Katrin Hänsel

Interaction Design for Semi-Public Ambient Displays with Mobile and Motion-Tracking Components

eingereicht als

Masterarbeit

Hochschule Mittweida

University of Applied Sciences

Fachbereich

Mathematik Naturwissenschaften Informatik

Betreuer:

Prof. Dr.-Ing. Robert J. Wierzbicki

Prof. Dr Roderick Murray-Smith

Verteidigt am:

31.07.2012

Bibliographic Description

Hänsel, Katrin:

Interaction Design for Semi-Public Ambient Displays with Mobile and Motion-Tracking Components,

2010 - Mittweida, Hochschule Mittweida, Faculty Mathematics / Sciences / Computer Sciences, Master Thesis

Abstract

This thesis deals with the design and prototypical implementation of a social enhancing display for semi-public working groups with special focus on the interaction design by using mobile phones and whole body motions.

Keywords: *Kinect, smartphones, ambient intelligence*

Table of Contents

List of Figures

Glossary and Abbreviations

SDK	*Software Development Kit:* Set of tools to develop software.
UX	*User Experience:* see subsection 2.1.2
AmI	*Ambient Intelligence:* see subsection 2.1.1.1
API	*Application Programming Interface:* Libraries and tools for programming.
UCD	*User-Centred Design:* Term for a design process that focuses on the user needs limitations and abilities to create a product that is highly fitted to these.
PDF	*Portable Document Format:* File format for document which is supported on most platforms.
WPF	*Windows Presentation Foundation:* A framework from Microsoft to develop user interfaces
XAML	*Extensible Application Markup Language:* XML-based language for defining the user interface of a WPF application

Preface

This thesis is especially addressed to people of the computing science sector and in particular the field of Human Computer Interaction and Interactive Software Development. During some chapters of this thesis, basic knowledge in the field of programming or software development is needed for understanding.

Persons have been referred, for simplicity reasons, with "he" instead of "he or she" in this thesis.

Acknowledgment

This thesis was written during a six month internship in the School of Computing Science at the University of Glasgow. This internship and the project would not have been possible without the support of many people.

I would like to express my gratitude to my supervisor, Dr Roderick Murray-Smith who offered invaluable assistance, support and guidance and especially ideas for this thesis.

Special thanks also to Prof. Dr.-Ing. Robert Wierzbicki for supporting and supervising me from afar and under these special circumstances.

I would also like to thank Lauren Norrie for the helpful suggestions and creative and productive discussions. A huge thanks to the whole research group on level 2 and 3 for the inspiring conversation, exhilarant activities, the warm feeling of being welcome and of course the time spend attending my user study.

I would also like to express how honoured and grateful I am for the "Erasmus Prakitum" scholarship and therefore the financially facilitating funding of this this internship.

Last, but not least I would like to thank René Weber for his support and love in weal and woe.

CHAPTER 1

Introduction

This introductory chapter highlights the motivation behind this thesis and it's main topics, such as interaction with mobile and motion tracking devices and the characteristics of ambient systems. It will also provide an overview of the latest developments concerning ambient environments. Furthermore, this chapter will outline the objectives and structure of this thesis.

1.1. Motivation

Over the last decade the concept of flexible working arrangements has become very common. Originally, flexible working arrangements were intended to create a family friendly work environment with the chance to plan the time spent at work - which might be the most time consuming part of the day - in a more flexible way. Increasingly often it is also possible to do a certain amount of work from home without the need to go to the office. Especially, in the research departments of universities an increasing trend of home office work is noticeable. For example, Ph.D. students benefit from flexible working hours.

New technologies and systems support this trend by providing more and more ways to communicate over large distances. 1.1 shows the development over the last hundred years.

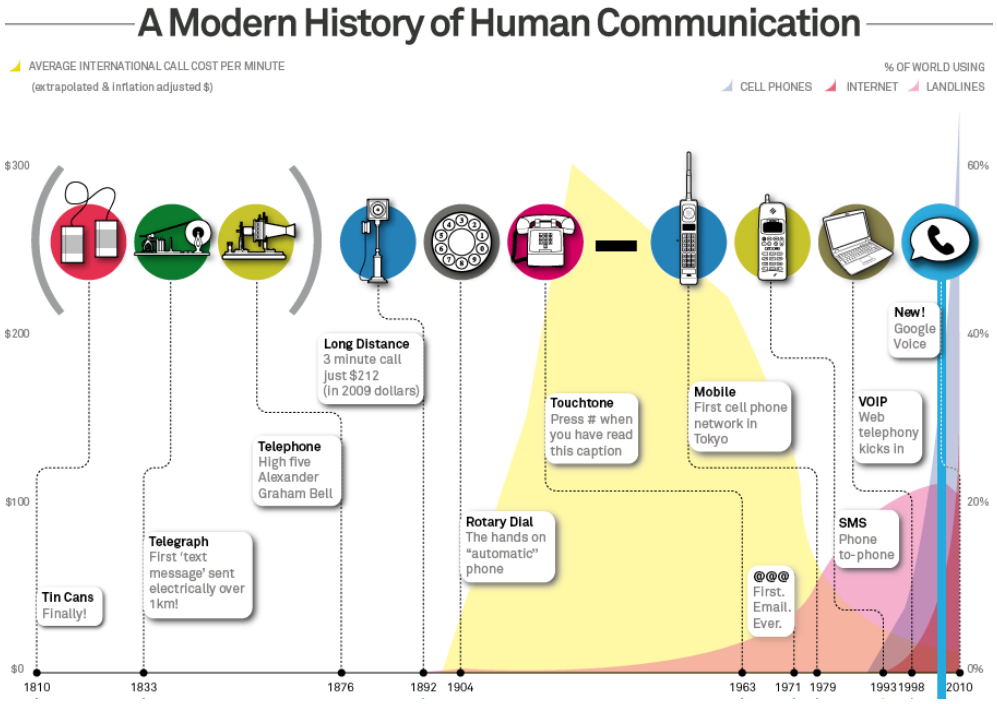


Figure 1.1: History of Communication (detail, source: `http://images.tipb.com/images/stories/2010/06/google_voice_inforgraphic_big.png`)

All these developments improve the flexibility of interpersonal communication. We do not have to move physically to the location where the communication with other people is happening. Video conferences make it possible to even hold whole meetings whilst every participant is at a different location.

It is foreseeable that project work does not profit from this. It suggests itself that working from home degrade creative team work due to the reduced communication between the team members (see [Rad10]). Of course, the communication can be accomplished with tools like Skype or via telephone, but this is no substitution for face-to-face communication. Flexible working hours will also decrease the social relatedness and affinity of the colleagues because they are working at different times. The result of this trend is that the people in working groups may hardly know each other. But to know each other well, even though they are not working on the same project, could not just improve the working atmosphere but also the work itself. If colleagues know the interests, strengths and weaknesses of their co-workers, they could support each other more efficiently. It also strengthens the trust and the sense of well-being in the group.

This thesis describes the design of a tool to enhance this communication between the group members by explicitly abandon the accessibility from remote locations and instead motivating the users to visit the location of the tool and come together with the other group members. This should also improve the face-to-face communication and the tool could act as a source of topics for conversations. The main goal of such a system would be a strengthened awareness of the other group members and their activities and interests, to improve the collaboration and connectedness in the team.

1.2. Background

This section introduces the influential technologies and terms of the thesis title and highlights their interplay.

1.2.1. Public and Semi-Public Displays

Due to the decreasing prices of large displays, they became very common in public spaces that are accessible by everyone. Shopping malls, entrance halls in museums or subways are such places. These public displays are intended to provide information about products, the weather or the surrounding area. They present their information either statically or with the option of user interaction, e.g. with touch displays or voice input.

For this thesis semi-public displays are defined as displays placed in semi-public spaces, which in turn are defined as spaces accessible by a limited number of people. Working environments can be considered as spaces. They are normally accessible by the workers who work there. But occasionally outsiders or visitors might enter this area. Another example for a semi-public area is the stairwell of an apartment building which is usually just passed by residents of the building and their friends or family members.

1.2.2. Mobile and "Smart Phones"

Since the first generation of Apple's iPhone, the "smart phones" have become very popular. The number of these devices, which combine pocket computer, mobile phone, music player and the potential of a nearly never-ending expandability of the through apps, increases every year. In a project environment there are usually a lot of people using their smartphone to communicate and share information via E-Mail, schedule their meetings or accessing their files remotely.

Smartphones are also a good way to extend social networks like Twitter and Facebook. With a smartphone and an internet connection it is possible to send text, photos or the current position to these social networks. It makes one's friends even more aware of one's current activities.

1.2.3. Kinect - Depth Sensing Made Ready for Mass Market

In 2010 Microsoft released a motion tracking input device for their video console Xbox 360 ([Low11]). This made the Microsoft Kinect competing with the two other large console producers Nintendo with the Wii and PlayStation with PlayStation Move. But unlike these motion-sensing controller technologies, no controller is needed for the Microsoft Kinect. The whole interaction is done with motions of the body which are tracked via a depth sensing camera.

This made the Kinect popular to developers who wanted to program own applications that take advantage of this technology. Shortly after the release of the Kinect device for the Xbox, developers released their own SDKs and drivers for developing applications for the Windows operating system.

In early mid-2011, Microsoft released the beta version of their own development kit for the Kinect and Windows. The SDK made it possible to access video and depth data as well as calculated skeletons of people standing in the vision field of the device. The Kinect also has an integrated microphone and the SDK provides speech recognition features.

1.2.4. Ambient Systems

The Oxford Dictionary [Dic] describes the adjective ambient as "relating to the immediate surroundings of something". An example is the Ambilight technology. The term Ambilight is short for "ambient light" and describes the extension of the content shown at the TV screen to the surrounding area by creating corresponding light effects around the TV.

Ambient systems can be considered as systems that enhance the user's environment and the space for the user to interact with the system. A further classification and definition will be made in the second chapter.

1.3. Objectives of the Thesis

The goal of this thesis is the design of a communication enhancing display that is meant to be placed in a semi-public environment of a co-located, collaborating working group. The interaction with this display should be realized using mobile phone input and body motions caught via the depth sensing of a Microsoft Kinect. This will enable the system to track people's motions in the surrounding area of the display. The combination of mobile phone and motion interactions can provide new ways of interacting with the system.

All this should be considered with the aim to engage and reward people to use the screen for a broadened communication with the people in their working environment and strengthen the awareness in the group. It could help people to keep track of the current topics that people are involved in, what they are currently up to or their general fields of interest. But this should not be a replacement for real communication rather than an impulse to discuss things further and starting up new conversations about the shown content. The overall question is how such a display could bring people together in their working environment and how it could be beneficial compared to other social platforms. In addition to the theoretical considerations a prototype will be

implemented which shows how some of the major design decisions could be realized. This prototypical implementation will then be evaluated in a small user study.

1.4. Thesis Layout

The following chapter will overview some related projects and define some later used terms. Some of the conclusions and results from this previous chapter shall be used in the third chapter of this thesis to discuss the design decisions for the functionality and appearance of the display. The fourth chapter will describe some implementation details of the prototype. This prototype will then be tested by users in a small user study and the results are evaluated in the fifth chapter. The last chapter will focus on summarizing the following chapters and the drawn conclusions. It will also provide a perspective for further developments and improvements.

CHAPTER 2

Related Work and Definitions

This chapter gives and introduction to some topics related to this thesis. It defines and explains some terms and deals with the work other people have done in the field on social enhancing public or semi-public displays.

2.1. Related Terms

This section will describe some terms related to the thesis topic.

2.1.1. Ambient Interfaces and Ambient Intelligence

As mentioned in the introductory chapter, ambient systems can be seen as an enhancement to the user's environment and the surroundings of the user. The paper of [Gro] deals with ambient interfaces that are the point of interaction between a human being and a system. They are supposed to be richer than the normal graphical interfaces and go beyond usual input devices like mice and keyboards. They might produce rather indirect changes in the environment of the user, such as light changes or sounds, to make the user aware of something. But they can also detect changes in the environment like the presence of a person, movements or sounds made by the user and react to these changes. These changes are detected by sensors embedded in the environment.

Additionally, they aim to hide the computer from the human and provide easy and intuitive interactions. They could even provide a certain degree of intelligence which leads to Ambient Intelligence systems.

Ambient Intelligence (AmI): Ambient Intelligence [NAA09] describes systems that try to ease the lives of people through the use of sensors and intelligent actions and decisions. These systems are mostly embedded and try to hide the computer as much as possible.

The development in the sector of AmI benefited mainly from the more and more low-cost, powerful and space-saving sensors and processing units that can be integrated into household devices, shopping carts ([Spa+09]) or even clothing ([CS09]). Based on this they can support the user with intelligent decisions and be sensitive to the user's needs.

This often involves *Pervasive Computing* which describes the embedding of microchips in everyday devices which then will be enabled to communicate in an unobtrusive way with each other. An example could be the alarm clock in the bedroom which communicates with the coffee maker to make the good-morning-coffee be ready at the right time.

Smart Homes are also closely connected to AmI. Smart Homes are domestic environments equipped with sensors to monitor activities in the household with the aim to support the residents with intelligent and supporting reactions. The monitored data will be processed and the system is able to react on special incidents. [Sad11] instances the use of such systems for observing a person's health status by observing the vital functions. If measured data indicates that the user needs emergency aid the system calls for help. Smart Homes are often intended to support impaired or elderly people to provide them a more independent living and an improved quality of life.

[Gag05] described that AmI should even learn from the human behaviour and emotions and adapt to them. Another important statement he made in relation to this thesis is:

> *"The feature of "embedding" means that miniaturized devices will increasingly become part of the invisible background of peoples' activities, and that social interaction and functionality will move to the foreground."* ([Gag05])

But the main topic of this paper remains the optimization of the experience with AmI which leads the focus to User Experience.

2.1.2. User Experience and Usability

The User Experience (UX) is often mentioned in association to the usability of a system. Sometimes they are even used interchangeable. This section tries to give a survey on what these both terms mean and which association they have.

Usability: The usability of a system describes the easiness of use of a system. This includes things like the time needed to learn how to use a system as well as the efficiency of use - all this with the focus on improving and supporting the user's ability to solve a problem or complete a task successfully and efficiently.

[Nie] has a whole website concentrating on usability. According to him usability is defined by 5 quality components. These can be seen in Figure 2.1.

These factors are important to improve the efficiency and productivity of the user who is working with the system. They have economic implications when it comes to paying the employees for their time working with the system. For example, errors the user makes while using the system lead to the distraction of the user and let him forget about the main task. This is even more frustrating when such errors are caused by a bad and ambiguous user interface. In order to obtain a better level of usability, systems should be fault-tolerant and let the user easily correct the mistake.

To design systems with good usability it is important to have an understanding of the human psychology and physiology. Some key factors of this are:

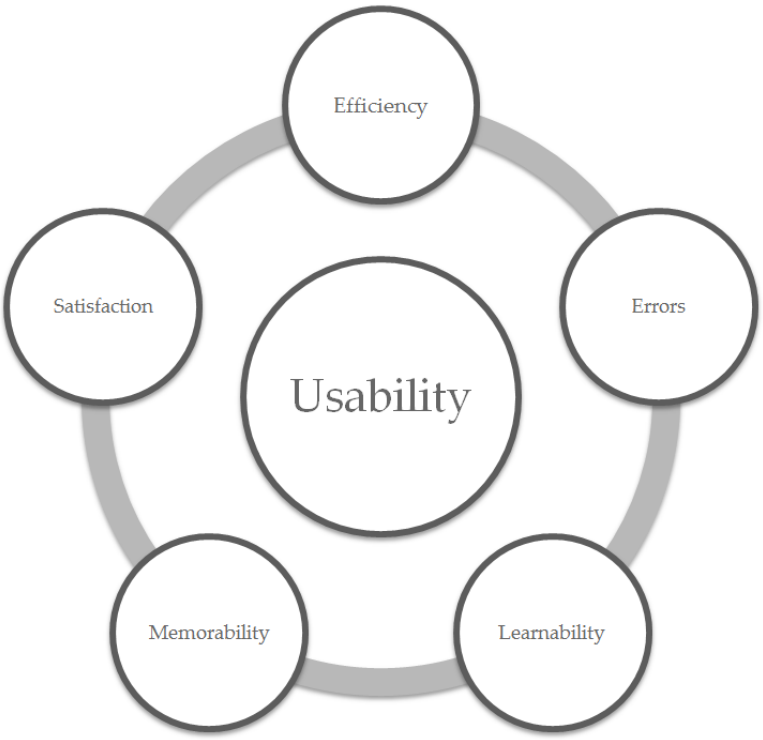


Figure 2.1: Components of Usability (designed after [Nie])

- Understanding the human memory (Humans can only remember a certain amount of information and easily forget things when overloaded with too much information.)
- Visual perception of things (e.g. Field of vision, colour perception and effect)
- Expectations (e.g. if the user has used a system with a submit button before, he might have an idea of what might happen when clicking on a submit button in a different system.)

Although there are different guidelines and principles it is still necessary to ratify the usability of a system by letting some users test the system and observe them whilst they are performing a task. Often things might not have the expected effect on the potential user.

For years, the focus of improving a system laid on improving the software quality characteristics [ISO01]:

- Functionality

- Reliability
- Usability
- Efficiency
- Maintainability
- Portability

The first four characteristics are user-focused and particularly important for the user of the system while "maintainability" and "portability" are more important features for the developer of a system.

The main goal of these user-focused quality criteria is to support the user as much as possible in solving tasks under the use of the system. The user should be able to use the system to correctly solve a task in a preferably short period. This also has an economic background because an employee who can solve a task in a rather short time and with fewer errors is more productive during their hours of work.

Over the last few years, a more individual-focuses and subjective view on the software became the focus of attention, in order to adapt to the changes in the decision process consumers of software systems - the User Experience.

User Experience (UX) According to [Sik08], the ISO standards for the quality of an interactive system is mostly focused on the needs of professional users and their criteria for buying and using a system. These criteria are most often focused on the functionality and efficiency of a system, but over the last years a shift in the group of users of interactive systems and devices occurred. There are more and more users using such interactive technologies for their personal use in their everyday life. Personal Computers, Smartphones and other personal electronic devices are more popular than ever.

The criteria for buying such devices are most often are beyond the mere quality aspects such as the usability or efficiency of the device. Subjective characteristics like an appealing design, affordability or the "hip factor" are becoming more important for the purchase decision. All this leads to the need for a more detailed examination

of the emotions and perceptions a user has by using a system or device and how the interaction with the system can be turned into a pleasant and positive experience.

During these changes the term User Experience (UX) became very important characteristic influencing the subjective opinion about the quality of a system or interactive device. But it is challenging to find a general definition for UX and many proposals can be found in the literature. Two of them shall be listed below:

The International Organization for Standardization defines UX as follows ([ISO10]):

> *"A person's perceptions and responses that result from the use and/or anticipated use of a product, system or service"*

The definition of [HT06] is a bit more comprehensive:

> *"UX is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)."*

Both these definitions point out that UX it is a very subjective and personal thing that is strongly related to the individual. Therefore, it can be said that one of the key features of UX comprises emotions and feelings of the individual towards the system. These can be either experienced before actually interacting with the system, in the meantime or after the usage and they can differ from user to user due to the complexity of the emotions and perceptions of a person.

For example, a person can have some expectations before using a system. The person might have heard rumours or have seen somebody else using the system and prejudice the system before using or purchasing it. Even just a look on the product can provoke this. [Has03] called this apparent product character. This can be enough to let the person feel attracted by the system and he might be prejudiced by that before actually using the system. It shall be quite evident that the actual use of the system is also an

emotive act. For example, the user can be experience the interaction with the system as joyful or annoying. All these feelings, perceptions and expectations before and during the use can last after finishing the interaction or might even change in retrospect. They could be an impulse for the person to create a connection or averseness to the system. All these different, complex and first of all personal and subjective influences make it very hard to quantify and measure UX.

But before a further insight into the measurability of UX will be delivered, the association between Usability and UX should be highlighted.

The Association between Usability and User Experience

There are different opinions about the association between Usability and UX but it is widely recognized that they cannot be treated synonymously. To understand the association and differentiation of Usability and User Experience, the personal view of Hassenzahl should be surveyed.

In the term product character has been mentioned before. Now it will be examined in more detail. According to [Has03] and [Has08] the product character has *pragmatic attributes* which are focused on the fulfilment of a goal ("do-goal") and are strongly connected to the Usability and it has *hedonic attributes* which are important in focus of the user's well-being ("be-goals") and is therefore related to the positive experience a user has. He pointed out that this product character is the base for rating the attraction of the system. A product can be found satisfying in terms of achieving a goal or pleasuring and consequently good for one's well-being. The hedonic attributes focus on the "self" of a person and are "be-goals" which support the user in being something and feeling accordingly. He argues that the fulfilment of the hedonic attributes and the "be-goals" is the driver of experience [Has08, p. 2]. He also points out that an important factor while designing an interactive system is the focus on the hedonic goals.

Back in 2003 he argued that hedonic and pragmatic attributes are totally independent from each other ([Has03, p. 6]) whilst in the more recent paper he admits that pragmatic quality might affect the hedonic quality of a product and therefore the positive experience [Has08, p. 2] a user has while using a product.

In this thesis, the position is taken up that the attributes may be independent from each other but the value of the quality can indirectly influence the other quality. For example: A hammer with a specific brand can have the hedonic quality of making the user feel like being a professional. This hammer might be totally equal to a no name product except of the little brand logo on it. This might influence the way he uses the hammer by giving him confidence and therefore supporting him by the task to drive a nail into the wall more efficiently and therefore the product can have a better usability. A no-name hammer can make the user worry if it might break and therefore use it more reserved.

On the other hand could the successful, efficient task fulfilment with the tool make him feel like a professional and strengthen his confidence or he could be discouraged by a failure, which is a negative feeling and may last even after the usage. Therefore, a product with a bad pragmatic quality can, but not necessarily has to, lead to a worse hedonic quality or the other way around. This leads to the conclusion that Usability and UX can influence each other in indirect ways.

Measuring User Experience and Usability

Since the first software and interactive systems has been developed, researchers have attempted to asses how good these systems support the user fulfilling a task. There are a lot of techniques and metrics to measure the usability of a system. An obvious example is to measure the time the user needs to accomplish a task with the system. This time can be compared to other times measured by solving a similar task with a slightly changed system. The results can then be compared to find out which system design alternative supports the user more by efficiently solving the task. A second method is to observe and measure the success or failure rate while performing a task. [Nie, Usability Metrics] further proposes to ask the user about the subjective satisfaction he has while using the system and solving tasks with it.

The difficulty to measure UX arises from the difficulty to measure and quantify the key components of it like emotions because they are very elusive, personal and subjective experiences. Observing the user's behaviour and expressions are common to predict the experience a user has with a product. It is also common to let the user fill out questionnaires. The thesis [Zim08] deals with different methods in detail.

