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Look Who's Talking

Erforschung von wertegetriebener Innovation in Smarten Meetingräumen

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Wien, 13. Oktober 2020

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Exploring Value-Driven Innovation in Smart Meeting Rooms

DIPLOMA THESIS

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Johannes Herrnegger BSc

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Wien, 13. Oktober 2020

Johannes Herrnegger

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Kurzfassung

Angesichts des heutigen Trends des Internet der Dinge und der wachsenden Anzahl von Geräten, die uns täglich umgeben, ist es äußerst wichtig, sich der menschlichen und gesellschaftlichen Auswirkungen bewusst zu sein, die diese Lösungen haben können. Große Unternehmen sowie Startups entwickeln Produkte häufig, indem sie zu viel über Lösungen und zu wenig über die Probleme nachdenken. Wir können Konsequenzen dieser Entwicklungen sehen, die von erfolglosen Produkten bis hin zu gezielter Manipulation und Kontrolle von Gesellschaften mit politischen Absichten reichen. Als Unternehmen, das Verantwortung im Bereich Internet der Dinge nehmen möchte, ist es notwendig Anwendungen zu erstellen, die für Menschen wertvoll und sinnvoll sind, indem sie ihre Werte berücksichtigen und auf sie eingehen.

Diese Arbeit basiert auf den wertorientierten Designansätzen Value-based Participatory Design, Critical Design und Reflective Design. Nach der Untersuchung der bisherigen Innovationsmethoden eines Startups wurde ein wertorientierter Innovationsansatz im Bereich intelligenter Meetingräume untersucht.

Die zentrale Methode dieser Arbeit ist eine Technology Probe, die entwickelt wurde, um einen Diskurs bei Besprechungsteilnehmern anzuregen und zu provozieren mit dem Ziel die Werte zu erforschen, die bei der Benutzung von Internet-der-Dinge-Technologie in ihren Besprechungen eine Rolle spielen und diese Werte dann in die Gestaltung einfließen zu lassen. Die Probe bestand aus einem Gerät, das Sprachrichtungs- und Luftqualitätsparameter erkennt und visualisiert. In einer Probing-Phase in drei verschiedenen Unternehmen konnte ein Verständnis für deren Bedürfnisse und Besorgnisse gewonnen werden. Es war möglich, das Bewusstsein für das eigene und fremde Sprechverhalten sowie für die Gruppendynamik innerhalb der Sitzungen zu verbessern. Bedenken betrafen hauptsächlich Fragen der Privatsphäre und Sicherheit der Probe sowie die Beobachtung und Beurteilung ihrer Vorgesetzten und Mitarbeiter.

In einem Debriefing-Interview mit Entscheidungsträgern des Startups konnte der Schluss gezogen werden, dass sie den Wert und die Bedeutung des Ansatzes und die Möglichkeiten verstehen, die diese Methode oder ähnliche Methoden bieten können. Sie hatten jedoch Bedenken hinsichtlich der Durchführbarkeit dieser Methoden innerhalb Startups, welche meist nach ihrer Gründung über zu limitierte Ressourcen und Geld verfügen, um mit hohem Aufwand in Innovationsmethoden zu investieren.

Abstract

In today's trend of Internet of Things and its growing amount of devices surrounding us every day, it is extremely important to be aware of the human and societal impact those solutions can have. Big corporations as well as startups often create products by thinking too much about solutions and too little about the problems. We can see consequences of those developments reaching from unsuccessful products up to targeted manipulation and control of societies in political uses. As an Internet of Things company who wants to take responsibility it is necessary to create applications that are valuable and meaningful for the people by responding to their values.

This work draws from the value-driven design approaches Values-led Participatory Design, Critical Design and Reflective Design. After investigation of the former innovation methods of a startup, a value-driven innovation approach has been explored in the field of intelligent meeting rooms.

The central method of this thesis is a technology probe, which was created to inspire and provoke a discourse in meeting participants to elicit their values while using Internet of Things technology in their meetings and incorporate those values further in the design process. The probe consisted of a device that detects and visualizes direction of speech and air quality parameters. In a probing phase within three different companies it was possible to get an understanding about their needs and concerns. It was possible to improve awareness of their own and other's speaking behavior and of the group dynamics within the meetings. Concerns mainly related to matters of privacy and security of the probe and observation and judgment of their superiors and coworkers.

In a debriefing interview with decision-makers of the startup it could be concluded that they understand the value and importance of the approach and the opportunities that this method or similar methods can result in. However, they had concerns with the feasibility of those methods within startups, which after their founding have limited resources and money to invest in innovation methods with a high effort.

Contents

CHAPTER 1

Introduction

1.1 Motivation

The term Internet of Things describes the network of interconnected everyday objects like home appliances, vehicles, physical devices, sensors and actuators to enable those to communicate and share data with each other. This extends what we know as the Internet from only PCs, notebooks, mobile devices and so on to a ubiquitous network of devices in our surroundings and everyday lives. With technology becoming increasingly affordable and with companies such as internet service providers, insurances and energy providers bringing Smart Home products on the market, IoT becomes increasingly common place.

In the midst of this trend, smaller companies and startups try to get their share in the IoT market. However, while the market is hyped, a lot of companies create their products with putting little value on people and society. A central concern is that much work is driven by what is technologically possible instead of what is meaningful to people. In today's world the industry wants to answer a lot of the day-to-day problems or non-problems that we have with technological gadgets and tools. It appears that technology creators are thinking more about solutions than about problems and so there are many solutions developed for problems that are either not there, not clear or not identified. The term for this is technological solutionism. Smart fridges, internet connected juicers and coffee machines are only a few of the examples that appeared within this phenomenon. They mostly solve problems that do not exist and are only there because it is technologically possible and not because it is meaningful for people.

But not only does this trend create those mostly unnecessary use cases, they also create additional security and privacy issues. Also, often those connected devices lead to shorter product lifespans, because they have to be connected to a company's server and if the company does not provide the service anymore because it cannot or decides not to [Bha17]. The well-known story of the smart juicer *Juicero* is a good example for this

solutionism paired with non-sustainable thinking and a lot of controversial discussion. Funded in 2013, They sold the main device *Juicero Press* for $400 (originally $700) plus $5-8 per package of juice with the promise of getting organic and fresh ingredients, customize the juice from an app with not having to be at home and getting reminders and automatic refills when the system detects that the ingredients get expired. It was a closed system, so officially only the juice packages of the company could be used. One of the packages had a life span of 8 days and the packages had to be verified via an active internet connection before it could be used. The sales were lower than expected, also after the realization that the main device is not needed to press out the packages because it could be done by hand [Sil17], so in 2017 they had to close the company.

Voice recognition systems like the Amazon Echo or combined with cameras like the Amazon Echo Show or Amazon Echo Look bring features 360-degree photos of your body combined with an AI for fashion advice [Gar17b]. In 2019 smart speakers were installed in almost 90 million US households, while Amazon held 61% and Google 24% of the market share (Google increasing) [Gar17a, Sma19]. While the owner consider them as useful home helpers to provide information, play music, set timers or do online shopping, there are a number of security and privacy issues connected to those appliances, where also US law enforcement officials understand the collected information as useful in their investigations and in court [JO].

To use data in retrospective to investigate and clarify crime is one side of the picture, but in the last years data was also used to predict crimes beforehand. With this method, called predictive profiling, machine learning algorithms calculate the likelihood of committing crime at specific places or of individuals in the future based on the nature of past crimes. This system is already active in some of the states in the United States. Predictive profiling is often marketed as a scientific solution for the problem of racial profiling - that some ethnicities are more investigated in than others because of prejudices of the inspectors. But the studies that tested this promise found no statistical evidence that they reduce crime and the promise of objectivity and race neutrality could not be met. On the contrary, those methods potentially even legitimize discriminatory police practices [GC, BVM18]. In particular, through feeding the algorithms with crimes in the past they tend to re-create those crimes and therefore also the subjective approaches of the police officials.

This phenomenon of discriminating algorithms can also be seen in a lot of other examples like facial recognition misidentifying black and asian people up to 100 times more than white people [cai] or speech recognition systems understanding black people much worse than white people because the underlying datasets are mostly filled with speech samples of white people [KNL+20].

How dangerous it can be also for whole societies when corporate and political interests will use personal information is described by the prominent case of Camebridge Analytica, a company which took 50 million Facebook profiles without authorization in 2014 [CG]. They used this data to profile individual voters and manipulate elections by targeting the people with individual advertising and fake news articles. With this method, they

were able to manipulate 2016 US presidential elections in favor of Donald Trump and also the UK Brexit election in favor of leaving the EU.

Another example of political usage and societal influence of technology is the Chinese Social Credit System [Loo], where people's actions get rewarded or penalized in representation of a score that is assigned to every citizen. This score is an indication for the government to see how trustworthy a person is and determines what they are allowed to do, like if they are allowed to board a train or get a loan. The data is collected by surveillance cameras, smart appliances and also "information collectors", people who are responsible for writing down the actions on their neighbors. If people have a low credit state or even are discredited, it makes it hard to get a job, a hotel room or to educate their children in certain schools. Furthermore, people get publicly shamed with photo galleries, public screens and apps that show people in your surrounding who are in dept. This is one of the most extreme examples, which shows that the collected information not only will be used by governments sometime, but is already the present for many Chinese citizens.

As a counterpart for those developments, the European Commission founded the Next Generation Internet (NGI) initiative in 2016, which has the goal "to shape the future internet as an interoperable platform ecosystem that embodies the values [...] openness, inclusivity, transparency, privacy, cooperation, and protection of data" [DIS]. The scope of this project also includes the Internet of Things and to shape it to be in a human-centric, value-centric, human and inclusive Internet for People.

The problem that emerged over the last decades is that there is a need for technology that considers human and societal values. Cases like Cambridge Analytica and the developments in China, indicate the importance to be conscious of the consequences and the impact certain technologies can have. Particularly the Internet of Things collects a massive amount of data and is surrounding us more and more in our daily lives, often also without our knowledge or consent. This gives rise for a lot of fundamental questions in how this data is collected and used and how it influences people and society.

In this work I want to investigate paradigms and methodologies that address designing technologies with a focus on human values and using some of those methods to innovate IoT in ways that responds to people's needs and values, considers alternative business cases and societal responsibility.

1.2 Aim of the thesis

This work aims to explore possibilities for small and medium-sized companies to innovate products and create applications that are valuable, meaningful, empowering and trustworthy, maximize their utility and reflect responsible innovation. This will create opportunities for businesses which try to take their social responsibility seriously and create Internet of Things applications that respond to the needs of the users.

"Internet of Things" is an umbrella term that encompasses many sub-fields like Smart Home, Smart Office and Smart City. Smart Home focuses on the connection of home appliances, while Smart Office focuses on the workspace. This thesis is focussing on Smart Office and in particular on smart meeting rooms.

The overarching research question this thesis wants to answer is:

How can Internet of Things technology be developed driven by values and ethical responsibility?

To contribute to this question I will do a case study focusing on the context of Smart Office within a small IoT company. In specific, I want to answer the following research questions:

1. Can a technology probe be used to inform innovation processes of an IoT company to responsibly innovate in the context of a smart meeting room?
2. How does the particular small IoT-company relate to value-driven innovation?
3. In which ways can smart technology affect a meeting?
4. Which concerns do meeting participants have when using smart technology within the meeting?

To answer those questions I will use interviews, surveys, and a technology probe as methods.

1.3 Setting

This thesis is an accompanying work to a research study COMPASS[1], where next to Vienna University of Technology several other institutions were involved, including the University of Vienna, the Austrian Institue of Technology, the Austrian Computer Society and the Research Institute AG & Co KG. The goal of the project is to build a guide for "businesses which seek to create IoT technologies and services that respond to user needs and are mindful of their societal responsibility".

The study group within COMPASS discussed and explored how companies and institutions can recognize and use opportunities in the space of IoT by creating applications that are valuable, meaningful, empowering and trustworthy, maximize their utility and reflect responsible innovation. Like illustrated in 1.1, its scope was to view Internet of Things as

[1] http://compass-project.at

the three subfields Smart Home, Smart Office and Smart Cities from different perspectives (technlogy, user, society and policy) and provide tools for connecting those fields and opening negotiation spaces within and inbetween them.

The **technology perspective** is driven by technological possibilities, technological innovations and questions on how systems are technically developed. One example is how the sensors and actuators are connected with each other. There is the centralized approach, where the devices are registered at a IoT platform and the platform's logic allows the sensors and actors to interact with each other and have other (wanted) side effects. Most of the commercial solutions follow the centralized approach (Amazon AWS, Google Cloud, Apple Homekit and many more). The problem with those services is that because the data runs over the provider's servers the users have to trust the provider not to disregard their privacy. As an alternative, COMPASS argues in favor of a decentralized approach, as it opens new opportunities for the users to create smart local environments around them without the need to upload the data to a central server.

The **user perspective** concerns with understanding how and why people interact with the systems and which values their actions are based on. In HCI (human-computer interaction) the field of PD (participatory design) involves participation of people in the design process to not design just *for* people but together *with* people. This approach is described in section 2.2.2.

The **societal perspective** embraces the societal responsibility, that technology brings with it. It is aware that technology is able to shape and change societies.

The **policy and market perspective** also invites law-making entities into the discussion of enabling the negotiation spaces between all the stakeholders. Recognizing that legal boundaries can make sustainable decisions in order to empower users' interests.

Different stakeholders within those different perspectives usually have their own opinions, values and interests. One of the visions for Compass was to open negotiation spaces, where the different perspectives can come together in an open discussion to create a human-centered next-generation internet (NGI) or internet of people.

One explorative format created by Compass was the Parliament of Smart Things. Inspired by improv games, Bruno Latours Parliament of Things[2] and the Theatre of the Oppressed[3], there is an audience, from which a fixed amount of roles will be assigned. The different roles represent different stakeholders within the IoT area like "programmer", "public health official", "data rights activist", "pensioner couple", "earth" and the "joker", who facilitates the experiment. After being primed with a particular critical design video, the selected people are presented with a "What if..." question, which they then discuss within their respective roles. At any given point the people in the audience are encouraged to say "freeze" and take over the role of someone else. This playful method allows the creation of negotiation spaces about potential concerns and innovation and

[2] https://theparliamentofthings.org/about/
[3] https://en.wikipedia.org/wiki/Theatre_of_the_Oppressed

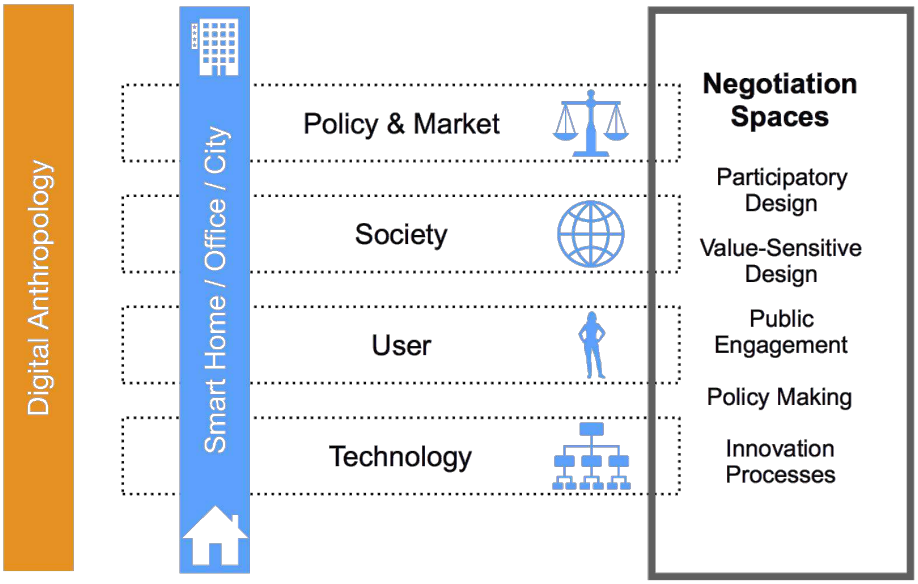

Figure 1.1: COMPASS areas and perspectives [Fra19]

furthermore give more understanding and empathy about different perspectives. Within the scope of the project COMPASS, two of those experiments were held. One at an HCI and Ethics seminar in an university, and one at an event at a conference with focus on digitalization.

My main part in COMPASS was this master thesis, which acts as an example case on how to use participatory design to create negotiation spaces between a company and potential users. Furthermore I took part in the meetings of the project and contributed some parts to the deliverables.

The work focuses on the company Flatout Technologies, a small company I was employed at when the project started. Its staff agreed to take part of this study. It investigates their current innovation processes and product development strategies with the aim to facilitate critical self-reflection and mutual learning in the company about their existing innovation models through interviews and participatory design processes with potential future users. Afterwards it evaluates how likely it is that they will use the learned approaches in the future and adjust their innovation models to build more sustainable products (in terms of the former discussed values). For that it is important to identify the drivers, reasons and arguments that are or are not in favor of why the company would use similar methods in the future. Ideally, the company finds value and new opportunities with the new insights.

A similar thesis, also an accompanying work to the study COMPASS, was done by Valentina Tessa, a student in the University of Vienna. The outcome of her work is described in Section 2.2.6.

1.4 The company

Flatout Technologies provides an IoT platform that modularly connects sensors and actors. On top of this platform, they integrate products for several use cases. Until now, Flatout Technologies' primary focus were solutions for the Smart Home. While Smart Home also was the original theme of the thesis, the first interview and several discussions afterwards revealed that in the future it will also be attractive for the company to develop solutions for Smart Offices and intelligent meeting rooms.

1.5 Structure of the thesis

The thesis is structured as follows. Chapter 2 first should give the reader a background about what values are in a scientific way and describes important value theory models in section 2.1. Subsequently section 2.2 explores how values are considered in Human Computer Interaction and section 2.3 explores current research and the market of smart office applications. In chapter 3 a description of the used methods is given. Chapter 4 describes the introductory interview and the the decisions about the direction of the following work. The concept, creation and development of the technology probe as well as the probing and the results are presented in chapter 5. Chapter 6 describes the debriefing interview and its results. Finally in chapter 7 the thesis is discussed and concluded and a consideration about future work is given.

CHAPTER 2

Related Work & Theoretical Background

2.1 Value Theory

In this section I want to investigate human values in a scientific sense and elaborate works from the past decades from the field of psychology.

As human beings, we all have an opinion on what is important to us in life, what we consider good or bad. Sometimes we call those preferences "values".

"Human beings, whether in their role as employers, consumers, citizens, or patients, have moral values, moral preferences and moral ideals. Information technology cannot and ought not to be at odds with them, and preferably should support and express them" [van17]

While this statement of van den Hoven appeals to the ethical stance, there can also be economic advantages for companies, like [Fri96, p. 7] puts it: "Moral values can also support economic goals. Yet this point often gets lost in bottomline cost—benefit analyses. For example, protecting user autonomy means giving users control at the appropriate level over their machines. This protection can translate into marketable features, such as of privacy and security."

As [Spi15, pp. 168-170] uses full-body scanners in airports as an example, with which the staff as well as other passengers could see the bodies of the passengers in detail, which is a privacy issue. While some companies saw it as a threat to their business or did not see the importance, one company saw it as an opportunity and developed a privacy-friendly version and came to dominate the market.

Another example demonstrates that taking values seriously can also prevent the company from financial loss is the VW emission scandal, in which the company deliberately devel-

oped software that was contradictory to the company's corporate values of "responsible thinking". This led to a 25% drop in sales within a year [HMW18].

Allports' "Study of Values" describes six value types: social, theoretical, economic, aesthetic, political, and religious [KR06]. [Rok73] states that those value types are rather likes, dislikes and attitudes toward occupations. Also he argues that values are more like idealized standards. He created a list of 36 values and stated that it is less important how people rate one singular value on its own, but how they rate the values *relative to each other*.

What's missing in the Allport-Venon-Lindzey and Rokeach's theory is the relationship of the main value categories to each other. This is what Schwartz's circular model of human values explains [Sch12].

In the following subsections I will examine different value theories: *Schwartz Theory of Basic Human Values*, Maio's *Mental representation of Values* and *Functional Theory of Human Values*.

2.1.1 Schwartz Theory of Basic Human Values

The most popular theory of values is the Schwartz Theory of Basic Human Values. Due to this theory, *values* are what is important to us in life. This is very subjective. A value can be important to you, while it is not important to another person. Schwartz identified ten values that are universal across all cultures around the world. Based on the Schwartz value theory, a value incorporates the following features:

- Values **are beliefs connected to emotions**. When they get activated they lead to feelings. When achievement is of high importance to you, you will get aroused negatively when your status in your job is threatened.
- Values **refer to desirable goals** that lead to action. When honesty is of high importance to you, you're more motivated to act accordingly to this value.
- Values **go beyond specific actions and situations**. When stimulation (f.e. to live a varied/exciting life) is important for you, you probably will actively try to aim for novel situation with your friends, but also try to be innovative in your work or school.
- Values **serve as standards**. You evaluate people, policies, societies, norms, actions and events based on your values.
- Values **are ordered by importance** for each individual and the order forms your character. Is it more important for you to achieve success or to to be fair? Do you value security over individual freedom?

- **The relative importance of multiple values guides action**. Usually your mindset and behavior is influenced by multiple values and also contradicting values.

The ten cross-cultural values Schwartz identified are listed below:

- **Openness to change**
  - **Self-Direction** means independent thought and action – choosing, creating, exploring.
  - **Stimulation** refers to have excitement, novelty and challenge in life.
- **Self-enhancement**
  - **Hedonism** is to seek pleasure or sensuous gratification for yourself.
  - **Achievement**'s goal is to strive for personal success with demonstrating your competence within social standards.
  - **Power**. To have control over people or resources and demonstrate social status and prestige.
- **Conservation**
  - **Security**'s goal is safety, harmony and stability of society, relationships and self.
  - **Conformity** contains not wanting to upset other people.
  - **Tradition** means that you respect and accept the customs and conventions of your culture or religion.
- **Self-transcendence**
  - **Benevolence** maintain and enhance the wellbeing of your loved ones, family, friends, social group.
  - **Universalism** understand, appreciate, tolerate and protect the welfare of all people and nature.
- **Other**
  - **Spirituality**

The theory not only identified the former listed values, it also illustrates the relationship between them. While *self-direction* and *stimulation*, for example, often go hand in hand, a person who values *stimulation* is likely to not value *tradition* that much. Another example: while *power* and *achievement* are compatible, *power* contradicts *conformity*.

Pursuing values motivate actions, which have practical, psychological and social consequences. When you choose to act according to a value you may also be aware of that

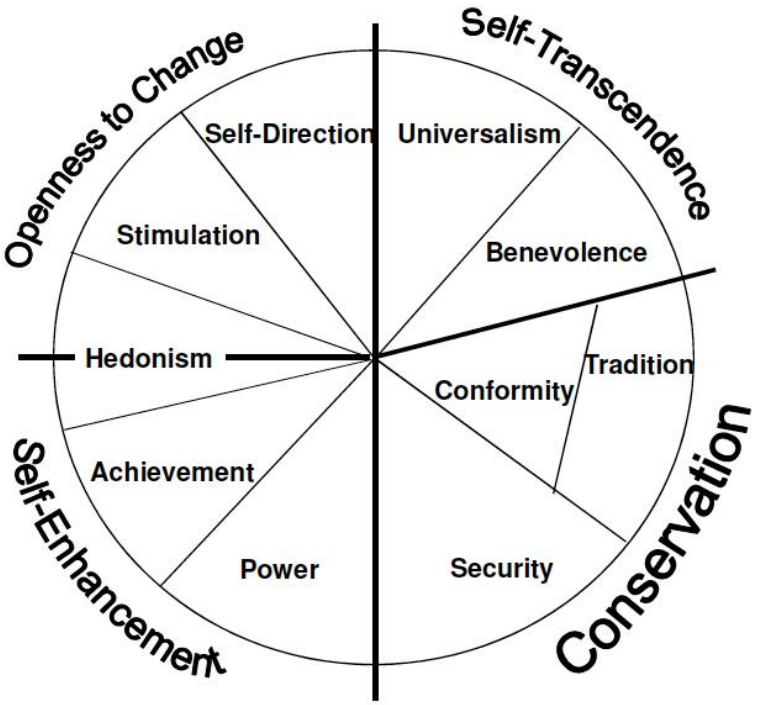

Figure 2.1: Schwartz Theory of Basic Human Values Circular Model [Sch12]

there are alternative actions that act according to a contradicting value. You can also pursue competing values, but not in the same act, but through different acts, times or settings.

Figure 2.1 shows the values in their relation to each other with corresponding value items.

2.1.2 Maio's Mental Representation of Values

Another approach is Maio's Mental Representation of Values, which is an alternative, but also influenced by the Schwartz Theory [Mai10]. About twenty years after Schwartz published his value system, Maio argued for an additional model. It takes on some flaws of Schwartz's theory, which are described in the next paragraphs.

The most important feature of the model is how the features relate to each other. So, values that are next to each other in the circular model should have similar correlations and values that are on the opposite side should have opposing correlations. Additionally, research supported the circular model by revealing sinusoidal pattern of relations between values and other constructs (attitudes and behavior). That means that if the model is valid, any construct that is related to one value should be negatively related to the opposing set of values.

