Cognition On The Edge tries to combine two branches of Distributed Cognition: The concepts of Embodied Cognition on the one hand and Socially Distributed Cognition on the other. The former is describing our bodily-based existence in the world as a highly important foundation for all cognitive processes, while the latter tries to outline the distribution of intelligence across several or many people. The practical part of this diploma thesis by Ludwig Zeller is the **CubeBrowser** project, which is an experimental interface object between both described phenomena.

A tangible user interface that allows for browsing cyber-places, which are created out of **Flickr** tags and images. Thus, both branches of Distributed Cognition meet at the edge between the embodied user and the socially created cyber-place. This project has been inspired by an alternative thinking about interaction, beyond the limits of today's technologies and habits. Nevertheless the realisation as a product is thinkable. Two working prototypes have been developed in order to make this novel way of data-browsing and the dream of a tactile screen cube real already today.

COGNITION ON THE EDGE

Ludwig Zeller

COGNITION
ON THE EDGE

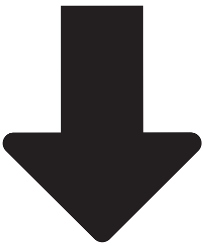
Adapting Between Socially Distributed and Embodied Cognition

Ludwig Zeller

COGNITION ON THE EDGE

Adapting Between Embodied
And Socially Distributed Cognition

LUDWIG ZELLER



Unless stated differently all figures are created by Charlotte Krauß and Ludwig Zeller. This book was set by the author using LaTex in Helvetica and Times Roman and was printed in Germany. You can obtain digital copies of this book at http://www.cubebrowser.de

@mastersthesis{Zeller:2009fp,
Address = {Peter-Welter-Platz 2, 50676 Cologne/Germany},
Author = {Zeller, Ludwig},
Keywords = {interaction, interface, cognition,
flickr, tui, tagging, perception, screens, tangible},
Month = {August},
School = {Academy of Media Arts Cologne},
Title = {Cognition On The Edge: Adapting Between
Embodied And Socially Distributed Cognition},
Type = {Diploma thesis in Audiovisual Media program},
Year = {2009} }

Credits: Yahoo! Design Expo

Concept:
Andreas Muxel, Charlotte Krauss, Ludwig Zeller

Hardware:
Andreas Muxel, Martin Nawrath, Heinz Nink, Bernd Voss

Software:
Lasse Scherffig, Ludwig Zeller

Graphic Design:
Charlotte Krauss, Andreas Muxel

Sound Design:
Ludwig Zeller

Support:
Prof. Zilvinas Lilas, Prof. Frans Vogelaar

Project Partners:
Yahoo! Research
http://design.yahoo.com
Yahoo! User Experience & Design
http://research.yahoo.com

Sponsoring:
XSENS Motion Technologies
http://www.xsens.com

Special Thanks:
Monica Batra, Tobias Beck, Michael Hoch, Prof. Zilvinas Lilas,
Joy Mountford, Lasse Scherffig, Larry Tesler and Franziska Windisch

Credits: Diploma Thesis

Concept:
Ludwig Zeller

Hardware:
Martin Nawrath, Nando Nkrumah, Bernd Voss, Ludwig Zeller

Software:
Ludwig Zeller

Graphic Design:
Charlotte Krauss, Christoph Haag, Ludwig Zeller

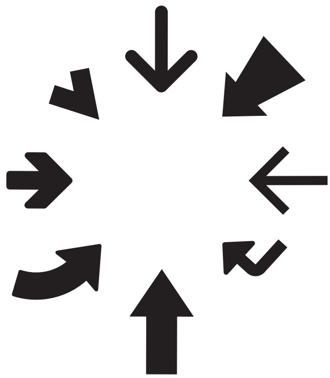
Sound Design:
Ludwig Zeller

Advisors:
Prof. Zilvinas Lilas, Prof. Dr. Georg Trogemann, Lasse Scherffig

Sponsoring:
Mostron GmbH
http://www.mostron.de
VTQ, Video Technik Querfurt
http://www.vtq.de

Special Thanks:
Anselm Bauer, Urs Fries, Christof Groos, Christoph Haag,
Matthias Neuenhofer, Martin Rumori, Prof. Julia Scher,
Therese Schuleit, Heiner Simons and Prof. Frans Vogelaar

Contents



0 PREFACE

Inter - Trans - Multi - Disciplinarity

In the beginning, this book was started as the formal, written part of my diploma thesis at the Academy of Media Arts in Cologne. It was my declared goal for that to bring some of the thinking that I learned there to the world of Computer Science. In a way that is taken serious within the formal literacy of that discipline. By having been invited to the CHI conferences in Boston and Leiden as well as many other venues I can state that this goal as successfully achieved.

But the revised edition of my thesis that you are reading right now has been lead by yet another motivation. During all the presentations I have had with this project so far and with all the nice feedback I received, people asked the same question over and over again: How can somebody come up with this? How can you leave the paths of the known to create something like a CubeBrowser? And people wanted to know about my background, the discipline I have been educated in. They wanted to know whether you have to be an engineer and inventor or if you have to be a designer and artist. My answer to these questions is that you have to be all of them at once. You cannot make it if you stick to one discipline alone.

Technology is mirrored in society and vice versa. Since the machines we create become more and more a part of our lives, serving ever more purposes and senses, we have to think broad and interconnected between different disciplines, techniques, materials, styles and philosophies.

As mentioned above, the initial motivation was to contribute to the current discourse of computer science, but in the end I had the impression that I had adopted to that style of science with my project too much. The effort and concentration that was necessary to finish the prototypes of this project have kept much time from thinking in that really interconnected way of design and development. Therefore, I decided to create this overworked edition of my thesis, that documents much of the processes around the CubeBrowser in a more design oriented way.

Whom is this book for?

Obviously, it addresses the interests of engineers, artists, philosophers and designers. With these designated goals nothing else would be appropriate. This project is an adapter between man and machine and this book should be understood as a bridge between the professions as well. I hope that everybody who is coming from his side of the bridge can find something valuable on the other side.

But being a diploma thesis, this book can only touch the peak of the iceberg. Therefore, I would like to encourage you to have a look into the work of the other people who I am referring to.

How to use this book?

The single chapters and appendices of the book can be seen as mostly modular and independent. After two chapters of theoretical background and introduction to cognition science and hyper-text theory the CubeBrowser project is presented. While these chapter should be easy and brief to read, it makes perfectly sense to skip them and jump directly forward to the CubeBrowser chapter. The most important ideas of this project will be repeated there. After that, you find four CubeBrowser related appendices with a mostly photographic documentation of the different international presentations, exemplary user paths through the Flickr database and a technical documentation.

Acknowledgments

I want to thank many people at the academy: Prof. Georg Trogemann and Lasse Scherffig for teaching their unique, experimental approach to Computer Science and running the fabulous lab3, Prof. Zil Lilas for his incredible talent to motivate and fascinate people to explore unknown terrains of design and play, Prof. Peter Friedrich Stephan for his seminars on philosophy and hyper-text theory, which created the foundation for many thoughts in this project, and Prof. Frans Vogelaar for his steady encouragements towards a radical rethinking of design.

Special thanks for Andreas Muxel and Charlotte Krauss, their early interest in and helpful hand for the project gave it a marvelous kick-start at the Yahoo! Design Expo in California. And I want to thank Martin Nawrath and Bernd Voss, none of the prototypes could have been built without their technical support.

Furthermore, many thanks go to Anselm Bauer, Martin Rumori, Therese Schulheit, Charlotte Krauss and Jana Paapenbrook for being the beta-readers of this document. Special thanks go to Christoph Haag: without his LaTex magic this book definitely would not have been possible. Last but way not least I want to thank my family for giving me the freedom to develop my ideas.

Ludwig Zeller
Cologne, August 2009

1 INTRODUCTION

To almost have allowed once fingers
To stroke
The fingers I was given to touch with

We'll live in a hidden place

Björk[1]

1.1 Abstract

"Cognition On The Edge" tries to combine two branches of Distributed Cognition: The concepts of *Embodied Cognition* on the one hand and *Socially Distributed Cognition* on the other.

The former is describing our bodily-based existence in the world as a highly important foundation for all cognitive processes, while the latter tries to outline the distribution of intelligence across several or many people. In this thesis, the area of research for *Tangible User Interfaces* (TUI) will be presented as an example for the application of Embodied Cognition. Furthermore, the World Wide Web (WWW) will be presented as Socially Distributed Cognition. This thesis proposes ways to create *cyber-places* out of *cyber-spaces* that give a certain notion of situatedness to the users by feeding back their collective perceptions into the WWW.

The practical part of this thesis is the CubeBrowser project, which is an experimental interface object between both described phenomena. A TUI that

---

[1] Taken from the lyrics of "Hidden Place".

allows for browsing cyber-places, which are created out of Flickr tags and images. Thus, both branches of Distributed Cognition meet at the edge between the embodied user and the socially created cyber-place.

1.2 Motivation

Technology changes fast, faster than people. With little reflection about the cultural consequences, the electronics industry is developing more and more sophisticated illusion machines that are woven into our daily lives. The term "cocooning" describes the trend that people make themselves comfortable at home, filling it with entertainment electronics that is creating a convenient and wonderful oasis of digital, audiovisual illusions. But even though these living rooms are small local spaces, their inhabitants have countless gates to networked, global places at their finger tips.

The electronic artifacts open gates to these hidden, virtual places, making these living rooms a similar cultural phenomenon as the train stations have been in the 19th century due to the introduction of the railway. Train stations back then were considered "portals" between cities, because of the fast point-to-point connections the railway made possible. From a trans-humanistic point of view, this technological development creates a "natural" augmentation of the human body.

I have been studying for four years in the audiovisual media program at the Academy of Media Arts in Cologne. The first two years were coined by studying art and media history as well as the practical exploration of the creative possibilities of analog and digital media. In the latter two years I concentrated on experimental interfaces and hypertext. My studies of audiovisual media are filled with fear and fascination for this trans-humanistic view of technological progress. This thesis tries to bring both areas together, integrating thoughts on interfaces and hypertext. The practical part of it, the "CubeBrowser" project, is the direct consequence of that, trying to be a physical interface for browsing and exploring the hidden places of cyber-space in an immersive way.

The early mock-up version at the Yahoo! Design Expo 2007, Sunnyvale / California

Very early in its development, the project had been presented at the Yahoo! Design Expo in July 2007, where it received the "Best User Experience" Award by Joy Mountford and Larry Tesler. Since then, another prototype has been developed, but it should not simply be understood as the production of a new electronic toy, but rather as an experimental "comment" on the convergence of cyberspaces and physical interfaces.

Furthermore, this thesis puts special emphasis on the idea of embodiment for interacting with digital systems. In this report, we find a quite comprehensive summary of the idea of embodiment in philosophy, cognitive science and interaction design. It is the goal of this thesis to discuss immersive environments that locally bring together system and user as well as globally unite users and networks in a way that feels natural to our normal perception.

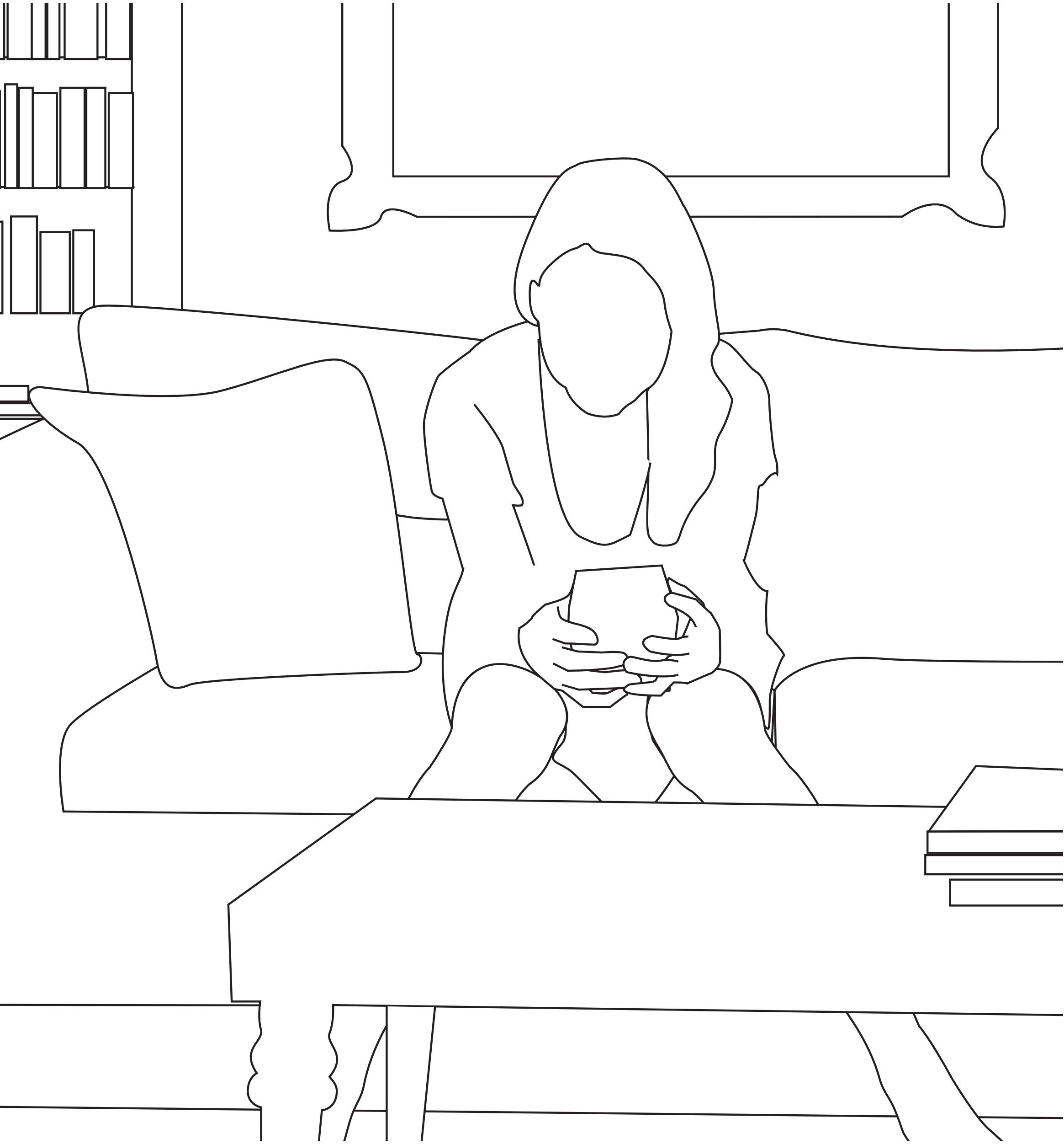
1.3 The gate in the living room

CubeBrowser is the concept study for a cube that has a square monitor on each of its six faces and a Wi-Fi connection as well as an orientation tracker inside. Images from the Web 2.0 archive Flickr are shown on it and navigation is playfully realized by performing manual actions on the cube.[2] The classical desktop setup with keyboard, mouse and monitor is completely left behind and besides a power switch, there are no buttons at all. Thus, control should be as easy as turning a cube in space. The object is mobile and only depending on a wireless connection.

The images that can be viewed are directly loaded from Flickr, while the cube is turned and are organized in sets that are clustered by the tagging the users gave to the images. CubeBrowser allows to travel this collectively created and described cyberspace by browsing through the network of tags and images that can be formed within this database. It tries to bring the realm of embodied interaction and virtuality together, merging the local with the global. A more comprehensive description follows in chapter 4.

---

[2] Basically, it is a very versatile interface that could serve lots of other purposes. Furthermore, the idea to have displays on a cube is not new. There are numerous comparable but rather different projects such as: *Z-Agon* (http://www.z-agon.com) and *intercube* (http://www.bsalem.info/Projects/inter00.html)



Let's hear a short description about the context of CubeBrowser and the kind of user experience it is meant to create:

A young woman enters her living room, she dims the light and turns on the stereo, which starts playing "Hidden Place" by the icelandic artist Björk. Her "CubeBrowser", lying in front of her couch, reacts with a slowly pulsating glow in order to draw attention. It stops pulsating, when she lifts the cube. Sitting comfortably on the couch, she can view several images of Iceland that appeared on the cube's faces.

"We go to a hidden place"

By turning the cube to the right, the young woman starts moving through these pictures, revealing more and more images from Iceland. After several horizontal revolutions, she stops; something comes to her mind while seeing an image of an erupting volcano. She is interested, takes a peek on the top face, where she can see another volcano. She turns the top face fully towards herself and continues her travel through the images by turning left and right, where now an endless amount of volcano images is being loaded. That way, she is passing through landscapes, sky panoramas and ocean sites.

Millions of data-sets lie in her hands, streaming into the CubeBrowser from the Internet, while she is using it sitting in her living room. She dives into it, taking a trip through the database. Intuitively, each change of direction is flowing out of her hands, directly into the system. She doesn't think about what she is doing, she doesn't have to think about how to do it. The tactile intuition replaces the technical reflection.

"We'll live in a hidden place"

Meanwhile, the song ended and changes to a new one. The cube offers to adapt the images to the new music by showing a small notice on the side, she is currently facing. She denies that proposal by giving the cube a little push and continues her journey...[3]

---

[3] Please note, that this is actually science fiction and does not completely represent the state of the existing prototypes.

1.4 Thesis overview

CubeBrowser is just one incarnation of a bigger picture, that shall be presented in this thesis. It is the idea of merging virtual spaces and embodied interaction, in order to “get in touch with Socially Distributed Cognition”.

In chapter 2, we will review the historical changes in the paradigms of interaction (2.1), visit parts of the scientific and philosophical background of embodied interaction (2.2) and take an insight into frameworks for the evaluation of interfaces that have been proposed by computer scientists and psychologists (2.3), followed by a summary and personal statement (2.4).

In chapter 3, we will explain the distinction between Socially Distributed and Embodied Cognition (3.1), talk about the Web 2.0 paradigm (3.2) and present tagging as a means for collective perception (3.3). In the rest of that chapter, we will discuss the topology of the WWW (3.4) and present clustering as an important tool for creating something like meaning in the noise of the web, which is an important pre-requisite for navigation. (3.5).

In the final chapter 4, the CubeBrowser concept and its prototypes as the practical part of this thesis will be presented (4.1). There will be a detailed description of its usage (4.2) and some ideas around a “romantic interface” will be presented (4.3).

In the appendices you will find documentation about the international exhibitions (A), some exemplary user trajectories through the Flickr database (B), a small technical description of the second prototype (C) and a work-in-progress documentation from the lab (D).

The so-called “Differential Analyzer” was an analog computer.
This piece was built and used by the NASA.
(Copyright NASA, 1951)

2 THEORY: Distributed Cognition in Interaction

"Many things about computers are not changing at all. Our basic ideas what a computer is, what it does, and how it does it, for instance, have hardly changed for decades."

Paul Dourish[1]

2.1 Paradigms of interaction

Computers have always been tools, and as such they have to fulfill a certain task. "Time is money" is a common saying in western thinking and therefore accomplishing tasks as fast and efficient as possible is desired. This is also reflected in the term "time-expensive", that was coined in Computer Science to describe the temporal efficiency of an algorithm.[2] With regard to its foundation in costly hi-tech engineering, it was therefore for a long-time much easier and particularly cheaper to save time somewhere else than by simply financing faster machinery.

If the task is "Interact with a human!", then the machine has to *present* its interaction possibilities, *read* and *evaluate* input from the user and give meaningful *feedback* - and usually all this on top of the other, "actual" tasks of the given application.

---

[1] [Dourish, 2001, p. 1]

[2] An algorithm A that is running faster than algorithm B on the same machine while maintaining the same output is called less "time-expensive".

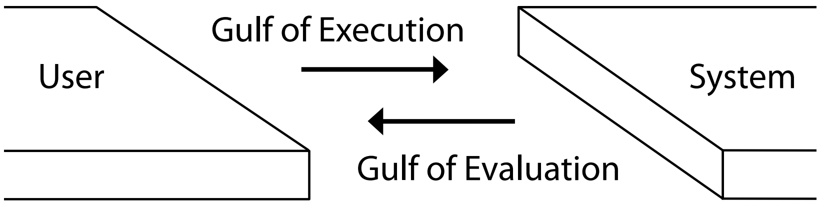


Figure 2.1: Gulf of Interaction; modified according to Donald Norman in [Hutchins et al., 1985], (Original copyright Donald Norman, 1985)

In figure 2.1 Donald Norman is describing the *distance* between the user and a system as the Gulf of Execution on the one side and the Gulf of Evaluation on the other. Both together form the Gulf of Interaction. The distance is the ever-lasting danger of misunderstanding between two partners of communication in the sense of the semiotics of Peirce and has to be bridged or decreased in order to support meaningful interaction.

The effort to realize this interaction cycle may be arbitrarily simple or complex, but one has to keep in mind, that "effort" is relative to the available computing power.

More expensive presentation doesn't necessarily close the distance between user and system, but in the very beginnings of computing every bit of presentation was expensive.

As a result, the user had to come closer to the system by learning extremely formal ways of interaction with computing machinery in order to save the much more expensive computing time.

Today, many areas of computer application such as browsing the web, writing mail or using office packages put a ridiculously small load on the shoulders of our computing machinery, so that "performance over convenience" is not a must anymore. According to Paul Dourish "... those powerful computers spend 95% of their time doing absolutely nothing."[3]

Furthermore, sensor/actuator components are becoming cheaper and more sophisticated, so that the *computer's prison*[4] is opened more and more by "windows" to the outer world. With increasing miniaturization these systems begin to vanish from our active perception as "system" and resemble an unconscious background phenomenon.[5]

In this section, we will rehearse a brief history of that development as Paul Dourish outlines it in the first chapter "A History of Interaction" of his book "Where the action is".[6] Dourish segments it into four phases of interaction, namely *electrical*, *symbolic*, *textual* and *graphical*. Even though he applies a rather conventional[7] grasp of interaction and computing, it fits in the frame of this discussion quite well.

2.1.1 Electrical

The first computers have been analog. As such, these machines were often used for electrical simulations of continuous phenomena like waves and the effects of gravity.

Let's distinguish between interactive and non-interactive machines. Many of them were not able to read user input and thus they were non-interactive from today's view. But the inscription of behavior through construction can be considered as a form of *author-time* input. Author-time refers to the creation period, while run-time describes everything during the machine's execution. Dourish coined this era of interaction as *electrical*, since in this case the only way to control the machine has been electrical engineering. The behavior of a machine was circuit bound and therefore you had to reconfigure the machine for any new purpose. Needless to say, that usage of these machines has been limited to a very small group of experts.

---

[3] [Dourish, 2001, p. 2]
[4] [Trogemann and Viehoff, 2005, p. 113]
[5] Also referred to as *Ubiquitous Computing*, Marc Weiser has been one of its visionaries
[6] [Dourish, 2001, p. 5ff]
[7] See e. g. [Mumford, 1977] in [Trogemann and Viehoff, 2005, p. 47ff] for a much broader view on input/output machinery

> *"The boundary that we now take for granted between hardware and software was much fuzzier then; interacting with the system, and developing new programs, relied on a thorough understanding of the electronic design."*[8]

But nonetheless, Dourish neglects the fact that many other computers had actually quite rich ways of interaction like knobs and sliders, which reacted very directly due to the immediate nature of analog simulation.

2.1.2 Symbolic

When computers came into industrial production, the analog paradigm already had been replaced by the digital. With it came the programmability in digital code, first as machine language and then in assembly language. Furthermore, standardization and regularization of the commonly understood capabilities of computing machinery emerged, so that programs written in code were much easier to run on different machines than programs that were implemented directly in electric components.

While machine language as a very low level requires codes like "a9 62 82 2c", assembly language allowed for a more intuitive representation such as "movl (r1+), r2".[9] Dourish describes that paradigm shift as *symbolic* in the sense of a more intuitive notation of control structures.

> *"We are generally able to exploit a greater range of skills - visual, cognititve, and so on - as we move from electrical to symbolic forms of interaction."*[10]

That is actually a little confusing, since every piece of electrically represented data within a digital computer is a symbolic representation anyway.[11]

---

[8] [Dourish, 2001, p. 7]
[9] [Dourish, 2001, p. 7]
[10] [Dourish, 2001, p. 9]
[11] See [Schröter and Böhnke, 2004], [Trogemann and Viehoff, 2005] for a closer look in the details.

2.1.3 Textual

With the step to *textual* interaction, Dourish is referring to the rise of UNIX-like systems that are controlled over a commandline interface: They read commands and arguments by their names as typed on a keyboard, compute them and feed the output of that program back on a computer screen.[12]

```
ludwig@LAMPe:~$ ps -a
  PID TTY          TIME CMD
 4916 tty1     00:00:00 bash
 8549 tty1     00:00:00 ps
ludwig@LAMPe:~$ who
ludwig   tty1         2008-01-23 22:55
ludwig@LAMPe:~$ ping www.khm.de
PING elefant.khm.de (194.95.161.40) 56(84) bytes of data.
64 bytes from elefant.khm.de (194.95.161.40): icmp_seq=1 ttl=243 time=50.3 ms
64 bytes from elefant.khm.de (194.95.161.40): icmp_seq=2 ttl=243 time=52.6 ms

--- elefant.khm.de ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 2368ms
rtt min/avg/max/mdev = 50.396/51.501/52.606/1.105 ms
ludwig@LAMPe:~$
ludwig@LAMPe:~$
ludwig@LAMPe:~$ ls
Desktop  download  evolforslug.tar.gz  Examples  marcexports.txt  OSX  www
ludwig@LAMPe:~$ echo "hello world"
hello world
ludwig@LAMPe:~$ _
```

Figure 2.2: Screenshot of the output of some simple commands.

> *“Arguably, this is the origin of ’interactive’ computing, because textual interfaces also meant the appearance of the ’interactive loop’, in which interaction became an endless back-and-forth of instruction and response between user and system.”*[13]

While the machines described before only allowed for the inscription of behavior during author-time, these *interaction machines* can be manipulated while they are running by reading input from and writing output back to the environment as illustrated in figure 2.3.

[12] Again, this is a difficult term, since writing assembler code can also be done with text. The difference, that is important for Dourish, is the interaction by text *during run-time*.

[13] [Dourish, 2001, p. 10]

According to Georg Trogemann, this run-time interaction introduces a *symbiotical* relationship between the user and her machine. Through the cooperation of both, tasks can be accomplished that would be impossible for either of them alone.[14]

The textual paradigm is still alive today in some communities of UNIX-derived operating systems such as Linux or Apple OS X. The formalized communication between user and system offers a number of benefits, such as compositional character and a history of commands, omnipresent scripting possibilities, computational efficiency, easy remote action, etc.

