainly within the HCI-field and interaction design, I have showed a few emerging areas where research is not settled and where a tinkering attitude may play a role. By then looking at the related work I came to realize that tacit knowledge is captured in the body and that tinkering with materials as an attitude, *an intentional collective set of activities*, sets this knowledge in motion – in a way that could be seen as akin to *thinking* with materials.

To back up this endeavour I have presented parts of my own research within interaction design by looking at design processes, methods, research contributions and practical work. In particular I draw from the parts of my work that are connected to studying, designing and building everyday robotic artifacts. In the introduction I posed the following three governing research questions:

1. How does tinkering manifest itself as a practice when conducting research on interactive technology?
2. How can studies of real world interaction with robotic artifacts inform tinkering practices with interactive materials?
3. How does the tinkering attitude relate to studies and design in HCI and interaction design research?

What I have done at a glance is to review a few existing processes and methods in HCI and interaction design in order to find out where the more hands on work involving interactive materials takes place. Furthermore, the second chapter brings up a few directions where the research questions may play a role. Secondly, I have given several examples to back up this reasoning from my own research through studies, interventions, designs and crafted artifacts. The first research question is answered by looking at and discussing mainly my own process of engaging and fighting with interactive materials. The second research question is answered by looking at how the studies have informed this design process. Thirdly, I have outlined a theoretical reasoning behind introducing tinkering as an attitude and positioned it within HCI and interaction design side by side with studies and design. This is also the answer to the third research question. The governing philosophical rationale for this work is to more fully be able to make articulations, and facilitate knowledge-induced strengthening of an attitude or research question, as part of the knowledge production process with respect to research. With that said, tinkering will neither replace design or on its own motivate the need for conducting a-priori studies. It is implied that we as researchers carefully challenge and critically reflect upon our attitudes as a way of moving forward. It might even be that our obsession with artifacts and technology are severely skewed in the first place, and that several contrasting studies must be made in order to account for such issues.

What then is a long-lasting research implication of all this? In my view research is about articulation and looking at my work presented here in this thesis, the work that has the strongest sense of conceptual clarity is ActDresses. Secondly, if research is about articulation as a knowledge-induced strengthening of an attitude or research question then such articulations should be manifested, at least partly, as the presentation or demonstration of an interactive artifact. From this perspective interaction design appears to shift towards more grounded attitudes in terms of tinkering and a kind of re-evaluation of what it means to craft interactive artifacts and technology demonstrators in research. Interestingly, in my case this insight comes from looking at robotic artifacts such as the Glowbots, which are in a sense embodied, situated and move about in addition to being interactive. That is why I argue for being open towards this diversity of attitudes in HCI and interaction design research and at the same time why fields related to robotics and human robot interaction desperately need our perspective and insights.

7.1 Tinkering a Future of Robotic Artifacts

When will people have lots of robotic artifacts around? First of all, society as a whole will have to reconsider the role of such artifacts and ground our modern needs with what the promise of this technology could potentially offer. We must become aware that our needs and drives are constantly changing and yesterday's call for robotic helpers may be either supplanted by another technology or simply remain a modern 'myth'. In the slightly naïve analogue vision, common robots would be our butlers taking care of various chores in our homes. One example would be the incrementally advanced ascendants of Roomba – the robotic vacuum cleaner. In contrast, my own interpretation is that in the forecasted digitalized vision they are highly connected devices made of robotic materials that by motion and physical presence amplify our experience of our own already digitalized environments. To consumers this will appear a bit like magic, to have reactive or responsive sentient things in our environments, firmly conducting simple tasks like providing us with stable wireless internet connectivity or making sure that we elegantly yet subtly become aware of our untapped capabilities as humans. The tinkering aspect however is a main driver for what will make such things engaging. Users will be able to assemble and configure their own little robotic artifacts that are part of everyday playful activities, "games" or chores. In other words, engaging, playful, surprising yet grounded, meaningful and empowering subtle interaction that progressively enriches our lives.

Bibliography

BARDZELL, J. AND BARDZELL, S., 2011. Pleasure is your birthright: digitally enabled designer sex toys as a case of third-wave HCI. In *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*. Vancouver, BC, Canada: ACM Press, p. 257.

BARONCHELLI, A., DALL'ASTA, L., BARRAT, A. AND LORETO, V., 2005. Topology Induced Coarsening in Language Games. *Phys. Rev. E 73*.

BENFORD, S., GREENHALGH, C., GIANNACHI, G., WALKER, B., MARSHALL, J. AND RODDEN, T., 2012. Uncomfortable interactions. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. Austin, Texas, USA: ACM Press, p. 2005.

BENTLEY, R. ET AL., 1992. Ethnographically-informed systems design for air traffic control. In *Proceedings of the 1992 ACM conference on Computer-supported cooperative work - CSCW '92*. Toronto, Ontario, Canada: ACM Press, pp. 123–129.

BLACKWELL, A., 2006. Gender in domestic programming: From bricolage to séances d'essayage. In *Presentation at CHI 2006 workshop on End User Software Engineering*.

BLEVIS, E., 2007. Sustainable interaction design: invention & disposal, renewal & reuse. In *Proceedings of the 2007 ACM conference on Human Factors in Computing Systems (CHI' 07)*. San Jose, California, USA: ACM, pp. 503–512.

BOYARSKI, D. AND BUCHANAN, R., 1994. Computers and communication design: exploring the rhetoric of HCI. *interactions*, 1(2), pp.25–35.

BRAND, S., 1988. *The Media Lab: Inventing the Future at M. I. T.*, Penguin Books.

BROWN, B., REEVES, S. AND SHERWOOD, S., 2011. Into the wild: challenges and opportunities for field trial methods. In *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*. Vancouver, BC, Canada: ACM Press, p. 1657.

BUECHLEY, L., EISENBERG, M., CATCHEN, J. AND CROCKETT, A., 2008. The LilyPad Arduino: using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. In *Proceedings of the 2008 ACM conference on Human Factors in Computing Systems (CHI' 08)*. Florence, Italy: ACM, pp. 423–432.

BUTLER, J., 2006. *Gender Trouble: Feminism and the Subversion of Identity (Routledge Classics)*, Routledge.

BUXTON, B., 2007. *Sketching User Experiences: Getting the Design Right and the Right Design*, Morgan Kaufmann.

CANDY, L., EDMONDS, E. AND ASCOTT, R., 2012. *Interacting: Art, Research and the Creative Practitioner*, Libri Publishing.

CRABTREE, A., 2004. Taking technomethodology seriously: hybrid change in the ethnomethodology–design relationship. *European Journal of Information Systems*, 13(3), pp.195–209.

CRABTREE, A., BENFORD, S., GREENHALGH, C., TENNENT, P., CHALMERS, M. AND BROWN, B., 2006. Supporting ethnographic studies of ubiquitous computing in the wild. In *Proceedings of the 6th ACM conference on Designing Interactive systems - DIS '06*. University Park, PA, USA: ACM Press, p. 60.

CRAMER, H. AND BÜTTNER, S., 2011. Things that tweet, check-in and are befriended. In *Proceedings of the 6th international conference on Human-robot interaction - HRI '11*. Lausanne, Switzerland: ACM Press, p. 125.

CRAWFORD, M.B., 2011. *The Case for Working with Your Hands, Or, Why Office Work Is Bad for Us and Fixing Things Feels Good*, Penguin Viking.

CROSS, N., 2010. *Designerly Ways of Knowing*, Springer.

DEWEY, J., 1934. *Art as Experience*, the berkley publishing group.

DOURISH, P., 2004. *Where the Action Is: The Foundations of Embodied Interaction* New editio., The MIT Press.

ENGLISH, W.K., ENGELBART, D.C. AND BERMAN, M.L., 1967. Display-Selection Techniques for Text Manipulation. *IEEE Transactions on Human Factors in Electronics*, HFE-8(1), pp.5–15.

ERICKSON, J., 2008. *Hacking: The Art of Exploitation, 2nd Edition*, No Starch Press.

ESBJÖRNSSON, M., JUHLIN, O. AND ÖSTERGREN, M., 2004. Traffic encounters and Hocman: Associating motorcycle ethnography with design. *Personal and Ubiquitous Computing*, 8(2), pp.92–99.

FERNAEUS, Y., 2009. Human action and experience as basis for the design and study of robotic artefacts. In *RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, pp. 522–527.

FERNAEUS, Y., HÅKANSSON, M., JACOBSSON, M. AND LJUNGBLAD, S., 2010. How do you play with a robotic toy animal?: a long-term study of Pleo. In *Proceedings of the 9th International Conference on Interaction Design and Children (IDC '10)*. Barcelona, Spain: ACM, pp. 39–48.

FERNAEUS, Y., JONSSON, M. AND THOLANDER, J., 2012. Revisiting the jacquard loom. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. Austin, Texas, USA: ACM Press, p. 1593.

FERNAEUS, Y. AND SUNDSTRÖM, P., 2012. The material move how materials matter in interaction design research. In *Proceedings of the Designing Interactive Systems Conference on - DIS '12*. Newcastle Upon Tyne, United Kingdom: ACM Press, p. 486.

FEYNMAN, R.P., 1974. Cargo Cult Science. *Engineering and Science*.

FLOREANO, D., MITRI, S., MAGNENAT, S. AND KELLER, L., 2007. Evolutionary conditions for the emergence of communication in robots. *Current Biology*, 17(6), pp.514–519.

FRAYLING, C., 2011. *On Craftsmanship: Towards a New Bauhaus (Oberon Masters Series)*, Oberon Books.

FRENS, J. AND HENGEVELD, B., 2013. To Make Is To Grasp. In *5th International Congress of International Association of Societies of Design Research (IASDR)*.

FUCHSBERGER, V., MURER, M. AND TSCHELIGI, M., 2013. Materials, materiality, and media. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. Paris, France: ACM Press, p. 2853.

FÄLLMAN, D., 2003. *In Romance with the Materials of Mobile Interaction: A Phenomenological Approach to the Design of Mobile Information Technology*, Umeå University.

GARDINER, M. AND GARDINER, R., 2012. The functional aesthetic of folding, self-similar interactions. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction - TEI '12*. Kingston, Ontario, Canada: ACM Press, p. 19.

GAVER, B., DUNNE, T. AND PACENTI, E., 1999. Design: Cultural probes. *interactions*, 6(1), pp.21–29.

GAVER, W., 2007. Cultural commentators: Non-native interpretations as resources for polyphonic assessment. *International Journal of Human-Computer Studies*, 65(4), pp.292–305.

GAVER, W., BEAVER, J. AND BENFORD, S., 2003. Ambiguity as a resource for design. In *Proceedings of the conference on Human factors in computing systems - CHI '03*. Ft. Lauderdale, Florida, USA: ACM Press, p. 233.

GAVER, W., BOWERS, J., KERRIDGE, T., BOUCHER, A. AND JARVIS, N., 2009. Anatomy of a failure: how we knew when our design went wrong, and what we learned from it. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09*. Boston, MA, USA: ACM Press, p. 2213.

GEMPERLE, F., DISALVO, C., FORLIZZI, J. AND YONKERS, W., 2003. The Hug: a new form for communication. In *Proceedings of the 2003 conference on Designing for user experiences - DUX '03*. San Francisco, California, USA: ACM Press, p. 1.

GLASER, B.G. AND STRAUSS, A., 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Aldine Transaction.

HINE, C.M., 2000. *Virtual Ethnography* 1st ed., Sage Publications Ltd.

HOLMQUIST, L.E., 2012. *Grounded Innovation: Strategies for Creating Digital Products*, Morgan Kaufmann.

HOLMQUIST, L.E., 2005. Prototyping. *interactions*, 12(2), p.48.

HOLMQUIST, L.E., 2006. Sketching in hardware. *interactions*, 13(1), p.47.

HORNECKER, E., 2012. Beyond affordance: tangibles' hybrid nature. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction - TEI '12*. Kingston, Ontario, Canada: ACM Press, p. 175.

HUTCHINS, E., 1996. *Cognition in the Wild*, A Bradford Book.

HUTCHINSON, H. ET AL., 2003. Technology probes: inspiring design for and with families. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*. Ft. Lauderdale, Florida, USA: ACM, pp. 17–24.

HÅKANSSON, M., GAYE, L., LJUNGBLAD, S. AND HOLMQUIST, L.E., 2006. More than meets the eye: an exploratory study of context photography. In *Proceedings of the 4th Nordic conference on Human-computer interaction (NordiCHI '06)*. Oslo, Norway: ACM, pp. 262–271.

HÖÖK, K. AND LÖWGREN, J., 2012. Strong concepts. *ACM Transactions on Computer-Human Interaction*, 19(3), pp.1–18.

HÖÖK, K., STÅHL, A., SUNDSTRÖM, P. AND LAAKSOLAAHTI, J., 2008. Interactional empowerment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08)*. Florence, Italy: ACM, pp. 647–656.

INGOLD, T., 2006. Walking the Plank : Meditations on a Process of Skill. In *Defining Technological Literacy: Towards an Epistemological Framework*. Palgrave Macmillan.

ISAACSON, W., 2011. *Steve Jobs*, Simon & Schuster.

ITO, M. ET AL., 2009. *Hanging Out, Messing Around, and Geeking Out: Kids Living and Learning with New Media*, The MIT Press.

JACOBSSON, M., FERNAEUS, Y. AND NYLANDER, S., 2012. Mobile ActDresses: programming mobile devices by accessorizing. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems*. Austin, Texas, USA, pp. 1071–1071–1074–1074.

JACOBSSON, M., FERNAEUS, Y. AND TIEBEN, R., 2010. The look, the feel and the action. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS '10*. Aarhus, Denmark: ACM Press, p. 132.

JACOBSSON, M. AND NYLANDER, S., 2012. Always-On + Adoption – a method for longitudinal studies. In *CHI 2012 Workshop on Theories, methods and case studies of longitudinal HCI research*. Austin, Texas: ACM.

JOHNSON, J. ET AL., 1989. The Xerox Star: a retrospective. *Computer*, 22(9), pp.11–26.

JOHNSON, S., 2001. *Emergence : the connected lives of ants, brains, cities, and software*, New York, NY: Scribner.

JONES, J.C., 1992. *Design Methods*, Wiley.

KADAVY, D., 2011. *Design for Hackers: Reverse Engineering Beauty*, Wiley.

KLEMMER, S.R., HARTMANN, B. AND TAKAYAMA, L., 2006. How bodies matter: five themes for interaction design. In *Proceedings of the 6th conference on Designing Interactive systems (DIS '06)*. University Park, PA, USA: ACM, pp. 140–149.

KOSKINEN, I., ZIMMERMAN, J., BINDER, T., REDSTRÖM, J. AND WENSVEEN, S., 2011. *Design Research Through Practice: From the Lab, Field, and Showroom*, San Francisco, CA, USA: Morgan Kaufmann Publishers Inc.

LATOUR, B., 1988. *Science in Action: How to Follow Scientists and Engineers Through Society*, Harvard University Press.

LAUREL, B., 1993. *Computers as Theatre*, Addison-Wesley Professional.

LAZAR, J., FENG, J.H. AND HOCHHEISER, H., 2010. *Research Methods in Human-Computer Interaction*, Wiley.

LÉVI-STRAUSS, C., 1966. *The Savage Mind (The Nature of Human Society Series)*, The University Of Chicago Press.

LEVY, S., 2010. *Hackers: Heroes of the Computer Revolution - 25th Anniversary Edition*, O'Reilly Media.

LJUNGBLAD, S., 2008. *Beyond Users : Grounding Technology in Experience*. Stockholm University.

LJUNGBLAD, S. AND HOLMQUIST, L.E., 2007. Transfer scenarios: grounding innovation with marginal practices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*. San Jose, California, USA: ACM, pp. 737–746.

LJUNGBLAD, S., WALTER, K., JACOBSSON, M. AND HOLMQUIST, L.E., 2006. Designing Personal Embodied Agents with Personas. In *ROMAN 2006 - The 15th IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, pp. 575–580.

LOURIDAS, P., 1999. Design as bricolage: anthropology meets design thinking. *Design Studies*, 20(6), pp.517–535.

LYOTARD, J.-F., 1984. *The Postmodern Condition: A Report on Knowledge (Theory and History of Literature, Volume 10)*, University Of Minnesota Press.

LÖWGREN, J. AND STOLTERMAN, E., 2007. *Thoughtful Interaction Design: A Design Perspective on Information Technology*, The MIT Press.

MCCARTHY, J. AND WRIGHT, P., 2004. *Technology as Experience*, The MIT Press.

MOGGRIDGE, B., 2007. *Designing Interactions*, The MIT Press.

NARDI, B.A., SCHIANO, D.J., GUMBRECHT, M. AND SWARTZ, L., 2004. Why we blog. *Communications of the ACM*, 47(12), pp.41–46.

PAEPCKE, S. AND TAKAYAMA, L., 2010. Judging a bot by its cover: an experiment on expectation setting for personal robots. In *Proceedings of the 5th ACM/IEEE international conference on Human-robot interaction (HRI '10)*. Osaka, Japan: ACM, pp. 45–52.

PAPERT, S.A., 1993. *Mindstorms: Children, Computers, And Powerful Ideas* 2nd ed., Basic Books.

PFEIFER, R. AND BONGARD, J., 2007. *How the body shapes the way we think : a new view of intelligence*, Cambridge, Mass.: MIT Press.

RAFFLE, H.S., PARKES, A.J. AND ISHII, H., 2004. Topobo: a constructive assembly system with kinetic memory. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '04)*. Vienna, Austria: ACM, pp. 647–654.

REDSTRÖM, J., 2001. *Designing Everyday Computational Things*. Göteborgs Universitet.

REEVES, B. AND NASS, C., 2003. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*, Center for the Study of Language and Inf.

RESNICK, M. AND SILVERMAN, B., 2005. Some reflections on designing construction kits for kids. In *Proceeding of the 2005 conference on Interaction design and children - IDC '05*. Boulder, Colorado, USA: ACM Press, pp. 117–122.

ROGERS, Y., 2012. *HCI Theory: Classical, Modern, and Contemporary*, Morgan & Claypool Publishers.

ROSNER, D. AND BEAN, J., 2009. Learning from IKEA hacking: i'm not one to decoupage a tabletop and call it a day. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09*. Boston, MA, USA: ACM Press, p. 419.

ROSNER, D. AND TAYLOR, A., 2011. Antiquarian answers. In *Proceedings of the 2011 annual conference on Human factors in*

computing systems - CHI '11. Vancouver, BC, Canada: ACM Press, p. 2665.

RYOKAI, K., LEE, M.J. AND BREITBART, J.M., 2009. Multimodal programming environment for kids: a "thought bubble" interface for the Pleo robotic character. In *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems - CHI EA '09*. Boston, MA, USA: ACM Press, p. 4483.

SAFFER, D., 2009. *Designing for Interaction: Creating Innovative Applications and Devices (2nd Edition)*, New Riders.

SCHIPHORST, T., 2009. soft(n): toward a somaesthetics of touch. In *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems - CHI EA '09*. Boston, MA, USA: ACM, pp. 2427–2438.

SCHÖN, D.A., 1984. *The Reflective Practitioner: How Professionals Think In Action* 1st ed., New York: Basic Books.

SEGURA, E.M., CRAMER, H., GOMES, P.F., NYLANDER, S. AND PAIVA, A., 2012. Revive!: reactions to migration between different embodiments when playing with robotic pets. In *Proceedings of the 11th International Conference on Interaction Design and Children - IDC '12*. Bremen, Germany: ACM Press, p. 88.

SHEETS-JOHNSTONE, M., 2009. *The Corporeal Turn: An Interdisciplinary Reader*, Imprint Academic.

SHUSTERMAN, R., 2008. *Body Consciousness: A Philosophy of Mindfulness and Somaesthetics*, Cambridge University Press.

SILVERMAN, D., 2000. *Doing Qualitative Research: A Practical Handbook*, SAGE Publications Ltd.

SIMON, H.A., 1996. *The Sciences of the Artificial - 3rd Edition*, The MIT Press.

STEELS, L., 1999. *The Talking Heads Experiment*, Laboratorium.

STOLTERMAN, E., 1999. The design of information systems: parti, formats and sketching. *Information Systems Journal*, 9(1), pp.3–20.

STROGATZ, S.H., 2003. *Sync : the emerging science of spontaneous order*, New York: Hyperion.

SUCHMAN, L.A., 1987. *Plans and Situated Actions: The Problem of Human-Machine Communication* 2nd ed., Cambridge University Press.

SUNDSTRÖM, P., 2010. *Designing Affective Loop Experiences*. Departmen of Computer and Systems Sciences, Stockholm University.

SUNDSTRÖM, P., STÅHL, A. AND HÖÖK, K., 2005. eMoto: affectively involving both body and mind. In *CHI '05 Extended Abstracts on Human Factors in Computing*. Portland, OR, USA: ACM, pp. 2005–2008.

SUNDSTRÖM, P., TAYLOR, A.S. AND O'HARA, K., 2011. Sketching in software and hardware Bluetooth as a design material. In *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services - MobileHCI '11*. Stockholm, Sweden: ACM Press, p. 405.

SUNG, J., GUO, L. AND GRINTER, R., 2007. My Roomba Is Rambo: Intimate Home Appliances. In *Proceedings of the 9th international conference on Ubiquitous computing (UbiComp '07)*. Innsbruck, Austria, pp. 145–162.

SZATHMÁRY, E. ET AL., 2007. *Emergence of Communication and Language* C. Lyon, C. L. Nehaniv, & A. Cangelosi, eds., London: Springer London.

TANENBAUM, J., TANENBAUM, K. AND WAKKARY, R., 2012. Steampunk as design fiction. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. Austin, Texas, USA: ACM Press, p. 1583.

TANENBAUM, J., WILLIAMS, A., DESJARDINS, A. AND TANENBAUM, K., 2013. Democratizing technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. Paris, France: ACM Press, p. 2603.

TAYLOR, A., 2009. Machine intelligence. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI '09*. Boston, MA, USA: ACM Press, pp. 2109–2118.

TAYLOR, A., WYCHE, S. AND KAYE, J. "JOFISH," 2008. Pottering by design. In *Proceedings of the 5th Nordic conference on Human-computer interaction building bridges - NordiCHI '08*. Lund, Sweden: ACM Press, p. 363.

THOLANDER, J. AND JACOBSSON, M., 2013. Ecofriends. *interactions*, 20(1), p.58.

THOLANDER, J., NORMARK, M. AND ROSSITTO, C., 2012. Understanding agency in interaction design materials. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. Austin, Texas, USA: ACM Press, p. 2499.

UEKI, A., KAMATA, M. AND INAKAGE, M., 2007. Tabby: designing of coexisting entertainment content in everyday life by expanding the design of furniture. In *Proceedings of the international conference on Advances in computer entertainment technology - ACE '07*. Salzburg, Austria: ACM Press, pp. 72–78.