For measuring the hedonic and pragmatic qualities of a product which are key influences for good usability and UX there is an online evaluation tool called "AttrakDiff" ([Gmb12]). This tool has been developed in collaboration with Hassenzahl. The evaluation is based on a questionnaire which consists of contrasting word pairs. Between each pair there is a scale parted into seven intensities and the user has to vote for the intensity he experienced while using the system.

Respectively seven of the word pairs are combined to measure a specific product quality of these four:

- Pragmatic Quality: Describes how successful someone is achieving their goals.
- Hedonic Quality - Identity: Describes if the user can identify with the system.
- Hedonic Quality - Stimulation: Describes if the user is stimulated by the system.
- Attractiveness: The overall attractiveness and value of the system.

The AttrakDiff framework will be used later to evaluate the quality of the developed prototype.

A good quote to close this section about UX and Usability up might be the two last lines of [HT06]:

> *"From our perspective, one of HCI's main objectives in the future is to contribute to our quality of life by designing for pleasure rather than for absence of pain. UX is all about this idea."*

2.2. Related Systems

This section introduces some systems and the findings made during their development process which may influence the design process of the social display developed in this thesis.

2.2.1. Public and Semi-Public Displays with Social Aspects

In this subsection some other public or semi-public displays with social aspects will be presented.

TwitterSigns The TwitterSigns display [Buz10] is a public display which shows Tweets. It was tested in the several locations within university and the times the people looked at it were compared to the times the people looked at the usual university information display.

To make the passers-by more aware of the happenings in the immediate environment of the display two ways for retrieving Tweets were chosen:

- Following the other Twitter users: The Twitter account of the TwitterSigns display follows
- Twitter Search for nearby Tweets: The TwitterSigns display searches Twitter for posts which were made in a 25 km radius around it.

To evaluate the success of the display, face detection were used to measure the gazes from passers-by and the time they viewed the display. These times were compared to the time the passers-by looked at the university's normal information display. The individual times the people looked at the display were significant longer than the view times for the university information system. Although the results were not significant, it seemed that the TwitterSigns display gained more attention because the overall view times per day were mostly higher than the view times of the university information display. During interviews they found out that people are more interested in Tweets from people they know or about the university. They also found out that the recency or a close locality is not primarily important for gaining the interest of the people.

One very interesting result were that one person changed his Twitter account photo to a photo of someone else after he realized that his Tweets can be seen on the Twitter Signs display and that the students could recognize him and might get negative impression of him.

ReflectiveSigns ReflectiveSigns [Mül+09b] is a public display which initially shows the content in a random order. The order and time, in which the content is shown, is then gradually adjusted to the audience attention. The system tracks the viewing time of each content and calculates an expected viewing time. This is used as a weight for calculating the probability for this content to be shown next. During the two month of deployment, they found out that the location of a display has a huge influence on the mean view time. The sofa corner and coffee kitchen had the highest mean view times while places which are most of the time just passed like the entrance or the hallway, had lower view times. During interviews they also found out that the rating, if the content is good or not, does not correlate with the actual mean viewing times.

Other Experiences with Public Displays [Aga03] dealt with the question how displays can be designed to enhance the sense of community and togetherness of people. He said

> *"Half the battle in designing an interactive situated or public display is designing how the display will invite that interaction"* ([Aga03, p. 4])

It has been pointed out that it is important for a public display to gain the attention of the passer-by in the first place and invite them to interact. This might happen for example through motions or by making the person curious. Another recommendation they gave, were to keep always in mind how the user can be motivated over a long period of time to use the system. This can happen if the user has the feeling to get something in return for interacting with the product or if the product shows respect and may even remember the user.

2.2.2. Awareness Enhancing Systems for Working Groups

This chapter introduces a system which was developed with the aim to enhance the awareness in working groups.

Notification Collage The Notification Collage [GR01] has been developed with the aim making people in a working group more aware of each other's activities and improving their communication and collaboration. The design is inspired by a collage and the different content elements such as videos, messages or photos can be places freely on the collage. The system can either be shown on each user's desktop PC or on a public display. They found out that a lot of people liked the opportunity to create a sense of presence in the group by placing live videos of them on the display. This helps to get a feeling for who is around in the office.

The system seemed very popular and almost everyone in the group had the Notification collage shown on a second monitor. This is a good example for how interactive systems can enhance the communication in working groups.

CHAPTER 3

Analysis and Design

This chapter deals with the design of the ambient intelligent, social enhancing display considering the findings from the last chapter. Some personas and scenarios will be considered as an aspect of the environment the display can be operated in. Then requirements and design decisions will be described.

3.1. Project Scope

Before the actual design process will be disclosed, the scope and the goals should be repeated again to recall the objective of this thesis.

The focus of this thesis lies on the design of an ambient-intelligent, semi-public display controlled by mobile-gestures and body-motions for co-located working groups to enhance the social connectedness and awareness in the group by creating new impulses for communication and collaboration. Modern technologies like smartphones and depth-sensing cameras will be combined and used to design interactions between one or multiple users and the system.

There will also be some suggestions and contemplations about the motivations for using the system, and it will be considered how the users could be stimulated to use the display in the first place and over a longer period.

In this thesis the designed social enhancing display will be herein referred to as "SocioDisplay".

3.2. Description of the Operational Environment

This chapter should describe a fictional environment for the operation of such an ambient-intelligent semi-public display, which will be accessible with mobile phone and motions, with the aim to give the reader an idea and overview of possible interactions and system functionalities which may result from the combination of these technologies.

For this purpose, some personas of fictional users and some scenarios will be described. But beforehand, a short overview of the general operational environment should be given.

3.2.1. Environment

A typical operational environment would be an office environment or a research lab with a medium group size of about 10 to 20 people working together and communicating several times a week with each other. These environments could possibly benefit from an improved inter-group awareness, which might not just create the feeling of connectedness within the group but also establish new work-related links. Therefore, the usage for personal communication, as well as work-related exchange, is desirable.

The display should be placed in a frequently transited common area like a kitchen or lounge of the working group, due to the fact that a larger group of people can be reached by this. Another advantage is, that most people will be less focused on their work in these areas, and they might be open for additional information than they would be at their desk.

3.2.2. Personas of Possible Users

Personas can be seen as descriptions and archetypes of possible users and are often used in the Human Computer Interaction (HCI) and User-Centred Design (UCD) design process. They can help to point out some characteristics, needs and problems of a user. The use of personas can help to keep the user and the user's problems in mind during the design process.

All personas that are introduced below work in the research lab of a university. They work in different offices, which are possibly on different levels in the building, but run into each other occasionally. Due to their daily work with computers they have a mean understanding of modern technologies and are open minded to new technologies. A bigger part of the group own smartphones and use e-mails and calendar functionalities on an occasional basis.

Researcher has no mobile or is not keen to use the App:

> *Bob is a researcher in the research group. He is shy and loves to be on his own. He is also not very communicative and most of the communication he does is over IM or mails. Bob is neither registered in any social network nor does he own a smartphone.*

Bob is a very shy and secluded person. He might not be very enthusiastic to use a display for enhancing communication and social connectedness. But this kind of persons, which would prefer to be left alone by such an intelligent and stimulating system, should also be considered for the system design.

Research supervisor:

> *Tom is a research supervisor. He is really a man of vast reading, and he is always suggestive of good literature and articles for his students to read. But since he is also a lecturer, he is hardly to catch. But the other way around it is also hard to catch all of the students in the rare time he is around in the research lab.*

Tom is the supervisor and may therefore have not a very personal relationship to the other researchers due to his higher position. The communication between him and the other students or researchers might be more impersonal and work-related.

Researchers with affinity for social interaction and social networks:

> *Alice is a Ph.D. student in the research group for almost 2 years now. She knows everyone in the project team. Alice is very interested in talking about new stuff she found on the internet. She sometimes shows pictures and videos on her smartphone to the group members during lunch. She is a very pleasant and outgoing person, who likes to share working related stories as well as private stories with her colleagues to connect with them. It is no surprise that Alice extensively uses Facebook and Twitter to communicate with her friends and posts a lot of personal things but also stuff related to her Ph.D. topic.*
>
> *But in spite of everything and due to her upbringing, she always tries to preserve a distanced, polite and just-working relationship with her supervisor Tom.*
>
> *Alice is kind of a night person and the later it is the better she can concentrate and work. There are weeks in which she comes to work in the evening, when a lot of people are already gone home and works the whole night. It is quite hard for her to engage with the group in these periods because no one is around in the office when she is.*

Alice is an example for an outgoing and confident person with possibly not many difficulties to connect to other people apart from her slightly nocturnal tendencies to work at night. It would beneficial for her to get a system which makes her more aware of the things going on in the group to feel more connected to it. It could also encourage her to be present in the office a bit earlier and at more busy times, to catch up with the group members personally.

Visitor for a couple of month:

> *There is Betty. She is just doing an internship in the research department of the university and will be there for six month. In the first week she had problems to remember the names of everyone, and she was too shy to ask everyone for the name.*
>
> *Betty is always very interested in the things going on in the research group, even if it has nothing to do with her own work. But on the other hand, she is too shy to ask around and start conversations just to find out what everyone is doing.*
>
> *However, Betty is also very interested in participating joint adventure and would also set up some gaming nights but do not know how to address everyone.*

Betty is a very shy girl. It is hard for her to connect to the group because of that. A system which supports her and make her feel more accepted and connected to the group could possibly help her overcome those issues.

These personas will build the base for the upcoming sections about scenarios.

3.2.3. Scenarios

Scenarios are narrative stories about the personas interacting with the system to solve a problem, achieve a specific goal or as in case, of an ambient intelligent system, they can also describe how the system can interact or react on the presence of a person.

Scenarios can be used especially in early project stages to give the different parties involved in the design and development process an overview of the requirements, conceptions and ideas of the other team members and make it easier to discuss about them. Furthermore, they can help to identify problems by putting oneself in the position of the persona.

The below listed scenarios are supposed to give the reader an overview of the system and possible functions. Many of the aspects and problems occurring in these personas will be addressed in the following sections. However, these personas will rather describe a vision of the system which will be designed here and not every aspect mentioned in the personas will be realized in the design and implementation process.

In the common area of a research group, an intelligent and responsive public display has been installed. It is responsive on the presence of people and tries to react in an intelligent way. Almost every researcher passes the display a couple of times a day because the common area is close to the toilets and the kitchen.

Scenario 1: Newcomer

On Bettys first day in the department she passed by the display which has initially just shown some random tweets and other messages. At first, she did not really notice the display much but when she passed it, the display reacted by stopping to move around the content. This let her pause and aroused her attention. She looked as the display and stepped closer to it.

When she came closer to it the display changed and showed a welcome message. It suggested that she can download the app under a given link. This app would enable her to communicate with the display. But since she was a bit busy she decided to come back later.

During the lunch time she came back to have a closer look at the screen. The system remembered that Betty has been here before and that she is a new user who has not seen the full introduction to the display yet. It suggested her again to install the accompanying app. This time she decided to do that. After the first launch of the app she has been asked if she would like to leave a short "Hello" message at the display to introduce her to the other group members.

Of course, it is the perfect opportunity for her to introduce herself to the new group because she is too shy to do it in person.

One problem, which is indicated by this scenario and which should be discussed later, is the way the user is enabled to retrieve the smartphone app for interacting with the system. This scenario gave Betty a download link which she then would have to type in her smartphone browser. This is not a very effective way.

Scenario 2: Do not Bother me

> *Bob is not very excited about the new display in the common area of the office space. But he is very thankful that the display tries not to bother him much since he has not shown any attention and openness towards the screen the first days he passed it. The system has just remembered that Bob does not want to be bothered. It is able to identify Bob by his figure, size and motion pattern and thus it just does not react if he passes by. It just continues to show some public content randomly.*

The question aroused by this is which feelings this behaviour would arouse. Would Bob feel a bit disintegrated when the screen reacts on every passer-by except him? Another more technical question is the realization of the identification of a person who just passes-by and the prediction of the mood of this person.

Scenario 3: Nocturnal

> *It is Alice's first day after her holiday and she sees at the display that the group members have planned a common lunch together. She has not got any oral information about this because she came to work in the later evening. That would be the perfect opportunity for her to catch up with the latest news and tell the others about her fantastic holiday. She even decides to be in the office early for once.*

This scenario shows that such a system will also bring the people together for common activities, which would not have happened without it. Such things as a common lunch are most often planned verbally and no e-mail is sent around for this. If someone sticks a note on the display, it could also reach people which are not present at this time but at a later time.

Scenario 4: Photo show during Lunch Time

Alice just came back from holiday and wanted to show the photos of her trip to her colleagues during an organized common lunch break, which they spend normally in the common area.

Instead of using her small mobile phone display Alice wanted to use the larger display in the common area. Since she is always excited about new technologies and gadgets, she has been one of the first users of the display and the accompanying app. Within the app she can browse her photos in private and if there is a photo she would like to show the colleagues she is able to just make a throwing gesture towards the display or just flick it with her finger in the direction of the display. The photo is then shown there. It is a lot more fun to view the pictures at the larger display and talk about them.

But then her supervisor Tom entered the room through a door behind Alice. She could not see him but her mobile vibrated and symbolized her that someone entered the room. She did not want him to see her private photos and make a gesture to her body which symbolizes "hiding" and the photo on the display disappeared.

An ambient intelligent system should always be sensitive concerning privacy. It therefore seems like an appropriate reaction to inform Alice, who shares information with a group of people, about the newcomer and let her decide if she would like to continue sharing the information or not. If Alice would like to hide the content, she just made public on the display for the purpose of the photo show, then there should be an easy and quick way to hide the content from people she does not want to share the photos with. It should be considered how such easy and quick ways could look like. One intuitive way has been illustrated in the scenario: She could move the phone to her body like she would hide her mobile phone display from a person looking over her shoulder.

But this scenario should not just be considered from Alice's point of view but also from Tom's. When he enters the room, he can still catch a glimpse of the photo show and

then sees it stopped because of him. Would that not make him feel like an intruder and excluded from the others? But the aim of the display is to bring the people together and should always be kept in mind during the design process.

This scenario shows also a very interesting concept. The small smartphone display can be used as a private display to browse private files and data. If the user would like to share specific files or data, this can be done by sharing and showing it on the larger public display.

Scenario 5: Project Meeting

> *Tom and Alice had a little chat in the common area about the current status of her project. After Alice described her problems to Tom, he had a good paper in mind which could help her. As it happens, Tom just had a PDF version of this paper on his phone. He just "throws" it towards the large social display and Alice could pick it up with her phone.*
>
> *While they discussed this topic Bob entered the room. Tom suggested showing the paper to Bob because he might have some good ideas about it. But Bob does not have a mobile phone and so Tom just made another gesture towards the display. This made the PDF open on the display and now all three can view, read and discuss it. When they left the common area the PDF disappeared from the display because it is not relevant for other people from the project team.*

This scenario describes how the system could be used as a simple short time sharing and exchange tool between people.

Scenario 6: Time relevant private message

> *The guys from the project group are just about to go to the pub after work and Alice just wonders where Betty is because she would like to invite her. She just left her a private message at the display and if Betty will be around again in the next hour, her mobile will vibrate to alert her and call her attention. If Betty decides to look on the phone, she will find a short message that she is welcome*

to join the group in the pub. If Betty will not be around in the next hour, the message will just expire because it will not be relevant any more.

This scenario is very interesting because there are many possibilities how to realize such a private messaging functionality with time relevance. In the scenario the message will just expire at a certain point of time and Betty will not get any notification, if she will not be around the display before the expiration.

But it is necessary to also consider how she could feel if she gets the notification. She might feel bad because she missed the event and regret she has not been around at the right time. But on the other hand she knows that someone thought about her and this might strengthen her feeling of being accepted by the group and connectedness to it.

The above described scenario has no feedback for the sender included if the message were read in time or not. But this could also lead to privacy issues. If Betty would have read the message in time but did not show up in the pub, the other people might think she avoids the other group members.

Scenario 7: Planning a Games Night

Betty loves to do game nights and so she plans to do one with the group members. She has experienced that most people ignore circular emails and she is too shy to go around and ask everyone in person.

So, she wants to use the social display for that. While she is sitting in the common area, she just types in some information and a date for the games night and sends it to the display.

When Alice passes the display, her phone vibrated to make her aware of the new announcement for the games night and decides to join. She makes a gesture which symbolizes "pick up" and the display shows her icon around the announcement to indicate that she will attend. Furthermore, she has now an entry of the games night in her smartphone calendar.

[Fas05] already pointed out that some people are not really happy with reading emails or other messages during their work time because *"Interruption and setting aside time to check messages are two components of the receiving cost of communication"* (p. 2). But he also said that they might be more open-minded for receiving messages in breaks. Especially in lunch breaks the content can be seen on the display placed in the common area and might be paid more attention to it.

Another thing is the gestures described here. It should be considered in a separate section of this thesis what gestures are appropriate, natural and easy to perform for each action and how many gestures should be there over all. Too many gestures might be hard to distinguish and harder to learn for the user, but too few could may not tap the full potential.

Scenario 8: Sharing

> *Betty has found a very interesting, but non-work-related article and she would like to share it with the whole group because she thinks that it would be interesting for them. She uses the display for that and post the link to the article from her smartphone to the display.*
>
> *When Tom and Alice passed by the display, they found the paper interesting and picked it up with the smartphone and then made a gesture to show that they liked it. Betty sees this the next time around and feels encouraged and good about that.*

It might have been easier for Betty to send the paper around per mail but this may have not reached everyone because, as already mentioned, most people get too many e-mails and feel distracted by them in their work flow. They also often delete them after running over them. Since the display is placed in a common area, which is used in the breaks, people might be more open-minded for such kind of content because it does not distract them from working and might even entertain them.

3.2.4. Delineation of the Display Installation

Four hardware components are needed for the display installation. The most apparent component might be the large display for showing all the content. Depending on the actual operational environment, the content should be visible from a distance of about 2 to 5 meters so it should have a size to support these distances.

The display has to be connected to a computer which administers the whole system. The computer program has to manage the content, manage the mobile phone access and evaluate the information about the observed environment. The latter will be realized with a Kinect depth sensing camera.

The last component is rather indirect. The mobile phone is not necessarily needed for interaction with the display. A simple interaction should be enabled without phone to not exclude people without smartphones.

Figure 3.1 shows how the installation could look like. It can be seen that both the display and the Kinect are directly connected to the computer which operates as a server. The Kinect has to be connected via USB and the display is just treated like a normal monitor and connected via VGA or HDMI cable. The Kinect device has an operation range of 0.8 to 4 meters and a horizontal vision angle of about 57.5 degrees ([Cor12]). This should be considered when the location for the installation is chosen.

This figure furthermore shows that the smartphone is also connected to the server, too. In contrast to the Kinect and display connection, this mobile connection is wireless. But it will be defined later in this thesis which technologies will be suited and finally used for that.

The figure anticipates the division of the environment in different interaction areas which make the extent of the interaction depending on the proximity of the user. This will be discussed in a later chapter as well.

For chosing the location, where the display should be installed, the findings from the ReflectiveSigns ([Mül+09b]) display should be considered. They found out that people

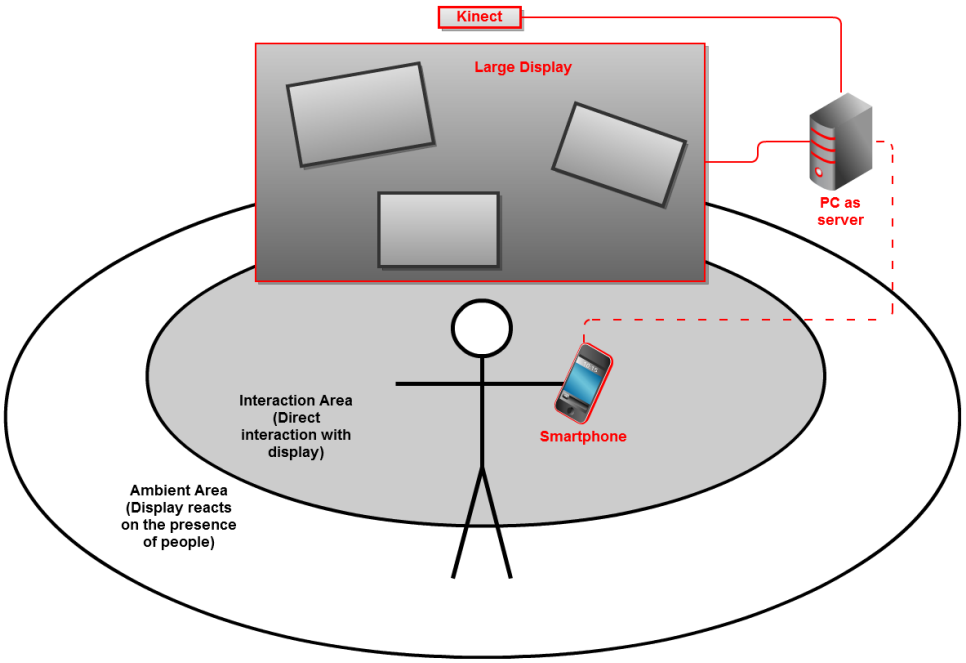


Figure 3.1: Hardware Environment of the Display

looked longer on the display when it has been placed at a location where people stay longer like the kitchen or a seating area than at locations which are just passed like hallways. It will be suggested to place the SocioDisplay in a common seating area where people will have their lunch breaks.

3.3. Requirements for the Display

This section deals with the requirements for the display.

3.3.1. Displayed Content Types

The scenarios showed that the social display can be mainly used to exchange and share content with the group members. This section will describe and argue which content is suitable for this.

Before talking about the content types itself it might be useful to roughly define the actions which can be made with the content.

As the scenarios showed, the content is supposed to be shown at the display. Passers-by can then view it when they are in the area where the display is installed. The user is therefore enabled to consume the content if he is present at the display location.

But it should also be possible to actually share content between one party and the whole group. This means that everyone in the group can pick the content up and store it on the smartphone and consume it any time and as often as wanted.

The third action could be a sharing between multiple attendant people by using the system just as an intermediary. The content will in this case just be shown on the private smartphone screen of the involved people and not on the public display itself.

These above mentioned cases could be expanded by adding a restriction which user or users should be able to consume the content or by defining a time span in which the content is accessible to other people.

Text The most obvious type of content is simple text content. Such a text content could just be structured like a short e-mail or letter. The user should be enabled to leave such a short message in a familiar format, consisting of a header to point out the topic of the message and the message itself, at the display.

The SocioDisplay is just supposed to initiate real-life communications rather than enable the user to just communicate over it. It can be also assumed that most users do not want to read long texts at such a public display. Therefore the message size should be limited to a certain number of characters.

Images Images and photos are always a very visual and descriptive way to show something. When a user wants to describe the beautiful beach, which he has been at in the holidays, it would be much more concrete if he would just show a picture of it. It is also obvious that images are nice to look at and might draw more attention than pure text.