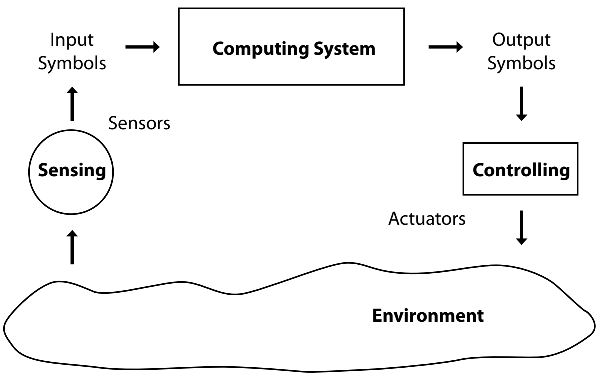


Figure 2.3: An interaction machine with sensors and actuators according to [Trogemann and Viehoff, 2005, p. 112], (Original copyright Trogemann and Viehoff, 2005)

[14] [Trogemann and Viehoff, 2005, p. 88]

2.1.4 Graphical

With the development of the WIMP[15] idea for the XEROX Alto computer in 1973 and the introduction to the mass-market by the Apple Macintosh in 1984, *graphical* interaction caused a major paradigm shift that still represents the established mode of interaction today.

> *"... the move from textual to graphical interaction did not simply replace words with icons, but instead opened up whole new dimensions of interaction - quite literally in fact, by turning interaction into something that happened in a two-dimensional space rather than a one-dimensional stream of characters."*[16]

The presentation of objects on the screen, that can be directly manipulated by mouse clicks or even drag'n'drop[17], replaced the need for learning formal commands and syntax to a large extent.

In reference to figure 2.1, these computers bridge the *distance* between user and system by assimilating to the perception of humans. Obviously, without the step from textual to graphical interaction the world's pervasion with personal computers would be unthinkable today.

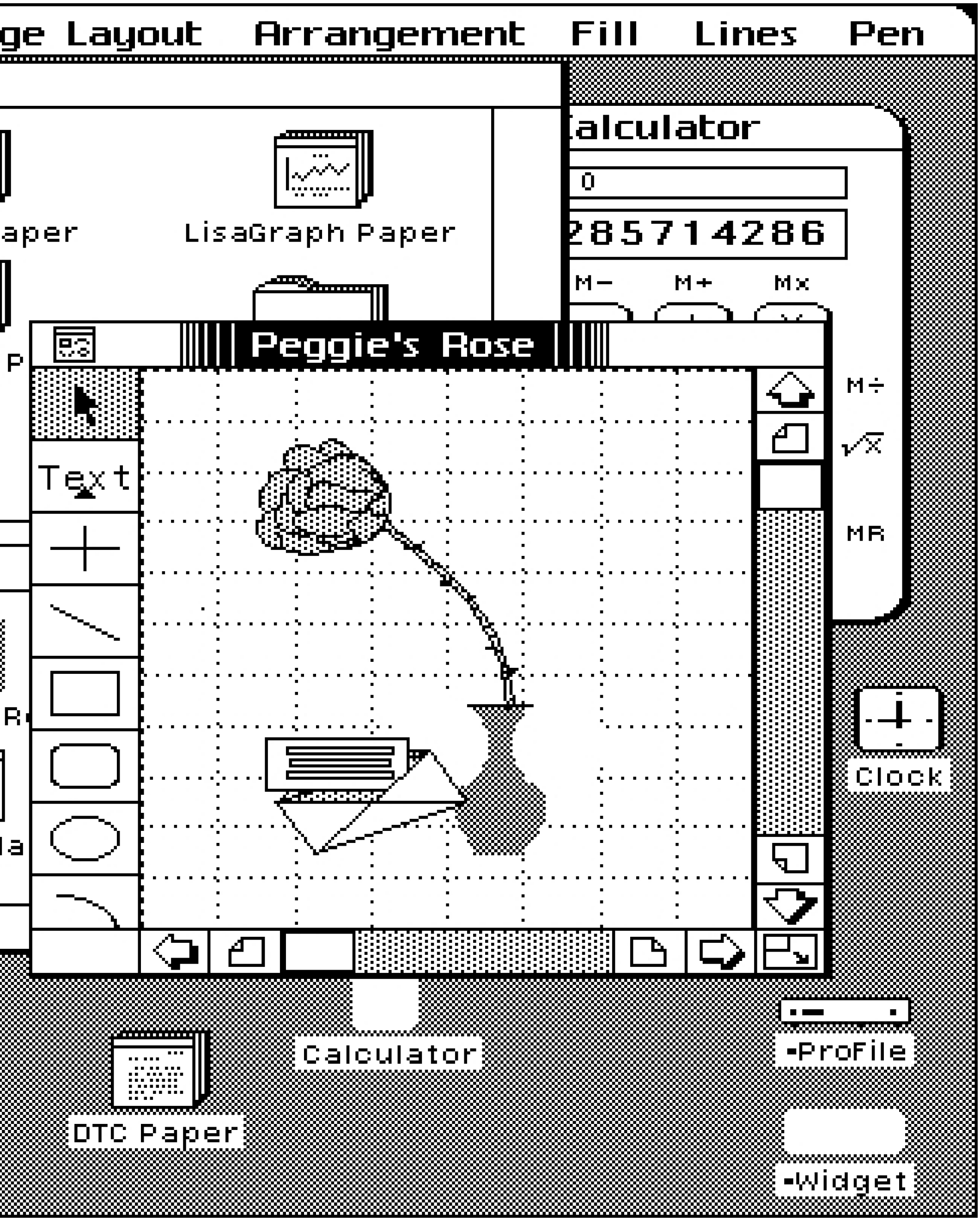
---

[15] According to http://en.wikipedia.org/wiki/WIMP_(computing) (accessed on 1-4-2008) WIMP is short for "window, icon, menu and pointing device". This refers to the so called *desktop metaphor* that presents the data containers of the computer on a 2D screen as files organized in folders. Several other analogies to an office workplace are maintained, e. g. a trash-bin container for keeping files that are to be deleted soon.

[16] [Dourish, 2001, p. 11]

[17] With drag'n'drop you can move an object by grabbing it with a mouse click and releasing it on another one, e. g. moving a file into a trash-bin.

GUI screenshot of the Apple Lisa, released in 1983. It is interesting to see that the basic structure is still the same 25 years later. But still the computer industry is conceived as re-inventing itself at least once a year.
(Original copyright Apple Inc., 1983)


ge Layout Arrangement Fill Lines Pen
alculator
0
285714286
M− M+ Mx
aper
LisaGraph Paper
Peggie's Rose
Text
M÷
√x
MR
Clock
Calculator
DTC Paper
▪ProFile
▪Widget

2.1.5 Embodied... and beyond

> *"There is a considerable difference between using the real world as a* metaphor *for interaction and using it as a* medium *for interaction."*
> *Paul Dourish*[18]

We have taken a very brief tour through the last few decades of interaction between human and machine. According to Dourish, "the trend [...] is the gradual incorporation of a wider range of human skills and abilities. This allows computation to be made ever more widely accessible to people without requiring extensive training, and to be more easily integrated into our daily lives by reducing the complexity of interaction."[19]

As we have seen in section 2.1.4 graphical interaction approximates the system to the user by mimicking the behavior of her perceived environment. But of course, as long as the computer presents itself *there* on a screen while the user is acting *here* in her environment, the convergence of the computer and the human perception is incomplete.

There have been countless proposals in Computer Science and Interaction Design on further augmenting of interaction experience in order to immerse the described *here* and *there*. These efforts can be loosely divided into two areas. One of them is *Virtual Reality*, which tries to close the distance between user and system by bringing her perception *into* the machine by trying to simulate her natural environment artificially. The benefit of this approach is a high flexibility in regard of presentation, but downsides are numerous: perfect illusion for all senses is technically limited, you have to isolate from your natural environment by using sensory prostheses and ultimately, it will always be just a computed model of a world, restricted to a frame defined at author-time.

On the other hand, there is an approach that could be coined "Real Virtuality", but is popularly called *Tangible Computing*. Physical objects are augmented with representations of digital information, that read the manipulations which are issued on them and map them as modification of that hidden digital model.

---

[18] [Dourish, 2001, p. 101]
[19] [Dourish, 2001, p. 14]

It is important to state, that the digital model, which is superimposed on the physical objects, underlies the same strict limitations as the world model of a Virtual Reality application. But in some cases of Tangible Computing the use of physical objects can open up this deadlock of virtuality. If applied cleverly, this principle yields to a very natural and intuitive interaction, since the computer is bridging the distance between it and the user even further. These objects can be discovered and experienced like physical tools, and thus, this discourse of Computer Science is willing to open itself to several kinds of other disciplines such as Product Design and Architecture, which have traditionally been associated to the creation of tools or physical objects in general.

Both Virtual Reality and Real Virtuality target the superimposition of digital and physical domains in order to provide perfect interaction experiences. In a brave extrapolation, both would dream of something like a “Holodeck”[20], that is able to dynamically present the best way of input and output facility for a certain application at any time.[21]

This perfect embedding of interaction with digital objects in a place that seamlessly interfaces with our natural sensorimotor and cognitive abilities can be called *Embodied Interaction*.

2.1.6 Limitations of Directness and Embodiment

There are a number of limitations of Directness and Embodiment for interface design that are usually not addressed. The user is getting more and more immersed in the digital systems allowing her to do tasks almost in the same way she does in physical world, but this also opens up some problems.

The coupling of physical objects with digital ones might work for a number of cases, but basically one also looses the flexibility and “volatility” of the digital domain. Removing the latter is actually one of the main targets of Tangible Computing. But what if you have to copy a digital item? A physical token

[20] According to http://en.wikipedia.org/wiki/Holodeck (accessed 1-4-2008) “the holodeck is a simulated reality facility located on board starships and starbases”, which has been part of the Star Trek series. Another fictive illusion machine would be the “bio-adapter”, described by [Wiener, 1969]

[21] see [Trogemann and Viehoff, 2005, p. 43ff] for a discussion on self-constructing, evolutionary interfaces. The described machines would be able to “break out” of their “sensory imprisonment” by creating their own channels to the physical world as appropriate.

representation is unable follow the digital object. Tangible User Interfaces have to be narrowed down to a specific application, because these cannot offer full flexibility. Other actions in the digital domain are so abstract, that there will never be a fully embodied representation in physical world possible.

But this limitation did not start with TUIs and is also visible in using “drag’n’drop” for GUIs, “talking” with the machine using text commands or using symbolical representations for programing processor directives. These are all just models and layers that are placed in between you and the computer. Observing the development of interaction, it becomes obvious that these layers get more and more specialized for one certain task that, therefore, feels very natural. But doing different than planned actions feels clumsy or is even impossible, since these models use metaphors of the physical world and every metaphor only holds to a certain degree.

To give another example, things might work great for the desktop metaphor and throwing something into the trash-bin, but experienced users actually prefer to use a simple shortcut that they learned and which is just quicker than to “pretend it was reality”.

The author of this thesis, for instance, is using TEX[22] to create this document, instead of using one of the many office packages. Their WYSIWYG[23] approach would allow to be directly connected to each element of the document, being able to write directly in the final look of the document, making it possible to be a creative typesetter oneself. Using Tex on the other hand is highly unintuitive, you have to learn commands to control text structure as well as formatting. You only get a glimpse of a preview every now and then and still there is a huge benefit. Using TEX means to describe the structure and look of a document to the computer, which is formatting your text accordingly for you then, while using WYSIWYG means to do everything yourself. The computer is becoming more of a serving assistant, while in the case of WYSIWYG you find yourself alone in a typesetting studio.

These have just been a few examples, which should give a comment on

---

[22] A markup oriented typesetting system created by Donald Knuth. See http://www.tug.org

[23] According to http://en.wikipedia.org/wiki/WYSIWYG (accessed 20-03-2008) “WYSIWYG is an acronym for *What You See Is What You Get*, used in computing to describe a system in which content during editing appears very similar to the final product.”

the changing paradigms of interaction interfaces. Nonetheless, Directness and Embodiment carry an immense potential as we will see in the rest of this thesis. It all comes down to the way it is used, and for what purpose.

Now, we will first have a look at the theoretical background of Embodiment in philosophy and Cognitive Science, before we will closely discuss the properties of Embodied Interaction in section 2.4.

2.2 Theoretical background of Embodiment

2.2.1 Phenomenology

> *"Denk nicht, sondern schau!"*
> *Ludwig Wittgenstein*[24]

As we will see in this section, *Embodiment* is not a new idea, since it has been discussed in large extent by the *Phenomenology* of philosophers such as Edmund Husserl, Martin Heidegger and Maurice Merleau-Ponty in the first half of the 20th century. Phenomenology states, that perception and understanding ground in physical existence (embodiment of mind), and thus tries to put emphasis on the role of the human body in philosophy. In the following paragraphs we will have a very brief look at Phenomenology with focus on Heidegger.

Phenomenology is the very opposite of René Descartes' idea of the separation between the human mind (*res cogitans*) and body (*res extensa*) and his claim "cogito ergo sum".[25] In relation to that, Heidegger argued that "being comes first", "thinking is derived from being" and that "... thinking and being are fundamentally intertwined".[26] Phenomenology "... rejected abstract and formalized reasoning, looking instead at the pretheoretical, prerational world of everyday experience."[27]

---

[24] "Don't think, but look!" [Wittgenstein, 1967, text 66]
[25] "I think, therefore I am"; in "Meditations", 1641
[26] [Dourish, 2001, p. 107]
[27] [Dourish, 2001, p. 106]

Thus, Descartes' assumption of an ontology, an objective projection of the world onto the res cogitans, does not hold in Heidegger's view. Instead, he coined the idea of *being-in-the-world* as the one true condition before all rational thinking. Perception and cognition therefore cannot be thought separated from the body: "The subject which controls the integration or synthesis of the contents of experience is not a detached spectator consciousness, an 'I think that', but rather the body-subject in its ongoing active engagement with [the world]."[28]

The shift of the understanding of Embodiment in the philosophical discourse serves as a foundation for further investigations. We will come back to the discussion of Phenomenology from time to time within this thesis. We will now move on to the findings of Cognitive Science in terms of Embodiment.

2.2.2 Embodied and Distributed Cognition

In the end of the 20th century the idea, that the human body and the interaction with environments play a central role for understanding cognition, was introduced as a new paradigm to Cognitive Science. This new approach has been coined "Embodied Cognition", while the search for its proof is called the "Physical Grounding Project".[29]

This new thinking tries to enhance the older Behaviorism and Cognitivism, since both did not sufficiently address the context in which cognition takes place in real-life. Behaviorism concentrated on clean and dedicated laboratory setups for its experiments while Cognitivism, which grounded on a positivist idea that tried to model human cognition much like a computer system with central processing unit and peripheral input/output channels, i. e. senses and muscles. Thus, Cognitivism shared much similarity with the central world-modeling approaches of Artificial Intelligence in Computer Science at that time.[30]

But with the idea of the developmental psychologist Jean Piaget to emphasize sensorimotor abilities as the grounding of cognitive capabilities as well as

---

[28] [Hilditch, 1995, p. 111] in [Anderson, 2003, p. 14]

[29] See [Anderson, 2003, p. 17]

[30] According to http://en.wikipedia.org/wiki/Cognitivism_(psychology) (accessed 01-04-2008)

the work of the linguists Lakoff and Johnson[31], who argued that abstract concepts might be based on metaphors for bodily concepts, a new explanation for human cognition was born. At the same time, research in Artificial Intelligence started to engage in more behavior-based robotics: instead of holding a modeled image of the world in memory, these machines should realize similar behaviors like animals, which try to search for food or avoid predation or simply manage to move without crashing into the next obstacle.[32] The idea of these approaches is not to model a top-down approach of how we think our mind could be working like, e. g. while reflecting from our viewpoint within our mind about our mind, but rather to lay similar foundations of cognition as evolution probably did, starting with bodily-oriented basic tasks.

According to Margaret Wilson's report "Six Views of Embodied Cognition"[33], this emerging field can be summarized with the following set of six assertions that have been made within the scientific discussion. We will use these for a broad overview of this area of research.

[31] [Lakoff and Johnson, 1980]

[32] See the vehicles described by [Braitenberg, 1984] as referred to in [Degele, 2002, p. 108ff] or the research of [Brooks, 1999] as an example

[33] [Wilson, 2002]

1. Cognition is situated

   We are acting in a real-world environment and thus cognition has to take interaction with it into account. An example is moving around while placing objects in order to find good positions for furniture.

2. Cognition is time-pressured

   Since we are embedded into an ever-changing environment, we do not have unlimited time for making up our mind. The thread of predation, etc. in our evolutionary history is highlighted in particular.

3. We off-load cognitive work onto the environment

   Because of our limited cognitive performance, we save information (e. g. archive) in or manipulate information (e. g. tool use) through the environment.

4. The environment is part of the cognitive system

   Our interwoven relation to our environment makes it necessary to incorporate it into any analysis about cognition.

5. Cognition is for action

   In an ultimate sense, all cognitive mechanisms are for conducting situation-appropriate action.

6. Off-line cognition is body-based[34]

   Even thoughts that do not directly address a specific situation are grounded in mechanisms that evolved for interaction with the environment.

In her report she is discussing these assertions very dialectically, also arguing many reasons against them. But nonetheless she admits, that “areas

[34] Wilson used *on-line* and *off-line* as terms to describe the situatedness of mental activity. On-line in that sense describes a high degree of relevance for a given mind-external situation, with more or less “real-time” demands for reaction, e. g. driving a car or fleeing a predator for a pre-historic hominid. Off-line in contrary refers to the high-level abstract thinking of man that may bring object and actions to one’s mind, which are not directly related to the current environment.

of human cognition previously thought to be highly abstract now appear to be yielding to an embodied cognition approach."[35] Some of these findings are of very foundational character, while others such as the third and fourth hypothesis have a very direct connection to the way in which humans interact with their environment and thus are highly interesting in the discussion of Embodied Interaction Design. The acceptance of the environment as part of the human cognitive system also leads to what is called *Distributed Cognition*. This branch of Cognitive Science is asking "where the mind stops and the rest of the world begins"[36] and heavily insists, that "skin and skull" should not be taken as a nature-given border. Since the intersection with Embodied Cognition in general is that large, we will only put their argumentation in a nutshell:

> *"If, as we confront some task, a part of the world functions as a process, which,* were it done in the head*, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world* is *(so we claim) part of the cognitive process. Cognitive processes ain't (all) in the head!"*
> *Andy Clark, David J. Chalmers*[37]

Helping yourself for instance by trying several, different positions for pieces of furniture in your new appartment *is* a cognitive function, since it *would* clearly be considered as cognitive, if you were to imagine the possible positions only in front of your eyes.[38]

The presented, emerging fields stay of high interest and should be observed by everybody, who is reflecting about Interaction Design. We will now concentrate on two scientists, whose ideas already are several decades old but nonetheless fit into the line of discussion or even anticipated much of the discussion of embodiment from a different point of view.

---

[35] [Wilson, 2002]

[36] [Clark and Chalmers, 1998]

[37] [Clark and Chalmers, 1998]

[38] These actions, that are issued in purpose of off-loading cognitive effort to the environment, are coined as *epistemic* by [Kirsh and Maglio, 1994], while actions, which are done to reach a known, precise goal, are called *pragmatic*.

2.2.3 Tacit knowing

Michael Polanyi was a Hungarian British polymath whose thought and work extended across physical chemistry, economics, and philosophy.[39] In his book "The Tacit Dimension"[40], Polanyi is examining how people apparently know more things than they are able to name or describe. "We know a person's face, and can recognize it among a thousand, indeed among a million. Yet we usually cannot tell how we recognize a face we know. So most of this knowledge cannot be put into words."[41] According to Polanyi, a whole realm of knowledge seems to be *in us*, emerging out of the neural structure of our brain and nervous system, without us being *aware* of it but still, being able to apply this knowledge.

This idea is largely parallel to the ideas of Embodied Cognition, since there, the mind also arises from simple layers that are invisible to our mind and yet constitute the very same. Nonetheless, Polanyi is not speaking of embodiment, since that discussion probably has not been in vogue at that time.

In the first chapter of his book, Polanyi introduces the terms *proximal* and *distal*, which he borrows from the language of anatomy.

"We may say, in general, that we are aware of the proximal term of an act of tacit knowing in the appearance of its distal term; we are aware of that *from* which we are attending *to* another thing, in the *appearance* of that thing. We may call this the *phenomenal structure* of tacit knowing."[42]

There is an obvious connection to the terminology of Martin Heidegger's phenomenology. According to Heidegger, you have a tool as subject of action "ready-to-hand", while you are using it to experience another thing as object of your action in another, remote place. In the example of figure 2.4 a blind man, who is experienced in using a stick to feel the ground in front of him, will not feel the pressure of the stick while sliding along the ground, but instead will have the *impression* of feeling the ground *directly* on his fingers. Back in Polanyi's words, "whenever we use certain things for attending *from* them to other things, in the way in which we always use our body, these things change

---

[39] According to http://en.wikipedia.org/wiki/Michael_Polanyi (accessed on 01-10-2008)
[40] [Polanyi, 1966]
[41] [Polanyi, 1966, p. 4]
[42] [Polanyi, 1966, p. 11]

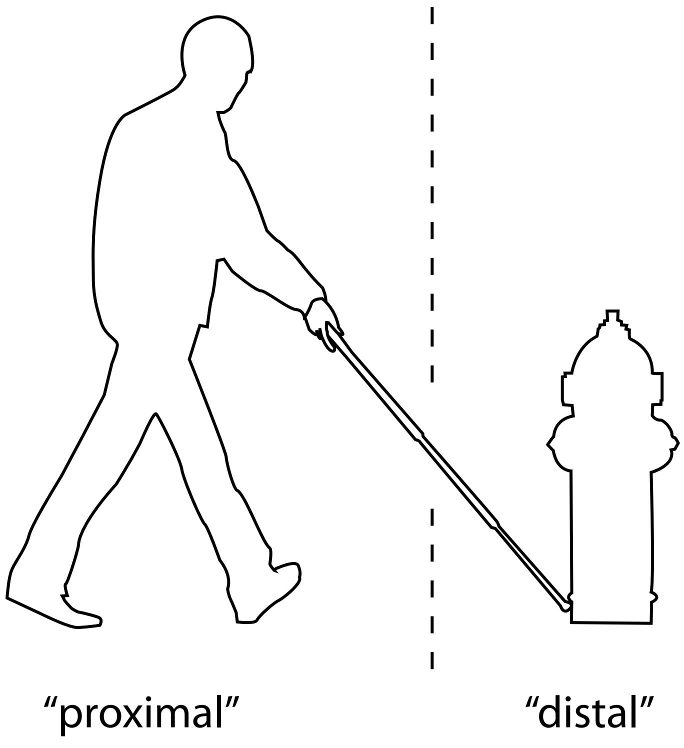


Figure 2.4: A blind man, who uses a stick to get around, doesn't feel the obstacle as remote. (According to Polanyi, 1966)

their appearance. [...] we can say that when we make a thing function as the proximal term of tacit knowing, we incorporate it in our body - or extend our body to include it - so that we come to *dwell* in it [the tool]."[43]

The consideration of tool usage as a "dwelling for the mind" and the parallel to Embodied and Distributed Cognition's treatment of the environment as part of the cognitive system render Polanyi's statements a very interesting notion for interaction and interface design in general.

2.2.4 Flow as feeling directness

The last idea we will present in this overview of the theoretical background of Embodied Interaction is the mental state of "Flow", as it has been coined by Mihalyi Csikszentmihalyi. Csikszentmihalyi is a professor of psychology at Claremont Graduate University in Claremont, California and is the former head of the department of psychology at the University of Chicago and of the department of sociology and anthropology at Lake Forest College.[44]

According to himself[45], he coined the usage of the term "Flow" to describe mental states in psychology in his book "Beyond Boredom and Anxiety"[46] in 1975. He undertook very intensive morphological interviews with people from several fields, such as chess and sports professionals as well as "simple" conveyor belt workers, to ask them about the moments of immersion they experience in their specific activity. In his numerous publications on this topic, he is giving a very comprehensive, anthropomorphic declaration of the Flow phenomenon.

Csikszentmihalyi is opposing *psychic entropy* against the mind in an ordered state, namely *flow*. He is defining the human mind as a information processing system, with a limited bandwidth of *attention*.[47] The experiencing

---

[43] [Polanyi, 1966, p. 16]

[44] According to http://en.wikipedia.org/wiki/Mihaly_Csikszentmihalyi (accessed on 01-10-2008)

[45] [Csikszentmihalyi, 1975]

[46] The english editions of [Csikszentmihalyi, 1975] and [Csikszentmihalyi, 1990] have not been available to the author of this thesis. Thus, citation is made according to the german editions: [Csikszentmihalyi, 1985] respectively [Csikszentmihalyi and Charpentier, 1992]. All direct quotations are translated back to english by the author of this thesis or taken as seen on http://en.wikipedia.org/wiki/Flow_(psychology) (accessed 10-1-2008)

[47] [Csikszentmihalyi, 1985, p. 48ff]

of Flow is described as follows:[48]

- Concentrating and focusing, a high degree of concentration on a limited field of attention (a person engaged in the activity will have the opportunity to focus and to delve deeply into it).
- A loss of the feeling of self-consciousness, the merging of action and awareness.
- Distorted sense of time, one's subjective experience of time is altered.

The following conditions are required for a situation, environment or activity in order to promote Flow:

- Direct and immediate feedback (successes and failures in the course of the activity are apparent, so that behavior can be adjusted as needed).
- Balance between ability level and challenge (the activity is neither too easy nor too difficult).
- The activity is intrinsically rewarding, so there is an effortlessness of action.
- A sense of personal control over the situation or activity.

In the mental state of Flow, actions are literally flowing out of your body, you are forgetting about bodily limitations and do not worry, whether your actions are correct or not. Again, there are parallels to Heideggers's discussion about tool-use. Being in Flow, your tool is obviously perfectly *ready-to-hand*, while it will become *present-at-hand* if you leave Flow again, due to an irritation in the interaction with the environment, that Heidegger would call *breakdown*.

As we will see in section 2.3 and 2.4, the conditions of Flow can be fulfilled by systems of Embodied Interaction because of their high degree of directness between human and system. We will present this as one central facet of the concept of the CubeBrowser project.