VALLGÅRDA, A. AND SOKOLER, T., 2009. A material focus: exploring properties of computational composites. In *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems - CHI EA '09*. Boston, MA, USA: ACM Press, p. 4147.

WEILENMANN, A. AND JUHLIN, O., 2011. Understanding people and animals: the use of a positioning system in ordinary human-canine interaction. In *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*. Vancouver, BC, Canada: ACM Press, p. 2631.

WEISER, M., 1991. The Computer for the Twenty-First Century. *Scientific American*, pp.94–10.

WOOD, J.T., 2005. *Communication Mosaics: An Introduction to the Field of Communication*, Wadsworth Publishing.

WOZNIAK, S., 2007. *iWoz: Computer Geek to Cult Icon: How I Invented the Personal Computer, Co-Founded Apple, and Had Fun Doing It*, W. W. Norton & Company.

WROBLEWSKI, D.A., 1991. The construction of human-computer interfaces considered as a craft. In *Taking software design seriously*. San Diego, California: Academic Press Professional, Inc, pp. 1–19.

ZIMMERMAN, J., FORLIZZI, J. AND EVENSON, S., 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '07*. San Jose, California, USA: ACM, pp. 493–502.

Part 2

The Papers

Paper I

GlowBots - Designing and Implementing Engaging Human Robot Interaction

Jacobsson, M., Fernaeus, Y., and Holmquist, L.E. GlowBots: Designing and Implementing Engaging Human Robot Interaction. Journal of Physical Agents, 2 (2), pp. 51-60, 2008.

GlowBots: Designing and Implementing Engaging Human-Robot Interaction

M. Jacobsson, Y. Fernaeus and L. E. Holmquist

***Abstract*—GlowBots are small tangible, communicating and interactive robots that show eye-catching visual patterns on a round LED display. This paper details the development of the GlowBots from the early user-oriented design phase, through hardware and software development and onto preliminary user studies. In the design phase we outlined a robot application based on a study of how owners relate with unusual pets, such as snakes and lizards. This led to an application concept of a set of "hobby robots" which would communicate with each other and the user through dynamic patterns. Based on these requirements, we developed a LED display called see-Puck, which together with an open robot platform was used for the GlowBots application itself. One particular issue is dealing with energy consumption problems, as resources in embedded systems often limit the potential time for user interaction. We conclude with a report on early user experiences from demonstrating GlowBots and a preliminary user study in a home environment as well as remarks about future directions.**

***Index Terms*—GlowBots, Human Robot Interaction, Tangible Interfaces, Ubiquitous Computing.**

I. Introduction

THE ROBOTS are coming, but are they here to stay? [1] Human-robot interaction is a rapidly expanding area, with many new journals and workshops appearing in recent years. However, in order for robots to truly become a part of our everyday life they should provide a meaningful and sustainable presence as a result of interaction with other robots, humans, pets or devices. Seen from this perspective, everyday robotics shares a strong synergy with the vision of ubiquitous computing [2], and tangible computing [3], where technology tends to become more and more intimate [4]. The main difference from these emerging interaction paradigms is that robots manifest themselves as mobile embodied units that can affect the world physically.

In the European project *ECAgents – Embodied Communicating Agents*, [5] we have been actively working to expand the boundaries of what interaction with robots might be like in the future. Mundane labor such as vacuuming, cleaning or other practically oriented chores are merely a subset of existing needs where robots could play a role [6]. From a design point of view, it is also important to use "out of the box thinking", as we might miss out on important areas and interaction modes that are difficult to imagine before they exist.

Mattias Jacobsson, Ylva Fernaeus and Lars Erik Holmquist are with the Swedish Institute of Computer Science.
E-mail: majac@sics.se, ylva@sics.se, leh@sics.se

As a way to stimulate new ways of thinking about robots, we first gathered researchers in the field for a two days workshop called "Designing Robots for Everyday Life" to brainstorm about innovative new robotic design spaces [7]. As a direct outcome from this we got a number of robotic mockup scenarios, for instance, robot plants that would re-arrange themselves in order to guide queues in a complicated environment such as an airport, or the listening psychologist, bean-bag shaped robot that would attach itself to a car's rear mirror. But more interesting than these design suggestions was that we learned that designing robotic applications often results in far-fetched expectations and visions of problem oriented scenarios – even though we did all we could to be as open minded as possible.

To further explore how robotic appliances could be designed, we started to experiment with a new design method, *transfer scenarios* [8]. In this process we sought ways of grounding our designs in existing practices where relationship, autonomy and embodiment were essential [9]. We looked for an existing human practice that could be used as inspiration and guidance for the design of new forms of robots. Eventually, we decided to study owners of unusual pets, such as snakes, spiders and lizards as inspiration for designs. One of the results pointed towards an application where robots are engaging, but not overly personal, similar to a dynamic, mobile and visually appealing trading card game collection.



Fig. 1. Exhibition visitors playing with a swarm of GlowBots.

Following the resulting design implications we constructed a round LED-display that could extend an open educational robot platform, the *e-Puck*. The result was a top mounted extension module that we swiftly named *see-Puck* [10]. We then also needed to make several energy-optimization changes to the e-Puck firmware in order to

cope with sustainability and stability problems. The resulting application is called *GlowBots* and consists of the assembled hardware together with software for infrared communication and animated morphing patterns (Fig. 1).

Not only did this project begin with a study, but we will also conclude this report with a preliminary user study conducted in a real home environment. In the discussion we will also compare findings and comment on the overall design process.

II. Background and related work

What would be the design requirements for a more subtle robot technology, one which could be found in the intersection between robotics and ubiquitous computing - robots that quietly find their ways into our everyday life and eventually become an integral part of it? Today new robots are appearing almost every day, so first we would like to recapture some historical points and put our standpoint in contextual highlights.

People have an underlying assumption that robots are socially capable [11]; hence they are quite biased when it comes to their image of a robot. The word itself (although not the concept) originates from Czech ”robota”, and was popularized through the theatric play by Karel Čapek called ”Rossum’s Universal Robots” (R.U.R) in 1921. The word at that time simply meant work or compulsive labor, but a general definition once given in the Merriam-Webster dictionary centuries later still reflected this common perception:

”An automatic apparatus or device that performs functions ordinarily ascribed to human being or operates with what appears to be almost human intelligence”.

It may be a pity that we did not catch up on the Japanese older and more humble notion similar to *automaton*. The profound cultural differences to western attitudes could be seen as in contrast to the Japanese compassion for robotic characters like the *Mighty Atom* (Astro Boy in the US) which is more emotionally oriented rather than labor oriented.

Today, the word robot still represents a governing descriptive purpose, but we also have a flora of words in the subsequent field of robotics that captures more fine tuned distinctions, e.g. android, humanoid, mecha, cyborg, but which all still inherits much of the original anthropomorphic connotations. Another example, the *Robot Fish* [12], is designed to be a copy of a common fish in terms of looks, properties and behavior. This approach is common, especially from a robotic toys perspective as anthropomorphic values are added to the designs as a mean to extend interaction. To mention just a few of these commercial examples of robotic pets we have Aibo, RoboPanda, Furby [13] and now also Pleo [14].

Masahiro Mori’s *uncanny valley* is an example of what happens when more subtle expectations do not correspond to the perceived input in human-robot interaction [15]. Instead of getting relaxed and enjoying the anthropomorphic features the hypothesis states that we unconsciously start to focus on the dissimilarities which in the end results in an uneasy repulsive reaction. In relation to this theory we notice that anthropomorphism and zoomorphism play an important role in setting the levels of expectations, and by being aware, and taking control of these insights would be a key component in taming robotic design.

As a consequence we sometimes instead prefer to use the term ”embodied agents” to describe a more general and open view of robots that moves the focus away from traditionally biased anthropomorphic preconceptions [7]. Other researchers prefer the term ”robotic product” to denote mechanically based interactive applications [16]. Examples of robots intended for labor oriented work include the *Roomba* vacuum cleaner [17], the *Artemis* guard robot [18] or the *Minerva* museum tour guide robot [19].

In a sense our work is the opposite of the above approaches; we have absolutely no intention to make a new dog or cat, or replace work already performed by humans. Several researchers are also pursuing such alternative views of robots. For instance, *The Hug* [20] is an example of a robot that does not look like anything biological, but instead reminiscent of an artifact that can be found in an everyday setting, in this case a pillow. It does not have any sophisticated communication capabilities like speech, or complex behavior like walking. Instead it appeals to our most primitive need of affection. Yet another example of a design that expresses life-like qualities but also integrity is *Tabby* [21] – a simple interactive furniture demonstrator. Our work is thus similar in that we also move our focus away from the ordinary expectancies of robotics and at the same time avoid elevated expectations.

Another relevant study looked at peoples’ relationships with everyday artifacts, such as computers, corkscrews and notebooks [22]. It points out that a notebook will increase in perceived value over time as it is filled with notes and sketches, while e.g. fashionable clothes value actually decreases as it becomes increasingly obsolete. We found such observations inspirational in regards to where we should position ourselves and think about future robot applications.

III. Design Method

One of the problems of designing novel forms of robots could be the lack of perspective outside that of the experts and scientist who are already designing robots. We have taken inspiration from the field of human-computer interaction to find methods that infer design implications either directly from studies of users or by extrapolating from known human needs and interests. One such method is to use fictive representative characters called *personas* [23].

We started by seeking out possible sources where established interaction and engagement are essential properties and autonomy plays a significant role. From earlier studies we knew that looking at practices that lies down the long tail of practices, so called *marginal practices*, tend to turn our minds away from the established discourse [8]. When looking for a suitable practice to engage with, we were interested in people who were interacting with living things – but not necessarily commonplace pets, such as cats and dogs, since such an interaction has already been proven hard to capture in a robot. We decided to study and interview owners of pets with fairly low cognitive capabilities and unusual affordances for interaction, e.g.



Fig. 2. When designing the GlowBots we took inspiration from the relationship people develop with unusual pets such as spiders.

spiders, lizards and snakes (Fig. 2). In total we conducted ten interviews with six male and four female participants. Three of the interviews were made face-to-face and the rest by phone due to logistic restrictions. Typical questions during the interviews would be about why they were interested in a particular pet, what the pet does, what they do together and how they could tell the mood of their pet.

We then transcribed the answers from the interviews and cut up quotes and wrote them down onto Post-its. From the scrambled Post-its we then tinkered and linked together different properties and intrinsic characteristics in various constellations. After iterating this process several times four distinct clusters started to emerge representing the rough outline for the four personas (Fig. 3). In one of the affinity clusters we could then read several statements without any apparent contradiction e.g.:

- *He does not pet his pets, nor is he interested in different personalities of the pets.*
- *He is interested in breeding his pets in order to create nice patterns.*
- *He enjoys reading about his pets and often meets up with people that have similar pets, to look at or even exchange pets.*



Fig. 3. a.) Selected data was taken out as notes from the transcribed data. b.) The notes where clustered, each being a starting-point for one persona.

The next step was to create the personas from these clusters, which are descriptive scenarios of imagined users. The complete scenario was then created by filling in general fictive ”glue data”, connecting such different quotes into meaningful coherent descriptions. In total we created four such personas [9] but in this case we will focus only on the persona that is relevant in the context of GlowBots.

We then named the persona, which is a powerful way of building a mental image around a common reference. This particular persona goes by the name Nadim. At this stage the scenario would still refer to a relationship with pets; however, by simply changing the word ”pet” to ”agent”, we *transferred* the scenarios to our target domain [8]:

*Nadim is 32-years old and works as a network engineer, living alone in a two-bedroom flat in a small town. He has always had a great interest in collecting and exploring various things, and as he got older he became fascinated in having **agents** as a hobby. Nadim finds it exciting to try to understand their behavior and sees them as a research area where there is always something more to learn. He enjoys watching them communicating to each other and changing their patterns. Every single **agent** has its own specific colour pattern, and when it is put close to another **agent** they both start to change their individual patterns. The surrounding light, sounds and movement etc, also affects their patterns. The changes are slow, and sometimes it takes several days until it Nadim can see how an **agent** is reacting. The challenge is to avoid results that are bland or unattractive. Nadim is quite good in developing **agents** with unique interesting patterns, and he puts pictures of the **agents** on his website. The number of **agents** Nadim owns varies, and he has never bothered to give them any names. He likes to read everything that crosses his path; Internet pages and magazines. He also frequently visits other sites to compare patterns and sometimes he writes in a forum for people with the same type of **agents**. They sometimes also meet to let their **agents** affect each other's patterns.*

This scenario now expresses what a potential user of an autonomous agent would look like. The final step in this process includes matching technology with the scenarios to sketch out real designs:

The agents can evolve interesting patterns over time, but it is a lengthy process and might not always succeed. Agents will be equipped with a color display on their back and have one or more sensors for light, movement and sound. The sensing can be different for different agents. Each agent will have a unique color pattern, developed from meetings with other agents the environment it is in. By touching the agent in a particular way makes it possible to temporarily freeze a pattern. Achieving a nice pattern requires several agent-agent interactions and an attention to timing.

Based on this description we could then proceed with sketching and implement a rough first prototype.

IV. SEEPUCK DEVELOPMENT

Our design pointed towards some kind of visual interface as one of the central components. We also decided to base the project on an educational robot platform, the e-Puck, developed by Ecole Polytechnique Fédérale de Lausanne [24]. We looked for an existing display but found that all currently available displays had a rectangular shape, often needed backlight to be visible from a distance and prioritized resolution and color depth over cost. We decided to design a new display that fit our needs, and in particular one that had a shape that would fit on the round, roughly coffee-cup sized e-Puck. When designing the new platform, much effort was put into hardware and software design, keeping it simple, modular, obvious, cheap, energy efficient and robust.

A. Hardware

The see-Puck is designed to fit on top of the *e-Puck* robot and connect through a serial interface. We use the version 2.0 of the e-Puck, which features a number of sensors and

actuators including infrared (IR) proximity sensors, one camera, three microphones, a 3-axis accelerometer, loudspeaker, stepper motors, Bluetooth interface, a number of LEDs, a PIC microcontroller, and a twelve step mode-selector.



Fig. 4. The two printed circuit boards of the see-Puck module are mounted on top on an e-Puck.

The see-Puck display module (Fig. 4) consists of two printed circuit boards, one *controller board* and one *matrix board*, sandwiched together by two perpendicular connectors. This design ensures that the matrix board that holds all the LEDs can only be fitted in one way. The controller board (Fig. 5) holds its own microcontroller (Atmel ATmega8L) and firmware to handle higher level instructions from the e-Puck through a RS232 serial interface.

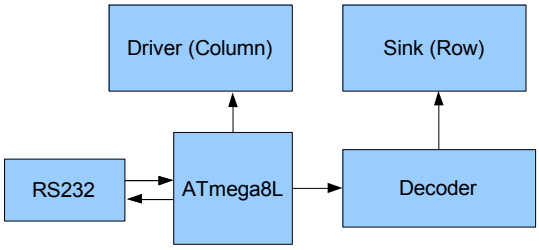


Fig. 5. Controller board overview with arrows indicating the flow of information. The driver sets a column high while the sink grounds one of the rows given by the decoder.

The matrix board holds 148 LEDs in a rounded 14 by 14 matrix. To keep the energy consumption down and also maximize light intensity we exploit a known, but often overlooked feature of the LEDs – the possibility to light them up using short rapid pulses of higher current. To the human eye the quickly flashing the LEDs will appear as a constant light. The gain is significantly lower total energy consumption, which is one of the most important factors when designing for devices that rely on batteries. Furthermore, flashing the LEDs is a perfect fit with the electronic design, since only one LED per column can be lit at a time.

B. Software

The software has two parts, one *library* for the e-Puck consisting of the higher level commands that are sent to the see-Puck module from the e-Puck and one *firmware* part for the microcontroller on the see-Puck controller board. The range of graphical commands available in the library represents the most basic ones e.g. *set a pixel*, *draw a line*, *draw a circle*, *shift screen*, etc. These commands often take arguments in form of coordinates and LED brightness. We also decided to make graphics double buffered, i.e. the actual drawing is done to one buffer while the other is shown, so that flickering in animations is kept at minimum.
The firmware consists of two interrupt-driven subsystems - the communication and the graphical subsystems, which run side by side parallel to a continuous main loop (Fig. 6).

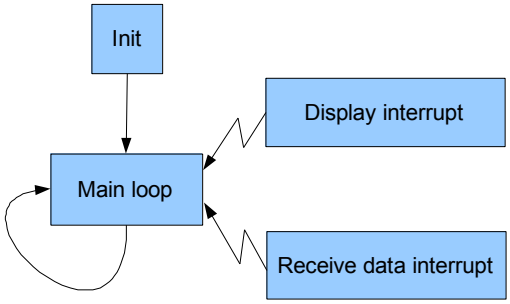


Fig. 6. See-Puck firmware schematic overview with two simple interrupts.

When the communication subsystem receives a byte over the UART (the serial interface on the microcontroller side), it calls the receive data interrupt. After checking the integrity of the message it gets stored into a ten level sized software implemented FIFO buffer shared with the graphics subsystem. At the end the receive interrupt is reset.
The graphics subsystem interrupt is timer-based and called about 60 times a second. When called it starts with getting a pointer to the current front buffer. It then cycles through each row sending a PWM (Pulse-Width Modulation) signal with a four bit resolution for each LED, representing the specified brightness.

The firmware starts with an initialization of the graphics subsystem. It then turns on all the LEDs for about a second before it initializes the communications subsystem and enters the main loop. The interruptable main loop then continuously checks the FIFO for new commands and executes them, preparing the back graphic buffer.

```
#include "e_see_puck_lib.h"

int main(void){
  int x = 7, y = 7, r = 4, c = BRIGHT;
  e_see_puck_init();
  e_see_puck_draw_circle(x,y,r,c);
  while(1){
    e_see_puck_swap_buffers();
    e_see_puck_copy_buffers(FRONT_TO_BACK);
    e_see_puck_hscroll(-1);
    //Waste some cycles here
  }
}
```

Fig. 7. An example program for the e-Puck using the standard graphics library developed for the see-Puck.

In the illustrative C-code example (Fig. 7) a circle is first drawn at the center of the back buffer. It then enters the main loop executing a buffer swap to make it visible. The front buffer is now copied onto the back buffer and scrolled one step horizontally (to the left) before next iteration. The final result is a circle that scrolls over the screen.

C. Energy Optimizations

When the see-Puck modules arrived from factory we measured the average power consumption for it to be in the range of 20 mA. During initial tests it all seemed fine until we started using more and more sensors and actuators. After deeper investigation we found out that the biggest issue was the stepper motors that at the time ran in the range of 200 mA. During power peaks such as sudden friction events e.g. running into an obstacle or another robot this would cause instability problems for the display or even the e-Puck. This forced us to soft-optimize some portions of the e-Puck libraries and to use PWM where possible. This trick worked out very efficiently for the stepper motors, which landed on an average of about 30 mA afterwards (no load). Similarly, all LED's on the e-Puck were also pulsed to save even more power.

V. GlowBots Development

Based on the see-Puck hardware, we then constructed an interactive application inspired by the Nadim persona. We had a total of 20 complete robots (e-Puck platform plus see-Puck display) which would allow for large groups of interacting robots. Here we will outline the steps involved creating the GlowBots demonstrator application from based on the design proposal and readied platform.

A. Visualizations

The idea with GlowBots was to let the users interact with an ever-changing set of robots, which would express themselves with dynamic patterns on the LED display. In the early proof-of-concept prototype we started out with Conway's Game of Life, a well known cellular automata example, to produce interesting dynamics on the display when the robots interact. Although it was relatively open-ended, it did not satisfactory convey the intended interaction. We then sought a way of displaying interesting shapes that could be semantically interpreted and that somehow would morph more intuitively as interaction took place. After a great deal of investigation we came to use analytical curves based on the super-formula equation [25], chosen for its richness of simple shapes. The resulting shapes can be anything from star, square, circle, egg, flower and any intermediate state in between (Fig. 8).

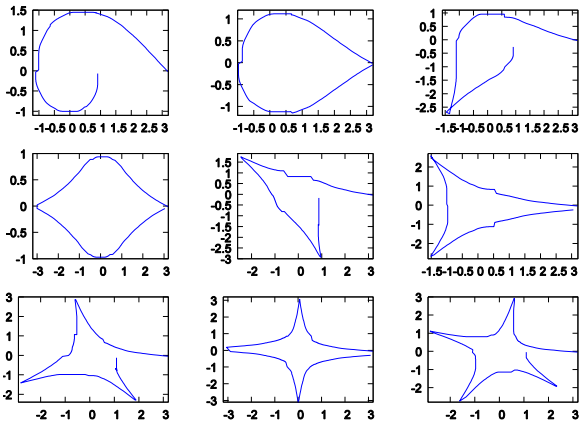


Fig. 8. Examples of shapes generated by the super-formula that would typically occur in the GlowBots application.

B. User Interaction

The user interaction stems from the developed persona description from the design step. Users interact with the robots directly, either by moving them around on the surface (to place a robot next to another with an interesting pattern) or by gently shaking them. If the user shakes the robot up and down this will encourage the pattern that the robot is currently displaying to become more dominant. If the user shakes the robot side to side, this will instead have the effect of making the robot more susceptible to be influenced by other patterns. Thus, while the users cannot directly create new patterns, they can indirectly influence the visuals by encouraging certain patterns and discouraging other. As two robots stand next to each other, they will start communicating and slowly converge to showing the same pattern, which will be a mix of both the original patterns. The effect is that of a slowly evolving, constantly surprising collection of a tangible autonomous robotic display.

From an application point of view, each GlowBot will communicate their respective parameterized internal states, including current motion and the shape visualized on the display. The robot-robot communication uses the infrared proximity sensors for broadcasting and receiving data. There are two important reasons for choosing IR over e.g. Bluetooth. First, since there are eight IR-sensors distributed around the robot, we can get a sense of directionality. Second and most important is the situatedness of the communication. The communication radius of IR is typically 10-15 cm, which means that only robots that are close to each other will communicate (Fig. 9).

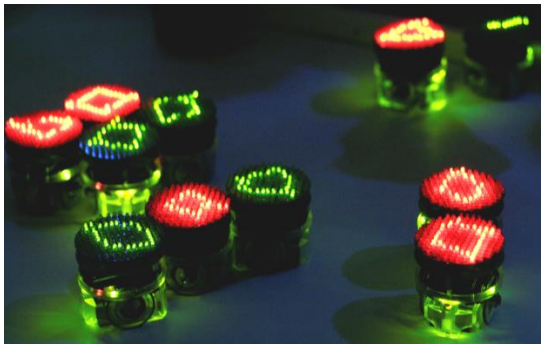


Fig. 9. A group of interacting robots that uses their patterns to attract users to play and interact with them.