In less developed countries (for example India, Malaysia and some African countries) the use was not as supportive of the Schwartz Value Survey (SVS) [Sch92]. One of the main arguments was that the interpretation of the values in the abstract level were not equivalent across cultures. Maio sees this problem "as one of the key challenges that faces research on values. The abstract nature of values is vital to their conceptualization, but complicates their assessment." [Mai10, p. 8] When we take equality as an example, there is the possibility to think of equality between races, genders, religions and many other instantiations. So that could be a problem, that when you think of one abstract value, you cannot really say which instantiation people have in mind when they think about it. Schwartz created another kind of questionnaire for that reason (Portrait Value Questionnaire, PVQ) that supported the model more than the SVS in some countries. Maio finds that "the Schwartz model provides a reasonable 'prototype' for modeling value relations across cultures, despite some potential variability in the applicability of it to different cultures" [Mai10, p. 9].

"The abstract nature of values is essential to their conceptualization" [Mai10, p. 8] argues. It is completely valid that people don't necessarily have strong connections between their values and *all* of their attitudes and behaviors. Some attitudes serve values, but others might serve useful concerns, social adjustments or ego-defense purposes. He explains further that the use of values in an abstract level is justified and important, but it cannot be sufficient for complete understanding of values. They must implicitly refer to something. "Freedom to kill means something different from freedom to live, and equality of outcomes means something different from equality of opportunity. People refer to values in ways that are abstract, but when applying them people must do so concretely." [Mai10, p. 10]

Further Maio tries to explain values as mental representations, and that they can vary in breadth, concreteness, connections to other constructs, accessibility and other features. He puts the mental representations in three levels: *systems of abstract values*, *specific abstract values* and *concretely instantiated values* as shown in Figure 2.2.

The first, system level, is based on the idea that values are not isolated from each other and influence each other, which is supported by Schwartz's circular model. The second, level of specific abstract values, is meant to discover which abstract-value judgements are influenced by different types of psychological information. The third, level of concretely instanciated values, is useful for studying the process that occurs when a value gets more thought through. It enables to grasp how people come to action from concrete instantiations of values.

2.1.3 Functional theory of human values

Another alternative approach to Schwartz's circular model is illustrated by Gouveia et al. [GMG14]. Since the introduction of Schwartz's value model throughout the years there were so many different configurations of the value theory promoted, which have different

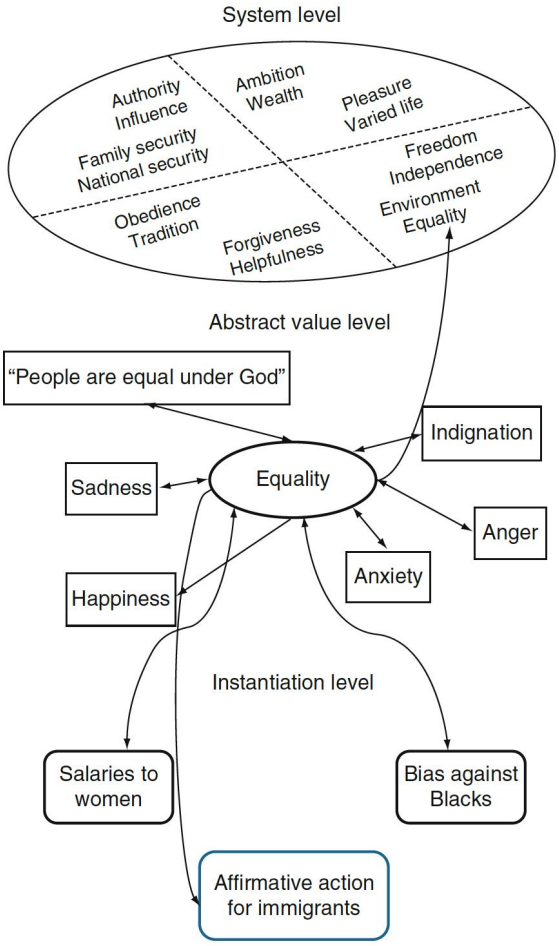

Figure 2.2: Maio's mental representation of levels [Mai10]

dimensions and are also sometimes conflicting. They reach from two bipolar higher-order dimensions to nineteen motivational value types. He argues that this lacks parsimony and theoretical focus and might hinder comparison and meta-analyzing of studies. The "theory integrates models that conceptualize values as guiding actions and expressing needs" [GMG14, p. 1].

In psychological theory two value functions of values can be identified: *values guide actions* and *values are cognitive expressions of needs.*

Those value functions are the basis for the functional theory of human values, which tries to explain the underlying characteristics of the value domain structure. They form distinct functional dimensions. The first dimension complies to the 'circle of goals' (personal, central, social goals) and the second dimension outlines the 'level of needs' based on the type of motivator (survival or thriving needs).

		Values as guides of actions (circle of goals)		
		Personal goals (the individual by itself)	*Central* goals (the general purpose of life)	*Social* goals (the individual in the community)
Values as expressions of needs (level of needs)	*Thriving* needs (life as source of opportunities)[2]	**Excitement Values**	**Suprapersonal Values**	**Interactive Values**
		Emotion	Beauty	Affectivity
		Pleasure	Knowledge	Belonging
		Sexuality	Maturity	Support
	Survival needs (life as source of threats)[1]	**Promotion Values**	**Existence Values**	**Normative Values**
		Power	Health	Obedience
		Prestige	Stability	Religiosity
		Success	Survival	Tradition

Figure 2.3: Facets, dimensions and basic values [GMG14]

Guiding actions The functional theory identifies three different value types on the dimension of *guiding actions*: personal values, central values and social values. People who are guided by personal values have a more self-centered or interpersonal focus, while people who are guided by social values have a more society-centered or interpersonal focus. There is another value type, which is neither completely personal nor social. Theories like Schwartz's define this third value type in opposition to the other two values, but functional theory places it in between personal and social values. It assumes that this set of values is congruent with personal and social values and not in opposition to them. Furthermore, it not only puts it in between the two value types, it also makes them the central reference source for the other values, because they have general purposes of life like basic needs (e.g., survival) and more general needs (e.g., self-actualization).

Expressing needs On the dimension of *expressing needs*, there are two sets of values: materialistic/pragmatic and humanitarian/idealistic values. Materialistic/pragmatic values express biological and social needs like food acquisition. Humanitarian/idealistic values express needs of information, self-esteem, intellectual/emotional stimulation and become more important when the materialistic values are met.

As materialistic values are important for survival needs, they tend to lead to specific goals and actions, while humanitarian values express thriving needs and are often not that specific and directed towards concrete goals like creativity and open-mindedness.

2.1.4 Summarizing values

In the previous subsections I gave an overview over three theories that try to explain human values. In HCI literature Schwartz's Theory of Basic Human Values is the most popular and the most known theory.

Maio addresses the flaw of the Schwartz Theory that the interpretation of abstract values can be widely different and introduces three levels in his theory: *systems of abstract values*, *specific abstract values* and *concretely instantiated values*, which are supposed to tackle this flaw.

The functional theory of human values disengages from the circular model and converts the values into a 2-dimensional structure to make different approaches more comparable.

Because of its popularity, in the next sections mostly the Schwartz Theory gets attention, but it is also important to have the other theories in mind when designing with human values in mind.

2.2 Values in Computing

The last subsection elaborated the basic understanding about general theories of values and what values are. This subsection investigates how values are interesting in the design and creation of computer systems and explores how values are considered in computing and more specifically in Human Computer Interaction.

As scientists and also designers in HCI have identified the need for designing new systems with values in mind, there are a number of different approaches that are attempting to give solutions for this challenge. Some of them are Value Sensitive Design (VSD, [FHB17]), Values in Design, Values for Design ([VVV15]), Values-led Participatory Design ([IHL10a]). As [van17] states, in those approaches similar claims are appearing: (1) values can be expressed and embedded in technology, (2) technologies have real and sometimes non-obvious impacts on those who are directly and indirectly affected, (3) explicit thinking about the values that are imparted in technical design is morally significant and (4) value considerations should be surfaced early in the technical design process;

Reflective practice Before describing the different approaches, I want to briefly digress to give an understanding about Schön's *reflection-in-action*, because some of the approaches and critique is referring on his philosophy [Sch83]. He was an organizational scientist, whose work is mainly concerned with practitioners think and how they make decisions. According to his theory, there are two different kinds of reflection. One is *reflection-on-action*, which describes the reflection on a situation in hindsight – after the situation is over, reflecting back on something – an *ex post* reflection. And the other one is *reflection-in-action*, which means that the reflection is applied in the midst of the action. While the practitioner can use his knowledge within the situation with *reflection-in-action*, it often is hard and gets compromised by several factors as for example how little time managers have for reflection during their actions. Schön's theory has been influenced across a wide range of disciplines studying professional work in various organizational settings, such as nursing, teaching, planning and management. "Reflection-in-action and reflection-on-action form the two ends of a continuum of reflective practice." [YT09, p. 2]

2.2.1 Value Sensitive Design

"Value Sensitive Design (VSD) is a theoretically grounded approach to the design of technology that accounts for humanvalues in a principled and comprehensive manner throughout the design process" ([FHB17]). It consists of an iterative methodology that integrates *conceptual*, *empirical* and *technical* investigations: With *conceptual investigations* VSD asks questions like who are the direct and indirect stakeholders? How are they affected? What values are implicated? How should we handle competing values? *Empirical investigations* means to use quantitative and qualitative methods to analyze the questions that needs to be evaluated because they cannot be answered by conceptual investigations. For example to measure the success of a particular design or prioritizing competing values in design trade-offs with stakeholders. *Technical investigations* focus on how different technologies support or hinder human values.

In VSD, Values are defined as follows: "what is important to people in their lives, *with a focus on ethics and morality.*"

[HT08, chapter 4] presents three case studies that illustrate how VSD can be put into practice. The first one is about cookies and informed consent in web browsers implicating the value of informed consent. The second case discusses the use of plasma displays in office spaces, that displays real-time outdoor scenes to investigate the value of psychological and physical wellbeing as well as privacy in public spaces. The third one is a simulation package for predicting patterns of urban development to help stakeholders to make informed decisions, implicating the values of fairness, accountability, support for the democratic process.

[Fri96] discusses two values: *user autonomy* (Individuals are able to decide, plan and act in ways they believe will help them to achieve their goals) and *bias in computer systems* (Does a system systematically and unfairly discriminate certain individuals in favor for others?)

VSD Methods

To get an overview about the methods one can use in VSD, I refer to [FHB17], where they present a selection of fourteen of them that are particularly interesting or shaped by VSD. The described methodologies include *Direct and Indirect Stakeholder Analysis*, *Value Source Analysis*, *Co-evolution of Technology and Social Structure*, *Value Scenario*, *Value Sketch*, *Value-oriented Semi-structured Interview*, *Scalable Information Dimensions*, *Value-oriented Coding Manual*, *Value-oriented Mockup, Prototype or Field Deployment*, *Model for Informed Consent Online*, *Value Sensitive Action-Reflection Model* and *Envisioning Cards*$^{\text{TM}}$.

In the following paragraphs I will describe two of the methodologies that are related and particularly interesting for this thesis: *Direct and Indirect Stakeholder Analysis* and *Value-oriented Mockup, Prototype or Field Deployment.*

Direct and Indirect Stakeholder Analysis In a traditional stakeholder analysis, organizations clarify the project scope by identifying individuals and groups by the investigated technology [BKS04]. VSD enhances this by including not only individuals and groups, but also institutions and societies. They distinguish between two categories: (1) *direct stakeholders* interact directly with the technology; while (2) *indirect stakeholders* are significantly affected by the technology, either positively or negatively, without directly interacting with it.

Value-oriented Mockup, Prototype or Field Deployment Mockups and prototypes are tools with the purpose of testing a design early on in the design phase and get early user feedback. In VSD, those together with field installations can be used to elicit the views and values of the stakeholders concerning the technology. While those prototypes may seem similar to technology probes, there are some fundamental differences which are discussed in Section 3.2.

Critique on VSD

While VSD is one of the first approach including values in the space of HCI, some researchers expressed their concerns about it. [LDPW09] argues that the mechanics of the approach invites designers to be less sensitive to values. It articulates its critique in three issues:

The first issue they have is the twelve values with ethical import, which is given as a heuristic to determine which values designers should consider when they work with VSD. The problem with this is that by providing twelve distinct values, which are given as an ethical guideline , a "nimbus of morality", it cultivates a dogmatic search of those values and which of the values of ethical import are worthy of consideration, which makes it harder to be sensitive about nuances of the values that the stakeholders hold.

The second issue is that VSD does not describe which empricical instruments are effective in which context in question of value.

The third issue they have is that the intended order of the investigations (*conceptual* to *empirical* to *technical*) is prioritizing known values (such as the values of ethical import), because the investigation of values is emphazised in the *conceptual* phase.

Another part that they critique discusses that the given case studies are presented in a way that suggests that you can just put values on already developed projects. By reflecting on how the system affects stakeholders after already designed and installed, they achieve an “ex post facto exploration”. The paper refers to two projects: "UrbanSim" and "The Watcher and the Watched". UrbanSim is a simulation for predicting patterns of urban development like pollution, traffic jams and resource consumption with the goal of providing information for urban planners for their decision-making and a secondary goal to support democratization of the planning process [FBD+]. The Watcher and the

Watched is a study with a screen that serves as a window and a camera on the outside of the building so the participant can see what's happening on the outside [FJH+]. In the beginning of the study they wanted to address psychological discomfort that arises when working in an office without windows. Within the study they reframed the subject to investigate questions of surveillance in public and privacy while inhabiting public spaces. The initial intention of the study was presented as an ex post facto exploration as argued by [LDPW09].

The former discussed UrbanSim is frequently discussed in VSD literature. In [TM], they take this case as an example for arguing that VSD lacks of reflexivity. The researchers focus on some values that they think are important, which is highly dependent on the values of the researcher and questions on which basis those values are selected and how personal views and opinions of the researchers affect the selection and interpretation affects the design. They plead for more reflexivity in the researcher's influence on the resulting system design, such as discussion within the work about professional and philosophical background of the researchers involved and how they understand and prioritise certain values.

The "Value Sensitive Action-Reflection Model" presented in [YHW+] is a method that takes a step towards these issues by implementing ideas of *participatory design* (Section 2.2.2) and Schön's *reflection-on-action* (Section 2.2.5).

2.2.2 Participatory Design

This subsection gives an introduction to Participatory Design (PD), which is the used approach in this work. Participatory Design is a design approach, which includes different stakeholders and actively tries to engage them in the design process.

While in a typical design project designers get a goal from paying clients and then design for users and test their assumptions, maybe in several iterations, PD in contrast is a different approach. It requires designers to get into a different mindset and to invite and involve different stakeholders into the design process. Everyone has their own set of experiences, while the designers' views may be more experienced in the creation of things or systems, while users made their own experiences which forms their perspective of the world. PD tries to embrace this and attempts to find a common ground that lies between the perspectives of the different stakeholders. Stakeholders are not limited to designers and users, but they can and should involve everybody that is involved in the project. In examples below this will illustrated more clearly.

In [Mul03], they define PD as "a set of theories, practices and studies related to end-users as full participants in activities leading to software and hardware computer products and computer-based activities". But it first came up in the 1960s in Scandinavia in a political context during a workplace democracy movement and has since evolved to also face social justice issues like inclusive design, women's needs and disability challenges and many more. [Mul03] furthermore argue that the field is "extraordinarily diverse, drawing

on fields such as user-centered design, graphic design, software engineering, architecture, public policy, psychology, anthropology, sociology, labor studies, communication studies, and political science, and from localized experiences in diverse national and cultural contexts", which leads to a large number of different methodologies in the toolbox of PD.

To create this common understanding and common space between the designers and the different stakeholders, there are some questions and methods that can be used in the process. One of the easiest parameters to influence it is the **site of the work**: Bringing the designers to the stakeholders, bringing the stakeholders to the design room or a site that is somewhere completely different. Even this decision can have an impact on the course of the design process. **Workshops** can be another alternative and are usually held to support two or more stakeholders to communicate and find new outcomes, goals or strategies. The future workshop is the best-known format in PD, where participants envision the future of a particular space. Also workshops that borrow methods from improv theater are used, like the Parliament of Smart Things used by COMPASS, that was broached in Chapter 1.3. **Games** like card games are another method to inspire designers and stakeholders to talk about and develop ideas. There are many more methods that would go wide beyond the scope of this work. Two further methods, **interviews** and **probes**, were used in this work and will be described in chapter 3.

2.2.3 Values-led Participatory Design

As [IHL10a] puts it, "PD is about negotiating values realized through participation". They present an approach to PD that cultivates values. They find that often designers think they are practicing PD just because they use some PD methods, but it's not just PD methods that makes a work PD. "Although some PD practitioners are already engaged with values as their core concern, we argue the need to engage with values more explicitly, to view values as the engine that drives our design efforts". Their approach differs from other value-driven approaches like Value Sensitive Design that the values emerge in collaboration with the stakeholders by recursively define and refine them. It's also important to note that while the users have their values, the designers also bring their values in the design process. "in ordinary discussions, people usually hold relatively fixed positions and argue in favor of their views as they try to convince others to change. At best this may produce agreement or compromise, but it does not give rise to anything creative" ([BN03])

In values-led PD, it's important to cultivate the *emergence*, *development* and *grounding* of values.

Emergence describes when the values first come up. [IHL10b] found that important contributions to the emergence of values rely on the designer, the participation of stakeholders and methods. They emerge from a dialogical process between stakeholders and designers and the designer has to be aware of not only the stakeholders' values,

but also his or her own values. While on smaller projects described in [IHL10b] the values emerged early in the process on meetings, in larger projects they first met every group of stakeholders in separate meetings and then decided to bring everyone together in very large-scale workshops that were highly facilitated. They found that important contributions to the emergence of values rely on the designer, the participation of stakeholders and methods. They emerge from a dialogical process between stakeholders and designers and the designer has to be aware of not only the stakeholders' values, but also his or her own values.

Development After emergent values are identified, they select appropriate actions to develop those values. This can go in two different directions. When everyone agrees what the emergent values are, the development process focuses on refining, clarifying and honing the values. For example the values are translated from abstract descriptions to more concrete design concepts. In one project they created a card game which they used to reflect and verbalized their views. When, on the other hand, not everyone is on the same page a dialogical development process is initiated to overcome the dilemmas. Then you would try to create opportunities for them to question and renegotiate their values. Like on emergence, the development also relies on the judgment of the designer, but also on how willing the stakeholders are to engage and participate in the process.

Grounding When the values are successfully negotiated, it is important that these new-found conceptualizations go into everyday practice of the stakeholders. The authors used PD methods like future scenarios, workshops and presentations. [IHL10b] see that as a sign that the values were not successfully grounded and appeal to support stakeholders at the point when values are to be grounded to "really change practice that reach beyond simply the design of the artifact."

Appreciative judgement of values It requires the designer to be introspective to appreciatively judge the values. They will become aware of their own values and how it influences their own actions and the design process. Also, they need to be familiar with various methods and how those methods can work with values.

2.2.4 Critical Design

Another design approach that can be used to work with values is Critical Design. It is defined as "a research through design methodology that foregrounds the ethics of design practice, reveals potentially hidden agendas and values, and explores alternative design values."[BB13, p. 1] This approach aims for making consumers more critical about their everyday lives, their assumptions, values, ideologies and behavioural norms by asking uncomfortable questions with the designed things. The term originally stems from the designers Dunne and Raby, whose intention was to make people think through their

designs. They say that Critical Design is "more an attitude than a method or anything else" ([Dun]). Design can be distinguished in two different categories: (1) *affirmative design*, which reinforces how things are now and conforms to cultural, social, techincal and economic expectation and (2) *critical design*, which rejects how things are now as only one possibility and provides a critique through design in the former mentioned characteristics. [DR01, p. 58]

[BB13] argue that this approach can also be useful and has high potential for HCI, but not strictly in the way that Dunne and Raby had originally in mind. They make a case for using critical design in HCI by questioning the ideas and statements of Dunne and Raby and adapting them for the use in Human Computer Interaction. Finally, they explore critical ideas and put them into practical uses for HCI researchers and present two projects which were probably would not be considered critical designs in Dunne and Raby's definition, but would fit to the authors' adapted definition:

"Hydroscopes" and "Silence and Whispers" are a pair of design studies in which the researchers investigate the idea of an "interactive peephole". "Hydroscopes" is an installation in an aquarium where visitors can watch a virtual ocean, prototype a fish and release it the ocean. "Silence and Whispers" is an audio installation at a historical sight in Finland, that engages visitors in collaborative storytelling. The visitors can explore stories from the site's history, which get presented as audio snippets and chalk writing snippets and act as metaphorical peepholes.

For the designers, the interactive peepholes "refer to aspects of interactive artifacts and environments that utilizes the tension between what is hidden and what is revealed to foster engagement through curiosity and inquiry" [DD09]. It "helps us think in a new way about theories of user engagement and it also trains us how to read designs that use peepholes in both literal and figurative ways; and it suggests ways that it can support future design work. [...] Throughout they assess the limitations of their theories and the designs themselves, showing an ongoing reflexivity to their work" [BB13, p. 9].

The Prayer Companion is an installation of screens on which news headlines and associated comments of people on social media sites on how they feel about those headlines are displayed [GBB+10]. The devices are placed in a convent, so that the nuns can pray for the people affected by the referred events. The authors of [BB13] take this project as an example for critical design, because the researchers found that the installation changed the nuns thinking, although they did not intend to try to provoke critical thinking. Furthermore the paper was used to critique procedures of HCI reserach. "Critically speaking, the Prayer Companion's "users" might be us: it is our eyes that are opened, our complacency that is transgressed, and our ideology that is exposed to interrogation." [BB13, p. 9]

2.2.5 Reflective Design

Another approach is reflective design, which is a framework which borrows and integrates approaches and methods of the former discussed Value Based Design, Participatory Design and Critical Design together with *Ludic Design* and *Critical Technical Practice*. Ludic Design and Critical Technical Practice (CTP) won't be be discussed here in detail, but I will describe them in a sentence to give a general idea: Ludic Design is taking on the ideas of Critical Design, but tries to avoid "preaching to users" by trying to trigger reflection by playful design. CTP is grounded in Artificial Intelligence, which should assist the designers in the process of eliciting and reflecting values.

The authors of [SBDK05] present Reflective Design as a framework that draws from the ideas from the former discussed frameworks and combines them with the addition, that reflection should be in the core of designing new technology. "Rather than focusing on a particular assumption, we argue that critical reflection itself, can and should be a core principle of technology design for identifying blind spots and opening new design spaces." [SBDK05, p. 1], where they define *reflection* "as referring to *critical* reflection, or bringing unconscious aspects of experience to conscious awareness, thereby making them available for conscious choice."

Furthermore, reflective design tries to spark reflection in multiple groups from designers to users but also the whole HCI community. They do this by integrating the former mentioned methods. For instance, they argue that in participatory design, value clashes between designers and different stakeholders can be elucidated, but reflective design tries to also reflect over the common values that may unconsciously be held between all groups.

2.2.6 Value Driven Innovation Model

The project Compass was accompanied by another master thesis by Valentina Tessa, a student of the University of Vienna, which is focusing on innovation in a large international IT-consulting company [Tes20]. Starting from expert interviews and a subsequent survey within the company, information was collected about how the company has used different processes and innovation models with a focus on values. The findings were that they already have used innovation and design methodologies like design thinking and also participatory design, but mainly without the explicit focus on the stakeholders' values. The values they take into account for the specific projects are mainly the general company values and were not specific to certain processes. They also faced challenges in the implementation of participatory design tools. Those challenges included that stakeholders were included too late, the client did not understand the importance of keeping the user in the process or the employees were not aware of how to provide information about the user's needs to the innovation team.

Resulting from the outcomes of the survey, a novel method is proposed as a guide for companies of this scale: the Value Driven Innovation Model (VDIM). It combines a number

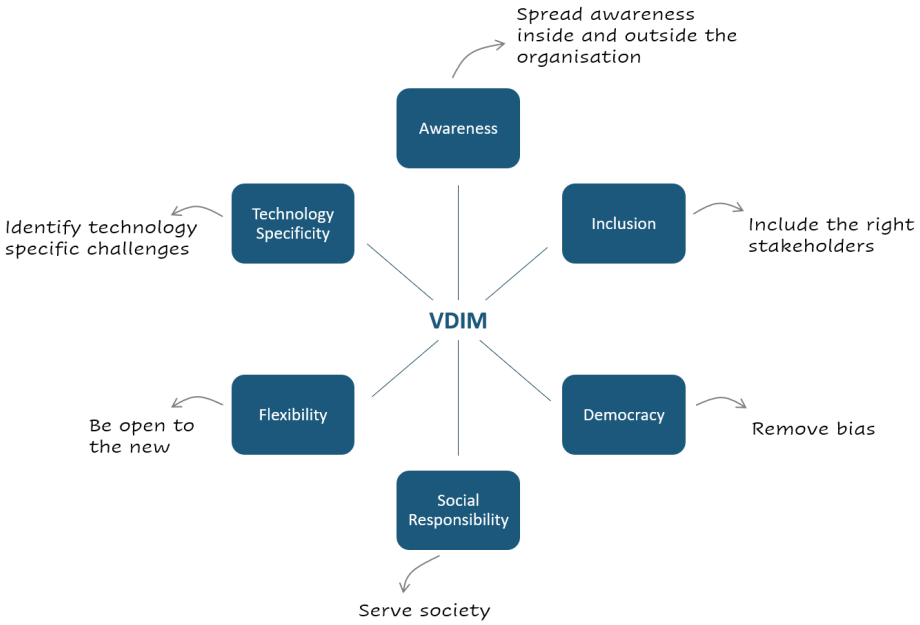

Figure 2.4: The VDIM model proposed by the accompanied thesis [Tes20]

of findings from literature with the challenges that a company of that size faces and is based on the six main pillars "Awareness", "Inclusion", "Democracy", "Social Responsibility", "Flexibility" and "Technology Specificity" as can be seen in figure 2.4. The pillar "Inclusion" is meant to include the right stakeholders, which also encompasses participatory design. A suggested additional element of VDIM is the CTA agent (Constructive Technology Assessment). This role is meant to be a neutral actor supporting teams incorporating the VDIM method. It is an interface between the company and the outside world and cooperates with other stakeholders.