[48] according to [Csikszentmihalyi, 1975, p. 61ff]

2.3 Frameworks for embodied interaction

In this section we will introduce several concepts, descriptions and taxonomies, which have been developed either directly for analyzing Embodied Interaction systems or came from a more general interaction approach but fit nonetheless in the frame of this investigation. These taxonomies and frameworks can provide a useful toolset of re-occuring standard approaches for the analysis of interactive objects. While they can never fully reflect the complexity of interaction due to their modeled character, they are in general very helpful as a starting point of investigation. As we will see, all of them advocate reducing the distance between user and system in their own way. The first two examples will summarize the rather early and founding work of Donald Norman and Ben Shneiderman, while the last two examples will be newer findings from dedicated research on Tangible User Interfaces.

2.3.1 Affordances, Constraints, System Image

Donald A. Norman is a professor emeritus of cognitive science at University of California, San Diego and a professor of Computer Science at Northwestern University.[49] Norman became popular as the author of a series of usability oriented books.

In the following, we will have a closer look at the terms and ideas he describes in his famous book "The Design of Everyday Things". Inspired by the visual and functional clarity of some of our everyday things such as doors or light switches, Norman tries to explain the principles of intuitive and self-explaining usability design that can also be applied in large extents to screen design or interaction design in general.[50] Figure 2.5 tries to place Norman's terminology in a visual context.[51] Basically, this can be seen as a more detailed version of the Gulf of Interaction of figure 2.1, which now tries to highlight the processes of *bridging between* system and user.

---

[49] According to http://en.wikipedia.org/wiki/Donald_Norman (accessed 6-1-2008)
[50] [Norman, 2002, p. 24], the first edition was entitled "The Psychology of Everyday Things" and has been released in 1988.
[51] It is an enhanced version of figure 1.10 in [Norman, 2002, p. 16]

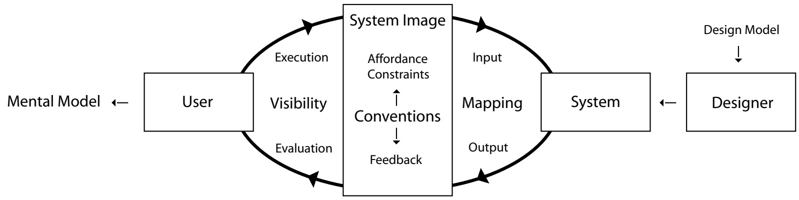


Figure 2.5: This illustration places Donald Norman's central terminology in a visual context. (According to Norman, 2002)

Mental Model, Design Model, System Image

According to Norman the *Mental Model* is the personal imagination that a user is receiving from a system through interacting with it. Opposite to the Mental Model is the *Design Model*, the conceptual model according to the ideas of the system's designer. In between both is the *System Image*, which arises from the physical appearance of the given object. The designer is never communicating directly with the user, but always over the System Image. If the System Image does not reflect the Design Model of the creator, then this will result in a wrong Mental Model for the user.

Visibility

Visibility is the expression of the system, so it is more or less equivalent to the System Image. If a functionality of a system is rendered visible, then this will be more understandable to the user according to the "What You See Is What You Get" paradigm. Thus in general, more Visibility is better.

Mapping

For Norman *Mapping* describes the relation between a control element and its effect for a system. For instance, if we turn the steering wheel of a car left while driving straight ahead, then the car will turn left accordingly. Norman recommends *Natural Mappings*, where these are possible.[52] Norman shows an example, in which the light switches of a room are not as usual in a vertical line at the wall, but are mounted analogous to their actual position on a two-dimensional miniature view of that room.

Conventions

Each perception of the System Image, regardless if plain observation or interaction, depends on the cultural context of the user. The manifestation of this kind of previous knowledge is taking a long period of time and if already adopted, are not easily overcome.

Affordance

Originally, *Affordance* has been introduced by James J. Gibson to describe all existing action possibilities within a given environment. For Gibson, it has not been crucial, if an observer within that place actually realizes all of these options.

According to Norman on the other hand, Affordance only describes perceived features of an object, especially those basic properties, which show the potential user how to use it properly.[53] Therefore, rotary knobs suggest the user to rotate them and sliders suggest to be moved linearly.

Constraints

Norman uses the term *Constraints* for restrictions or conditions for the proper usage of a system.[54] He differentiates between “Physical Constraints”, “Semantic Constraints”, “Cultural Constraints” and “Logical Constraints”. “Physical Constraints” are limitations for a certain way of handling, e. g. you cannot move an item through a smaller sized hole. “Semantic Constraints” rely on the meaning of the context of a certain situation, e. g. we know that a chair

---

[52] See figure 1.13 in [Norman, 2002, p. 24]

[53] see [Svanæs, 1999, p. 35ff] for a discussion of this difference in the understanding of the term Affordance between Donald Norman and James J. Gibson.

[54] [Norman, 2002, p. 82]

in a room can be used for sitting. “Cultural Constraints” ground in cultural conventions. Thus we know, how to turn a written paper in order to read it. “Logical Constraints” assume that the user is able to understand the handling of a system through his own rationale. Natural Mappings for example often work through Logical Constraints. In general the borders between the different types of Constraints are rather fuzzy and a system can have several types of constraints at a time.

Feedback

Each action of the user should be confirmed by an immediate and clear response of the system.[55] A conversation between human and system is desired. The response can be of any kind, e. g. visual or auditory.

2.3.2 Direct Manipulation

Ben Shneiderman coined the term *Direct Manipulation* in a number of publications.[56] In “Direct Manipulation Interfaces”[57] Hutchins et al. comprehend Shneiderman’s idea to the following three characteristics.

Continuous representation of the object of interest

The benefit of a constant presentation is obvious: The affordances of the object will be presented to you at any time and you won’t be confused by having to search for a vanished object. In the reality of screen design for graphical operation systems, this is a rather difficult task. Through the windowed presentation of today’s application, it easily happens that objects of interest are occluded by other windows or are only presented in a certain mode.

The use of tangible objects as representation[58] has another nature. In principle, the existence of physical objects imply a continuous representation

[55] [Norman, 2002, p. 27]
[56] [Shneiderman, 1983, Shneiderman, 1982, Shneiderman, 1974]
[57] [Hutchins et al., 1985]
[58] Which is not explicitly advised by Shneiderman, since his findings have been made in a time, when the emerging graphical interaction paradigm was to be manifested

through their very nature.

Physical action or labeled buttons instead of syntax

With textual interaction, the user had to learn a certain syntax and its nouns, i. e. the name of commands in a shell prompt, while with graphical or even embodied interaction "... all opportunities for action are *out in the open*."[59] In the words of Norman, this would suggest to present the possibilities of a system by showing appropriate affordances. The claim for labeled buttons, however, refers to a WIMP-style graphical interface and this makes clear in what time this advise has been formulated, namely during the paradigm change from textual to graphical interaction[60]. Nonetheless, the suggestion of physical action is very visionary for that time.

Rapid incremental reversible operations with immediate impact

The proposal carries three facets: First, *incremental reversible operations* refer to the investigation of physical environments. For instance, if you drive around in a car, there will always be a way back to where you started, regardless the sequence of turns you made, neglecting unforeseen events of course. This also refers to the continuity of our existence. Second, *immediate impact* means about the same as Norman's feedback. To stay in our example of driving a car, a turn to the left also means that you are really rotating position in space, maybe enter another street and thus are presented a new view. Third, *rapid* refers to the immersive character, that the communication of human and system should characterize. Since a machine has to compute the output for your input, it is important that you do not have to wait too long, since otherwise, the feedback loop would suffer and your attention might get lost.

---

[59] According to [Dourish, 2001], who advocates the same
[60] See 2.1.3 and 2.1.4

2.3.3 Spatial Mapping, I/O Unification, Trial-And-Error

After having had a look at the early work of Norman and Shneiderman, we will now continue with two scientific papers on Tangible User Interfaces (TUI): “On tangible user interfaces, humans and spatiality”[61] by Sharlin et al. and “A taxonomy for and analysis of tangible interfaces” [62] by Kenneth P. Fishkin.

Sharlin et al. propose a heuristics of three components and evaluate a number of interesting TUI projects with it. As we will see, they actually repeat the ideas of Norman and Shneiderman, whose large coverage is therefore emphasized, and adapt them to their specific scenario.

Spatial Mapping

Spatial Mappings, as the first component they present in their paper, aligns perfectly to Norman’s idea of Mappings, but emphasizes the spatial quality of them.[63] They present the mouse as an example for a good mapping since the cursor follows the same movement as the mouse is moved, while the keyboard is not intuitive in itself, but rather a learned mapping. Obviously, “...good spatial mappings will be achieved most easily, if the application itself is inherently spatial - that is, if it mediates interaction with shape, space or structure.”[64]

I/O Unification

One commonly accepted design goal of Tangible User Interfaces is the fusion of input and output space. Interaction with computers normally means controlling something that happens *there* on a screen, while the input is made *here* in front of it. That results in a “...decoupling of action and perception space, and uncertainty about state.”[65] This obviously refers to the discussion of Direct Manipulation and the overcoming of the Gulf of Interaction described

---

[61] [Sharlin et al., 2004]
[62] [Fishkin, 2004]
[63] For Norman Mappings could also be realized using other qualities than size, position and orientation such as volume, color, temperature, pitch and so on.
[64] [Sharlin et al., 2004, p. 339]
[65] [Sharlin et al., 2004, p. 339]

in the previous sections. In their paper the authors add an interesting notion to this idea, namely an analogy to mechanical tools in the physical world, which make it possible to "...exploit visual, tactile and other sensory cues to deduce the state of their activity and its progress from [their] condition and motion ...".[66] Due to their existence in our space, physical tools tend to tell a lot more then digital ones. For instance a motor tells a driver if its number of revolutions is high or low through its volume and pitch and thus, she can react on it by changing to the correct gear without reading the dashboard. I/O Unification doesn't necessarily lead to the described situation of embodied feedback, since still every output of the digital system has to be designed and engineered in order to be presented in physical space.

Trial-And-Error

The last component of their proposal is the support of Trial-And-Error activity. They differentiate between pragmatic and epistemic actions[67] and describe the latter as "...using the physical task space itself in order to improve our cognitive understanding of the task."[68] These investigations lie in our nature, we explore the offered action possibilities without a complete understanding by simply trying them. The situation of a curious boy in front of a mysterious switch on the wall has been told in many stories. This curiosity is helping us to learn without reading a manual, even though quite often we cannot fully explain to others what we found out by simply trying it. Again, this proposal is very close to what Shneiderman demanded with "Rapid incremental reversible operations with immediate impact", since immersive input/output iterations are necessary in order to get a "grasp" of an unknown system. According to Sharlin et al. traditional software is not designed very well for epistemic actions, but expects goal-oriented, planned pragmatic actions.[69] They continue, that the famous "undo" function, that became ubiquitous in almost every application, is a good start for trial-and-error use, but has the downside of removing

---

66 [Sharlin et al., 2004, p. 340]
67 As proposed by [Kirsh and Maglio, 1994]
68 [Sharlin et al., 2004, p. 340]
69 This is also manifested in the formal nature of software, which usually forces the developers to think about limited use-cases, which are then presented to the user.

all following steps of the action that one wants to undo.[70] Furthermore, traditional software simply doesn't reflect the kind of physical investigation by touching and moving, positioning and turning, viewing from different angles that is typical for epistemic actions.

2.3.4 Embodiment and Metaphor

The last framework we will be talking about is "A taxonomy for and analysis of tangible interfaces"[71] by Kenneth P. Fishkin. He describes a two-dimensional grid that features the degree of embodiment on the one axis and the degree of metaphorical character on the other. The higher the levels of these attributes in a system, the more tangible it is. It is very important to note, that Fishkin doesn't use the term embodiment in the broad sense of Paul Dourish as described in section 2.1.5, but rather to describe the successful superimposition of a physical object with a digital one as it is characteristic for Tangible User Interfaces. Thus, they explain this degree as the question: "To what extent does the user think of the state of computation as being *embodied* within a particular physical housing?"[72] In this regard, the spatial distance between input and output device is crucial. The degree of metaphor on the other hand describes structural similarities between the physical and digital system, i. e. how much of an analogy is realized between both.

The degree of metaphor is very closely related to Norman's mappings, while the degree of embodiment is more difficult to be linked, but can be found in Norman's bridging of the Gulf of Interaction. In the following paragraphs, we will have a closer look at the levels that embodiment and metaphor offer.

[70] There are implementations of non-linear construction histories in 3D packages, that allow for removing one step without breaking off the whole branch of following actions. Nonetheless, most programs have the described limitations.

[71] [Fishkin, 2004]

[72] [Fishkin, 2004, p. 348]

Embodiment

1. Full

   In the extreme case, output and input device are identical. For instance physical clay reflects each single press on it directly on itself.

2. Nearby

   This is used for more proximate spatial relations, such as the early light pen interfaces or today's touch-screens.

3. Environmental

   An environmental embodiment is usually given if you alter some parameter of the space or surrounding you are in by giving a certain input. Quite often, this is the case for installations of media and sound art.[73]

4. Distant

   The other extreme case would mean no embodiment at all, as it is the case with a TV remote, which is clearly acting *there* in the TV set, when you act *here* in your hand.

Metaphor

1. None

   This extreme case would mean that there is no metaphor at all. For example the command-line interface of the textual interaction paradigm would carry no metaphor in it, since typing letters on a keyboard has nothing to do with the action you are performing, e. g. moving a file.

2. Noun

---

[73] For instance the sound installation "Offener Schaltkreis" (open circuit) [Rumori et al., 2007] by Martin Rumori, Christoph Haag, Franziska Windisch and the author of this thesis. The interaction of this installation is mainly characterized by environmental embodiment, mixed with nearby interaction facets. This is a good example for the permeability of these categories.

"... an X in our system is like an X in the real world."[74] Files, folders and the trash-bin of the graphical interaction paradigm have a comparable duty as the equivalents in physical space, even though they usually do not allow for the same richness of unforeseen interaction.

3. Verb

   "... X-ing in our system is like X-ing in the real world."[75] Controlling a computer game character by moving the sensor-enabled controller the same way as you would for performing the real task is an example.

4. Noun and Verb

   "... X-ing an A in our system is like X-ing something A-ish in the real world."[76]

   An example for the combination of noun and verb metaphors would be the deletion of files on a WIMP-oriented system by dragging them into a trash-bin.

5. Full

   This is the case if doing something to an object actually modifies the object. This also implies a perfect superimposition of physical and digital object. Fishkin gives the example of a pen-controlled computer, with which writing on a displayed presentation document is directly altering the document itself.

2.4 Conclusion: Make it real

In this section, we will have a summary of the theoretical background that we have discussed so far in this chapter as well as its implications for design.

The first section (2.1) gave a condensed overview of the historical developments of the paradigms of interaction, as Paul Dourish presented them in

[74] [Fishkin, 2004, p. 350]
[75] [Fishkin, 2004, p. 351]
[76] [Fishkin, 2004, p. 351]

his book “Where the Action is”. This process has been projected into the future, showing that the systems are coming closer and closer to their users in regard of interaction. Following that, we heard about the philosophy of phenomenology (2.2.1), which places emphasis on the bodily-based being instead of an uncoupled mental existence. The recent findings of Cognitive Science (2.2.2) regarding how the meaning of our mental presence can emerge out of our physical brain and body were shown. Furthermore, some older positions of psychology have been presented in tacit knowing (2.2.3) and flow (2.2.4), broadening the view on the topic of embodiment. And on top of that, we had an overview of several analytical frameworks (2.3), that have been developed by researchers of Computer Science and Design.

Putting these pieces together, on the one hand one can say that *embodiment* is describing the emergence of the mind out of matter. Therefore, it seems obvious that this mind also is connected and dependent on the process of the body regarding its cognition. *Directness* on the other hand, describes the degree of immersion between an interaction system and its user. Succeeding in this can create intuitive and powerful ways of interaction, that use the potential of our body perception for a very rich experience. Ultimately, this means that our so called tacit knowledge can be used to integrate us quickly and deeply within complex computer systems, creating an inspiring immersion that could often promote the entering of the state of Flow while using them, probably more often than more abstract forms of interaction.

Design for Embodied Interaction

A whole realm of new knowledge is becoming interesting for system developers, who have to open themselves for creative disciplines like design and architecture in order to create these rich environments. Since the surrounding counts now, everything is becoming a “material” for interaction processes. Furthermore, Embodiment is also getting more and more important for design itself.

Embodied Interaction, as a consequence of that, “is the creation, manipulation, and sharing of meaning through engaged interaction with artifacts.”[77]

[77] [Dourish, 2001, p. 126]

Now we will summarize a few things that design for Embodied Interaction systems should characterize. The way of *discovering* a system through epistemic actions[78], instead of just *using* it in the way it has been designed for, can create an easy and playful way of exploring complex environments. “The world is its own best model”[79] is describing the benefits of representing the functionalities of a system directly in its own presentation. This relates to good “spatial mappings” and “I/O unification”[80] and is often achieved by using Tangible User Interfaces, which represent their model directly bound to physical objects. The constant representation of elements of these systems get rid of the problem of WIMP-oriented operating systems, which usually allow to do multiple things at once, hiding their functionality through occlusion caused by the window management. Additionally, the use of real space and real material for these interaction tokens[81] allow us to think of many more ways of interaction. “One sees the environment not just with the eyes, but with the eyes in the head on the shoulders of a body that gets about. We look at details with the eyes, but we also look around with the mobile head, and we go-and-look with the mobile body.”[82] That makes it possible to incorporate our tacit knowing and the unconsciously inspiring nature of using our body.

Furthermore, these physical objects also allow a freedom of *use* and *abuse* that computer systems usually cannot offer. The phenomenological assumption of a pre-ontological experience allows for possibilities that may lie beyond the frame of expectation. A frame, that is usually modeled, designed and created during author-time and that is somewhat a priori inherent in discrete, digital systems. A physical object is rich, because of the endless complexity of nature, while a digital object is limited to its predefined symbols. Thus, a system that is made of physical objects may hold emergent phenomena, is more than the sum of its parts and may be used in surprising ways. Let’s see an inspiring example made by Margaret Wilson:

> *“... we can note that our mental concepts often contain rich in-*

[78] [Kirsh and Maglio, 1994]
[79] [Brooks, 1991a, p. 139] in [Wilson, 2002]
[80] [Sharlin et al., 2004]
[81] As described by [Ullmer et al., 2005], but not necessarily limited to those ideas.
[82] [Gibson, 1979]

> *formation about the properties of objects, information that can be drawn on for a variety of uses that almost certainly were not originally encoded for. We are in fact capable of breaking out of functional fixedness, and do so on a regular basis. Thus, I can notice a piano in an unfamiliar room, and being a non-musician I might think of it only as having a bench I can sit on, and flat surfaces I can set my drink on. But I can also later call up my knowledge of the piano in a variety of unforeseen circumstances: if I need to make a loud noise to get everyone's attention; if the door needs to be barricaded against intruders; or if we are caught in a blizzard without power and need to smash up some furniture for fuel."*[83]

As mentioned before developing for Embodied Interaction should take over principles of design and architecture. The discussion in the latter field is trying to think about promoting spaces, which allow the emergence of unforeseen usage scenarios, too. Kalay and Marx have presented some findings on how to take over the design experience of architecture to the construction of cyberplaces in the internet.[84] They place emphasis on the difference between a mere space and a vivid place, for them the latter only is created through the combination of space and the people, who live in and use it, and carry out their cognitive processes on-site, creating a symbiosis-like relationship with the place and among each other.

If we open our view even more, than it becomes obvious that embodiment is, what everybody else basically always has done: the early humans getting around and avoiding predation, the handy craftsmen with their tools, the people who created our cities as well as their inhabitants in their daily lives. Bringing this natural discourse to Computer Science and the construction of its systems is not a trivial task, but is the central idea of design for Embodied Interaction.

---

[83] [Wilson, 2002]
[84] [Kalay and Marx, 2001]


working newyork project reading
hailand trackback utilities ux war
udapest camping clients dub
x mega modules notes people
eeks tv videos volunteering wire
ghts future go googletalk gps gra
oreilly outsourcing phuket portal
op wikis ******** pasta ads bikepat
d collection computer conspiracy
lakebaikal life machineproject ma
parks paypal pda podcast policy
eetart techno terror thinking train
kipedia xp yoga *submunition ad
ndars cash cell cellphones chacoca
e cthulhu cycling damascus datab
antasy favicons feynman flickr.com
s japanese job kerry killfest lanver
ivation mountainbiking nasa natu
ohptemplate physics portable po
ting semantics ships site slashdot
cruise url www

3 THEORY: Distributed Cognition in cyber-space

"Where does the mind stop
and the rest of the world begin?"

Andy Clark and David J. Chalmers[1]

3.1 Socially Distributed vs. Embodied

After having heard much about the role of the human body for cognitive processes in chapter 2, we will now broaden the context of cognition in order to include collectives. Let's clarify the terms used from here on, so that we don't get confused. I will distinct between *Socially Distributed Cognition* (global) and *Embodied Cognition* (local), where the first one describes cognitive phenomena that happen across several persons and the latter is concentrating on the role of the human body for cognition as described before. This aligns to the proposals of the cognitive scientists James Hollan and Edwin Hutchins[2], who see both terms as an expression of Distributed Cognition. Physical artifacts lie somewhere in between and are able to augment one person's intellect[3] or connect the cognition of several people. We will have a closer look at the bridging role of these artifacts in chapter 4, since this is the central conceptual idea of this thesis and CubeBrowser. But in the following sections of this chapter we will concentrate on Socially Distributed Cognition, which is happening

[1] [Clark and Chalmers, 1998]
[2] [Hollan et al., 2000]
[3] See e. g. [Wilson, 2002], as discussed in chapter 2

in our networks today. We will learn about the hidden, virtual places that are emerging and vanishing in the fluid matter of cyber-space.

3.2 The all new Web 2.0

Discussing social phenomena of the internet today you cannot avoid talking about the Web 2.0 paradigm as well, even though it has been used for everything and everywhere.

When Tim Berners-Lee presented the WWW infrastructure to the world in his famous usenet post from 1991[4], he had a vision of a network in mind that should serve knowledge, wisdom and free participation. Actually it did not perfectly hold his promises for several years, which had political, financial and technical reasons. But in the beginning of this decade the web experienced several paradigm shifts that have been coined Web 2.0 by the influential publisher and author Tim O'Reilly and his colleagues in 2005.

The Web 2.0 conference has been held in order to discuss a number of paradigm shifts that could be observed already in that time and are still gaining influence on the perception of what the web should be today. Among the central concepts, which have been characterized in that discussion, are the integration of user-generated content and classification through tags as well as technical facets such as AJAX, RSS feeds, wiki and blog systems as illustrated in figure 3.1.

Especially the easiness for users to contribute and classify content on the web is important for the increasing amount of immersion and integration and thus democratization and emancipation of this medium. The character of the web developed from a rather static archive to a constantly evolving database that is easier to read *from* and now even write *to* than ever before.

> *"While archives institutionally and legally have shut [their] databases against public access [...], off-line, an on-line database does not come to an end, but instead is subject of a constant evaluation."*[5]

[4] See http://tinyurl.com/kn8fr

[5] [Ernst, 2002, p. 132], translation by the author of this thesis.

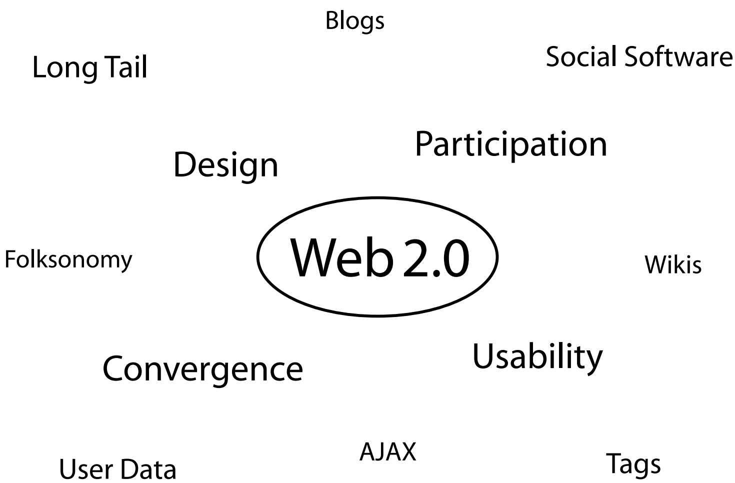


Figure 3.1: A “cloud” of terms that have to do with Web 2.0

In large parts the web of today is created and filled by users using their blogs and wikis. Furthermore, it is also structured and formed by people who do not create, but only move around in this space. By automatically recognizing important and often referred places on the web its structure is changing in every moment, even when somebody is only strolling around in cyber-space. Hartmut Winkler spoke of this feedback of user cognition already in 1994, when he stated that "...the data-net is only then becoming interesting, when the decision is made to re-feed the user's movements into the topology of the net itself" and "that the user's movements are a kind of writing, even though this writing is currently volatile and disappears immediately."[6]

This predictions have turned out to be true and there is much discussion about terms such as *Collective Intelligence*[7] and the *Wisdom of Crowds*[8]. While both describe slightly different phenomena[9], both have in common that cognitive processes are spread across several or many persons and brought together to one result.

> *"A process is not cognitive simply because it happens in a brain, nor is a process non-cognitive simply because it happens in the interactions among many brains."*[10]

Socially Distributed Cognition is a branch of Distributed Cognition as it has been introduced in general in section 2.2.2. Therefore, Socially Distributed Cognition is cognition that is happening across several people, who are exchanging or adding up their cognitive partials in some way.

Let's recall the idea of Andy Clark and David J. Chalmers to see parts of the world, which function as part of our cognition, as part of our cognitive process. In the case of the web, these parts are the services and their users. A strength of many of today's web services is to harvest this collective cognition and to aggregate it into something one person alone could not achieve, as in the case

---

[6] [Winkler, 1994, sec. 5], translation by the author of this thesis. Please note, that the german term "Schrift" has been translated to "writing".

[7] Pierre Lévy in [Lévy, 1997]

[8] James Surowiecki in [Surowiecki, 2004]

[9] See http://tinyurl.com/2mbu68 for a good introduction by Henry Jenkins

[10] [Hollan et al., 2000]

of the large amounts of articles on wikipedia for which many people are coordinating their opinions. This would be an example of Collective Intelligence as proposed by Pierre Levy, since people have to actively find a compromise in order to merge their knowledge. A slightly different notion is described by the Wisdom of Crowds of James Surowiecki. Among other things, he is demanding that the cognitively participating persons don't know of each other, so that everybody can give his independent voice into a pool, where it is merged down by some statistical means into one voice, that is said to be of high correctness, even though the individuals may state rather incorrect opinions.