Video Like images videos are also a very illustrative and visual medium. Due to the linkage of many pictures to a moving medium, which is often emphasised with audio, a much richer source of information arises. The same argumentation as with images applies which makes a video file a suitable type of content to share with the social display system.

PDF Documents Portable Document Format (PDF) is a broadly supported format for documents. This means that it does not matter on which platform or in which application a PDF document is viewed, it should look the same everywhere.

PDFs most commonly contain text, images or even form elements. It is also very common to exchange read-only documents in this format like conference papers. It is not practical to show the actual content of the PDF file on the screen. But the file could be offered to download it and read it later. For this the title and a short abstract of the document content could be provided.

Files Whilst videos and images contain information which is visible at the first glance and they may be something to talk about easily, this might not be the case for other files. PDFs can also contain information which might be apparent by knowing the title of the document or some keywords. Images, videos and PDFs can also be catalysts for conversations when people talk about their meaning or matter. Therefore no other files than images, videos and PDF documents should be exchanged.

For exchanging all sorts of file other platforms and exchanging tools like e-mail can be used.

Calendar Entries: To come together and socially interact with each other, it is sometimes necessary to define some appointments for a special activity. This could be non-work related appointments for lunch or a games night as well as professional meetings. The users of the system will surely benefit from offering them to share such a type of content.

To schedule such appointments it is advantageous to mark them in a calendar. Calendar entries are usually defined by a start date/time, the duration, a location and a description or title to indicate what the entry is about.

Content from Other Social Sources Social networks are gaining more and more popularity. Not just individuals use these communication media but also companies and organizations. They use it to share information with customers or other people who are interested in what these companies are doing and news of them.

Such kind of content could be beneficial for the social display users as well. The display could show for example tweets from companies or organizations which are related to the work or fields of interest within the working group. This could serve as a catalyst for new conversations and discussions. But there are already multiple projects dealing with the display of Social Network content on large displays and the focus in this thesis shall therefore be on the other mentioned content types.

Another argument for showing content from external sources is the fact, that it is likely that there are times when no one in the working group creates any content, like e.g. during holidays when just a few people are around. The display should not show content which is old and not relevant any more but if no new input is created by the group members, there is nothing to show. Thus good source for new content could be social web platforms like Twitter.

To sum this up, the following types of content are considered as beneficial for the users:

- Text messages

- Photos
- Videos
- PDF documents
- Calendar Entries
- Content from social networks and in particular Twitter

3.3.2. Privacy Concerns

As mentioned in the description of Scenario 4 and Scenario 6, there are possible privacy issues which are aimed to be avoided. As an ambient intelligent system, the social display should always consider and protect a person's privacy. A system with missing privacy might appear not very reliable to the user.

The user should always be aware of the consequences an interaction with the system has and which consequences this has for his private information and content. Scenario 6 is such a case. It has been described that the sender of a private message can get a feedback if the message has been received or read. The sender of the message could use this functionality to spy on the receiver. If the sender for example asked the receiver to do something for him and then sees that the message has been read, the receiver cannot pretend anymore that he has not received this message. This behaviour of the system can lead to distrust or other negative feelings.

3.3.3. Good User Experience

As mentioned before, User Experience might play a major roll when it comes to the attractiveness and acceptance of interactive systems. It might be obvious that the social display presented in this thesis is not a "necessary to use" professional tool in the working environment, like e.g. a special type of word processor or e-mail client, but rather a voluntarily to use enhancement of the working environment. The main goal of the system is to help the user to feel integrated and more comfortable in the group. This is a very hedonic goal and it seems likely that a system which actually can achieve this goal and make the user feel integrated and connected may be used more often by the

user because he just experiences this in a good way and might feel better. If using the system can arouse mainly positive feelings the user might use it again. Such feelings can on one hand be directly evoked by the system like joy or surprise but they can also be triggered by the social side-effects like the arising communications and a feeling of connectedness.

As mentioned in the Section 2.1.2 about User Experience and usability, a system with good hedonic quality which helps to satisfy some basic human needs like the need for social connectedness lead to a good User Experience and this is definitely desired for the system designed in this thesis. A good User Experience can therefore influence how often people will use the system because this is something which depends on the feeling and attitude they have towards it. A good User Experience is therefore a main requirement for this interactive social display.

The challenge is to design a system which may lead to a good User Experience. This shall be discussed in the next Section.

3.4. Design Decisions for a Good User Experience and User Motivation

As mentioned in the last section, good User Experience (UX) is a main requirement for the social display. But it is challenging or even impossible to design good UX because it something which highly depends on the user and the situation the user is in while using the system. These situations, the users' internal states and former experiences and the environmental factors cannot be influenced directly by the designer. [Fre11] also argued that UX cannot be designed because the designer cannot predict the state the user is in or the situation while he uses the system. He also pointed out that the UX is something that can change and evolve over time. Even the same user can experience the system in a different way during the use because they discover different functionalities of the system or they are in a different situation.

Fredheim therefore suggested designing for a good UX but to keep in mind that this does not guarantee that the user actually will have the good experience the designer wanted him to have. The following sections will describe some decisions made with the aim to improve the chances that the user has a good time and experience using the system and motivate him to come back and use the system again.

3.4.1. Motivating the User to Pay Attention to the System

A user passing-by the first time might not notice the display or just ignore it for the fact that he assumes that it cannot provide valuable information for him. This effect has been discovered in connection with advertising public displays and it has been named as "Display Blindness" ([Mül+09a]). But even if the user might notice the display, he might not know that it is available for interacting with it.

The first problem to solve is therefore to gain the users attention. This can be made by using movements. Moving objects are more likely to gain attention than static ones. The SocioDisplay should have access to a depth sensing camera which can be used to observe the surrounding area and detect the presence of people. This functionality can be used to just show movements when someone is around. For example, a person passes the display for the first and in this moment it shows a slight movement just to be seen from the corner of the passer-by's eye. This could gain the attention and even make him curious if this movement was just randomly shown or if his presence has something to do with it. On one hand this could be a good method to make the user aware of the display and even of the fact that it has a camera attached that reacts on the presence of people which in turn could make him realize that this system not just react on people's presence but also on their gestures and movements which leads to innovative form on interactions with it.

On the other hand such behaviour could scare the user and lead to distrust. Especially when the Kinect or any other camera is not visible at the first sight the user could come to the conclusion that he has just imagined the movement and feel sad about this. But even if the camera is visible the user might not like the fact that he has been observed and filmed.

If the movement which is intended to gain the user's attention is too fast, attention-seeking or to abrupt it might distract passers-by which are busy at the moment. This is also an undesired behaviour.

To sum this up: The movement which is intended to attract the attention should be subtle and continuous. To make it more comforting and show a higher degree of presence awareness the type or execution of the movement could even depend on the direction the user is heading to. If he is entering the field in front on the display from the right sight the movement could begin at the right sight and follow him while passing-by.

3.4.2. Motivating the User to Actively Interact with the System

The next barrier after attracting the user's attention is to get him to use the display and actively interact with it.

Overall it can be said that it is tricky to design an innovative interactive system without the need of a manual describing how to use it. It is not desired that the people in the working group have to read a manual first or get an introductory session to get to know how to use the display and to learn what it is meant for. It would be the best if the users would explore the system by themselves and it could even be the first communication impulse if they explore it as a team and talk about what they found out.

The keyword to achieve this is a good *affordance*. The theories of what affordance actually is, are slightly different and just a short abstract should be given. It should be focused on the theory of D. A. Norman. He defined affordance as follows:

> *"...the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. [...] Affordances provide strong clues to the operations of things. Plates are for pushing. Knobs are for turning. Slots are for inserting things into. Balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction needed."*
> [Nor88, p. 9]

An example can be a push button in the real world. Such a button often bunches out of the surface he is placed on and it often can be seen that there is a gap between the button and the surface surrounding it. This can be a hint for someone that pressure can be imposed upon it and that it eventually will move. The pendant for this is a virtual button on a website or in a computer program. Buttons are often designed with a shadow effect to make them appear bunching out of the underlying surface and let the user get an idea of what to do with it and that he can press on it.

The definition of Norman also points out that object with affordance do not need an instruction to get the user know what to do with it. This is important for the SocioDisplay system because the user should get a clue of how to use the system and interact with it without reading a manual.

The first step to make the user find out about the ways of interaction is to make him realize that he can interact with it and how this could happen. The display already reacted on the presence and moving direction of the user so he might get the hint that the system is able to detect him as a person and that it also can detect movements from him. He could even be more supported in this process if the content appearance changes when the user pays attention to it. It could change from randomly ordered content into a more ordered layout which invites him to interact with it and explore the content. The layout and graphical design of the screen will be described in the next section 3.5

But the user should not just be aware of the fact that he can use motions to interact with the system but also get access to the corresponding smartphone app to create and share own content. Over the last years, QR codes got very popular because they provide an easy opportunity to share and spread information. QR codes can encode word, telephone numbers or links to websites which then can be read with special barcode readers or special smartphone apps. Figure 3.2 shows a QR code which has the string "SocioDisplay" encoded.

They became very common to provide quick access to websites for smartphones because the user does not need to type in the URL anymore but instead he just can use an app which decodes the QR code and let the user access the URL or the text encoded inside. The SocioDisplay could also show a QR code when a user shows attention to the screen.

Figure 3.2: QR code with the word "SocioDisplay" encoded

Most smartphone users know what to do with such a code. After scanning the barcode with an according app the user can be redirected to a webpage where he can find a short introduction and a download link for the app.

Social embarrassment can be an inhibiting factor when it comes to animate the user to interact with the system. Some people might feel weird if they perform gestures in front of a display where other people might see them. But this will not be surveyed further in this thesis.

3.4.3. Motivate the User to Repeatedly Use the System

It is not just important to motivate a user to use the system for the first time and explore it, it is also important to keep him motivated and interested in using the system. In general it can be assumed that the user will most likely use the system again if he gets some for him valuable experiences and information which in addition outbalance the costs for receiving these experiences. For example, if the user experiences that he has to spend several minutes doing something with the system which has merely any use for him, he will not use it again. This is a simple cost-benefit-calculation. The aim of the designer is now to lower the receiving costs and to increase the benefit a person has by using the system.

Lower the cost for using the system To lower the increasing cost has a lot to do with the efficiency and therefore usability of a system. A system which is designed to optimally support the user by efficiently solve a task has a lower cost for the user. Next to the characteristics introduced in Section 2.1.2 the usability criteria of [Que01]will be considered.

He has introduced the five E's of usability. They are:

- Effective
- Efficient
- Engaging
- Error Tolerant
- Easy to Learn

These were adapted to create some examples which help to increasing the usability for using the SocioDisplay.

The effectiveness of a system describes the fact if the system supports the user to successfully complete a task. For the SocioDisplay this could mean if the gestures the user performs are detected in a right way because otherwise he would not be able to use these gestures to perform the task.

The efficiency describes how fast a task can be performed. The user must have the chance to easily and quickly access the information he wants to get. An intelligent system could support him by finding out and learning about his interests and show him the according content.

For every input, a response or feedback should be given almost immediately and with just a short delay to avoid the user wondering if the system currently processes his request. Missing feedback can lead to frustration or confusion because in real life the user is used to feedback on actions. For example, if a user presses a button in real life the button moves down which is a haptic feedback in itself. If the user clicks on a button in a computer program by using a mouse, it is beneficial to give him a similar and instant feedback like e.g. changes in the colour of the button or the relief of the button

image. Often the buttons are designed with a shadow effect to make it appear bunch out of the surface and when the user presses the button this effect changes to make the button appear pressed into the surface. But also feedback on actions which are not adapted from real life actions is important. If the user started to invoke a process then it is good to inform him on the progress of it. Good placed and timed feedback can help to increase the efficiency and effectiveness of a system because the user does not have to spend time wondering if the system is processing his input. It can also help the user to successfully accomplish a task.

The engagingness has a lot to do with the visual appearance of a system and like it can be perceived and cognitively processed by the user. This can comprise how the colours of the system will support the user in retrieving information. For example: The colour red can make the user pay attention to the coloured object.

Simple navigation can be a criterion for engagingness: If the navigation is too complex the user may have problems finding the functionality he wants to use because there is too much information shown at one time. If a system has very much functions to offer it is advantageous to design and implement a hierarchical navigation. If there are just a few functions a hierarchical navigation may be too oversized and would rather confuse the user than help him finding the right function.

The error tolerance describes the ability of the system to handle errors made by the user and how they can be prevented in the first place. The SocioDisplay should be error tolerant. This means a wrong action from the user which is not allowed is restricted by the system. Especially if gestures might be used for input the system should detect gestures which are not allowed in the current context and make the user aware of this with a feedback that this was a not allowed gesture. Otherwise the user might wonder if he has not performed the gesture in a right way and tries it again. The results are similar to missing feedback which has already mentioned above.

Another point for supporting the user by using the system is to give him the option to easily undo mistakes he made or to change his mind and wants to revoke an action he made. It is human to do mistakes and a system should always support the user to erase these mistakes.

If a user is able to learn quickly how to use the system then he can begin to use all the functionalities of the system earlier. The SocioDisplay is a tool with just a few functions and it should be easy for the user to use it. Therefore it should be self-explanatory and simple.

The sending cost for posting content could drastically lowered if the restriction of just posting content while actually being present in the adjacencies of the SocioDisplay, would be lifted. The user than could post content from anywhere and would not have to move to the display to do so. But this is not how the system should be designed. It is an intentionally design decision not to offer this functionality. The area around the display should be a place where people come together and the user should feel like this is a comfortable place and therefore he should be willing to accept the higher costs for sharing the content with his work colleagues through this medium.

Increase the benefit a user has when he uses the system At this point it should be more focused on increasing the benefits a user can get from the SocioDisplay. The whole idea of this is to bring people in the working group closer together and improve their awareness and relationship. Feeling connected to other people and socially connected is something which improves most peoples well-being because it is a human need to socialize with other people. If this could be achieved by such a display it would be a propulsive factor for the user to use the system frequently. The question how this can be archived should be answered below.

It the user is just able to post content and not to respond to content the communication direction concerning this content is just unidirectional. To a certain degree this is a welcomed behaviour because the SocioDisplay is just meant to be an impulse for real-life communication and therefore communication solely over the channel of the SocioDisplay is not desired. If the user sees something on the screen and really feels the need to talk about that, this should be done by a face-to-face conversation. But if the user can just create content which is then totally independent from the other content shown and he cannot respond or interact with other content in any way, the system would easily become boring and cumbersome. Sometimes the user maybe just wants to express that he likes something someone else has posted. To actually go and call on

this person just to tell him that the content is appreciated and liked would simply be too time-consuming and almost no one would do that. Social networks like Facebook or Google+ offer an easy option for the user to express the enjoyment of the content without much effort. Facebook offers a "like" button while Google+ users have the "+1" button to express that they like something someone else has shared or posted. The user just presses a button and that is it. A user of the SocioDisplay should also have such an option to easily express the liking for something posted on the screen. This creates a slightly bidirectional communication without the risk of shifting more complex conversations to the SocioDisplay channel.

The adoption of a "like" functionality has also the effect that it is very easy to reward people for interesting content they shared. On one hand this encourages people to share valuable and interesting content. The user who posted the content can also gain an insight in what his colleagues endorse and like and what not. On the other hand the act of being rewarded is a very pleasant feeling and it can enhance the sympathy and feeling of connectedness and relatedness in the group.

But just expressing the enjoyment for something posted is not the only content interaction form offered. As mentioned in Scenario 5, Scenario 7 and Scenario 8 the user could also pick up content which was shown on the screen. They were hence enabled to get a PDF document on their phone or a calendar entry which can be inserted in the smartphone calendar. That might abet the user to come back to the display and check if someone has posted new content which may be interesting for him. The condition for this is that other users produce new content. If hardly anyone produces new content there is not much reason to come and view the display of new content is there because it is most likely not. It has been mentioned before that resources like Twitter or other social networks are predestined to be used as a source for new content which matches the interests of the work group members. For example, the SocioDisplay could show Tweets from local facilities or cities to gain the attention of the group members. This could also be used in the initial phase of the display when no one has posted content yet.

The last point which should be mentioned here is an attractive appearance of the display. It should look appealing and maybe even beautiful to the user. This might lead to more

joy the user perceives using the system and might also animate him to use it again. The next section will describe how the graphical interface has been designed.

3.5. Designing the Graphical Interface and its Different States

This section describes how the graphical interface and the appearance of the SocioDisplay have been designed. A pleasant appearance can be helpful to get the user using the system. It may also influence the atmosphere in the surrounding are. All this has to be considered by designing the appearance.

3.5.1. The "Fish Tank Design"

For overall theme of the SocioDisplay an underwater theme has been chosen. It is commonly known that the colour blue has something calming and relaxing. Many people also experience watching a fish tank very calming. Is has been decides to use such a calming design for the SocioDisplay because the space around the display should be a relaxing and comforting zone. A users spending their time in the common area or wherever the SocioDisplay might have been placed, should experience this calamity. The design should almost be art like. But it is on the other hand not supposed to obtrude and distract. Therefore the colours red or orange would be to attention seeking and not suitable for the SocioDisplay.

All this can be achieved by using blue and turquoise colours. Colour gradients can also help to create a pleasant and enjoyable appearance and they also make the display more premium and less boring. The display should also have just a small colour spectrum because too much colour variation can appear uneasy.

To make this a bit more modern and interesting and of course to support the underwater theme some slowly moving and rising bubbles can be added in the background. The purpose of the moving bubbles is not to arouse attention in the first place then rather to

make the display more attractive and interesting. These rising bubbles therefore should be moving very subtle should not push themselves into the foreground too much.

3.5.2. The Content Presentation and the two Animation States

After the general theme of the display has been discussed it is time to talk about the way the content is presented to the user. In a previous section is has been mentioned that there are different types of content destined for the SocioDisplay like e.g. simple text, pictures or calendar entries. Even these content types have different natures they should be presented in a mainly consistent form. The content will therefore be presented on a panel.

Figure 3.3 shows how the different information of each content type can be placed and presented on the panel. The rounded corners shown in this draft should also be retained in the prototypical implementation because they look more smooth and pleasant than angular corners.

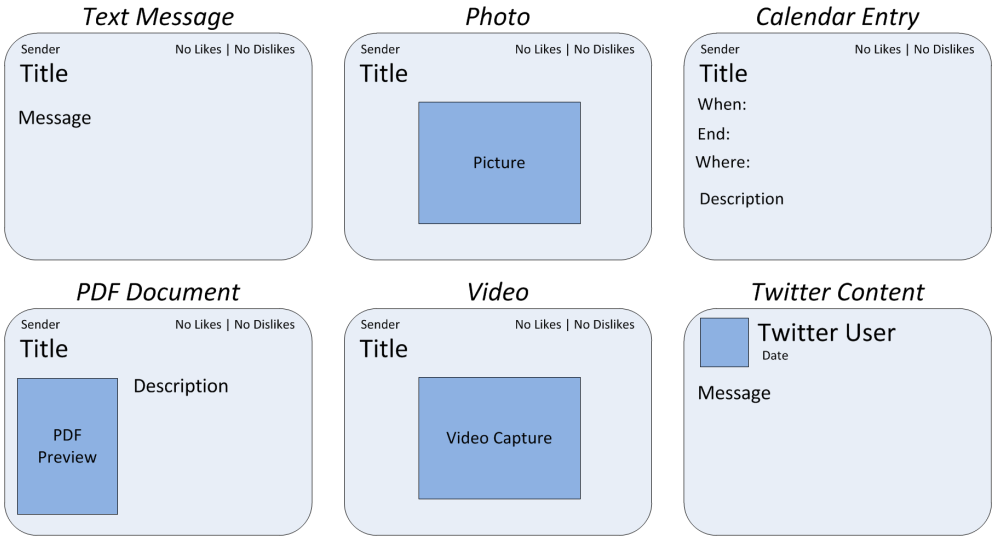


Figure 3.3: Draft of the Content Panels

These panels can now be placed on the Social Screen. How this can be done will be surveyed now.

The SocioDisplay is enabled to track the presence and proximity of people in the environment around the display. This information can be used to build different states of how the content is presented. It has also mentioned before that the proximity of a person is important to detect in which interaction area he is. There are respectively 3 interaction areas:

- Outer Area: The area cannot be detected by the Kinect and there is no reaction on people in this area.
- Ambient/Proximity Area: The presence of someone can be detected and the display can react accordingly to gain interest. But no direct and willing interaction with the display is possible.
- Interaction Area: To actually interact with the system and to share content, it is necessary to be close to the display. The area for this is the Interaction Area.

It is beneficial to present the content in different ways depending on whether someone wants to actively interact with it and therefore is present in the Interaction Area of if no one is around or someone just passes by and does not want to interact with the SocioDisplay right now.

Randomly Floating Content If no one is in the direct adjacencies of the display or someone is just passing by then the content panels can be floating around in the underwater environment. This should also be a smooth and soft movement which does not push too much to the foreground. Even if someone is sitting in the common area and for example eats something he can also watch the moving content and read it.

The same rules as in with the raising bubbles in the background apply. The motion of the content has to be smooth and not too rushed because otherwise it would distract or flurry the user. The speed of the floating content could be adjusted to the speed of the background bubbles. The moving content can also arouse the attention of people because it is human to pay more attention to moving things than to static ones.

Ordered Content for Interaction If someone comes close to the screen and therefore shows the intention to actually interact with the display, the content alignment should transform to be more accessible and searchable. This is a tricky thing to achieve. The SocioDisplay has no input devices like a mice or a keyboard. All the input can either be done with the mobile phone or with motion gestures.

It has been discovered that it is possible to get mostly accurate results by using the Kinect data to detect where a user is pointing his finger at. But this will not be used for this system. It has been chosen to design the SocioDisplay in a manner that one content is in focus at a time and the user can than interact with this content. The user can then perform actions to change the content which is currently in focus. Which actions this could be will be discussed in a later section for gestures.

The graphical adjustment of the content panels is modelled on a horizontal wheel. The content is attached to this wheel. A wheel usually implies that it can be rotated. This is the way the content can then be browsed. If the wheel rotates the content fixed to it rotates too. The content currently shown in the middle of the screen is the content currently in focus. In addition, the content currently in the middle and therefore in focus could be highlighted to make the user more aware of that fact.

Figure 3.4 shows a draft of the content alignment in an ordered and searchable form[1]. To browse the content two different input gestures will be needed to either rotate the wheel to the left or to the right side.

Something else can be extracted from the figure. The content is aligned on different layers along the wheel. The layers have been chosen to represent the current popularity of the content. A content which is very popular will be aligned on a higher level than content not so popular.

[1]It may be noted that although the content panels on Figure 3.4 is shaped as an ellipse the shape of a rounded rectangle as shown in Figure 3.3 will be kept for the implementation.