2.3 Smart Office and Intelligent meeting rooms

In this section I want explore and give an overview about the research and products on the market which are concerning Smart Office and Intelligent Meeting Rooms.

The research on the Smart Office applications go back to 1992. There researchers documented the system Active Badge, which "is considered the first smart office application" ([WHFG92, RMS10]) with the goal of forwarding calls to the nearest phone. Another early application is Robotic Agents from 1999 [MONH99], which presents a robotic system that delivers printed pages to several users.

There are a number of use cases for Smart Office applications. Some of those cover systems that should help maximizing productivity by reducing distractions, optimizing the work environment in terms of air quality, navigation helpers for finding people in

a large office and communication and voting systems for meetings. In the following paragraphs I want to first present the research I found on this topic and then some products of the Smart Home market.

2.3.1 Research

There is research on reducing distractions on the workplace with smart technology. The system presented in [DS08] is a virtual secretary that mediates phone and in-person communication in smart offices. It passes on information about the receivers current situation (currently available, in office, alone, meeting, phone). They achieved that the receiver had significantly fewer inappropriate workplace interactions. In their work they also recognize that the tradeoff privacy is a concern when working "with any system that exposes personal information" and that "such systems must balance the trade-offs between making information public and protecting the user's senses of privacy and information ownership." They also suggest solutions for the virtual assistant to abstract information, but state that "when designing context-aware systems there will always be a trade-off between relying on the intelligence of a system or taking advantage of human decision-making skills by broadcasting private context information to others." In another project [KVWS16], the researchers want to achieve that people don't have to read notifications on their phones, because they have "disruptive effects on tasks or social situations". They built an infrastructure for smart spaces that allows forwarding and displaying smartphone notifications of inhabitants in intelligent context-sensitive ways directly in their surroundings. I would argue that because of reasons explained in [New16], ambient notifications probably also have a disruptive effect on tasks and that the notification on an ambient device - if it's in the same room - probably has little positive effect on the productivity.

Some research focuses on optimizing the work environment. [FCGL16] argue that air pollutants, temperature, CO2 and humidity has an effect on productivity. "The term Sick Building Syndrome (SBS) was coined by the World Health Organization in 1986 for buildings that cause the occupants various health and comfort problems, and is most commonly linked with air quality.". They developed a system that senses different qualities and generated an ontology to simulate actions based on the different values. The used sensor inputs were temperature, humidity, CO2 and the open/closed state of the window. The researchers in [SAcs17] also focus on temperature. They experiment with a different concept for smart thermostats to consider also social dynamics, expectations and contextually specific factors. Their goal is to ensure that "a smarter thermostat does not create dumber humans." The research in [Ara17] found how technology can affect behavior change with technology that recognizes the current activity and tries to intervene with just-in-time intervention and gamification. They state that they were able to estimate about 10-20 kinds of behaviors by about 90% with sensors (power consumption, indoor position, open/close). One presented example project concerns behavioral change concerning the health of workers. They placed several sensors and

digital signages (to display the wished change and a reward) in an office. For example, they want the workers to take the stairs instead of an elevator with the reward of turning the air condition some degrees down.

Other research in HCI focusses on different kinds of displaying the information [RMS10]. They point out that there are also some authors that consider the common monitor as a GUI, keyboard and mouse not user friendly and argue for Perceptual User Interfaces (PUI) that are based on actions like speech, gesture or interaction with objects. Good examples for this kind of interfaces are Wellner's MagicDesk ([Wel91]) and Berard's MagicBoard ([Bér94]), which are detecting user commands with human gestures to copy from physical paper, solve equations or print.

2.3.2 Products in the market

This subsection explores some of the products in the smart office area.

One patent of 2005 ([Roz]) describes a smart chair that automatically adjusts adjustable features to the current user's preferences.

The company Ahrend present their smart office solutions on their website [Ahr]. They have multiple smart products that combine to one solution. One similar product to the former named smart chair is a desk with integrated smart features. It has a wireless charging module installed, which is also used as a tag to check-in or check-out of the workspace. It also has ventilators, heating modules and biodynamic lights. As soon as the employee is checked in, it will adapt the desk height as well as the settings for ventilators, the lights and the heating to her personal preferences. There is also powernap furniture. On top of the system there is an "asset management" app, which gives insights into how the furniture is used. This is one feature that I am sensitive about, because it gives the permitted people detailed insight into the behavior of their co-workers or employees. The official reason for the app is to act economically as a company and save workspace if the space is not used enough. But I can see scenarios where this feature allows to have some potential for monitor employees.

A similar solution is Sony's Nimway ([Jön]), which is a system designed for large office spaces. It provides different interfaces with a map of the whole office and its desks and meeting rooms and is designed to help finding free meeting rooms and free desks easily by using presense sensors. It also provides a feature with which you can search and find the location for co-workers. While this may be an interesting feature, it brings it own privacy issues in addition to the issues discussed in the last product (Ahrend Smart Office).

Amazon sells its virtual speech assistant Alexa also for businesses ([Ale]). With this device it is possible to find out whether a room is booked, book rooms, start online meetings, get reminders for important events. It also offers to automatically release booked rooms after some time if the room is booked but no meeting is held there.

The company Humanyze created a system to analyze workplace data "to help companies make better, faster business decisions that improve both performance and the employee experience" [Hum]. They provide smart hangtags which the employees of a company wear during their work time. Those read data about where the employees currently are, how much they talk and how much they communicate with other people with the aim to analyze the performance of the organization and to provide tools for improving the system. They are very clear about their privacy statement that the system is "designed to protect employees first" (No speech contents are recorded and it does not provide insights about individuals). However, it raises the question which implication this system has on the individual employee being tracked constantly. A step further went some first companies, which implant a microchip in their employees for observe their working behavior [She17], which goes along with a series of other ethical implications.

2.3.3 Conclusion

In this chapter I investigated different theories on human values. Subsequently I gave an overview over some of the approaches that the HCI community developed to work with values in technology followed by an exploration of research and products concerning Smart Office and Intelligent Meeting Rooms.

For this thesis it was important to gather different perspectives and observe how the different approaches are described in the literature with their different characteristics and also their critique. The former mentioned value-driven design approaches may not be complete, but they are a purposeful selection of the most important concepts for this work.

The given case studies were also helpful in the understanding about how the different approaches work and the used methods can also be an inspiration for using the methods in practice. Here I want to conclude this section with the key outcomes of this review:

- Designing technology with considering values is possible and important.
- People shape technology and technologies shape our lives. There is most often an non-obvious impact next to the obvious impact of the created technology. When working with values, it is important to be aware of the direct and indirect stakeholders.
- It is important to integrate stakeholders in the design process. Approaches like Participatory Design strive to empower people to influence (in this case) technology in a direction that aligns with their values.
- There are dozens of methods that support the work with values and a lot of those methods appear in multiple of the former described design approaches.

- As a designer it is important to be aware of your own values and your own impact on the design. That is why approaches like PD, Critical Design and Reflective Design try to rise reflexivity in the users as well as the designers and possibly even within the HCI community.

While the elaborated literature covered value-driven design approaches, it was not able to specifically answer the question on how to apply those methods within a small company in the field of IoT. As startup companies often have particular processes and requirements, this is where this work wants to contribute to.

Another area of interest is presented in section 2.3, which covered a range of applications and systems in the smart meeting space. However, the presented literature did not explicitly consider working with values or the former discussed value-driven design approaches within the smart meeting space and intelligent meeting rooms. With this work I want to open a discourse within this area and contribute to this field.

CHAPTER 3

Methodology

As the last chapter gave an understanding about the different approaches that can be used to design and innovate with values in mind, this chapter gives an introduction about the concrete methods that were used in this thesis.

Within the thesis two interviews were held, one technology probe was developed and used that also was connected to a questionnaire as can be seen in figure 3.1. One introductory interview was held with a decision maker who is responsible for innovation within the company with the goal of getting an understanding about how innovation was done in the past and how values were considered during those conscious or unconscious processes. Afterwards the results of the interview influenced the goals and development of the technology probe and the questionnaire, which was used within three companies with the goal of eliciting values of the stakeholders. After the results of the probe were analyzed, there was a debriefing interview held to wrap up the study with the goal of investigate whether and how the process of the study will affect future innovation processes and development.

The technology probe was a given methodology by my research topic. The interviews are the only possible and practicable method to find out possible fields of innovation, how innovation has worked before and if I could influence the innovation processes. To get the data of the participants of the technology probe, first I wanted to also take interviews. As it was in the companies for longer times and I did not have the access to the participants, I decided to use a survey.

While this chapter gives an overview over the used methodologies, the concrete ideas and implementation of the methods will be described in the following chapters.

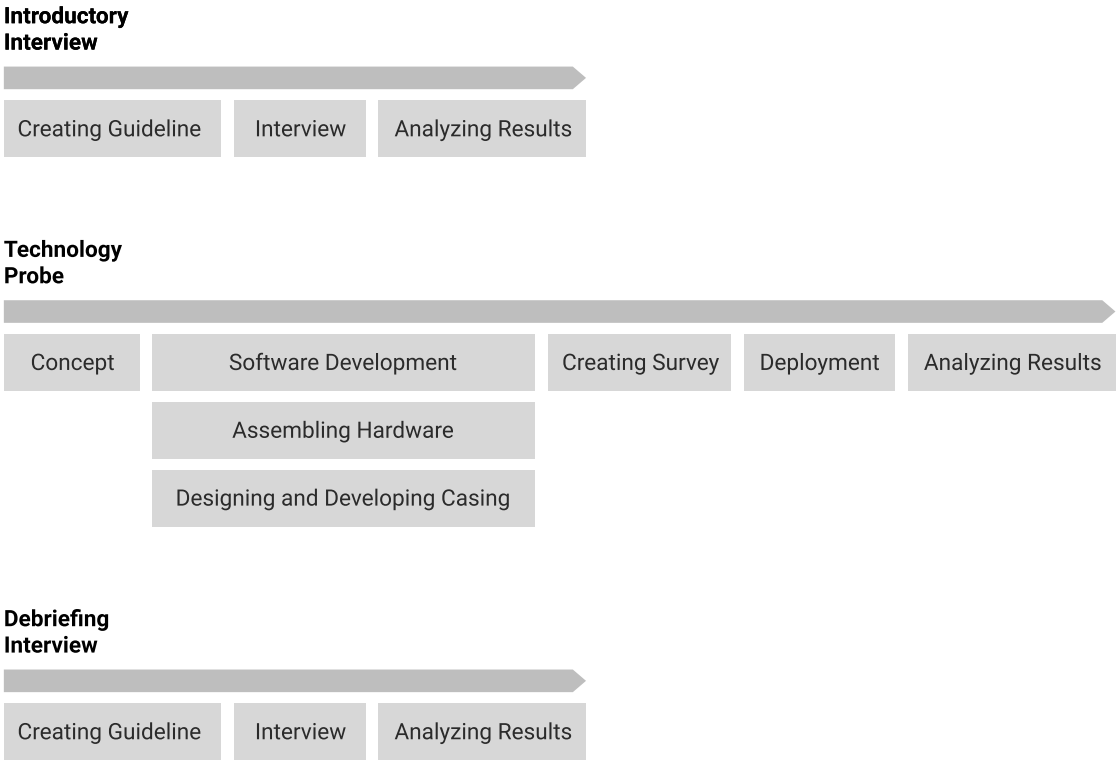

Figure 3.1: Methodology Timeline

3.1 Interviews

An interview is a conversation with someone to get information. Ususally there is one interviewer who is leading the interview and one or more interviewees who answer questions. Interviews can be categorized in three different types of interviews: (1) **structured interviews** (quantitative) follow a strict set of predefined questions (2) **semi-structured interviews** (qualitative) use an interview guide with leading questions that can also deviate depending on the answers of the interviewee and (3) **unstructured interviews** use only open questions. To get to the intended results within this thesis, I decided to do semi-structured interviews, because this kind of interviews allows to prepare for topics and questions, but also allows to get unintended answers and results.

An **interview guide** within a semi-structured interview is a document that the interviewer prepares before the interview. It covers a list of broad topics and themes to explore together with some questions that the interviewer *can* use. The important thing here is that the purpose of the interview is met and not every single question is asked.

How the interview is structured can strongly influence the outcome and the results. There are some guidelines on how interviews can be held to become more successful. For example, it is best practice to start with a question that is easy to answer like "What

does a typical day look for you". The aim for asking this first question is about making the interviewee feeling comfortable and easing into the more specific and harder questions. There are a many more things to consider when preparing and conducting interviews and there are great resources that provide detailed information about this topic [Mak, Whe].

3.2 Probes

Probes are often used in Participatory Design projects. They are simple and flexible tools that allow designers to learn more about their potential users in order to elicit innovative design concepts from both designers and participants. [MCAWL14]

In 1999, [GDP99] described a design technique called "cultural probes", in which he handed packages of maps, postcards and other material to elderly people with the goals of provoking inspirational responses, collect data over time, understanding local cultures and leading discussions with the groups towards unexpected ideas.

After cultural probes, there were also other variations of probes:

- domestic probes (Gaver 2004)
- empathy probes (Mattelmäki and Battarbee 2002)
- value probes (Voida and Mynatt 2005; Boehner et al. 2007).
- technology probes (Mattelmäki 2005)

As described in [MCAWL14], the four main purposes of probes are:

- Inspiring design
- Gathering data
- Increasing participation
- Facilitating Dialogue

As Mattelmäki (2008) describes, the probe design process typically consists of five stages:

1. Creating the probe pack
2. The probes are distributed to the participants and they interact with it
3. The collected data gets interpreted
4. The returns of the probe inspire more detailed questioning of the participants
5. The creation of a new design inspired by the probing process

Technology probes

In this subsection I will describe technology probes, which I will use in my work.

[MCAWL14]4 describe technology probes as "low-fi technology applications that are designed to collect information regarding ICT (information and communication technology) use and the environment of the participants in order to inspire design.".

In [HMW+03]1 technology probes are defined as "simple, flexible, adaptable technologies with three interdisciplinary goals":

- the social science goal of understanding the needs and desires of users in a real-world setting
- the engineering goal of field-testing the technology, and
- the design goal of inspiring users and researchers to think about new technologies.

[HMW+03] argue that instead of interviewing the participants, developing technology based on those interviews and testing the technology, probes enable it for users to become active partners in the design process and "more directly inspire and shape the technologies that are developed". Their hypothesis is that this will lead to designs that work better in the long run. This supports the sustainability of the created designs and products.

[HMW+03] also point out that when working with probes there is also an element of risk. They can fail or lead to unexpected results, because they are "deployed to find out about the unknown to hopefully return with useful or interesting data".

While cultural probes usually have only one particular activity at a time, technology probes combine different goals and activities:

- Social science goal: Collecting information about the use and the users of the technology in a real-world setting;
- Engineering goal: Field-testing the technology
- Design goal: Inspiring users and designers to think about new kinds of technology

[HMW+03] The difference of a probe to a prototype or a product can be is:

- Functionality: As simple as possible. Prototypes can have many layers of functionality and address many needs
- Flexibility: Should be designed to be open-ended with respect to use, users should be encouraged to reinterpret them and use them in unexpected ways. Prototypes are usually more focused to a purpose and manner of use.

- Usability: Probes are not about usability. They are not changed during the use period based on user feedback. For prototypes that's one of the main concerns.
- Logging: Probes collect data about users and inspire ideas for new technology. The data points can be visualized and discussed by users and designers.
- Design phase: While probes should be introduced very early in the design phase to challenge existing ideas and generating new ideas, prototypes are used in a later step of the design process and improved iteratively.

[WMV16] "The values implicated by a system emerge from: the technology itself; the people involved the design and use of the technology; and, the social context in which that technology is used [10,27]. As values are 'enacted' through the use of the technology by many people, 'multiple interpretations of a single value arise, as well' [27]. How these values "play out" will vary based on cultural factors at a specific point in time [9]. Further, a person's use of technology will change over time as that person as different situations arise [12]. Therefore it is important to explore and understand how different stakeholders enact values when interacting with a system in a specific real world use context and how these values evolve over time [13,27]."

In the project Sensorstation, they used a probe with the goal to gain insight into how residents in a shared apartment "co-design, co-speculate, and appropriate smart sensor application in their home". It consists of several sensors (humidity, light, movement, temperature, air pressure) that are connected to a base station, on which the participants could create notifications on events triggered by the sensors. Those notifications were always visible on the base station and also could be sent as mobile notifications. The researchers goal were interested which effects those smart home applications have on the communal life inside a shared-flat. With this probe, the researchers recognized that the participants created applications that create positive connections and self-monitor, but also monitor and reward others for wished behavior. With the gathered data and a following group discussion they found that the "previously acknowledged physical boundaries in the home, such as closed doors that would demarcate private rooms, have been compromised by smart home applications" and "how power distances between seemingly eye-level people can be disturbed by technology for shared apartments".

The researchers in [WMV16] placed a probe in the home of five participants that collected and shared data about their activities at home for 10 to 14 days. The probe consisted of several sensors. A passive infrared sensor and a sound pressure sensor were used as a trigger. When activated, data from temperature, humidity and air quality sensors were sent and recorded in a database. While the data got recorded, the device was also glowing. At the end of the study period, the participants got interviewed to get a general reflection on living with the probe, explaining the collected data and how they felt about the results that could be drawn from the data and also if the data was more publicly available. In regard of the probe, they conclude: "The probe, despite its minimal level of functionality and the pre-existing relationship with one of the researchers, was useful in

providing some insight into the human values that are implicated when living with IoT technology. It supported the participants' developing of an understanding of the actual experience of living with IoT technology in a specific context and how that experience evolved over time. From this experience, it then supported the participants' exploration of different perspectives of living with this technology. This exploration provided rich information of: the values implicated by the technology; how those values were enacted by the participants; and, how values might be enacted in response to other IoT technology and in other contexts."

[MVV+15] placed a technology probe (noise, color, air quality, self-reported mood, and self-reported activity) in 2 offices for a period of 4 months to "to understand which workplace metrics are useful and why, how employees engage with the system and what privacy or other concerns they have".

They argue that the sociotechnical or human concerns about ubiquitous computing are mainly about privacy and identify three domains of privacy:

- Information Privacy: "large amounts of identifiable data are being collected and stored; errors, both deliberate and accidental, may exist in that data; the data may be used for a purpose different than the stated purpose; and, the data may be used by people other than those who were initially authorized to use that data;
- Being Tracked: Not knowing when and how they are are being sensed, which data is collected and how it is used.
- Big Data: A large amount of available data leads to the concern that this data is abused, people were treated as if they are numbers instead of individuals and incorrect and inhuman automatic decisions.

3.3 Surveys

A survey is a set of questions aimed to extract data from a particular group of people. They may be conducted via different media like over the phone, in person or over the internet.

In the case of this thesis there was only one survey conducted over the internet. Although surveys are more suitable to get quantitative data, surveys can also be used to collect qualitative data. In their most basic, qualitative surveys consist of a series of open-ended questions [CB13, p. 337]. The purpose of the survey within the thesis was to get mostly qualitative data after the participants used the probe.

The answer format of one question can have different formats. The formats that were used in this thesis are the following:

- **Free Text**: In a free text input without validation, the user can type a text of their choice and is not limited to a set of answers. This was useful for getting qualitative input in form of open questions.
- **Validated Text**: It is also possible to limit the input to a minimum or maximum amount of characters or other validations like if the given text fits a specific format. This was used to validate given email addresses and meeting codes.
- **Single Choice List**: A list of choices from which the participant can choose exactly one choice.
- **Multiple Choice List**: A list of choices from which the participant can choose more than one choices.
- **Array**: An array is a set of questions with the same set of answers (single or multiple choice) for each question. This was used in the thesis to make Likert-scales possible, which means that the set of answers is coded within a specific rate with descriptions. For example the question "It made me/us more aware of our own speaking time" can be rated with a range from "Strongly disagree" to "Strongly agree" and some steps in between.

3.4 Thematic Analysis

For the introductory interview, the debriefing interview and the open questions of the survey a method called thematic analysis was used. This methodology can help the researcher to collect the important information out of qualitative data. There are a number of approaches and methods that can be used to support this goal including thematic analysis, interpretative phenomenological analysis, grounded theory and pattern-based discourse analysis. Qualitative analysis covers a range of descriptive analysis (giving voice to people) to interpretative analysis (what can be interpreted behind the raw words of the people?) [CB13]. Thematic analysis is about recognizing patterns within the data and breaking them down into the important key points.

Although thematic analysis is a rather loose method that can be constructed differently within different approaches, Braun and Clarke identified six key phases [BC06].

1. First the researcher tries to get familiar with the data. Therefore the material that is not written out gets transcribed and (re-)read.
2. In the second step, the initial codes are generated by the researcher. This is done by documenting and labelling recurring and important patterns that appear in the data.
3. Then the codes will be combined into initial overarching themes that accurately describe the content of the data.

4. In the reviewing phase, the researcher looks if the collected information completely answer the questions that she or he aims for answering and if required goes back to an earlier step to complete the themes.

5. The existing themes will be named, defined and redefined in order to prepare them for the last step.

6. Finally, the researcher produces a final report containing the themes that are meaningful contributions for answering the research questions.

While the interviews had to be transcribed for the first step the survey data was already in written form. The results and the reports of the different steps can be seen in the respective chapters.

CHAPTER 4

Setting the Stage

The goal of the first phase of the work was to investigate the current innovation models of the company and find an area of interest for the company to explore the participatory methods on.

It consisted of an introductory semi-structured interview with a decision maker at the company and several discussions afterwards.

4.1 Interview Guide

This section describes how the interview guide was created in preparation for the interview.

One goal of the COMPASS study was to empirically study how values are being considered in innovation processes in the Internet of Things context. For this purpose, a series of qualitative interviews were conducted with different companies with different characteristics. First there were two pilot (or "deep-dive") interviews, where one of them was this introductory interview for this master thesis. The outcomes and experiences of those interviews were considered in the design for a wider interview series.

The first drafts of the interview guide were created by Patrick Zwickl and Andreas Martin from the partner company Austrian Institute of Technology and subsequently we revised it together. As the guide was very big and detailed at that point, a smaller version "Diet Guide" was created. From this version, which was still generally-purposed for all interviews, I changed some parts to make it more individual for the company that I was interviewing. This (for this interview) final version can be seen in appendix B.2.

Another part of the preparation was the creation of the consent form. This is a document, which the interview partner is asked to sign before the interview is held and clarifies the general purpose, the rights and limitations of the interviews. Specifically, in the consent form for this interview

The "Deliverable D3.1: Report on current innovation cultures and processes in the IoT domain" of the COMPASS study this.

The interview guide can be found in appendix B.2. The consent form can be found in appendix B.1.

4.2 Interview Result

In this subsection I will summarize an interview with a decision maker at Flatout Technologies in the context of the COMPASS study and my master thesis. The goal of the interview was to investigate how the company practices innovation and if and how values are considered in their processes. The interview guide for this semi-structured interview was made in collaboration with members of the COMPASS project.

4.2.1 Product

In the first part of the interview, the interviewee described their products. The underlying technology behind their products is an IoT Platform that modularly connects sensors and actors. On top of this platform, they integrate products for several use cases. Their only hardware product is their gateway that connects with devices of third-party manufacturers. In addition, they provide several Apps & other User Interfaces.

Flatout Technologies primarily focus on B2B customers, who can use their solution as-is, white-labeled or for custom use cases they provide commissional work. The product can include a platform licence, support and maintainance.

The two main solutions the interviewee mentioned are "Smart Home" and "Smart Access". Smart Home includes use cases like alarm & security systems or ambient assistant living (AAL). Smart Access will be discussed in the following section in more detail.

4.2.2 Smart Access

To get more concrete answers, I asked the interview partner to focus on one product for the largest part of the interview. He decided to focus on the most recent product "Smart Access".

The Smart Access solution consists enables keyless entry to properties to make key delivieries obsolete. It typically consists of automatic doorlocks and a box to automate the intercom. The current target groups are:

- real estate industry: estate management businesses, property developers, property owners, Cleaning businesses, and other businesses where key delivery is a time consuming task;

- companies and private individuals that want to short-term rent their apartments;

According to the interview partner, the business model of their Smart Access solution changed a lot since the beginning. It started out as a recurring model, before it became a one-time fee and now also sometimes is a combination of one-time and recurring. Their pricing model also adapts depending on the customer group. Additionally, revenue is produced by selling devices of third-party manufacturers: automatic doorlocks, keyboard codes, key safes and intercoms. It seemed to be important for the interviewee to stress that all prices are transparently visible for the customer and there are no hidden fees.

4.2.3 Innovation

The innovation models of the company are not clearly defined or written down. Innovation comes from the wants and needs of the target groups. The interviewee states that he is strongly in contact with people of the target groups and that through that most of new concepts and ideas come from them. In case of Smart Access a potential corporate customer approached the interview partner with the idea. In a research phase they called potential customers in their target group and saw that there is a broad need for this product. He points out that this was not always the case. When they initially started with their idea in 2011, he saw the company as "very innovative" in terms of disruptive innovation (innovation that creates a new market or disrupts an existing market), because the term "Internet of Things" was introduced in 2009 and the market was still in a very early stage. Also, there are no official vision documents except from the business plan. The general vision behind the company has been to simplify everyday tasks.