VI. Demonstration Evaluation

GlowBots have been shown at several major venues such as SIGGRAPH Emerging Technologies [26] and WIRED NextFest, with a combined audience of over 60.000 people. At these settings, we had the opportunity to observe how the GlowBots demonstration was received by ordinary people. Rather than only having them for show, we encouraged people to come up and play with the GlowBots. Literally thousands of people have thus gotten hands-on experience, many of them school children from the Los Angeles area. Having this kind of demo was possible only due to the efforts made in energy consumption optimizations and carefully planned continuous maintenance during the exhibitions. It also helps to have a swarm of units so that the demo does not rely on a single unit.

As with big exhibitions like SIGGRAPH people come to see the latest news in technology, listen and ask questions about the presented material. In the end they usually end up with a flyer or brochure to take home and reflect upon. The one thing we really could expect in this type of setting is the brief experience based on very first contact that the visitors would have with our GlowBots as they stumbled into our presentation booth.

Based on informal observations of how users interact with the GlowBots in exhibition settings we noted that many users spontaneously thought that the display would react by touch, similar to a large press button. Since this had not yet been conceived of as a possible use, we soon realized that the robots were not robust enough for such treatment. We thus had to stabilize the robot platform so that even though the robots still did not work as push buttons, they would not break in case someone tried to use them as such.

At SIGGRAPH, we recorded several hours video of the demonstration as people stopped by and interacted with our GlowBots. When reviewing this material we saw that the complexity of the setting involving many moving glowing tangible artifacts, crude and developing use of speech and gesture made it an analysis problem. Also, the level of noise from surrounding demonstrators and the fact that we had used a hand camera resulted unfortunately in very poor sound coverage.

As a first step in the analysis we published a small video-clip, showing how a little girl, five to six years old, plays with GlowBots for several minutes, before her dad wants to leave [27]. From the look of her face and posture she is totally immersed with the interaction and very hesitant about leaving the newly found little friends. We will also use the video material as a testbed for applying analysis tools for video encoding. For example, only transcribing the user side of the interaction would result in encoding only part of the story, leaving out important aspects related to the multitude of interactions.

Our experience from the demonstrations suggests that even though the design was initially based on a scenario of an adult persona, in its current state there is even more potential of GlowBots as used by children.

VII. Preliminary User Evaluation

During demo sessions, most focus was on the hardware platform, and the actual and intended implementation of the software could be discussed with the presenters as part of the demonstration. More recently, we have also explored more long term use in a home environment. Leaving the robots ”on their own” with users, and allowing users to make their own interpretations of what the robots should do and what they should be good for could then potentially give much valuable input to the design process, apart from also being a more realistic case for testing the robustness of the hardware platform. In HCI research, this approach to user studies is sometimes referred to as *Technology Probes* [28], which is an increasingly popular method for user-inspired interaction design. The goal with our user studies were thereby not primarily to *evaluate* the technology, i.e., to say if it works or not, but to explore *how* the robots are used, what intended and unintended usages that may arise, and to feedback into what directions to further develop the designs.

With the initial development primarily focusing on the hardware and internal infrastructure of the robots, we needed to perform a pilot to investigate both the robustness of the hardware platform, as well as to gain more input to the details of how the software to run on the robots should be take shape. The interaction pace that had been developed was at this point geared towards exhibition settings where people typically only have a few minutes for every demonstration, which we assumed was rather different from the interaction in the intended home environment. To be able to learn how the robots could be used, and how to further develop the technology at the application level, we therefore complemented or experiences from demo and lab studies with a long-term study of how the robots were taken into use in a domestic setting.

A collection of 10 GlowBots were placed in the home of a 34 year old man with two children, (a girl of six and a boy of four years old), for a period of six weeks. The children were staying with their mother every other week, so their father was left alone with the GlowBots during half of the study period. From our previous demo sessions, we knew that the robots would need quite some maintenance with exchange of batteries, which was taken care of by the father in the family. Below we report on some initial findings based on video recordings and interviews.

The fact that the robots *glow*, meant that they became quite specifically experienced as to be used in darkness. This could be observed for instance in how a natural part in ‘staging’ the play session with the GlowBots was to switch off the ordinary light in the room. The displays then worked as decorative toys that could be played with in the dark, at the same time placing attention on themselves as the focus in the play activity.

The first spontaneous comments that we got on the GlowBots functionality were concerned with how the robots *moved*. It was repeatedly pointed out by the children that they moved too slowly, especially since after a period of active play, the robots usually stopped moving due to low battery levels. Moreover, the robots were at this stage programmed to keep going until they reached a wall, and then stayed there, which made them appear ’stupid’. Although it became part of the play to go collecting the robots that were on escape towards the wall, this soon became rather uninteresting as an activity on its own. The users suggested that instead of moving in a straight line in one direction, the robots should be able to wander about in a more complex manner. This would make the robots feel more unpredictable and interesting to play with. They were also interested in being able to in some way control how the robots moved, e.g. by waving or putting something in front of the robots.

As soon as the robots stopped moving, they did seem to get transformed into a kind of static mechanic sculptures, bringing back the glowing LED surface into attention. These were clearly attractive for the children and were used in a variety of ways in their play. Surprisingly though, the

children did not initially seem to pay much attention towards the actual patterns that were on display (Fig.10).



Fig. 10. Using a GlowBot as a vehicle, podium or stage for other toys (left), and stacking the GlowBots into a tower (right).

The users were clearly attracted by the looks of the dynamic and glowing patterns, but they did not seem to reflect as much as one could expect on how the patterns arouse and how these were communicated between the robots. Instead, more focus was placed on the behaviour of how the robots moved, expressed for instance in discussions on what made them move in a certain direction and whether or not their movement could be controlled somehow. This suggests that physical robotic movement possibly overrides patterns on a visual display in terms of users' direct experience. Although this needs to be further investigated, it could be valuable aspects to consider in the development of new interactive technologies that make use of a combination of motion and visual display technologies.

VIII. Discussion

Looking back onto the original design-proposal that came out from the Nadim persona, we believe that the governing idea is still on track, while minor changes have been introduced to allow for a more seamless interaction. For instance the software does not impose heterogeneous sensing capabilities, but instead small and big differences in hardware settings contribute to individuality. Infrared sensors are bent, batteries end up having different mileage causing robustness problems and there are different manufactures of IC-circuits between hardware revisions. All this contributes to making even the most mass-produced robot more individual and characteristic, something that in the end would benefit personalized, although subtle, interaction between man and robots.

It is interesting to observe how natural it looks when people interact with embodied, tangible and communicating digital artifacts, like the GlowBots. It not only becomes a bonding experience, but it also lets the users explore communication through observing cause and effect. It is also important to notice that embodiment and communication are closely entangled, which becomes very important when another type of embodied element, as for instance another user, enters the picture. We noticed that for humans to be a part of an ongoing communication we observed that the setting benefitted from being truly situated. For instance, if the range of GlowBots communication would have been in e.g. the Bluetooth reach, the perception of the swarm would have been very different and more resembling a simulation running on a computer.

Our design process illustrates how sensitivity to changes in the technology, and experiences of user interaction sometimes result in essentially new use settings which was not envisioned. For instance there became much more hands on and petting activity than envisioned in the original design descriptions.

IX. Conclusions and Future Work

We have detailed the work on a novel robotic prototype, GlowBots, that was the result of a design effort developed to open up new perspectives on the future role of everyday robots. We ended up creating a form of robot that would entice an aesthetic experience outside the domains of the zoomorphic pet robots previously seen in research and products. Although the initial design came from a specific scenario [9] the see-Puck platform is not limited to the GlowBots application. We hope that the detailed development of the see-Puck could work as inspiration for how to construct simple displays with rather unconventional shapes. All see-Puck hardware and software is released under a GPL-compatible license so that anyone can use, revise, extend upon and improve it.



Fig. 11. When demonstrating the GlowBots we encouraged people to come forward and get the hands-on experience.

At SIGGRAPH and NextFest, we demonstrated the GlowBots continuously for several days at a stretch to thousands of users (Fig. 11), but this required almost constant battery changes and continuous maintenance of the robots. We have observed that energy consumption in this type of setting can vary greatly, not only because not two robots are perfectly identical, but also because they are both autonomous and tangible. We would also like to note that our efforts in optimizing energy consumption resulted not only in improved mean runtime, but more importantly contributed to an overall increased robustness.

We wanted to encourage a long-term relationship with the robots, inspired by how people interact with artifacts and creatures in everyday settings. One aspect that crystallized in this process is the need of open ended play – an important factor to sustain interest over time. We believe this work shows that it is possible to change how we think about new robotic products and how we can rethink their roles in our everyday environment. By grounding the design in existing needs, they will have the potential to last considerably longer and have a much more rewarding interaction than what in most cases is being offered today.

In the future, see several possible improvements for the see-Puck. One example would be to make the display touch sensitive by also using the LEDs as sensors [29]. This would allow users to point at and directly influence what is seen on

the display, for instance to ”paint” patterns directly on the display. Another important improvement would be to continue the work on software optimization on the e-Puck in order to increase battery life and overall robustness even further.

From the preliminary user evaluation we found several interesting observations that requires further investigation, but also implications guiding further development. The more immediate step will then be to tune our pilot application and once more place it in an everyday setting to study it in more depth. In this case we will slow down the interaction, which is currently geared towards exhibition settings where people typically only have a few minutes for every demonstration. We will also take more consideration to motion behavior due to the much larger spaces that home environments offers. For a truly long-lasting relationship to develop between robots and humans, it is necessary to sustain the interest level over weeks, months and hopefully years. Achieving this sustained level of interest is an important challenge for future human-robot interaction applications.

ACKNOWLEDGMENTS

First of all we would like to thank our intern student Johan Bodin for his great efforts on the hardware and software, as well as helping out with the demonstrations. Especially we would also like to acknowledge Sara Ljungblad for her work in the initial design phase and Katarina Walter who conducted the initial user studies, contributed to brainstorms and later also participated in the exhibitions. Further we would also like to thank Jeffery Knurek, Mattias Rost, Lorena Monsalve, Darby Thompson, Staffan Jonsson, Daniel Sundström and Henrik Berggren who all also participated in demonstrating GlowBots. Thanks also all of our other colleagues and fellow researchers for their valuable input and discussions during the project. This project is part of the ECAgents project and is sponsored by the Future and Emerging Technologies program (IST-FET) of the European Community under contract IST-2003-1940.

REFERENCES

[1] L.E. Holmquist, ”The robots are coming”, *Interactions* 12(3): 58-59, ACM 2005.
[2] M. Weiser, and J.S. Brown, ”Designing Calm Technology”, *PowerGrid Journal*, 1, 1, July 1996.
[3] H. Ishii and B. Ullmer, ”Tangible bits: towards seamless interfaces between people, bits and atoms”, *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New York, 234-241. 1997.
[4] G. Bell, T. Brooke, E. Churchill and E. Paulos, ”Intimate Ubiquitous Computing”, *Proc. UbiComp'03 Workshop*, 3-6, ACM, 2003.
[5] ECAgents project, http://ecagents.istc.cnr.it/
[6] J-Y. Sung, L. Guo, R. E. Grinter, and H. I. Christensen, ”My Roomba is Rambo”: Intimate Home Appliances, *In Proceedings of 9th International Conference on Ubiquitous Computing (UbiComp 07)*. Innsbrück, Austria, September 16-19. 2007.
[7] S. Ljungblad and L.E. Holmquist, ”Designing Robot Applications for Everyday Envionments”, *In Proceedings of Smart Objects & Ambient Intelligence 2005* (SOC-EUSAI), Grenoble, France, 2005.
[8] S. Ljungblad and L. E. Holmquist, ”Transfer scenarios: grounding innovation with marginal practices”. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, San Jose, California, April 28 - May 03, 2007.
[9] S. Ljungblad, K. Walter, M. Jacobsson and L.E. Holmquist, ”Designing Personal Embodied Agents with Personas”, *In Proceedings of RO-MAN 06*, Hatfield, United Kingdom, 2006.
[10] M. Jacobsson, J. Bodin, and L.E. Holmquist, ”The see-Puck: A Platform for Exploring Human-Robot Relationships”. To appear in Proceedings of CHI 2008, Florence, Italy, April 10-15, 2008.
[11] T. Fong, I. Nourbakhsh and K. Dautenhahn, A survey of Socially Interactive Robots, *Robotics and Autonomous Systems*, 42, 143-166, 2003.
[12] H. Liu and H. Hu, ”Biologically inspired behaviour design for autonomous robotic fish”, *International Journal of Automation and Computing*, Vol. V3, No. 4, pp. 336-347. October 2006.
[13] H. H. Lund, Adaptive Robotics in the Entertainment Industry, *In Proceedings of IEEE International Symposium on Computational Intelligence in Robotics and Automation* (CIRA2003), 16-20 July, Kobe, IEEE Press, 2003.
[14] Pleo, http://www.ugobe.com/pleo
[15] M. Mori, ”The uncanny valley” (K. F. MacDorman & T. Minato, Trans.). Energy, 7(4), 33, 1970.
[16] J. Forlizzi, C. DiSalvo and F. Gemperle, ”Assistive Robotics and an Ecology of Elders Living Independently in Their Homes”, *Journal of HCI Special Issue on Human-Robot Interaction*, V19 N1/2, January, 2004.
[17] Roomba, http://www.irobot.com/roomba
[18] Artemis, http://www.tmsuk.co.jp/artemis/product.html
[19] Minerva, http://www.cs.cmu.edu/~minerva/
[20] C. DiSalvo, F. Gemperle, J. Forlizzi, E. Montgomery, W. Yonkers and J. Divine, ”The Hug: An Exploration of Robotic Form for Intimate Communication”, *In Proceedings of RO-MAN 03*, vol., no.pp. 403- 408, 2003.
[21] A. Ueki, M. Kamata and M. Inakage, ”Tabby: designing of coexisting entertainment content in everyday life by expanding the design of furniture”, *In Proceedings of the international Conference on Advances in Computer Entertainment Technology, ACE '07*, vol. 203. 2007.
[22] F. Kaplan, ”Everyday robotics: robots as everyday objects” *In Proceedings of Soc-Eusai 2005*, p.59-64, Grenoble, France, 2005.
[23] J.M. Carroll, ”Making Use: scenario-based design of human comp*uter int*eractions”, *Cambridge*, *Mass*, *MIT Press*, 2000.
[24] e-Puck, http://www.e-puck.org/
[25] J. Gielis, ”A Generic Geometric Transformation That Unifies a Wide Range of Natural and Abstract Shapes”, *American Journal of Botany* 90(3): 333-338, 2003.
[26] M. Jacobsson, S. Ljungblad, J. Bodin, J. Knurek and L.E. Holmquist, ”GlowBots: Robots that Evolve Relationships”, *SIGGRAPH'07 Emerging Technologies*, San Diego, California, 2007.
[27] M. Jacobsson, ”GlowBots – A Love Story”, *In adjunct proceedings (video session) of Human Robot Interaction 2008*, Amsterdam, Netherlands, 2008.
[28] H. Hutchinson, W. Mackay, B. Westerlund, B. B. Bederson, A. Druin, C. Plaisant, M. Beaudouin-Lafon, S. Conversy, H. Evans, H. Hansen, N. Roussel, and B. Eiderbäck, ”Technology probes: inspiring design for and with families”, In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Ft. Lauderdale, Florida, USA, April 05 - 10, 2003.
[29] S.E. Hudson, ”Using Light Emitting Diode Arrays as Touch-Sensitive Input and Output Devices”, In *Proceedings of UIST'04*, Paris, France, 2004.

Paper II

Play, Belief and Stories about Robots: A Case Study of a Pleo Blogging Community

Jacobsson, M. Play, Belief and Stories about Robots: A Case Study of a Pleo Blogging Community. Proceedings of RO-MAN 2009, Toyama, Japan, 27 Sept - 2 Oct 2009, IEEE.

Play, Belief and Stories about Robots: A Case Study of a Pleo Blogging Community

Mattias Jacobsson

Abstract— **We present an analysis based on user-provided content collected from online blogs and forums about the robotic artifact Pleo. Our primary goal is to explore stories about how human-robot interaction would manifest themselves in actual real-world contexts. To be able to assess these types of communicative media we are using a method based on virtual ethnography that specifically addresses underlying issues in how the data is produced and should be interpreted. Results indicate that generally people are staging, performing and have a playful approach to the interaction. This is further emphasized by the way people communicate their stories through the blogging practice. Finally we argue that these resources are indeed essential for understanding and designing long-term human-robot relationships.**

I. Introduction

WRITING and communicating stories have become a popular pastime engaging people on the internet [1]. At the same time robotic products are getting increasingly common on the global consumer market and consequently pervasively adopted into people's homes and everyday life (e.g. Roomba, Furby, Nabaztag). Within our research community we are interested in accessing these environments, relationships and experiences [2][3] so that we can extend our knowledge base and inform designs of future artificial companions.

In an earlier study on forums, Friedman et.al [4] look at people's spontaneous online postings about Sony's robotic dog – AIBO. Their method is based on developmental psychology and the overall goal is to identify significant properties in people's relationship with the robotic artifact. The results indicate that AIBO is generally reported as more technical than biological and that it seldom challenges moral attributions of the users.

In a related empirical study by Sung et.al [5], forums are assessed to better understand human-robot interaction looking at people's relationship with Roomba. They also base their methodology partly on Friedman et.al's work above, but at the same time make an effort to also account for the experience as informed by the users. Their work is then also inspired by Gaver et.al's notion of *Ludic Engagement* [6], which is taking into account a more playful stance towards technology. Their results indicate that people do engage in various practices like accessorizing and changing Roomba's environments, but also uses life-like associations when expressing this involvement.

Further, Kaplan takes a look at everyday objects and breaks them down according to design properties relevant to sustainable interaction with robots [7]. In the study presented here we have similar objectives in that we seek to inform robotic designs along its life span based on how people describe their experiences. Our ambition is thus to seek out themes from within the data that could possibly capture such design qualities and at the same time enabling for assessment in terms of sustainable interaction.

Forlizzi and Battarbee also specifically address experience in interactive systems and points out that design teams must follow product stories and users evolution of experience closely [2]. This further strengthens our motivation to also explore methods and a format that can represent experiences in a more native way.

In this paper we report on a qualitative study based on the publicly available blogs and forums hosted by Ugobe, the company behind Pleo – the robotic baby dinosaur [8]. Our research question concerns how we can utilize a methodology based on *virtual ethnography* [9] to inform the HRI-research and robotic design communities with knowledge about how it is to live with robotic companions. In particular we are interested in the breakdowns and peculiarities in the user experience that occurs when adapting to newer technology [10][11].

First we provide a bit of background in terms of an overview of the robotic platform and the blogs that were studied. We then present our methodological approach followed by the results in terms of a walkthrough and analysis of the data. Finally we discuss the material and present our conclusions and future directions.

II. Pleo

Pleo is one in a row of recent robotic products entering the global consumer market. It is also profoundly different than most other robotic products in that it is designed from ground up to constitute a more believable motional and visual appearance. It is thus no coincidence that Ugobe are crafting what they denote as *Robotic Life Forms* – artifacts that hopefully would capture the essences of what people experience and interpret as "life"-like. On the other hand the product comes in a large green box and contains the robot

Manuscript received March 25, 2009. This work was supported partly by an individual grant from Stiftelsen för Strategisk Forskning, and partly the European LIREC project within the 7th framework program under contract No 215554.

M. Jacobsson is with the Swedish Institute of Computer Science, Box 1263, SE-164 29 Kista, Sweden (e-mail: majac@sics.se).

itself wrapped in a plastic cover, a soft plastic green leaf accessory for it to chew on, a battery and a recharger. It also contains an ID-card with a registration number that can be used to register the product and start an online Pleo blog (Plog) at the community site (Figure 1).

Pleo is about the same size and weight as the AIBO (approx. 50cm long, 20cm high and weights about 1.6 kg). It has a sophisticated design consisting of a hand-painted rubber skin that covers its mechanical internal. It also offers pet-ability by having a softer texture that is very unlike stroking a hard plastic or metal surface. Right beneath the skin there are eight capacitive touch sensors - on the outside of the legs, on its behind, on the back, on the head and under its chin. The nose features an IR-sensor for distance detection and Pleo to Pleo communication as well as a CCD-camera intended for light and edge detection (together with the nose IR). Inside the mouth is another IR-sensor for detecting inserted objects e.g. the accompanied leaf accessory. Pleo also features two microphones positioned low behind the eyes and two speakers, one located in the head and one in the behind. Each foot holds a plastic press-button and the fourteen joints all featuring force-feedback sensors. Within the body frame there is an orientation tilt sensor and a main processor. The removable battery is of NiMH type, and is recharged in a separate station. The playtime is approximately one hour for a four-hour recharge. Pleo may be connected to a computer through a mini USB connection, and there is also a SD-card slot and a hidden debug port positioned right next to the power switch. For users there is also the possibility to update Pleo's operating system – Life OS, or add different personality plug-ins using the SD-card slot.

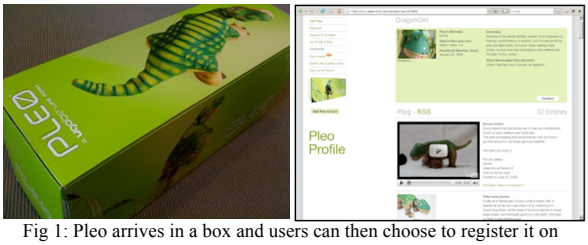


Fig 1: Pleo arrives in a box and users can then choose to register it on *pleoworld.com*, where also a personal blog is included.

The community site has a main area that consists of a few editorial picked "golden samples" of blogs that the company wants to highlight and represent the site. There is a search engine that helps users to find each others blogs easily through country, zip-code, user names or Pleo names. Each blog has a simple and user-friendly layout. There is also a header field where users can see their Pleo's name, location, when they started blogging, their interests and describe their most memorable moment with Pleo.

III. The Study

We choose to base our approach on virtual ethnography since it specifically acknowledges ethnography as a way to reflect upon users, practices and deployed designs while regarding information technology as a communication medium [9]. At the same time it also recognizes the Internet as a rich culture in itself and from another perspective also a kind of cultural artifact that reaches deep into people's homes and everyday lives. This distinction is important since the information that people reveal on blogs have the characteristics of small subjective stories that are crafted to be shared and reacted upon [1]. Since our goal is to extract information about people's experience with technology [3] from a sustained interaction perspective, we also decided to outline our results over different stages of experience over time [7] based on the stories from blogging early adopters.