Levy and Surowiecki's ideas are kind of opposite extremes and many phenomena of Socially Distributed Cognition cannot be completely classified by them, because they are somewhere in between of both.

In the following section, we will concentrate on the classification of content on the web through *tagging* as an example of collective perception. Even though there would be a number of other examples, tagging is of special interest for this thesis.

3.3 Tagging as collective perception

A tag is a keyword or term associated with or assigned to a piece of information, thus describing it and enabling keyword-based classification and search of information.[11] Tags are usually saved in databases that allow for numerous applications: among them are the creation of tag-clouds, which visually emphasize the most frequently used tags, searching for tags instead of using full-text search and the proposal of related items while viewing a another one. Tagging is very popular nowadays and most user-driven systems feature it. One reason for its success is, that it is aligning to the way the human brain is working while perceiving. According to Vannevar Bush, who proposed the "memory extension" system "MeMex" already in 1945 in order to shift science from weapon development to some more useful duties, "... the human mind [...] operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with

[11] According to http://en.wikipedia.org/wiki/Tag_(metadata) (accessed 01-17-2008)

some intricate web of trails carried by the cells of the brain. [...] the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature."[12] Thus, he concludes in his report back then, that "it affords an immediate step [...] to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another."[13]

There are a number of advantages of tagging, when compared to categorizing. Tagging uses the associations that come to our minds, when we simply look at something. It is a natural process in which all kinds of semantical concepts dwell out of us, simple categories that can be written down and saved as tags. Categorizing on the other hand, demands one single choice for classification. That means, that we also activate all these concepts, but have to find the single best proposal among them by judging the similarity of the mental image and the perception of the item to classify. Even if neglecting the fact, that some complex or abstract items might not be classifiable with a single category, it is still clear, that this filtering process is more exhausting than simply writing down everything that comes to mind. Furthermore, tags can be presented and aggregated in numerous ways by computational means using their fine-grained semantic structure, as we will see in the next section. Rashmi Sinha speaks of a "post activation analysis paralysis"[14], which is happening often while categorizing, since the reduction to one concept makes you fear, that a wrong choice might hide the analyzed item somewhere deep in your ontology, where it doesn't belong, making it hard to retrieve it again. It is this personal interest in "finding things again" that make people tag in the first place. But in most services on the web, the personal tagging is not kept secret, but published to everybody. One of the Web 2.0 paradigms described earlier is, that services get automatically better the more people use it, since more collective cognition is coming together.[15]

---

[12] [Bush, 1945, sec. 6]
[13] [Bush, 1945, sec. 7]
[14] See his article "A cognitive analysis of tagging" at http://tinyurl.com/7pu5b (accessed 01-17-2008)
[15] From a pragmatic point of view, the founder of the social bookmarking service del.icio.us, Joshua Schachter, states that "for a system to be successful, the users of the system have to perceive that it's directly valuable to them". When he began setting up the first version of that service entitled "memepool" in the beginning of the decade, it has only been him, who used the service,

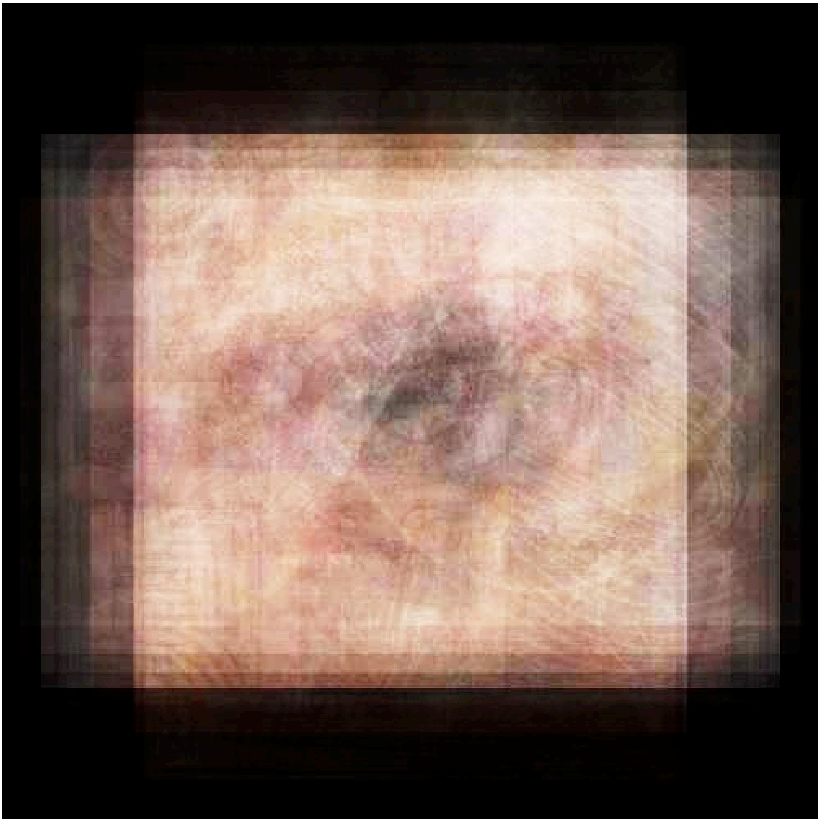


Figure 3.2: “50 people see an eye” (taken from the series “50 people see...”, Copyright Neil Kandalgaonkar, 2005)

Tagging is also helping making auditory and visual data indexable, searchable and thus findable. The research in computer vision is far from creating semantical descriptions of imagery and therefore the *meta-data* gained through tagging *media-data* is one of the few ways of making it searchable at all.[16]

In figure 3.2, you can see an artistic visualization of collective perception. Neil Kandalgaonkar wrote a program to fetch 50 arbitrary images that are tagged with a certain keyword, in this example “eye”, and superimposed them translucently on top of each other. The result is a fuzzy and blurry impression of an eye that is created out of user contributed and classified content. In order to express a brave assertion towards artificial intelligence, one could claim that this illustrates the beginning of a viewing aid for the so far blind computer systems, an aid to overcome their dark prisons of meaninglessness and bluntness.

Tagging is creating a semantical description of the web, a collective cognitive effort, driven by personal motivation. The users of the web become authors on several levels: as content contributors, as reviewers, taggers or simply as pedestrians.

Back in the words of Hartmut Winkler in 1994:

> *“Who is moving around in the net, getting an overview, keeping structures in mind and returns to places, which have proven useful for his information desires, is exactly doing that, what is currently missing in net architecture: he is organizing in hierarchies, is creating structure and is differentiating.”*[17]

The feedback mechanisms of today’s web are trying to harvest all this cognitive work and presence. But as told before, tagging is a granular semantical description, that also can bring much entropy and noise with it. In the following section, we will see how to computationally re-factor this meta-data, and why.

---

but it had value for him right away. According to http://tinyurl.com/3ywhga (accessed 01-17-2008)

[16] In computer science the need for metadata of visual content is indeed that high, that Luis van Ahn proposed using “wasted human-cycles” of online-gamers to make them tag the visual data of the entire public web disguised in some kind of simple online-game. He presented the idea in a talk he held at Google, who are currently testing an early implementation for their Google Images search. See http://tinyurl.com/hkg6z (accessed 01-17-2008)

[17] [Winkler, 1994, sec. 5], translation by the author of this thesis.

3.4 Cyber-space needs culture

If the web wants to become a natural-feeling place, it has to compensate its missing qualities such as physical experience and continuous presentation. It is easy for us to navigate in physical space, even if it is very complex. A good example would be large cities, which can reach enormous dimensions filled with bustling life, but still allow us to orient within them. But urban areas have a completely different structure compared to mere data-spaces. In the first place, data is not structured at all, it is just entropy. Only by differentiating data, it is becoming information and therefore carries meaning for us. Mere entropy is not helpful for us, so it lies in our very nature to structure our surroundings according to our perceptional needs. This does not mean, that we plan everything only using top-down actions, but also includes manifold emerging processes of our real-life, bottom-up situatedness.

> *"The topology of large cities is characterized by the intuitive and reliable differentiation between central and peripheral areas."*[18]

These agglomerations allow us to orient in cities. For instance, we set our movements in reference to highly visible objects, center our explorations around places of high interest and recognize them, when we return. In order for cyber-space to become a navigable place, Winkler predicted the emergence of important locations, while unimportant ones will be displaced to outer regions.

> *"Thus, the emergence of 'islands' is not a defect of the data universe [...], but one of several mechanisms for the creation of structure, which generate significant differentiations by exclusion."*[19]

This spatial comparison to the physical world sounds obvious, but yet, cyber-space is different. We can use spatiality to accommodate ourselves in it and decrease its degree of volatility, but we do not have to take over the

[18] [Winkler, 1994, sec. 3], translation by the author of this thesis.
[19] [Winkler, 1994, sec. 3], translation by the author of this thesis.

very downsides of physical space. The “law of the strongest” that often is creating the organization of urban areas or physical spaces through displacement doesn’t have to be applied in virtual space. We can apply new kinds of displacement, new kinds of sorting and filtering. Everybody can structure cyber-space to be his own personalized cyber-place, his own city, built from the same material, but yet structured differently. Just re-tune your cognitive dwelling to another “frequency”, and cyber-space is bending in front of your eyes...

This allows for another politics of space. The Web 2.0 discussion about the inclusion of the “Long Tail” is exactly about the technical and conceptual possibility of creating personalized copies of the same space without any additional production costs at all, it’s all dynamic, digital and reproducible.

Exclusion or inclusion is defined by whether it fits to your filters or not. But what are the criteria for filtering? As described before, computers don’t know anything about the data they are managing. So, in order to come to meaningful decisions, it is necessary to use the description of the citizens of cyber-space. Tagging makes it possible to align data to your personal preferences. It’s the description, the meta-data about our cyber-entities, the name badges and the instruction books for the machines that constantly re-build and re-bend cyberspace for us.

But even though these machines don’t know anything about what they are doing, they are able to create the required, meaningful differentiation. In the following, we will present *clustering* as a rather simple principle of re-factoring the granular information of tagging to create a more meaningful, less noisy and better recognizable cyber-space.

3.5 Clustering creates culture

There are currently two really popular ways of using the meta-information of tags on the web: you can either search for a certain tag by typing its name, resulting with a list of matches or view a so called *tag-cloud*. These are visual arrangements of popular tags used within the scope of a certain system. The tags are visually emphasized according to their popularity. To maintain the city metaphor I would suggest, that doing a precise search is like going into a phone booth and looking up an address or number in the phone book. You probably already know, who you are looking for. But if you don't know who to meet, you might be in the mood for wandering around, preferably at vivid places that match your interests. In an extreme case, you might also want to climb some large building and have a look around, an overview. The latter example matches the principle of tag-clouds, since they allow you to get a qualitative overview of what is happening around you. But tag-clouds are missing one important quality, namely the ability to group similar and related tags together. As mentioned before, this is an important emergent functionality of real space. Here, clustering comes into play:

> *"Clustering is the classification of objects into different groups, or more precisely, the partitioning of a data set into subsets (clusters), so that the data in each subset (ideally) share some common trait - often proximity according to some defined distance measure [...], which will determine how the similarity of two elements is calculated. This will influence the shape of the clusters, as some elements may be close to one another according to one distance [measure] and further away according to another."*[20]

Nature knows similar principles as well: Oil and water have different chemical properties, forcing them to separate from each other physically, creating groups.

Here, the distinction is made through chemical and physical laws. With clustering, you can define the law of distance yourself, and as described before, this is an important step. Let's see a simplified clustering procedure for tags in pseudo-code notation:

1. Collect all tags that have been created so far
2. Create a graph with all possible connections between them
3. Weight the connections according to the distance measure

[20] According to http://en.wikipedia.org/wiki/Data_clustering (accessed 01-14-2008)

4. Find regions with high agglomeration

5. Cut them off the other regions

For two tags a sensible distance measure could be the dice probability of being tagged for the same item simultaneously. This probability is the fraction between the number of simultaneously tagged items and the sum of overall appearances for both.[21]

That way, you end up with collections or regions, that contain the tags that have been examined in a more or less semantically correct way. Without going to much into the details here, it can be said, that even though tags are usually only given without additional information about the type of relation between the item to be tagged and the concept of the tag, clustering can create very useful results. It is also an example for the Wisdom of Crowds proposed by James Surowiecki, since most of his requirements are fulfilled in examples for clustering in the web. So, even though, there are many wrong assertions made in tagging, these often can be neglected through the numerical evaluation and merge-down by clustering, resulting in semantically good groupings of tags.

In figure 3.4 you can see clusters for the tag “computer” on Flickr that split all the images tagged with “computer” into four sub-areas, which show different but related topics: computers in relation to “apple” and “mac”, in relation to “desk” and “office”, in relation to “cat” and “kitten” and in relation to “portrait” and “self”. The consistency of the shown images is pretty good. But the application of clustering is not limited to tags. Any kind of text and also lots of other symbolical systems can be clustered as well.

[21] The algorithm, the graph illustration and the formula for dice probability are taken from http://www.pui.ch/phred/automated_tag_clustering/ (accessed 01-18-2008)

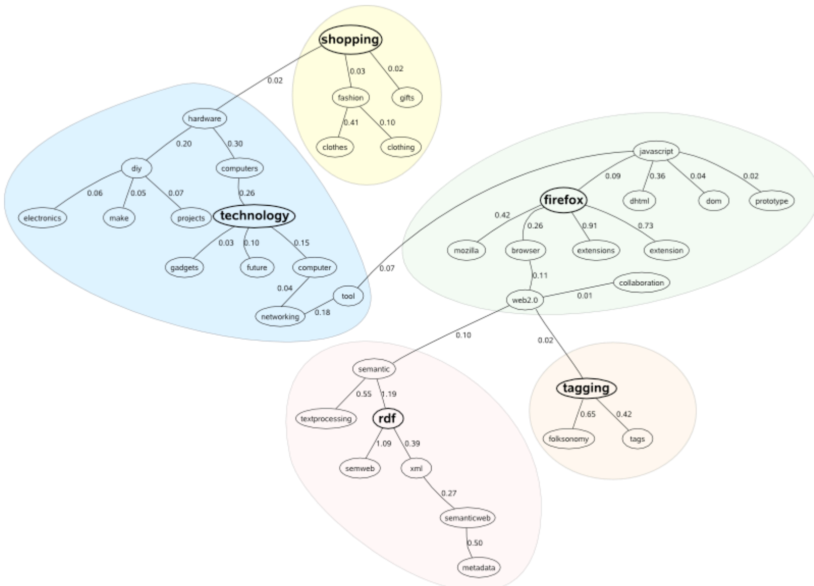


Figure 3.3: A graph of tags after clustering. Five clusters have been created. (Copyright Begelman et al., 2006)

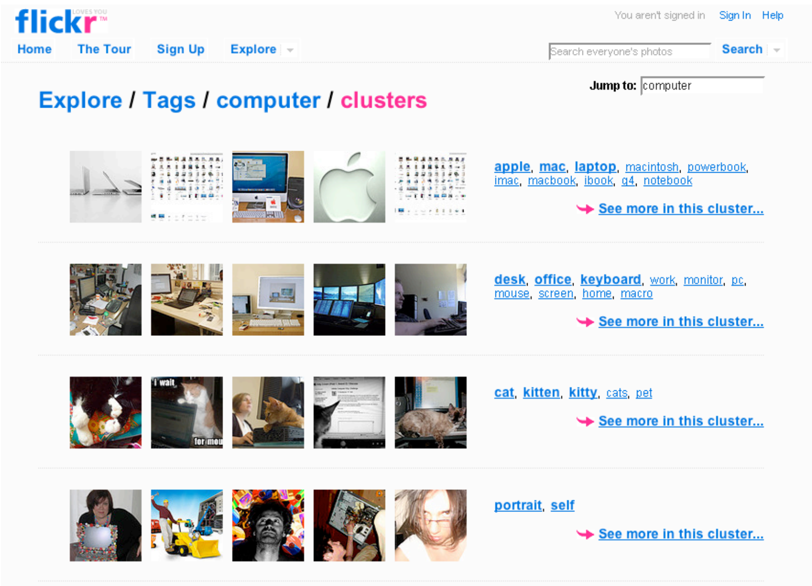


Figure 3.4: Clustered images for the tag "computer" on Flickr.
Found at http://news.google.com

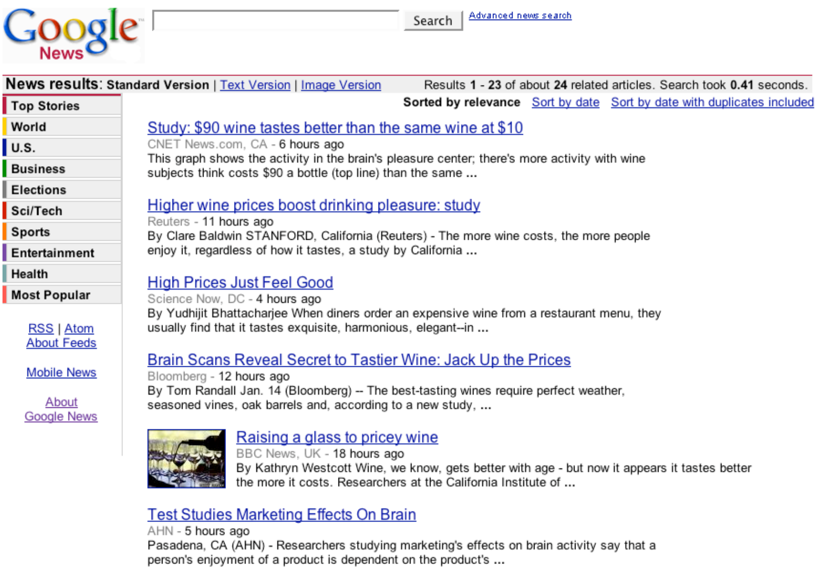


Figure 3.5: A clustered result set on Google News.
Found at http://flickr.com/photos/tags/computer/clusters

For example Google is offering their service Google News, which “is a computer-generated news site that aggregates headlines from more than 4,500 English-language news sources worldwide, groups similar stories together and displays them according to each reader’s personalized interests.”[22]

In figure 3.5 you can see 23 articles from completely different sources on the web that all cover the same story. The task of an editor to select stories for presentation in his channel is done by a computer. It is definitely by far not the same thing, since the machine only calculates distance measures, but it is always running, doesn’t apply political bias[23] and can be personalized by the reader herself. It is your personal editor, your personal newspaper only written for you, creating a piece of your own cyber-place. And this personalized filtering is absolutely necessary in order to cope with the information flood. In the same way that the ability to read and write are necessary cultural prerequisites today, it is getting more and more important to be able to select and to know how to select from the large pool of information. Clustering is a crucial technique, that could become as ubiquitous as the written language itself.

To put it in a nutshell one can make the following brave assertion: If places in physical life create culture, then cyber-places can create culture as well. Thus, if clustering creates personalized cyber-places, then clustering can create personalized culture.[24]

3.6 Conclusion: Seek or browse

The contact with cyber-place can profit from the experiences we know from our existence in the physical world. The convergence of data and meta-data through user annotation and user participation is creating a structure that can give comparable qualities of orientation and existence as the emerging structures of vivid cities. These places can be a cognitive dwelling for our minds, like the shelter that the physical world provides us. Of course, tagging and

[22] According to their own website: http://news.google.com/intl/en_us/about_google_news.html (accessed 01-18-2008)

[23] At least in theory, but obviously, the selection of news feeds that are parsed is playing a big role.

[24] This notion of culture refers to the kind emergent architectural space that is both *influenced* by and actively *influencing* our human cognition.

clustering are just small facets in this discussion, and you could take completely different journeys through this emerging field, but this wouldn't lie in the scope of this thesis.

A core element of our existence as individuals, who are situated in a social and physical environment, is the explorative contact with our surrounding. Epistemic actions in the sense of Kirsh[25] are a necessary complement to goal-oriented, pragmatic actions. Therefore, it lies in our nature to stroll around and to be open for inspirations. To be situated means to dissolve in the environment. It is the *being-in-relation-to* and the *being-part-of*.

Taken over in cyber-space, these assertions can hold true as well. Even though it can never be the same, the emerging cyber-places afford comparable actions as places in physical world. Therefore, the same ideas apply for dealing with them: You can choose to stroll around in your personalized virtuality with the chance for a surprise, instead of just intervening selectively and surface again immediately.

Thus, it is to question, if you want to seek or browse in your new environment. Considering them as the equivalent to pragmatic and epistemic actions, obviously none of them is the best way on its own, but both form a pair of options that belong together.

In figure 3.6 you are presented "seeking" and "browsing" as graphical illustrations. On the left side, you see the typical iterations of seeking that are necessary for getting to a single point of interest, whose properties are known but whose location is unknown. By using filters and other appropriate methods, you can fade more and more of the surrounding away, until you are close enough. On the right side, you see a network of paths, which you move along when you browse. Many points of interest are connected by these paths, which run accordingly to the associative relation between them. In the case of tagging and clustering, this architecture is created by computation and human annotation, and thus forms the described cyber-places, that allow to be strolled, explored and discovered. Wandering around in a street offers a similar grouping of themes and possibilities, which branch every now and then off to other places, that have other characteristics. Ludwig Wittgenstein also used the metaphor of a city, in order to describe the structure of our language:

[25] [Kirsh and Maglio, 1994]

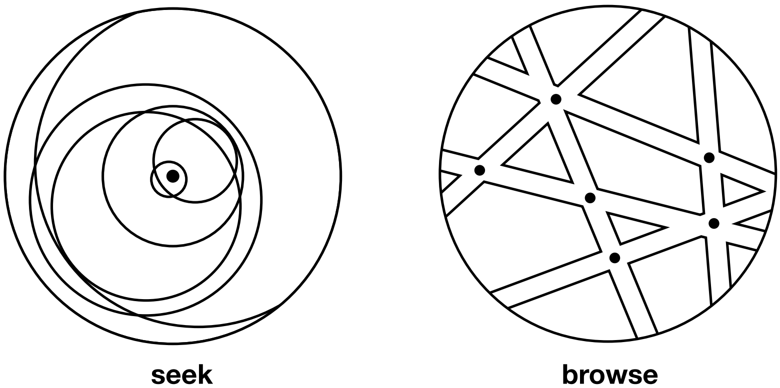


Figure 3.6: When you seek, you narrow your search in order to find. But when you browse, you are exploring more and more and with the chance for a surprise.

> *"Our language can be considered as an old city: A complex structure of small alleyways and places, old and new houses, and houses with extensions from different ages; and all that surrounded by a crowd of new suburbs with straight and regular streets and uniform houses."*[26]

These tags, which as words are part of our language, can build an ever-changing multitude of streets and suburbs inside the web, with numerous branches and side-trails.

For Vannevar Bush it has been obvious, that "going off on side excursions" is an essential element of every kind of research and epistemic action. Back in his essay from 1945, he envisioned that "new forms of encyclopedias will appear, ready-made with a mesh of associative trails running through them, ready to be dropped into the MeMex and there amplified."[27] Today, the web is becoming more and more a place that resembles Bush's vision.

> *"To learn how to get astray in a labyrinth is the option of a future cultural technique, beyond the archives and as form of a voyage, whose final destination is yet to be determined* - destinerrance *in the sense of Derrida."*[28]

[26] [Wittgenstein, 1967, text 18], translation by the author of this thesis.
[27] [Bush, 1945, sec. 8]
[28] [Ernst, 2002, p. 132], translation by the author of this thesis.

CubeBrowser

4 PROJECT: CubeBrowser

> *"One of the crucial issues for me currently seems to be to reconstruct the tension between a* networked topology *and a basically* linear mode of discovery."[1]

4.1 About the project

In this final chapter, the usage principle and technical realisation as well as the concept of CubeBrowser will be explained.

4.1.1 Abstract

As already told in the first chapter, CubeBrowser is the concept study for a six-sided cube that has a square monitor on each face and a Wi-Fi connection as well as an orientation tracker inside. Images from the Web 2.0 archive Flickr are shown on it and navigation is playfully realized by performing manual actions on the cube. The classical desktop setup with keyboard, mouse and monitor is completely left behind: besides a power switch there are no buttons at all. Thus, control is as easy as turning a cube in space. The object is mobile and only depending on a wireless connection. The images that can be viewed are directly loaded from Flickr while the cube is turned, and are organized in sets that are clustered by the tagging the users gave to the images.

---

[1] See section 2 in [Winkler, 1994]

4.1.2 The double sided cube

CubeBrowser is a project that is marked especially by two facettes: On the one hand it is applied interaction design that proposes an alternate input/output device as a database interface. Today there is an overwhelming and constantly growing amount of data on the net. Especially media databases such as flickr, which can be explored by using the CubeBrowser, are growing at a pace that is hard to cope with. This project tries to create a novel and intuitive gateway to this visual wealth. And on the other hand, by taking the individual user on a trip through the collaboratively networked database, CubeBrowser can also be understood as some kind of artistic comment on the contemporary retreat into the immersive worlds of entertainment electronics. The exploration of far-away worlds with the focus on discovery and satisfaction of the individual needs of the traveler resembles the topoi of Romanticism in substantial characteristics. In this text both positions are presented in detail and with references to the according research disciplines.

4.1.3 Creating a cognitive adapter

Before we come to speak in closer detail about the concept of CubeBrowser, let's rehearse what has been told in the previous chapters. The theory of Distributed Cognition assumes, that cognitive processes are not only existing in one brain alone, but can span over many persons and even physical artifacts. We presented two branches of Distributed Cognition, namely Embodied Cognition in the second and Socially Distributed Cognition in the third chapter.

In the context of Embodied Cognition, the historical development of Human Computer Interaction and its trend to reduce the cognitive distance between system and user has been outlined. In that field of research, the digital domain becomes embodied in physical objects, which are intended to serve as intuitive interfaces for a range of applications that are made graspable and tangible. Later in this thesis that trend has been theoretically founded in philosophy, cognitive science and psychology, which all experienced a turn towards the conceptual convergence of mind and world. A special emphasis was placed on certain claims of cognitive science, which say that "the environment is part of our cognitive system", that "we off-load cognitive work onto the environment" and that "cognition is situated".

As a result, "epistemic actions" are a natural way of investigation and exploration, since the "world is its own best model". Our "tacit knowing" can and should be used to promote the feeling of "Flow", since in that circumstance our cognitive system can "grow" for a certain period of time, which is a very attractive and valuable mode of operation. The result for the design of user interfaces has been, that one should learn to understand the environment as a powerful material and part of the interaction between man and machine.