New Technologies are for example introduced by trade fairs, newsletters from consulting firms and announcements of suppliers.

4.2.4 Negotiation Spaces

In the question of negotiation spaces, the interview partner named privacy, data privacy, threat of getting hacked and usability (like cultural differences and tradeoff functionality vs. usability). He mentioned that users often don't know the possibilities of IoT and that they have to be educated what is and what is not possible.

4.2.5 Values

In one part of the interview the interview partner was asked about his personal values and the company values and how they relate to each other. After that he was asked to rate different values with cards, where he also elaborated his choices. As personal values he named:

- to create something that makes sense and has a purpose; technology should help;
- relationship to customers: He wants to take care of customer, get customer feedback frequently. He stresses that customers can call any time and it is important for him to be reachable for them;
- transparency and honesty within the company and to the customers; "technology for charity": he wants to do good with the company and emphasizes that part of their profit is donated to charity;

The company values are in his opinion strongly connected to his own values, because as the company is small and therefore the values of every single person within the company is higher than in a large one. Also it is important to integrate the values of the employees to strengthen the belonging to the company.

There is no official document that states the company values, they are communicated via direct communication between the coworkers.

Often the company is faced with values from customers on commissioned work. There the process is that in the initial phase the team comes together and discusses the requirements of the project and possible problems. The interviewee mentioned an example, where one potential customer wanted to integrate a feature in the app, with which it was possible to track the other users of the system with the background of finding family members in case of an emergency. The engineering team commented that they see conflicting values with their values of privacy and tried to find solutions that would make the project possible, while respecting the privacy of the users.

The interview partner also mentioned multiple times that privacy is important to the company and also that it has to be, as it is located in the DACH-region. The system shifted a few years ago from being cloud-based (all data is in the cloud) to edge computing (cloud is used to communicate, but data is primarily stored on the user's gateway). He sees the value of privacy more important in the DACH-region, but mentions that this can be used as a USP.

He also sees longevity of products as important (livelong licences right now).

4.2.6 Discussion

The goal of the interview was to investigate how the company practices innovation and if and how values are considered in their processes. Currently, most of the innovation happens implicit through communication with the target group and commissioned work. Company values are not written down, but come along with the values of the staff. The values that elicitated during the interview were transparency, creating things with purpose and that technology should help. Most important for the interviewee was that he could pay the salaries of the employees. I saw an potential area of conflict in that, because of that it is sometimes hard to produce products that fully align with the company values.

Another interesting finding was that the communication occurs primarily with the B2B-customers, but rarely with end-users. That means that end-user values are mostly carried forward over the B2B-customer and that's also where I see potential to improve on within the work for my master thesis.

The cards seemed to be a good tool to elicit values, as the participant did not only rate the statements, but also talked along while doing so.

The interview gave insight into the current innovation models of the company, but it did not reveal a potential area of interest for exploring the participatory methods on. To clarify this step, I first talked to two decision makers in the company separately and afterwards organized a meeting where we discussed on which area of interest we want to focus. The outcome of the meeting were several areas, of which the most interesting idea was the topic Smart Office and intelligent meeting rooms.

- The company is interested in this area
- It is an interesting topic to explore on social values
- The access to end-users is realistic

CHAPTER 5

Technology Probe

As the research questions of this thesis aim to answer how a technology probe can be used to inform innovation processes, the main part of this thesis was the development and usage of such a probe. This chapter describes the creation of the technology probe from the concept to the results.

5.1 Concept

Within the initial phase in became apparent that we want to innovate into the direction of Smart Office and intelligent meeting rooms (chapter 4). There appeared some interesting questions discussed in the last chapter in this area:

- How can IoT-technology influence the behavior, awareness and satisfaction of attendees of meetings?
- How can IoT-technology influence the group dynamic within a meeting?
- Which meaning do those sensors have for users of a smart meetingroom?
- Which concerns do those sensors cause in users of a smart meeting room?

To explore those questions, together with my colleagues I created the concept of a technology probe that will be placed in the middle of a meeting room, which measures some values in the room and displays it to the participants. The ideas that appeared to be valuable and interesting for provoking critical thinking within the attendees were the following: humidity, CO2, loudness, duration of the meeting and directions of speech. The most important feature of the probe appeared to be the last-mentioned value, to display a graph of the incoming sounds accumulated over time. It should be possible to see who

of the participants is speaking how much and therefore provoke critical thinking about their behavior, awareness and group dynamic. The air quality parameters aim to cause awareness awareness about the meeting quality and the satisfaction of the participants related to the air quality in the meeting room.

The first research was about the technical feasibility of the direction of speech. I collected resources about possible ways and components that could be used to solve this problem. During the research I found out that it should be possible to attach a board to a Raspberry Pi which is attached with an array of microphones. Those boards are available in different extents like with four microphones[1] or more. As we already used a board that provided an eight-microphone array[2] for another product, I had the chance to try the first steps with this board. After the first proof-of-concept was working, I decided to further use this board as it had some other features that were helpful for displaying the wanted values. Detailed information about the components can be found in section 5.2.1.

Probe Placement The initial idea was to place the probe in small or medium sized companies *or* co-working space that rents out meeting rooms. What spoke for placing it in companies that the same people use it for a longer period of time, while in the co-working space we would get a broader range of people and results. During the course of the development of the probe I decided to use it in companies, because co-working spaces were not accessible for a longer period of time due to the corona pandemic. The process of the probing phase can be read in section 5.7.

Probe Results One crucial factor in the design of the probe was also how to get the data after the participants used the probe. For this is was important to find a method that allows to ask for qualitative data, but is also accessible. The first approach was to do interviews, but after consideration I decided to design a survey to get the results. While interviews would probably lead to more comprehensive answers, it was difficult to access the people after they had the meeting with the probe as usually people have a lot on their agenda within a workday and little time for interviews. Also it made it possible to leave the probe for a longer time period and wait until the participants fill in the survey instead of having to be available at every meeting (as this was also less stressful for the participating companies).

To motivate the people to participate and to fill in the survey, I created a handout and a link and QR code that was displayed within the app and on handout cards. The process of creating the handout and the cards can be read in section 5.6 and the results can be found in section 5.8.

[1] ReSpeaker 4-Mic Array (`https://www.sparkfun.com/products/14645`)
[2] Matrix Creator (`https://www.matrix.one/products/creator`)

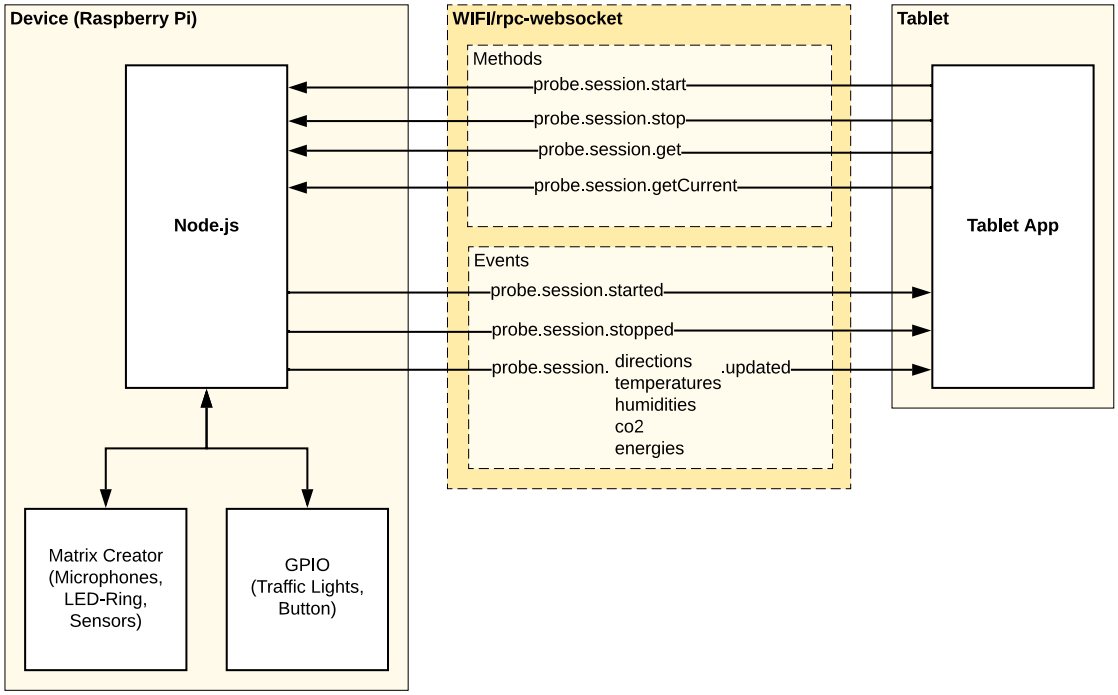

Figure 5.1: The components of the finished probe

5.2 Implementation

In this section I first give an architectural insight into the final state of the probe and after that the development process that lead to this state.

Figure 5.1 intends to provide an overview about the different components of the finished probe and how they communicate with each other. You can see the two main components: the device on the left side and the tablet on the right side. They are connected via WIFI and an RPC implementation of websockets.

In the following subsections the different components are described in detail. First the device hardware is described in section 5.2.1, then the device software is described in section 5.2.2 followed by the frontend application in section 5.2.3. How those components communicate with each other is described in section 5.2.4 and finally an example illustrates the lifecycle of one selected event in section 5.2.5.

Section 5.2.6 leads chronologically through the development process and may explain further how the decisions were made about the chosen technologies.

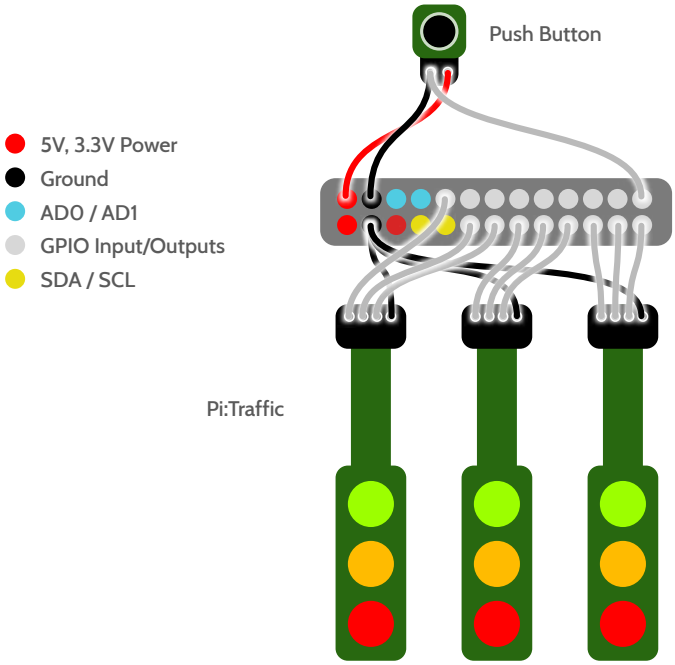

Figure 5.2: GPIO Pin Configuration

5.2.1 Device Hardware

The probe consists of a Raspberry Pi 3 B+ with a MATRIX Creator board, 3 Pi:Traffic traffic lights and one simple push button. The for the work relevant features of the MATRIX Creator are an array of 8 microphones (useful to detect arrival of speech), humidity and temperature sensors, GPIO pins as well as a LED-ring with 35 LED.

GPIO Pin Configuration

For controlling the traffic lights and the button, there are several pins exposed by the MATRIX Creator board. The important pins for this project are 17 GPIO (general purpose input/output) pins, 5.5V Power outlets and ground pins.

As it can be seen in figure 5.2, every traffic light is connected to three GPIO pins and one ground, where each of the GPIO pins controls one of the colors red, yellow or green.

The button is connected on one pin to the power and on the other pin to one GPIO pin and the ground through a resistor. With this configuration is it possible to get a signal that outputs 0 or 1 depending of whether the button is pressed or not.

5.2.2 Device (Server) Software

In this subsection first the used technologies and libraries are described and then how the architecture of the server application looks like.

Requirements

The requirements the server software should meet are the following:

- Start and end meetings sessions and generate a unique code that gets displayed to the users.
- Start and end meetings over a physical button.
- Start and end meetings over the API that can be controlled by the frontend app.
- Publish events over an API when a session started or ended.
- Possibility to detect direction of sound.
- Can measure and save environment values like temperature, humidity and CO2 over time.
- Displays the measured value somehow with the hardware components (without a screen).
- Provide the measured values over the API for the frontend app.
- Works without an active internet connection, as we cannot trust that the connection in the test field is reliable.
- Therefore, it should use database on its own system and not on external servers to store the sessions with the values.

Raspberry Software

On the Raspberry Pi runs the operating system Raspbian Stretch with a Node.js environment, MongoDB 2.4 and ODAS.

The server, which acts as the core software of the probe, is written in TypeScript and runs in a Node.js environment. It uses a Dependency Injection mechanism to load the different services and classes.

Node.js

Node.js is an open source, cross-platform JavaScript runtime built on Chrome's V8 JavaScript engine. It makes it possbile to run JavaScript without a browser on the server side. Because of that it is became very popular amongst web developers and many concepts of Node.js that were introduced only on the server side like modules are nowadays part of JavaScript.

I decided to use Node.js in the backend because I have an extensive knowledge in JavaScript and also basic understanding of server side programming with this environment. Furthermore there are high-level libraries for the Matrix Creator board that can be used within Node.js.

TypeScript

TypeScript is an open source programming language developed by Microsoft. It is a superset of JavaScript that compiles to plain JavaScript. It can be used both for frontend code (in the browser) and server-side code with Node.js. With Typescript there JavaScript is extended by many concepts like interfaces, enumerated types, type interference, type annotations, compile-time type-checking.

As it is supported by many IDEs, it is very useful for large teams as well as for single developers. With those IDEs it is possible among other things to have code completion, errors, warnings and a documentation outline within the editor for code that is typed, such as self-written code but also many open-source libraries. So the choice to write an application in TypeScript may be more work in the beginning of a project, but will over time save more time as the projects are getting larger.

I used TypeScript before in web application frontend projects and decided to use it also in the server-side with Node.js as a way to learn how to set it up and to have an easy way to write classes and interfaces.

MongoDB

To store the data persistently there is a database needed. While several years ago it was standard to use relational databases like MySQL, PostgreSQL or SQLite, nowadays it is also a very popular choice to use NoSQL databases like MongoDB. It is a document-based database, which means that it has collections with objects (which are very JSON-like) instead of tabular data.

In the time of writing there was already version 4.2 released. The version 2.4 that is used in this project is rather old. It is used used, because it is the latest version supported by the Raspbian Stretch operating system.

Websocket

For communication with the frontend app the Node.js application uses the library rpc-websockets. The library and the used methods and events are described in Section 5.2.4. The library is abstracted in the server code via the WebsocketService, which is described in appendix A.2.1 on page 102.

Direction of Arrival

For detecting the direction of arrival of sound, a library called ODAS (Open embeddeD Audition System) was used, which is an open source software "dedicated to perform sound source localization, tracking, separation and post-filtering" [ODA19]. The library allows to localize sound in 3d space by using a microphone array. It uses a method called SRP-PHAT-HSDA, which "perform at least as well as other sound source localization and tracking methods while using up to 4 and 30 times less computing resources respectively." [GM18]

The matrix creator board has an array of 8 microphones integrated. With a configuration file it is possible to configure the positions of the microphones so that ODAS can perform the calculations.

With the used configuration, ODAS generates an output, it can detect multiple locations of sound simultaneously, which are then transmitted over a socket to the server application. One distinct output of the stream looks like the following:

```
{
    "timeStamp": Date,
    "src": [
        { "x": number, "y": number, z: number, E: number },
        { "x": number, "y": number, z: number, E: number },
        { "x": number, "y": number, z: number, E: number }
    ]
}
```

The objects within the `src`-array are the different detected locations.

Dependency Injection

One pattern that is used within the architecture of the server code is dependency injection. It is a technique where one object holds dependencies (for example a class, a service or a configuration variable), that can be injected into classes.

Within the Node.js application, I use a library called "InversifyJS", which helps with the implementation of dependency injection within JavaScript. It also allows services

to work as singletons, which is exactly what was needed for some use cases within the architecture. In the following paragraphs, I will use `DirectionService` as an example to illustrate how it is injected in the code:

Usually you would begin by defining interfaces for the classes you want to inject. In this project I did not do that for sake of simplicity. First it is necessary to define symbols that identify the injected service. They act like names in the world of the dependency injection library.

```
1 // Within dependencies.ts
2 let DEPENDENCIES = {
3   DirectionService: Symbol('DirectionService'),
4   // ... other dependencies
5 };
```

Then it has to be defined which concrete class (or object/variable/...) should be loaded when it gets injected. The following code tells container to load the DirectionService class when DEPENDENCIES.DirectionService gets injected.

```
1 // Within inversify.config.ts:
2 import { Container } from 'inversify';
3 import { DirectionService } from './services/DirectionService';
4 import DEPENDENCIES from './dependencies';
5 var container = new Container();
6 container.bind<DirectionService>(DEPENDENCIES.DirectionService)
    .to(DirectionService).inSingletonScope();
```

In the class itself there is only an additional annotation needed (@injectable) to tell the system that this is a class that can be injected.

```
1 // Within DirectionService.ts
2 @injectable()
3 class DirectionService {
4 // code ...
5 }
```

Finally, to inject the service into another class, it can be injected by container.get. In my example, I instatiate a class variable `directionService` and populate it with the injected class from `DEPENDENCIES.DirectionService`, which then gets resolved to the DirectionService we defined before.

```
1 // Within SessionService.ts:
2 import container from '../inversify.config';
3 import DEPENDENCIES from '../dependencies';
4 constructor() {
5     this.directionService = container.get(DEPENDENCIES.
        DirectionService);
```

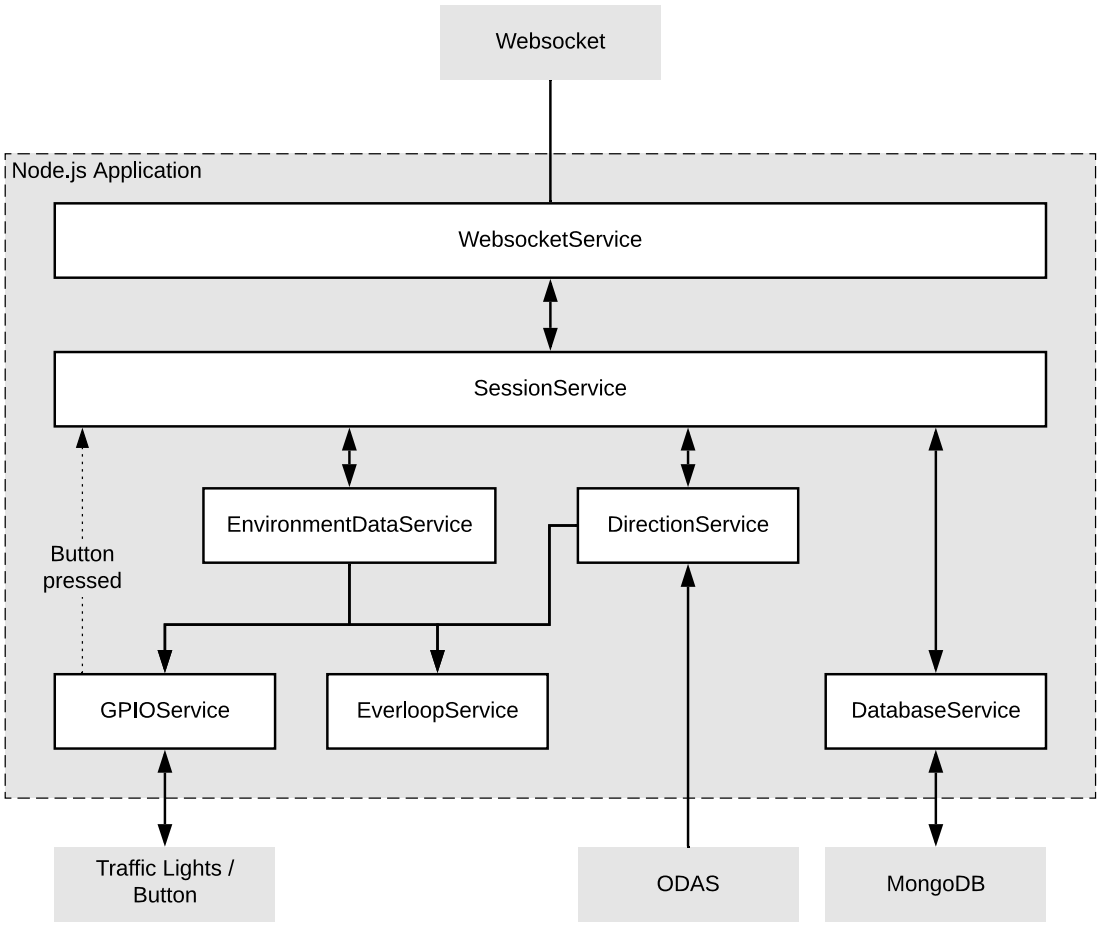

Figure 5.3: Software architecture of the server application

```
6 }
```

Application

In Figure 5.3 you can see the different modules of the application and their responsibilites. Detailed documentation about the server code with its classes and functions can be found in appendix A.2.

5.2.3 Frontend

This subsection describes the frontend application, which main responisbility is to vizualize the measured values and display it to the users. It is written in Typescript with the Ionic framework based on Angular.

Requirements

The requirements the app should meet are the following:

- Can be used on one tablet that is delivered as part of the probe.
- Start and end meetings sessions via the tablet.
- React to starting and ending meeting sessions when it is pressed on the physical button on the device.
- Displays the measured directions and values on a screen.
- Explain the purpose of the probe and guide the user through the experience of using it.
- Invite the user to take part in the survey.

Ionic

Ionic[3] is a component library and app development framework for apps that can be deployed as mobile apps on both Android and iOS as well as Progressive Web Apps (PWA) and even as standalone apps for Windows, Linux and MacOS. The general idea is that developers can use one code base for all the different clients, which leads to faster development time, less project overhead and clearer structure.

The framework is also interesting for developers who want to develop native apps for Android and iOS, but only have experience with web technologies and not native programming languages.

The app in this project will only be developed as an iOS application, because there is only one iPad used in the probe and it can be sufficient to only run it on this particular device. Nonetheless there could be other manifestations with little affort if it is needed in the future. In the beginning of the project this flexibility was also one important factor why Ionic as a framework was chosen.

Ionic was originally based on Angular. (Ionic 1.0 on angularjs), but with version 4.0, the framework was untied from the specific web framework and in the time of writing

[3]Ionic Framework (`https://ionicframework.com/`)

also supports React. An adapter for Vue.js is currently in development. In this project Ionic/Angular is used.

Typescript

As Ionic/Angular is written in Typescript, also the code of the frontend application is written in Typescript. As this programming language is already described in Section 5.2.2, I will focus on the features that are used in app. Angular and Ionic use the annotation feature of Typescript for most of their features. The following listing contains an example of an Ionic component. The annotation already describes the selector (how it is referenced in other templates), the template and the style.

```
@Component({
  selector: 'app-result',
  templateUrl: './result.page.html',
  styleUrls: ['./result.page.scss']
})
export class ResultPage implements OnInit {
// ... code
}
```

While it was necessary to use InversifyJS for dependency injection in the Node.js application (see Section 5.2.2), Angular already provides a built-in dependency injection system. By using the `Injectable` annotation, it is possible define a service that can be injected in other parts of the application. Each injected class serves as a singleton and is therefore only instantiated once during the App lifetime. By using the `providedIn` attribute, it is not needed to define the service in a configuration file for the module.

```
@Injectable({
  providedIn: 'root'
})
export class DeviceService {
  // ... code
}
```

RXJS

rpc-websocket

For communication with the device the frontend app uses the library rpc-websockets. The library and the used methods and events are described in Section 5.2.4. The library is abstracted in the frontend code via the WebsocketService, which is described in this section on page 109.

Architecture of the app

A typical Ionic app consists of modules, pages, components and services. It became a best practice that every page is contained in one module, which then is also contained in other modules itself. This makes it easy to enable shorter loading times, because the browser does not have to load all of the data at once. In the case of this application is not as important, because it is published as a native app, but nonetheless this best practice is adhered. The app module loads only the basic modules and configurations and when a specific page is loaded (for example the home page), the associated module loads all needed components.

A page consists of an own template and components that can be used. The application follows the principle of the distinction of stateful and stateless (presentational) components. The pages serve as the stateful components. That means that the page class handles business logic like the communication with the services and holding the data. It then uses stateless components, which present the data. Those components do not know about the services, but have inputs and outputs to communicate with the stateful component (page).

Services handle business logic that is likely to be used within multiple parts of the app. They could be utility functions and helpers, but in this application they are mainly used to provide methods to communicate with the device application.

In the following sections the pages and components of the frontend application are described. Figure 5.4 illustrates the architecture of the application. For a detailed description of the used services I refer to appendix A.3.1.

Pages

This subsection describes the pages of the frontend application. There are three pages: Home, Session and Result. While all three of them have their own layout filled with components, Session and Result share most of their components.

Figure 5.5 illustrates the interactions and routing between the pages.