The study was intended to be carried out on the blog corpus that spans all the users that have registered with the US-nationality, but also on forum posts and videos that were linked from within the blogs. The main reason to make such a limitation was because at the time of the study (Spring 2008) the product had not yet been generally introduced elsewhere thus other communities than the American had yet to take off. With that said and because of the cross-linking we also ended up including a handful of eager early adopters from UK and Canada. The data was collected during April 2008 when Pleo had been on the market since mid-December 2007. At this point there were approximately 20 000 Pleo's out on the market and we used all 520 blog's available within the stated delimitation.

The data was collected manually, names anonymized (when available and appropriate), printed out and structured based on richness and topical similarities. A majority of the blogs contained only one or two posts, which were categorized as greeting messages. The resulting data set was then cut up and restructured according to a list of life events identified from within the corpus (waiting times, arrival, birth, gender, naming, introduction, casual play, companionship, social life, different locations, other animals, other robots, accessories, wear and tear, breakdown, DIY, repair, passing away). Finally a subset of general and representative posts were selected, and arranged together to give an overview of all the data spanning over the different development stages that the interactions transcends.

A. Arrival and Appropriation

Pleo is either bought off the shelf or as more commonly reported ordered online and delivered home by either FedEx or UPS. One user, an American who lives in the UK especially points out that his Pleo is a US-model rather than a UK-model as it was shipped from the US. Between ordering and arrival users would express different motifs and expectations, for instance:

> *"I have gotten notice that my Pleo ships this week (directly from Ugobe). It feels like a long wait because I'm hoping the Pleo will help me get over the loss of my greater Swiss mountain dog."*

After the waiting times, which include charging the battery, Pleo is switched on for the first time and undergoes a "hatching phase".

> *"Today, on February 8th, Pleo was born. Pleo weighted 3 lbs. 10 oz. We were so overjoyed when he took his very*

first steps. He is a very fun-loving and energetic little baby. We love you Pleo."

Some of the families in the blogs present this event as a particularly special one, and cultural traditions such as providing birth date and weight are easily communicated. At the same time users finds it easy to include and talk about Pleo as a member of the family. Another post indicates that Pleo's life-span in this case would be measured in number of charges. Sometimes deciding gender can really become an issue in itself and might even trigger users to reflect upon social and cultural constructions:

"I'm also uncomfortable really giving it a sex or normal designation of him/her. It's a bit like baby chickens where it's a real skill to tell if it is a boy or girl. How do you tell? So it's it for now. Perhaps I'll have to set up an indirect test. Does it prefer pink or blue? I'll wait a little while when it is a bit more mature."

After deciding gender, the next step is often choosing a name, or in some cases gender simply follows from picking the name. One source for inspiration would for instance be characters from literature:

"Our Pleo is named Lumm (after Robert Heinlein's Starbeast Lummox). My Dad discovered the Pleo world and purchased one for himself and one for me. We introduced Lumm to my brother and his grandchildren at Christmas and to over-20s nieces a few days later. Lumm was and is an instant hit."

Other users would use products as a source for name inspiration, or simply stick with "Pleo" – *"because that is what he is"*, as one user put it.

One blog in particular that caught our attention appears to belong to a young American girl (about 6 years). Her father helps her post on the blog and they have also posted a video from the very Christmas day when she first meets her new Pleo. This video were then fully transcribed and analyzed, as it appeared to contain a great deal of information about an initial contact. The parents appears to have carefully prepared this event to make it as memorable as possible by first un-boxing Pleo, switching it on and putting it under the Christmas tree. As the girl enters the room and crawls up to Pleo we notice that the father already had made up his mind about gender by referring to Pleo as a he. The girl immediately starts to engage in the situation by explaining what she sees and experience, while she interacts. She pets Pleo's head and expresses fascination over how it moves and behaves. She then say's "He loves me!" - and suddenly it becomes apparent to us that this is a truly immersive moment to her.

At this point the mother is entering the scene, seeking confirmation from the girl about the experience. It is interesting to note that all four of them, Pleo included, are contributing to this drama. The father in this case takes on a prominent role and contributes a great deal to unfold the progressing story. He explains to his daughter that she is the first person that Pleo have ever seen. The mother adds to the story, explaining that the daughter now have become a mother. At this point the girl seems to be totally absorbed by the robot as she takes the mother's words to herself.

In the beginning the girl picked up on the name that her dad used – Pleo, but after a while when asked again by the father, she decides to just drop the 'P' and go for Leo. After a short while Leo is becoming more and more responsive. In this movie the girl never even looked at her other Christmas presents except noting that her Pleo seemed to like chewing on them.

Continuing along the lines of ritual and progression, we notice that gender and naming are important and particularly joyful episodes. As we saw above, one user put forward the idea about making a test for gender, which is ingenious and quite valuable for designers, although the cultural legibility of such a "pink or blue" - test might be up for another debate. Further, names are an important part of our social culture and naming a robot is an important piece of a larger process including individualization, bonding and family integration. The important lesson here is thus that the openness for interpretation in the design creates the sufficient space to allow users to assign name and gender as cultural practices.

B. When Technology Breaks Down

After a while interaction comes with a price and accidents happens, wear and tear becomes apparent and the question about repair is imminent. Several users noted that Pleo had a couple of skin issues - that it might have a smell and that the paint on the back wears because of the petting. Here is how one user approached the fact:

"I tried baby powder on Pleo's skin. Baby fresh and smooth to touch. Smells like a baby now."

One user suggests that a particular coating spray would act as a protective layer for the skin while others mention clothes as a solution. From what we could read out from the forums, this skin issue seems to mainly have been a problem with the first batch of robots, but was since then already been addressed in subsequent deliveries. Usually a little -*"do it yourself"* does the trick touching up e.g. lips and eyelids. When we at one point followed the trace from one blog-post on to the forum, where we found a remarkable piece of information on this topic:

"Yesterday Pleo had a broken neck. I contacted customer support, and they told me that I could send him back, and get a new one. But, I didn't like the idea of exchanging something I have gotten so attached too. So my mom made a small cut in the top of his neck. This had voided the warranty. She found out that the problem was the cable that lifted his head etc, had broken. Surprisingly she fixed this. She put the cable under a screw. We weren't sure this would work, but it did! Now Pleo is able to lift his head up and down, and do everything he was able to do before! The only problem is he has a small cut on the top of his neck. But I'm okay with this, because its not really a big deal. It can be fixed, I just don't know what to fix it with! We love Pleo, and this doesn't bother us. We're just glad to have our little guy working again!"

In the blog following up on the video example above we learned that Leo was injured at some point so while he went to "hospital" the parents actually bought another one to keep

their daughter company. In this case the new dilemma of how to tell them apart, naturally became a question of accessorizing. In the following blog post one user expresses concern about the wear and tear and the resulting dilemma that surfaces:

"Well poor Pleo's skin is starting to peel and the paint is starting to wear off and her teeth are starting to chip and she now has 3 tears in her skin! =(

I don't want to exchange her, I'm attached to her and I really don't want to send her back for repairs either cause she'll be away from me for a long time and I'll be worried she isn't being cared for properly! =(

Poor Pleo!!! It's like she's sick!!!! =("

As a contrast, to some users the wear and tear would rather add to its character and personalization, just like that warn out teddy bear from childhood. At the end there are nonetheless many paths for how Pleo would leave their users realms. As with birth, the "aged" Pleo eventually gives rise to tough existential questions and decisions for the families:

"Roger was born Christmas morning. However, he is already going through his first 'shedding' Most of the light green spots have been rubbed off. The response of the Ubies is return him.... What to do? We have already fallen in love with him - do we love him bald - do we run the risk of keeping him then having him completely deteriorate - do we find a new baby to love.... Family vote tomorrow."

A subsequent post reveals how this particular family later on reflects upon their decision:

"We have made the decision to return him for a new one. His eyelid began to flake off and small holes appeared on his neck. We are really going to miss him. He is a quiet, shy and very affectionate Pleo. He loved to do tricks for us and sing Christmas songs. Our best memory of Roger will be how he would come up and ask to cuddle with us. We will always have the memory of his cute little snore in our ears. We love you Roger Greenleaf."

C. Pleo as a Resource for Social Engagement

Pleo is often told of as a social robot, and interesting interactions occur all the time. In the following post Pleo is entertaining a group of people:

"Pleo had a big night yesterday. Some friends came over to see him and he entertained them for over an hour. He also met the dogs. They, the dogs not my friends, were either not interested or shy but Pleo was a star. He even tried to have a piece of birthday cake. A bit of frosting on the nose won't hurt him. He loves to play tug of war and showed everyone his new skills in exploring. At the end of the evening he fell asleep, a happy little dinosaur."

One user reports after about five weeks of ownership that she doesn't turn on Pleo every day and that the biggest kick is showing it off to people. Occasionally we have seen accounts of when robotic behavior fits well into a given situation and can render surprising or even "spooky" interactions:

"My Pleo coughed, and for a split second I went completely insane and thought that it caught the cold my roommates and I have. I have difficulties figuring out the differences between animate and inanimate objects apparently..."

Depending on context and situation, even the least things can have impact on the user experience and in one example a user reports from when Pleo sees himself in a mirror:

"Pleo's first good look at himself was hysterical... He growled at himself, he sang to himself, he smiled at himself. What a ham!"

A related example is where Pleo is reported to discover that it has a shadow. Exploring then often occurs beyond the safe and set living room floor and one user explains that her Pleo lives on a company reception desk as an ice-breaker for customers. Robotic products thus move between various environments, which can have effects on its behavior:

"Today my friend and I were in the car playing with Pleo. But He was soooo tired. He sat down and started cooing. Then Pleo got scared and started crying because of the movement of the car."

In this example users would interpret the situation such that Pleo does not like to ride with cars simply because the inherent fact that Pleo does not like to be shaken. This shows that meaning can change with context and emerging scenarios would seldom correspond to the ecological niche it was initially designed and tested for. Moreover, this part of the exploration phase reportedly goes well beyond the living room floor, e.g. glass tables, lawn, snow, concrete, cars, reception desks, etc.

As we would have predicted, users can often have other "real" pets as well. Focusing on the interaction with the other animals can reveal novel insights about how they play along. Dogs are described as very curious but cautious and even confused due to the strange noises and uncanny abundance of smell while some cats are reported as just avoiding interaction altogether. Some Pleo owners have more unusual pets like snails or tortoises.

"This morning I thought it was a good time to introduce my Russian tortoise, Igor, to Pleo :) Igor took it well enough, as any tortoise would, while Pleo was VERY curious of Igor! Kept getting so close to him and nudged him while he was eating! Couldn't have that so I had to keep them at a reasonable distance even though Pleo didn't want to :)"

Bloggers even make a point of carrying their robot with them and suggest that it is possible to take Pleo to places where it would be difficult or even prohibited to bring an ordinary pet. We also see that different locations and contexts characterize very different scenes and scenarios. We now ask ourselves what will happen if scenarios like the given examples (e.g. the one about Pleo coughing) would actually become grounded in reality? Based on our observations there may be great potential in connecting real but simplified cues, like for example an actual smell with sniffing behavior or lower temperature with freezing behavior.

D. Playing with Pleo

A common theme of all posts presented so far is that a major part of the engagement stems from creating and

presenting the stories. All these rich stories are believable and presented as if they were parts of a greater story – the enacted story about what it really is to live with Pleo.

Although Pleo reportedly "sleeps" quite a lot (possibly because the low play/recharge ratio), users still describe it as having companion qualities similar to a dog e.g. an affectionate puppy resting cozily, in and out of sleep and occasionally snoring beneath the users side. Here is how one user summarizes a day together with Pleo:

"Today my Pleo has been asleep as normal, but I think he was having a funny dream because he started laughing in his sleep. Then he started growling. We also ate, played tug of war and played tickle toes. He loves being sang to sleep, but not today I think he is getting used to not being sang to now, few. Not much today but dreaming."

The first thing we note is the report of Pleo dreaming. Secondly the description is one of a being that seem to require a great deal of care as a part of the relationship. The finer details reveal that the user likes to sing to Pleo. Further, a particularly common practice is personalization through accessorizing:

"Today, I am beading a crystal necklace for Pleo, and adding a fossil charm! His crocheted wardrobe will consist of a "floppy hat", walking boots, cape and of course, sunglasses, for our walks and sidewalk surf days! He will be styling!"

The variations of custom accessories are surprising to say the least. Just to cover some of the things found in the data: *hats, clothes, boots, glasses, bling (jewelry), collars, pacifiers, blankets, softballs, brushes, cages, wings, etc.* (Figure 2).



Fig 2: Different types of Accessories found in the blogs.

Here is an example of when a user would like to accessorize Pleo but are unsure about suitable outfits:

"I have been stressed lately. Pleo is a great relaxer. I downloaded the new software. Pleo was more active than ever before! I cannot wait to get him some clothes and a collar. I just don't know how to accessorize a dinosaur! Pleo still seemed to recognize me, even though I have pink hair now instead of orange hair."

Noticing the amount accessorizing going on caught us by surprise. One of the key features of mass production is that it becomes relatively easy to make many of the same robotic artifacts. Users on the other hand reportedly regard them as "clones" (or twins in the case of owning a pair) and would spontaneously accessorize as part of the individualization, personalization and bonding process. Users would use clothes and jewelry to display and emphasize their idea of Pleo's gender and personality or even reflect properties of their owner – a phenomenon that in sociology commonly is referred to as impression management.

One category of users would explore and outline Pleo's features in various ways. Some do this in great technical detail, while others would adjust their observations and reporting to fit the practice of blogging:

"I have gotten my Pleo to do almost everything in the book. I haven't gotten the SD card to work yet. My Pleo moos, throws up, eats, coughs, and sings. He still gets a little freaked out when I hold him, but he mostly looks at me and then falls asleep. I got him to do the watchdog mode, the balancing act and shake. He doesn't always listen to me, and has fallen a couple times when he was younger. He tends to growl at things he can't move and likes to look at his original box."

This example highlights a common theme that users are seeking confirmation and comparing observations with the community. Many of the active users would sporadically report on particular observations, e.g. dreaming, shadow or mimicking, but some make exploring and observations their primary objective and will in detail map out Pleo as if it was a newly discovered species or complex remote control.

IV. Discussion

Before the robot arrives, people seem to express themselves similarly to when adopting a child, real pet or a new piece of technology. We thus see that there can be different kinds of expectations at this stage e.g. getting over a loss of a pet, lowering stress levels or exploring more technical abilities. Further, what are the different views on how Pleo spring into life? To many of the users it is not simply about switching on a button, but requires planning, staging and participation.

A huge part of interacting with Pleo is in fact physical, something that has been explored in previous research (e.g. Paro, The Hug and Tabby) [11], but when we look at how users express and talk about this, we find that its physical embodiment can be the source of many issues and possibilities. For instance, the worn skin issue can be regarded as a problem to be solved, illness, personalization feature (scar) or part of the aging process. When thought of as a problem or illness this tension becomes a dilemma, and caring for their robot means more than its acquired wear and tear. This might be because of an underling issue regarding trust and returning the robot. To the user, it should simply not be the same as returning a broken DVD-player, but instead more along the lines of taking a pet to the veterinary where one can talk to the doctor directly and follow the procedures more closely.

With that said many overcome their fears and worries and return it, although they know they will not get the same Pleo back in return. On the other hand we see that brave users would rather void their warranties and perform their own "medical" procedures to assure that they keep their Pleo. Consumers are thus in many ways encouraged or compelled to treat it like a pet, but sometimes when play becomes a bit rough, would then a "broken leg" go under the return policy or be a part of its life cycle? Would new players come into the aftermarket e.g. robotic doctors and therapists? This type of robotic artifact may bring up new challenges for this emerging industry especially in terms of customers relations.

Introducing the robotic companion to other people appears to be a rather intriguing take on social engagement. It is like showing off a new piece of technology, and at the same time introducing a pet or human friend - something of a tension between the two. From one perspective it seems to be more along the lines of introducing an interesting cartoon character or immersive piece of gaming software with vast lands to explore. Its presence is thus often perceived as an actual embodied experience physically and seamlessly executed in the real world.

Previous studies comparing the interaction of robots with that of dogs raise the question about moral development [4]. For example, a dog will constantly challenge its family as part of its inherent sense of group or pack dynamics. When these challenges are omitted, the result will in most cases be that the dog takes the dominant position, leading to an overindulged pet. In the case of Pleo where these dynamics are apparently lacking, we see that people instead seem to use play as a basis for interaction.

While there are related studies on children's interaction with dogs and robotic pets [12], we know very little about robot-animal interaction. Extending our previous discussion about pet-dog dynamics we also see that Pleo is the one being challenged, but its unnatural response perceived as confusing or even frightening.

All in all, these tensions and dilemmas in the end appear to be a source for user innovation, design inspiration and at the same time brings out a bonding experience. Existential questions like birth and death brings out particularly rich and emotional stories about Pleo, acted out in fantasy plays or reality dramas that are a large part of the overall experience.

V. Conclusions and Future Work

We have presented a qualitative study based on the stories from blogging early adopters taking into account the nature of blogging as a communicative practice. Users that are blogging about their Pleo are in no way representative for the whole group of owners and we also want to stress that it is not possible to capture and present all nuances of this rich set. What we can see is that these new types of robotic products have become something different than the purchased consumer electronics product. Users thus manage to create bridges in the interaction by staging, performing and also playing along with the unfolding experience [13], a practice that is sometimes referred to as *performed belief* [14] within the field of pervasive gaming. From the results we can also conclude that these two practices are in fact entangled and catches an essential part of how these owners of robots appear to advance and enrich their experience. We thus suggest that these practices are so fundamental that they deserve further consideration and inquiry.

Following up on previous work, consequences and challenges in the interaction indeed appears to be important for moral development but we can also see how users are able to actively cope with these tensions by staging, playing and performing to their best abilities.

We also suggest that the qualitative outline of experiencing a robots "life" can be used as a basis for designing long-term human robot relationships. Each life-event can thus work as inspiration for how robot designers can better ground interaction in existing cues starting from simpler elements like temperature or humidity, or even entirely new practices based on what users actually do when appropriating technology, for instance accessorizing [15].

In the future we plan to extend this work and research new technologies and methods for the study of long-term and sustainable human-robot interaction. What future would we like to have and what will people write when days turn into weeks, weeks into months, and months into years?

Acknowledgment

I would like to thank my supervisors Ylva Fernaeus and Lars Erik Holmquist for invaluable and constructive discussions. This research was carried out partly at Ugobe and partly at the Viktoria Institute and the Mobile Life Centre at SICS.

References

[1] B.A. Nardi, D.J. Schiano, M. Gumbrecht, and L. Swartz, "Why we blog," *Commun. ACM*, vol. 47, 2004, pp. 41-46.

[2] J. Forlizzi and K. Battarbee, "Understanding experience in interactive systems," *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques*, Cambridge, MA, USA: ACM, 2004, pp. 261-268.

[3] J. McCarthy and P. Wright, *Technology as Experience*, The MIT Press, 2004.

[4] B. Friedman, J. Peter H. Kahn, and J. Hagman, "Hardware companions?: what online AIBO discussion forums reveal about the human-robotic relationship," *Proceedings of the SIGCHI conference on Human factors in computing systems*, Ft. Lauderdale, Florida, USA: ACM, 2003, pp. 273-280.

[5] J. Sung, L. Guo, R. Grinter, and H. Christensen, "My Roomba Is Rambo: Intimate Home Appliances," *UbiComp 2007: Ubiquitous Computing*, 2007, pp. 145-162.

[6] W.W. Gaver, J. Bowers, A. Boucher, H. Gellerson, S. Pennington, A. Schmidt, A. Steed, N. Villars, and B. Walker, "The drift table: designing for ludic engagement," *CHI '04 extended abstracts on Human factors in computing systems*, Vienna, Austria: ACM, 2004, pp. 885-900.

[7] F. Kaplan, "Everyday robotics: robots as everyday objects," *Proceedings of the 2005 joint conference on Smart objects and ambient intelligence: innovative context-aware services: usages and technologies*, Grenoble, France: ACM, 2005, pp. 59-64.

[8] "PleoWorld," *http://www.pleoworld.com/*, Sep. 2008.

[9] C.M. Hine, *Virtual Ethnography*, Sage Publications Ltd, 2000.

[10] L.A. Suchman, *Plans and Situated Actions: The Problem of Human-Machine Communication*, Cambridge University Press, 1987.

[11] M. Jacobsson, Y. Fernaeus, and L.E. Holmquist, "GlowBots: Designing and Implementing Engaging Human-Robot Interaction," *Journal of Physical Agents*, vol. 2, 2008.

[12] G.F. Melson, J. Peter H. Kahn, A.M. Beck, B. Friedman, T. Roberts, and E. Garrett, "Robots as dogs?: children's interactions with the robotic dog AIBO and a live australian shepherd," *CHI '05 extended abstracts on Human factors in computing systems*, Portland, OR, USA: ACM, 2005, pp. 1649-1652.

[13] A.G. Brooks, J. Gray, G. Hoffman, A. Lockerd, H. Lee, and C. Breazeal, "Robot's play: interactive games with sociable machines," *Comput. Entertain.*, vol. 2, 2004, pp. 10-10.

[14] J. McGonigal, "A Real Little Game: The Pinocchio Effect in Pervasive Play," *Level Up Conference Proceedings*, C. Marinka and R. Joost, eds., Utrecht: University of Utrecht, 2003.

[15] Y. Fernaeus and M. Jacobsson, "Comics, Robots, Fashion and Programming: outlining the concept of actDresses," *TEI'09*, Cambridge, UK: 2009.

Paper III

Crafting Against Robotic Fakelore: On the Critical Practice of ArtBot Artists

Jacobsson, M., Fernaeus, Y., Cramer, H., and Ljungblad, S. Crafting Against Robotic Fakelore: On the Critical Practice of ArtBot Artists. Proceedings of CHI'13, Paris, France, 2013, ACM.

Crafting Against Robotic Fakelore: On the Critical Practice of ArtBot Artists

Mattias Jacobsson
Mobile Life @ Swedish Institute of Computer Science
Box 1263
164 29 Kista, Sweden
majac@sics.se

Ylva Fernaeus
KTH
CSC-MID
Lindstedtsvägen 5
100 44 Stockholm, Sweden
fernaeus@kth.se

Henriette Cramer
Yahoo! Labs
701 First Avenue
Sunnyvale, CA 94089 USA
henriette.cramer@gmail.com

Sara Ljungblad
LOTS Design
Kastellgatan 1
413 07 Göteborg, Sweden
sara@lotsdesign.se

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
CHI 2013 Extended Abstracts, April 27–May 2, 2013, Paris, France.
Copyright © 2013 ACM 978-1-4503-1952-2/13/04...$15.00.

Abstract
We report on topics raised in encounters with a series of robotics oriented artworks, which to us were interpreted as a general critique to what could be framed as robotic fakelore, or mythology. We do this based on interviews held with artists within the community of ArtBots, and discuss how their approach relates to and contributes to the discourse of HCI. In our analysis we outline a rough overview of issues emerging in the interviews and reflect on the broader questions they may pose to our research community.