Socially Distributed Cognition as another branch of the rather general theory of Distributed Cognition has been presented in the context of collective cognitive processes in the WWW. We learned about the postulation of Hartmut Winkler regarding the significance of forming cyber-space to a cyber-place, in which our cognition can be situated and epistemic actions are possible. Furthermore, we saw that the web can fulfill more and more of these requirements through the integration of user contributions and user annotations such as tagging. These collective cognitive processes can create a dynamic topology or semantic network that resembles the known structure of large cities and thus allows us to stroll, browse and explore it in order to orient and inspire us within it.

But even though both Socially Distributed and Embodied Cognition share phenomena of Distributed Cognition in general, they are nonetheless separated. The former is concentrating on rather global cognitive partials, while the latter describes local facets. Therefore, the conceptual idea of CubeBrowser is to bring both together. To think globally while acting locally, to participate in a global mind that is bodily-based. CubeBrowser allows you to stroll along these virtual paths and alleyways that are filled and formed by a large amount of online users in a collective effort. The material of this architecture is user contributed, its building plans for the dynamic restructuring is fed by user annotation. Thus, CubeBrowser tries to be another piece in this theatre of immersion that fades away the edges between here and there, local and global and the defined borders of cognitive phenomena.

In figure 2.4 of chapter 2, we spoke about proximal and distal perception in the example of a blind man, who is using a stick. He doesn't feel the touch of

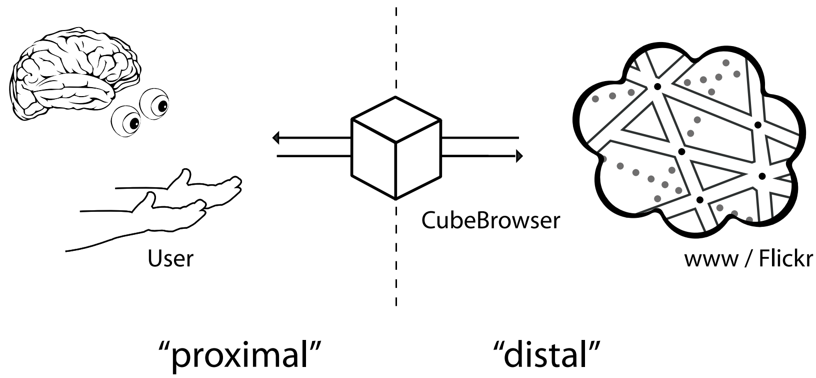


Figure 4.1: CubeBrowser is comparable to the blind man’s stick of figure 2.4: The proximal perception is what is happening in your hands, but your distal perception travels to virtual places by using the cube

the stick, but only the touch of the remote objects the stick is in contact with. As illustrated in figure 4.1, CubeBrowser is meant to be like the blind man's stick: You can use it to feel into distant places, but "distant" doesn't mean just a few meters away. With CubeBrowser you can touch the volatile paths of the virtual architecture of user contribution and annotation.

By turning the cube from side to side as a small child would do in order to explore a small toy, you are not exploring the cube in your hands, but something else. As it is the case with the stick, your mind will not be focusing on what you do *here* with the cube, but your concentration will move *there* into the data you are browsing.

Without noticing, you are issuing complex database queries, without knowledge about the machine or networks or the protocols, you are discovering the images of an open archive. The decisions about what to see and where to go do not require you to think about how to get there. In volatile moments of bodily-based inspiration, you can build your trajectory through the database by the decisions that flow out of you.

Through the convergence of the embodied cognition that spans across the cube and the virtual places you stroll along, CubeBrowser can be considered as a portal. Let's repeat the words of Mihalyi Polanyi from chapter 2:

> *"Whenever we use certain things for attending* from *them to other things, in the way in which we always use our body, these things change their appearance. [...] we can say that when we make a thing function as the proximal term of tacit knowing, we incorporate it in our body - or extend our body to include it - so that we come to* dwell *in it [the tool]."*[2]

4.1.4 Different prototypes

The CubeBrowser project is the practical part of this diploma thesis, but it already began in February 2007 as a project proposal for the Yahoo! Design Expo. The surrounding third-party cooperation with Yahoo! had been coordinated by Prof. Frans Vogelaar and finally, the CubeBrowser project was invited

[2] [Polanyi, 1966, p. 16]

for demonstration at the Expo in July 2007. Andreas Muxel, Charlotte Krauss and myself finished a first prototype and presented it at Yahoo! in California together with Prof. Zilvinas Lilas, who kindly supported the project from that point on.

On the previous pages you can see the first prototype and the second one in comparison. The former already gave an impression of control that is achieved by turning a cube, but showed the image output only on a 3D simulated cube that moved according to a wireless, wooden one. Obviously, this could not be seen as the fulfillment of a true Tangible User Interface, so I decided to create a second prototype within the frame of this thesis. This seemed to be a necessary step, since the convergence of input and output device is crucial for the concept of CubeBrowser.

In figure 4.2 Hiroshi Ishii and Brygg Ullmer compare the popular MVC design pattern between GUI and TUI applications. In the case of the former, all parts of an application reside within the digital domain, while the control and the view are at the border to the physical world in order to read input from something like a keyboard or mouse and present the changes of the application model to a view component that is rendered on some kind of monitor. TUIs in contrast move input and output even more into the physical world: The input is read from a physical object that is also coupled with the superimposition of the digital representation of the model. In the case of the second prototype of CubeBrowser, this representation is the cube, whose orientation is directly linked to the contained orientation tracker. The digital model is superimposed on this object using the screens on all sides. This makes a complete TUI setup in the sense of Ishii and Ullmer.

But the first prototype of CubeBrowser obviously stays somewhere between the GUI and TUI concept. Nevertheless, it was easy to build it as a fast visualization of the interaction concept. If a large projection screen is used to show the 3D simulation of the cube, a public visibility is created that makes using and sharing the cube in a group of people fun. The fact that a small cube in your hands is remote controlling a fairly large 3D cube over there on the wall impressed many people and invites to spend a joyful time playing around with it. It is lighter, smaller and more stable than the 2nd prototype and thus is “more finished”, even though it does not fulfill the initial CubeBrowser idea.

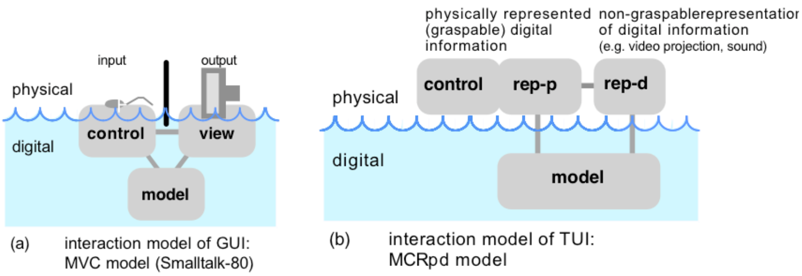
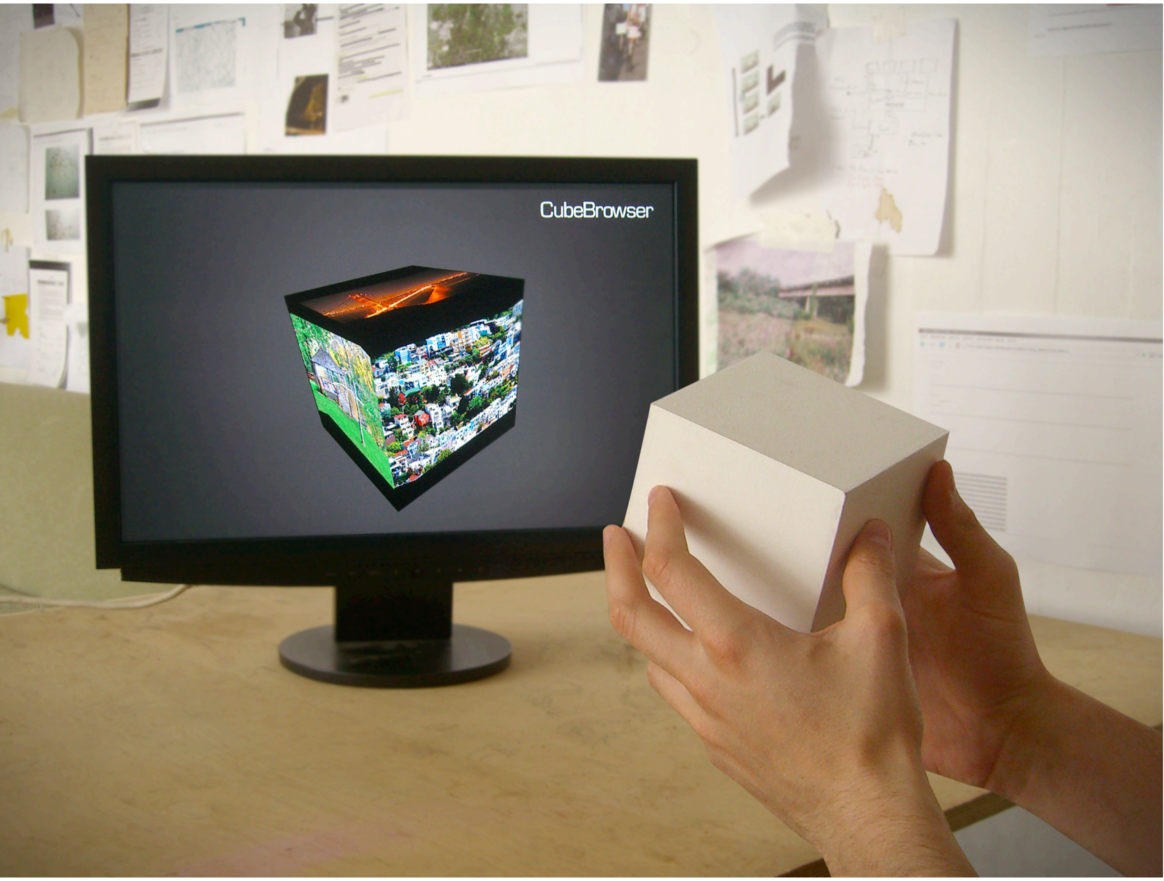
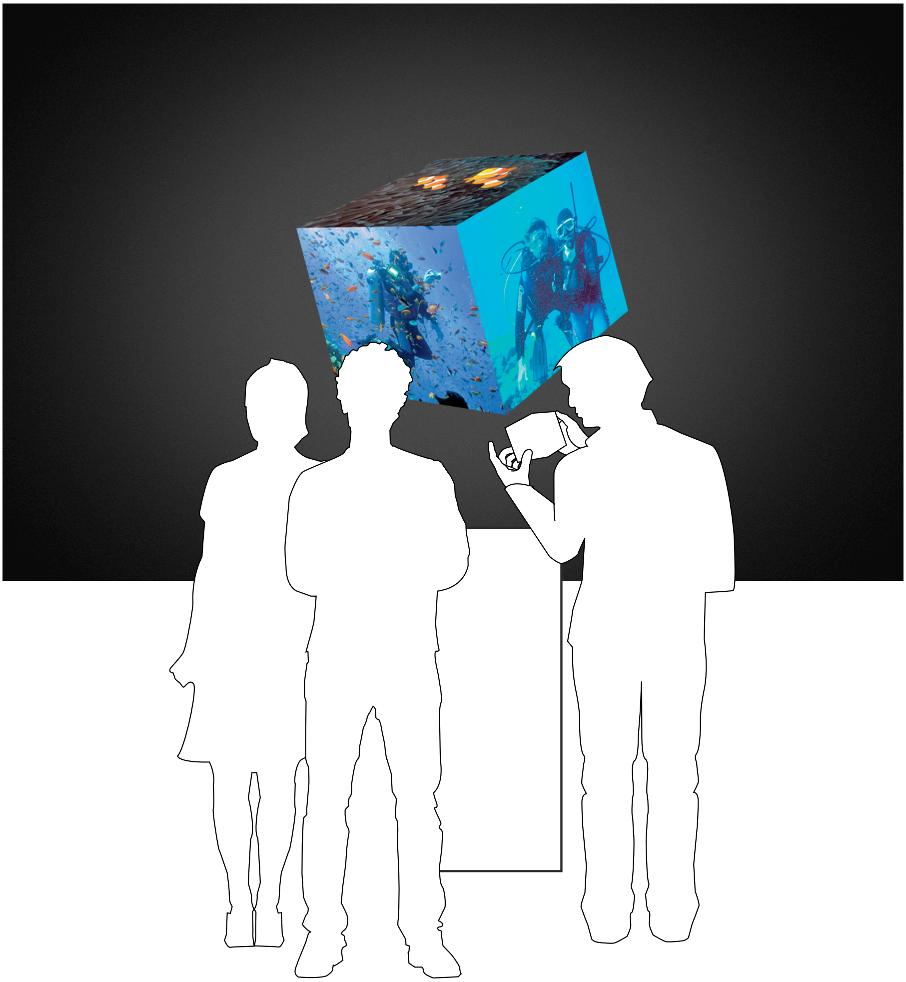


Figure 4.2: The Model-View-Controller (MVC) pattern of Object Oriented Programing for GUIs in comparison to TUIs as proposed by [Ullmer and Ishii, 2000]



On the left page you see the first and on the right page the second prototype of CubeBrowser

4.1. ABOUT THE PROJECT



The first prototype controls a projected 3D cube and therefore creates a public visibility

4.1.5 Creating networks of tags and images

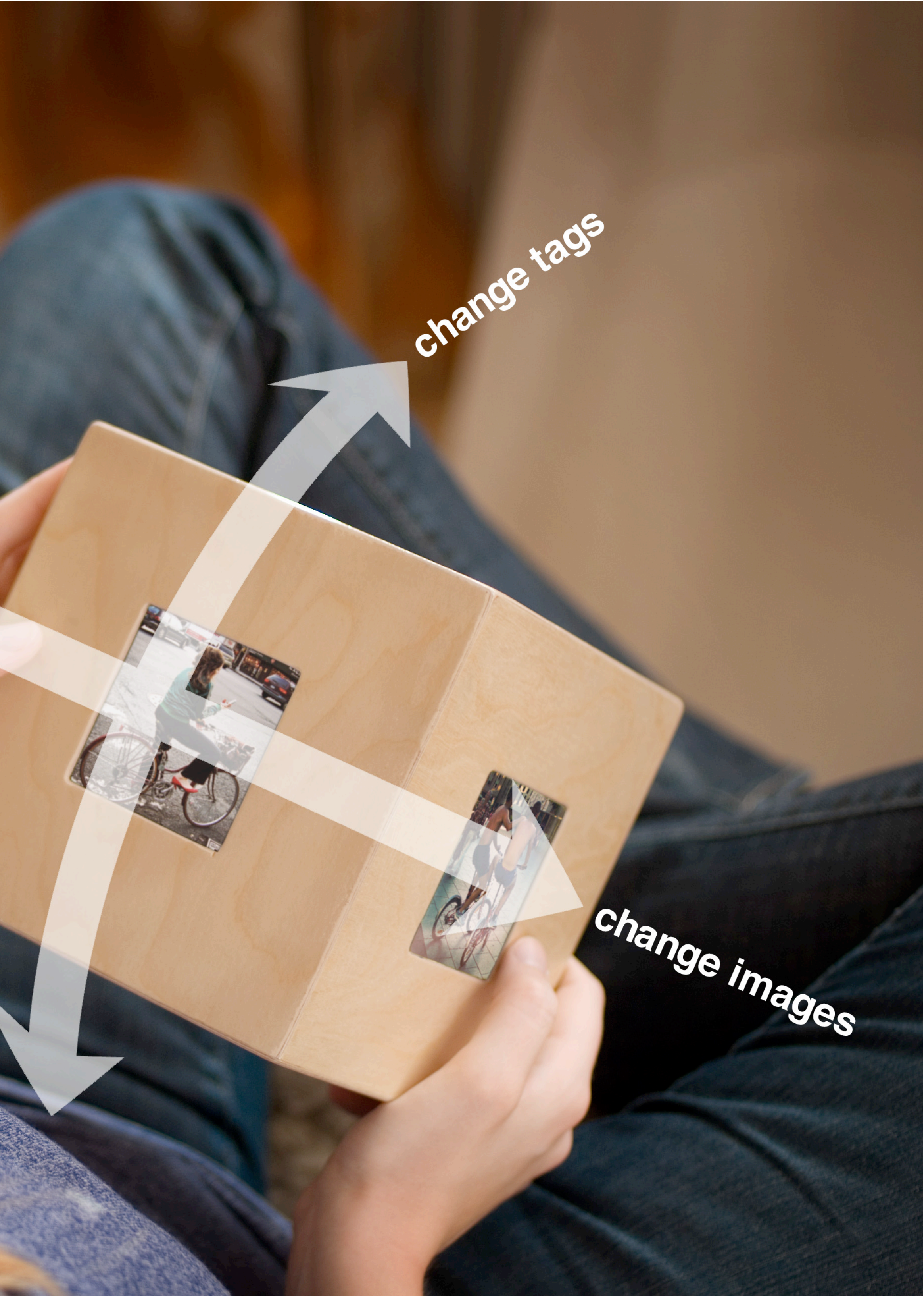
In this section, we will discuss how the virtual architectures, which are described in chapter 3, are created out of Flickr images and tags in order to be browsed with CubeBrowser.

Flickr stores over 100,000,000 images that are described by the users with tags. Usually, there are more images than tags, since common tags are repeated by several users simply because there are intersections between the content of many images. With this meta-data, it is easy to select the images for a certain keyword and find related images by comparing the tags of these images with all the others.[3] By drawing connections between these related images, you can create networks, which are constantly changing their structure each time the images and tags in the database or the parameters for the network computation are altered.

As described before, you can consider these networks of associations as architecture or paths that you can stroll along. In figure 4.3 you can see a small network of tags from Flickr. Even though the number of tags is small, there are numerous ways to travel this network. Please note that an arrow is drawn towards another tag, if the number of joined entries exceeds a certain threshold that is evaluated separately for each tag. Thus, uni- and bi-directional connections are possible as well as no connections at all. Endless loops are also possible, but in the case of CubeBrowser, these are removed by Filters.

Using that network, you can browse images for a certain tag and are able to branch off to other related tags that are offered to you at each moment.

[3] Basically, this is the same as in clustering, since you calculate the distance between images regarding their tagging. Computationally, this can be extremely tedious, but it is not within the scope of this thesis to discuss efficient alternatives.


change tags
change images

4.2 Control principle

So far, we spoke about the “Browse” in CubeBrowser. Now, we will discuss the usage of a cube as an input device.

One criterion for the CubeBrowser object had been, that it should be possible to map the necessary actions for navigation in a large number of data structures onto it. A ubiquitous organization we find in Computer Science is the tree structure. Computers are hierarchical systems and trees perfectly represent them. As you can see in figure 4.5, the network of figure 4.3 can also be presented as a tree.[4]

In figure 4.4 you can see the five Platonic Solids and a sphere to give you an impression why a cube has been chosen as especially suited. A two-dimensional structure needs four basic actions in order to be navigable: Moving to the next and the previous item along the axis of the current level as well as descending and ascending across the hierarchy. This can be mapped to a cube quite easily, since each face has exactly four edges. By turning over one of these edges, two things will happen: On the one hand, you leave the side that you have faced so far, which will actively give you the impression of *leaving* something behind. And on the other hand, you are moving in a *direction* that will bring you to something new. Thus, turning a cube in space provides the necessary steps for tree navigation. All the other shapes in that figure do not have rectangular faces, but have three or more than four edges instead. Even though using one of these solids might be interesting for another project, they are not well suited for the generic approach of the CubeBrowser.

Since all sides of a cube have the same square format you can be sure, that after a turn you will come to another “place” that will have precisely the same properties. Furthermore, the square format is ideal for images, since it is the neutral middle between landscape and portrait format, which both are very common for photos. The free space is simply filled with a background color. The last feature of a cube is its edges: Their tactile impression tells you

[4] Forming trails of consistent items, from which a user can branch off to associated content, has already been proposed by Vannevar Bush in 1945 in his famous article “As We May Think”: “Moreover, when numerous items have been thus joined together to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever like that used for turning the pages of a book.” See section 7 in [Bush, 1945]

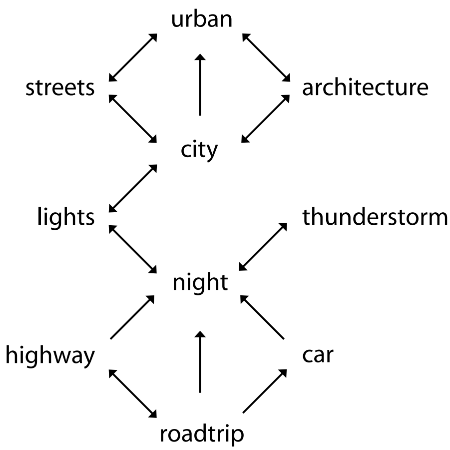


Figure 4.3: A small network of tags from Flickr.

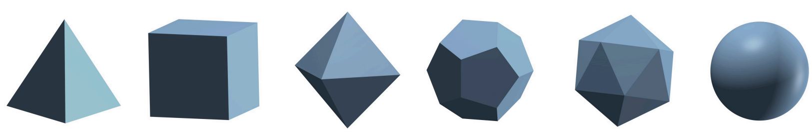


Figure 4.4: Primitives from left to right: tetrahedron, cube, octahedron, dodecahedron, icosahedron and sphere

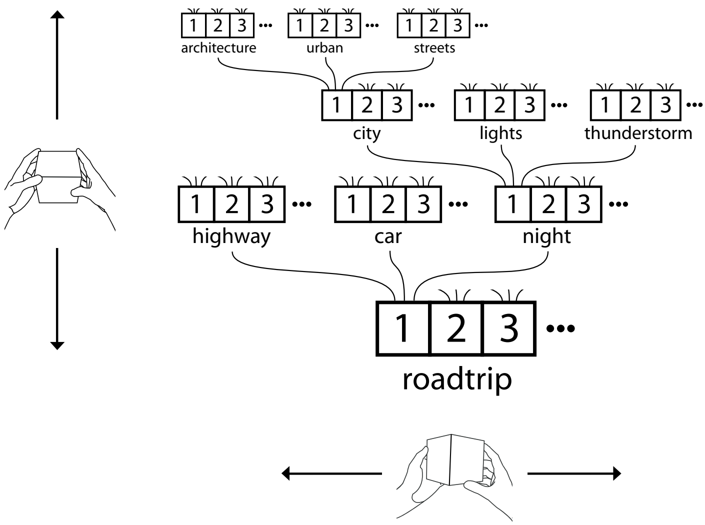


Figure 4.5: CubeBrowser presents the images of a certain tag on its horizontal axis. For each image, a number of tags that are associated to the current tag and image are available for further navigation on the vertical axis. By giving the cube a little push, you can switch between these proposals as illustrated in figure 4.8

exactly about the orientation of the cube, even without looking. Without them, it would not be possible to separate discretely between the individual faces. The orientation of a sphere for instance is hard to tell.

Therefore, the “Cube” in CubeBrowser allows to control two-dimensional qualities at each moment and to undertake explorations and epistemic actions easily. As a user, of course, you don’t have to know about tree navigation and the like, it will just feel natural.

Let’s see how the control of CubeBrowser works in detail.[5] There is a very reduced set of possible interactions and therefore, the amount of “commands” that have to be learned is very small. The only things you have to do is turning, pushing and shaking the cube in order to navigate through the networks of tags and images.

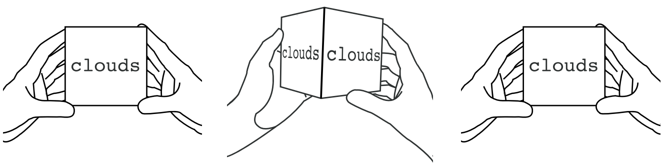


Figure 4.6: Horizontal turn: Navigate through images

As you can see in figure 4.6 a result set for a given tag is loaded on the horizontal faces of the cube. There is always one side, that is the closest to your calibrated position and therefore known as current face by the system.[6] If you turn the cube left or right from that current face, you can browse through all the images in the current result set, which will wrap and start over from the beginning, when you hit the end of it.

[5] You can also find video demonstrations on our website at http://www.cubebrowser.de.

[6] Neglecting edge situations, which would be possible in theory, but actually can never be held still, because of the jitter in the sensor data of the orientation tracker.

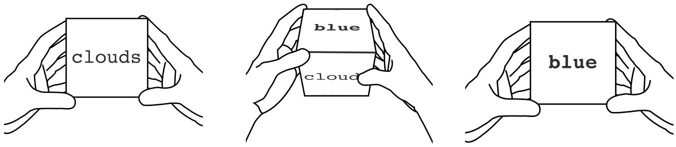


Figure 4.7: Vertical turn: Navigate through tags

For each image on the horizontal axis, you are given a proposal on the top face, which is the first image of another tag's result set. This other tag has been identified as related by the cluster algorithms of Flickr. As shown in figure 4.7 you can enter this related tag by turning the cube upwards respectively towards you. From that moment on, the images on the horizontal axis are loaded from that new result set the same way as before in figure 4.6. Furthermore, you can go back to all the images and tags you came from at any time, reconstructing the history of your actions, by simply turning the cube downwards or away from you again. The bottom face will present precisely the last image from which you came from.

Since the clustering algorithm of Flickr usually does not only provide one related tag but several ones, the proposed tag on the upper face can be changed to all the other related tags by simply giving the cube a little push as seen in figure 4.8. A metaphor for that mapping is giving the object to understand, that its proposal is not accepted. As soon as the push is done, the cube will show the first image of the new related tag on the top face, giving you a preview. Once you have seen all clustered tags, you will start over with the first one again.

Occasionally you might want to start over completely. In order to do so, you simply shake the cube heavily for about one second as illustrated in figure 4.9. This will completely reset the system and you start again with a tag that is randomly picked from Flickr's list of popular tags.

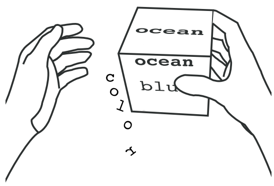


Figure 4.8: Short push: Branch off to another tag

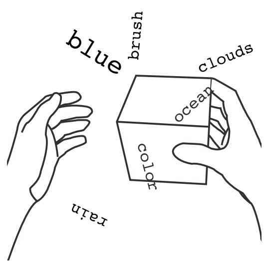
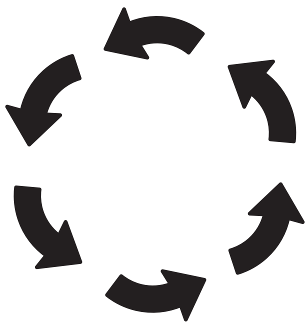


Figure 4.9: Strong shake: Reset system with random popular tag



4.3 CubeBrowser in an art context

In the following CubeBrowser will be presented as an artifact that parallels some basic ideas of Romanticism and therefore can be allocated as an interactive artwork within the so-called "New Romanticism". This classification of the CubeBrowser in an artistic context points out the social comment that this piece carries in it.