Home Page The Home page (see figure 5.6) is the first page the participants see. Its purpose is to guide the user through the usage of the probe and motivate them to take part in the study. It is also possible to start the meeting session through the push of a "Start Session" button as an alternative to the physical button on the device. The different components and hotspots can be seen in figure 5.7.

The page consists of the following parts:

- A headline with the title of the project "Look Who's Talking".

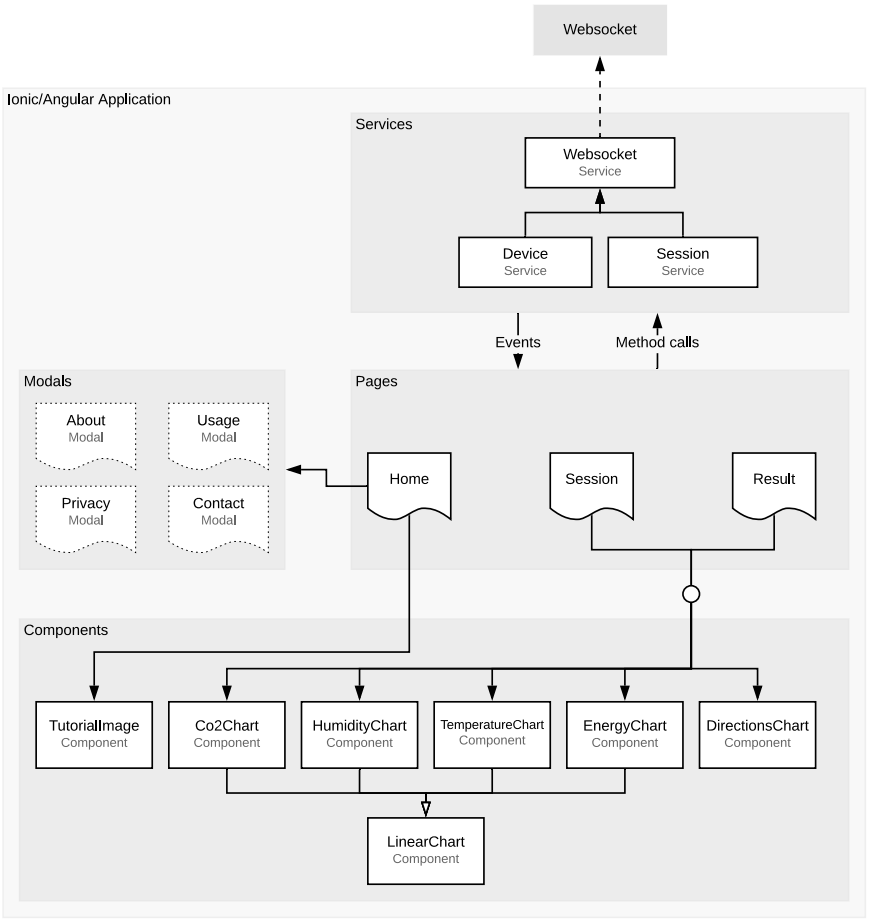

Figure 5.4: Ionic Application Architecture

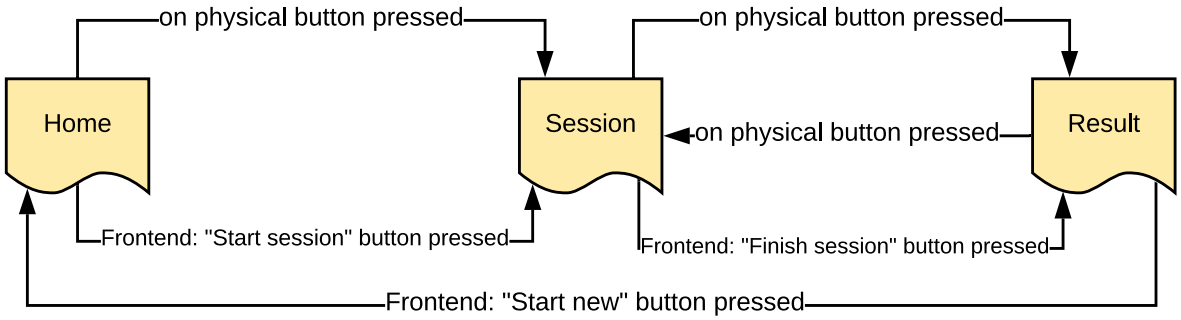

Figure 5.5: Page Routing

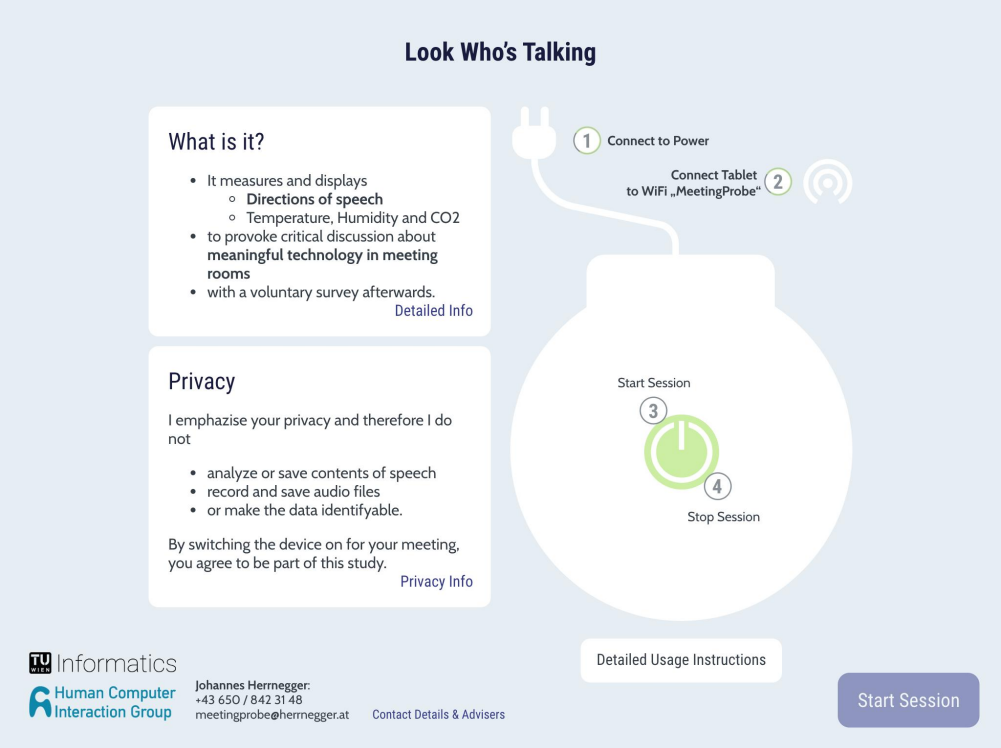

Figure 5.6: Home Page.

- The block "What is it?", which describes the idea of the probe in a short list. The button "Detailed Info" leads to a modal, which contains a more detailed description of the project.
- The block "Privacy" should increase the trust of the users and clarify that there is no personal data saved by the device. There is also a button "Privacy Info", which leads to detailed information displayed in a modal.
- The tutorial image, which should give a simple introduction in how to use the probe. This is a component, which is described in more detail in this section on page 60. If the users need more support with setting up and using the probe, they can get help by clicking the button "Detailed Usage Instructions".
- Logos of the Technical University of Vienna and the Human Interaction Group.
- Short contact information with my name, phone number and email address. Clicking on the button "Contact Details & Advisers" leads to a modal, which displays detailed contact information about me and my advisors.

Session Page The Session page (see figure 5.8) is the page that is displayed during the a meeting session. Its purpose is to visualize the current values during the session. It

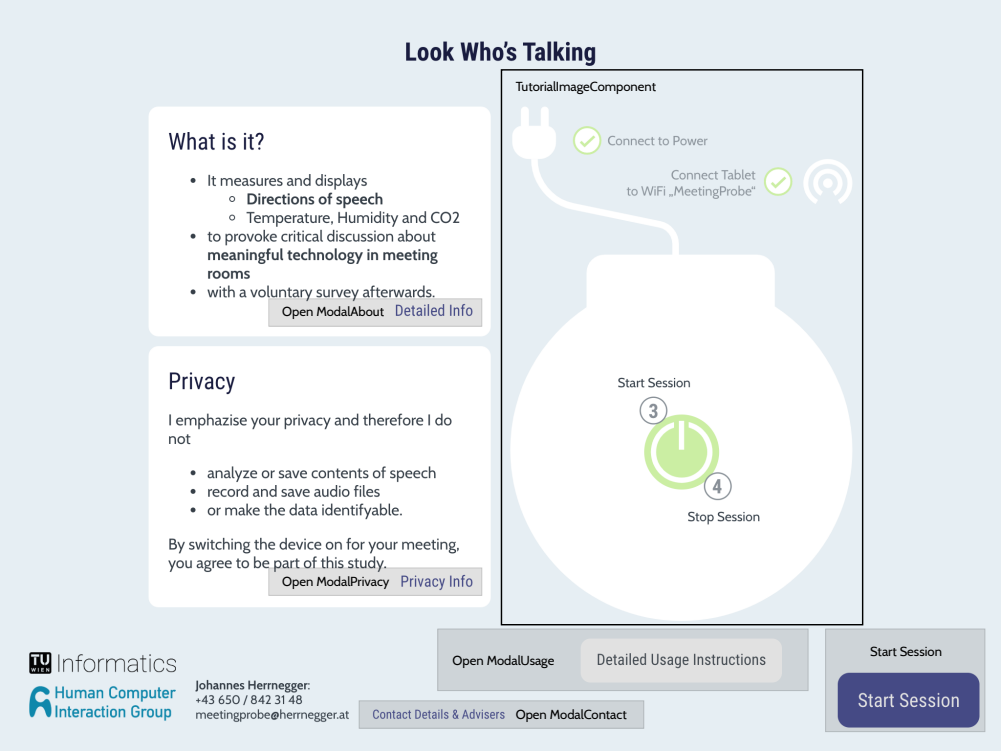

Figure 5.7: Home Page Components and Hotspots.

is possible to finish the meeting session through the push of a "Finish Session" button as an alternative to the physical button on the device. The different components and hotspots can be seen in figure 5.9.

The page consists of the following parts:

- Four charts vizualizing the different environment measurements "loudness", "temperature", "CO2", "humidity". Those are implemented by using the components `EnergyChartComponent`, `TemperatureChartComponent`, `CO2ChartComponent` and `HumidityChartComponent` which are described in this section on page 61.
- The DirectionChartComponent, which vizualizes the measured directions of speech. It is described in more detail in this section on page 62.
- The current session code.
- The current session duration.
- A "Finish Session" button, which will finish the session and tell the router to navigate to the Result page.

Figure 5.8: Session Page.

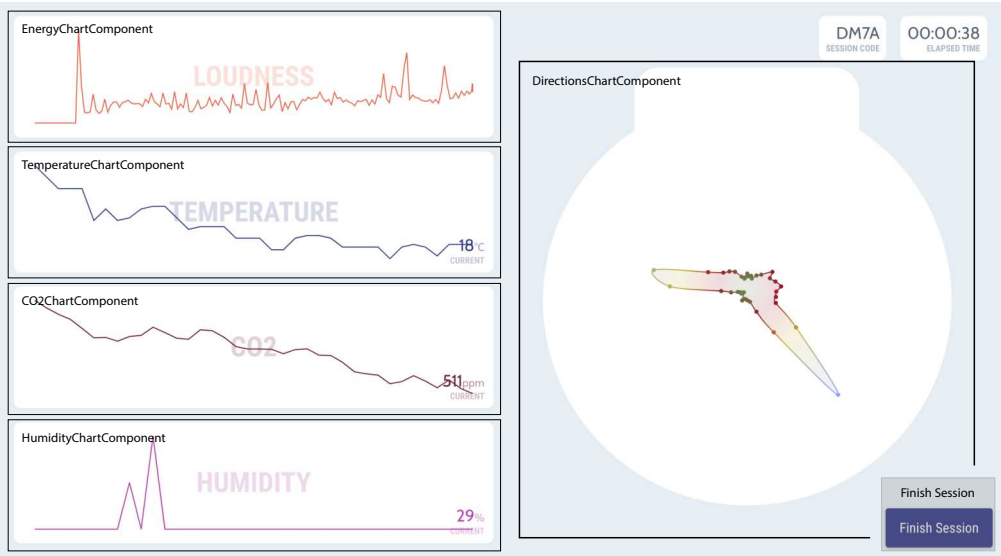

Figure 5.9: Session Page Components and Hotspots.

Figure 5.10: Result Page.

Result Page The Result page (see figure 5.10) is the page that is displayed after a meeting session. Its purpose is to visualize the values which were collected during the session. This page is almost identical to the session page. There is an additional block, which should motivate the users to fill in the survey. The different components and hotspots can be seen in figure 5.11.

The page consists of the following parts:

- Four charts vizualizing the different environment measurements "loudness", "temperature", "CO2", "humidity". Those are implemented by using the components `EnergyChartComponent`, `TemperatureChartComponent`, `CO2ChartComponent` and `HumidityChartComponent` which are described in this section on page 61.
- The DirectionChartComponent, which vizualizes the measured directions of speech. It is described in more detail in this section on page 62.
- The current session code.
- The total session duration.

Figure 5.11: Result Page Components and Hotspots.

- A "Start New" button, which tells the router to navigate to the Home page in order to enable it for the user to start a new meeting session.

Components

TutorialImage The TutorialImageComponent is used in the Home page to give the user a quick start and help how to use the probe. Its purpose is also to guide the user through the setup. Therefore it changes due to the state of the app. When the tablet is not yet connected to the device, it does not have an active WIFI connection or the device is not reachable it displays a pending icon that circles around the first and second step. When the connection is upright, it displays a checkmark and lowers the visibility of the text to indicate that the users do not have to care about those points anymore. Those states are shown in figure 5.12.

LinearChart The `LinearChartComponent` is a base component for all environment measurements that are vizualized by a linear chart (humidity, temperature, CO2 and loudness). It is contains some basic methods that are necessary in all linear charts

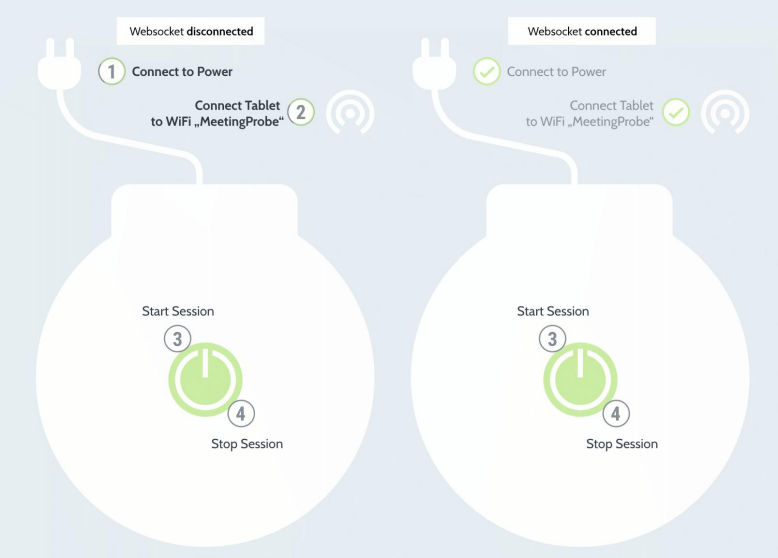

Figure 5.12: State of the TutorialImage Component.

that are used within the application and uses the line chart component by the library `ngx-charts` to display the chart.

Next to the data, colors and labels, the `ngx-charts-line-chart` also takes an `yScaleMin` and `yScaleMax` parameter, which would be 0 and the maximum of the input data if there was no input. The data usually has a minimal alteration. If we take CO2 as an example, which starts somewhere in between 500 and 700 usually changes only a little bit during the meeting, you would not see much effect in the chart shows the scale with a scale of 0 to 700. The `LinearChartComponent` handles this by setting the minimum and maximum scale for the given input data.

It also extends the component by a current or total value that is displayed in the bottom right corner of the component, depending on the type of parameter and view.

Humidity-, Temperature-, CO2-, and EnergyChart Every environment parameter has its own component that is responsible for vizalizing that parameter. The components that vizualize loudness, temperature, CO2 and humidity are `EnergyChartComponent`, `TemperatureChartComponent`, `CO2ChartComponent` and `HumidityChartComponent`. It prepares the data and, as described above, they all use the `LinearChartComponent` and fill it with their customized parameters. For example, the HumidityChartComponent uses the following code in its template:

```
1 <app-linear-chart
2   [results]="results"
3   label="Humidity"
4   color="#B243A5"
```

```
  [currentValue]="currentValue"
  [averageValue]="averageValue"
  [showCurrentValue]="showCurrentValue"
  [showAverageValue]="showAverageValue"
  unit="%"
></app-linear-chart>
```

The session and result pages can also modify how the component is displayed by passing arguments into the several components. There it is defined if the current or average value is displayed.

DirectionsChart The `DirectionsChartComponent` displays the accumulated directions of speech. It consists of a background image in the shape of the device and a polar chart component by the library `ngx-charts`. The component gets the data of the directions by the session and result pages and handles how the data is presented to the user.

5.2.4 Websocket with rpc-websockets

The library rpc-websockets[4] is used within the server application as well as the frontend application and acts as a communication layer between those two components. It handles websocket communication and creates a JSON-RPC 2.0 layer on top of it. This enables the following features:

- **Remote Procedure Calls**: With this feature it is possible to call methods on the server from the client (or methods on the client from the server). The server could provide a method `probe.session.start`, which contains the logic for starting a session. It is not necessary for the client to know implementation details about this method to call it.

  The server can provide the method like this:

```
// This means: When a client calls 'probe.session.start',
   call the startSession method (which handles the logic
   for starting a session).
this.wss.register('probe.session.start', startSession);
```

  On the client this method can be called like this:

```
// After the websocket opens, is is possible to call:
this.ws.call('probe.session.start', /* There could be
   arguments */);
```

[4] rpc-websockets library (`https://github.com/elpheria/rpc-websockets`)

- **Events**: Another important feature that is used are Events. With those it is possible to send notifications from the server to the client or vice versa. The server could tell the client about important updates within the state of the session like when a session has successfully started. Then the frontend could react to this by displaying the user information about the current session.

  In code, this example looks like this on the server:

```
1 // First the event has to be registered so that the client
     knows that this event exists:
2 this.wss.event('probe.session.started')
3
4 // And when a session has started it emits an event:
5 this.wss.emit('probe.session.started', {code: 'AB12'});
```

  The client on the frontend can react to events in the following way:

```
1 // First subscribe to updates
2 this.ws.subscribe('probe.session.started');
3
4 // And then it is possible to react to events. When 'probe.
     session.started' is emitted on the server, it will call
     the 'sessionStarted()' function here
5 this.ws.on('probe.session.started', () => sessionStarted())
```

Please note that this code serves explanatory purposes. The actual server and frontend code provides additional classes, which are described in Section 5.2.2 and 5.2.3.

Methods and events

The Node.js server running on the Raspberry Pi reads and controls GPIO inputs and outputs like the traffic lights and the button, controls the LED-ring and reads from the sensors and ODAS input. It also provides websocket-rpc methods and events for the frontend application, which can be found in appendix A.1.

5.2.5 Full-Stack example

This subsection takes one call and describes what happens through all layers of both applications from user interaction to the database and illustrates it in figure 5.13. The action that demonstrates this example is when the user wants to start a session.

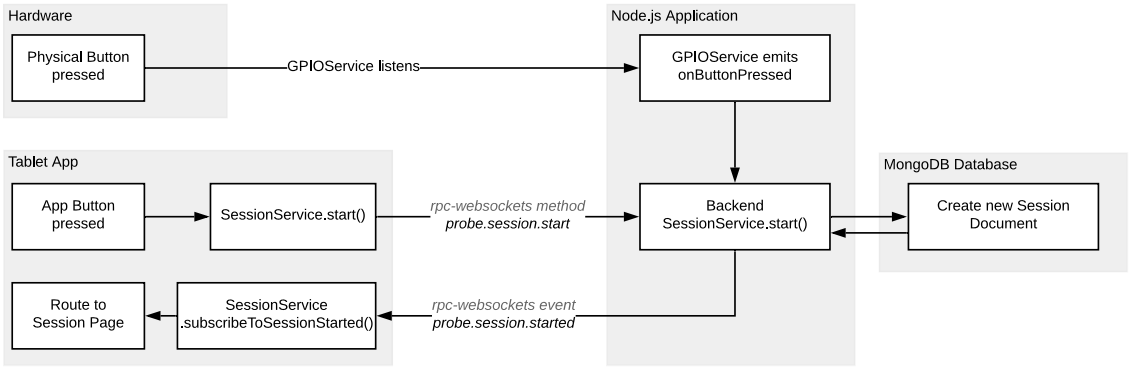

Figure 5.13: Communication Example: Starting a session

User interaction

A session can be started in two different ways: by pressing the physical button on the device or the "Start Session" button on the tablet app. The mechanisms to listen to those interactions are different in code and the following paragraphs describe both ways.

Physical Button While the application works, the `GPIOService` constantly listens to changes of the button pressed state. When the user presses the button, it detects this change and dispatches the event `onButtonPressed`. This event is listened to by the main application class `App.ts`, which calls the `startSession()` method on the `SessionService`.

App Button In the tablet app, the template of the home page `home.page.html` contains the button "Start Session", which calls the function `startSession()` of the corresponding component class in `home.page.ts` when the button is pressed. This method then calls the method `start()` in `SessionService`, which calls the rpc-websockets method `probe.session.start`.

On the server, the main application class defines that the rpc-websockets method `probe.session.start` calls the method `startSession()` in the `SessionService`.

Server SessionService

As soon as the method `SessionService.startSession()` is called, the server acts in a unified way for both of the two different user input possibilities: It (1) generates a unique code, (2) creates a new database entry, (3) calls the methods to start on `DirectionService` and `EnvironmentDataService`, (4) sets the session

as current session, (5) notifies the frontend by emitting the rpc-websockets event `probe.session.started` with the new session as an argument, (6) returns the new session in the method, which will then also be returned over the rpc-websockets call;

Frontend Effect

The `SessionService` on the tablet app listens to the rpc-websockets event `probe.session.started`. As soon as it gets notified by the `SessionService` on the server application, it sets the current session to the session provided in the event arguments and tells the router to navigate to the session page.

5.2.6 Development

During the development of the probe there came a lot of technologies into consideration, which not all of them were used in the final version. This subsection describes the process of developing and how the final technology came into existence.

Initial Local Version

In the beginning the idea was to build a proof of concept on a local development environment before the hardware components were ordered. This had the advantage that I could learn and try some technologies before ordering the hardware.

For this first version, I used a Node.js environment with Typescript and webpack and the following components:

- **WAMP and crossbar.io:** WAMP (Web Application Messaging Protocol) is a Websocket subprotocol that enables multiple machines to communicate via *Remote Procedure Calls* and *Publish/Subscribe pattern*. Crossbar is the server software that implements this protocol and connects the different machines. Every connected machine can provide and consume functions and events, which is particularly useful in IoT applications with a lot of different devices connected to each other. In my case, I wanted to run crossbar on the gateway and connect the Node.js environment and the frontend to the crossbar server.
- **PostgreSQL with TimescaleDB:** TimescaleDB is a time series extension for PostgreSQL. It optimizes the database for writing timed data and reading them with time-agnostic functions like average of a specific timeframe. This seemed useful for me, as the sensor data during the session should be saved over time and in the end be vizualized in graphs.

In this first version it was already possible to start and end a meeting session from the frontend and save some demo values with using all the wanted components.

When the "Start meeting" button in the frontend got pressed, the frontend called a function on the backend through crossbar. The backend then generated a new entry in the database and returned it to the frontend with the generated code. Then the backend started to fill it with random test values.

When the "Stop meeting" button in the frontend got pressed, another function on the backend was called, which ended the session and returns the results to the frontend. The frontend then displayed a graph with the values.

Setting up the Raspberry Pi

After the initial version was proved to work, I tried to set it up on a Raspberry Pi 3 (Model B+). For that, there are multiple operating systems available. The most popular ones are *Raspbian* and *Ubuntu*. As it is the official one with the most support, I first chose Raspbian in the version 9 (Stretch). To install it you need to download the image and write it on an Micro-SD card. After inserting the SD Card into the Raspberry Pi, it was possible to setup the OS with some prompts. In addition to the basic preferences, I also activated some features that helped me in the development process:

- **FTP** to transfer files from my local machine to the Pi.
- **SSH** to access the terminal without a monitor.
- **VNC** to access the graphical user interface without a monitor, mouse and keyboard.

Trying ODAS The first step after installing Raspbian was to try if I can get the library ODAS (Direction Detection) to work with my Raspberry and Matrix Creator. I followed the blog entry in [Dir], which describes how to install a demo program that uses ODAS to activate the LEDs of the detected direction. This worked as expected.

Node.js For the server software I wrote for Node.js and Typescript, I needed to install Node.js. I first installed NVM, which is a version manager for node and enables multiple different node environments to be installed simultaneously. Then I installed the most recent stable Node.js version 11. The actual installation of the software was straightforward by checking out the initial version of my Git repository and installing the modules with npm, the package manager of Node.js.

Installing crossbar There are multiple ways to install crossbar. One of them is with docker, which I wanted to avoid, because docker needs a lot of resources and space on the machine and should not be used in production. But as the other versions (installing in a virtual python environment and snap) did not work on Raspbian, I installed it via docker in the version for the architecture armhf, which is the architecture that Raspbian uses.