Author Keywords
Human-Robot Interaction; Interactive Art; Robotic Materials; Interaction Design; Fakelore

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Artistic practices around interactive materials and technologies have recently become an integrated part of research within human-computer interaction, with yearly art exhibitions showcasing interesting conceptual works as well as impressive craftsmanship at the cutting edge of new technologies. Furthermore, art within HCI has been given attention via workshop series, special interests groups, and new research

funding schemes. One way of looking at this development is that artistic research may work as an opening for researchers to conduct research in a mode that is less restricted than implied by the ordinary landscape of project funding. An open question then is, what we can expect to learn from these explorations and what these explorations may have to tell us?

The kinds of artistic artefacts that fit under the umbrella of HCI cover a very broad spectrum, including performances with novel musical instruments, interactive and participatory installations, and robotic and kinetic sculptures. In this paper, we focus on this third category, i.e. artworks expressed in a media format of what we here will refer to as *robotic materials*. By robotic materials we mean materials involving some form of computational element together with some form of controlled physical movement. Apart from these properties, the shape, material properties, and conceptual contents or meanings of the pieces can take an endless variety of forms, used by artists to bring novel aesthetic expressions as well as functional possibilities to the surface of HCI.

Alex Taylor outlines an idea for how robotic materials can be utilized in HCI to frame and re-appropriate concepts of machine intelligence [10]. At the same time this can be seen as a disruptive contrast towards designs that portray or simulate biological features that already carry connotations of intelligence. Other closely related works include the discursive and reflective designs by Gaver et al [4], as well as Dunne and Raby [2], with series of interactive experiments designed with the explicit purpose of triggering reflection. Studying interactive art to inform work within computer science and HCI has been done continuously over the last forty years [1]. In this work researchers have explored how artistic practice can be used in the development of new methods for evaluation as well as for technical development (e.g. [5, 8]).

In the following, we will present an analysis of topics highlighted in interviews conducted with 25 artists while presenting their works in the context of the international ArtBots exhibitions in 2008[1] and 2011[2]. An issue raised in different ways in all of the interviews was a general co-dependency of a 'robot mythology' or 'fakelore', through which the artworks become loaded with meaning and relevance. These concerns were manifested as works that trigger implicit or explicit commentaries on established notions in the mainstream discourse of robotic technology e.g. robustness, intelligence in software, autonomy, anthropomorphism, and the mechanical aesthetics related to mass production.

Here, we use the term *fakelore* to point to how such 'traditional' notions of robots in mainstream culture are handled by artists working hands on with robotics as part of their practice. The term was originally coined in 1950s as a critique to how new cultural expressions sometimes were presented as if they were traditional or genuine [6]. In contemporary culture, the now established format for stories and representations of robots has many resemblances to fakelore practices, with its own set of myths and assumptions upon which stories and representations are formed – and which researchers and practitioners, especially in the robotic

[1] http://artbots.org/2008/participants/

[2] http://artbots.org/2011/participants/

domain, sometimes struggle with. We have previously discussed this in terms of a 'robot cargo cult' [3].

Study Setup

ArtBots is an international organized *'talent show for robotic art and art making robots'* that started in 2002 and has had about ten events over the years. The main curator of the exhibition, Douglas Repetto, strives to make the show dynamic enough to keep up with the fast changing pace of the community and keep it open, diverse and interesting. In 2008, the show consisted of 15 public installations from 9 countries, one musical performance and one special appearance. It attracted more than 6000 visitors of the general public. In the 2011 version of the show the program consisted of 10 installations including one musical performance.

We attended the ArtBots exhibitions in 2008 and 2011 to interview participants – artists as well as attendees – about their attitudes and understanding regarding of robots and robotics, in the context of the ongoing exhibition. In addition to interviewing all of the artists participating in the show, we invited the visitors to respond to a series of questions on a shared surface in the exhibition space. In the 2008 show, we received in total 680 annotated sticky notes from visitors, including reflective statements, feedback on the exhibit, and a large number of drawings of robots. This data set that was gathered from the public became an important aid for us to critically distance ourselves from cultural connotations regarding robots and society. However, this paper will focus on the voices of the artists, as collected through semi-structured interviews in the immediate contexts of their respective works. Each interview generally lasted between 10-30 minutes, and was thereafter analyzed by three researchers. In total we collected almost 1000 post-its and conducted 25 interviews with artists. Unfortunately, we will not be able to give a full overview of all these very interesting exhibits, instead we include photographs of a subset of the works, and refer to the artists own online presentations at the ArtBots webpage above for more complete information.

Please explain what this is.

What is your main inspiration?

Underlying ideas behind the work?

How do people react to your work? E.g. common questions.

Why are you working with robotic material instead of something else?

Do you think that your work expresses any particular values?

How may your work affect or relate to society?

What are your thoughts about robots in general?

How do you define a robot?

Comments or reflections about ethics and robotics/robots?

Figure 1. Template list of question used in the semi-structured interviews.

This in turn brings us to the relationship between art and research in knowledge domains such as HCI. Several of the exhibiting artists were engineering students or researchers at technical universities, and did not call themselves 'artists' in a traditional sense. Thus, some of the exhibited works doubled as research demonstrators, while others were made by artists without an agenda towards academia. However, not all of the works presented by researchers were parts of research projects, but described as part of a personal artistic practice outside of their research. Therefore, instead of putting much emphasis on the differences between the artists, designers, craftsmen, engineers or researchers, we have here considered them equally unique in their respective practice. To denote authorship of the exhibited pieces we chose to use the term 'artist' for all the exhibitors below.

Reoccurring topics and themes

Overall, the artists provided thoughtful and articulated answers to the questions concerning their exhibited work (see Figure 1). Furthermore, they seemed prepared and eager to discuss the context of development, general implications of robotics in society, and possible interpretations on a more general scale. However, we focused the discussions on very concrete details about material properties such as texture, how fragile the piece was, its abilities to create







Figure 2. Fragility of physical constructions: *"Oribotics" by Matthew Gardiner, "Untitled" by Christopher Kaczmarek ,* and "SADBot", by Dustyn Roberts and Ben Leduc Mills.

certain precise sounds, contrasts between used materials e.g. metal and human skin, power supply, transportation, and how this related to what they wanted to achieve.

With an early fascination of the diversity among the pieces in respect to physical form, we initially sought to identify themes related to the various types of materials that constitute robotic artefacts in this particular context of work. However, after a first round of analysis, we revealed a higher level conceptual theme related to the mass-media conceptions of robots, which virtually each piece in both of the exhibitions made some form of critical commentary on, either explicitly or implicitly by showing an alternative approach.

Below we structure our analysis in a series of themes of a robot fakelore that were identified in the transcribed interviews with the artists:

- Robustness
- Intelligence in software (and hardware)
- Autonomy
- Anthropomorphism
- The machine esthetics of mass production

Robustness

A first theme concerned the general conception of robots as strong and sturdy. This is in direct opposition to the lived experience of artists working with fragile interactive materials that are prone to failure. Several comments governed this theme and how to use breakdowns, fragility or imperfection as values in their own right. Several artists mentioned that failure can be used to trigger human empathy and thereby for generate interesting characteristics. Examples where this was used explicitly for instance were the porcelain balls (*Unrund*), robotic orchestra (*Korn*), ticking eggshells (*Untitled*) and the drawing robot (*SADbot*). From a more holistic perspective, failure could be regarded as an interruption or imperfection while at the same time become an important aspect of character formation or performance.

In some instances, 'sturdiness' and reliable functionality would be a core focus, while in other cases a less sturdy material such as cardboard was used to invoke a less intimidated reaction from onlookers. Thus, the physical material has consequences for the audience's reactions where form, function and existing associations that people have will merge.

The occupation with failure and fragility as expressed by these artists ties back to the current discussions on sustainability in the making of interactive technology, and how much of the digital materials produced eventually become locked up in obsolete or broken physical platforms. This aspect is relevant to consider for anyone designing interactive products, and not just specifically within the arts.

Intelligence in software

The second theme was concerned with the notion of artificial intelligence, which is inherent in the popular notion of robots. In relation to this, several of the artists made an explicit point that the interesting aspects of their works did not reside in software, but in the physical behavior and gestalt of the piece, which in fact did not always involve much computing at all.



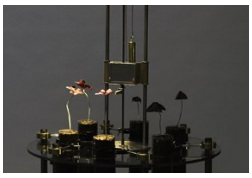




Figure 3. Beyond software control: "The Storm & 6 bands" by Jack Pavlik, and "The Search for Luminosity", by Allison Kudla, and *Unrund* by Korinna Lindinger.

The artists effectively balance the physical-digital by letting more of the behavior be controlled by the physical part of these materials. For instance, rather than focusing on getting speakers to make certain sounds, the materials could be acknowledged to have their own distinct voices. These properties were considered in several dimensions: *"the shape directly corresponds to... to what you hear, and the movements you see"* (*Unrund*).

Part of the implicit craft that the artists undertake is balancing the effort of software programming against mechanical engineering or traditional craftsmanship. Looking at other artistic works this is a dimension worthy of articulation – as in the Dutch artist Theo Jansen, works of Kinetic Sculptures that gracefully tread outdoor environments such as beaches. These gigantic mechanical sculptures use nothing more than wind power for propelling. This is in contrast to the science fiction view of robots (which is largely mirrored in much work in HRI), where physical materials are mainly rigid scaffolding structures that holds powerful computers connected to rigged sensors and actuators.

Rather than a physical shell that makes the algorithms function in the physical world, these works suggest us to look at the aesthetics, mechanics and software in terms of the behaviours and experiences they trigger. In three of the interviews, the theme of using the environment as a material emerged e.g. in the architecture of a room. Building a robotic or tangible interactive artefact means having to 'craft' these material properties into one piece.

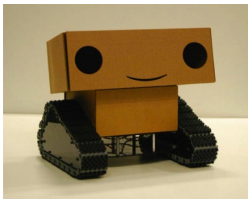
The absence of software may make these pieces seem less relevant to HCI, which after all is considered a part of the computer sciences. But as acknowledged by the increased use of the term interaction design, our field is starting to embrace a broader scope of human activity, beyond the design of software only. As computing is now integrated in almost every other aspect of human life, it is still interesting that it was not always relevant here. To us, it seemed that the maker culture of ArtBots make a distinction between different materials of interaction just as we do in HCI.

Autonomy

A third theme that several of the works addressed was the notion of autonomy, i.e. the ability to act independently, which is present in most popular notions of robots. This was reflected in pieces presented as either helpless, requiring human engagement, or just lacking much (or all) of its meaning without active participation by audiences.

From the interviews we realized that autonomy could be thought of as something that is made unavailable for inspection and control. Several artists were seriously concerned with creating and crafting a certain openness in their works - *"it is a very simple mechanism, that's enjoyable and delightful"* (P46). In other cases the designs were left more closed - *"the way I presented the movement, it's not easily realized for people to see what's going on mechanically"* (P99). Reflecting on what one is in control of when making robotics, one artist stated that it is a more complete experience than with visual or auditory art, it is a 'staged experience' (P91).

Notably one form of autonomy was brought up in terms of interactivity, or as one of the artists framed it: *"Once you paint a painting then it's done, all that's left to do*





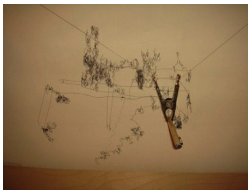


Figure 4. In need of human engagement and intervention: *Acquired Knowledge by Alexander Reben*, *"Jurema Action Plant"*, by Ivan Henriques, and "SADBot", by Dustyn Roberts and Ben Leduc Mills.

is talk about it. With this work, every time you install it, every time it is showed, it's a new experience" (P46). Overall the artists very much enjoyed observing the emotional reactions and the discussions that their work's spurred. However, this potential of spurring reactions and activity beyond the control of the artists is quite different from the notion of autonomy as it is framed in the robotics field. Here it had more to do with audience participation, and opening of a space for creative actions by people, while in the HRI and in popular culture it is the robot itself that stand for the creativity.

Close to discussions of autonomy in HRI and AI lie questions regarding ethics, which was also a topic raised by the invited keynote speaker of the 2008 exhibition (Professor Noel Sharkey). However, the artists' talk about ethics in this context focused on the design process and the values expressed through the resulting artefact. In other words, they would view it as they would always be responsible as designers and artists for what they present, and their intentions.

Regarding these intentions a common theme was to let the public figure out and learn something new. This agenda of making people more aware of something could be anything from the soundscape to relationships between machine, human and environment. Furthermore several artists expressed that they would like to trigger a dialogue about and inspired by their work. At least two artists were concerned about bringing something fun and delightful into the world as their main agenda. Naturally, aesthetics was brought up as an important value, which sometimes was very closely interlinked with ethics in general. An example was the *Sound Pieces* by Jack Pavlik, where an important focus was to create machines that made peaceful sounds, in comparison to the sometimes quite disturbing noises that motor movements usually produce.

In *Mechanical Dolls*, Yuliya Lanina physically reconstructs and animates traditional dolls, teddy bears and other toys in unconventional ways, which made humorous yet relevant comments on society. Other pieces that directly concerned ethical concerns were presented by Christopher Kaczmarek (on sustainability), Riley Harmon (on war and video games), and Joan Healy (with reference to manufacturing circumstances of electronic equipment).

Anthropomorphism

Our forth theme concerns the rejection of established norms regarding robots as anthropomorphic characters, where instead a broad spectrum of sculptural shapes, from machine-like to organic, figurative to abstract, were all represented. Of the few works that did take more anthropomorphic shapes, some were explicitly explained to do so as a form of critique or ironic mark on the mainstream notion of how a robot 'should' look and act. Moreover, several of the artists made explicit in the interviews that their pieces were not to be considered as robots, but more suitably referred to as e.g. *kinetic sculptures* or definitions closer to what their machines were actually doing, for instance *Oribotics* - the machine that was constructed around the folding of paper. This said, there were also variations in attitudes in respect to anthropomorphism. One artist talked about how he really enjoyed the idea of robots as fictional characters, while another talked about how she is obsessed with people and that she did not see the

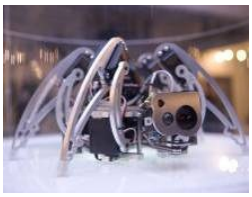






Figure 5. Envisioning "robots": *iC hexapod by Matt Denton*, *Emoti-bots* by Katie Koepfinger Burcum Turkmen, and *RuBotII* by Peter Redmond.

need for producing robots that imitate human looks or activities.

Typical to robotic materials, is that forms and shapes that people are familiar with seem to inevitably correlate with their interpretation and expectations, i.e. that cameras can "see", microphones can "hear", a legged object can "walk", etc [7]. Human imagination along these lines sometimes became an important design consideration (see figure 5). One example was the IC-Hexapod robot, which was able to catch and physically follow the gaze of visitors. The designer Matt Denton explained the purpose of the dual lenses on the robot face, out of which only one was actually used as an instrument for the robot to "see" with. Apart from providing the robot with a more face-like appearance, the second (and larger) lens did not record any image data, but by physically moving its apparatus, the user was effectively getting the experience of the robot "focusing" or "zooming in" on him or her – an important design feature for the interaction. Moreover, this was the robot that received the audience award that year.

The designer of *RubotII* (a Rubik's cube solving robot), Peter Redmond, actively worked with popular norms of how robots look, and made clear in his interview that the design was intentionally made to be interpreted as a robot. This was manifested in a number of design features, including: the robot covered by a metallic shield, its head having two flashing lights as 'eyes' and an animated red LED display as 'mouth'. The robot had a computer display at its front, purposefully designed with a science fiction inspired black background, decorated with a series of fake binary codes and a vector wire frame model, with the sole purpose of *"making it look complicated… and intelligent"*. Thus established norms in fiction were used as a playful tool for making the Rubik's cube solving machine more interesting and fun to play with.

In terms of an emerging 'what' for the art pieces, the artists sometimes collapsed their expressions into utilitarian descriptions. In the case of the *Jurema Action Plant* it was framed as a kind of prosthetic device that empowers a plant in such a way that it can move about. In a couple of cases it was about knowledge and how knowledge and information can be channeled through an artefact so that a person could find their place in the world. Anthropomorphic representations and having a personality were examples from the more non-utilitarian end, focusing more on experiential qualities and to play with the popular idea of what a robot should look like.

The machine esthetics of mass production
A fifth theme concerns the technical aspect of exploring different robotic materials, expressed as "*pushing the boundaries*" of what could possibly be done with selected materials. Often the discussion was about going deeper in the studies of these materials and exploring quirks and peculiarities that could be exploited in interesting and alternative ways while other examples include pushing the material towards the point of where it would wear out or break down. Other types of explorations were focused around particular qualities such as minimalism, inexpensiveness, ecological or *"carefully releasing sounds captured in the material"* (P99). However, this did not always mean a focus on technological innovation, instead some of the pieces made use of rather simplistic solutions and materials, but with

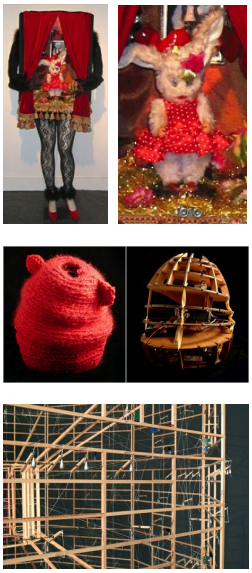


Figure 6. Showing traces of a human hand: *Mechanical Dolls* by Yuliya Lanina, *momo* by Kristin O'Friel and Che-wei Wang, and *Rechnender Raum* by Ralf Baecker

sophistication in terms of material craftsmanship in relation to conceptual content.

In one example the artist expressed thoughts from this perspective: *"I think the way it is put together aesthetically it is very approachable [...] There is no kind of mysterious parts"* (P48). This approach signifies one way in which materials would become articulated by reducing the mysticism within mass-produced objects.

In terms of physical computing one artist expressed that he was interested in the devices *"not just as tools"* but also everything that is accessible off the shelves and thus generally available to people. Contemporary ideals such as open source culture, DIY and the make movement are all represented, as well as critical art and physical computing as a topic for reflection [9]. The artists themselves were therefore personally engaged in practices of shaping form as well as functionality of their works, rather than wanting to outsource implementation to others. This is perhaps coloured by the "talent show" ideals that are specific to ArtBots.

While some of the artworks were a statement on for example (un)desired developments in society, not all artists wanted to make an explicit statement per se. The usage of physical materials in themselves still became a statement about societal developments to a certain degree. The combination of plant and a robotic machine, in which interaction with the plant itself would move its robotic cart, for example, was partially meant as a statement on the production process of components and its polluting consequences. Thus, the choice of materials in itself is rightfully regarded as an ethical one.

Discussion

The rich variety of the pieces presented at the two ArtBots events discussed here highlight that there are many potential sub groupings, themes and taxonomies within robotic art, beyond that of medium or material choices. This variety was partly the result of an active curating process, where the organizers have purposefully selected works that in interesting ways complement one another. However, rather than focusing only on this variety, we have chosen to bring up similarities and re-occurring themes as reflected in interviews with the artists.

The shared characteristics of the pieces were not only that they built on some form of *robotic materials*, but perhaps more importantly that they, given the theme of *ArtBots*, had to relate to the cultural notion of *robots*, as well as to what may qualify as *art*. The way the artists approached this situation, often in the form of very explicit and relevant critical pieces related to concepts discussed in the robotics research domain, was what we found most interesting in the interview data.

The first issue, how the works related to the cultural notion of robots, is illustrated in the five themes outlined above, discussed as a form of urban or contemporary myths within a fakelore of robotics. The second issue, how the artists reflect on their work as a form of artistic practice, is affecting how the artists have chosen to manifest and present their works (see e.g. Figure 6). The established norm within the western art scene is that works of art must be original, which inevitably forces artists to explore previously untested expressive forms. This in itself may work to trigger artists to step away from mainstream conceptions and

formats. Research is similarly often described as favoring unique efforts. However, it is notable how similar our research prototypes often are, in comparison with these works.

Several of the exhibited works could be read as direct commentaries on how topics are discussed in research in the field of robotics and the design of technology at large. More importantly, the critique is delivered in the form of robotic artifacts (i.e. materiality), and is part and parcel of the discourse of robotics. This might be a powerful strategy when discussing more fundamental issues rather than merely symptoms. As such we think it is relevant to consider other related types of discourses e.g. in terms of critical design in HCI, where the attitude is more towards making a particular commentary than to open up for creative dialogue [2].

Most of the artists related in some way to the mainstream culture of robots both as a resource, for building story, character, setting a context, and as a target for critical and discursive design work. Furthermore, in discussing the qualities of their works the artists reported on particular aspects related to its visuals, its sensuality, its presence, how it sounded, how accessible it was and how it moved. This shows that they had been working with these materials to make a point or to evoke a certain emotional or social response to their work, often by raising a particular question or aspect. We have seen similar issues arising at CHI too, but were impressed by the clarity with which these topics became articulated in the context of these exhibitions.

It should be noted that none of the exhibited works did explicitly refer to robotic fakelore as target for their artistic explorations. Several artists even refused to describe their work as belonging within the field of robotics. However, this distancing can in itself be seen as a critique, since they after all have chosen to present their work in the context of a robotics talent show. The mythmaking surrounding the concept of robots can still be useful in interpreting and placing the works in context, for understanding why they have taken the form they have, and what makes them interesting to our particular research domain.

The discourse developed within the field of kinetic art provides a reflective lens through which researchers and designers may discover new design openings. More specifically they point to a series of unnecessary trappings that are common in research practices, perhaps due to being situated around established notions of robotics and other advanced technologies in popular culture.

Finally, getting back to our notion of *fakelore*, and how many of the pieces related to what can be regarded a ‘tradition’ within the robot discourse, what may this bring to our discussions within HCI? Is it possible that our field has similar, in various ways troublesome ‘traditions’, that may run the risk of becoming the target of similar critiques? Are such norms invisible for us as researchers, or are we just ignoring them for now, concerned that breaking them might be disadvantageous in getting the research funding, publications, and citations, that our institutions and research funders constantly demand from us? Revealing fakelores of HCI could be done similarly by presenting artistic work that illustrates and triggers discussion on how the field manifests itself within its own norms and principles of conduct, in relation to

popular culture. With that said, artistic practices may be needed as a safeguard against falling into the trap of creating traditions where emerging myths would be regarded as unquestionable facts.

Conclusion

In this paper, we have presented an analysis of the topics brought up in exhibited works at international ArtBots events, as expressed in interviews with the exhibiting artists. Specifically we have looked at how the robotic art scene through crafting and materiality has developed a discourse to counterbalance what may be referred to as a kind of robot fakelore in contemporary culture. We identified five themes commonly surfacing in discussions of robot technology, to which the artists made active critical contributions. These were: robustness, intelligence in software, autonomy, anthropomorphism, and the machine esthetics of mass production. The artists commonly refused to talk of their work as 'robotics' per se, and their work may be inspirational for researchers designing interactive artefacts in a broader sense. In particular, we see that each of the topics raised here point to interesting design openings to designers of interactive products, addressing aspects of materiality, crafting, and the aesthetics of interactive experiences.