4.3.1 The "romantic interface"

The artists of Romanticism are unified by the search for the paradisiacal, beautiful and fabulous that wants to surpass daily experiences. Furthermore, they share "the desire for intimacy and security against the infinity and homelessness of the sole subject." Pieces such as "The Wanderer above the sea of fog" by Caspar David Friedrich use the typical motifs of nautics and travel and therefore issue the complexity of world perception. The human individual experiences itself in the confrontation against the magnitude of nature through a process of intrinsic growth.

These topics recently regain a stronger relevance in contemporary art as "New Romanticism". This can be seen as a movement against the social and political discourse of Postmodernism, as a "... provocation that lies in the intentional overstepping of the political as well as aesthetical correct of the past years." Also the basic conditions for a renewal of the romantic discourse are opportune: the departure into the yet unknown century creates a comparable uncertainty like in the beginning of the Industrial Revolution back then. This romanticizing is not limited to visual arts alone but incorporates in an extended understanding of the term also the so-called "cocooning": The homely barricading with cozy lifestyle interiors and modern entertainment electronics. The success of photorealistic computer games or virtual environments such as "Second Life" exemplifies the following: The ideal of the wonderful, rich and grand experience in nature is replaced by electronic media illusions. "For many this is a satisfying escape – sometimes a marginal one as it is currently offered by many lifestyle magazines, which call out the new Romanticism in fashion and interior as a way of living. Sometimes it is a thoroughly life-changing one, e.g. when a whole generation of gamers insulates themselves from reality to find a better subsistence in the world of fantasy."

In the new Romanticism the everyday experience is not necessarily surpassed as lonesome wanderer in nature, but within the shelter of one's apartment. The CubeBrowser also can be seen as an "instrument for discovery" or "wanderings tool" and therefore serves in a way the wander motif of Romanticism. The trip through a database and thus the discovery of a Cyber-Space replaces the movement across the physical world. The natural richness is traded for the sea of experiences in the wide world of global data. However it has to be pointed out, that this artistic format does not function as a visual medium or even as painting, but as an interface process: a dynamical symbiosis between user, artifact and database. It lies in the will of the user, if she wants to approach associations of nature or not and therefore her individuality determines the visual output. According to that the idea of a "romantic interface" obviously does not take into account the nature motifs that are numerously offered by flickr, but compares this individual exploration of the data space with the romantic ideal of self-discovery on an abstract level.

The CubeBrowser picks up moments of subtle inspiration through its simple, tactile use or even encourages letting you flow in a personal stream of consciousness. This embodied interaction addresses the inner self of the user as an interface for unconscious association. In volatile moments of bodily control the user forms her trajectory through the database: through a flowing sequence of decisions. Like a blind man's stick the CubeBrowser is meant to disappear in the perception as material interface, is reduced to the epistemic action and serves the discovery of data as a vehicle. The fragment thus explores the whole: the individual browses in the collective, global pool of associations. This trip across the unknown resembles the trip through the wealth of nature, resembles a personal sighting of the own personality in the context of a global consciousness. Within Romanticism self-exploration always had to be understood as a process that doesn't know an ending and therefore does not have an aim: it is meant as an ideal of lifelong search. The CubeBrowser likewise is not meant for target-oriented searching, but offers a voyage without arrival.

"To learn how to get astray in a labyrinth is the option of a future cultural technique, beyond the archives and as form of a voyage, whose final destination is yet to be determined - destinerrance in the sense of Derrida." "Getting astray" offers the chance for a surprise, a challenge that helps you to identify oneself and to grow. Today's world of data could develop a structure that fulfills the conditions for this. Finally, the comparison with the ideas of Romanticism serves as yet another analogy to make the concept of a data voyage more comprehensible and graspable. Through the ongoing development of media illusions this can be a founding key to the interface between man and machine.

“Data-Traveller Above The Cloud Sea”
In an homage to Caspar David Friedrich romantic paintings, this collage visualises the search movements of a CubeBrowser user as being embedded as a traveller within a virtual data world.

4.4 Conclusion: Think globally, act locally

The idea behind CubeBrowser is the combination of the locally embodied user on the one and the globally distributed cognition of the WWW on the other side. The reason for this project is the creation of a metaphor or comment for paradigm shifts that are currently happening in our world.

These shifts include numerous fields, but the ongoing immersion of the internet within our daily lives and the increasing embodiment of software applications using sensor/actuator technology are to be highlighted in this conclusion.

The number of internet users with broadband access increased tremendously within the industrialized countries in the last decade. And with it, online applications matured and are now used by a very large amount of people every day. Many of these web programs and applications harvest user generated content and annotation, and thus are creating immense sets of data and meta-data. It is an enormous amount of cognitive work, which is saved in these databases. The internet not only became ubiquitous, but also became unthinkable to live without it. Therefore, “globalization” is not only referring to an economical issue, but also to the way we have to think about computing and information in general.

On the other side, there are changes in the way we interact with computers as well as in the very understanding of “computing”. The introduction of the Nintendo Wii with its multi-sensory controller Wiimote marked a popular milestone in the shift towards embodied interaction. Furthermore, mobile phones like the Nokia N95 allow for the tactile control of generic functions like locking the keypad or ending calls. Another example is the Apple iPhone that brought multi-touch interaction to mobile devices for the masses.

All these devices bring a richer way of digital interaction than ever before. Embodied Interaction starts to be swapped into our daily lives through a permanent stream of technological development. As a result, almost everybody adopts cultural practices that would have been considered cutting-edge only yesterday.

This raises the question, how our culture should and will deal with these changes and how it will be influenced by them itself. CubeBrowser combines and comments both global and local interaction between man and machine. It is a mean of “thinking globally, while acting locally”: A task that is set for us by these technological systems. Therefore, CubeBrowser can be seen as a temporary artwork, even though its original intention is to be considered as a design study. Virtuality is gaining importance in the world. We can make it a part of our lives, in order to find a creative and natural relationship. We have the opportunity to incorporate technical possibilities in our existence, instead of alienating them as artificial phenomena. It is an idea of trans-humanism, but not the vision of the cold cyber-space and the idea of Virtual Reality with its embarrassing goggles and gloves. There are ways to bring the systems to us, instead of us going there, ways to create something like “Real Virtuality”.


3
EI 137 DUBLIN

A International presentations

Both editions of CubeBrowser have been invited for presentation on a number of exhibitions, conferences and festivals. Hundreds of people had the opportunity to try the object and give interesting feedback about their impressions.

2009
Lecture and exhibition at technarte conference, Bilbao / Spain
Exhibition at CHI Nederlands conference, Leiden / Netherlands
Presentation at SIGCHI conference, Boston / USA
Presentation at V2_ Institute, Rotterdam / Netherlands
Exhibition at f/stop Festival for Photography, Leipzig / Germany
Exhibition at art.fair, Cologne / Germany

2008
Talk at Linux Audio Conference 2008, KHM Cologne / Germany
Presentation at Bayer AG Innotech 2008, Cologne / Germany

2007
Presentation at Institute Echangeur, Paris / France
Talk and exhibition at Yahoo! Design Expo, California / USA
Best User Experience Award at Yahoo! Design Expo, California / USA

A.1 SIGCHI 2009

April 4th - 9th 2009
Boston / USA

CubeBrowser has been presented as a scientific paper and a hands-on demonstration in the Design Vignette track of SIGCHI 2009. SIGCHI is one of the biggest conferences for technologies, designs and ideas on human factors in human computer interaction.

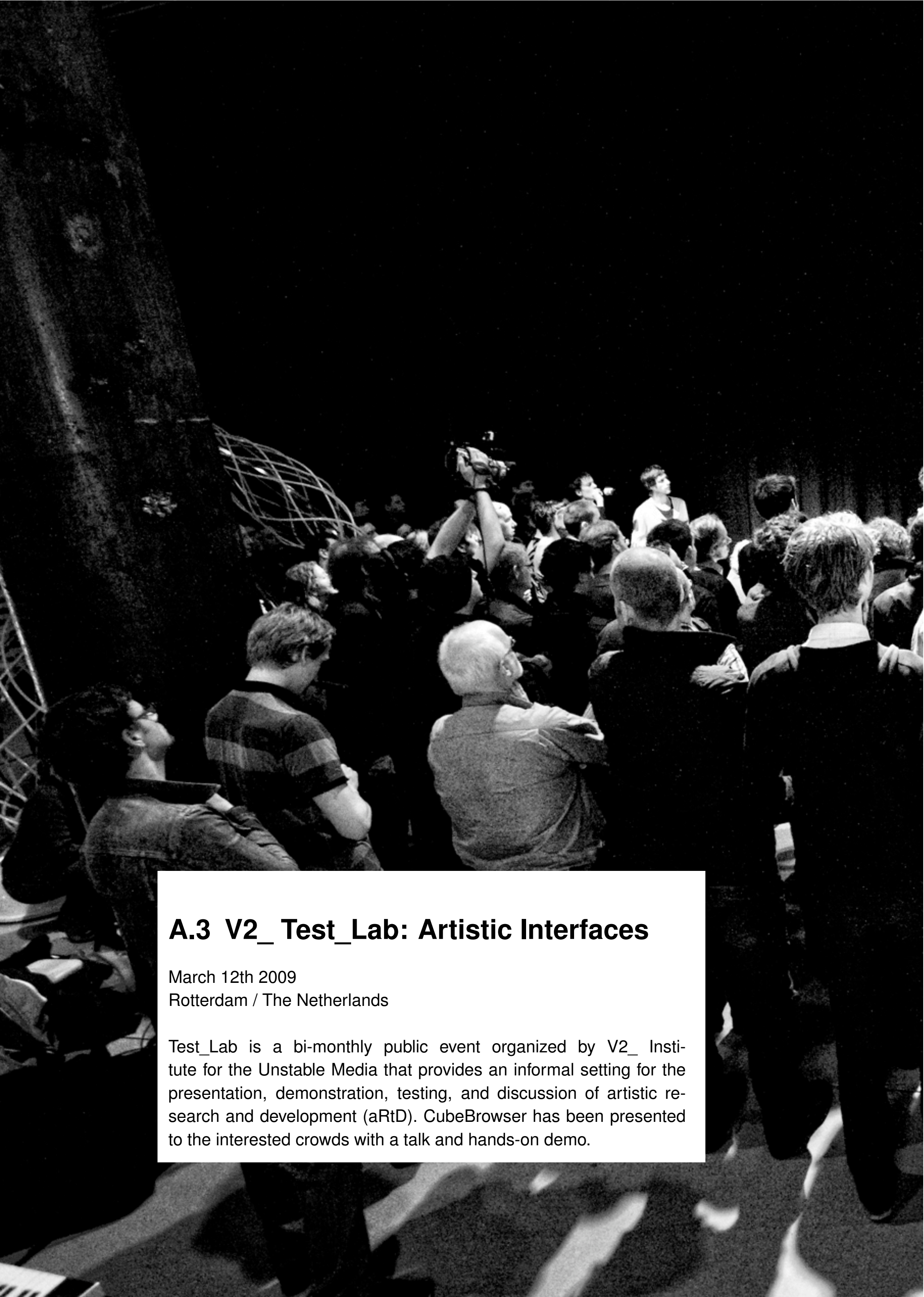

EXIT

A.2 Technarte

International Conference on Art and Technology
April 23rd - 24th 2009
Bilbao / Spain

The theoretical background and design process behind this project has been presented in a lecture. Both prototypes have been available for experimentation.


CubeBrowser
Technarte
International Conference
on Art & Technology
Conferencia internacional sobre arte y tecnología
April 23 - 24 abril 2009
Bilbao, Euskalduna Jauregia
Nanoart
Bioart
Art & Robotics
Architecture
Augmented reality
Organiza / Organizer
innovalia
CREA
TIVIDAD
INNOVA
CION



A.3 V2_ Test_Lab: Artistic Interfaces

March 12th 2009
Rotterdam / The Netherlands

Test_Lab is a bi-monthly public event organized by V2_ Institute for the Unstable Media that provides an informal setting for the presentation, demonstration, testing, and discussion of artistic research and development (aRtD). CubeBrowser has been presented to the interested crowds with a talk and hands-on demo.

A.4 Yahoo! Design Expo

July 23rd - 26th 2007
Sunnyvale / USA

Talk and presentation by Charlotte Krauss, Prof. Zil Lilas, Andreas Muxel and Ludwig Zeller. This has been the final presentation within the cooperation with Yahoo! Research. Special thanks to Michael Hoch, Monica Batra and Joy Mountford.

A.5 f/stop Festival

July 1st - 7th 2009
Leipzig, Germany

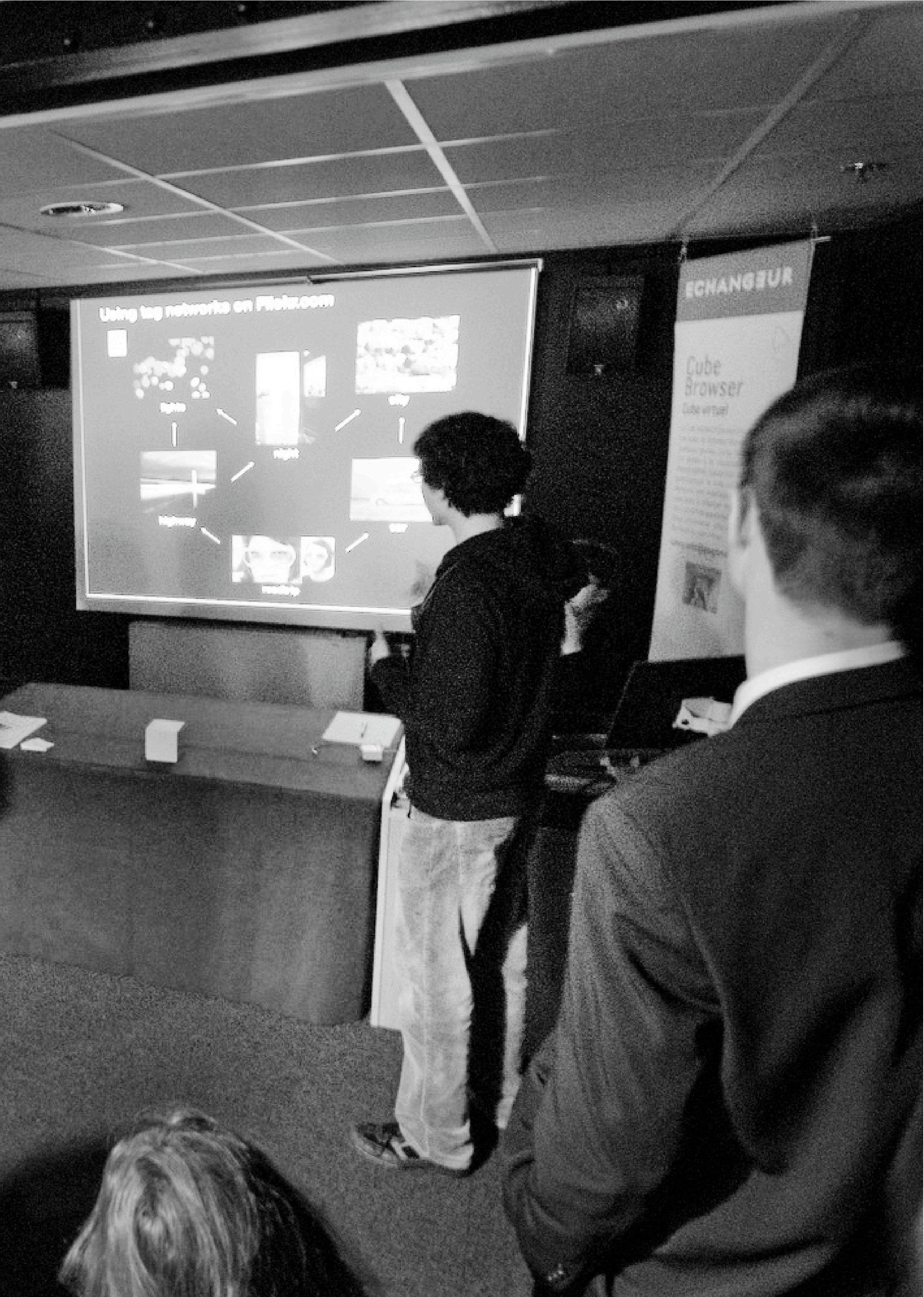
In a cooperation with the photography competition 1/AWARD, the CubeBrowser has been adopted to present the submissions to and archived winners of the award. f/stop is an international festival for contemporary photography.

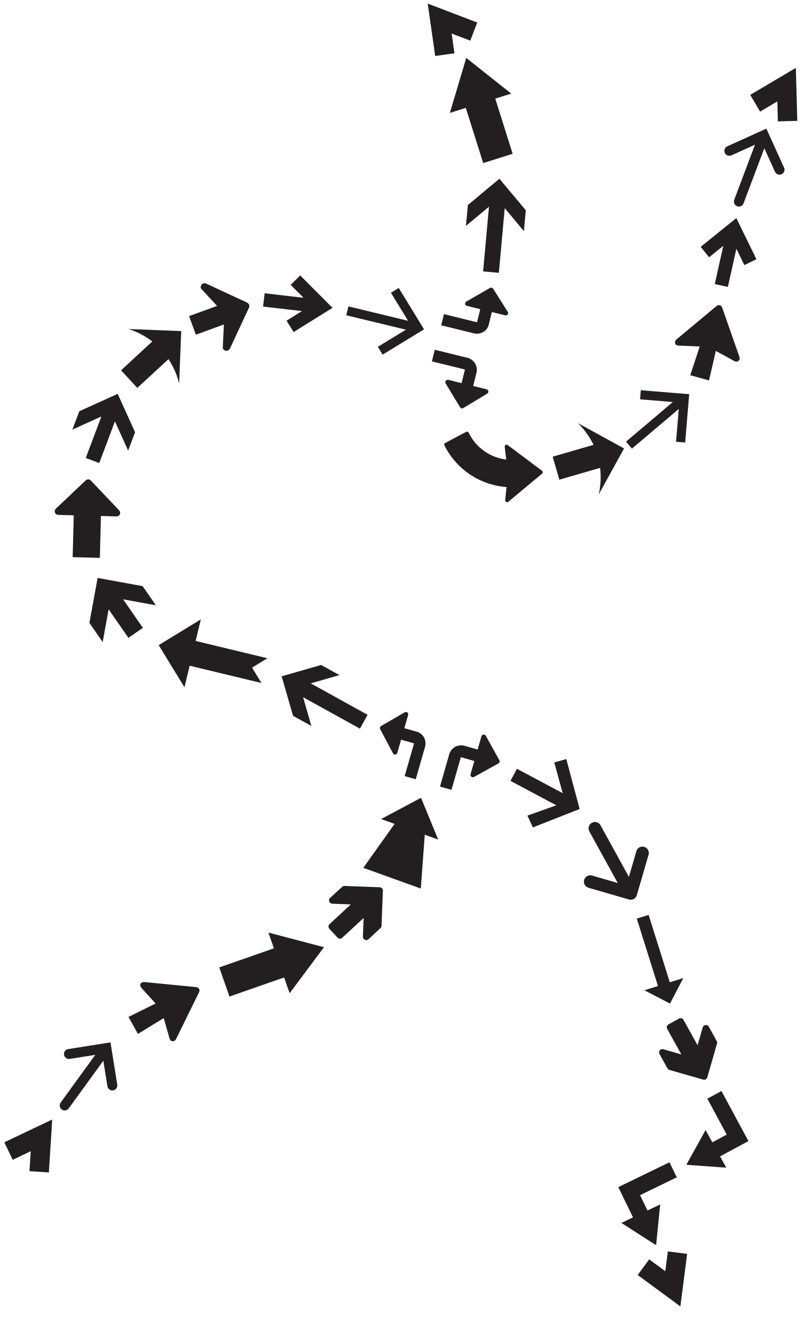

AWARD
2. Staffel >>6AUSX<<
4 / 6
1. Staffel >>6AUSX<<
vorheriges Bild
Gewinner 2008
F/STOP
WATCH OUT
FOTOGRAFIE-WETTBEWERB
FÜR NACHWUCHSKÜNSTLER
WWW.ONE-AWARD.DE
AWARD

A.6 Institute Echangeur

Venez vivre une journée en 2017
Institute Échangeur, Paris

Presentation by Charlotte Krauss, Andreas Muxel and Ludwig Zeller. The CubeBrowser project has been invited to this event in order to demonstrate the impact that physical interfaces and upcoming sensor technologies might have within the next 10 years. Special thanks to Benjamin Thomas (Échangeur).


Using tag networks on Flickr.com
ECHANGEUR
Cube
Browser

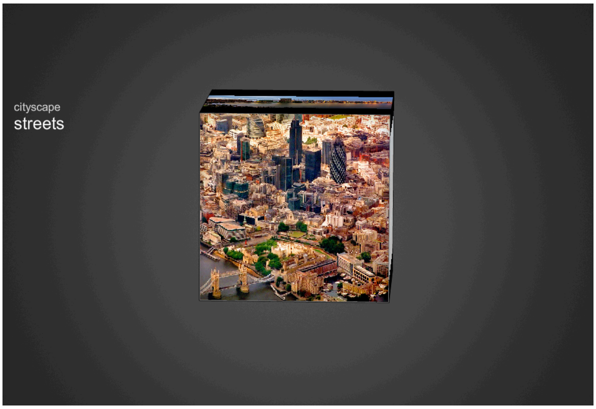


B Usage trajectories

Flickr stores millions of photos and tags in its database. The CubeBrowser allows to move through this wealth. Each turn and each decision changes the navigation through the network keywords and images, bringing you to highly different areas within the archive.

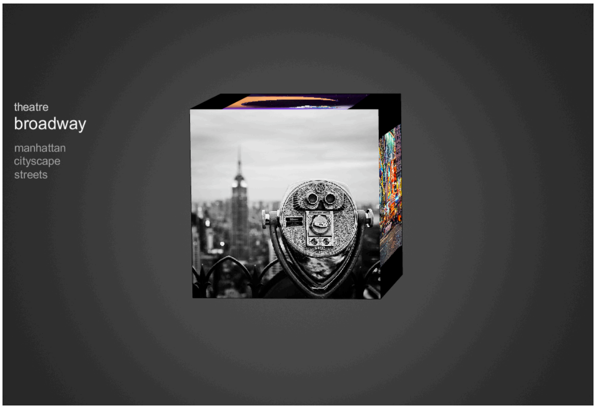
On the following pages, you will find screenshots of the first prototype[1] showing five individual user trajectories. On the left side of each screen you find the current tag and a breadcrumb history that sometimes reads like a "haiku", illustrating the movement through associations.