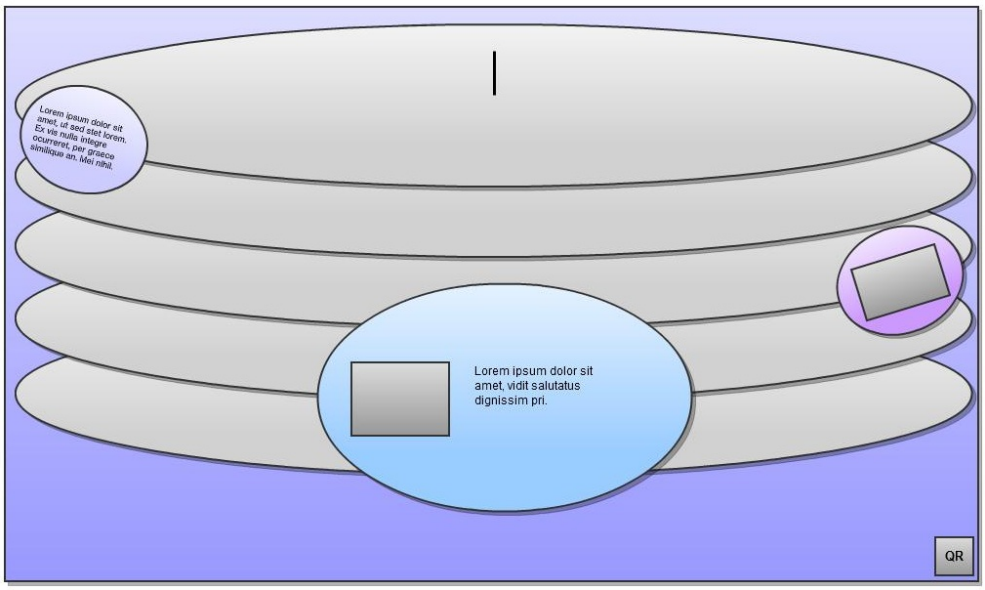


Figure 3.4: Draft of the Content Alignment

3.5.3. Other Attention-Arousing Graphical Elements

When a user passes the display it should gain his attention. It has been mentioned in subsection 3.4.1 that this should happen with a subtle and continuous movement shown at the display which shows a high degree of presence awareness by depending on the direction the user is heading to. Since the theme of the SocioDisplay is motivated by the underwater world a wave would be a good movement for this purpose. It could also depend on the direction the user is entering the field in front of the screen by starting at this end of the display and then spreading in the direction the user is heading to. Multiple slightly shifted and interfering waves could ripple over the screen.

To make this even more realistic these waves could also make the background bubbles and the content panels swing. Seen from the corner of the eye of the passer by this could be a subtle and unobtrusive way to seek his attention and make him aware of the fact that the SocioDisplay can detect his presence.

3.6. Designing Mobile-Motion Gestures and Interactions

This section will described what suitable body motion and mobile interaction will be designed for interacting with the SocioDisplay. The interactions with the display can be divided into motion-only interactions which do not require a mobile phone because they are not depending on knowing who actually interacts with the system and mobile-motion interaction. This indicates that sometimes the mobile phone is just needed to identify the user. These interaction and the interactions which actually need the mobile phone as an input device are named as mobile-motion interactions.

But before these two actions will be described, a feature of the Kinect and the software libraries[2] to access it has to be introduced. It has been mentioned in the introductory chapter that the Kinect is a device which equipped with a depth camera and a normal camera. The Microsoft Kinect SDK and the OpenNi library are now able to use this data to create a skeleton representation of a person who stands and moves in front of the Kinect. Such a Skeleton is a 3D representation of this person consisting of the calculated positions of the person's joints in the 3D space. These joint positions can be analysed to detect the pose a person is striking. If the skeleton data is analysed over a time period then movements and therefore gestures can be detected. Some illustrations in the following sections are based on a 2D mapping of the 3D skeleton data recorded.

3.6.1. Motion-Only Interactions

The motion only interactions are not relying on knowing who perform them because they cannot identify the user without a mobile phone[3]. To fully experience the functionality of the SocioDisplay it is essential to use it in combination with the corresponding mobile phone app. There is just one action a user should be enabled to do without being identified by the system and this is the browsing of the content posted on the display.

[2] The Kinect and its libraries will be discussed in a more detail in section 4.1.2 and 4.6

[3] It might be possible to identify the user by using other techniques like face recognition of the analysis of the body shape and body movements, but these are not considered here.

In the last chapter the two animation states has been introduced. The way the content is presented depends on the presence and distance of a user. If a user enters the Interaction Area in front of the display the content presentation will transform into the ordered mode. It has also been illustrated that this ordered mode adapts a horizontal lying wheel with the content fixed on it which can be rotated to show the other content.

The rotation axe is vertical and therefore the content is moving horizontally. To initiate the rotation the swipe gesture has been chosen. To perform this gesture the user has to put forth his arm and hand and then move it either to the right or to the left to rotate the content to the right or to the left. Figure 3.5 illustrates this gesture.

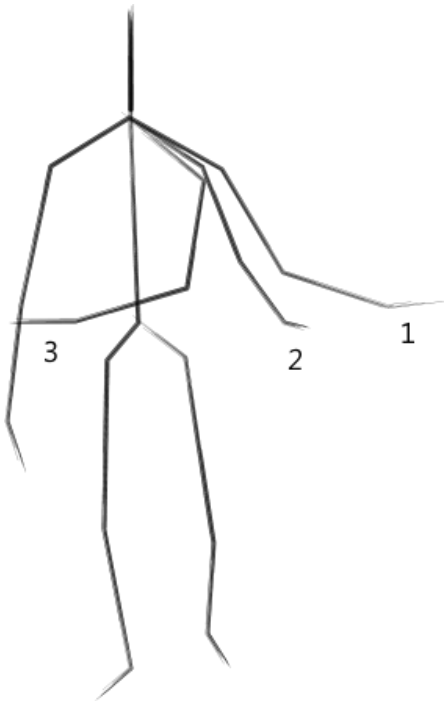


Figure 3.5: Illustration of the Swipe Gesture

3.6.2. Mobile-Motion Interactions

As Mobile-Motion Interactions, gestures are referred which are performed with the need of a mobile phone being in use by the person who is willing to interact. The mobile phone has two functions. It can on one hand be used to identify the user by looking up the mobile phone he uses and on the other hand it can be used for some actions which

require mobile phone as an input or output device. But first the process of identification of the user will be discussed.

The Wave Gesture To wave someone can be interpreted as a form of greeting. In this case the wave gesture will be used as a welcome gesture. The problem is that if multiple users are around in the area in front of the display and a mobile phone connects to the SocioDisplay, it is hard for the system to predict to which person the mobile phone belongs. The purpose of the wave gesture is to help the system to match the mobile phone user and the person detected by the Kinect together.

If a user starts the mobile phone app he will be asked by a message appearing on the phone to perform the wave gesture in front of the display. The system now can detect the person and his skeleton and can match this to the mobile phone he uses.

The wave should be performed with the hand the mobile phone is held in. The acceleration data from the mobile phone's acceleration sensor can be matched with the skeleton movement tracked by the Kinect. If the user performs this action with his mobile phone in the hand then there will be a higher acceleration which can be measured.

The Throw Gesture The user should be enabled to post content he has generated from the mobile phone to the SocioDisplay. For this action the Throw gesture is designed for. The gesture symbolizes that the user throws the content from his phone to stick it on the SocioDisplay and show it there. This gesture is quite tricky because people might have a different execution how this gesture might be performed in mind. One possible execution is illustrated in Figure 3 6. This shows a user initially holding his arm close to the body and then moves it down.

This gesture is meant to be performed with a mobile phone in the hand performing the throw gesture. One reason is that this supports the metaphor of throwing the content from the phone to the display. On the other hand it could also be used to verify if the right mobile phone has been matched to the person performing the action.

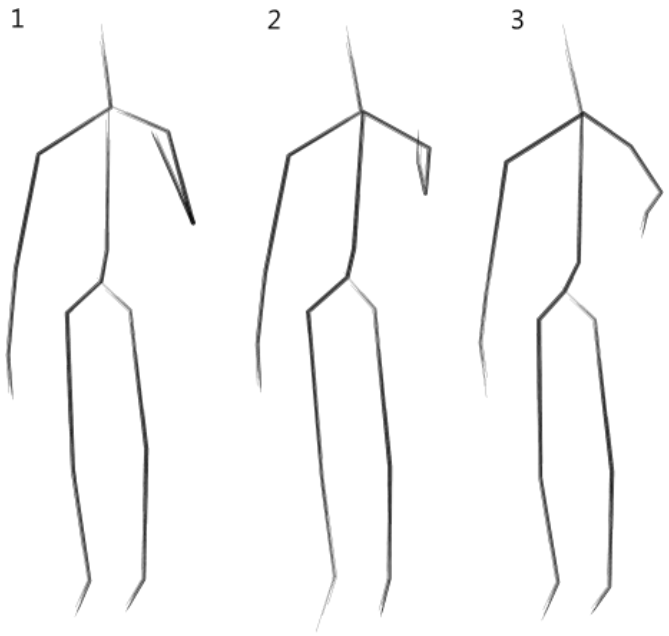


Figure 3.6: Illustration of the Throw Gesture

The Pick Up Gesture The Pick Up gesture is the counterpart of the Throw gesture. The user this time does not create content with the mobile phone but retrieves it from the SocioDisplay. Therefore this gesture could be realized by letting the user perform the Throw gesture the other way around. So the illustration in Figure 3.6 could be read from the right to the left. This means the Pick Up gesture would start with the user holding the phone in front of his body and the makes an upwards movement with his arm and bring his arm close to his body until the hand is in front of his shoulder. The user should also use the arm with the mobile phone in it for this gesture to use the mobile phone's acceleration data for evaluation if the performer has been identified as the right mobile phone user.

Thumbs Up and Thumbs Down Gesture The last action apart from browsing, posting or picking up content is to vote for content. On one hand the user should be able to like content or to show that he does not like it. A gesture very common for expressing that something is well done is to show thumbs up. The opposite is the thumbs down gesture. These two gestures or poses should now be used to express these opinions and vote for content.

CHAPTER 4

Details of the Prototypical Implementation

This chapter describes the details of the prototypical implementation and comprises aspects of the software and hardware environment and architecture as well as specifics about the server implementation.

4.1. Chosen Software and Hardware Environment and Architectural Overview

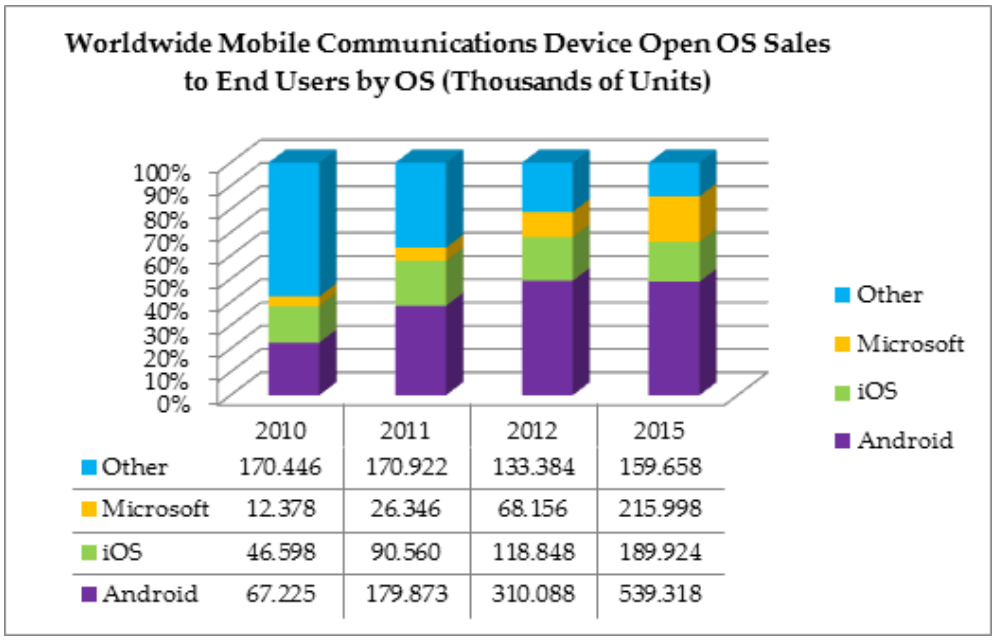
The following sections will detail the aspects for the chosen hardware and software environments and give an overview of the architectural realization of the prototype.

4.1.1. Mobile Platform

Mobile devices and especially smartphones enjoy great popularity. The following graphic shows that especially Android devices are very popular amongst the users.

As seen in Figure 4.1 the percentage of sold Android devices increases every year. In 2012 it almost every second sold Open OS mobile device has been an Android device. Open OS means in this context a device running an operating system with a public available

software development kit. Other operating systems of this category are amongst others Blackberry OS, Symbian or Bada.



	2010	2011	2012	2015
Other	170.446	170.922	133.384	159.658
Microsoft	12.378	26.346	68.156	215.998
iOS	46.598	90.560	118.848	189.924
Android	67.225	179.873	310.088	539.318

Figure 4.1: Worldwide Mobile Communications Device Open OS Sales to End Users by OS (Thousands of Units) (based on data from [Gar12])

The different smartphone operating systems have advantages as well as drawbacks for the owners and developers. The three operating systems iOS, Android and Windows phone should be highlighted further:

iOS Apple's operating system iOS is the only one of the three examined operating systems which is just sold on Apple devices. This gives the benefit that the operating system can be attuned more precisely to the hardware. This also means that programmers do not have to deal with adapting their apps to the different hardware and specifications of the phone like screen resolution or the absence of components used by the app like for example a gyroscope. This excludes the backwards compatibility with older Apple devices which have a different hardware than the newest version.

Another benefit of the Apple mobile OS is the restricted access to the app store. This means that every app submitted will be verified and tested. Just approved apps can be offered in the Apple App Store.

The access to the file system is also very restricted and every app operates within an own sandbox [App12]. In general, it is not possible to access files outside of the own sandbox directory except through public system interfaces which enable an app to access things like user's contacts or music stored on the device.

A drawback for developers might be the restriction of the development environment to Apple computers. This means that iOS apps are just supposed to be developed on Mac OS systems using the Objective-C programming language. Apple provides a comprehensive environment for the app development including amongst others a visual designer for the graphical interface and an app profiler for observing the app's performance and consumed resources.

Windows Phone Windows Phone is the successor of Microsoftś operating system Windows Mobile and was released in 2010. It is characterized by a very modern looking and typography-based user interface called Metro UI. Unlike iOS it is designed to run on devices from different manufacturers. However, Microsoft made some demands on the hardware including amongst other things like a minimum processor speed of 1 GHz and GPS functionality. [rec10]

Microsoft has also a restricted app store and submitted apps will be approved first before they are offered in Microsoft's Marketplace.

Another similarity to the Apple iOS is the access to the file system. The apps just have access to their own isolated storage [Mic12b] and cannot access the underlying operating file system or the isolated storage of other apps.

Apps for the Windows Phone are developed in Microsoft's Visual Studio with the programming language C# and the graphical user interface will be defined by the XAML language which is designable via a visual designer. For a more advanced graphical design programs like Expression Blend are offered.

	iOS	Android	Windows Phone
Development Platform	Xcode on MacOS	Eclipse with plug-in on various platforms	Visual Studio on Windows
Programming Language	Objective-C	Java	C#
File System Access	No, access restricted to the app's sandbox	yes	No, access restricted to the app's Isolated Storage

Table 4.1: Summary of the Mobile OS Comparison

Android Android is the mobile operating system from Google. The first device with the Android OS has been released in 2008 [Tec11]. By now, most of the mobile manufacturers have multiple devices with Android OS in their product line-up.

Android Apps can be developed on Windows, Linux and Mac OS systems using the Java programming language. The developed apps can be offered in Google's app store "Google Play".

In contrast to the above discussed mobile operating systems, Android OS not very restictive. Every app can access the file system and also access files from other apps, too. This could be considered as a security issue but can also be seen as an advantage.

The following table will summarize the above mentioned facts:

A very important aspect for the chosen mobile platform is the file access. The social app should have access to PDF documents, pictures and other files to share them with the other users of the app. This functionality would have been very complicated to realize with iOS or Windows Phone.

Another aspect is the popularity of Android. Many researchers in the development area have Android phones and this could be advantageous in the user study phase.

4.1.2. Server Platform

As described in the last chapter the SocioDisplay should react on the userś presence. To track the activities in the surrounding areas a Microsoft Kinect depth sensing camera is used. There are multiple ways to access the data from the device. The advantages and disadvantages of the two different frameworks OpenNI and the official Microsoft Kinect SDK will discussed below.

OpenNI OpenNI is actually the name of the organization which wants to promote the development of Natural Interface (NI) devices and applications [Ope12]. The outcome was an open source framework which provides an API for communicating with the vision and audio sensors of NI devices like the Microsoft Kinect. An advantage of the OpenNI framework is that it also supports other sensors and different sensor types like other depth sensing cameras, infra-red cameras and different microphones.

Microsoft Kinect SDK It took Microsoft a while to release a development framework for the Kinect which has been released in 2010. The beta version of the SDK was released in spring 2011 [Gad11]. The current version of the SDK enables the developer to access skeletons of standing or even seated people and to track the face position and orientation of a person.

In order to complete this paragraph about the Kinect SDK it should be mentioned that it is also possible to track audio signals from the Kinect and that the Kinect SDK provides a speech recognition API in multiple languages [Mic12a].

One reason why Microsoft Windows has been chosen for the server platform is because the official SDK for the Microsoft Kinect is meant to for it. For this project it is not important to support other depth sensing devices or multiple platforms.

Another reason might be that during the evaluation phase there were some issues with the installation of the OpenNI framework which consist of multiple components which

has to be installed in a certain order whilst the Microsoft development kit was very easy and straight forward to install.

Furthermore, the Microsoft SKD provides a lot of reusable samples which makes it very easy to start developing with it. It can be used with the .NET Framework and the .NET programming languages C#, Visual Basic and C++. For the server platform C# will be chosen.

4.2. Content and User Information

Not every content type which has been mentioned in the last design chapter has been implemented in the prototype. The PDF content for example has been left out in this implementation. The focus was on implementing the following content types:

- Text
- Pictures
- Calendar Entries
- Twitter Content

Just the three first content types and the information about the users using the system have to be administrated and permanently stored by the system. The twitter content can always be retrieved from the Twitter platform.

Storage of the Content Types and the User Information For storing the content generated by the users a MySql database is used. The design of the database has been done with the MySQL Workbench. The scheme in Figure 4.2 represents the database for storing the data.

The Entity Relationship Model (ERM) shows the tables created in the database and their relations to the other tables.

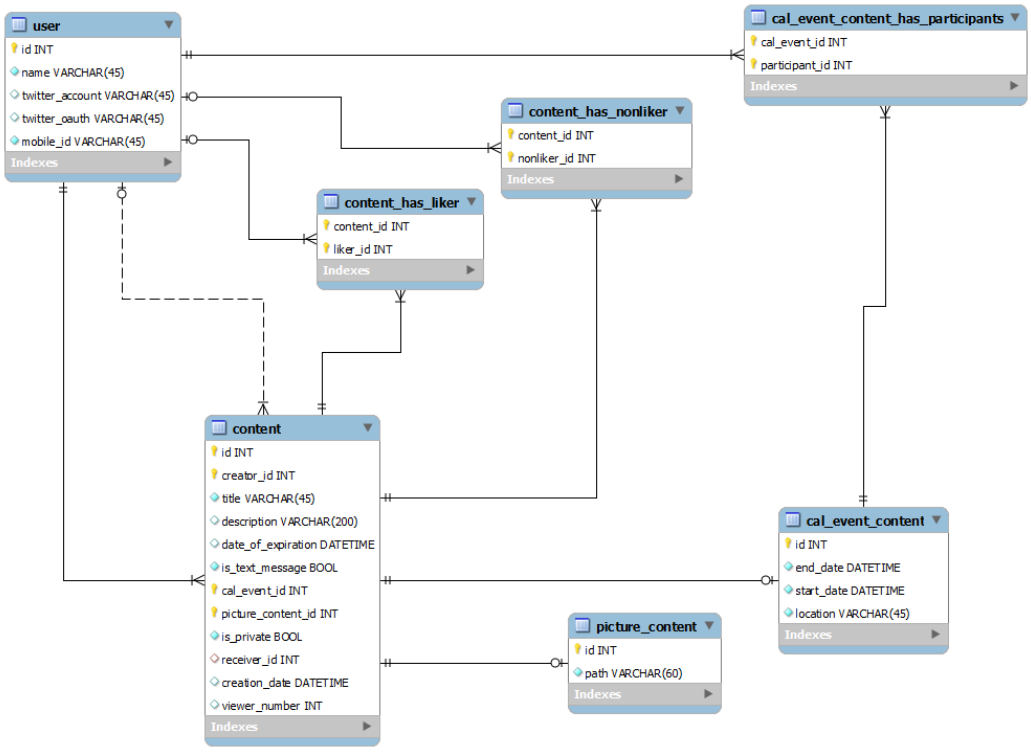


Figure 4.2: Entity Relationship Model of the Database for the Content and the User Information

Every content is stored in the *content* table. If the content is either picture or calendar content than a reference to a entry in the *picture_content* or *calendar_content* table is added. The user is then enabled to vote for this content. He can either like or non-like it. Since every user can like (or non-like) multiple contents and every content can be liked by different users, there has been a many-to-many relationship established between these two tables and a junction table called *content_has_liker* (or *content_has_nonliker*) has been put in between those two tables. Another many-to-many relation can be found between a calendar entry and the participants of the event.

After the database has been created the ADO.NET Entity Framework was used. The Entity Framework is an Object-Relational-Mapping Framework which provides the mapping of relational information of a database to objects. The Visual Studio IDE makes it easy to create a new Entity Data Model out of the database because it offers an option that a new ADO.NET Entity Data Model can be generated from an existing database. The Entity Data Model consists of an .edmx file and a code behind file with the generated code to access the data in the database. The .edmx file will be shown in a visual editor in Visual Studio. This can be seen in Figure 4.3. Every change made will also change the entities generated in the code behind file.