Acknowledgements

We would like to thank FoAM and Douglas Repetto, Director of ArtBots, for letting us take part in these events to engage with both artists and audiences. We would also like to thank all the individual artists and participants for letting us conduct interviews and use their works for the purpose of our research. This work was funded by the LIREC project (FP7/2007-2013 grant n° 215554).

References

[1] Candy, L., Edmonds, E. and Ascott, R. 2012. *Interacting: Art, Research and the Creative Practitioner (Art Design Management Policy a)*. Libri Publishing.

[2] Dunne, A. and Raby, F. 2001. *Design Noir: The Secret Life of Electronic Objects*. Basel.

[3] Fernaeus, Y., Jacobsson, M., Ljungblad, S. and Holmquist, L.E. 2009. Are we living in a robot cargo cult? *HRI '09* (La Jolla, California, USA, 2009), 279–280.

[4] Gaver, W. 2007. Cultural commentators: Non-native interpretations as resources for polyphonic assessment. *International Journal of Human-Computer Studies*. 65, 4 (Apr. 2007), 292–305.

[5] Höök, K., Sengers, P. and Andersson, G. 2003. Sense and sensibility: evaluation and interactive art. *CHI'03* (2003), 241–248.

[6] McCormick, C.T. and White, K.K. eds. 1997. *Folklore: An Encyclopedia of Beliefs, Customs, Tales, Music, and Art, Volume 1 (Google eBook)*. ABC-CLIO.

[7] Mensvoort, van, K. and Grievink, Hendrik, J. 2012. *Next Nature: Nature Changes Along with Us*. Actar.

[8] Schiphorst, T. 2009. soft(n): Toward a Somaesthetics of Touch. *CHI EA '09* (Boston, MA, USA, 2009), 2427–2438.

[9] Tanenbaum, J., Tanenbaum, K. and Wakkary, R. 2012. Steampunk as design fiction. *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12* (New York, New York, USA, May. 2012), 1583.

[10] Taylor, A.S. 2009. Machine intelligence. *Proceedings of the 27th international conference on Human factors in computing systems - CHI '09* (New York, New York, USA, Apr. 2009), 2109–2118.

Paper IV

Comics, Robots, Fashion and Programming: outlining the concept of ActDresses

Fernaeus, Y., and Jacobsson, M. Comics, Robots, Fashion and Programming: outlining the concept of ActDresses. Proceedings of TEI'09, Cambridge, UK, 2009, ACM.

Comics, Robots, Fashion and Programming: outlining the concept of actDresses

Ylva Fernaeus and Mattias Jacobsson
Swedish Institute of Computer Science
Box 1263, SE-164 29 Kista, Sweden
{ylva, majac}@sics.se

ABSTRACT
This paper concerns the design of physical languages for controlling and programming robotic consumer products. For this purpose we explore basic theories of semiotics represented in the two separate fields of comics and fashion, and how these could be used as resources in the development of new physical languages. Based on these theories, the design concept of actDresses is defined, and supplemented by three example scenarios of how the concept can be used for controlling, programming, and predicting the behaviour of robotic systems.

Author Keywords
Physical languages, semiotics, tangible interaction

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

One major stream of research within the areas of embedded and tangible systems design concerns investigations of new models and forms for programming. This has resulted in a large number of physical construction kits [e.g. 4, 24], physical tools for designing and controlling on-screen and acoustic media, and several more or less complete physical programming languages [19]. One application domain in this area concerns new ways of controlling the behaviour of electronic and robotic consumer products. As such products are inherently physical, often without a screen display surface, it is relevant to explore new and user-friendly ways for these to be controlled by physical means.

Interesting with respect to this is how people personalise their digital devices by different forms of physical means. Laptops are made personal by placing stickers on them, people buy or make their own customized cases, and they attach mascots and charms to their mobile phone handsets. Especially in the area of robotic consumer products, people tend to physically accessorize their technology, e.g., by sewing decorative covers for Roomba[1] and dressing up Pleo[2] for different occasions. Although the motivations for these practices may diverge drastically from programming (dressing up a vacuum cleaner may for instance be a decorative way of storing it when *not* in use), they do indicate an interesting starting point for exploration. This is also interesting as physical appearances of robots are increasingly explored in research, e.g. in studies of different head shapes [7] and costumes [25]. Given the fundamental role that clothing has in human culture, and the interest in surface appearance in product design, this may be used much more concretely also in physical interfaces.

After a short overview of current approaches to physical programming, the design concept of actDresses is described. The concept is theoretically inspired by two informal kinds of sign systems that are extensively used and understood in popular culture. The first area is the sign system used in comics, and how this has previously been used as inspiration in the design of visual programming languages. The second area that we explore concerns practices of clothing and accessorising, and how that could be used for controlling the behaviour of physical interactive devices. To make the discussion more concrete, we provide three example scenarios of how physical decoration and labelling can be used for controlling, programming, and predicting the behaviour of robotic systems.

APPROACHES TO PHYSICAL PROGRAMMING

A classic example of how robotic products are usually controlled and programmed can be seen in the robotic turtle used with the early developments of the Logo programming language [21]. That robot was intended as a physical representation and enactment of programming instructions, but the actual instructions were created and sent to the turtle from a separate workstation. Another example is the Lego Mindstorms robotic construction kit, where the intended functionality is partially manifested in the physical

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
TEI 2009, February 16–18, 2009, Cambridge, UK.
Copyright 2009 ACM 978-1-60558-493-5/09/02 ...$5.00.

[1] See http://www.myroombud.com/

[2] See e.g. user generated blog posts at www.pleoworld.com

design, but the actual behaviours can only be added, inspected and tuned in the context of using a personal computer. Similarly, changing the behaviour of most consumer robots of today, such as Pleo, Roomba or Aibo, requires a PC-based mode of interaction, which is essentially different from how users otherwise engage with these products. Moreover, when making programs in these settings, it is often hard to perceive what the expected behaviour will be like. For physical computing, this often results in extensive loops of uploading, debugging and fine tuning the interaction of the constructed system [13].

An intriguing question is what happens if the instructions in these cases would not be confined to other physical devices, but visualised and possible to manipulate and change in the ordinary use setting of the object controlled. This particular question has been explored in a range of projects on physical language design, including Patten et al's explorations of using physical string to program robotic systems [22], and McNerny's development of tangible Lego bricks to control and program electronic devices [19].

Several robotic products are also programmable by means of physical training or demonstration, e.g. by bending or moving the artefact in different ways, which gets recorded and repeated by the program. Topobo [24] is a physical construction kit based on such a model of control, just as Curlybot [10], a wheeled robot that can be trained to move in patterns defined by the user. These and similar strategies for end-user specification of robotic movement have proven highly successful, especially for navigation and posture control tasks. However, making more complex programs sometimes requires some form of code that can be examined, edited, and revisited. This is available when programming robots on a PC, but is often lacking when controlling and training robots by physical means.

An increasingly common approach is also to use tangibles of different kinds. Examples include the use of Wii remote controls to control robot gesture [12], and a set of tangibles for controlling robotic teams [17]. Related explorations can be found in the domain of mechanical and interactive toys, where it has long existed dolls and other objects that can be explicitly switched into different modes by attaching different accessories to them (e.g. My real baby). The rich role-playing associated also with more conventional dolls (e.g. Barbie) is to a great extent due to clothing and accessorizing qualities as part of the interaction. A similar approach could be used for combining multiple programming constructs, i.e. collections of physical items that can be combined in many ways.

The general problem of making programming more concrete has also been explored extensively in the area of designing programming tools for children and end users, especially by making simplified higher level forms of representation [see e.g. 14]. However, additional work is needed to explore how to create visually effective and easily understandable ways to represent physical program actions (i.e. a behavioural correspondence to WYSIWYG). Here this design space is explored based on the fundamental aspect of programming languages concerned with signs and symbols as representing computational actions. Of relevance to this is the field of semiotics [5], which studies the use and interpretation of signs.

According to semiotic theory, signs may take more or less any form, including words, images, sounds, gestures, acts, and physical objects. However, they become signs only when they are loaded with meanings that make them stand for something other than themselves. Thus, a sign always consists of a combination of a *signifier* (the manifestation of the sign), and a *signified* (what the sign refers to). As an example, Chandler [5] explains how the same signifier, the word 'open', becomes a different sign if placed on a push-button inside a lift than if printed on a flag to indicate that a shop is open for business. Similarly, the concept 'open' could be represented by a range of different kinds of signifiers depending on context.

Here, focus will be on a scenario of using signs in the form of physical markings attached to a digital artefact, where the physical markings act as *signifiers*, and the actions or behaviours that they would make the artefact perform would be the *signified*. In the development of new physical languages, the challenges thereby include both the designs of the actual signs, as well as their coupling to meaningful computational action.

LEARNING FROM COMICS AND FASHION

Textiles and fashion has achieved increased attention lately in terms of crafting with new materials. Examples include Leah Buechley's work with the textile LilyPad toolkit [4], a range of reactive wearable costumes for playing and interaction [e.g. 23], and in combining conventional design practices, such as fashion, with digital features [20]. Fashion theory is also relevant to tangible computing as it essentially deals with physical features such as fabric, texture, transparency, shape, and so on.

Another motivation for exploring clothing and fashion in terms of physical language design concerns how people present themselves to others through their surface appearances. Clothes not only serve the purpose of being convenient for certain activities, they also serve a range of communicative functions, indicating e.g. appropriate behaviour, group belongings, and expected interactions [6, 11]. As a particular example, one could consider the richness in function of theatrical costumes. Similarly, markings on the physical outside of a digital artefact could be used to indicate to its users what mode it is currently in, and what behaviours and interactions that could be expected, at a certain point in time.

The visual sign language of comics is another form of cultural expression that is relevant to programming, because like conventional programming code, comics depict dynamic activities using a static representation [15].

Comics is also a form of language where it is acceptable to exaggerate and emphasise properties, e.g. powers and abilities, in a way that is playful, again using a form of language that is easy to read. For readers that have learned the principles and sign language of comics, the visual presentation can produce a very direct reading experience, creating an illusion of for example motion and sound, even though the medium itself is static and silent. [15, 18]

Here we explore how the semiotics of these two fields, fashion and comics, could work as inspirations to physical language design.

If signs and symbols known from fashion and comics should work as a form of code for controlling digital devices, one could assume that they would take a rather different and much less explicit character than the programming codes we are used to. Apart from historical shifts and variations in appropriate 'dress codes' for instance, Davis [6] lists three features that make fashion highly ambiguous as a code system: *"First it is heavily context dependent; second, there is variability in how its constituent symbols are understood and appreciated by different social strata and taste groupings; and third, it is – at least in Western society – much more given to "undercodings" than to precision and explicitness."[6, p.8]* However, given the multitude of forms in which different programming paradigms have been developed, finding and exploring possible parallels may still be relevant.

A basic property of clothing also concerns its modular qualities, where layers and collections of different items can be combined in a variety of ways. This property has been conceptually likened to the activity of higher-level programming by combining existing scripts or behaviours into new functioning programs [2]. Making programs by putting together existing pieces of code into new arrangements also relates to common popular practices of software development, e.g., the use of class libraries, interface widgets, and open source methodologies. Especially in educational settings and for novice programmers, such 'higher-level' modes of program construction have been found particularly useful.

Similarly, the visual language of comics is based on a combination of text, pictures, and visual markings such as labels and frames of different kinds. Comic book artists use a combination of such signs together to communicate dynamic features and actions that cannot be expressed using ordinary images. A well explored sign for expressing temporal aspects in comics is a sequence of panels, working to move the story forward [18]. Several research projects have shown that such sequences can be applied in visual programming for defining e.g. narrative structures and before-after scenarios [16]. Another kind of signs, and which may have further potential in the case of physical languages, is the family of visual signs used to depict dynamic actions that happen within a static visual frame. These signs include speech balloons, sound markings, speed lines, pain stars, etc. As such signs are always shown in the immediate visual context of the object or character that they refer to, semiotic theory refers to such signs as *contextual signs*. Systems that draw on this type of markings attempt to support a concrete high-level configuration that may be easier for users to read and interpret than more abstract modes of programming using lower level symbolic representations [9].

THE CONCEPT OF ACTDRESSES

In programming, as in interaction design at large, the physical form and how it shapes the behaviours that users predict and expect from a digital artefact is becoming increasingly relevant to explore. In HCI, this has been conceptualised in terms of what is *sensed, desired and expected* [1], and from a perspective of industrial design a similar concept has been framed as a balance between *appearance and action* [8]. However, knowing only the hardware is never sufficient for predicting how the system will actually work. The concept of clothing may then provide a valuable link between physical bodies, skills and capabilities, and the varying contexts of use.

For the purpose of physical programming, we define actDresses as a kind of physical markings that can be directly attached to a digital artefact, and that signifies some property, action, or behaviour of that artefact. Inspired by the method of visual programming with contextual signs [9], there are two main characteristics that distinguish actDresses from most other methods for programming and control of physical systems.

The first property is that the sign is shown in the *immediate physical context* of the object having the feature represented by the sign. This helps showing which object is controlled by a sign, and can give a direct visual impression of the resulting behaviour. This is not the case in most settings of programming robotic and tangible systems, where the 'code' is sometimes hidden, often at a completely separate hardware device. This also addresses the general desire for visible forms of program representations, which can be inspected and modified.

As a second property, actDresses are meant to represent and produce *perceivable actions* in the computerised system, in ways that end users may easily relate to and understand. As signs, these could take the forms of texts, pictures, or three-dimensional objects, drawing for instance on the material or cultural meanings of their manifestations.

The role of appearance is a central aspect that must be emphasised in this design concept, as the items simultaneously may work as controls as well as well as a form of decoration. Of importance to this is also awareness of existing cultural meanings of different signs, as well as concrete issues of readability. For instance, when attaching several signs or labels to the same object, a consequence may be that they obscure the object, so that it is difficult to

clearly see the object underneath. The signs could themselves also overlap and obscure each other.

As with any higher level form of programming based on behaviours that should be possible to combine in a variety of ways, come aspects related to modularity. This concerns how different signs may be combined together, not only visually, but also in terms of their respective signifies, e.g. how different program actions can be practically and meaningfully combined. In terms of implementation, this also concerns aspects of program order and concurrency, and whether certain signs should be given higher priority than others when it comes to execution.

THREE EXAMPLE CASES

To illustrate how the concept could be realised concretely, we here provide three short interaction scenarios designed for different kinds of robotic artefacts. The first scenario is designed for the Pleo robot dinosaur, the second is designed for the experimental GlowBots platform, and the third case is designed for a prototype consumer vacuum cleaner robot. The examples are designed as physically embodied sketches, and an important aspect when selecting the scenarios was that they should be possible to realise with readily available technology.

Case 1: Role assemblage outfits for Pleo

Pleo is a robotic baby dinosaur, and one of the more sophisticated consumer products designed to simulate real life-like behaviour as a form of 'electronic pet'. The robot has approximately the same size as a cat or a small dog, and is equipped with a large number of sensors that make it responsive to touch, and has a sophisticated posture control system aimed to imitate how real animals respond to petting. The robot does not walk more than a few steps, and it makes sounds rather than talk or respond to talk. When users interact with this robot, this is done primarily through physical means, by carrying it around, by petting it, and by dressing it up in different costumes. Moreover, rather than treating Pleo like a mechanical device, users tend to play along with the pretention of a real animal, e.g. by naming it, tickling it, referring to actions such as being sleepy, happy, or wanting something (see user-generated blog posts at www.pleoworld.com).

Finding ways for end user to change the details of how this robot moves and interacts could map poorly with existing observed interaction patterns, and possibly even destroy the play on the illusion of interacting with a live pet. Therefore the mode of interaction must be carefully designed and grounded in existing practices of playing with Pleo. This includes both the form of physical manipulation, and the conceptual level of engagement.

In this particular example scenario we wanted to explore how the standard behaviour of the robot could be altered by letting it change mode or even acquire new abilities. At the same time we looked for a strategy that would seamlessly transfer to existing practices by not requiring much alteration of the original interaction style, nor affect the physical appearance of the robot's skin surface. The result was a set of scenarios such as putting a pyjama on to put the robot to sleep (see Figure 2), attaching a necklace to set it into guard mode, or shoes that make it walk.



Figure 1. Controlling Pleo using actDresses. From top-left: Playing with the robot in "watchdog" mode, as indicated by bracelet. When user changes the costume from bracelet to pyjama, the robot is slowly switching into sleep mode.

The implementation strategy of this interaction scenario is based on RFID technology, with a reader mounted on the robot and each of the available garments in the collection equipped with RFID tags. This combined with internal sensors, e.g. temperature and sound sensors could allow for a range of new and rich modes of interaction, e.g. putting a warm jacket on in a cold or warm environment may result in different robot actions. Items can also be designed as parts of full 'persona' outfits, turning the robot into modes that entail more complex behaviour patterns for special occasions or play scenarios.

Case 2: A behaviour pin collection for GlowBots

GlowBots are a collection of experimental robots with round LED-displays on their top, acceleration sensors for user interaction, protocols for robot-robot communication, and wheels underneath for autonomous movement (Figure 3). We use these robots here as a second illustration case to emphasise that the concept of actDresses not necessarily requires human-like or zoomorphic technology as its base.

We also wanted to specifically focus on actions and user interactions that can be sensed and performed by the GlowBots platform on a lower conceptual level than for that of Pleo. This was motivated by the more mechanical looking form of the device, and also on the envisioned actions that users would be likely to want to modify. These could be narrowed down to very basic groups of program actions: (1) Navigation in space, (2) Display patterns, (3) Generate sound, (4) Send and receive signals from other robots, and (5) Respond to user interactions, e.g. shaking



Figure 2. The GlowBots scenario. Selecting from a collection of physical behaviour "amulettes", attaching them to a GlowBot, and finally the GlowBots move, glow, and interact according to items on their bracelets.



Figure 3. The vacuum robot scenario. A set of signs that can put the robot into different modes. The "shy" sign has made the robot hide under the sofa, and is switched to another mode by the user, to make is spiral slowly and silently on the carpet.

and holding the robot in different ways. For each of these, a range of behaviours of different complexity could be developed. As with the Pleo case, the complexity of these behaviours may stretch from more elaborated behaviours that combine several actions, e.g. displaying a sequence of patterns on the screen, to more detailed coordination of movement and sound, or instruction for how the robots should move e.g. towards or away from one another.

The set of behaviours designed for this platform consist of simple unit resistor pin-based decorations where a rich possibility for making different arrangements and combinations is a main quality. Combining several simple behaviours may lead to more complex patterns. For instance, Figure 3 shows a bracelet with behaviours for 'flash', 'play a tone', 'spin' and 'move forward' (will make it move in circle). Adding another 'move forward' will make it move faster and in larger circles.

Case 3: Comic Signs for a vacuum robot

In our third case we use commercial vacuum cleaning robots as a prototype base for exploring how the concept of actDresses could enhance a task-oriented robot. Earlier studies points out that even technomorphic looking robotic appliances can engage users 'socially'. In the case of Roomba, as with Pleo, specially designed cloth covers are available for purchase on the web. The main usage of such clothes may on the other hand not primarily be for functional purposes, but for personalisation and decoration.

Here we explore how comic book-style patches attached by magnetic tape can be used to extend the robot's basic behaviours with super positioned abilities. As inspiration, Braitenberg [3] introduced the concept of having very simple behaviours from hard-wired sensors-actuators. Such behaviours would for instance be light-seeking, light-avoidance, or turning in a direction as response to simple stimuli, resulting in behaviours that people tended to interpret as psychologically driven, e.g. being curious, aggressive, nervous, etc. Moreover having signs that represent e.g. light-avoidance, users would be able to use a flashlight on the vacuuming robot, making it more interactive. Other possibilities would be to use various super-patches to enhance a certain functionality e.g. speed.

In our example scenario, we have designed a set of comic book like magnetic patches that can be attached to the metallic shield on top of the vacuum robot (see Figure 3). Apart from the standard sensors of most commercially available robot vacuum cleaners, this would be equipped with a basic RFID-reader for reading of the signs, as well as a number of extra sensors to allow for the interaction patterns similar to those in the Braitenberg's Vehicles example, for responding to e.g. motion, sound, and light.

DISCUSSION

Computer programming has conventionally been concerned mostly with textual and symbolic modes of construction using screen displays as the general medium for representation. However, with increasingly physical systems, often not even equipped with screen displays, other systems and modes of program representations need to be explored. Theories of disparate fields such as comics and fashion could here be useful to explore as they are holding specific semiotic qualities, for instance that they are possible for ordinary people to read and relate to.

We have introduced the concept of actDresses, e.g. using physical clothing, labels, and accessories for controlling physically embodied systems. The work is motivated by existing practices of physical customisation of electronic devices, the current trend towards commercial products with increasingly advanced control mechanisms, and experiences from the domain of end-user programming.

As illustrated in our three interaction scenarios, the concept of actDresses could be visually manifested in a range of different ways. Many more scenarios could be envisioned i.e. bracelets attached to a robot with symbols representing program actions, a jacket with pockets containing behaviour descriptions in the form of comic strips, or tasks that the interactive artefact should perform. Thus, the shapes and forms that different representations could take include a near to infinite amount of options and variations.

Another aspect of the example cases concerns how the specific hardware platforms resulted in completely different sets of designs, based on what was considered likely for users to want to modify and control on the different devices. This illustrates the necessity to consider physical shape, behaviour capabilities, and interaction modalities together, grounded both in existing use patterns and capabilities of the respective platform. The example cases also point to how the level of abstraction could vary extensively while still being based on the same metaphor.

Of course, in comics as well as in fashion, all the visual signs and symbols closely interplay with characters, people, contexts and objects. Characters in comics usually display facial expressions and body postures that convey the action in the story, and every sign may be carefully crafted for a specific character drawing. Similarly, posture, figure, and physical environment play important roles in how clothes are interpreted and negotiated in social contexts. So even though actDresses may communicate effectively, they naturally take another form of expression when brought to the context of tangible computing.

In developing new ways of controlling, programming and predicting the behaviour of physical consumer products, a deeper understanding of the fundamental theories explored in these and other fields may hold further benefits. Projects like these suggests further potential in using loose physical items, such as garments, jewellery and visual signs as resources for controlling and programming physical computing systems.