PostgreSQL/TimescaleDB As the initial version of the probe uses a PostgreSQL database with a TimescaleDB extension, I tried to install it on the operating system. This was not possible, because the database was not built to work with the architecture armhf, which is a 32-bit system. I needed to find another solution.

SQLite As it was impossible to install PostgreSQL/TimescaleDB on the used operating system, I tried to install SQLite, which is another relational database.

MongoDB The installation of SQLite worked, but as there are no optimizations for working with a large set of timed data like in TimescaleDB, I decided to look into another solution. I did not have any experience in NoSQL databases, but I found an article about how to design data models that are efficient in MongoDB [Tim]. That is why my next approach was to install this database. Unfortunately, MongoDB was on Raspbian only available in the version *2.4*, while the most recent version was *4.0*, because everything over 2.4 needed a 64bit operating system. As the Raspberry Pi would support 64bit, but the Raspbian OS is in 32bit, I tried to use another operating system.

Ubuntu That is why I chose to try Ubuntu for Android. Before doing that, I backed up the current state by creating an image of the SD card. So I was able to go back to this exact state of the operating system with the same installed software and files. Installing Ubuntu worked as expected. Also MongoDB 4.0 worked.

Moving away from crossbar Installing crossbar on Ubuntu did not work with any described method. I created an issue in the GitHub crossbar repository [Nee], but as the time of this writing nobody could help. In my search for an alternative solution, I found the library *rpc-websockets* [JSO19], which enabled to use Remote Procedure Calls and also events with JSON signatures. That was a valid alternative for my usage of WAMP and crossbar, because I just needed to have one Node.js server running on the Raspberry Pi, which provides the calls. The frontend just consumes - but not provides - RPC functions.

ODAS on Ubuntu After having a working setup in Ubuntu, I found out that there is no working configuration for the direction detection library ODAS on Ubuntu.

Back to Raspbian The library ODAS was critical for my setup, so I went back to the previously installed Raspbian image and tried to install all components there again. As a solution I made the Node.js server work with MongoDB 2.4 by using an older driver version 2.2.36. (Drivers are the libraries that connect the specific programming languages to the databases).

Working setup In this subsection I illustrated the challenges of getting the initial version of the probe to run. The following list summarizes the steps:

- Operating System
  1. **Raspbian 9 (Stretch)**
  2. Ubuntu 18.04
- Database
  1. PostgreSQL with TimescaleDB
  2. SQLite
  3. MongoDB 4
  4. **MongoDB 2.4**
- Programming environment: **Node.js v11**
- Module bundler: **webpack**
- Websocket connection
  1. WAMP & crossbar
  2. **rpc-websockets**

To make sure the probe works after a reboot, it was required to start the server as a service as soon as the operating system starts. Therefore I tried different approaches: Several approaches[5,6] did not work until finally I found `pm2`[7], which worked perfectly for my usecase.

Frontend

While working on the server, I also built the frontend side of the project to see if the components are working together properly.

The initial idea was to place show the information on a tablet. With this in mind, there are several options for building an interface that is meeting this requirement.

- **Native iOs or Android App**: Building a native app with the tools and programming languages that the platforms provide (Java on Android or Swift on iOs.

[5] crontab (`https://www.linuxwiki.de/crontab`)
[6] forever (`https://www.npmjs.com/package/forever`)
[7] pm2 (`https://github.com/Unitech/pm2`)

- **Hybrid App**: Building an app that uses one shared codebase for both Android and iOs devices. Popular choices for hybrid apps are cordova and capacitor, which use a web layer inside a native app to display a website that should act and feel like an app. React Native and Flutter are other popular choices that are natively rendered and therefore promise to be more performant than the web wrappers.
- **Progressive Web App**: Another choice is a progressive web app, which is basically a website that is enhanced by additional features like the ability to receive notifications. A very popular framework for building PWAs is Ionic, which on the one hand is able to compile into a hybrid app with cordova or capacitor, but also to be served as a PWA.

I decided to use Ionic for the development of the frontend because of the following reasons:

- Flexibility: I only have to develop it once and have the possibility to deploy it on iOs, Android and web platform. For the initial requirements it was only necessary to deploy it on one system, but I saw it as an advantage to be flexible if the requirements change.
- Universality: When developing for a web platform, the app can afterwards be used by any machine with a web browser. With the corresponding URL, the participants could also access it on their own computers, tablets and mobile phones.
- Performance: As in this project it is not needed to have the highest performance with a lot of smooth animations, I do not have this constraint and Ionic (instead of native, React Native or Flutter) remains a valid option.
- Familiarity: In former projects I already gained some experience with working with Ionic, which was also an important factor in choosing the framework.

After choosing the framework the frontend was based on, I started developing an initial proof of concept and afterwards I enhanced this initial app step by step. In the following paragraphs I will describe the progress that was done while the app was developed.

For the initial version, I wanted to have three pages: a home page with a button to start a session; a session page, where there is a timer and the current session code and a stop button; and a result page, which displays the code and the timer. As the development of the frontend is tightly bound to the server, I first built all the services for working with WAMP and crossbar, as I also used for the initial local server version. The first success was to be able to start and stop the session via the frontend, which called the corresponding methods on the server via the WAMP interface. On the session and the result page, I showed the database output in JSON form to proof that the starting and stopping of the session works on all the different layers (frontend, server, database) and the connections between each other.

After setting up the Raspberry Pi and changing the technologies server side, the frontend part had to be updated as well. So

5.3 Casing

As the probe should animate to use it and have the feeling of a real device, it should also attract the interest of the meeting users and look better than the raw Raspberry Pi with its extensions. That's why I decided to create a casing for the probe.

5.3.1 Procedure

The main requirement for the casing was that it should not hinder the probe to work properly. With working with detection of arrival on the Matrix Creator board, it is important that the sound still arrives at the microphones. Also, the LED-ring should be visible for the participants when placed in the middle of the meeting table. The buttons to start and end the meeting sessions should be clear and visible.

There are multiple possibilities that I though of for this task:

- **Folded paper**: With paper you can create a wide range of quick prototypes.
- **Handcrafting**: Buying handcrafting material and create a casing by hand.
- **3D print**: Creating a model in a 3D modeling software and printing it with a 3D printer.

At first, I tried to learn how to do it with paper by trying some exercises from the book [Jac12]. After some time spent I saw some problems that emerge when designing with paper. It might be a good material for prototyping, but (at least with my skills) it is not robust enough for usage in meeting rooms. If a cup of coffee spills, the material might not be a sufficient cover for the electronic parts. Or it breaks or tears while it gets transported from one meeting room to another.

With those reasons in mind, plastic as a material was a better choice. That's why I chose to have a 3D-printed casing.

5.3.2 3D-printing software

As I never worked with 3D-printing before and have very little experience in 3d-modeling, I tried to find a suitable software to create the 3D-model first. There are many different possible solutions, from which I first tried SketchUp and then I decided to use Autodesk AutoCAD.

There is a free web-app version of SketchUp. There are also paid options for the full version for desktop with more features. For my use case, the free version seemed too imprecise and unintuitive and also it had problems with speed in my browser. After some hours trying to get familiar with the software, I decided to try something else.

Because AutoCAD has a one-year free plan for students, I decided to give it a try. Although the software is known to have a steep learning curve, for me the interface made more sense than (the free version of) SketchUp. It probably needed more time to learn AutoCAD, but in the end I had more confidence in the exact measurements of the model.

5.3.3 Creating and printing the 3D model

This subsection describes the process of how the case was designed and printed. The idea was to create a concave surface that spans over the electronic parts of the probe. In addition, there should be a part that contains the status-LEDs for the environmental values.

The process of creating the 3D model for printing consisted of several iterative steps of designing the model and printing test prints. The test prints are smaller-sized prints, in which possible problems can be detected and changed in the model.

First iteration

The first idea was to have three parts: The bottom part, the concave part and the top part, which is meant to be the button for starting and stopping the meeting.

Fortunately I found an existing 3D-Model of a casing for the Raspberry Pi and the Matrix creator. This model was the basis from which the unnecessary parts were removed. What was left was the bottom part with the holes for the Raspberry Pi to mount on. My strategy for designing the concave part was that I created a sphere and substracted most of the lower part. Then I splitted away the button and extended the size of the bottom to fit the outer curved shell.

For the LED-part I created an additional part that I connected with the shell.

Because the case like that would block a lot of the sound that at the microphones in the next step I created holes in the shell. This was done with a tool that is called "Polar Array" in AutoCAD: It copies an object around an axis in circluar order. With that it was possible to create a structure that was substracted from the shell in the following step.

With this model, I created a test print in a smaller version with the help of Peter Purgathofer. The longest part of the model was 25cm in original, which we printed as 12,5cm. As seen in figure 5.15(a) the finished test print contained several problems, as we tried to avoid structure material. Those problems arise either when the printer tries

Figure 5.14: Development of the probe casing.

to print and there is no material below the added plastic; or similarly, when there is not enough material to hold below it and the plastic gets colder it sometimes shrinks and loses the grip to the rest of the model.

Other interesting insights were in the design of the parts: It is hard to find a beautiful way to attach the bottom to the shell. So I decided to combine the two parts and make an insertable part for the Raspberry Pi and the matrix board instead. Because of this it is necessary to change the display into a separate part that can be attached and detached, because only then it would be possible to place the status LEDs for the environmental values. Also there were some unnecessary elements left from the downloaded basis model.

Second iteration

I first removed the unnecessary elements. Those were some holes in the bottom that were needed in the downloaded model that I used as a basis. Also, I flattened the bottom part of the button to make it better to print and to use.

The next step was to cut out the part of the bottom on which the Raspberry raspberry will be attached. To attach the the bottom and the new insertable part to each other, I placed two "wings" on the insert and cut holes in both parts so that it is possible to screw them together.

In the next step the bottom was modified to be combined with the rounded shell surface.

Then the display part was removed and recreated to be a separately printed part. For that, I removed the old faces and rebuilt the surface. Then the "windows" were cut into the form and separating walls modeled inbetween the windows to prevent that you can see the color of the neighboring LEDs. In addition, the bottom part of those walls were made triangular to be able to slide it in and out. To make the complementing part, the display was duplicated and substracted from the shell and the bottom part.

The last step of this iteration was to build in small support structures within the model to avoid the need of support material (as this was not available with the used 3D-printer).

After printing the updated variant of the model, there was still the problem of hanging filament on some parts of the model. Also, the parts did not align well together. The part to mount the Raspberry and the insert of the display were slightly too thick and the display did not fit exactly the shell. That can occur with 3D printing, because the filament is sometimes too imprecise. The result of this iteration can be seen in figure 5.15(b)

Third iteration

For the next try, the big holes over the display were removed and replaced with smaller holes. Also, the display for the LEDs and its slots became bigger.

I made the insert part slightly smaller (0.5mm), because in the last print it did not fit into the hole.

Another problem with the last prints was that the units were not correct in AutoCAD. By enlarging the model a factor of 10 (ten times as big), I ensured that the model will be printed in the exact size. This was important at that step, because the following print was meant to be the first real-size print.

The print of the shell alone needed 27 hours and the other parts (display, top button and bottom insert) needed another 10 hours together.

There is the possibility to choose how the support of the model gets printed: "None", "Only on touch-platform" and "everywhere". Because of limited time ("everywhere" would

have needed about 10 hours more), I decided to print the parts only with support for only on the touch platform. This means that the support material did not cover every important part. To support also the parts that were not covered by the automatic support material, I designed my own support structures at the important parts.

After the print finished, which can be seen in figure 5.15(c,d), I saw that my custom designed support was not sufficient for the part over the display and it was hanging down, because the custom support structure was too weak. For the first test meeting, I decided to workaround this problem by heating the overhanging part with a heat gun and bending it.

This workaround worked well for the internal pilot meeting, but for the next steps I decided to modify the printed outcome from this step to fully fit together.

5.3.4 Fourth iteration

After the internal pilot meeting, there were still some imperfections on the casing that I wanted to change. One was the former discussed workaround. Also, the button to start and stop the meeting was still a raw and unattractive mechanical push button, instead of integrating it into the casing.

At first, the hanging part of the casing was sawed off. Then the 3d model was changed so that the display part fit into the new form of the shell. The difficulty of this step was to measure and guess the form of the shell, because it did not exist like this in the 3D software.

Additionally, there was the need to remove part of the bottom of the display part. In the last try it was unintentionally printed on the shell and also on the display part, so I had to break it away as a workaround. This was also fixed in this version.

After printing the part, there was still a gap between the shell and the display, but I decided it to be good enough for the intended purpose. See 5.15(e) for the outcome of this step.

Button

One thing that was not tackled at this moment was the integration of the push button into the casing.

The idea was to make a fixture in the middle hole of the matrix creator board to attach the button to the board.

The first step was to make the plate with the button as small as possible. I soldered the unnecessary electronic parts away that are remains from the second button, which I don't need anymore. After that, I re-soldered the electronic parts of the first button and cut away some parts of the plate to make it smaller.

Afterwards, I designed the fixture part. This consisted of two parts that are meant to sloth together. One part to put on the board from the top and one to slide into from the bottom after the button was put into place. As those parts are really small, a few iterations of printing and adapting to make them perfect were done relatively quickly.

To have a more haptic feel when pressing the button, the first design intended to have the big platform as a button. What was not considered before was that it is complicated when the big button part is attached to the small electronic push button. When pressed on the sides, it also has to push the electronic part. That's why I decided to split the top part in two separate parts: One smaller button in the middle and a bigger ring surrounding the button.

In this process, the first step was to split the two parts. The matrix creator board is luckily designed with some holes that can be used to attach something to it. Two holes were put into the button and subsequently the part to attach it to the board was designed. In the first step this was meant to be two sticks that are connected with a thin flexible part (U-bolt), to hold the button not too strongly that it can also be released.

After printing the U-bolt, I realized that the parts are too thin and therefore too fragile to be used reliably. When I tried to connect it to the button, it broke. Fortunately I found screws that had the exact size that I needed. So I used those instead of the printed sticks and designed two holes into the thin flexible part.

To make the connection to the screws more stable, the button was enhanced by two hollow cylinders where the screws can be screwed into and two cylinders to balance the button on the other two sides.

Unfortunately the button could not be pressed after assembling the parts together. There was the problem, that by pressing the printed button part, it pressed on the electronic button, which did not had enough pressure from the bottom and slipped away. So I created another part that was able to put pressure from the bottom of the Matrix Creator board by screwing it through two other close holes. That part had three challenges: It has to be screwed to the board; it had to put enough pressure to the button; and it should not hinder the button to be pressed (and therefore let loose the attached screws). The last challenge was accomplished by making slightly bigger holes that the screws can slide through. After two prints, this part was able to handle the challenges and, most importantly, created enough pressure to act as a counterweight for the electronic button.

On some locations on the outer ring there were also holes designed to mount the outer ring to the board with screws.

While assembling the parts, there were some unsteady parts. Those problems were evened out by putting foam between the parts to create some counterpressure. Figure 5.15(f,g,h) illustrates the work on the button.

The finished casing can be seen in figure 5.15(g).

5.4 Questionnaire

After the meetings the participants were asked to answer some questions in a survey. This subsection describes how this questionnaire was created.

5.4.1 Generating questions

The most important thing is to know which questions to ask. For this, I first created a mindmap, in which in the first put the research questions for the probe a bit simplified: "influence behavior", "influence awareness", "influence satisfaction", "influence group dynamic", "Which meaning do those sensors have for users?" and "Which concerns do those sensors cause?". From that, I tried to find useful questions to those topics.

After getting feedback on the mindmap, I elicited some questions out of the mindmap, that should be in the first version of the survey. Those questions were the following:

- What would happen if the device would show the distribution on talking time of gender?
- How would it affect the meeting if the device would show the role of the attendees? (Team Lead, Engineer, Secretary, ...)
- Did you become more aware of my role within the meeting? How?
- How did the shown data influence the speaking behavior of you and your coworkers?
- In which ways the system could provide feedback for the stress levels in the room?
- Do you see any concerns with smart technology in meetings? Yes, which?
- Could awareness of air quality have an influence on good meetings?
- Which other measures could you imagine could influence what makes a good meeting? (Don't worry about feasibility)
- Would you use a similar device frequently in your meetings? Why/Why not?

5.4.2 Searching for a tool

For asking those questions, there are many possibilities. At first the idea was to integrate it into the frontend to ask them right after the result page. This was insufficient, because the attendees could only fill the survey one at a time.

That is why I decided to provide two ways of filling the form:

1. Online Tool: On the result page in the frontend, there is an URL and a QR-Code provided, which links to an external online survey.

2. For people who prefer to fill it handwritten, there is also a printed-out form.

There are a huge number of such online survey tools. Some of the most popular tools that I found were Typeform, SurveyMonkey and SurveyGizmo. The problems with those were that they are proprietary and all had insufficient free options. There would be also the possibility to use Google Forms, which I also wanted to avoid, because of privacy considerations.

In search for an open-source alternative, I found some possible solutions. Some of them I had to exclude, because I only had a server available with PHP&MySQL, while they needed a Node.js or other environment.

- Tellform (`tellform.com`): An open-source Typeform alternative, which has a conversational interface, but unfortunately was deprecated and needs Node.js. It's rewrite OhMyForm also was not in a production-ready state at the time of writing.

- QuickSurvey (`https://github.com/simonv3/quick-survey`): A simple survey tool, which needs Meteor on the server.

- LimeSurvey (`www.limesurvey.org`) is a feature-rich open-source online survey tool, which is written in PHP and also supports MySQL.

Because of the limitations of the other software, I decided to use LimeSurvey. Installation was straightforward. I copied the files on the server, set the UNIX permissions, created a database and started the installation tool, which guided me through all necessary steps to setup the software.

After LimeSurvey was installed on the server, I transferred the previously created questions to the software and compiled them into categories/topics.

This was the first draft, which I first used to present in the internal pilot meeting. After the meeting I had a meeting with COMPASS-member Christian Löw from University of Vienna, who was able to give me feedback on the first draft of the questionnaire. His main points were the following:

- In the draft I used categories that bundled the questions by topic (e.g. behavior, awareness & satisfaction) and in those categories I had reactive questions (How was it for you?) and speculative questions (How could it be?). A better approach for the participants would be to bundle not by topic, but bundle the questions by first reactive and then speculative questions. For the people who fill in the form it makes more sense to first answer about what really happened during the meeting and afterwards what they think could happen in the future.

Figure 5.15: Internal pilot meeting

- There are a lot of open questions. After separating the questions into topics, he recommended me to combine them into Likert scales when it is possible.

With this feedback I was able to create the final version of the questions. For the final touch, I updated the colors, font and the logo of the survey to fit the style of the app. The final survey can be seen in appendix B.4

5.5 Pilot Study: Internal Meeting

As soon as I was confident with the backend, frontend and casing to work, I tried the first draft in an internal pilot meeting. This section describes the progress and the outcomes of this first meeting.

On August 29, 2019, the COMPASS project group held one of their monthly meetings. I prepared the probe within the casing and placed it in the middle of the meeting room before the meeting started. Despite of the size of the probe, it did not catch much attention beforehand. After the participants arrived there was a welcoming phase, during which I projected the frontend application on a big screen and started the meeting phase on the probe.

While there were some participants that did not notice the screen and that I started the probe, some of them looked curiously to the screen while it recorded the directions and the other values.

After some time, Chris Frauenberger, who was also the host of this meeting, lead the topic to the probe. The meeting session of the probe was still running, so when I introduced the other participants to the features of the probe, they could see the live effects on the screen. What followed was an interesting discussion about the state of the probe, what it could become and probable implications of such technology. After some time during the discussion I stopped the probing session to present the result screen. I also presented the first draft of the questionnaire in the end to get feedback on it.

In the following subsections, I will summarize the ideas and outcomes of the meeting.

5.5.1 Future Features & Concerns

Within the discussion, a lot of the contributions were about what this technology could develop to in the future. Those contributions were partly optimistic (Which useful features could devices like that have in the future?), but also concernful (What negative implications could devices like that have?).

One concern was that when the device would be collect personalized data over a longer period (e.g. a year), employers could interpret this data and label their employees as "good" or "bad" employees depending on the amount of contribution within the meetings. Another participant stated that it is not necessary to have a longer time frame and even within one meeting such interpretations could be met. For example when single meetings will be evaluated, there could arise questions like "Is someone who did not say anything (or anything useful) important?". While in some situations this could be useful for managers to optimize work capacities, it may be misinterpreted or misused and lead to unjust decisions.

One person even had the opinion that because of the usefulness for controlling, if I would take this idea and push it to the markets, I could make a lot of money with it.

Another contribution was that for some purposes it could be useful to have sanctions for some behavior like interrupting someone, being too aggressive and that this could lead to more balanced discussions. One example where a feature like this is already used is in political discussions in TV, where the politicians' talking time gets recorded and shown to them and the audience. Usually a moderator tries to provide balance there.

Some inputs were about how the data could be interpreted with AI/machine learning mechanisms. In addition to displaying the talking time, displaying the quality of the contributions. The algorithm could guess and label the role of the participants in the meeting. An interesting aspect could be which roles they are taking in the opinion of the AI and if it fits their actual role. An AI could also recognize certain events like someone interrupting someone else or sense when the discussion gets too heavy or stressful.

5.5.2 Observations

Some of the contributions were interesting observations.

One participant stated that she finds it interesting that not only the participants' voices are recorded, but also background noise like a dustcart from garbage disposal. In retrospective, one tries to reconstruct what the different spikes on the graph could be and mean.

5.5.3 Feedback on the probe

A lot of the contributions were directed as feedback on the probe. Some of this feedback I considered out of scope and decided to carry it into the subsection "Future Features & Concerns". The remaining feedback is something would actually be interesting to implement before the following phases.

One input was that it would be interesting to not only see the accumulated graph in the frontend, but also the current volumes. There were some ideas that supported this idea. One was that the peaks/nodes of the graph could be highlighted. Another one was that there could be a second overlapping polar chart behind the accumulated graph that shows the current spectrum.

"Ethical Visualization": An interesting observation was that by visualizing the data I'm also already making assumptions and therefore implicitly suggest valuation of the data. For example, the direction with the highest amount of speech is colored red in this first draft. Maybe this suggests that the more you speak the worse you perform in the meeting. If the visualization would be green on the highest point, it would probably have a different meaning for the participants. The question then was how the probe could be designed to make it as ethical as possible. An idea was that there could be provided several color schemes to choose from in the frontend application.

Something that I discovered was that right now the directions get filled with accumulation of the energies(volumes). The problem with that is that when someone speaks who sits closer to the probe or speaks louder gets recorded with a much higher ratio. It may be better to not accumulate the energies/volumes of the directions, but a static value per timeframe.

There was some feedback concerning the questionnaire. There was the common understanding that it should start with more open questions. Because the questions that were asked in the beginning already suggested ideas and could form the participants' opinion on the topic. So instead of asking "What do you think would be the impact on the meeting if the device would show the distribution on talking time of gender?" as the first question, I should ask "Which experience did you have while using the probe? Which thoughts did you have?". The survey could also start with some demographic questions, which I intentionally did not state in order to avoid privacy issues.

I stated the question, if the survey is the best choice for those kind of questions. I thought it would be better to hold interviews. The problem with this is that we probably don't have access to the participants after their probe sessions.

Finally, the participants of this first internal meeting gave me some feedback concerning the structure of the experiment. It is important to have a info sheet with an introductory text and contact information. The contact information would also be important and useful on the frontend application.

5.5.4 Conclusion

This section described the first usage of the probe in a test environment during an internal meeting of the COMPASS project.

The goal of the probe is to open negotiation spaces around IoT technology in meeting rooms. For this meeting, it did exactly that and caused an interesting discussion about the chances, ethical implications and concerns of likewise technology. We concluded that the probe is working and can – after some changes in the visualization and the casing – be progressed to the next phase in a partnered company.

5.6 Handout

One insight from the feedback on the first meeting was that a handout is needed. This will be a sheet of paper with the purpose of creating interest in the probe and explain how to use it. This section describes how this handout was designed.

The first step was a first draft of the text contents. Therefore I defined a structure with the headlines and afterwards filled them with contents. The first structure consisted of the following parts:

(1) TU Logo (2) Introduction/General Info (3) Privacy Info (4) Usage Info (5) Contact Info

After getting feedback on this first draft from my advisor, I started to work on the layout and visual design of the handout. In the beginning, I tried a few different approaches and got feedback from friends, until I was satisfied with the basic layout. The history of approaches are shown in figure 5.16. In this process I also worked on the text. The first draft contained a lot of text, which could have a deterrent effect on the participants and it was probably hard to read in a short time. For that reason I first tried to find out and address the most important contents that I want to communicate. Those points were (1) what the project is about, (2) how to use the probe, (3) what the participants' part is (and why I need their help) (4) and that their privacy is respected; After I reduced the contents of those points to the minimum, I printed the handout and laminated it.

During the design of the handout I had the thought that there should also be an easy way to fill in the survey at a later point. Meetings are often held during a stressful day with responsibilities before and after the meeting and so it is very likely that some people would like to participate in the study but are not able to take the time to fill in the survey. Therefore I decided to create a card with the link and the QR code after the handout was finished. The card also contains a field where the corresponding meeting code can be filled in. Interested participants can take this card home or for later as a reminder if they don't have enough time at this moment.

The final design for the card and the handout can be seen in figure 5.17.

5.7 Probing Phase

This section describes how the probe was used at the different participants and which challenges were faced in this process.