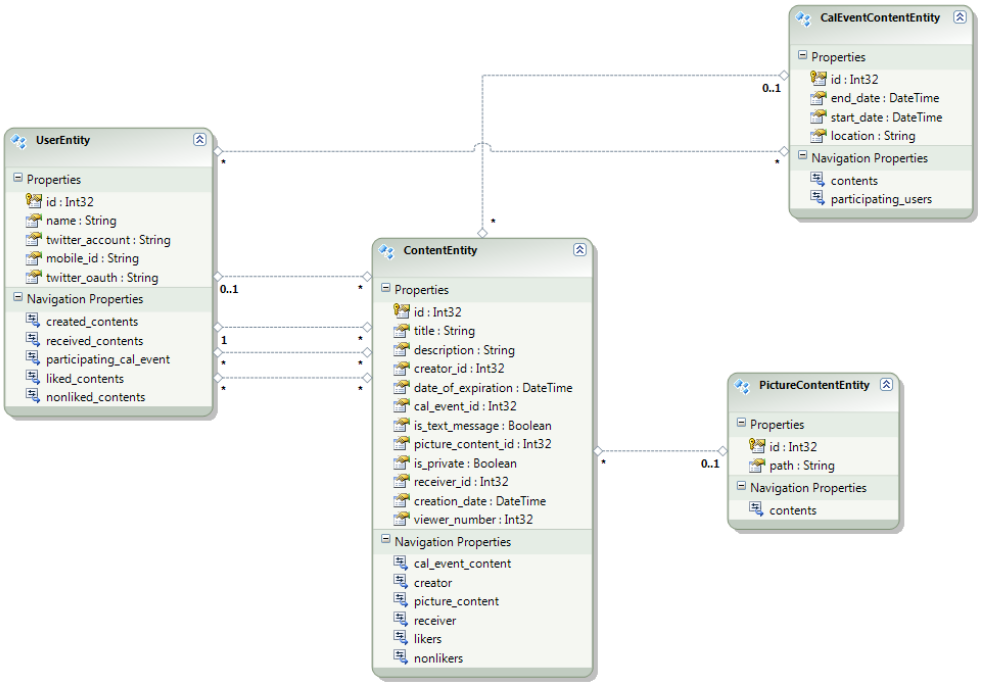


Figure 4.3: ADO.NET Entity Data Model of the Content and User Information

It can be seen that all the junction tables of the many-to-many relations from the ER model are hidden now but the information can still be accessed through navigation properties. For example, the relation between the content and the users who liked this content is a many-to-many relation and to query the information which users liked a specific content is complex to do in SQL. The SQL query would be as follows:

```
SELECT name FROM user WHERE id IN (SELECT liker_id FROM content_has_liker
WHERE content_id =[id of the specific content])
```

To access this information in form of objects in the C# code is in contrast easy and more flexible to handle in an object oriented program.

```
ContentEntity content = socialScreenEntities.ContentEntities
 .Where(x => x.id == 1).FirstOrDefault(); // selects the
    content with the id 1
List<String> userNames = content.likers.Select(x => x.name)
 .ToList(); // creates a list with all username of the users
     who liked the content
```

The `socialScreenEntities` object contains all the entities which are the object pendants to the information stored in the database. The `ContentEntities` represent an Entity collection of `ContentEntity` and therefore the information from the table content in the MySQL database. The information in the entity collections can comfortably accessed with the Language-Integrated Query (LINQ) commands. LINQ can be used to query data in collections, XML or databases. To create a gateway to other components of the SocioDisplay implementation, a class called `DatabaseManager` has been created. This class provides methods for inserting into the database and retrieving content from it. This class will hide the entities from the other parts of the system and will also handle wrong input and complex queries.

4.2.1. Content from Social Networks

The SocioDisplay should show content from the social platform Twitter. There are already multiple frameworks available which support the programmer to access Twitter

with C#.NET. The Spring Social Framework ([Com12]) has been used for this implementation. This framework provides an API binding to the REST service of the Twitter platform.

The content will be retrieved in an interval of 10 minutes and if new content is available an event will be thrown. This event will be caught by the content manager.

4.2.2. The Content Manager

The content manager will observe and handle all the content. The content manager is also responsible for providing the content from both sources - Twitter and the database - to other parts of the system like the graphical interface. The content manager provides therefore a method for retrieving a random next content. In this method it will be decided if content from the database or from Twitter will be returned. There is also a list with content which has been recently retrieved. This content will then be blocked for the selection in this method.

4.3. Animated Graphical Interface

In this section the development of the graphical interface for the SocioDisplay prototype will be discussed.

For the graphical interface the Windows Presentation Foundation framework as a part of Microsoft's .NET Framework has been chosen.

4.3.1. Windows Presentation Foundation

The Windows Presentation Foundation (WPF) is part of the .NET framework since version 3.0. The core of the framework is a resolution independent rendering machine which is in charge of presenting and rendering the user interface. The WPF framework offers controls, layouts, animations and 2D/3D graphics for the development of rich user interfaces. The Extensible Application Markup Language (XAML) can be used to define this interface. XAML is based on XML and is used to define the appearance of a program while the code behind classes are used to implement the logic and behaviour of a program. This separation of appearance and behaviour definition supports the development of the graphical look by designers while programmers can deal with the functionality.

4.3.2. Implementation of the Animated Graphical Interface

This subsection deals with the implementation of the graphical interface. The graphical appearance will be defined in XAML files and then the behaviour of the system will be implemented in code behind. The SocioDisplay is meant to be running on a semi-public screen and the application should therefore be presented in full screen mode without any bordering controls from the operating system like minimize, maximize or close buttons in the right upper corner or the border which is usually placed by the operating system around an application. The application will be, similar to a game, started in full screen mode. WPF Applications can be executed like this if the following properties will be set in the XAML file of the main window:

- `WindowState="Maximized"`
- `WindowStyle="None"`

Now the application will fill the whole screen without any borders.

The main application window view should consist of 3 layers shown in Figure 4.4.

The first layer presented here is the background layer.

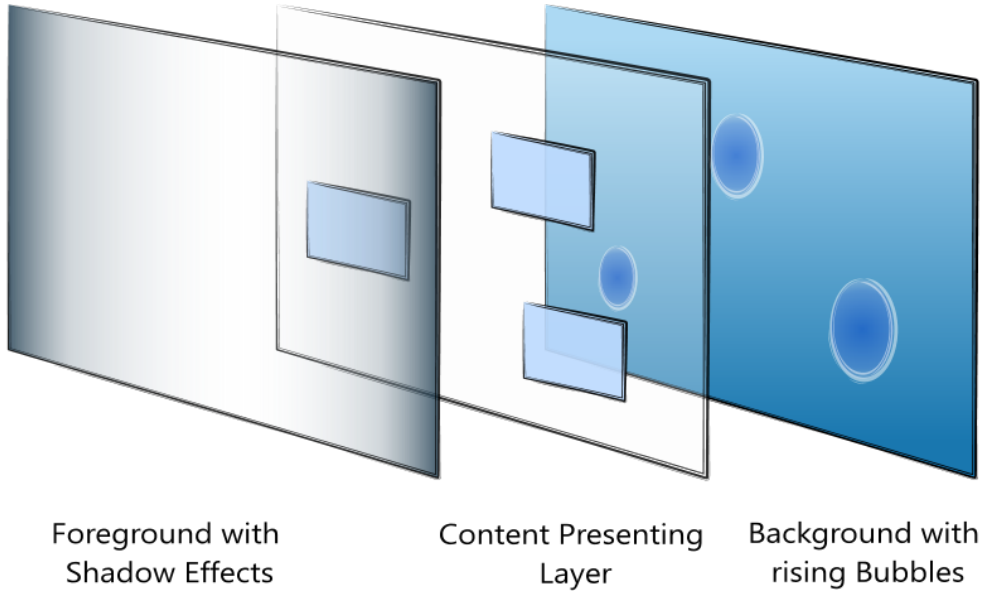


Figure 4.4: Layers of the Graphical Interface

The Bubbly Background The theme of the SocioDisplay should adapt a calming under water atmosphere with bubbles moving and rising in the background. The colour scheme of the display will be blue with a hint of green. To make the appearance more comfortable and appealing slight colour gradients will be applied.

To establish the basis for this underwater theme it has been chosen to add slowly moving bubbles to the background. To realize this, a new User Control called `BubblyBackground` has been created for this. The `BubblyBackground` consists of a XAML file with the definitions for the graphical view and a C# code behind file which implements the logic.

The XAML file contains the definitions for the background colour which is held in blue. It also contains an `ItemControl`. An `ItemControl` can store the information how a collection of items should be presented. It therefore has an `ItemTemplate` property which can store the information and description for the presentation of an object of the collection.

```
<ItemsControl.ItemTemplate>
 <DataTemplate>
```

```
  <local:BubbleControl HorizontalAlignment="Left"
     VerticalAlignment="Top" QuadraticSize="{Binding Size}"
     Margin="{Binding Margin}" />
 </DataTemplate>
</ItemsControl.ItemTemplate>
```

The above shown code implies that `ItemTemplate` property has been declared as a new `DataTemplate` which specifies the visualisation of the data objects in a collection. The collection will be assigned as the source for the `ItemsControl` in the code behind file.

The collection contains a type called `BubbleDefinition` which contains information of the size of the bubble stored in a property called `Size`, its speed of rising and its current position in a property called `Margin`. These values will be initialized with random values. It can be seen in the XAML excerpt above, that these two properties of the `BubbleDefinition` are bound to `QuadraticSize` and Margin to a locally defined element from the type of `BubbleControl`. Bubble control is a user control which just contains the image of a bubble. What happens now is that for each element in the Collection of `BubbleDefinitions` a `BubbleControl` with the image of a bubble is created and it has the size and position (defined by the margin) stored in the corresponding `BubbleDefinition` object.

At the moment this would create randomly placed and sized static bubbles. To make these bubbles move a timer has been created which calls a method responsible for changing the position data of a bubble by changing the Margin property accordingly to the speed the bubble got assigned. The `BubbleDefinition` class now implements the `INotifyPropertyChanged` interface and fires a `PropertyChangedEvent` in case a property has changed. This event will be caught by the User Interface (UI) and the view will be updated.

This is a very easy method to update the view on changes in the code behind classes and it is used to implement all the animations in the program. It is forbidden to change the UI directly from a thread which is not the UI thread. This causes errors and exceptions during the runtime. Data binding and the `PropertyChangedEvent` work especially well with timers and changes in the view from threads which are not the UI thread.

However, the bubbles are not the only moving elements placed on the background layer. It has been mentioned that there should be an attention seeking movement on the display when someone passes it. To achieve this, a wave will be shown. This wave will have its origin at the side the user entered the area in front of the screen and then will spread in the direction the user is heading to. This wave has been implemented by placing a quadratic panel on each side of the background control. This panel is placed so that one half of it is totally outside the view. In its default state this panel is totally transparent. If the method is invoked which is supposed to trigger this wave, the panel will be filled with a little ring of a radial gradient of alternating blue and white. This ring then enlarges and produces the effect of a spreading wave.

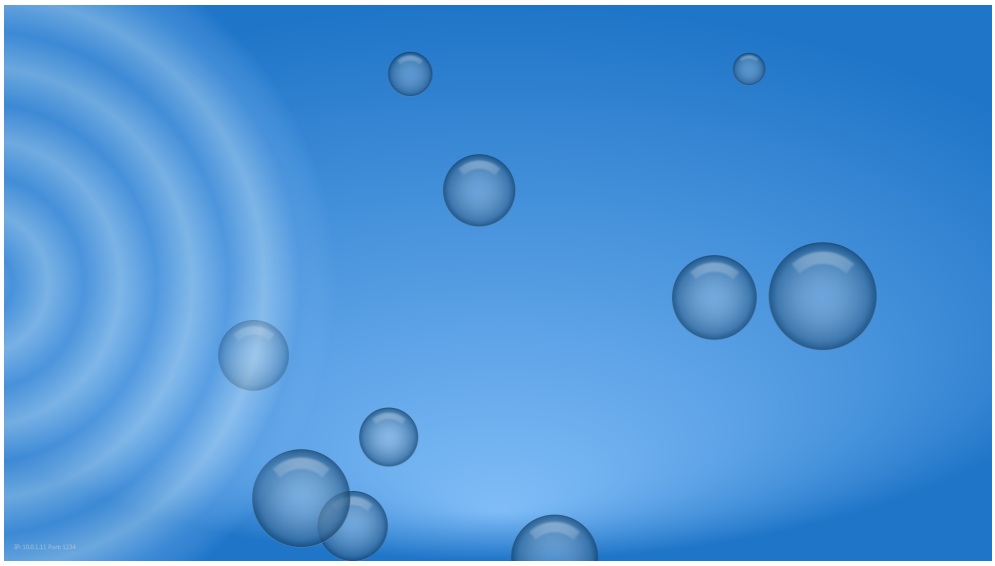


Figure 4.5: Screenshot of the Background with Bubbles and a Wave

The Figure 4.5 shows a screenshot of the background. It shows the bubbles and a wave which is meant to be shown when someone enters the area in front of the screen from the left side.

The Content Layer - Ordered Mode

In section **??** it has been pointed out that there will be two different states and appearances for the graphical interface of the SocioDisplay. One animation state shows the content floating around in a random order. This state will be shown when no one is in the adjacencies of the display or if the person is too far away from the display and thus no one is present in the Interaction Area of the display. But at first the

state, in which the content will be presented in an ordered form and ready for the user interacting with it, will be discussed.

It has already been mentioned and illustrated in Figure 3.3 and Figure 3.4 that there will be a panel for each kind of content. These panels will then be arranged on a wheel like 3D surface which can be rotated to bring other content into the focus. The element in focus should be highlighted to show the user that this is the content he can interact with and for example like it or pick it up with his phone.

WPF offers an easy way to render normal 2D controls in a 3D space. The 3D space is generated by using a `Viewport3D` control. This control has properties to define for example the position of the camera or the lightening. To position objects in this space the 3D Cartesian coordinate system is used. It is now possible to place normal 2D controls like panels, buttons or text boxes in this 3D space by using a `Viewport2DVisual3D` control. This control represents a planar object in the 3D space and the 2D objects are placed on its 2 dimensional surface.

In the case of this prototype panels containing the social content are placed on the `Viewport2DVisual3D` containers. The class which represents such a content panel inherits from `UserControl` and consists of a code behind and a XAML definition. The panel has controls applied which show information of the content like e.g. the creator, title, number of likers or photo. Some of these controls are hidden and just became visible when a specific type of content is shown. For example: the control showing the image of a picture content object is just visible if the content is of this type and otherwise it is hidden.

The appearance of the content panel also matches the underwater theme and is held in a lighter blue with a colour gradient to make it look smoother. It has also rounded corners to let it appear softer and more appealing.

The `Viewport2DVisual3D` panels can now be places in the 3D space and several transformations like rotation, scaling or translation can be applied. To create the wheel with the content placed on it, the content panels were places all at the same position in the coordinate system and then they have been rotated around the coordinate origin. This has been illustrated in Figure 4.7. With a good adjusted distance between camera, origin

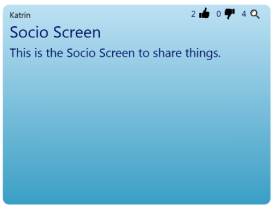


Figure 4.6: Example for the Layout of Information on a Content Panel

and the content panels this method creates the appearance of a wheel with content placed on it and the user can guess that he can interact with this wheel and rotate it.

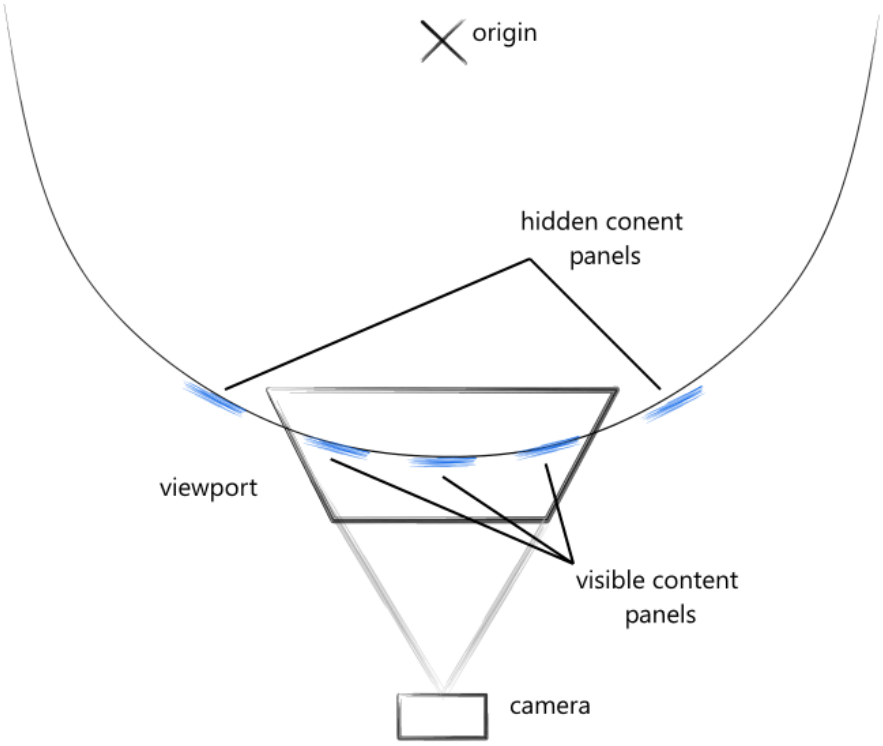


Figure 4.7: The 3D Space for the Ordered Mode from Above

For the rotation of the panels the Angle is been updated in an animation loop. Like the bubbly background, the update of the UI during the animation is realized with data binding and `NotifyPropertyChangedEvents`. If a user inserts new content an animation has been created which shows the content falling into the view area from above and the currently shown content will elude this inserted content. After the insertion the content is shown in the middle of the view area which means that the content is in focus and the user can interact with it, for example like it. The content in the middle of the area is additionally to its centred position highlighted and slightly larger than

normal content.

Content which has been liked by several users will be shown further up than content with a worse rating. This has been realized by changing the y position of the content.

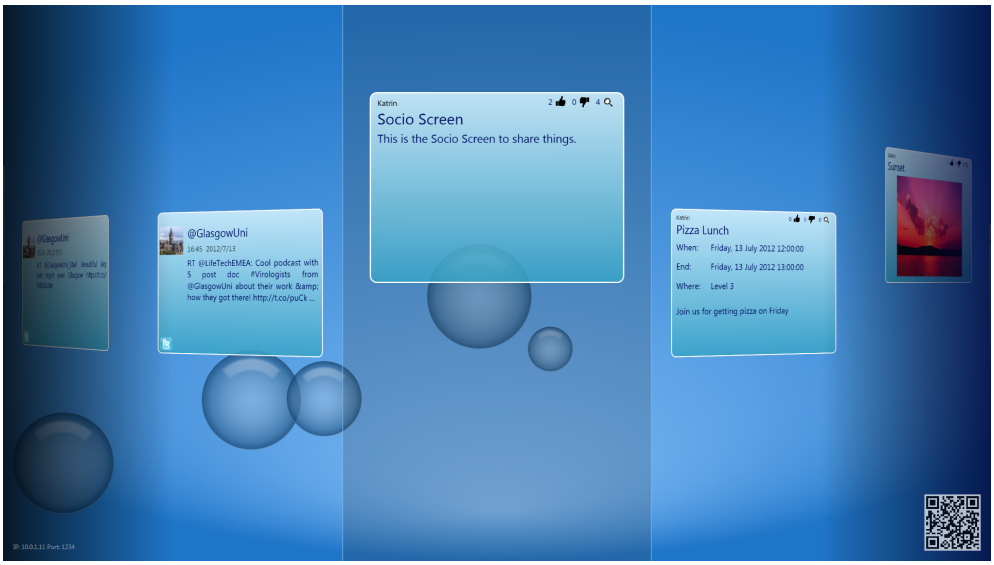


Figure 4.8: Screenshot of the Ordered Mode

The screenshot shows the result. The text content "Socio Screen" has the current focus and it is therefore shown slightly larger than the other elements. The shades at both sides of the UI support to direct the attention to the element shown in the middle. Additionally the content element is placed further up than the other content because two people already liked this content entry.

The Content Layer - Random Mode If no one is around the content should float around over the display. Although the mode is called "random mode" the movement of the content is not random. It is rather a non-straightforward movement of the content over the screen and therefore it seems like a random movement to the user. The content will perform a toppled Z movement over the screen. The content floating in the middle of the screen will be larger than the other content in order to make it easier for users passing by to read it.

The animation of the content is performed in the 3D space of the Viewport3D control by using translations and scaling to change the position and the size of the content.

Figure 4.9: Screenshot of Random Mode with the Movement Direction of the Content

Figure **??** shows a screenshot of the content floating in the random mode. The content in the middle of the screen is in this mode much larger than in the ordered mode because it has to address people which are outside of the Interaction Area and therefore further away.

4.4. The Android Prototype

The Android app prototype has the main functionality of creating content which will then be shown on the SocioDisplay. But it should also enable the user to pick up the content and show or store it on his phone. There will be two versions of the Android app created. One version will support motion gesture interaction with the SocioDisplay and the other version will operate without supporting these gestures. This gesture-based version will be presented first.

4.4.1. The Mobile-Gesture App Version

In this version the whole SocioDisplay system should be operated with body motion gestures. This means the user perform a gesture which is caught by the Kinect and then the appropriate reaction will follow. For example: The user performs the "pick up" gesture and the currently focused content will appear on his phone to either be just viewed and then discarded or stored permanently on the phone for a later access. This means that these actions which are triggered by a gesture do not need to appear in the Android app. This means that just actions which need the Android device as an actual input device should be included in the main menu of the app.

Therefore the UI of the Android app is very simple. It just consists of a main menu which enables the user to select the action he wants to perform. These options are

- Post Text
- Post an Event
- Post a Photo

If the user touches such a menu option another Activity will open. An Android Activity [Gui12] is a part of an Android application and it is strongly connected to a view shown on the Android device. An Activity summarizes a set of interactions with the app which have a main goal for example writing an email message. When writing an e-mail, an activity will be created which shows a view with text fields for the receivers address and the email message and a send button. But this activity is not just responsible for showing this view, it also handles the interactions the user does with it for example checking the format of the e-mail address the user filled in or handle the button press and will actually initiate the sending process. To create a custom Activity a class has to be generated which derives from the `Activity` class.

An Android Activity has a complex lifecycle. This lifecycle can be seen in 4.10. It can be seen that an Activity has multiple methods which are called during the lifecycle. If the custom Activity overrides such a method then it can handle changes in the state of the activity. For example: It is common to create a view when the activity itself is created.