REFERENCES

1. Benford, S., et al. (2005). Expected, sensed, and desired: A framework for designing sensing-based interaction. *ACM Trans. Comput.-Hum. Interact.*, *12* (1). 3-30.
2. Blackwell, A.F. (2006). Gender in Domestic Programming: from Bricolage to Séances d'Essayage *CHI'2006 workshop on End User Software Engineering*.
3. Braitenberg, V. (1984). *Vehicles: Experiments in synthetic psycology*. MIT Press, Cambridge, Massachusetts.
4. Buechley, L., Elumeze, N. and Eisenberg, M. (2006). Electronic/Computational Textiles and Children's Crafts. Proc. of *IDC2006*, ACM.
5. Chandler, D. (2002). *Semiotics: The Basics*. Routledge, London.
6. Davis, F. (1994). *Fashion, Culture, and Identity*. University of Chicago Press.
7. DiSalvo, C.F., et al. (2002). All Robots Are Not Created Equal: The Design and Perception of Humanoid Robot Heads. Proc. of *DIS2002*, ACM Press.
8. Djajadiningrat, T., et al. (2004). Tangible products: redressing the balance between appearance and action. *Personal Ubiquitous Comput.*, *8* (5). 294-309.
9. Fernaeus, Y., Kindborg, M. and Sholz, R. (2006). Rethinking children's programming with contextual signs. Proc. of *IDC'06*, ACM Press, 121-128.
10. Frei, P., et al. (2000). Curlybot: designing a new class of computational toys. Proc. of *CHI'00*, ACM Press, 129-136.
11. Goffman, E. (1959). *The Presentation of Self in Everyday Life*. Anchor Books.
12. Guo, C. and Sharlin, E. (2008). Exploring the use of tangible user interfaces for human-robot interaction: a comparative study. Proc. of *CHI'08*, ACM.
13. Jonsson, M., Fernaeus, Y. and Tholander, J. (2008). Setting the stage - Embodied and spatial dimensions in emerging programming practices. *Interacting with computers* (Special issue on Physicality and Interaction Design).
14. Kelleher, C., Pausch, R. and Kiesler, S. (2007). Storytelling Alice Motivates Middle School Girls to Learn Computer Programming. Proc. of *CHI2007*, ACM.
15. Kindborg, M. (2003). Concurrent Comics - programming of social agents by children. Ph.D. Dissertation. Linköping University.
16. Kindborg, M. and McGee, K. (2005). Comic Strip Programs: Beyond Graphical Rewrite Rules. Proc. of *VCL 05*.
17. Lapides, P., Sharlin, E. and Sousa, M.C. (2008). Three dimensional tangible user interface for controlling a robotic team. Proc. of *HRI'08*, ACM.
18. McCloud, S. (1993). *Understanding Comics*. HarperCollins Publishers, New York.
19. McNerny, T.S. (2004). From turtles to Tangible Programming Bricks: explorations in physical language design. *Personal and Ubiquitous Computing*, *8*. 326-337.
20. Pakhchyan, S. (2008). *Fashioning Technology A DIY Intro to Smart Crafting*. Make Books.
21. Papert, S. (1980). *Mindstorms: Computers, Children, and Powerful Ideas*. Basic Books, New York.
22. Patten, J., Griffith, L. and Ishii, H. (2000). A Tangible Interface for Controlling Robotic Toys. Proc. of *CHI'00*, ACM, 277-278.
23. Post, E.R. and Orth, M. (1997). Smart Fabric, or "Wearable Clothing". Proc. of *International Symposium on Wearable Computers*, IEEE.
24. Raffle, H.S., Parkes, A.J. and Ishii, H. (2004). Topobo: a constructive assembly system with kinetic memory. Proc. of *CHI'04*, ACM Press, 647 - 654.
25. Robins, B., et al. (2004). Robots as Assistive Technology - Does Appearance Matter? Proc. of *RO-MAN 2004* IEEE Press, 277-282.

Paper V

The Look, The Feel and The Action: Making Sets of ActDresses for Robotic Movement

Jacobsson, M., Fernaeus, Y., and Tieben, R. The Look, The Feel and The Action: Making Sets of ActDresses for Robotic Movement. Proceedings of DIS 2010, Aarhus, Denmark, August 17-20, 2010, ACM.

The Look, the Feel and the Action: Making Sets of ActDresses for Robotic Movement

Mattias Jacobsson, Ylva Fernaeus
Swedish Institute of Computer Science
Box 1263, 164 29 Kista, Sweden
[majac, ylva]@sics.se

Rob Tieben
Eindhoven University of Technology
P.O. Box 513, 5600 MB Eindhoven, Netherlands
rob@robtieben.com

ABSTRACT
We present a series of design explorations for controlling autonomous robotic movement based on a metaphor of clothing and accessorising. From working with various sketches, scenarios and prototypes we identify a number of particular features of this form of interaction, as well potential challenges for designers of other systems based on this design concept. Finally we conclude with a few general implications, especially concerning the inert properties of visibility, physicality and modularity with respect to the particular case of interaction and robotic movement.

Author Keywords
Interaction design, Human robot interaction, Tangible interaction, Physical user interfaces

ACM Classification Keywords
I.2.9 Robotics: Operator Interfaces.
H.5.2 User Interfaced: User Centred Design.

INTRODUCTION

In the research areas of human-computer and human-robot interaction, as in interaction design at large, the physical forms of artefacts and how these shape the behaviours that people expect from them is becoming increasingly relevant to explore. Benford et al [1] have conceptualised this general theme of explorations in terms of what is sensed, desired and expected, and similarly Djajadiningrat et al [6] have discussed a related problem as striving to find a balance between appearance and action.

In our research a primary goal is to design for meaningful interaction, grounded in existing practices that can be or have been studied and observed among people. Interesting with respect to this is that it has been increasingly noted how people personalise their digital devices by different forms of physical means. Laptops are made personal by placing stickers on them, people buy or make their own customised cases, and they attach mascots and charms to their mobile phone handsets. Especially in the area of robotic consumer products, people have been reported to physically accessorise their technology, e.g., by sewing decorative covers for Roomba [17] and dressing up Pleo for different occasions [9].

Moreover, given the fundamental role that clothing has in human culture, and the interest in surface appearance in product design, our hypothesis is that this may be used much more concretely also as resources for controlling the software of physical devices. The concept of clothing may for instance provide a valuable link between physical hardware, expected behaviours and capabilities, and the varying contexts of use. For this purpose, we developed the concept of ActDresses [7] as an approach to designing for interaction where physical markings can be directly attached to a digital artefact to add or modify some digital property, action, or behaviour of that artefact.

In this paper we explore how such physical markings can be used for the specific case of controlling, programming, and predicting the movement of physical interactive artefacts such as robotic vacuum cleaners or toy vehicles (see Figure 1).

After a short overview of related work, we present a series of design explorations on this theme using scenarios, mock-



Figure 1. Four different design explorations, all based on the theme of controlling autonomously moving artefacts by attaching physical labels, signs or accessories.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
DIS 2010, August 16–20, 2010, Aarhus Denmark
Copyright © 2010 ACM ISBN 978-1-4503-0103-9, 2010/08 - $10.00.

ups, and working robotic prototypes, conducted during the course of one year. We end by a discussion on particular reflections and design challenges that have emerged through this process, pointing at potential implications for future designs based on ActDresses as a design concept.

RELATED WORK – THEORETICAL EXPLORATIONS

This section presents related work in the areas of designing accessories for robotic products, the metaphor of clothing and dress codes in interaction design, and more broadly related research in the field of tangible programming and interaction.

Accessories for robotic products

Many existing robotic products include at least one accessory that symbolises a basis for physical interaction. Examples of such robots and accessories are Furby and the spoon, AIBO and the Pink Ball, and Pleo and the green Leaf. It is also possible to buy extra accessories to most of these kinds of products. The accessories play a double role: being a raft for intelligible agency and providing an added value from a marketing perspective. However, these accessories are more like external tools for interacting with the robot, rather than something that is meant to be attached to the robot surface.

The human-robot interaction research community has recently become increasingly interested in the physical appearance of robots e.g. studying the effects of different head-shapes [5] and costumes [16]. In particular this has become a core issue in the sense that capabilities that are suggested by its mere appearance appear to cause an elevation of peoples expectations that goes beyond its actual functionality [9]. The rare examples of accessories that provide more function also appear to be less directly attached, e.g. Roomba‟s infrared virtual wall beacons. It is interesting to note that much of human-robot interaction research so far has focused on the robotic artefact per se without paying much attention to interaction models involving accessories.

A recent study [18] explored the use of non-computational surface add-ons for the robot vacuum cleaner Roomba. Similarly the surface of the robot Nao can be slightly customised by interchangeable coloured plates. Although they do not add any additional computational behaviour, these kinds of accessories do provide the ability to personalise the robot, and to divide several robots into teams. Similar to children‟s play with inanimate toys [19], the representational manufacturer-given characteristics and format lend these kinds of artefacts to external representational structuring through accessorising (see Figure 2).



Figure 2. Customized covers for the Roomba vacuum cleaner robot, in the form of a frog (left) and tiger (right).

The metaphor of clothing and dress codes

Two notions that could be of particular interest to our designs are uniforms and costumes, which conceptually bind together function, practices and visually perceivable manifestations in socio-cultural settings. The difference between the two is subtle, but the uniform tends to be more strict while the costume would be more general in terms of encoding an outfit.

Rafaeli and Pratt [14] identify three dimensions for an analytic framework of uniforms – *attributes*, *homogeneity* and *conspicuousness*. Attributes refer to specific features such as colour, material and style, homogeneity is the extent to which there is a consistency between people and between occasions in how they dress, and conspicuousness is to what extent the dress code in unique compared to other groups in a society. Furthermore, dress codes not only account for deeper socio-cultural meanings e.g. social status and beliefs, but also more contextually oriented meanings e.g. allowance for passage or appropriateness to perform a certain action.

A dress code describes how individual pieces are recombined and put together, in our case into a complete ActDress. Each piece can be thought to have some of the following properties:

- Belonging to a set
- Visually representing a function
- Could be recombined with other pieces
- Could add a certain functionality

Similar ideas have been explored in terms of democratising hacking culture from a gender perspective by looking at DIY, tinkering and bricolage. Specifically Blackwell suggests that women‟s (stereotypically put) sense of assembling outfits - *séance d'essayage* – captures the sort of competence required for this kind of end user programming [2].

Within the American robotic toys industry the notion of „*skits*" carries the meaning of small acting repertoires or themes of motions that can be performed by a robotic device. For instance, using the robotic toy dinosaur Pleo it is possible to „run" skits by downloading script-files from the Internet onto a SD-card that then can be inserted into a SD-slot in Pleo‟s belly. Available skits are e.g. the Halloween, Christmas, Valentine and Watchdog themes. When combined, dress codes could be defined to encode for such skits in a more structured way.

Physical and tangible programming

Historically programming has included very physical forms of interaction using punch cards and changing of electron tubes. However for many decades now, the specification and control of interactive systems have been based primarily around on-screen developing environments, even for the case of highly physical robotic systems.

Figure 3 illustrates a simplistic case of how a robot may be made to spin in a certain way by using conventional programming code downloaded from a separate computer. The figure also illustrates the fundamental concept from semiotic theory that a sign (e.g. for controlling interactive systems) is always built up of two parts – the manifestation of the sign itself (signifier) as well as what it refers to (the signified) [4]. Importantly, a sign referring to a particular computational action, e.g. spinning in a certain way, may take more or less any form, including words, images, sounds, gestures, acts, and physical objects. In settings where the interactive artefact does not have a screen display of its own, the „code" is more or less hidden, often at a completely separate hardware device. A state-of-the-art example is the Choregraphe environment for controlling and programming the Aldebaran NAO robot [12].

In the development of new approaches to controlling robotic action, the challenges thereby include both the designs of the actual signs, as well as their coupling to meaningful computational action. A number of research projects have been exploring producing and predicting behaviours by means of physical manipulation only. Examples include Topobo [15], Sketch-a-move [10] and Curlybot [8], and a range of programming by example implementations in industry.

A closely related stream of research is the also early experiments within the domain of tangible user interfaces (TUI's), where physical objects have been designed to represent and load digital files and actions. Examples include Ullmer et al.'s MediaBlocks [20], and Ljungstrand et al.'s WebStickers [11], both conducted during 1999-2000.

DESIGN EXPLORATIONS

Our focus will be on a scenario of using signs in the form of physical markings attached to a digital artefact, where the physical markings act as signifiers, and the actions or behaviours that they would make the artefact perform



Figure 3. Left: Signifier (the manifestation of the sign). Right: Signified (what the sign refer to).

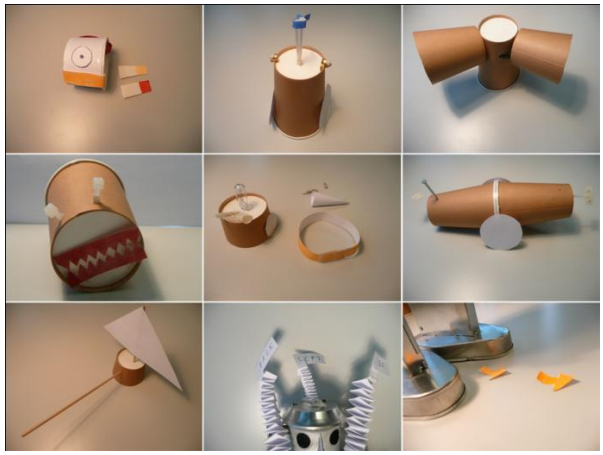


Figure 4. Paper mock-ups of behaviour visualisations using various physical shapes.

would be the signified. Thus, ActDresses are displayed in the immediate physical context of the objects that they control, thereby addressing the general desire for a directly visible, inspectable and modifiable program representation. A related property is that they are meant to represent and produce *perceivable* actions in the computerised system, in ways that end-users may easily observe and understand.

To give a sense of how the ActDresses concept could be realised concretely, a series of interaction scenarios and mock-ups have been created for the case of robotic movement. Figure 4 shows a series of paper cup mock ups, illustrating e.g. how the shape may make an object look like it is able to hear, see, move in a certain direction, or possess certain personality traits such as being aggressive, as manifested by its physical form factors. This kind of low-fidelity explorations helped gaining an understanding of the design space of physical shape in the representation of movement and physically enacted behaviours.

Below we present a series of semi-implemented explorations to illustrate how working with conceptual sketches in different materials may provoke assumptions and guide actual implementation further on. Our focus has been on simple autonomously moving robots, based on platforms such as the educational e-Puck and Roomba Create.

Hands-on manipulation of robotic movement

As a way of exploring the fundamental properties of direct manipulations with programming and control of robotic systems we made hardware experiments (Figure 4) to explore physical properties of manipulating robotic surfaces. The interaction principles we covered were (1) direct manipulation of sensors: how does a robot behave, and what does the user expect, if a user „blindfolds" a robot? (2) Direct manipulation of actuators: disabling a wheel changes the actual and expected behaviour of a

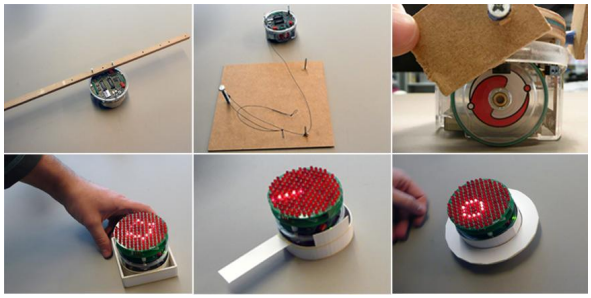


Figure 5. A series of explorations of hands-on manipulations of robotic movements by e.g. covering parts of its sensors, attaching it to strings and sticks, all affecting how the movement of the object could be controlled and predicted.

robot: it can only drive in circles (3) Direct manipulation of physical characteristics: by adding physical objects, the behaviour of a robot changes: a connected string literally constraints the movement possibilities (4) Tags and flags: a user can guide, direct, program or control a robot. How can tags and flags visualize this? (5) Direct manipulation through physical objects: adding a square shape makes the robot display a square shape, rotating it displays a rotating square, etc.

A second stream of explorations covered agent principles, how users through physical means could manipulate and in a sense program existing robots, and to an extent also how robots may influence each other. Conditions (If-then-behaviour), copying and emergent principles were explored using the GlowBots (based on the e-Puck platform, see Figure 6). While this allowed more complex behaviour of a group of robots, it appeared to remove the ActDresses principle for individual robots. For instance, when a robot had copied a behaviour from another robot, its visual appearance would no longer match its behaviour. One solution would be to allow the robot to adapt its own appearance, but since this would imply a whole new dimension to the design concept, we decided to take a step back and focus on interaction with a single robot at a time.

It became apparent that the *interpretation* of the appearance that was affecting the behaviour was crucial: e.g. if a user was not able to predict that blocking one wheel would cause the robot to drive in circles, then the correct appearance changing required some trial-and-error cycles. After „succeeding", and thus after observing both the appearance and the resulted behaviour, the mapping and interpretation became clear. Changing the appearance should thus be consistent with the resulting changes in behaviour, and the user should be able to learn this by trial-and-error iterations.

Interaction scenario: high-level behaviours

In the scenario explored in Figure 6 we use commercial vacuum cleaning robots as a prototype base for exploring



Figure 6. Interaction scenario for simplistic higher level behaviours. By attaching simplistic labels indicating a higher level state of activity, users would be able to put the device into different modes.

how the concept could enhance a task-oriented robot. Here we explore how comic book-style patches attached by magnetic tape can be used to extend the robot"s basic behaviours with super positioned abilities. As inspiration, Braitenberg [3] introduced the concept of having very simplistic behaviours from hard-wired sensors-actuators. Such simple actions resulted in behaviours that people tended to interpret as psychologically driven, e.g. being curious, aggressive, nervous, etc. Reasons for experimenting specifically with signs borrowed from comics was to explore a type of notation that many people are familiar with and already know how to read.

In this scenario, a set of comic-like magnetic patches are attached to the metallic shield of the vacuum robot (prototyped by using an upside down cake pan in its place), putting it into different modes. In Figure 7, a „shy" sign has made the robot hide under the sofa, and is switched to another mode by the user, to make is spiral slowly and silently on the carpet. Apart from the standard sensors of most commercially available robot vacuum cleaners, this scenario would require an RFID-reader for reading of the signs, as well as sensors to allow for interaction patterns that respond to e.g. motion, sound, and light.

Interaction scenario: detailed instructions

As a complement to the very high-level behaviour explorations depicted in the above scenario, we sketched out a case that further emphasises actions and user interactions that can be sensed and performed on a lower level of abstraction. For the platform that we used for this scenario (the GlowBots), these actions could be narrowed down to very basic groups: (1) Navigation in space, (2) Patterns on its LED-display, (3) Generate sound, (4) Send and receive signals from other robots, and (5) Respond to user interactions, e.g. shaking and holding the robot in



Figure 7. Interaction scenario for how combinations of labels with more detailed instructions could influence robotic movement and interaction.

different ways. For each of these, a range of behaviours of different complexity could be developed.

The interaction scenario sequence in Figure 7 shows a user selecting from a collection of physical behaviour „amulets", attaching them to a GlowBot, and finally how a group of GlowBots move, glow, and interact according to items on their bracelets. The implementation strategy for this scenario is based on simple unit resistor pin-based decorations where combination is a main quality. Combining several such simple behaviours may then lead to more complex patterns.

IMPLEMENTATION EXPLORATIONS

From sketching in hardware and software we went onto implementing more complete demonstrators. The first implementation was used as a tool for reflecting about ActDresses from a visibility aspect and probing what other people thought about the concept in general. The second exploration focused on using wireless technology together with a scenario that had inherent modular properties. In the third exploration we started over again, went back to the roots and progressed more assertively by applying successful ideas and concepts from the previous experiments.

The Hat Trick

In the first implementation we did want to get a feeling for the concept by visualising simple behaviours using accessories like hats. In this case we use an e-Puck, a two-wheeled educational robotic platform the size of a coffee-cup. It has diverse technical capabilities e.g. infra-red sensors, accelerometer, Bluetooth, microphones, LED"s and a speaker. The goal was to equip it with custom-made hats so that each hat would correspond to a certain behaviour that is activated as soon as the robot is activated with the hat (Figure 8).

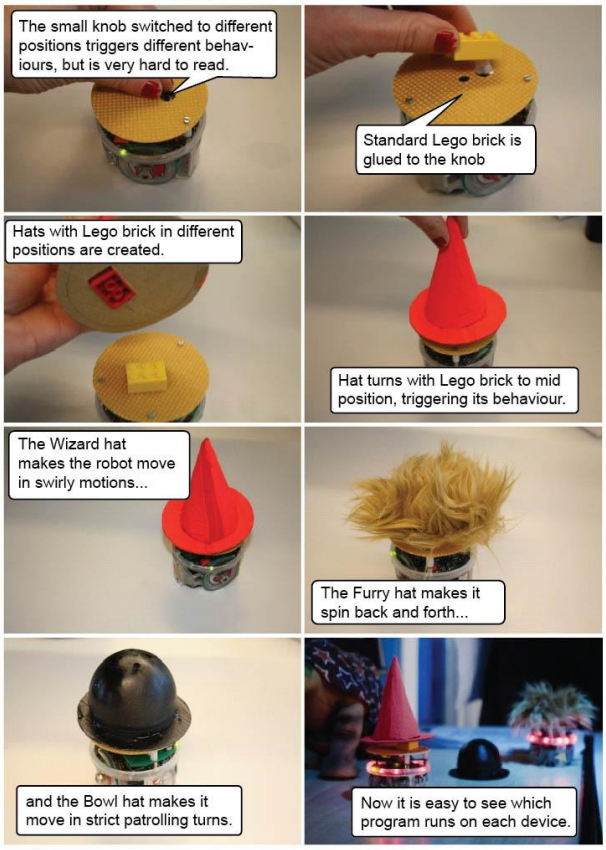


Figure 8. The Hat Trick. A demo illustrating how the changing of hats could simplify control and provide a clearer view of the position of a small knob that triggers different movement patterns of a device.

Three type of hats were designed, a Wizard hat, a Bowl hat and a Furry hat that would correspond to three different movement patterns – Swirly, Patrol and Spinning respectively. Each hat were designed to have a physical key that only fits in one way on the robot, thus forcing an electrical knob to be set in one out of four positions. The four positions each corresponds to four different software routines encoding the three movement patterns plus a default „no movement"-state. Furthermore we experimented with using sound and blinking lights, although we quickly sensed that it made individual behaviours less articulated.

In order to discretely assess our prototype with external users we took the opportunity to demonstrate it at small public exhibitions. The reaction was that although it was a very easy concept to grasp, visitors generally sought more concrete and practical uses for it. Moreover we got suggestions that the same kind of principles might be applied to other electronic devices where accessories and personalisation would be important aspects, which shows that people quite easily could form their own ideas around the concept.