The probe was used in three different organizations in different settings. In the first organization I gave the probe to one contact person, who was responsible for using the probe within meetings he held over the course of several months. The second organization was a middle-sized organization, where the probe was placed in one meeting room over three days. The third organization was a small company, who used the probe in one particular meeting.

The final package which was handed over can be seen in figure 5.18. It consisted of the created device together with a tablet, two handouts and some handout cards.

5.7.1 Big organization

The first company that agreed to use the probe during their meetings was a partner in the study project COMPASS. Unfortunately, there arose problems with the probe several times where they were unable to use it sufficiently. The next paragraphs describe those problems and how I handled them.

When they used the probe the first time, at one point the app crashed and it was not possible to open it again. With my assistance it was possible to reinstall the app and it worked again afterwards.

After the partner tried the probe at a next meeting, the application crashed again after time and there was the same problem as the first time. Apparently the application runs out of memory after some time. I drove there and tried to figure out another solution. Fortunately, I used Ionic as a framework and therefore it was possible for me to try the app also on an Android device and also as a progressive web app. The Android tablet even run out of memory sooner than the iPad, so I decided to configure a web server on the Raspberry Pi that serves the application as a progressive web app. I also "installed"

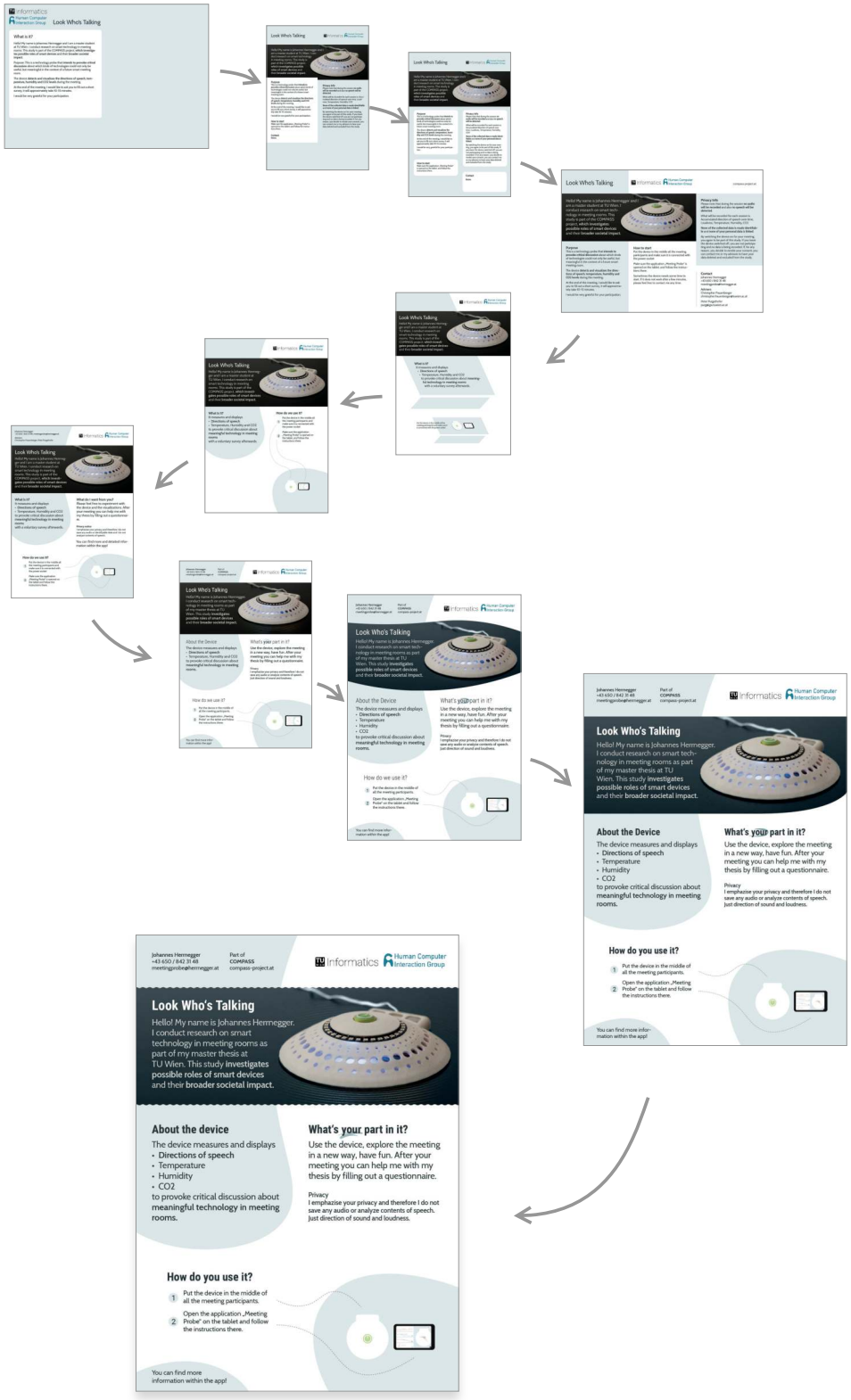

Figure 5.16: History of handout drafts

Figure 5.17: Final Handout and Card Design

the app by adding it to the home screen. This does not solve the memory leaks, but it will be possible to open the app again after it crashes.

When the partner tried the probe again, he contacted me via email and wrote that it was again not possible to use the probe, because the server could not be reached. As the issue was not solvable remotely, I asked them for a specific date and time for a meeting where they want to use the probe. At this time I visited them and prepared everything before the meeting and waited until it was over. This approach lead to a successful meeting with the probe and without any complications.

After this meeting the probe was working as expected and the participants were able to use them on their own without my presence. In the following weeks the probe was used four times and the participants filled in the form ten times, four of them partial and six complete, which concluded the probing phase in this company. Although some initial problems, it was possible to collect valuable data and insights.

After the probe was handed over to me, I ran into technical problems with the database.

Figure 5.18: Final probe package

Fortunately, I was able to fix the issues before the second company expected the device.

5.7.2 Medium-sized company

The second company I used the probe was a medium-sized software development company. To kickoff the probing phase, I had a short presentation to introduce them to the subject matter of the master thesis, what the experiment is about and what they should do.

Already during this presentation I saw that the participants were concerned about some privacy issues with the microphones in their office. "You said that you don't record any contents of speech, but in fact you have to record and save some data, right?". So although I stated it in the presentation that privacy is important to me and the matter of the thesis, I had the feeling that at first they were very skeptical about it.

I left the probe in this company for three days, where they had one meeting with it. During the three days, one participant filled in the survey.

5.7.3 Small Company

The third and last company I used the probe in was a small video production company. They invited me to one of their weekly meetings where they used my device.

Like in the second company, I started with a presentation to introduce them into the subject matter. Then I helped them starting the probe and went into a separate room to

Figure 5.19: Kick-off presentation (Photo ©Bogdan Zenecan)

Figure 5.20: Test-running and discussing the probe (Photo ©Bogdan Zenecan)

Figure 5.21: One Meeting Setting

not disturb their experience. After their meeting I also assisted during the survey, which all four of them filled in.

5.8 Results

In this section I describe the results of the probing phase. The survey was filled in by 16 people, from which 11 people completed it. From the completed records, six are from the first company (big organization), one is from the second company (medium-sized company) and four are by the third company (small company). How the questionnaire was created can be read in section 5.4. I analyzed the data with a Thematic Analysis (See section 3.4), where I combined the quantitative with the qualitative questions.

As elaborated in section 5.1, the questions that I tried to answer with the probe were the following:

- How can IoT-technology influence the behavior, awareness and satisfaction of attendees of meetings?
- How can IoT-technology influence the group dynamic within a meeting?
- Which meaning do those sensors have for users of a smart meetingroom?
- Which concerns do those sensors cause in users of a smart meeting room?

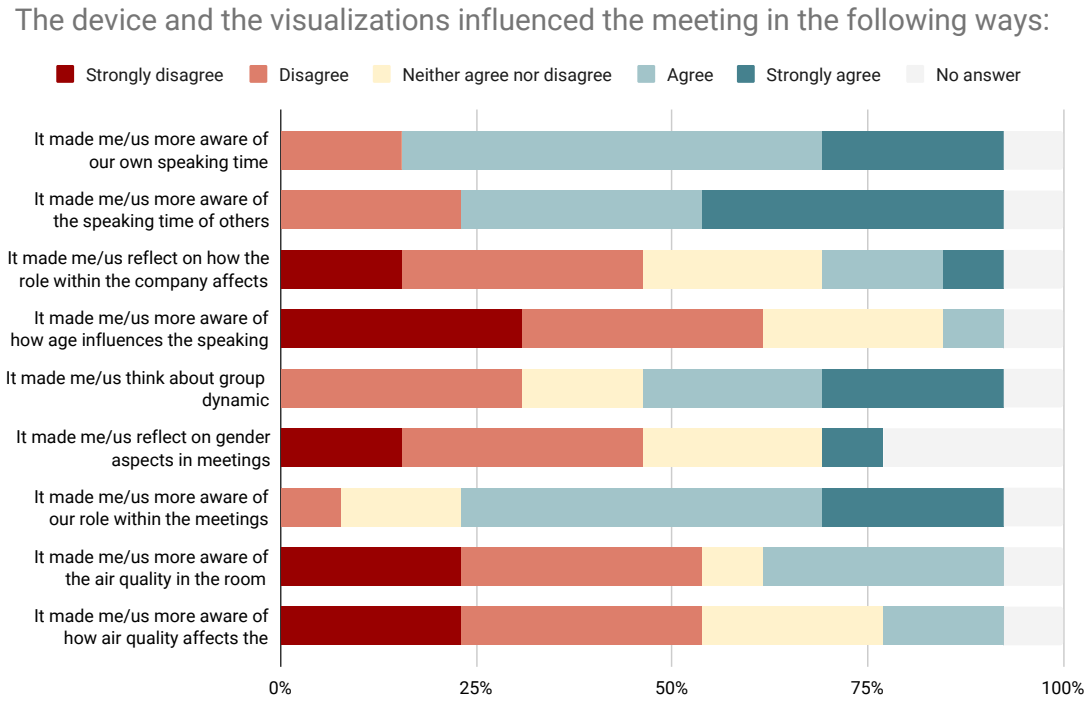

Figure 5.22: Survey Result (Probe influence on meeting)

5.8.1 Awareness

Speaking Time The majority stated that they were more aware of their own speaking time (7 agree, 3 strongly agree) and stated that it made them more aware of the speaking time of their colleagues (4 agree, 5 strongly agree). The distribution of speaking time was the most innovative and interesting for the participants. It was interesting to them which person speaks the most and "very helpful" to see the distribution. Some stated that they became more aware of that they usually talk very much and this awareness would help them in letting others speak more. Others would be motivated to speak more often and to show the superiors their engagement.

Gender As gender topics were difficult to read in the held meetings due to settings with mostly men attending, the probe had little effect in this area. Only one participant stated that they were reflecting about it. If they imagined having gender labels within the distribution, some participants thought that it "could have some positive effect" and also would probably try to keep balance. Others thought that it would not change much. One participant stated that it "would make it painfully obvious, how few females are found in IT companies".

5.8.2 Group Dynamic

Due to the quantitative data, half of the participants stated that the probe provoked them to think about group dynamics in their meetings. While nine were more aware of their role within the meetings, only three reflected about how their role affects their own speaking time. The participants reflected about whether their colleagues or they themselves "are necessary" in the meeting and stated that they were more aware of others in the room.

The statements indicate that depending on the type of the meeting it is often normal that someone is talking the most at a meeting — and mostly it is their boss. Some would even give the boss more speaking time or accept that the boss speaks the most. Others would try to achieve a more equal contribution from all meeting attendants.

It would be interesting for the participants if the device detects and displays dominant behavior, aggressiveness, competence and empathy of the participants. This could lead to calmer meetings with improved quality.

5.8.3 Engagement

Like already discussed in subsection 5.8.1, the participants thought about their own or their colleagues engagement within the meetings. While some would try to engage themselves more in meetings, others would ask others to speak more. One stated that "it can help to engage younger colleagues to be more present in meetings".

5.8.4 Air Quality & Timing

The values for air quality was less interesting for the participants and had little effect on the meetings. One participant stated that they were interesting in the beginning, but the interest faded in the course of the meeting. An idea here was to have fixed indicators within a meeting room that are displaying those values and remind the participants with a signal to open the windows or turn the heat up or down.

Another idea was a device to keep track of the total meeting time, which suggests breaks regularly based on air quality or meeting quality parameters and also notifies the participants when the end time approaches.

5.8.5 Concerns

Privacy Like presumed when putting a device into a meeting room that uses microphones, most of the participants had concerns with privacy. They had concerns about which data is recorded, how long the data is stored and if it is conform with the DSGVO. Also stated were fear of data theft. "Who will be listening?" was one response and

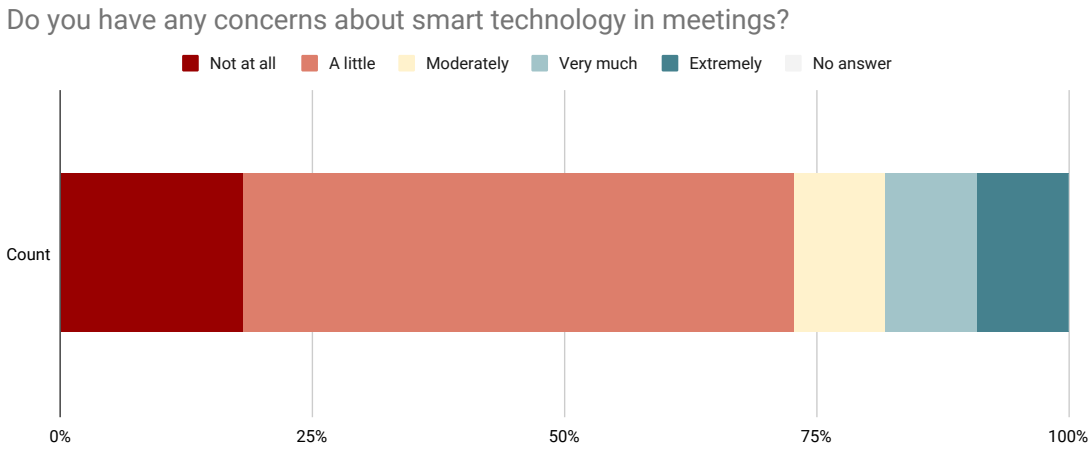

Figure 5.23: Survey Result (Concerns)

another participant was referring to distopian the literatures "1984", "Zero" and "Brave New World".

Observation & Judgement Others had the fear that their employer or colleagues will observe their behavior long-term and short-term and judge them based on their speaking time or meeting performances. The device could collect personalized data over a longer period, employers could interpret the data and categorize them based on their meeting behaviors.

5.8.6 Conclusion

The usage of the probe lead to more awareness of the participates themselves and regarding their colleagues. It was able to provoke some of the participants to think about their roles within the meetings and how a device like this could have a positive effect on group dynamic and fairness aspects of a meeting. There are concerns about privacy and security and a lack of trust in the intention of the device. However, the majority of the people would possibly use such a device again.

Some of the participants stated that the probe had no influence on their meetings at all, that they were not focused on the probe or even that the lights and/or the visualizations were distracting during the meeting.

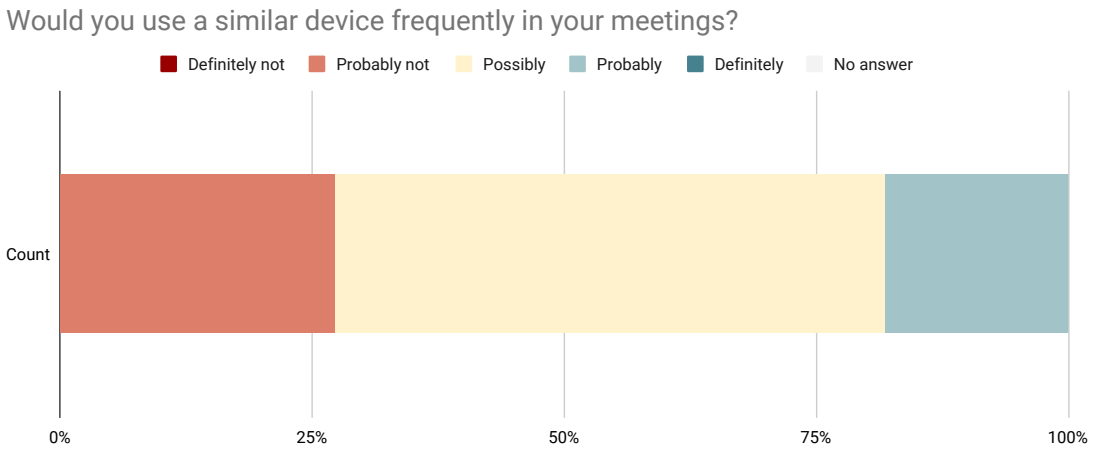

Figure 5.24: Survey Result (Would you use again)

CHAPTER 6

Debriefing Interview

This section describes the debriefing interview, which was held after the results of the technical probe were analyzed. It was one semi-structured interview with two decision makers of the startup.

6.1 Interview Guide

During the process of the master thesis the startup company had to be closed down. Originally, this interview should investigate whether value-driven innovation methods are approaches the startup would also use in their future. Because the circumstances changed, the theme of the interview was slightly modified. The goal was to answer the following questions:

- What is their opinion of the technical probe?
- What did they learn through the cooperation?
- Did the project change their views about value-driven innovation methods.
- Can they imagine using similar methods in their future work?

The interview was held with the following structure: In the beginning I presented the result of the probing phase of chapter 5.8. Afterwards I asked them general questions about their opinion on the probe and lead to the future usage. While they answered some parts of the questions already in the beginning, I tried to get a better understanding about it and asked the specific questions anyways.

The interview guide that I prepared for the interview can be seen in appendix B.3.

6.2 Interview Result

The general opinion about this technical probe and the method was that it was quite interesting for them to see how this worked and which results it elicited. Both of them were not aware of technical probes before the start of this project, so they had no expectations about it. They liked the approach because it was possible to provoke discussions and get insights into values of people by using a real device. With that the process enabled it to show problems that they were not aware before.

One of the two participants was the contact to one of the companies where the technical probe was used. So he also had insights about how it was to use the probe. "It was interesting to be part of the exploration of how creative processes can be changed."[1] To be part of the exploration made it possible for him to reflect about the displayed values and about other possibilities and opportunities in the context of smart meeting devices. Also, the probe triggered interesting personal conversations about meeting structures and processes. He pointed out that for him his current company (I used the probe in) was not very suitable for this kind of experiment, because in his opinion the participation in terms of speaking time within the meeting was not as important. The reason he named was that they had a meeting, which was more in the style of a presentation with mainly one person speaking most of the time. In personal talks with family and friends, he found areas where in his opinion the speaking time is more important and the probe would result in more interesting results: for instance a youth welfare office or a tenants association.

Concerning the air quality parameters there came up skepticism about how interesting those parameters are for this experiment. "Humidity, CO2, temperature - you can read only very little from this data. I would try to find out which data is really interesting for the employees - not the air quality but the meeting culture", which indicates that the interviewee saw an impact on the culture of the meetings. Furthermore they discussed some considerations at an earlier point about a product with air quality parameters: "It confirmed a concept that we discussed already before the master thesis concerning the air quality. It could be interesting, because it is simple enough and realizable to open a window for example." New products in this area would be considerable, although only if they could get enough resources and focus. "We also saw that there are groups of customers where speech participation is relevant. Those could be products which find a market. That I found interesting. But those would be separate projects which you have to develop with full focus. It would be too big to develop it on the side."

This leads to one central question the thesis wanted to answer, namely whether this method is suitable for a startup? Both of the interviewees had the opinion that my implementation of the technical probe took far too much time and effort. "In a startup there is only limited capacity to innovate in such a explorative or value-based way. The scarcest resource in a young company is money and therefore the focus is primarily on

[1] Transcription translated from German

earning money. And if this additionally can be connected with certain values - cool, but without the necessary revenue the company will soon not exist anymore and that [value-driven innovation] is less urgent. [...] It would be a very interesting process to create a project in a further step and create a product in the end, but I assume this blows the possibilities for a startup. You have one chance and this either works or you are broke." Because of the scarcity of the money in a startup the idea already has to be established and a concrete product has to be developed. "It is a pity that in this area of startups it is pretty difficult, but when we think more about it it is not particularly surprising considering that it is the nature of a startup to be under pressure."

Also they were skeptical about technical probes with lower effort, as a startup should already have a product they are building at the time of founding. It also depends on where the startup currently stands at. "I think it depends on where the startup is in their lifecycle. If it is in the very early beginning and the founders have another income it's a applicable way. From the moment when your main income discontinues you already need to have this behind you." In the early stages, before founding the company and in the very beginning before it is clear what the product should be, they could imagine to start with this to identify needs and concerns of the target group. Another possibility could be when the initial product is already in the market, well established and the company is searching for another product: "To be in such early stages for a product again as a startup you're not until you are a big company and have creative processes next to your core product." In the situation of this startup and with this effort it would not be a suitable method.

I challenged this thought with the question that we also had some pivots[2] within the lifecycle of the startup. One pivot was with creating the smart access solution with smart door locks and another one was to focus on water damages to prevent high insurance costs. "An explorative approach could have been a way. In our case the market was going into this way and there were already first products and so it was pretty clear that there is a need for this and there were no creative processes necessary. The water damage system was way more unclear and the creative process there was in conversations with insurances. They told us where their pain points were. It was a relatively theoretical process with little experiments physical things and very solution-oriented. Both of those processes were very short and I think in those situations with our pivots it did not really fit."

The last question I wanted to answer was if they can imagine using similar methods in their future work. Both of the decision makers found the method to have valuable outcomes. "What I found exciting was to observe the difference from abstract considerations to the technical probe, which was able to show unknowns. So through interaction with the probe it came apparent that there is a problem that was not conscious before. If people don't know that they have a problem with something before they cannot tell you. And the technical probe is real enough to show behavioral patterns. That I found

[2]Pivot: Changing the direction in a startup for developing businnesses and products.

really exciting. And depending on which field I am active in the future — for example a big company with an explicit innovation branch — I think it could be placed there well. The main restriction I see in the necessary resources and I think there are bigger organizations where the budget is given and there this tool makes sense." Although the conditions made it hard to conceive to use those methods within this startup, both of them found the methods to be valid for another context and interesting to use in their professional future. They saw the main restriction in the limited resources of a startup and depending on their future fields they will be able to choose methods like this.

CHAPTER 7

Conclusion

With this thesis I aim to address the overarching research question: "How can Internet of Things technology be developed driven by values to take ethical responsibility?". Related to that I developed a technology probe with a subsequent survey and I held interviews with decision-makers of the IoT-startup to investigate their former innovation processes and their opinion about the used value-driven approach.

By placing a technology probe within actual meetings, it was possible to open negotiation spaces (a common ground for different stakeholders to talk about values) to get insights about the potential users of smart meeting rooms.

The following sections should answer the specific research questions, tell the limitations and discuss future work.

7.1 Value-driven innovation in the startup

The initial interview gave the insight that the startup's way of generating new ideas for features and products was mainly focused on talks with the businesses that it built the products for. In case of their product Smart Access the contacts were providers of short-term rental sites and in the white-labeled Smart Home solution the contacts were Smart Home providers who were based on the startup's gateway, app and services. As the startup was already dealing with a money shortage and had to find a way to provide salaries to their employees at that time, the business model of the company shifted to sell services like creating customized products and therefore adapting to the client's wishes. In this scenario they did not have enough resources to setup new innovation models.

This was also the conclusion of the debriefing interview, where the decision makers elaborated that there are a few distinct moments in the lifecycle of a startup where they have time to spend time on innovation processes. They named two of them: before

the company is founded when it is not yet clear which product they will work on or when they already are successful with one or more products and are searching for new opportunities. So as soon as the idea is clear and the company gets funded, the main focus is to develop the product.

However, as this project made it possible for them to get an understanding about value-driven innovation approaches and methods, they were able to see that the technology probe can be an important tool to elicit user values and understand them better. With the created probe I was able to open negotiation spaces about some of the values that may be important within a meeting space. The users discussed the impact of the probe within the meeting spaces (for example in the internal pilot meeting) and in the survey. The decision makers of the startup also discussed the probe and its results in personal discussions and in our final interview, where they also stated that methods like this can be very useful to innovate with a higher consciousness of the people in the target group. Those arguments lead to answer the research questions *"Can a Technology Probe be used to inform innovation processes of an IoT company to responsibly innovate in the context of a smart meeting room?"* and *"How does the particular small IoT-company relate to value-driven innovation?"*. It can be stated that in this case the technology probe was able to give a better understanding about the values of users of meeting spaces within the decision makers. They understood the value of the results and why it is important to take responsibility in the innovation process.

7.2 Technology probe findings

The research question *"In which ways can smart technology affect a meeting?"* can be answered by the results of the technology probe, which are described in section 5.8. They support the following findings: It was possibe to influence the meeting participants in ways of awareness, engagement and in their group dynamics. The awareness was risen about their own speaking time, the speaking time of others and resulted in questioning their own behaviour in meetings. This lead to the assumption within some of the participants that a device like this could motivate themselves or others to speak more or let others speak more, which could influence meetings to be more diverse, fair and productive. The participants also got more aware about their role within the meetings and even started to question if their or others attendance is necessary. Another interesting finding was that it is accepted that the most senior is talking the most.

It was not possible to indicate more awareness about the group dynamics related to gender in meetings. This can be explained with the reason that the meetings with the technology probe were mostly held by men.