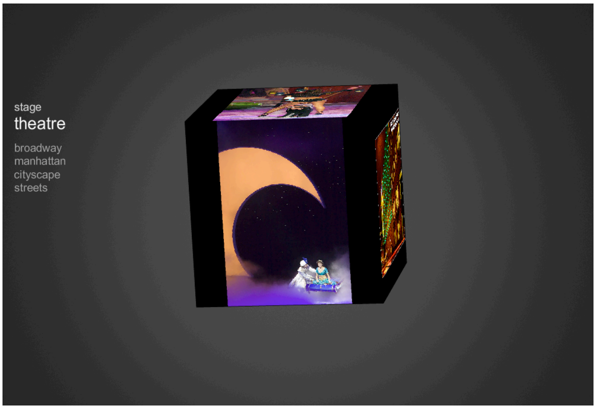
[1] The first prototype has been chosen here, because it was easier to take screen grabs of it. But the navigation, clustering and communication with Flickr is exactly the same as with the second screen cube.


cityscape
streets

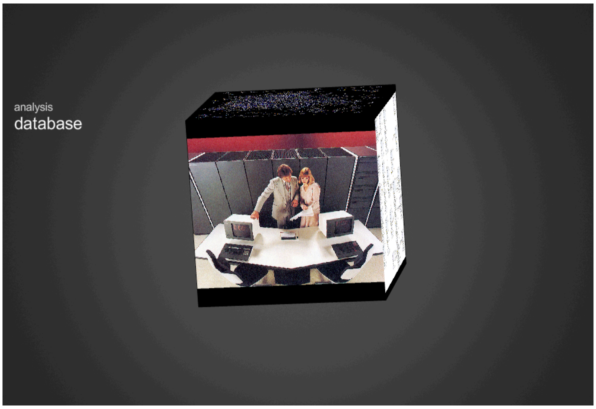

manhattan
cityscape
streets

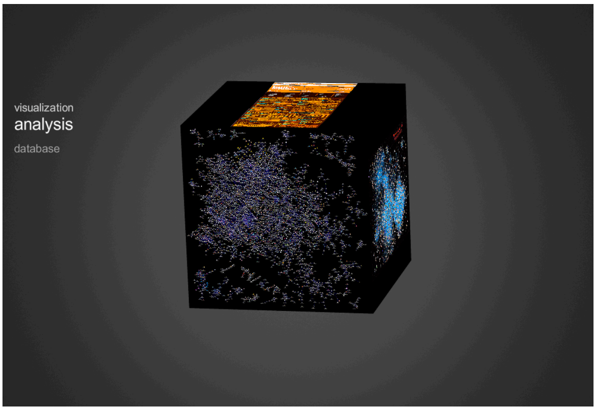

broadway
manhattan
cityscape
streets

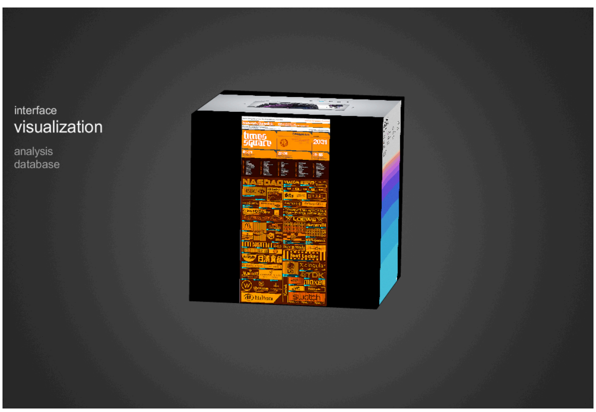

theatre
broadway
manhattan
cityscape
streets


stage
theatre
broadway
manhattan
cityscape
streets

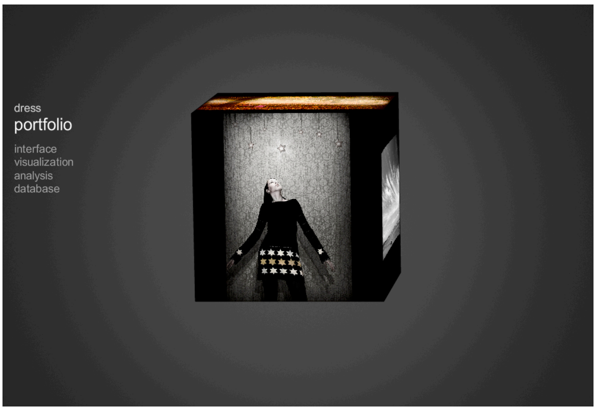

singer
stage
theatre
broadway
manhattan
cityscape
streets


analysis
database

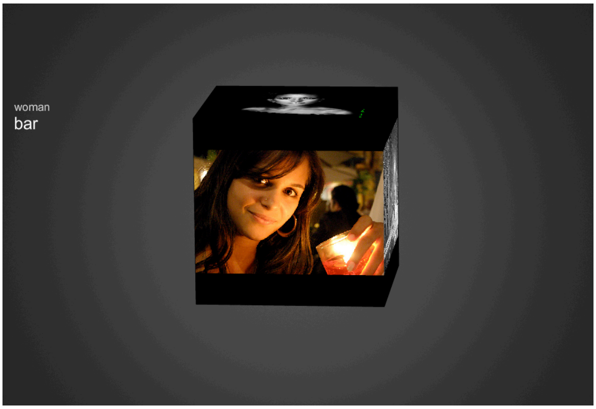

visualization
analysis
database


interface
visualization
analysis
database


portfolio
interface
visualization
analysis
database

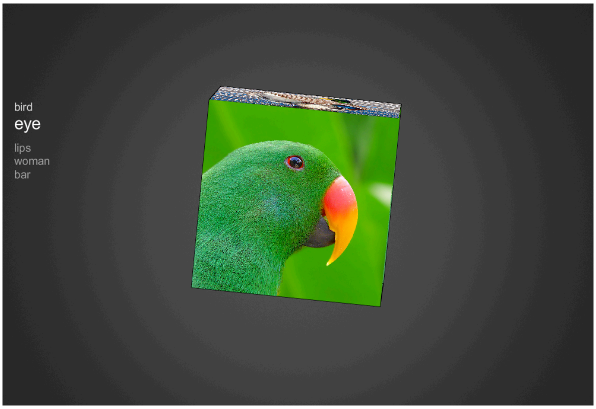

dress
portfolio
interface
visualization
analysis
database


child
dress
portfolio
interface
visualization
analysis
database

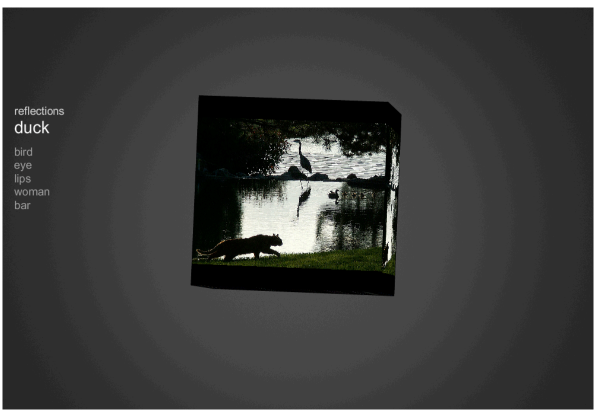

woman
bar


lips
woman
bar

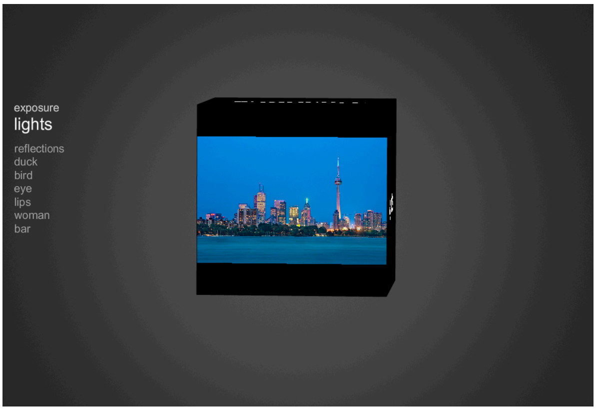

eye
lips
woman
bar

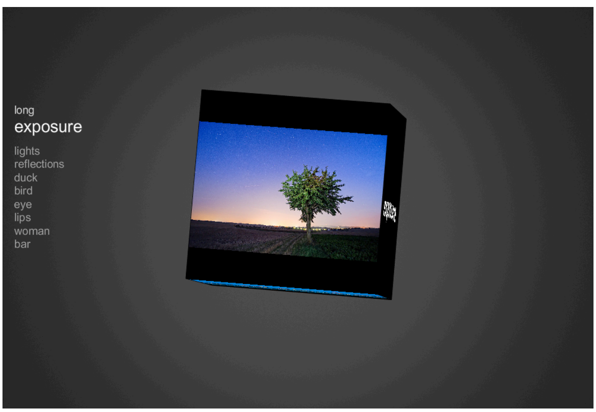

bird
eye
lips
woman
bar


duck
bird
eye
lips
woman
bar


reflections
duck
bird
eye
lips
woman
bar


lights
reflections
duck
bird
eye
lips
woman
bar


exposure
lights
reflections
duck
bird
eye
lips
woman
bar

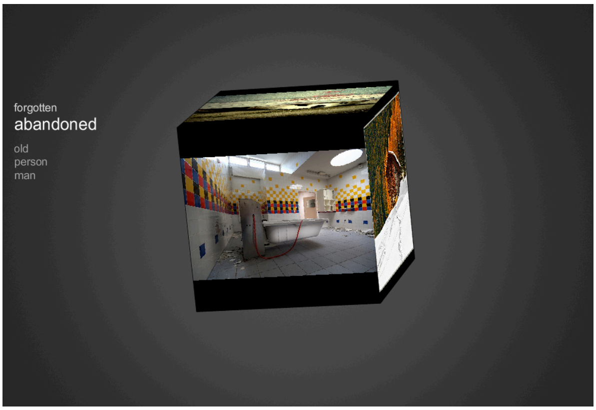

long
exposure
lights
reflections
duck
bird
eye
lips
woman
bar


canon
man


person
man


old
person
man


abandoned
old
person
man


forgotten
abandoned
old
person
man


lonely
forgotten
abandoned
old
person
man
forgotten


fog
lonely
forgotten
abandoned
old
person
man
lonely


dawn
fog
lonely
forgotten
abandoned
old
person
man


australia
dawn
fog
lonely
forgotten
abandoned
old
person
man


style
fashion


graffiti
style
fashion


banksy
graffiti
style
fashion


police
banksy
graffiti
style
fashion


nypd
police
banksy
graffiti
style
fashion


elmowantsatickle
nypd
police
banksy
graffiti
style
fashion


5
6

C Technical description

In this appendix you will find a short discussion of the technical setup that is driving the CubeBrowser. Please note, that the following information targets the second prototype.

C.1 Overview of activities

In figure C.1 you can see the full chain of input and output over all entities of the interaction system. Let's say the user starts the interaction feedback loop by executing an initial action, e. g. resetting CubeBrowser by heavily shaking it. This action is read by the orientation and acceleration sensor of the cube, which feeds this analog measurement into the computation system. If the necessary requirements for a certain pre-defined action are fulfilled, the system posts a query to the public web service API of Flickr via HTTP/GET, which will return descriptions of images and tags as XML and will present the actual image assets for HTTP/GET download from their servers. The result of these queries is fed back to the computing system, which will present the new data accordingly to a pre-defined scheme on the displays and speaker of the cube. From there, the user is able to see and evaluate the system output and can react upon it as she sees fit in the next step.

In reference to the MVC diagram of figure 4.2 the sensor input is the control part of the application, while the cube is the physical and the presented images and sounds are its digital representation, which is superimposed on the cube. All the information about tags and images from Flickr are held within the model that is completely non-perceivable on its own within the computing system.

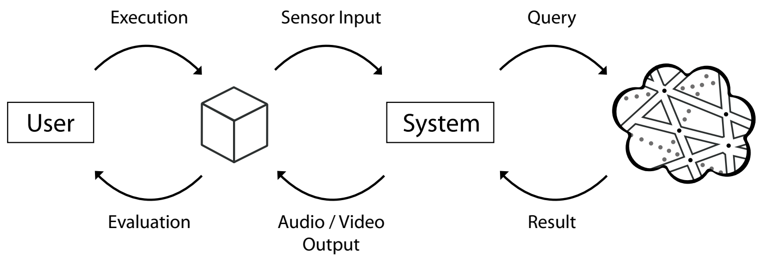


Figure C.1: This schematic shows the chain of input and output between the user and Flickr in reference to Donald Norman's terminology in figure 2.5

C.2 Overview of signal flow

Even the second prototype of CubeBrowser is not doing its computation inside the cube, but relies on an external PC that is connected to it using numerous radio connections. Driving six true-color graphic panels as well as calculating 3D heuristics for cube rotations and interfacing with high-level web services is possible, but not easy to implement in embedded systems today.

In figure C.2 important components of the setup are presented with their interconnections. The audiovisual output is rendered to a single XGA (1024 x 768) frame that contains the images for all separate sides of the cube. This frame is then reproduced six times in a VGA repeater and fed into six scan-converters that provide an adjustable QVGA (320 x 240) zoom feature, so that six interpolated independent PAL (768 x 576) signals are separated from the initial XGA composite.

In the following, these are treated as FBAS video signals, which makes it possible to use a six channel broadband radio link[1] that sends the images to the according mini-receiver modules inside the cube. There, they are pre-

[1] A/V transmission with up to 16 channels, provided by VTQ Videotronik GmbH, http://www.vtq.de

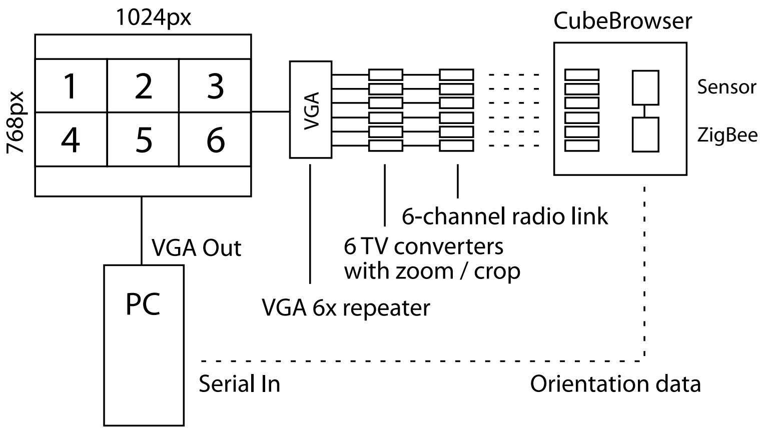


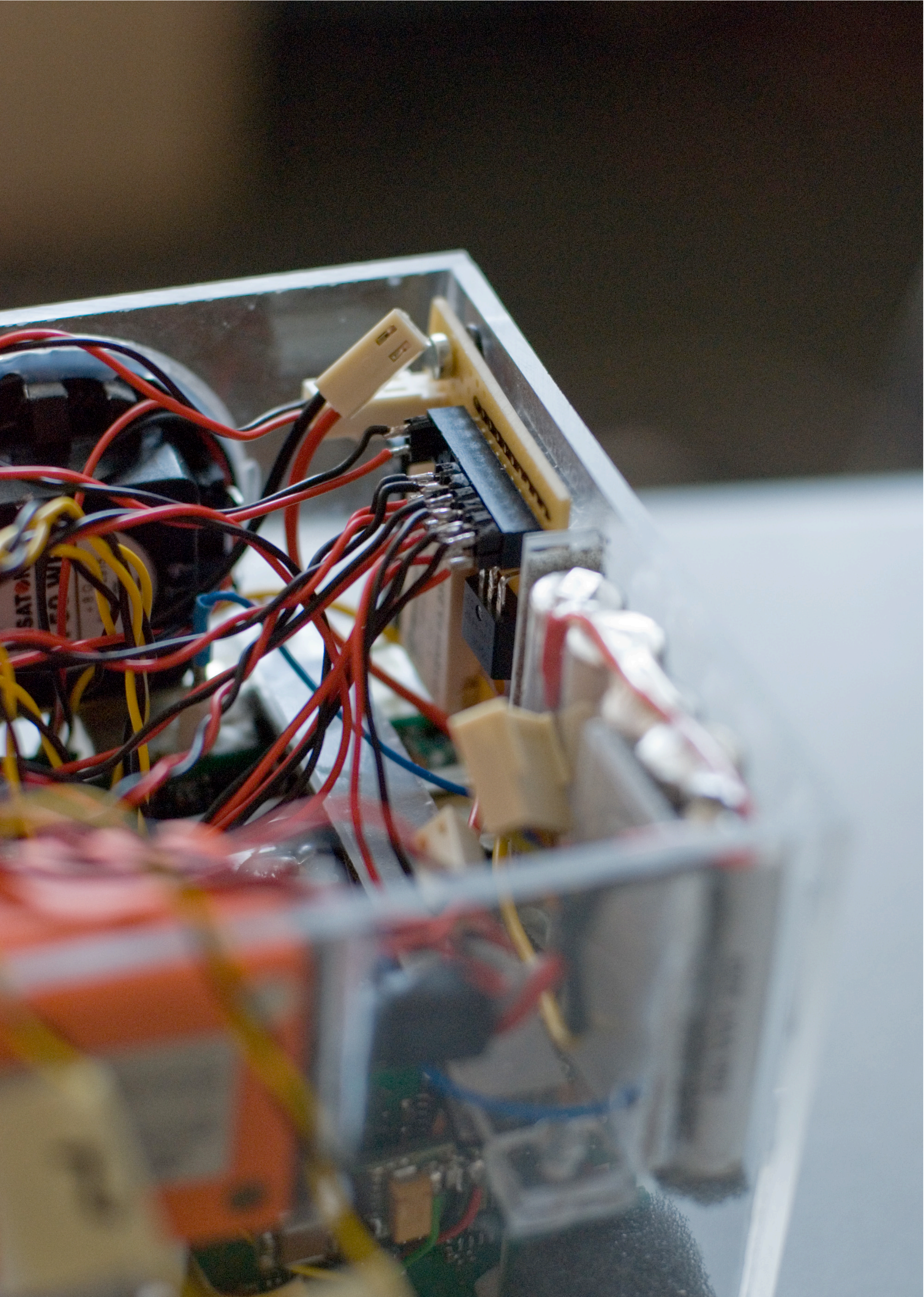
Figure C.2: This diagram illustrates the flow of signals between the external computer and CubeBrowser sented on six 4-inch 4:3 QVGA TFT modules with FBAS input[2] that are physically masked down to a square aspect ratio.

The returning path of the interaction loop carries the real-time data of an orientation tracker[3]. The sensor uses RS232 for its transmission, which is made wireless by using two serial radio modules inbetween[4].

[2] Kindly sponsored by Mostron Elektronik GmbH, http://www.mostron.de

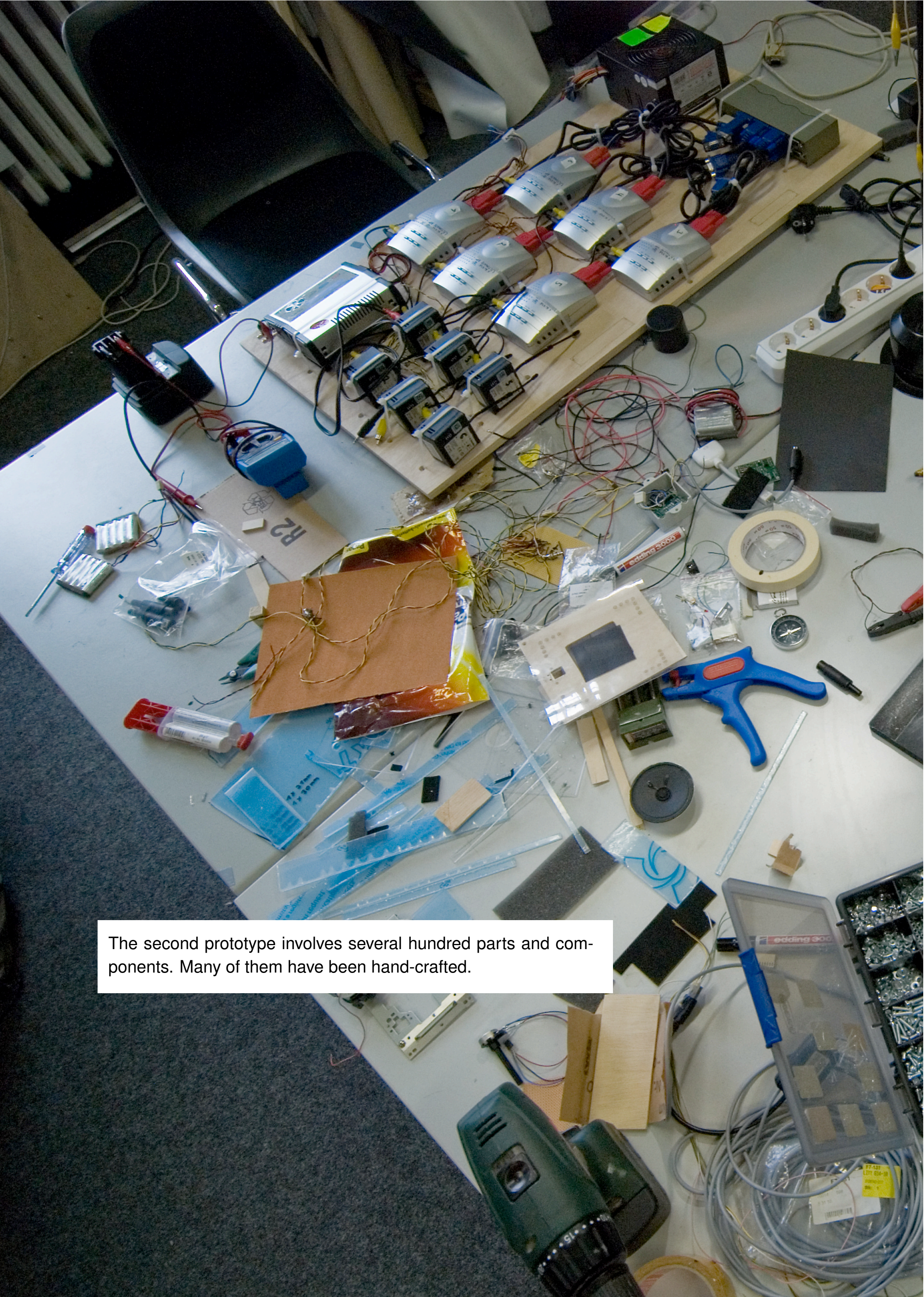
[3] MTx orientation tracker, kindly provided by XSens Motion Technologies, http://www.xsens.com

[4] 2,4GHz ZigBee standard based on IEEE 802.15.4, implemented on two connected XBee modules, according to http://en.wikipedia.org/wiki/Zigbee (accessed 03-21-2008)



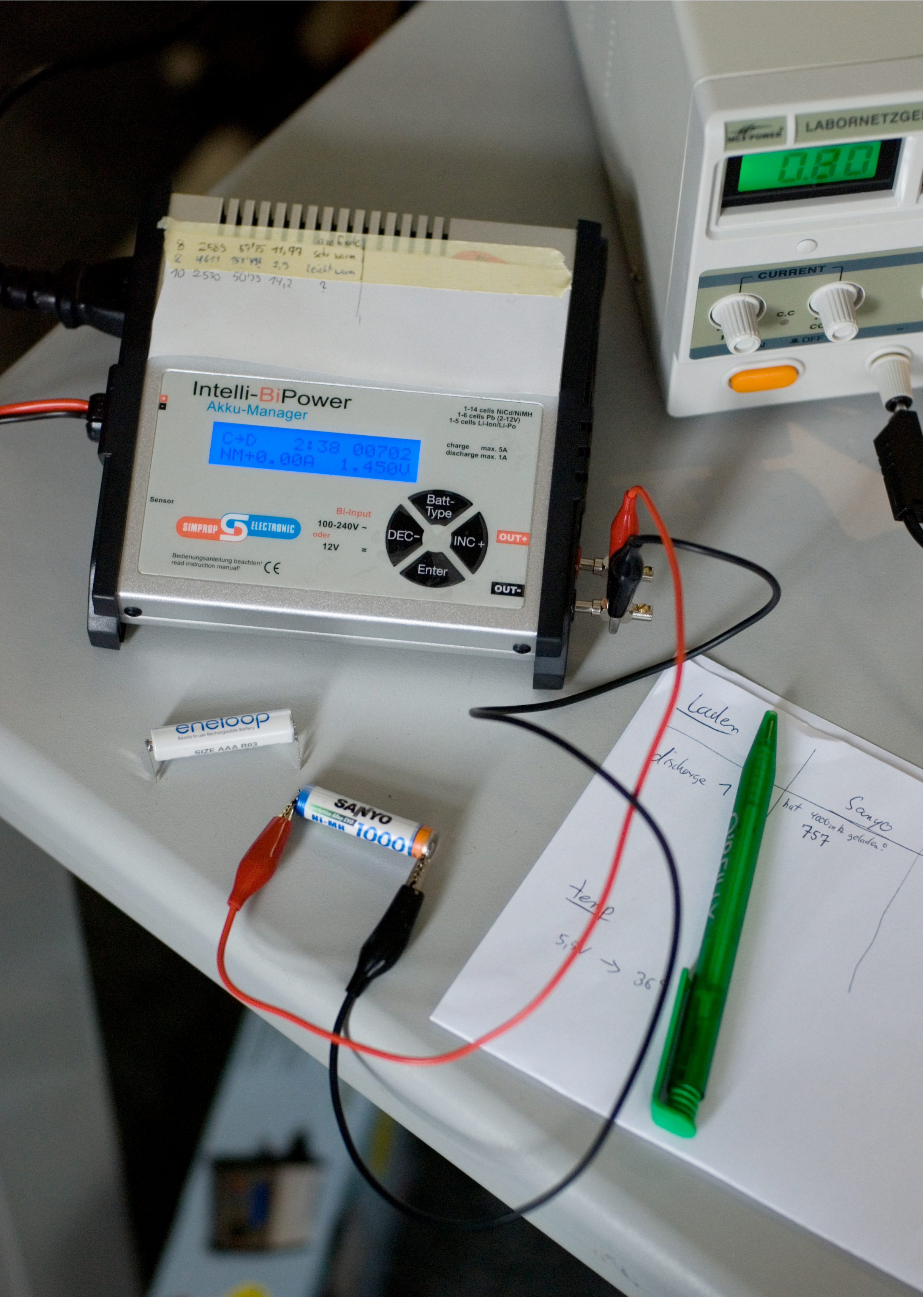
D Construction photos

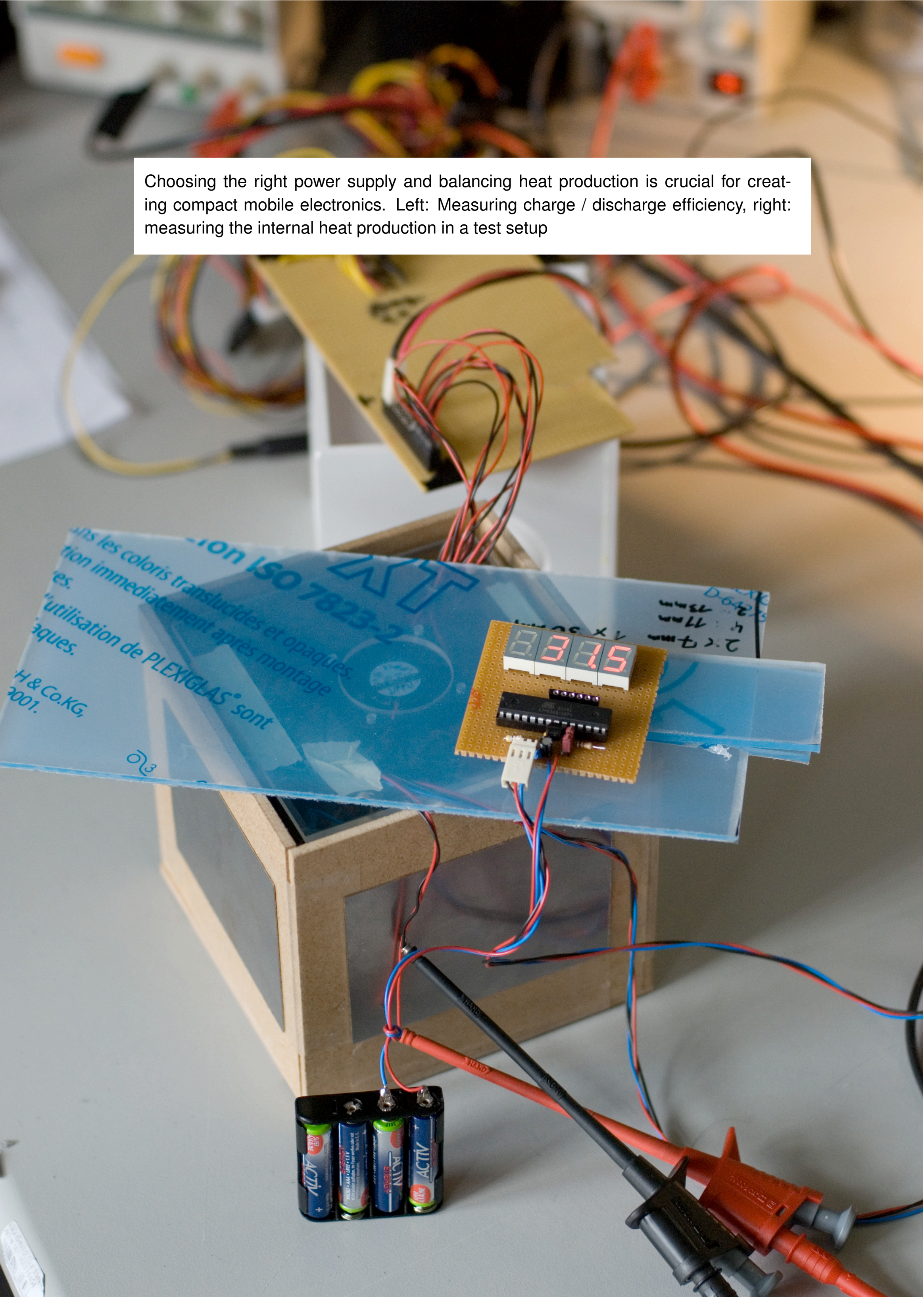
In this appendix you will find several images from the work-in-progress process at the Interface Lab / Lab 3 of the Academy of Media Arts in Cologne. This project would not have been possible without the splendid working environment and support there. Again, I would like to thank especially Martin Nawrath and Bernd Voss for their technical help.