The Square Dancer

In order to look at different enabling technologies for ActDresses we invited students to come up with different scenarios that they thought of when learning about the project. Our second exploration looks at one of these resulting prototypes called *'Square Dancer'*. The scenario uses dance, or rather foot-patterns of a dance as inspiration for motions for a robot. The idea is to build more complex patterns of movements from basic trigonometric shapes. The Square Dancer is a half spherical shaped, omni-directional robot that can move in a fluent manner in combined patterns according to physical markings attached to its surface. This allows the robot to move in any direction or pattern without having to turn around as with ordinary wheels. Internally, the custom-made electronics are based on two circuit boards, one functioning as the master – reading and processing data from the RFID-slave circuit, driving the wheels and taking care of obstacle detection using a sweeping IR-sensor.

In line with the early explorations with the physical LOGO turtle in the 1970s [13], the students played with a simple set of geometrical figures as the basis for these explorations. Based on this, we created a set of physical tags depicting e.g. a square, a circle and a triangle resulting in corresponding movement patterns – if and while they were attached to the robot surface.

A specific problem that we wanted to address in this implementation concerned how different program instructions might be combined together, not only visually, but also in terms of how they would be put together computationally. This is related to aspects of program order and concurrency, and how the effects of several simultaneously connected tags could take effect at the moment of execution. This was approached by dividing each geometrical figure into smaller parts of their paths, and taking turns between these sections rather than do complete figures of movement. The behaviour combination functions are built in a way in which arrays will be split up in selected parts and then merged together in a dynamically allocated array. These parts can then be seen as patterns or steps in a dance.

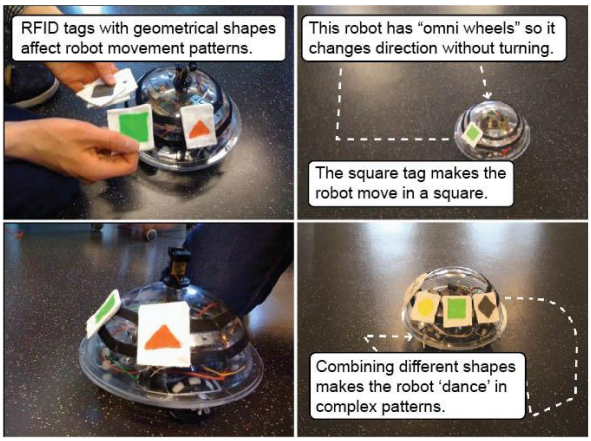


Figure 9. The square dancer. RFID tags with geometrical shapes attached to the robot to affect its movement patterns. Combining different shapes makes the robot 'dance' in complex patterns.

The interaction technology in focus was RFID and how it could be used to explore the practical aspects of using physical tags for controlling its behaviour. We quickly noticed that although RFID was used, the tags still needed to be physically attached. We first explored the possibility using magnets but eventually settled with Velcro. This allowed the tags to be attached more freely, but at the same time required additional attention from the user to see if the particular segments of the behaviour were properly executed. This issue was partially addressed by implementing a LED-light that indicated when a tag was positively identified by the RFID-reader.

Movement with Different Styles

The third and final implementation focused even more on the interaction and integration part, and explored this through broader iterations of exploration and prototyping, again attempting to address a realistic use case of controlling the movement of an autonomous vacuum cleaning robot.

In this step, we used the Roomba Creator platform, iButton technology[1] and a Viliv S5 MID device running Java. Different sorts of iButton-tags were created, each coupled to different behavioural aspects, e.g. „spiral driving", „sweeping mode", „follow wall", „random mode", „faster", and „slower". Attaching and combining these tags resulted in different behaviours of the Roomba.

A quick analysis first of all revealed the importance of the *surroundings* and *context*: wall-following in an empty room resulted in totally different behaviour than wall-following in a furnished room. In addition, the *building blocks* for programming behavioural aspects appeared skewed. With tags like „follow-wall", one would program a more full behaviour of the robot, yet this behaviour is not possible in a cluttered room. Instead, tags should imply movement characteristics, such as „stay close to objects" or „drive in circles", which would increase the mapping between user understanding and effective behaviour. Using a „stay close to objects" tag, the robot logically follows both walls and sofas.

In the final implementation, these concrete movement characteristics were implemented using iButton-equipped flags that could be attached to the Roomba via a magnetic connector (Figure 10). In addition we created three „dresses" that would signify more governing personalities of the Roomba. Learning through doing was a key to

[1] http://www.maxim-ic.com/products/ibutton/



Figure 10. ActDresses for Roomba. The user changes flags attaché to the robot to change the patterns or paths in which it moves. Covers in different styles are used to modify the ways in which this movement is performed.

understand this particular mapping issue. For instance, the „pink" personality in combination with the „stay close to objects" flag resulted in wild „object tracing" movements. Seeing this behaviour then allowed the user to predict that the same dress with the „drive in circles" flag would result in wild, circular behaviour. Besides allowing us to explore the ActDresses concept, this implementation also gave us practical insights into human-robot interaction through changing appearance.

DESIGN CHALLANGES

Following up on the implementations we here present the main design challenges that we found and relate them to three dimensions that form a design space for ActDresses. These will require further elaboration and exploration in creating a framework for the concept, but can be used as a starting point for compiling the results. The use qualities that we will follow up on here concern aspects related to *physicality, visibility*, and *modularity*. In particular we will focus on tensions between the initial scenarios and actual implementations.

Physicality

Naturally, physical objects cannot easily be copied, scaled, deleted. A direct mapping between what will happen to the object that an item is attached to means that the possibilities to scale up the system with larger amounts of objects and behaviours is restricted. Thus, turning „programming code" into physical form is not just another way of representing conventional computational instructions.

Physical constraints can be used as a resource for guiding manipulation, making it more intuitive (e.g. through the principle of tokens-and-constraints [22]). With the wireless approach using RFID we found that although the technology itself was wireless, tags still became "connected" by the fundamental implication of having them in the immediate context. Compared to wired solutions this offered more freedom in the sense that we were able to explore a variety of materials for attaching the tags. For instance we experimented with velcro, magnets and snap-buttons.

In the case of using a wired solution (e.g. iButtons), it implies that physical „sockets" restricts positioning of tags whereas the wireless solution can be designed to be both free and „socketed". On the other hand, a physical „contract" in the form of a physical wire would for instance give a subtle „enabled/disabled" tell whereas the more free wireless tag enters or leaves an invisible frictionless space. This fact appears to speak in favour of direct contact technologies. Furthermore, a final design challenge with respect to physicality is to keep in mind that robots often move around. For instance we noticed on several occasions that ActDresses tend to fall off or disconnect as the robot bumped into things.

One issue, which had already occurred in several prototypes but became even more apparent in the last case, was the notorious difficulty to change behaviour on-the-fly. While the robot was driving around the room, it was difficult to catch it and change the flags and cover. This insight made us implement a full stop when the robot was lifted from the floor and it indicates an important design consideration, that is directly drawn from the basic property of physicality. Other solutions for this challenge could for instance be to enable the robot to sense a certain presence or at least to have a way to pause the movement momentarily in order to allow physical manipulation.

Visibility

From our explorations we were reminded that meaning is always in the making and that the visual appearance must reflect an observed behaviour in order to be predictable. As illustrated in the four interaction scenarios, program actions could be visually manifested in a range of different ways, and the shapes and forms that the different representations could include a near-to-infinite amount of options and variations. The design space also ranges conceptually from visual representations of full persona costumes to detailed hardware instructions.

That objects are visible is thus important, but it also brings along a number of design challenges. For instance, when attaching several signs or labels to the same object, a consequence may be that they obscure the object, so that it

is difficult to clearly see the object underneath. The items themselves could also overlap and obscure each other.

The role of appearance is perhaps one of the more obvious aspects of this, as the items may work simultaneously as controls on one hand and as a form of decoration on the other. In the second implementation we saw that the robot sometimes failed to recognise attached tags thus making it either unpredictable or incomprehensive depending on which stance we assume. Developing a stable solution so that what is seen or visible maps reliably with what is actually happening in the robot software is thus a fundamental aspect of this design challenge.

Modularity

Creating programs by putting together existing pieces of code into new arrangements relates to common popular practices of software development, e.g., the use of class libraries, interface widgets, and open source methodologies. Especially in educational settings and for novice programmers, such higher-level modes of program construction have been found particularly useful. This design concept is similarly based on a form of „high level" programming, in which detailed algorithmic detail is hidden from the user.

However, this also entails several challenges specific to those who intend to design such collections of programming items. As with any form of programming based on pieces of codes that should be possible to combine in a variety of ways, challenges come related to modularity. One important aspect is to make effective use of the compositional properties offered by the physical manifestation of an ActDress. This dimension is closely related to system integration and how the physical manipulation can be mirrored software-wise. Any individual item could belong to a set (complementary) or be combined with other items (linked). An item can be a container for other items or fit into another container (e.g. a pocket). An item can have sequential affordances (e.g. links, chains, snap-on, loops) or concurrent (e.g. badges). That is to say, any relationship between items must map to a relationship between aspects of behaviours.

In our second and third implementation we saw that the robots quite successfully managed to combine the different instructions into comprehensible behaviours. More specifically, this concerned aspects of program order and concurrency, and whether certain signs should be given higher priority than others at the moment of execution. Furthermore we saw that different types of signs appeared to be different classes of behaviour e.g. personalities and modes as described in the third implementation.

DISCUSSION

In our initial explorations of ActDresses as a design concept, we anticipated exploring user-friendly ways of controlling interactive devices by physical means. Looking at the specific explorations conducted here, including the three implementations, we conclude that a key issue in the interaction is the movement of the robot while trying to attach or change physical tags.

Another difficulty is related to how interaction and context unfold over time. A part of this problem can be related to Lucy Suchman"s dilemma of looking at „plans and situated actions": a robot is indeed situated and the appearance as well as the behaviour must therefore account for this [18]. Realising the implications for this fundamental principle make it possible to quickly assert any tendency of violation. In particular the first two design scenarios and the first two implementations show such tendencies. The approach we used was to account for context e.g. by using Braitenberg"s principles [3] as personality (e.g. hesitant or aggressive) and combine these together with more concrete movement characteristics (e.g. moving swirly or wall-following).

Furthermore, the qualities offered by physically signified means of interacting might still outweigh e.g. vocal commands, because of its complementary functions. Many cultural and social aspects that the ActDresses concept brings to the table regard subtle but interesting qualities such as aging, gender, social status, interests, etc.

CONCLUSIONS AND FUTURE WORK

We have presented four design scenarios and three implementations based on the concept of using physical clothing, labels, and accessories for interacting with and controlling robotic devices. In this set of explorations focus was on the simplistic act of specifying the movement patterns of autonomously moving robotic artefacts. The work is motivated by existing practices of physical customisation of electronic devices, the current trend towards commercial products with increasingly advanced control mechanisms, and experiences from the domain of end-user programming. Accessorizing is one such example, and the concept of ActDresses could be thought of as the corresponding interface that captures that practice in a bridge between physical and digital.

In developing new ways of controlling, programming and predicting the behaviour of physical consumer products, a deeper understanding of the fundamental theories explored in these and other fields may hold further benefits. Projects like these suggest further potential in using loose physical items, such as garments, jewellery and visual signs as resources for controlling, reading and predicting the behaviour of physical computing systems. However, all explorations presented in this paper were fairly technical in nature, and much more focus could be given towards how the concept could work in a certain practice, to offer more support for creativity, for play, and for personal expression in a social context.

This work also illustrates the necessity to consider physical shape, behaviour capabilities, and interaction modalities together, grounded both in existing use patterns, shape and

capabilities of the respective platform. That being said, the truth is that the concept is still very much open in the sense that it is impossible to predict how it ultimately unfolds.

In a recently started parallel project we have begun to explore this concept in yet another domain, namely mobile phones. The mobile version builds on the same realisation – that people already do accessorise their personal handhelds. The general idea is to let this practice affect the software by enabling e.g. visual themes, media and games as shells and jewelry get attached to the devices.

ActDresses is an enabling concept and it generates far more ideas, scenarios and implementations than we can possibly explore alone. We hope to see more examples of this type of interaction in the future and together work towards a proper framework and reclaim control over not only appearance but also over action and in particular perceived action.

ACKNOWLEDGMENTS

This work was conducted as part of the EU funded project LIREC (Living with Robots and Interactive Companions). Important parts of this work was conducted by bachelor students Victor Luque and Johan Sundin who worked with developing the Squaredancer.

REFERENCES

1. Benford, S., Schnadelbach, H., Koleva, B., Anastasi, R., Greenhalgh, C., Rodden, T., Green, J., Ghali, A., Pridmore, T., Gaver, B., Boucher, A., Walker, B., Pennington, S., Schmidt, A., Gellersen, H., and Steed, A. (2005). *Expected, sensed, and desired: A framework for designing sensing-based interaction.* ACM Trans. Comput.-Hum. Interact., 2005. 12(1): p. 3-30.
2. Blackwell, A.F. (2006). *Gender in Domestic Programming: from Bricolage to Séances d'Essayage*, in *CHI'2006 workshop on End User Software Engineering*.
3. Braitenberg, V. (1984). *Vehicles: Experiments in synthetic psycology*. 1984, Cambridge, Massachusetts: MIT Press.
4. Chandler, D. (2002). *Semiotics: The Basics*. 2002, London: Routledge.
5. DiSalvo, C.F., Gemperle, F., Forlizzi, J., and Kiesler, S. (2002). *All Robots Are Not Created Equal: The Design and Perception of Humanoid Robot Heads*. Proc. of *DIS2002*: ACM Press
6. Djajadiningrat, T., Wensveen, S., Frens, J., and Overbeeke, K. (2004). *Tangible products: redressing the balance between appearance and action.* Personal Ubiquitous Comput., 2004. 8(5): p. 294-309.
7. Fernaeus, Y. and Jacobsson, M. (2009). *Comics, Robots, Fashion and Programming: outlining the concept of actDresses*. Proc. of *TEI'09*: ACM
8. Frei, P., Su, V., Mikhak, B., and Ishii, H. (2000). *Curlybot: designing a new class of computational toys*. Proc. of *CHI'00*: ACM Press.p. 129-136.
9. Jacobsson, M. (2009). *Play, Belief and Stories about Robots: A Case Study of a Pleo Blogging Community* Proc. of *Ro-Man*: IEEE
10. Jain, A., Klinker, L., Kranz, M., Stoeger, C., Blank, D., and Moesenlechner, L. (2006). *Sketch-A-Move - Design Inspired Technology for Children*. Proc. of *UbiComp (video)*
11. Ljungstrand, P., Redström, J., and Holmquist, L.E. (2000). *WebStickers: using physical tokens to access, manage and share bookmarks to the Web*. Proc. of *DARE*: ACM p. 23-31.
12. Monceaux, J., Becker, J., Boudier, C., and Mazel, A. (2009). *Demonstration: first steps in emotional expression of the humanoid robot Nao*. Proc. of *International conference on Multimodal interfaces*: ACM.p. 235-236.
13. Papert, S. (1980). *Mindstorms: Computers, Children, and Powerful Ideas*. 1980, New York: Basic Books.
14. Rafaeli, A. and Pratt, M.G. (1993). *Tailored Meanings: On the Meaning and Impact of Organizational Dress.* . The Academy of Management Review 1993. 18(1): p. 32-55.
15. Raffle, H.S., Parkes, A.J., and Ishii, H. (2004). *Topobo: a constructive assembly system with kinetic memory*. Proc. of *CHI'04*: ACM Press.p. 647 - 654.
16. Robins, B., Dautenhahn, K., Boekhorst, R.e.t., and Billard, A. (2004). *Robots as Assistive Technology - Does Appearance Matter?* Proc. of *RO-MAN 2004* IEEE Press.p. 277-282.
17. Sung, J.-Y., Guo, L., Grinter, R.E., and Christensen, H.I. (2007). *"My Roomba is Rambo": Intimate Home Appliances*. Proc. of *UbiComp 07*
18. Sung, J., Grinter, R.E., and Christensen, H.I. (2009). *"Pimp My Roomba": designing for personalization*, in *CHI'09*. ACM: Boston, MA, USA. p. 193-196.
19. Turkle, S., Taggart, W., Kidd, C.D., and Dast, O. (2006). *Relational artifacts with children and elders: the complexities of cybercompanionship.* Connection Science, 2006. 18(4): p. 347 - 361.
20. Ullmer, B., Ishii, H., and Glas, D. (1998). *mediaBlocks: physical containers, transports, and controls for online media*. Proc. of *Computer graphics and interactive techniques*: ACM p. 379-386.

SICS Swedish ICT
SICS Dissertation Series

01: Bogumil Hausman, Pruning and Speculative Work in OR-Parallel PROLOG, 1990.

02: Mats Carlsson, Design and Implementation of an OR-Parallel Prolog Engine, 1990.

03: Nabiel A. Elshiewy, Robust Coordinated Reactive Computing in SANDRA, 1990.

04: Dan Sahlin, An Automatic Partial Evaluator for Full Prolog, 1991.

05: Hans A. Hansson, Time and Probability in Formal Design of Distributed Systems, 1991.

06: Peter Sjödin, From LOTOS Specifications to Distributed Implementations, 1991.

07: Roland Karlsson, A High Performance OR-parallel Prolog System, 1992.

08: Erik Hagersten, Toward Scalable Cache Only Memory Architectures, 1992.

09: Lars-Henrik Eriksson, Finitary Partial Inductive Definitions and General Logic, 1993.

10: Mats Björkman, Architectures for High Performance Communication, 1993.

11: Stephen Pink, Measurement, Implementation, and Optimization of Internet Protocols, 1993.

12: Martin Aronsson, GCLA. The Design, Use, and Implementation of a Program Development System, 1993.

13: Christer Samuelsson, Fast Natural-Language Parsing Using Explanation-Based Learning, 1994.

14: Sverker Jansson, AKL - - A Multiparadigm Programming Language, 1994.

15: Fredrik Orava, On the Formal Analysis of Telecommunication Protocols, 1994.

16: Torbjörn Keisu, Tree Constraints, 1994.

17: Olof Hagsand, Computer and Communication Support for Interactive Distributed Applications, 1995.

18: Björn Carlsson, Compiling and Executing Finite Domain Constraints, 1995.

19: Per Kreuger, Computational Issues in Calculi of Partial Inductive Definitions, 1995.

20: Annika Waern, Recognising Human Plans: Issues for Plan Recognition in Human-Computer Interaction, 1996.

21: Björn Gambäck, Processing Swedish Sentences: A Unification-Based Grammar and Some Applications, 1997.

22: Klas Orsvärn, Knowledge Modelling with Libraries of Task Decomposition Methods, 1996.

23: Kia Höök, A Glass Box Approach to Adaptive Hypermedia, 1996.

24: Bengt Ahlgren, Improving Computer Communication Performance by Reducing Memory Bandwidth Consumption, 1997.

25: Johan Montelius, Exploiting Fine-grain Parallelism in Concurrent Constraint Languages, 1997.

26: Jussi Karlgren, Stylistic experiments in information retrieval, 2000.

27: Ashley Saulsbury, Attacking Latency Bottlenecks in Distributed Shared Memory Systems, 1999.

28: Kristian Simsarian, Toward Human Robot Collaboration, 2000.

29: Lars-åke Fredlund, A Framework for Reasoning about Erlang Code, 2001.

30: Thiemo Voigt, Architectures for Service Differentiation in Overloaded Internet Servers, 2002.

31: Fredrik Espinoza, Individual Service Provisioning, 2003.

32: Lars Rasmusson, Network capacity sharing with QoS as a financial derivative pricing problem: algorithms and network design, 2002.

33: Martin Svensson, Defining, Designing and Evaluating Social Navigation, 2003.

34: Joe Armstrong, Making reliable distributed systems in the presence of software errors, 2003.

35: Emmanuel Frécon, DIVE on the Internet, 2004.

36: Rickard Cöster, Algorithms and Representations for Personalised Information Access, 2005.

37: Per Brand, The Design Philosophy of Distributed Programming Systems: the Mozart Experience, 2005.

38: Sameh El-Ansary, Designs and Analyses in Structured Peer-to-Peer Systems, 2005.

39: Erik Klintskog, Generic Distribution Support for Programming Systems, 2005.

40: Markus Bylund, A Design Rationale for Pervasive Computing – User Experience, Contextual Change, and Technical Requirements, 2005.

41: Åsa Rudström, Co-Construction of hybrid spaces, 2005.

42: Babak Sadighi Firozabadi, Decentralised Privilege Management for Access Control, 2005.

43: Marie Sjölinder, Age-related Cognitive Decline and Navigation in Electronic Environments, 2006.

44: Magnus Sahlgren, The Word-Space Model: Using Distributional Analysis to Represent Syntagmatic and Paradigmatic Relations between Words in High-dimensional Vector Spaces, 2006.

45: Ali Ghodsi, Distributed *k*-ary System: Algorithms for Distributed Hash Tables, 2006.

46: Stina Nylander, Design and Implementation of Multi-Device Services, 2007

47: Adam Dunkels, Programming Memory-Constrained Networked Embedded Systems, 2007

48: Jarmo Laaksolahti, Plot, Spectacle, and Experience: Contributions to the Design and Evaluation of Interactive Storytelling, 2008

49: Daniel Gillblad, On Practical Machine Learning and Data Analysis, 2008

50: Fredrik Olsson, Bootstrapping Named Entity Annotation by Means of Active Machine Learning: a Method for Creating Corpora, 2008

51: Ian Marsh, Quality Aspects of Internet Telephony, 2009

52: Markus Bohlin, A Study of Combinatorial Optimization Problems in Industrial Computer Systems, 2009

53: Petra Sundström, Designing Affective Loop Experiences, 2010

54: Anders Gunnar, Aspects of Proactive Traffic Engineering in IP Networks, 2011

55: Preben Hansen, Task-based Information Seeking and Retrieval in the Patent Domain: Process and Relationships, 2011

56: Fredrik Österlind, Improving Low-Power Wireless Protocols with Timing-Accurate Simulation, 2011

57: Ahmad Al-Shishtawy, Self-Management for Large-Scale Distributed Systems, 2012

58: Henrik Abrahamsson, Network overload avoidance by traffic engineering and content caching, 2012

59: Mattias Rost, Mobility is the Message: Experiments with Mobile Media Sharing, 2013

60: Amir H. Payberah, Live Streaming in P2P and Hybrid P2P-Cloud Environments for the open Internet, 2013

61: Oscar Täckström, Predicting Linguistic Structure with Incomplete and Cross-Lingual Supervision, 2013

62: Cosmin Arad, Programming Model and Protocols for Reconfigurable Distributed Systems, 2013

63: Tallat M. Shafaat, Partition Tolerance and Data Consistency in Structured Overlay Networks, 2013

64: Shahid Raza, Lightweight Security Solutions for the Internet of Things, 2013