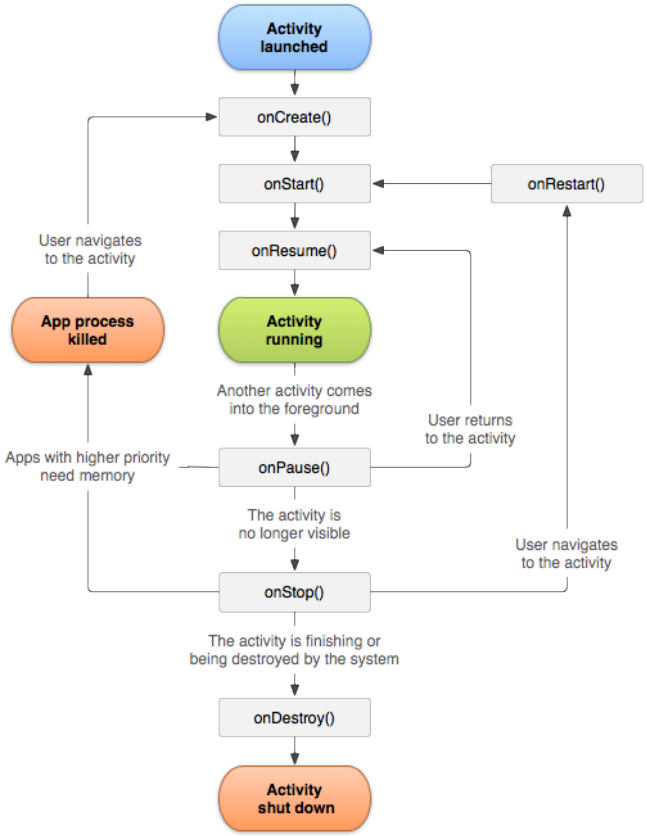


Figure 4.10: Activity Lifecycle (Source: [Gui12])

To do so the `onCreate()` method has to be overridden and has to take care of the view creation.

Each menu option, which is also an Activity, will now create an Activity and launch it. This activity will at first take care of showing the user the input controls for the action he wants to perform. This can be text fields for text input or a file chooser for selecting a photo to send to the server. After the user finished to put in the information and is ready to send the information to the server he should perform the Throw gesture in front of the screen and this gesture is then detected by the Kinect. The server than informs the client about this. The app should therefore not have submission controls like buttons because the submission should be done by making this gesture with the body. If the user performs the Pick Up gesture to pick up the content currently in focus then the server will inform the app about this and the app will then request this content and show it on the mobile display. The next section is about the client server communication which will describe in detail how this is realized.

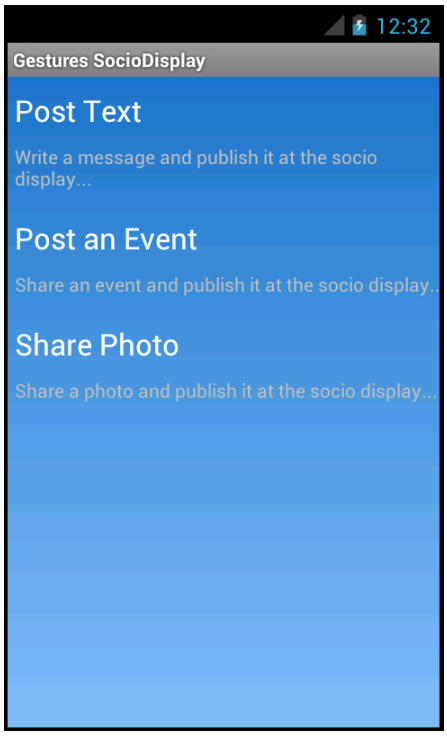


Figure 4.11: Screenshot of the Android App with Gesture Support

The Figure 4.11 shows a screenshot of the app. The app just needs the menu items for creating the three supported content types.

The Android app should be able to give the user feedback about his gestures, too. This is done by using the vibration functionality of the phone. If a user performs one of the mobile-motion gestures presented in subsection 3.6.2 then the mobile phone will vibrate when this gesture has been detected. This is especially important because it can take a little while until the content has transferred from the server to the phone. Especially large pictures might need some seconds for this. Without a feedback the user might wonder if the system has detected his gesture or if something went wrong.

This version of the app will support the user to interact with the system without using any gestures tracked by the Kinect. At first this version has been developed for debug purposes but it will also be evaluated in the user study of the next chapter.

If just the app will be used for interacting with the system then all the functionalities and actions using gestures which has been introduced in the last chapter have to be replaced. Now the Android app has to offer these functionalities which comprise:

- Navigation and Browsing through the content
- Initializing the content-sending-process
- Initializing the process for picking up content with the mobile phone
- Voting for content

The navigation through the content shown on the SocioDisplay has been realized with a remote control. The content can be rotated in the right or left direction and therefore two buttons has been placed on the remote control to do this.

If there is no gesture to send the content to the screen then the common submission buttons have to be used. At the bottom of the view for the content information input the user will find such a button and a pressing on it will initialize the transfer of the content to the SocioDisplay server to be shown on the screen.

The picking up of content and the voting for it can easily be done by selecting the appropriate menu option.

Feedback is also important in this version of the app. While the app and the server are busy to process the users input an Activity Indicator is shown. This activity indicator is

an animating wheel which is commonly known for indicating that an app or program is busy processing something.

4.5. Client Server Communication

This section describes the realization of the communication between the Android client and the SocioDisplay server application.

For this prototype it has been chosen to handle the communication between the Android client app and the server application via TCP sockets. The TCP protocol is a reliable network protocol. This means that the protocol takes care that all the data sent will be received by the other host in the right order and without the loss of packages. Nearly every programming language offers some functionality in libraries to program sockets.

The transfer of strings between applications based on different programming languages over the socket is therefore very easy. For the client server communication of the SocioDisplay and the corresponding Android app it has been chosen to transfer messages in form of strings. These strings will then be interpreted at the receiver host. The problem is that receiver and sender have to "speak the same language". This means that the receiver has to know how to interpret the message from the sender and filter the information inside the message correctly. This can be done by using standards which are supported by many programming languages and platforms like XML or JSON to store the information inside and they can also be referred as data interchange formats.

4.5.1. JSON and XML as Data Interchange Formats

JSON and XML both have the advantage that they are not just readable and interpretable by machines but they are also human readable. Using one of these technologies to

create a string message for communicating has the advantage of an easier debugging because the information inside can be easily read by a human.

JSON (JavaScript Object Notation) was originally developed for JavaScript to store data structures and objects in it. But by now many parsers are available for other programming languages, too. The Extensible Markup Language (XML) became very popular over the last years for storing complex and structured information inside. Common Technologies like XML-Remote Procedure Calls (XML-RPC) or Simple Object Access Protocol (SOAP) are based on it.

These both formats have also the advantage that there are multiple libraries for the common object oriented programming languages which support the serialization and deserialization of objects by using XML or JSON as the storage format. The following example shows the representation of a username with a password in XML and in JSON:

XML:

```
<user>
 <username>Tester</username>
 <password>PWD123</password>
</user>
```

JSON:

```
{"username": "Tester", "password": "PWD123"}
```

It is easy to see that the representation in JSON needs fewer characters than the XML representation but the XML representation on the other hand has more information included like the name of the whole structure "user". XML has also some other features like e.g. namespaces which are not prior necessary for the communication protocol described here. Therefore, JSON has been chosen for the message encryption and the communication between the Android app and the SocioDisplay server. The reason is that JSON is more lightweight than XML and [Nur+09] found out that JSON was significant faster than XML in their experiment testing the performance and resource

utilization of the encoding, transmission and decoding of a large number of Java Objects over TCP.

The usage of JSON for encoding message objects inside brings the advantage that the string messages can be decoded to objects on either the Android client or the C# server. These objects then can contain complex structured information and are easier to handle than the string. But before the message serialization with JSON will be surveyed the message types and hierarchy will be observed more detailed.

4.5.2. Message Types and Hierarchy

For the messages three abstract types Request, Answer and Event have been defined which in turn derive from the abstract base class `MessageBase`. The corresponding class overview for these messages in C# can be seen in Figure 4.12.

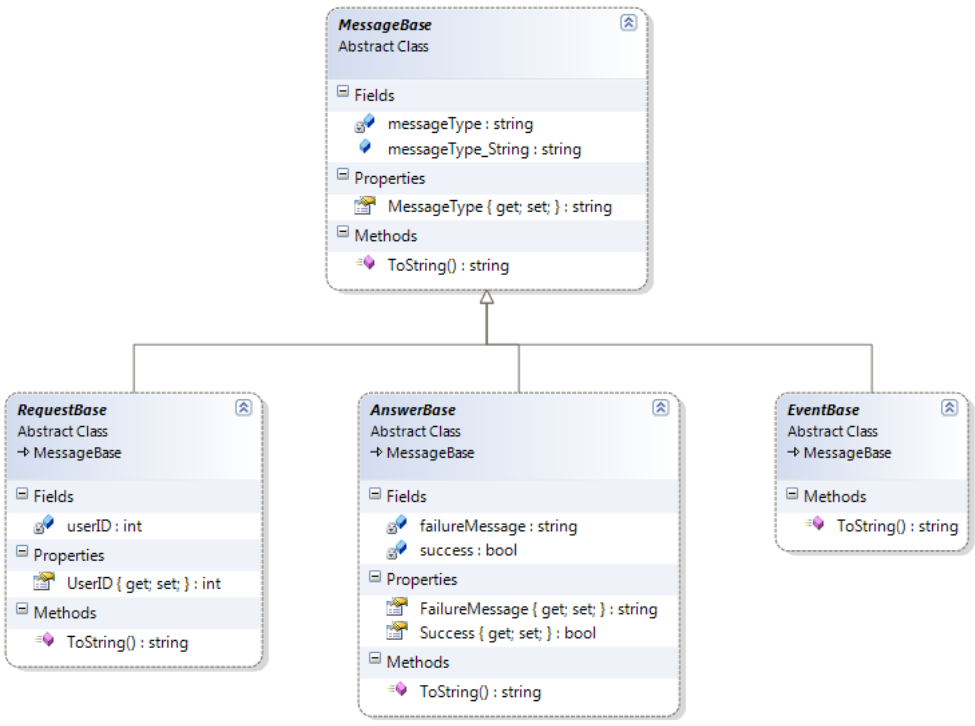


Figure 4.12: Class Overview of the Abstract Message Bases in C#

Multiple concrete message implementations derive from these base classes but due to the high number they have not been illustrated in the overview diagram. Subclasses

of the `RequestBase` class are used by the Android client to request something from the server like e.g. the request for the current content or the request to add content created by the app user. The request contains the ID of the user who sent it. Each request has a correspondent represented by a subclass of `AnswerBase` which will be sent to the Android app after the server has processed the request. The answer will contain a flag if the request has been processed successfully and if applicable other information defined in the subclass. A list of the messages can be found in Appendix A. These messages have been implemented in Java for the Android app and in C# for the server application.

These messages have been implemented in Java for the Android app and in C# for the server application.

4.5.3. Message Serialization and Parsing using JSON

For the C# server the Json.NET ([NK12]) framework has been used. This framework includes classes which provide methods for the serialization of objects and the deserialization of objects out of a JSON string. On the Java and Android app side the Jackson library has been used ([Fas12]). This library also offers the serialization of objects. The first step was to evaluate the JSON strings generated by serializing an object from a C# and a Java class which are similar. For this example a `HelloRequest` object has been used. The Jackson library offers the class `ObjectMapper` with the method `writeValueAsString(Object o)` which creates a JSON representation from an object. Every public attribute of the Java class will generate a JSON name-value-pair. The C# library of Json.NET offers a similar functionality with the static `JsonConvert.SerializeObject(object o)` method. The serialization process will include every public property of a class in the serialized JSON representation. The class definition for the `HelloRequest` on the systems is as follows:

C#

```
public sealed class HelloRequest : RequestBase
{
 private string helloString = "Hello";
 public string HelloString
```

```
 {
  get { return helloString; }
  set { helloString = value; }
 }
 public HelloRequest(): base()
 {
  MessageType = MessageTypes.HelloReq;
 }
}
```

Java

```
public final class HelloRequest extends RequestBase{
 public String HelloString = "Hello";
 public HelloRequest(){
  MessageType = MessageTypes.HelloReq;
 }
}
```

The `HelloRequest` derives from the abstract base class `RequestBase` and therefore inherits the `UserID` and `MessageType` (see Figure **??**). The serialization using Jackson or Json.NET creates the following strings:

Message generated in Java with Jackson:

```
{"MessageType":"RHello","UserID":4,"HelloString":"Hello"}
```

Message generated in C# with Json.NET:

```
{"HelloString":"Hello","UserID":4,"MessageType":"RHello"}
```

It can be seen that apart from the order of the elements, every element is included and represented in the same manor. To retrieve the objects from the JSON representation the class type must be known and specified when the methods for the object deserialization are called. To achieve this, the abstract base class offers a string element

called `MessageType`. This message type can be interpreted before the actual object is created. All strings for this purpose are therefore stored as constants in a class called `MessageTypes`. These strings have to be the same in the Java and the C# environment.

During the test of the JSON object serialization and deserialization between the Java and C# platform it has been found out that all the messages implemented could be exchanged between the systems using JSON. It was also possible to exchange pictures stored in a byte array within the message with this technique. This showed that also other files could be exchanged using JSON. The next section will talk about the TCP connection and the transfer of the JSON strings between the systems.

4.5.4. The Connection between Client and Server

It has been mentioned before that TCP has been chosen for the communication between client and server because it is a reliable protocol. This means that the protocol will request packets which might have got lost during the transmission and also orders the packets before they are processed. The counterpart is the unreliable UDP which has a better performance because it does not order the Datagrams or requests lost ones. This makes UDP suitable for e.g. streaming of videos because the loss of a package can be bore to a certain degree, which is not suitable for the SocioDisplay.

The connection between the Android client and the SocioDisplay server is a client-server-architecture. This means that the server actively listens to clients which want to connect with it. After the connection has been established between server and client, the client is able to send requests to the server and the server will process these requests and sends a response to the client if necessary. In the here presented protocol there will always be an answer sent to response a client request. It can therefore be considered as a synchronous communication because the client application waits until the feedback and response from the server came back. For example: If the client application sends new content to the server it will wait until the server responds and informs the Android app about the success of this action or the failure. In case of a failure the app can notify the user about the reason of the failure and can give him the opportunity to correct it. In case of the success the application can continue and wait for new input of the user.

The original client-server model did not provide an initial message from the server to the client. Usually such a thing is done by polling. This means the client sends requests to the server in a time interval and asks if there is some information for it available. There are some scenarios in which the SocioDisplay server has to inform the client about an event like a body gesture the user has made. After receiving such an event the client application decides how to react on this event. It would be impractical if the client application would poll for such events. Therefore, the event messages have been created. These are messages which do not have an immediate response and the sending party does not wait for a response. These events can be either sent from the server to the client in case of e.g. a detected body gesture of the user or they can be sent from the client to the server for e.g. sending mobile acceleration data for logging purposes. The event based communication is asynchronous because the server or client application will go on with the usual work after sending the event because no direct response is awaited.

The C# Server When the C# server is started it begins to listen for incoming clients which establish a TCP connection to the server. After the server accepted the connection of a client it starts to listen to request coming from the server and processes them if one is received. This is realized by a `Connector` class. This class is a singleton because it is supposed to be instantiated at most one time. This Connector has a `Run()` method which is started in a new thread and listens for incoming clients. If there is a new client connecting with a server, a new session with this client will be established by creating an object of the `MobileClientConnector` class. This object is instantiated with this new `TCPClient` and a reference to the `Connector`.

This `MobileClientConnector` now has an own `Run()` method which is started in a new thread. This method contains a loop which calls by turns the `ReceiveData()` and `SendData()` method. The first method tests if there is new data on the network channel. This happens non-blocking and means that in case that no new data is available the method returns. If there is new data then it will be received and stored in a byte array and then it is transformed into a string. This string contains the JSON encrypted message object and will be deserialized and processed. During the test phase it has been discovered that large messages may not be received in one piece because the `NetworkStream read()` method has to be called multiple times until the whole message

is received. Therefore a binary integer comprising the byte length of the message will be added at the beginning of the string message, before it is sent over the network. The four bytes representing this integer will be read out of the network stream by the receiver before the whole message is received. Now the system knows the length of the message and will call the `read()` method until the whole message has been received.

If there is a message which should be sent to the client then the serialized JSON string of this message will be stored in the `sendRequest` queue. The `SendData()` method which is called in the run loop will then check this queue if there are messages to send to the client. These messages then will be sent to the client.

There has been a listener interface created with the purpose to inform instances which implement this interface and register a listener to the `Connector` class, about incoming messages. The `HandleIncomingMessage` which has to be implemented by a such a listening class has to return a message which will be then sent to the client. If the received message was a request then the according answer will be returned. This listener interface is implemented by the `MainApplication` class. This class manages all the actions in the SocioDisplay server application.

Android Client On the Android client side is a `ServerConnector` implemented which is similar to the `MobileClientConnector` on the C# server side but this time the server connector is a singleton because an android app will just connect to one server at a time.

There is also a listener interface for incoming messages. The difference is that the method for handling the messages does not return an answer message for sending to the server because the client will not receive requests from the server which have to be answered. The client either receives answers for requests it has sent to the server or it can receive events from the server informing the client of something. Neither of these message types needs to be answered. If an event received from the server requires action of a client then the client will send a request to the server to acknowledge this. A concrete example: If the server application detects a gesture symbolizing that the mobile phone user would like to retrieve the content currently in focus to display it on his mobile phone, the server application sends a `GetCurrentToServerEvent` to the

mobile phone that this user has performed this gesture. If the Android app is running and if it is not used by the user to do something else like writing a message, then it will send a `RequestCurrentRequest` to the server to retrieve the current content and then show it.

It has been mentioned before that the main part of an Android applications are Activities. The app will have multiple activities for the different actions and states in the app like the main menu, the creation of text content or the remote control. All these activities must have access to the `Connector` to send messages and they must implement the interface for the message handling and register themselves as a message handler in the `Connector`.

To make this process easier there has been an abstract super `SocioActivity` class for all the Activities in the app created. This super class implements the message listener interface and processes some messages which are handled in the same way in every Activity. This class also overrides the methods `onCreate()` and `onPause()`[1] and registers as a listener when the first one is called and unsubscribes as a listener when the second one is called.

Due to the singleton status of the `ServerConnector` class it is easy to access the static and only instance of it from every activity.

4.5.5. Summary

For this prototype it has been chosen to create an own message protocol with the same message classes on the Android Java client and the C# server. The communication is done through string messages in the JSON format which represent the message objects. It has been found out that the used libraries Json.NET and Jackson are producing the same JSON representations and they can therefore be used for this communication. This has the advantage that complex message objects can be created and transferred.

[1] The position in the Activity lifecycle can be seen in Figure 4.10.

It has been very easy to create new messages on both systems. Due to the syntactical similarities between Java and C# it has been easy to implement a message on one system and then transfer it to the other system and just make some small modification to adapt to the syntax.

Tests have shown that the transmission time for complex and large messages like for the transfer of pictures has been adequate. During the user study of the next chapter no participant has felt that the transmission and the response times were too long.

4.6. Presence Aware Kinect-Detected Reactions

The Microsoft Kinect provides three types of data [Mic12a]. One of them is audio data recorded by a microphone. This data will not be relevant for the application. The other two types of data are a colour video stream and a stream of depth data recorded by the Kinect. The Microsoft Kinect SDK which has been used also calculates skeletons out of this data and makes them accessible.

Skeletons are a collection of the person's joints position in a 3D space. Figure 4.13 shows an illustration of the tracked joints. The joints can be used to identify poses or gestures a user is performing. This thesis will not deal with the implementation of the gesture recognition. The current SocioDisplay prototype has not been equipped with gesture recognition and this will be something which should be done in the future. For the user tests a remote control application for a Windows Phone mobile device has been developed which can be used to trigger the events which would have been thrown by a gesture recognizer. The implementation details of this remote control will not be part of this thesis.

Skeletons cannot just be used for gesture recognition but also for detecting the position of a person. The Kinect SDK just offers the joint tracking of two persons in front of the screen but the position of four additional persons can be tracked too ([Cor12]) and a centre position of them will be accessible.

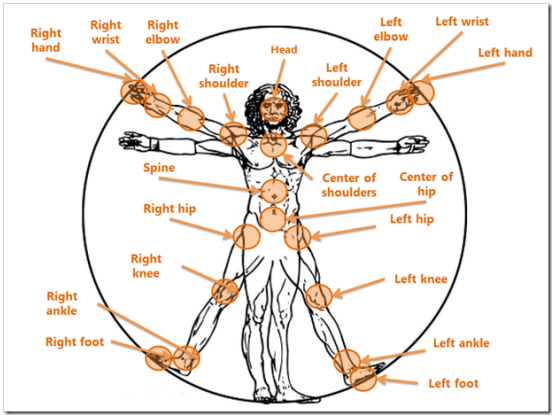


Figure 4.13: Joints of a Kinect Tracked Skeleton (Source: [Cat11])

For determining how far a user is away from the display and if he is close enough to be in the Interaction Area, the position data is sufficient. The z coordinate can be used to retrieve the approximate distance between the Kinect and the person. If the person steps close enough to be in the Interaction Area an event will be thrown by the `KinectManager` class which is then caught by the main application and can there be handled to transform the UI from the random mode to the ordered mode. If the person leaves the UI transforms back.

The SocioDisplay should also show a wave when a user passes by. For this it is impractical to use the skeleton data because the Kinect needs some time to recognize persons and provide their skeleton or position data. The person likely already passed the display until this is the case.

For this reason the raw depth data is used to detect movements at the right and left side of the Kinect vision field. One depth data frame has a dimension of 80 x 90 pixels. Each pixel can be accessed and the depth at this position can be retrieved.

The principle of a light barrier has been adapted to detect changes in the depth data and therefore detect movements which are closer than the background. On each side of the vision field three vertical light barriers have been places. This just means that when the system is initialized the first depth data frame is taken and sample data of points along three vertical lines on each side of the frame are stored in an array. These points are now checked when a new depth frame is available. If the depth value of one

point changed drastically, then it is assumed that someone or something broke through the barrier belonging to this point.

The reason for using three barriers on each side is to detect if the person is entering the vision field or leaving it. If the barrier, which is closest to the border of the frame, is interrupted then it is assumed that the person is entering the area and the wave animation is triggered. If the barrier, which is the furthest away from the border, is triggered than the person is leaving and no wave animation is shown.

4.7. Summary

This section described the development of the SocioDisplay prototype consisting of the C# server application and the two Android App versions for mobile-only and gesture use. Figure 4 14 shows a final overview of the system. The components introduced in the above sections can be seen in it.

Many of the communications between the components have been realized with the listener model and thrown events will be handled by the instance implementing the listener interface. The next chapter will evaluate how this prototype has been perceived by users.