The second prototype involves several hundred parts and components. Many of them have been hand-crafted.

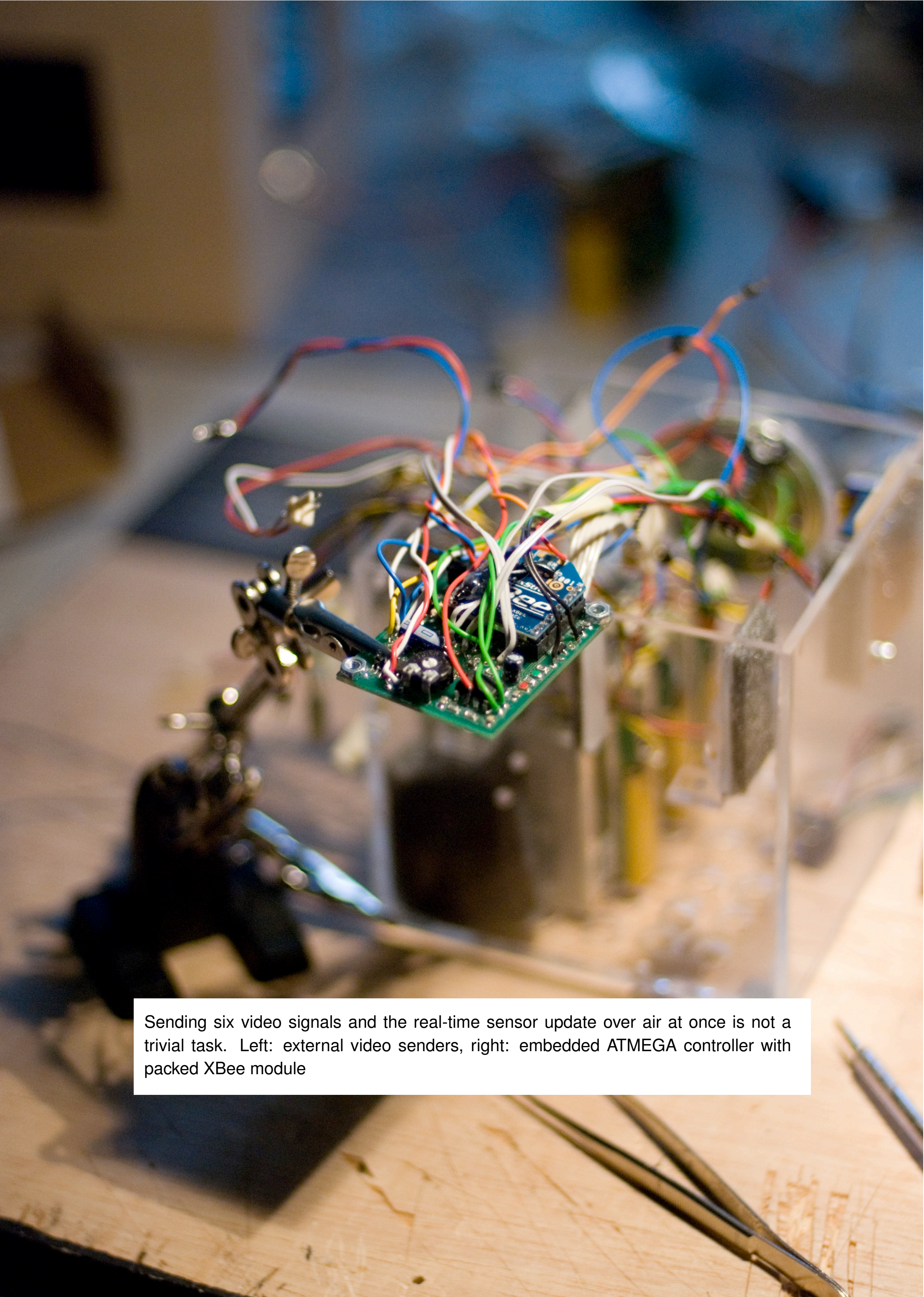

Epoxy
IPA
SPAX


CURRENT
Intelli-BiPower
Akku-Manager
1-14 cells NiCd/NiMH
1-6 cells Pb (2-12V)
1-5 cells Li-Ion/Li-Po
C→D 2:38 00702
NM+0.00A 1.450V
charge max. 5A
discharge max. 1A
Sensor
SIMPROP ELECTRONIC
Bi-Input
100-240V ~
oder
12V =
Batt-Type
DEC-
INC+
Enter
OUT+
OUT-
Bedienungsanleitung beachten!
read instruction manual!
eneloop
SIZE AAA R03
SANYO
Ni-MH
1000
Laden
discharge
Sanyo
temp

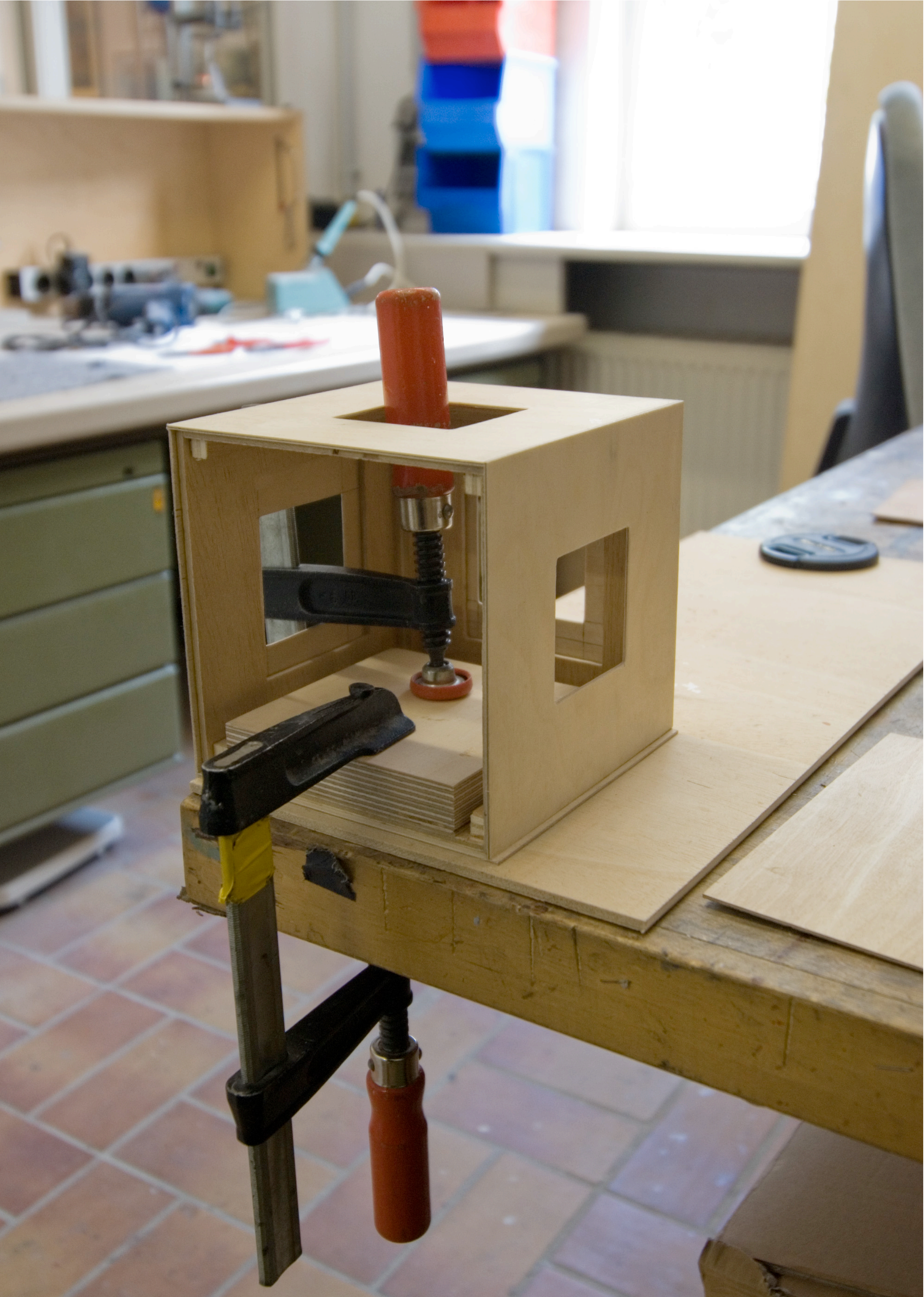


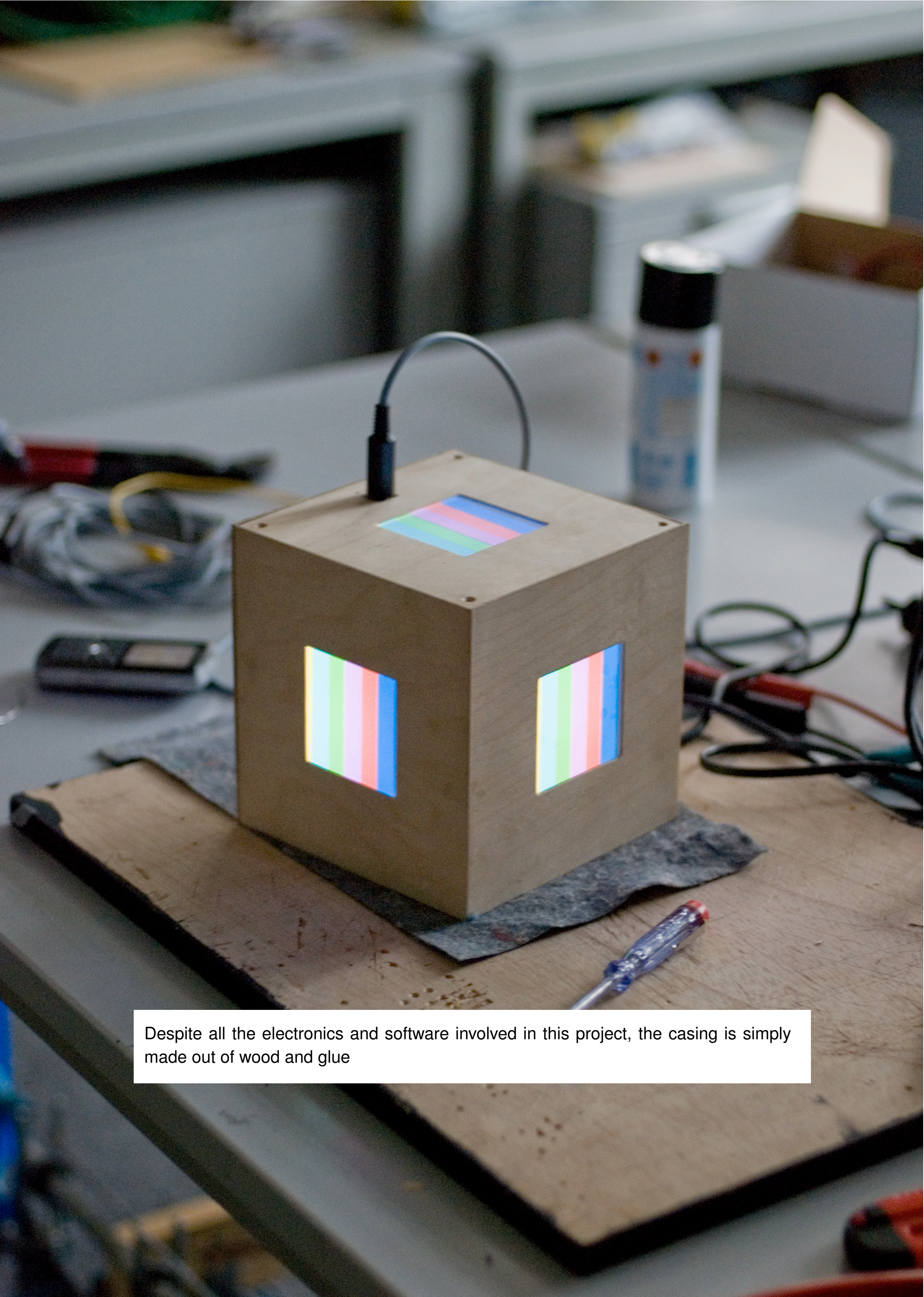
Choosing the right power supply and balancing heat production is crucial for creating compact mobile electronics. Left: Measuring charge / discharge efficiency, right: measuring the internal heat production in a test setup

1.4 GHz Mini Sender
Kanal
C-F
S-B
VTQ Videotronik
06268 Querfurt
www.vtq.de
Made in Germany
12V stab
5
4
3



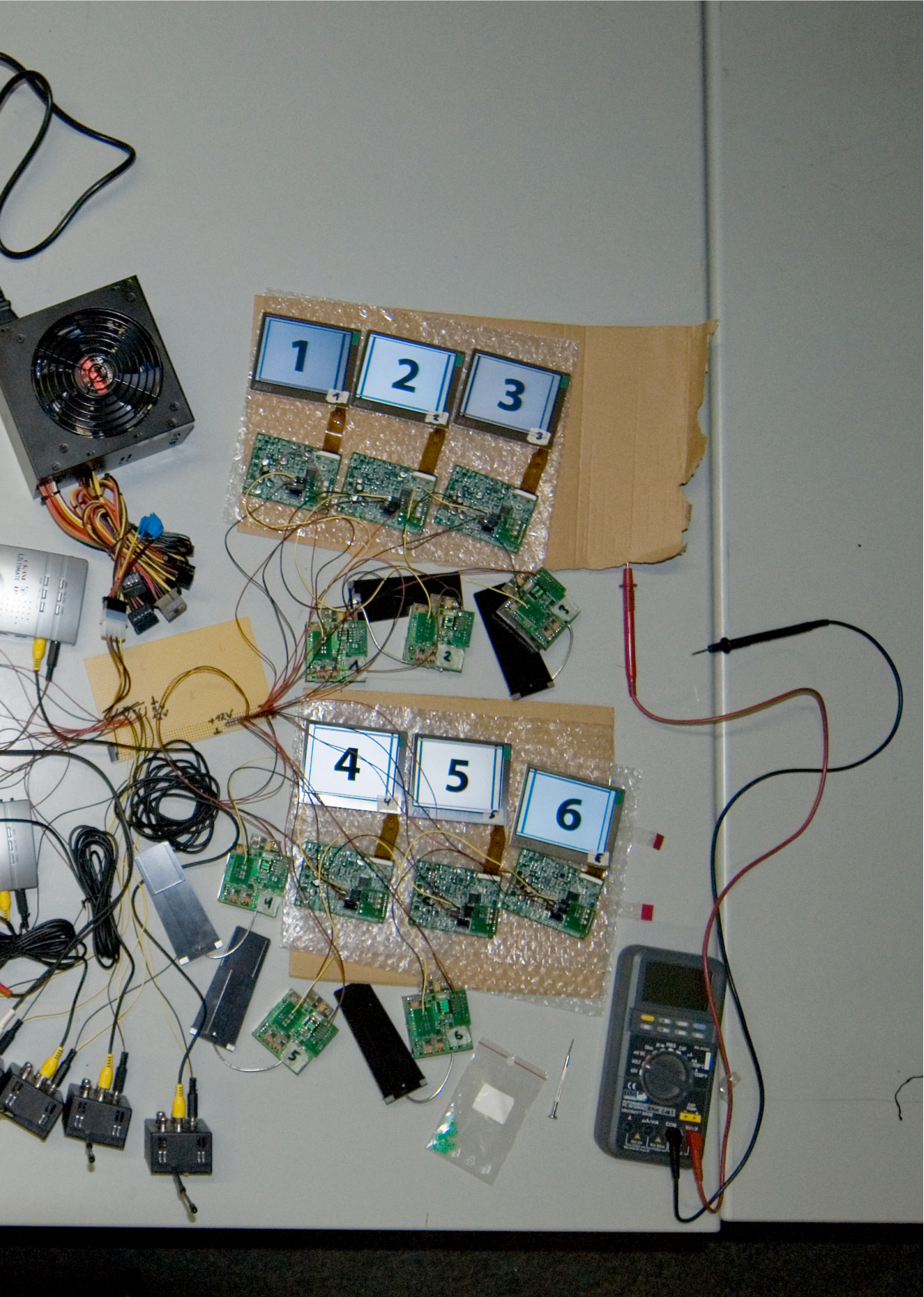
Sending six video signals and the real-time sensor update over air at once is not a trivial task. Left: external video senders, right: embedded ATMEGA controller with packed XBee module





Despite all the electronics and software involved in this project, the casing is simply made out of wood and glue

An early setup to test the six-channel video link


1
2
3
4
5
6

Bibliography

[Anderson, 2003] Anderson, M. L. (2003). Embodied cognition: A field guide. *Artificial Intelligence*, 149(1):91–130. 36

[Begelman, 2006] Begelman, G., editor (2006). *Automated Tag Clustering: Improving search and exploration in the tag space*, Edinburgh, UK. WWW2006.

[Braitenberg, 1984] Braitenberg, V. (1984). *Vehicles, experiments in synthetic psychology*. MIT Press, Cambridge, Mass. 37

[Brooks, 1991a] Brooks, R. A. (1991a). Intelligence without representation. *Artificial Intelligence*, 47(1-3):139–159. 55

[Brooks, 1991b] Brooks, R. A. (1991b). New approaches to robotics. *Science*, 253(5025).

[Brooks, 1999] Brooks, R. A. (1999). *Cambrian intelligence : the early history of the new AI*. MIT Press, Cambridge, Mass. 37

[Bush, 1945] Bush, V. (1945). As we may think. *Atlantic Monthtly*. 64, 77, 92

[Clark and Chalmers, 1998] Clark, A. and Chalmers, D. (1998). The extended mind. *Analysis*, 58(1):7–19. 39, 59

[Csikszentmihalyi, 1975] Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety*. The Jossey-Bass behavioral science series. Jossey-Bass Publishers, San Francisco, 1st ed edition. 42, 43

[Csikszentmihalyi, 1985] Csikszentmihalyi, M. (1985). *Das flow-Erlebnis : jenseits von Angst und Langeweile : im Tun aufgehen*. Konzepte der Humanwissenschaften. Psychologie. Klett-Cotta, Stuttgart. 42

[Csikszentmihalyi, 1990] Csikszentmihalyi, M. (1990). *Flow : the psychology of optimal experience*. Harper & Row, New York, 1st ed edition. 42

[Csikszentmihalyi and Charpentier, 1992] Csikszentmihalyi, M. and Charpentier, A. (1992). *Flow : das Geheimnis des Glücks*. Klett-Cotta, Stuttgart. 42

[Degele, 2002] Degele, N. (2002). *Einführung in die Techniksoziologie*, volume 2288 of *UTB für Wissenschaft*. Fink, München. 37

[Dourish, 2001] Dourish, P. (2001). *Where the action is : the foundations of embodied interaction*. MIT Press, Cambridge, Mass. 23, 25, 26, 27, 29, 32, 35, 48, 54

[Ernst, 2002] Ernst, W. (2002). *Das Rumoren der Archive : Ordnung aus Unordnung*, volume 243. Merve, Berlin. 60, 77

[Fishkin, 2004] Fishkin, K. P. (2004). A taxonomy for and analysis of tangible interfaces. *Personal Ubiquitous Comput.*, 8(5):347–358. 49, 51, 53

[Fishkin et al., 2000] Fishkin, K. P., Gujar, A., Harrison, B. L., Moran, T. P., and Want, R. (2000). Embodied user interfaces for really direct manipulation. *Commun. ACM*, 43(9):74–80.

[Fitzmaurice et al., 1995] Fitzmaurice, G. W., Ishii, H., and Buxton, W. A. S. (1995). Bricks: laying the foundations for graspable user interfaces. In *CHI '95: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 442–449, New York, NY, USA. ACM Press/Addison-Wesley Publishing Co.

[Gibson, 1979] Gibson, J. J. (1979). *The ecological approach to visual perception*. Houghton Mifflin, Boston. 55

[Gorbet, 1998] Gorbet, M. G. (1998). Beyond input devices : a new conceptual framework for the design of physical-digital objects. Master's thesis, Massachusetts Institute of Technology. Dept. of Architecture. Program in Media Arts and Sciences.

[Hilditch, 1995] Hilditch, D. (1995). *At the heart of the world: Merleau-Ponty and the existential phenomenology of embodied and embedded intelligence in everyday coping*. PhD thesis, Department of Philosophy, Washington University, St. Louis. 36

[Hollan et al., 2000] Hollan, J., Hutchins, E., and Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Trans. Comput.-Hum. Interact.*, 7(2):174–196. 59, 62

[Hutchins, 1995] Hutchins, E. (1995). *Cognition in the wild*. MIT Press, Cambridge, Mass.

[Hutchins et al., 1985] Hutchins, E. L., Hollan, J. D., and Norman, D. A. (1985). Direct manipulation interfaces. *Human-Computer Interaction*, 1(4):311–338. 47

[Ishii and Ullmer, 1997] Ishii, H. and Ullmer, B. (1997). Tangible bits: towards seamless interfaces between people, bits and atoms. In *CHI '97: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 234–241, New York, NY, USA. ACM Press.

[Kalay and Marx, 2001] Kalay, Y. and Marx, J. (2001). Architecture and the internet: Designing places in cyberspace. In *Proceedings of ACADIA 2001: Reinventing the Discourse*. 56

[Kennedy et al., 2007] Kennedy, L., Naaman, M., Ahern, S., Nair, R., and Rattenbury, T. (2007). How flickr helps us make sense of the world: context and content in community-contributed media collections. In *MULTIMEDIA '07: Proceedings of the 15th international conference on Multimedia*, pages 631–640, New York, NY, USA. ACM.

[Kirsh and Maglio, 1994] Kirsh, D. and Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science*, 18:513–549. 39, 50, 55, 75

[Lakoff and Johnson, 1980] Lakoff, G. and Johnson, M. (1980). *Metaphors we live by*. University of Chicago Press, Chicago. 37

[Lakoff and Johnson, 1999] Lakoff, G. and Johnson, M. (1999). *Philosophy in the flesh : the embodied mind and its challenge to Western thought*. Basic Books, New York.

[Lévy, 1997] Lévy, P. (1997). *Collective intelligence : mankind's emerging world in cyberspace*. Plenum Trade, New York. 62

[Manovich, 2002] Manovich, L. (2002). *The language of new media*. Leonardo. MIT Press, Cambridge, Mass., 1st mit press pbk. ed edition.

[Mazé and Redström, 2005] Mazé, R. and Redström, J. (2005). Form and the computational object. *Digital Creativity*, 16(1):7–18.

[Mumford, 1977] Mumford, L. (1977). *Mythos der Maschine : Kultur, Technik und Macht*, volume 4001. Fischer, Frankfurt, Main. 25

[Norman, 2002] Norman, D. A. (2002). *The design of everyday things*. Basic Books, New York, 1st basic paperback edition. 44, 46, 47

[Polanyi, 1966] Polanyi, M. (1966). *The tacit dimension*, volume 1962 of *Terry lectures*. Doubleday, Garden City, N.Y. 40, 42, 83

[Rumori et al., 2007] Rumori, M., Haag, C., Windisch, F., and Zeller, L. (2007). Offener schaltkreis. an interactive sound installation. In *Linux Audio Conference 07 (Berlin)*, Klanglabor, Academy of Media Arts Cologne. 52

[Scherffig, 2005] Scherffig, L. (2005). It's in your eyes. Master's thesis, Universität Bremen.

[Schröter and Böhnke, 2004] Schröter, J. and Böhnke, A. (2004). *Analog, Digital : Opposition oder Kontinuum? : zur Theorie und Geschichte einer Unterscheidung*, volume Bd. 2 of *Medienumbrüche*. Transcript, Bielefeld. 26

[Sharlin et al., 2004] Sharlin, E., Watson, B., Kitamura, Y., Kishino, F., and Itoh, Y. (2004). On tangible user interfaces, humans and spatiality. *Personal and Ubiquitous Computing*, 8(5):338–346. 49, 50, 55

[Shneiderman, 1974] Shneiderman, B. (1974). A computer graphics system for polynomials. *The Mathematics Teacher*, 67(2):111–113. 47

[Shneiderman, 1982] Shneiderman, B. (1982). The future of interactive systems and the emergence of direct manipulation. *Behavior and Information Technology*, 1:237–256. 47

[Shneiderman, 1983] Shneiderman, B. (1983). Direct manipulation: A step beyond programming languages. *IEEE Computer*, 16(8):57–69. 47

[Shneiderman, 1997] Shneiderman, B. (1997). Direct manipulation for comprehensible, predictable and controllable user interfaces. In *IUI '97: Proceedings of the 2nd international conference on Intelligent user interfaces*, pages 33–39, New York, NY, USA. ACM Press.

[Surowiecki, 2004] Surowiecki, J. (2004). *The wisdom of crowds : why the many are smarter than the few and how collective wisdom shapes business, economies, societies, and nations*. Doubleday, New York, 1st ed edition. 62

[Svanæs, 1999] Svanæs, D. (1999). *Understanding Interactivity: steps to a phenomenology of human-computer interaction*. PhD thesis, Norges teknisk-naturvitenskapelige universite. 46

[Trogemann and Viehoff, 2005] Trogemann, G. and Viehoff, J. (2005). *CodeArt : eine elementare Einführung in die Programmierung als künstlerische Praktik*. Springer, Wien. 25, 26, 28, 33

[Ullmer and Ishii, 2000] Ullmer, B. and Ishii, H. (2000). Emerging frameworks for tangible user interfaces. *IBM Syst. J.*, 39(3-4):915–931.

[Ullmer et al., 2005] Ullmer, B., Ishii, H., and Jacob, R. J. K. (2005). Token+constraint systems for tangible interaction with digital information. *ACM Trans. Comput.-Hum. Interact.*, 12(1):81–118. 55

[Wiener, 1969] Wiener, O. (1969). Der bioadapter. *manuskripte*, 25. 33

[Wilson, 2002] Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin and Review*, 9(4):625–636. 37, 39, 55, 56, 59

[Winkler, 1994] Winkler, H. (1994). Songlines. In Warnke, M. and Coy, W., editors, *HyperKult. Geschichte, Theorie und Kontext digitaler Medien*, volume published 1997, pages 227–239, Frankfurt. Georg Christoph Tholen. 62, 66, 67, 79

[Wittgenstein, 1967] Wittgenstein, L. (1967). *Philosophische Untersuchungen*. Suhrkamp, Frankfurt, Main. 35, 77