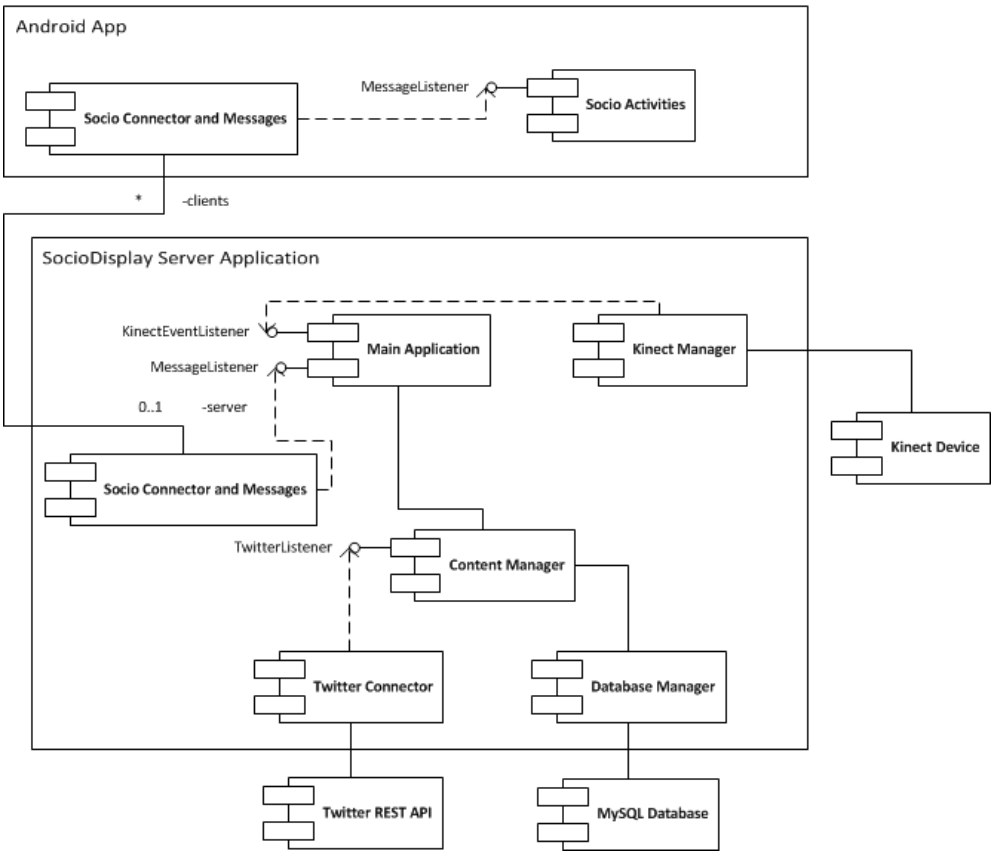


Figure 4.14: Overview of the Components of the SocioDisplay Prototype

CHAPTER 5

User Study

This chapter will describe the process and the results of a user study made to evaluate the developed prototype. At first the process and used methods will be defined and then the results will be presented and discussed.

5.1. Purpose and Goal of the User Study

The user study should evaluate if people are keen to use it and find it attractive. The pragmatic and hedonic qualities of the system should be determined for that. It is also important to get an overview how people interact with the system and how they perceive it. Questionnaire based evaluation should be used for this. Interviews with the participants could also help to understand issues they have or to get new ideas for improvements.

For this study two slightly different versions of the SocioDisplay should be compared. The first version should be a "mobile-only" version where all interaction with the system is made just by the use of the mobile phone. This means that the Kinect sensor will just be used for detecting the presence of a person but not their gestures. The second version however will enable the user to use gesture input for interaction and it is therefore referred as the "gesture" version.

5.2. Evaluation Method

For the evaluation the online evaluation tool AttrakDiff ([AttrakDiff]) is used. As already mentioned in subsection 2.1.2, the evaluation is based on a questionnaire which consists of contrasting word pairs. Between each pair there is a scale parted into seven intensities and the user has to vote for the intensity he experienced while using the system.

Respectively seven of the word pairs are combined to measure a specific product quality of these four:

- Pragmatic Quality: Describes how successful someone is archiving their goals.
- Hedonic Quality - Identity: Describes if the user can identify with the system.
- Hedonic Quality - Stimulation: Describes if the user is stimulated by the system.
- Attractiveness: The overall attractiveness and value of the system.

AttrakDiff offers three different evaluation modes. It offers the single evaluation which is meant for a single system with no changes. A single system can also be evaluated in different development states in the before-after survey. It is also possible to compare two different systems in the A-B comparison.

The evaluation is respectively made with an online questionnaire which consists of multiple word pairs which represent extreme opposites. The user can vote on a scale which is parted into seven graduations to express his opinion concerning the feeling and impression he had during the use. The word pairs are assigned to one of the product qualities listed above. By this average values for these qualities can be determined. The evaluator does not have access to the questionnaire results of each study participant. It is just possible to access the calculated and processed results for all participants.

The result report comprises a two-dimensional diagram with the hedonic quality on one axe and the pragmatic quality at the other. The products quality is then illustrated by a square placed in this diagram which indicates the variance of the results and a dot

to mark the medium value of the results. In case of the before-after or A-B evaluation two of these squares are drawn in a different colour.

5.3. Process of the User Study

For the study the two different version of the system should be compared. Therefore, it has been decided to use two different set of tasks which contain three tasks each which are similar among the task sets but with different interactions used to perform them. After each set of tasks the user will be asked to fill out the AttrakDiff questionnaire.

5.3.1. Introduction to the System

At the beginning of the study the participants were introduced in the purpose of the system. After that, a consent form was handed out to them and they were talked through it. The consent form can be found in Appendix B.

5.3.2. Tasks for the User

The tasks the user has to perform during each task set should on one hand cover a broad range of functionalities the SocioDisplay prototype has to offer. The tasks should include these functionalities:

- Share content
- Reward the posting good content by liking it
- Pick-up content to go and store it on phone

This should give the study participant a slight insight what the system is about. The tasks were described in a way a novel user without any experiences with the system can understand them. The tasks of the "gesture" task set contained the following gestures:

- Throw
- Pick-Up
- Thumbs-Up and
- Scroll

The participants were asked to perform these gestures in a natural way but it was not explained to them how they actually have to perform them. It was a part of the user observation to find what people imagine as a natural gesture by just knowing the name of the gesture. This can than compared what was envisioned in this thesis.

5.3.3. The Wizard of Oz

During the last chapter it has been explained that it was difficult to implement good gesture recognition and that therefore no gesture recognition functionality is included in the prototype. Hence, for this study it had been chosen to use the Wizard of Oz method. This method got his name from the Wizard of Oz a character of L. Frank Baum's book "The Wonderful Wizard of Oz"[1] . The Wizard were just an ordinary man who used magic tricks to make himself appear very powerful to other people.

The Wizard of Oz method is a technique where functionalities of a prototypical system are simulated by a human hidden to the person using the system. This can be used to provoke genuine and realistic behaviour from the subject which believes that the system works autonomously. This technique can especially be used when some functionality is too expensive to implement or just too novel and not supported by the present technology.

During the experiment the gesture recognition was simulated by the experimenter siting in the background and inconspicuously operating a remote control which was connected to the SocioDisplay server and triggered the events for the gestures.

After the experiment the whole thing was cleared up to the participants.

[1] L. Frank Baum, The Wonderful Wizard of Oz, G. M. Hill (1900)

5.4. Results

This section presents the results of the study.

5.4.1. Results of the AttrakDiff Questionnaire Evaluation

The AttrakDiff online questionnaire system offers just the access to the average values of the participants. Individual results cannot be viewed.

The AttrakDiff system generates a full report with the results and suggestions for improving the system. This report can be found in (APPENDIX) The key part of this report is a portfolio with the average values for the hedonic (HQ) and pragmatic quality (PQ) of a product and a confidence rectangle which indicates how reliable or coincidental the results are.

This portfolio can be seen in Figure 5.1. It shows that the confidence rectangles and the medium values for the mobile and the gesture version are close to each. This indicates that there is not a huge difference between these systems. This is indeed the case because they just differ in the kind of interaction.

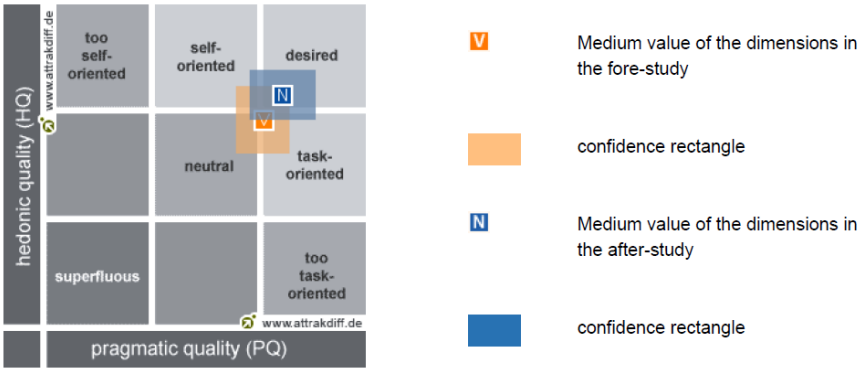
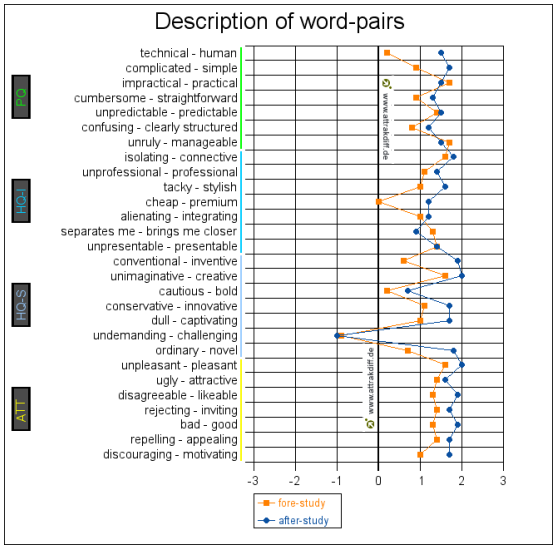


Figure 5.1: Portfolio of the AttrakDiff Evaluation

It can also be seen that the medium values and confidence rectangle of the gesture version is more shifted into the desired character-region. This means it has a higher hedonic and pragmatic quality than the mobile version of the app.

The shape of these confidence rectangles indicates how spread the values for the qualities were. A broader edge means that the participants votes differed more. It can be seen that the edge, parallel to the PQ axe, of the mobile version's confidence rectangle is less broad than the edge of the gesture version. This means that the participants did agree more about the PQ of the mobile version. But in case of the HQ it is the other way around.

The report also offers an illustration of the average values for each word pair. This can be seen in 5.4.1. It indicates that there are some qualities which drastically improved from the mobile version to the gesture version. The gesture version is more human, premium and inventive than the mobile version. But there are also qualities which are worse in the gesture version. These indicate that the gesture version is more unruly, separating and impractical than the mobile version.



The last diagram in 5.2 shows that the gesture version has better qualities than the mobile version. Especially the hedonic quality for stimulation (HQ-S) increased. This means that the system is more stimulating, interesting and novel than the mobile version.

5.4.2. Results of the Interviews

After the participants completed both task sets, they were asked to make suggestions and talk about their perceptions and opinions about the product. It can be said that all

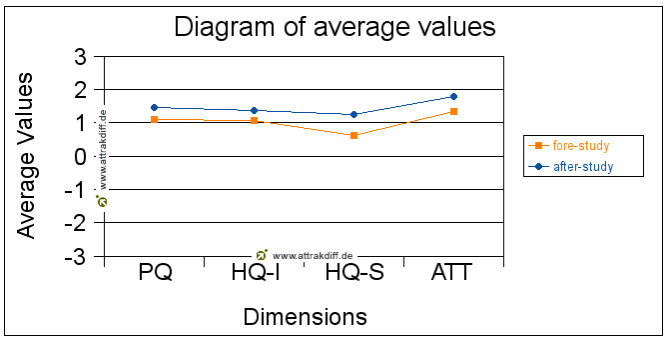


Figure 5.2: Qualities of the Evaluation

of the participants though that such a system is a good idea.

There were people which preferred the interaction without gestures. They argued that the user needs the mobile phone anyway for creating the content or for identification and a press on the button after generating the content of the phone is much easier than performing a gesture. But there were also participants who were totally enthusiastic about the gesture interactions. Especially the gesture "Thumbs up" was appreciated as a "smart gesture" (P7). But a lot of participants experienced that the swipe gesture is not very practical especially for browsing a lot of content because it to be repeated very often. One participant (P6) suggested introducing a gesture for starting the rotation of the content wheel. The wheel would then rotate until the user performs a stop gesture. Another participant (P7) suggested lying out the content in form of a 2D grid which then can be browsed with the swipe gesture for horizontal browsing and another gesture for vertical browsing. This would make it easier to access a specific type of content.

It has been observed that the natural gestures the users were asked to perform differed very much. For example, the "Swipe" was most of the time performed from the outside to the inside. This means if the right arm was used to perform a swipe to the left side and the other way around. But there was one participant (P1) performing this gesture from the inside to the outside. The "Throw" and "Pick Up" gestures differed even more. Some people picked the content up by bending down like they would like to pick up something from the floor. Some people just stretched out the arm the mobile phone was in towards the screen. To throw the content to the screen some people just made a very subtle gesture but others got really enthusiastic and made huge gestures. This shows that everyone has a different understanding how to perform a gesture naturally.

Most of the participants made positive comments on the look of the SocioDisplay. But some participants suggested that the look would not be appropriate for a professional business environment (P4, P6).

Other comments they made, were "playful" (P4), "pleasant" (P6), "quite fun" (P9) and "like Facebook combined with Minority Report" (P7).

But to sum this up it can be said that the participants liked the system and found it attractive.

CHAPTER 6

Conclusions and Future Work

This chapter will summarize the achieving, problems and conclusions from this thesis. It will also be considered what could be improved in future versions and which functions have to be implemented.

6.1. Summary and Conclusion

This thesis dealt with the design and prototyping of a semi-public ambient-intelligent display for work environments and under the use of mobile phone and motion components for interacting with the system. The main goal was to enhance the awareness and communication in the working group. This would also strengthen the connectedness and well-being in the group and therefore it could also improve the collaboration in the group.

During the design process, it has been considered how these goals could be archived and how such a system could support the user in the group. A key factor was to gain the attention of the passers-by and invite them to use the display, but also to keep them motivated to use it again over a longer period.

A functional prototype has been developed and the development process has been described. The functionality and the hedonic and pragmatic qualities of this prototype

have been evaluated in a user study. This study showed that the system was appreciated and liked by the participants. Some suggestion and issues could be used to improve the system.

6.2. Future Directions

The prototypical implementation of the SocioDisplay does not implement any gesture recognition at the moment. This could be something which has to be changed in the future. But it could also be possible to survey over a larger period if the people would be fine with just operating the system with their phone. The user study showed that some users preferred the interaction with just the mobile phone and no gestures. A suggestion would be to combine these operating methods and let the user choose if he would like to perform gestures for interaction of if he prefers the mobile interaction. It could be investigated in which situation which interaction method is chosen. It could also be observed which gestures are natural and easy to users. The impractical "Swipe" gesture could be substituted by a gesture which makes it easier to browse a lot of content.

To make the system more useful, some other content types could be added to the implementation like PDFs. There are also other parts of the design process which have not been implemented yet. These comprise the Wave gesture for identification which is the basis for multiple users operating with the system at a time. It could also be analysed how a person could be identified by the skeleton. This could make the use of the smartphone and the app unnecessary for some tasks. A mood prediction on the basis of facial expressions and movements could help to support the user by using the system and may help to create a more intelligent and sensitive system.

To evaluate if the goals of a strengthened awareness and communication has been reached a long term trial should be made. The display could therefore be installed in a work environment and it can be observed how the users react and how the display is used.

APPENDIX A

List of Messages for the Client Server Communication

The following table shows the message classes implemented. Abstract classes are italic and subclasses are indented.

Message	**Description**
MessageBase	
RequestBase	Contains the ID of the sending user.
HelloRequest	From the client after the connection with the server.
CreateUserRequest	From the client if a new user should be created
ChangeUserRequest	From the client if the data of the current user should be changed.
DeleteUserRequest	From the client if the current user should be deleted.
RemoteControlRequest	From the client to symbolize that the content should be rotated to the left or right.
SendContentRequestBase	From the client when content generated at the phone should be sent and displayed at the server display.
SendPictureRequest	The client sends a picture to the server.
SendTextRequest	The client sends a text message to the server.
SendCalEventRequest	The client sends a calendar event to the server.
NonLikeCurrentRequest	The mobile client user non-likes the current content.
LikeCurrentRequest	The mobile client user likes the current content.
RequestCurrentRequest	The client requests the content currently in focus to show it on the phone.
AnswerBase	Contains a flag if the request has been processed successfully.

HelloAnswer	The server has processed the new client.
CreateUserRequest	The server has processed the request for creating a new user.
ChangeUserRequest	The server has processed the request for changing the user data.
DeleteUserRequest	The server has processed the request for deleting the user.
RemoteControlRequest	The server has processed the request for rotating the content.
SendContentRequestBase	The server has processed the request to insert new content in form of a…
SendPictureRequest	…picture.
SendTextRequest	…text message.
SendCalEventRequest	…calendar event.
NonLikeCurrentRequest	The server has the processed the request to mark the current content as non-liked by the user.
LikeCurrentRequest	The server has the processed the request to mark the current content as liked by the user.
RequestCurrentRequest	The server has processed the request from the client to get the currently shown content sent to the phone.
EventBase	Events can be either sent from the server to the client or the other way around. They do not have an answer message.
MobileAccelerationEvent	The mobile phone sends the measured acceleration data to the server.
GetCurrentToMobileEvent	This event is sent from the server to the mobile when a certain gesture has been detected and the current content produced on the phone should be shown on SocioDisplay. The mobile sends a SendContentRequestBase subclass object in return.

GetCurrentToServerEvent	This event is sent from the server to the mobile when a certain gesture has been detected and the current content in focus should be shown on the mobile. The mobile sent a RequestCurrentRequest in return.

Appendix B

Consent Form

On the following pages show the consent form and the task sheets for the user study.

User Study Consent Form

The aim of this study is the evaluation of the usability and appearance of the SocioDisplay prototype as experienced by the user.

The SocioDisplay

The SocioDisplay is a public display which is meant to enhance social connectedness and awareness in co-located working groups (like groups in this research department).

Users with a smartphone can post content to the screen (like text, pictures or documents) which then can be viewed by other passers-by or they could pick up content with their phone. Furthermore, the display is enabled to track body motions and the presence of people and react accordingly to them.

Procedure

The procedure of this study is as follows

- At the beginning of the study, you will get a couple of minutes to familiarize with the system.
- After this you will be asked to perform 3 tasks using a smartphone and body movements for the interaction with the system. And fill out an online questionnaire about your experience you had during this.
- You will then be asked to perform 3 tasks very similar to the tasks in the first round and fill out the same questionnaire again.
- In a final discussion you may be asked to answer questions about your impressions of the system

The online questionnaire is for the evaluation of usability and appearance experienced by the user. Further information can be found on the AtrakDiff website (http://www.attrakdiff.de/). A copy of the Terms of Use and the Data Security declaration of the AttrakDiff Service can be seen by asking the experimenter.

Risks

During the study you will be asked to perform some gestures and body movements. You should be careful and perform them in a way your physical status allows you without getting injured.

You should be carefully handling the mobile phone during the whole study.

Recorded Data

The following data will be recorded anonymously during the study:

- Your answers of the online questionnaire
- Your answer to questions about your impressions
- Notes about how the gestures and movements are performed
- Acceleration data from the smartphone
- Kinect skeleton data (just skeleton data and no video data)

Your participation is completely voluntary and if for any reason you are uncomfortable with the study, you may end it at any time and without explanation.

Agreement

By signing below, you agree that the above information has been explained to you and all you current questions have been answered. You understand that you may ask questions about any aspects of this research study during the course of the study and in the future. By signing below you agree to participate this study.

_____	_____
Date	Signature

Task Set “Mobile-Only”

The following are meant to be performed by using the smartphone and the running app.

Please make sure that you stand in front of the screen while interacting with it.

Task 1: **Post text** with the Title “Hello” and the message “I am new here.”

(Hint: the ⮌ button can be used hide the keyboard)

Task 3: Browse the content shown on the screen by using the **“remote control“** functionality and bring the calendar object with the title **“Pizza Lunch”** into the focus.

Then add this event to the Andoid calendar by using the **“get the current content”** menu point and **save the calendar entry** you will then get on your phone.

(Hint: the ⮌ button can be used leave the “remote control” mode and return to the main menu)

Task 2: Browse the content shown on the screen by using the **“remote control”** functionality and bring the **picture of the cat** into the focus.

Return to the main menu and **“like” the picture of the cat**.

(Hint: the ⮌ button can be used leave the “remote control” mode and return to the main menu)

Task Set “Gestures”

The following are meant to be performed by using the smartphone app and body motions for the interaction with the system. (The smartphone is not necessarily needed for some tasks but it is necessary that the app is running the whole time.)

Please keep in mind to be careful by doing the gestures to not hurt yourself or other people around you and do not throw the smartphone around.

Please make sure that you stand in front of the screen while interacting with it.

Task 1: Send a picture to the display using the **“Share photo”** menu option.

Select the **sheep photo** and enter the **title “sheep”**.

Submit this message by performing a **“throw” gesture** towards the screen (Please, be careful not to actually throw the mobile phone!)

Task 3: Browse the content shown on the screen by making **“swipe” gestures** and bring the calendar object with the title **“Pizza Lunch”** into the focus.

Then add this event to the Android calendar by making a **“pick this up” gesture** with the arm you are holding the phone with and **saving** it to the calendar.

Task 2: Browse the content shown on the screen by making **“swipe” gestures** and bring the **picture of the sunset** into the focus.

Then **“like”** the picture of the sunset by doing a **“thumbs up” gesture**.

APPENDIX C

Results from the AttrakDiff Evaluation

On the following pages the results from the AttrakDiff Evaluation can be found.

Evaluation Report for Product

ocioDisplay - Mobile only" (fore-study) and "SocioDisplay - Gestures" (after-stu

Objectives:
How user-friendly and attractive is this product?

Contents of report

Method of investigation

AttrakDiff™ is an instrument for measuring the attractiveness of interactive products.

With the help of pairs of opposite adjectives, users (or potential users) can indicate their perception of the product. These adjective-pairs make a collation of the evaluation dimensions possible.

The following product dimensions are evaluated:

Pragmatic Quality (PQ):
- Describes the usability of a product and indicates how successfully users are in achieving their goals using the product.

- Hedonic quality - Stimulation (HQ-S):
  Mankind has an inherent need to develop and move forward. This dimension indicates to what extent the product can support those needs in terms of novel, interesting, and stimulating functions, contents, and interaction- and presentation-styles.

- Hedonic Quality - Identity (HQ-I):
  Indicates to what extent the product allows the user to identify with it.

- Attractiveness (ATT):
  Describes a global value of the product based on the quality perception.

Hedonic and pragmatic qualities are independent of one another, and contribute equally to the rating of attractiveness.

Characteristics of investigation

Product title of fore-study:	SocioDisplay - Mobile only
Product title of after-study:	SocioDisplay - Gestures
Product industry:	Other
Duration of fore-study:	06.07.2012 - 04.10.2012
Duration of after-study:	06.07.2012 - 04.10.2012
Project-type:	Comparison before - after, that means a product is rated twice
Variant:	The same test participants in both project parts.
Number of ratings in fore-study:	10
Number of ratings in after-study:	10

Portfolio of results

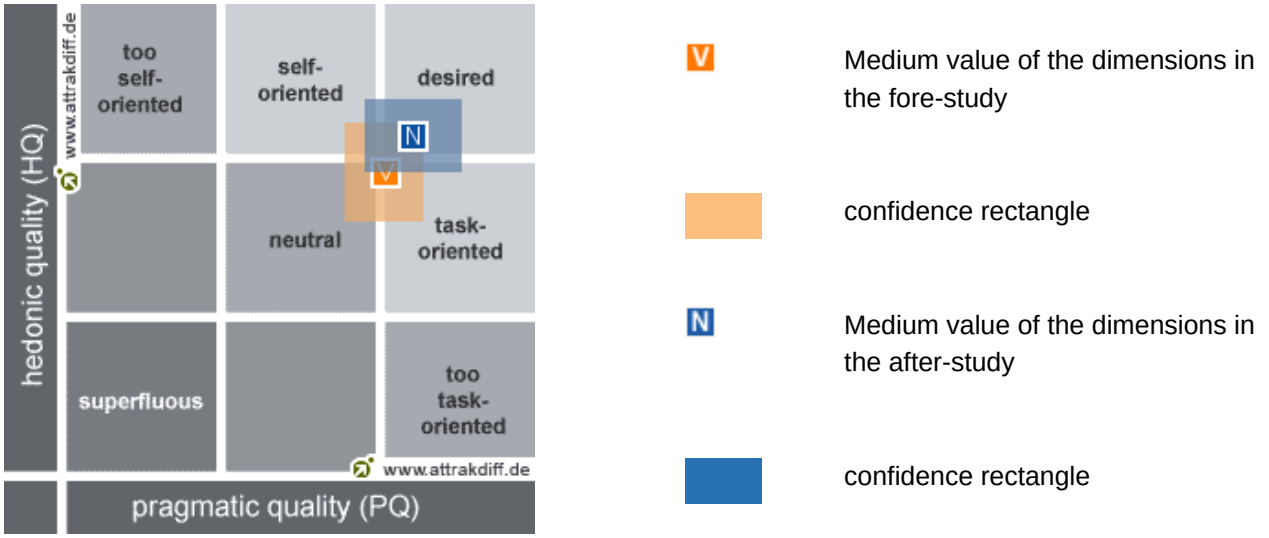


Diagram 1: Portfolio with average values of the dimensions PQ and HQ and the respective confidence rectangles of the product in the fore-study ("SocioDisplay - Mobile only") and after-study ("SocioDisplay - Gestures")

In the portfolio-presentation the values of hedonic quality are represented on the vertical axis (bottom = low value). The horizontal axis represents the value of the pragmatic quality (i.e. left = a low value).

Depending on the dimensions values the product will lie in one or more "character-regions".

The bigger the confidence rectangle the less sure one can be to which region it belongs. A small confidence rectangle is an advantage because it means that the investigation results are more reliable and less coincidental.

The confidence rectangle shows, if the users are at one in their evaluation of the product.
The bigger the confidence rectangle, the more variable the evaluation ratings (more information is available in the appendix).

Interpretation for help

Project part fore-study, product "SocioDisplay - Mobile only"

The products user interface was rated as "fairly practice-oriented".

The classification here is not clearly "pragmatic" because the confidence interval overlaps into the neighbouring character zone. The user is assisted by the product, however the value of pragmatic quality only reaches the average values.

Result: Consequently there is room for improvement in terms of usability.

In terms of hedonic quality the character classification does clearly not apply because the confidence interval spills out over the character zone. The user is stimulated by this product, however the hedonic value is only average.

Result: Room for improvement exists in terms of hedonic quality.

The confidence intervals of both dimensions are large. This could be attributed to limited sampling or to greatly differing product ratings.

Project part after-study, product "SocioDisplay - Gestures"

The products user interface was rated as "rather desired".

The classification here is not clearly "pragmatic" because the confidence interval overlaps into the neighbouring character zone. The user is assisted by the product, however the value of pragmatic quality only reaches the average values.

Result: Consequently there is room for improvement in terms of usability.

In terms of hedonic quality the character classification does clearly not apply because the confidence interval spills out over the character zone. The user is stimulated by this product, however the hedonic value is only average.

Result: Room for improvement exists in terms of hedonic quality.

The confidence interval PQ is large. This could be attributed to limited sampling or to greatly differing product ratings.

Comparison of results of both project parts

The product has improved in comparison with the fore-study. The pragmatic quality as well as the hedonic quality are higher compared to the fore-study.

The difference in terms of pragmatic quality between the fore and after studies is statistically insignificant. It might therefore concern a chance fluctuation of judgment (see details in appendix).
The difference in terms of hedonic quality between the fore and after studies is statistically insignificant. It might therefore concern a chance fluctuation of judgment.

The confidence interval for pragmatic quality is larger than in the fore study. The test participants are less at one in their rating than before the modifications took place.
The confidence interval for hedonic quality is smaller compared to that of the fore-study. The test participants are now more at one in their rating. Thus the ratings of the after-study apply with greater certainty to the product.

Diagram of average values

The average values of the AttrakDiff™ dimensions for the evaluated product are plotted on the diagram.

In this presentation hedonic quality distinguishes between the aspects of stimulation and identity. Furthermore the rating of attractiveness is presented.

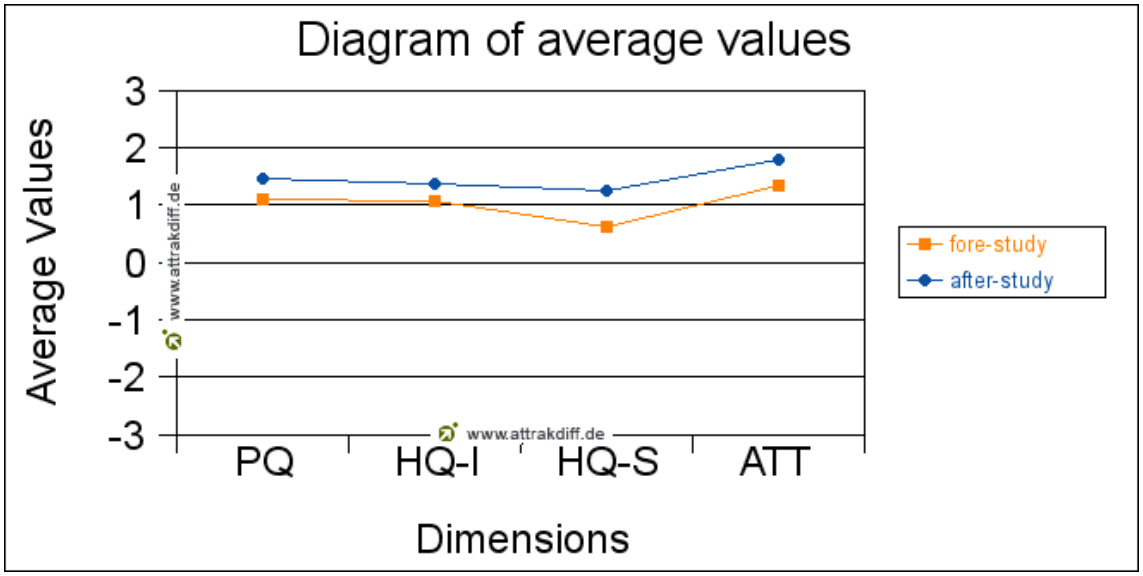


Diagram 2: Mean values of the four AttrakDiff™ dimensions for the product in the fore-study ("SocioDisplay - Mobile only") and after-study ("SocioDisplay - Gestures")

Interpretation for help

Project part fore-study, product "SocioDisplay - Mobile only"

In terms of pragmatic quality the product is located in the above-average region. It meets ordinary standards.

Result: Should you wish to provide the user with really great assistance you must strive to improve the quality even more so.

With regard to hedonic quality – identity, the product is located in the above-average region. It provides the user with identification and thus meets ordinary standards.

Result: Should you wish to bind the user more strongly to the product, you must aim at improvement.

With regard to hedonic quality – stimulation, the product is located in the average region. It meets ordinary standards.

Result: Should you wish to motivate, enthral and stimulate users even more intensely, you must aim at further improvement.

The product's attractiveness value is located in the above-average region.

Result: The overall impression of the product is very attractive.

Project part after-study, product "SocioDisplay - Gestures"

In terms of pragmatic quality the product is located in the above-average region. It meets ordinary standards.

Result: Should you wish to provide the user with really great assistance you must strive to improve the quality even more so.

With regard to hedonic quality – identity, the product is located in the above-average region. It provides the user with identification and thus meets ordinary standards.

Result: Should you wish to bind the user more strongly to the product, you must aim at improvement.

With regard to hedonic quality – stimulation, the product is located in the above-average region. It meets ordinary standards.

Result: Should you wish to motivate, enthral and stimulate users even more intensely, you must aim at further improvement.

The product's attractiveness value is located in the above-average region.

Result: The overall impression of the product is very attractive.

Comparison of results of both project parts

In terms of pragmatic quality, the product has improved in comparison to that of the fore-study. This difference is however statistically insignificant.

In terms of the identity aspect of hedonic quality, the product has improved in comparison to that of the fore-study. This difference is however statistically insignificant.

In terms of the stimulation aspect of hedonic quality, the product has improved in comparison to that of the fore-study. This difference is however statistically insignificant.

In terms of attractiveness, the product has improved in comparison to that of the fore-study. This difference is however statistically insignificant.

Description of word-pairs

The mean values of the word pairs are presented here. Of particular interest are the extreme values. These show which characteristics are particularly critical or particularly well-resolved.

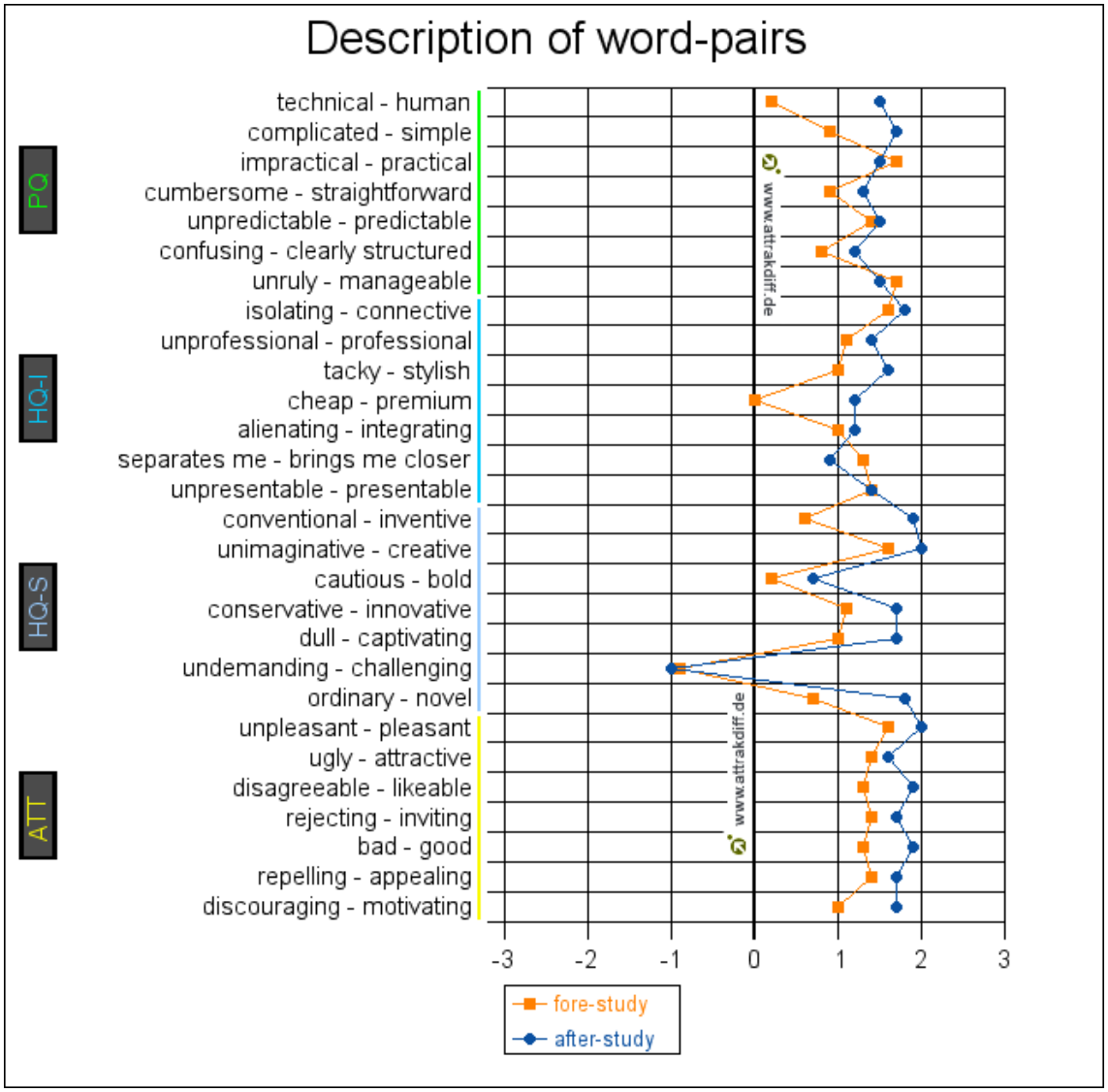


Diagram 3: Mean values of the AttrakDiff™ word pairs for the product in the fore-study ("SocioDisplay - Mobile only") and after-study ("SocioDisplay - Gestures")

APPENDIX

Classification of test participants

Age
20 to 40: 10 test participants

Gender
Male: 8 test participants
Female: 2 test participants

School qualification
University: 10 test participants

Profession
student: 1 test participants
researcher: 1 test participants
student: 1 test participants
student: 1 test participants
phd: 1 test participants
phd: 1 test participants
phd: 1 test participants
phd: 1 test participants
Student: 1 test participants
Student: 1 test participants

Product experience
less than a month: 10 test participants

Confidence Intervals

The confidence intervals create a so-called confidence rectangle. As it is almost impossible to involve all users in the evaluation.

The project co-ordinator has to settle for a number of selected product users to evaluate the product. For this reason one can never be 100% sure that the outcome of the evaluation is representative of the collective users. It might be that the evaluation by the selected users differ from that of the collective users were it possible to ask them all.

The confidence interval outlines the area where the "true" values would lie were it possible to ask all the users.

The confidence rectangle suggests with what certainty the product equals the mean values of the characteristic dimensions.

Significance Tests

Significance tests make it possible to test whether the difference between 2 values can be attributed to the qualities of the product or whether the difference is the result of incidental fluctuations. E.g. If a product receives a higher pragmatic rating than another it does not necessarily mean that it is more pragmatic than the other.

Small, chance fluctuations of judgement can result in a higher value even when there is no systematic difference between the two products. In this case the difference measured is not very relevant.
T-Tests for independent random sampling to check whether there are in fact significant rating differences between the two products. The significance standard lies at 0,05.

This is interpreted as follows:
The difference in ratings is considered "significant" when one can assume with 95% certainty that there are no incidental fluctuations. A difference is considered "insignificant" when the probability of incidental fluctuation is greater than 5%.

Bibliography

[Aga03] Stefan Agamanolis. *Designing Displays For Human Connectedness*. 2003.

[App12] Apple. *OS X Developer Library - File System Basics*. 2012.

[Cat11] David Catuhe. *Unleash the power of Kinect for Windows SDK!* 2011. URL: http://blogs.msdn.com/b/eternalcoding/archive/2011/06/13/unleash-the-power-of-kinect-for-windows-sdk.aspx.

[Com12] Spring Source Community. *Spring Social Framework*. 2012. URL: http://www.springsource.org/spring-social/.

[Cor12] Microsoft Corporation. *Human Interface Guidelines - Kinect for Windows v1.5.0*. 2012.

[CS09] Diane J. Cook and Wenzhan Song. "Ambient intelligence and wearable computing: Sensors on the body, in the home, and beyond". In: *J. Ambient Intell. Smart Environ.* 1 (Apr. 2009).

[Dic] Oxford Dictionaries. URL: http://oxforddictionaries.com/.

[Fas05] Adam M. Fass. "Messyboard: lowering the cost of communication and making it more enjoyable". AAI3166275. PhD thesis. Pittsburgh, PA, USA, 2005. ISBN: 0-542-01551-X.

[Fas12] FasterXML. *Jackson JSON Processor Home*. 2012. URL: http://wiki.fasterxml.com/JacksonHome.

[Fre11] Helge Fredheim. *Why User Experience Cannot Be Designed*. 2011. URL: http://uxdesign.smashingmagazine.com/2011/03/15/why-user-experience-cannot-be-designed/.

[Gad11] Gadgetsteria. *Microsoft: "Kinect SDK Coming in March"*. 2011. URL: http://gadgetsteria.com/2011/02/21/microsoft-kinect-sdk-coming-in-march/.

[Gag05] A Gaggioli. "Optimal experience in ambient intelligence". In: *Ambient Intelligence*. Ed. by G Riva et al. IOS Press Amsterdam, 2005.

[Gar12] Gartner. *Gartner Says Android to Command Nearly Half of Worldwide Smartphone Operating System Market by Year-End 2012*. 2012. URL: http://www.gartner.com/it/page.jsp?id=1622614.

[Gmb12] User Interface Design GmbH. *AttrakDiff*. 2012. URL: http://www.attrakdiff.de/.

[GR01] Saul Greenberg and Michael Rounding. "The notification collage: posting information to public and personal displays". In: *Proceedings of the SIGCHI conference on Human factors in computing systems*. CHI '01. Seattle, Washington, United States: ACM, 2001.

[Gro] Tom Gross. "Ambient Interfaces: Design Challenges and Recommendations". In: *Proceedings of the 10th International Conference on Human-Computer Interaction - HCII 2003*. Ed. by Constantine Stephanidis and Julie A. Jacko. Vol. II. Hillsdale, NJ: Lawrence Erlbaum.

[Gui12] Android Developers Guide. *Activity*. 2012. URL: www.developer.android.com/reference/android/app/Activity.html.

[Has03] Marc Hassenzahl. "The thing and I: understanding the relationship between user and product". In: *Funology. From Usability to Enjoyment*. Ed. by M. Blythe et al. Dordrecht: Kluwer, 2003.

[Has08] Marc Hassenzahl. "User experience (UX): towards an experiential perspective on product quality". In: *Proceedings of the 20th International Conference of the Association Francophone d'Interaction Homme-Machine*. IHM '08. Metz, France: ACM, 2008.

[HT06] Marc Hassenzahl and Noam Tractinsky. "User experience -ăa research agenda". In: *Behaviour & Information Technology* 25.2 (2006), pp. 91–97.

[ISO01] ISO/IEC. *ISO/IEC 9126. Software engineering – Product quality*. 2001.

[ISO10] ISO. *ISO 9241-210:2010 Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems*. Directly by the International Organization for Standardization. 2010. URL: http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=52075.

[Low11] Josh Lowensohn. *Timeline: A look back at Kinect's history*. 2011. URL: http://news.cnet.com/8301-10805_3-20035039-75.html.

[Mic12a] Microsoft. *Kinect for Windows Features*. 2012. URL: http://www.microsoft.com/en-us/kinectforwindows/discover/features.aspx.

[Mic12b] Microsoft. *MSDN Library - Isolated Storage Overview for Windows Phone*. 2012. URL: http://msdn.microsoft.com/en-us/library/ff402541%28v=vs.92%29.aspx.

[Mül+09a] Jörg Müller et al. "Display Blindness: The Effect of Expectations on Attention towards Digital Signage". In: *Proceedings of the 7th International Conference on Pervasive Computing*. Pervasive '09. Nara, Japan: Springer-Verlag, 2009. ISBN: 978-3-642-01515-1.

[Mül+09b] Jörg Müller et al. "ReflectiveSigns: Digital Signs That Adapt to Audience Attention". In: *Proceedings of the 7th International Conference on Pervasive Computing*. Pervasive '09. Nara, Japan: Springer-Verlag, 2009.

[NAA09] Hideyuki Nakashima, Hamid Aghajan, and Juan Carlos Augusto. *Handbook of Ambient Intelligence and Smart Environments*. 1st. Springer Publishing Company, Incorporated, 2009.

[Nie] Jakob Nielsen. *Usability 101: Introduction to Usability*. URL: http://www.useit.com/alertbox/20030825.html.

[NK12] James Newton-King. *JSon.NET*. 2012. URL: http://james.newtonking.com/projects/json-net.aspx.

[Nor88] Donald A. Norman. *The Psychology Of Everyday Things*. Basic Books, June 1988.

[Nur+09] Nurzhan Nurseitov et al. "Comparison of JSON and XML Data Interchange Formats: A Case Study". In: *CAINE'09*. 2009, pp. 157–162.

[Ope12] OpenNI. *OpenNI official website*. 2012. URL: http://openni.org/.

[Que01] Whitney Quesenbery. *What Does Usability Mean: Looking Beyond 'Ease of Use'*. 2001. URL: http://wqusability.com/articles/more-than-ease-of-use.html.

[Rad10] Jerome Radcliffe. "Working from Home: Issues and Strategies". In: (2010). URL: http://www.sans.edu/student-files/projects/201011.pdf.

[rec10] recombu. *What is Windows Phone 7?* 2010. URL: http://recombu.com/news/what-is-windows-phone-7_M12576.html.

[Sad11] Fariba Sadri. "Ambient intelligence: A survey". In: *ACM Comput. Surv.* 43.4 (Oct. 2011).

[Sik08] Marcin Sikorski. "HCI and the Economics of User Experience". In: *Maturing Usability*. Ed. by Effie Lai-Chong Law, Ebba Thora Hvannberg, and Gilbert Cockton. Human Computer Interaction Series. Springer London, 2008.

[Spa+09] Lübomira Spassova et al. "Innovative Retail Laboratory". In: *Roots for the Future of Ambient Intelligence. European Conference on Ambient Intelligence (AmI-09), 3rd, November 18-21, Salzburg, Austria*. 2009.

[Tec11] Tech2Crack. *History of Android*. 2011. URL: `http://www.tech2crack.com/history-android/`.

[Zim08] Philippe Georges Zimmermann. "Beyond Usability - Measuring Aspects of User Experience". PhD thesis. SWISS FEDERAL INSTITUTE OF TECHNOLOGY ZURICH, 2008.

Selbstständigkeitserklärung

Hiermit erkläre ich, dass ich, Katrin Hänsel, die vorliegende Arbeit selbstständig und nur unter Verwendung der angegebenen Literatur und Hilfsmittel angefertigt habe. Alle Teile, die wörtlich oder sinngemäßeiner Veröffentlichung entstammen, wurden als solche kenntlich gemacht.

Die Arbeit wurde noch nicht veröffentlicht oder einer anderen Prüfungsbehörde vorgelegt.

Katrin Hänsel