To answer the research question *"Which concerns do meeting participants have when using smart technology within the meeting?"*, I also draw on the results of the technology probe. They indicate that the biggest concerns were about privacy and security. They were concerned that the data is misused by the service providers or that the data gets

hacked and by that sensitive information can be seen by untrusted parties. Another concern was that the superiors and co-workers could observe their meeting behavior and make judgements and decisions based on how they perform in the meetings. The device could collect personalized data over a longer period, employers could interpret the data and categorize them based on their meeting behaviors.

7.3 Limitations and Learnings

Startup context As already stated before, the IoT-startup I worked in was already dealing with a forthcoming close-down throughout the development of the probe. As the time of writing the company was already shut down. This lead to changes in the debriefing interview, which became more focused on the role of value-driven innovation in the decision makers' future areas of responsibilities. Another consequence of the close-down was that I decided to refrain from holding a workshop after the technology probe. The workshop had the purpose of finding new product ideas and deepening the understanding of meeting participants by inviting some of the participants of the meetings to a innovation session within the startup. As this was not useful for the company anymore and the former co-workers were not available anymore, I decided to not do this workshop.

Survey instead of Interviews One learning that I had is that most of the participants answered the qualitative questions with minimal effort, which made it sometimes hard to understand their reasons and backgrounds of the answers. The decision of using a survey instead of interviews was based on the following arguments: as it was intended that one company (or co-working space) uses the probe over a longer period of time, due to the design of the experiment it was not possible to have interviews with the participants. The decision was also based on respect of the employees' time and the companies' resources. In retrospective and due to personal conversations, I got the impression that the data could be much more valuable using interviews instead of the survey.

Attendance during the meetings In the first company there appeared many technical difficulties that I did not expect. That lead to stressful situations in the contact person's already full work day. In meeting situations it is also not possible to take care of setting up or dealing with those problems. One solution for this could be that for the first meeting I set up the probe and stay close to assist in case of a problem. Another solution could be to change the format so that one company has the probe only for one meeting and I am close. This would also make it possible to have interviews afterwards instead of the survey.

Limited Scope According to Values-led Participatory Design (described in section 2.2.3, the elicitation of values consists of the three steps emergence, development and

grounding. The methods used in the process of this thesis are only covering the first step — the emergence of values. The development and grounding of the emerged values was out of scope for this work.

7.4 Future Work

This work is meant to be a case-study for the study project COMPASS. It was focusing on one startup and the resulting outcomes reflect the state of the company at that time and the opinions of the decision-makers. Future work could pick up on the results of this thesis and test the outcome that value-driven innovation methods are not feasible in startups or only at certain stages in their lifetime (before the founding or when they already have a profitable product).

Another way to interpret the outcome is that my implementation of the probe was very ambitious and took a big effort comparing to the scarce resources of a startup. The time spent on the technology probe was about half a year including the device software, tablet app, device manufacturing, casing design and print, handout design and more. The reasons of putting so much effort in it was on the one hand that the users should have the look and feel of a real device to trigger more real reactions, but reflecting over it, it did not need to be that perfect for the values to emerge. Perhaps also another method of the discussed approaches can have similar outcomes with the fraction of the time. Future work could investigate methods that are doable in a reasonable time for a startup during their current main product development. Also, it would be interesting to investigate how to assist young entrepreneurs who did not found their company yet or startups which have resources and want to use those to innovate responsibly.

APPENDIX A

Code Documentation

A.1 RPC-Websocket Communication

The following methods and events are used to communicate between the server and frontend application:

- Methods
  - `probe.session.start`: Starts a session and returns the session code.
  - `probe.session.stop`: Stops a session.
  - `probe.session.get`: Returns the session with the provided code.
  - `probe.session.getCurrent`: Returns the session that is currently active.
- Events
  - `probe.session.started`: Will be emitted when a session starts.
  - `probe.session.stopped`: Will be emitted when a session stops.
  - `probe.session.directions.updated`: Will be emitted when a new value for the directions is ready.
  - `probe.session.temperatures.updated`: Will be emitted when a the temperatures value is updated.
  - `probe.session.humidities.updated`: Will be emitted when a the humidities value is updated.
  - `probe.session.co2.updated`: Will be emitted when a the co2 value is updated.
  - `probe.session.energies.updated`: Will be emitted when a the energies (loudness) value is updated.

A.2 Server Application

A.2.1 WebsocketService

When the WebsocketService gets instantiated (because of Dependency Injection only once), it will create a websocket server to a specific URL and port and abstracts the library `rpc-websockets`. The service provides three essential functions:

- `register(name, func)`: Registers a method that can be called by the frontend (or any other software that connects via the websocket).
- `event(name, name)`: Registers an event that can be emitted.
- `emit(name, ...params)`: Emits an event.

At the initialization of the application, all methods and events are registered by the main application class and connected to the corresponding functions.

For example, `App.ts` registers `probe.session.start` to call the function `SessionService.startSession()`.

A.2.2 DatabaseService

The DatabaseService connects to the database in the initialization phase of the application and holds the database client. Other classes can use the client to read and write from the database by accessing `DatabaseService.db`.

A.2.3 SessionService

The SessionService manages meeting sessions. It provides functions start, stop, get and update sessions. They are evoked by the websocket methods and read or write from the database and handle possible side effects. In the following listing the methods are described in detail:

- `getUniqueID()`
  As codes are random alphanumerical strings with 4 characters, it has to make sure it is identical. The private function `getUniqueID()` makes sure to achieve this by checking the database and generating a new code in case it is already present.
- `startSession()`
  Called by `probe.session.start` or by pressing the button.

Creates a new session in the database with a unique Code generated by `getUniqueID()` and the current time as begin time. It also calls the corresponding DirectionService and EnvironmentService to start listening to new values. After finishing it emits the event `probe.session.started` and returns the new session object.

- `stopSession()`
  Called by `probe.session.stop` or by pressing the button (if a session is active). Stops the current session by setting an end time and calling the corresponding functions in DirectionService and EnvironmentService. After finishing it emits the event `probe.session.stopped` and returns the new session object.

- `getSession(code)`
  Called by `probe.session.get`.
  Fetches and returns the session with the giving code.

- `getCurrentSession(code)`
  Called by `probe.session.getCurrent`.
  Fetches and returns the session which is currently running or undefined, if there is no current session.

- `writeDirections(directions)`
  Used by DirectionService to write new directions to the current session in the database. Emits the event `probe.session.directions.updated`.

- `writeEnergyData(values)`
  Used by DirectionService to write new energies (loudness) to the current session in the database. Emits the event `probe.session.energies.updated`.

- `writeEnvironmentData(temperature, humidity, CO2)`
  Used by EnvironmentDataService to write new temperatures, humidities and CO2-values to the current session in the database. Emits the events `probe.session.temperatures.updated`, `probe.session.humidities.updated` and `probe.session.co2.updated`.

A.2.4 DirectionService

The DirectionsService is responsible for providing the direction information. It starts the ODAS server and listens to the socket for incoming directions. Then it converts them to angles from 0° to 360° and aggregates the values in corresponding buckets (35 buckets with 10° each). It also aggregates the loudest energies (loudness) of the currently loudest direction in a general energy bucket. At specific intervals it calls the corresponding functions in DirectionService to write the data to the database and notify the frontend application.

Specifically, the most important functions of the DirectionService are the following:

- `start(sessionId)`
  This function initializes and calls all needed parameters, intervals and functions, such as
  - starting the Everloop *STARTING* sequence,
  - starting ODAS,
  - intervals to write directions and energies to the database;
- `stop()`
  Stops and clears all initialized intervals and services.
- `initSocket()`
  Initializes the socket to which ODAS is writing the direction data. Whenever data arrives, it prepares the data and calls the corresponding function `receivedData()`.
- `startOdas()`
  Starts the ODAS programm by spawning a child process (calling an external software).
- `stopOdas()`
  Stops the process which was created in `startOdas()`.
- `receivedData()`
  Is called by the logic in `initSocket()` whenever the ODAS process transfers data over the socket. It gets the JSON object that ODAS transmits and calls functions that calculate the corresponding pots (which one of the 35 directions does the data refer to). It aggregates the directions for every detected location and also the energy from the location with the highest energy.
- `controlLEDs()`
  Normalizes the accumulated direction energies and tells the EverloopService to control the LEDs. Normalizing means that it assigns a value between 0 and 1 to every direction, where 1 is assigned to the highest and 0 to the lowest value of the direction array.
- `onTimeInterval()`
  On every time interval (in the current configuration every second) it tells the DirectionService to write the current directions to the database and notify the frontend.
- `onEnergyTimeInterval()`
  On every time interval (in the current configuration every 250 milliseconds) it tells the DirectionService to write the current accumulated energy to the database and notify the frontend.

- `prepareOdasDataToJSONArray()`
  Sometimes it happens that the ODAS socket receives multiple JSON strings within one data event. That is because TCP streams do not have packets with boundaries and so this is one thing, which sometimes happens and has to be considered. This function takes the stream output from the socket and returns distinct JSON objects in an array. The function is called by the data event handler within `initSocket()`, which takes the JSON objects and calls `receivedData()` for each of them.

A.2.5 EnvironmentDataService

The EnvironmentDataService is responsible for reading humidities and temperatures and calculating an assumed CO2.

- `start(sessionId)`
  This function initializes and calls all needed parameters, intervals and functions, such as the interval to write the environment data to the database.

- `stop()`
  Stops the intervals.

- `onTimeInterval()`
  In the current configuration, this function is called every second. It reads the humidity and temperature. Due to the circumstance that the temperature sensor is close to the processor, the measured temperature is usually much higher than the environment temperature. That's why within this function it also reads the current temperature of the board and then guesses a calibrated temperature with both the measured temperature and the board temperature. The code is listed below:

```
1 // Read the temperature from the matrix board
2 const { temperature } = matrix.pressure.read();
3 // Read the CPU temperature
4 const cpu_temperature = parseInt(fs.readFileSync('/sys/
    class/thermal/thermal_zone0/temp').toString(), 10) /
    1000;
5 // Calculate the calibrated temperature
6 const temp_calibrated = temperature - (cpu_temperature -
    temperature) / 1.0087417614956755;
```

  This calculation brings the temperature closer to the real value, but it is nonetheless only an estimated value that does not represent the real temperature.

  Then it calculates an estimated CO2 value. Beginning with a random value with a range between 500ppm and 700ppm (parts per million). Then, depending on the difference of the last two measured temperatures, it adds or subtracts a random value between 0 and 1.

```
if(temp_calibrated > this.lastTemperature) {
  this.lastCO2 = this.lastCO2 + Math.random();
}
else {
  this.lastCO2 = this.lastCO2 - Math.random();
}
```

Afterwards the function calls the corresponding functions for setting the temperature, CO2 and humidity LEDs.

- `setTemperatureLED(temp)`
  Decides about the state of the temperature LED and sets it accordingly by calling the corresponding function in the GPIOService.

- `setHumidityLED(humidity)`
  Decides about the state of the humidity LED and sets it accordingly by calling the corresponding function in the GPIOService.

- `setCo2LED(co2)`
  Decides about the state of the CO2 LED and sets it accordingly by calling the corresponding function in the GPIOService.

A.2.6 GPIOService

The GPIOService is responsible for handling the input and output pins (GPIO) of the Raspberry Pi such as buttons and LEDs. It provides functions for setting the LEDs and an event emitter that emits when a button is pressed.

- `initializePins()`
  Reads the pin number from the two Enums `GPIO_INPUTS` and `GPIO_OUTPUTS` and sets the GPIO pins accordingly.

- `bindButtons()`
  Sets an interval that reads the button state. If the value is different it means that the button was just pressed or just released. In that case it dispatches an event that is readable from other classes.

- `setTemperaturePin()`, `setHumidityPin()`, `setCo2Pin()` Calls the corresponding functions `|setTrafficLight[1/2/3]()`.

- `setTrafficLight1(lightStatus)`, `setTrafficLight2(lightStatus)`, `setTrafficLight3(lightStatus)` Sets the corresponding LEDs by calling the lower-level function of the matrix library. `turnOffTrafficLights()` Is called after the sessions to reset and turn off the LEDs.

A.2.7 EverloopService

The EverloopService is responsible for mapping colors to the current overall speaking distribution, coloring the current directions of speech and controlling the LEDs on the Everloop LED-ring. Furthermore it provides starting, loading and ending sequences that are played when a session starts or ends. Therefore it also has different states that are stored in the enum `EverloopOutput`: `OFF`, `STARTING`, `SPINNER`, `SESSION` and `STOPPING`. It contains the following functions:

- `setCurrentNormalized(accumulatedNormalized, current)`
  This function is called by the DirectionService. It takes the accumulated and normalized directions and the current speaking, transforms them into colors and assigns them to the LED-ring.

  The colors are calculated with the javascript libraries "tinycolor2" and "tinygradient". They make it possible to create and modify colors and gradients in different formats. For this there are two different gradients, which will be used in different situations `currentGradient` and `accumulatedGradient`. In figure A.1 you can see the gradients and how they are assigned to the LEDs.

  The algorithm works in the following way. For all LEDs:

  – If the current pot in this direction is active enough (threshold is 20% or more) fill it with the active color. This will take the currentGradient, which is from black to blue.

  – If the current pot is not active enough, calculate the color of the relative distributed value.

  Afterwards it sets the colors for all The algorithm only runs in case of `SESSION` is the current state. Otherwise the state is either `STOPPING` or `SPINNING`. If the state is `SPINNING` and this function gets called, it means that the spinner should end because the first values get in from ODAS. In this case the spinner will be stopped and the state is set to `SESSION`.

- `startSequence(sequence)`
  The function startSequence is responsible for the starting the sequences in the `STARTING` and `STOPPING` phase of the session. The sequences are charactarized by 2 short blinking of all the LEDs of the LED-ring. The starting and stopping sequence are illustrated in figure A.2. The ending sequence uses the same animation logic, but another color.

  In the beginning it starts an interval that will call a function every 20 milliseconds. In this function it determines the current color, which is a position in a gradient. Then it assigns this color to all LEDs of the LED ring.

  At the end of the starting sequence it starts the spinning sequence.

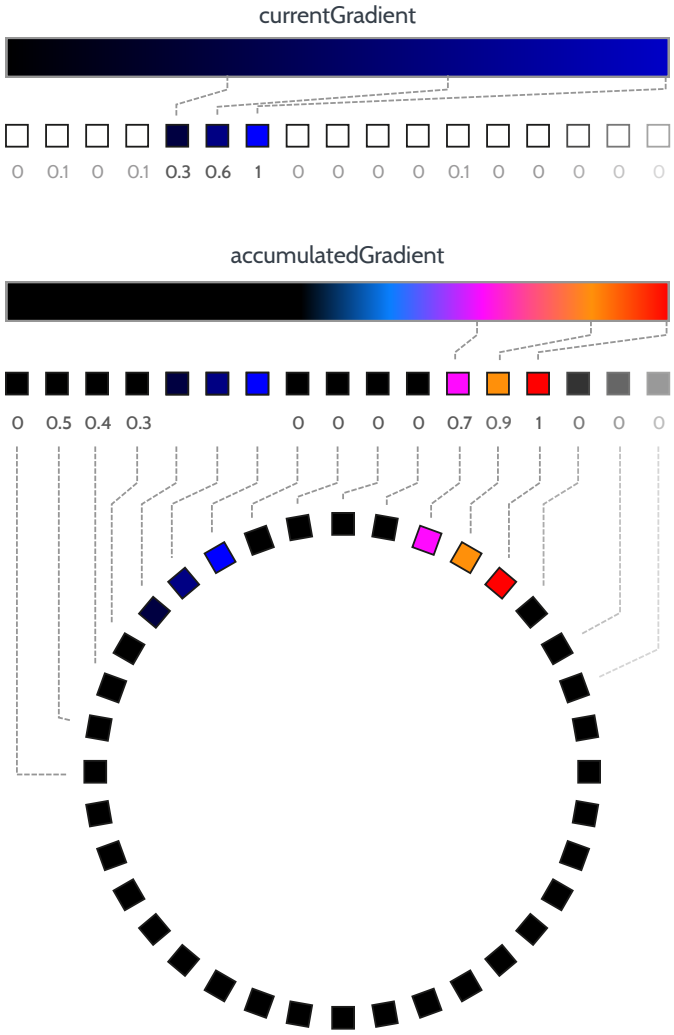

Figure A.1: Assigning LEDs in SESSION state.

At the end of the stopping sequence it turns off all LEDs and sets the state to `OFF`.

- `startSpinner()`
  The function `startSpinner` starts the spinner sequence. It creates an interval. The function that is called in the interval spins the colors and then it sets the colors on the LED-ring. The spinning mechanism works as follows: The constructor of the class initializes a `spinnerColorArray`, which holds 35 colors, where the first five colors are a gradient from black (no light) to blue. All other 30 colors are black. On the interval, it takes away the last element of the array and puts it in front of all other elements.

```
1 this.spinnerInterval = setInterval(() => {
```

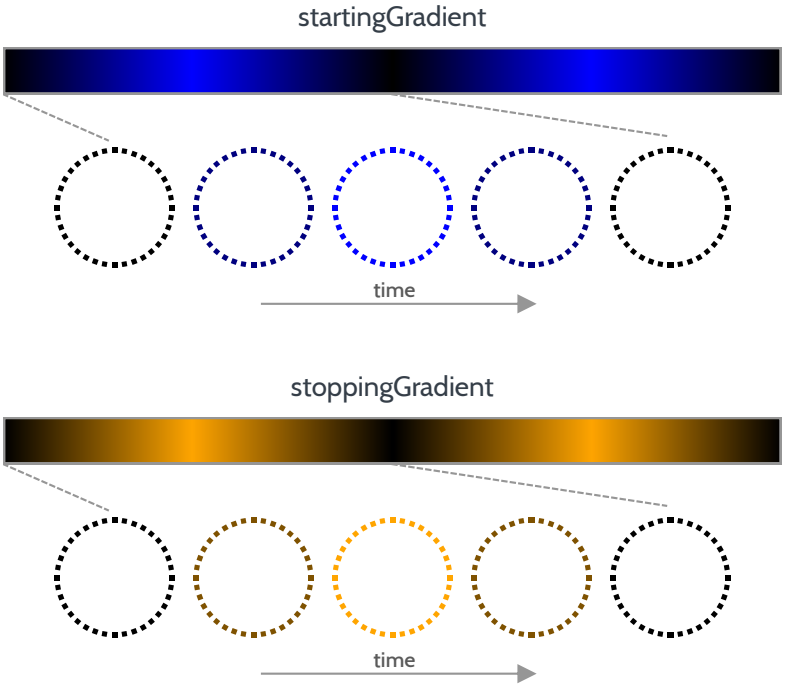

Figure A.2: Starting and stopping sequence.

```
2       ledArray.unshift(ledArray.pop());
3       this.setMatrixLeds(ledArray);
4   }, 20);
```

Over time it creates the spinning animation, because the blue gradient is moving at every interval. This is illustrated in figure A.3.

- `stopSpinner()`
  Is called by the function `setCurrentNormalized` when the first values are transmitted from ODAS (and therefore the spinner sequence can be dismissed. Its only function is clearing the spinner interval.

A.3 Frontend Application

A.3.1 Services

WebsocketService

The WebsocketService is an abstraction of the `rpc-websockets` library. As it is best practice in Angular to use RXJS, this class wraps the functionality of the `rpc-websockets` library in RXJS Observables for the other services and components to

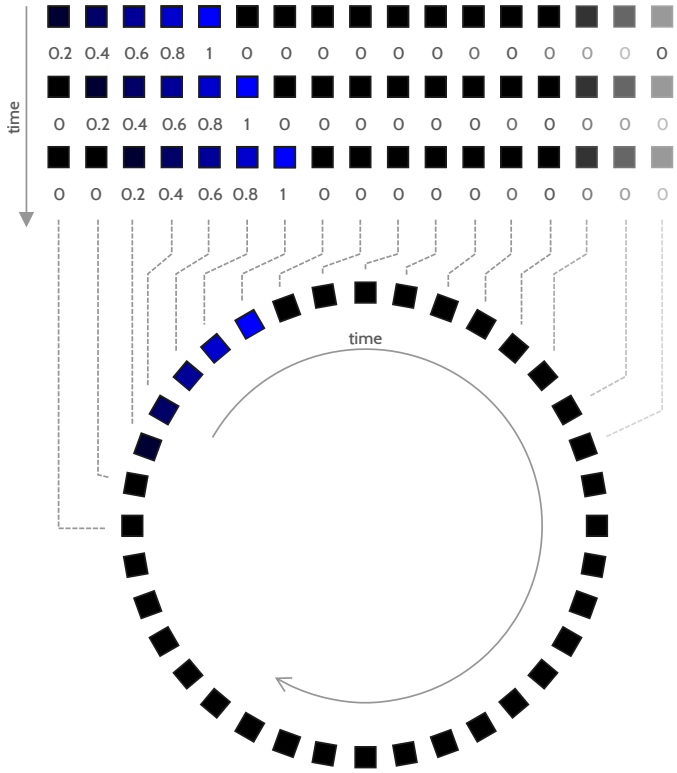

Figure A.3: Loading sequence.

consume. For example, it provides a public `ReplaySubject open`, which contains the information whether the connection is upright. The service also provides the following methods:

- `call(method, args)`: Wraps a call in an Observable and returns it.
- `subscribe(eventName)`: Subscribes to an event and returns an Observable that pushes whenever the given event gets emitted.

SessionService

The SessionService acts as an interface for all session methods and events of the Websocket. It also holds the current sesssion. It provides the following public functions for other classes:

- `start()`: Calls the method `probe.session.start` via the WebsocketService. This leads to a call of `SessionService.startSession()` on the server Node.js application.

- `stop()`: Calls the method `probe.session.stop` along with the current session code in the parameters via the WebsocketService. This will lead to a call of `SessionService.startSession()` on the server Node.js application.
- `get(code: string)`: Calls the method `probe.session.get` along with the given session code in the parameters via the WebsocketService. This will lead to a call of `SessionService.getSession(code)` on the server Node.js application and return the session with the specified code.
- `getCurrent()`: Calls the method `probe.session.getCurrent` via the WebsocketService. This will lead to a call of `SessionService.getCurrentSession()` on the server Node.js application and return the current session. It will replace the session If the returned session is different to the one saved in the class.

When the app is initialized and the SessionService gets instantiated, it subscribes to all important events and defines how it reacts when one of them is emitted. The following methods are responsible for connecting the events with the app.

- `subscribeToSessionStarted()`: Subscribes to the event `probe.session.started`. Sets the session from the event as the current session and tells the Angular router to navigate to the session page.
- `subscribeToSessionStopped()`: Subscribes to the event `probe.session.stopped`. Tells the Angular router to navigate to the result page.
- `subscribeToDirectionUpdate()`: Subscribes to the event `probe.session.directions.updated`. Takes the directions from the event's value and updates the directions of the current session.
- `subscribeToEnergyUpdate()`: Subscribes to the event `probe.session.energies.updated`. Takes the energies (loudness factor) from the event's value and updates the energies of the current session.
- `subscribeToTemperatureUpdate()`: Subscribes to the event `probe.session.temperatures.updated`. Takes the temperatures from the event's value and updates the temperatures of the current session.
- `subscribeToCO2Update()`: Subscribes to the event `probe.session.co2.updated`. Takes the CO2 values from the event's value and updates the CO2 values of the current session.
- `subscribeToHumidityUpdate()`: Subscribes to the event `probe.session.humidities.updated`. Takes the humidities from the event's value and updates the humidities of the current session.

APPENDIX B

Interview Documents

COMPASS Interview Einverständniserklärung

Sehr geehrter Teilnehmer!

Meine Masterarbeit ist Teil eines Forschungsprojektes COMPASS. Ein Ziel dieses Forschungsprojekts ist, für Unternehmen mit IoT-Fokus eine Hilfestellung/einen Kompass zu entwickeln, um menschlichen Werten in zukünftigen Produkten einen zentralen Stellenwert zu geben.

Ziel des Projektes ist es, eine Hilfestellung für die Schaffung neuer (kommerzieller) IoT-Anwendungen zu schaffen und dabei den Innovations- und Entwicklungsprozess sinnvoll erweitern – in Anlehnung an die stärkere Einbindung von Nutzern in den Entwicklungsprozess, wie er seit Jahren gefördert wird, möchten wir kritische Werte in wichtigen Diskursräumen erheben und fördern.

Ein Ziel dieses Interviews ist es herauszufinden welche Rolle Diskursräume und Werte in den Innovationsprozessen von Unternehmen einnehmen, die Lösungen im Bereich IoT anbieten.

Wir als Forschungsgruppe COMPASS sind für Ihre offene und ehrliche Meinung sehr dankbar. Vielen Dank für Ihr Interesse über Ihre Erfahrungen mit uns zu diskutieren!

Informationen zur Einverständniserklärung
Es ist bei Forschungsinterviews üblich, dass Sie vor Beginn Ihr Einverständnis zur Teilnahme geben. Im Folgenden möchten wir Sie über die wichtigsten Punkte des Interviews und über unsere Arbeitsweise aufklären:

- Sie können in diesem Interview nichts falsch machen, Ihre ehrliche Meinung ist uns wichtig.
- Sie können während des Interviews vollkommen frei agieren und sprechen.
- Der Verlauf des Interviews wird aufgezeichnet. Die gewonnenen Daten werden vertraulich ausgewertet und nicht an Dritte weitergegeben.
- Wir können das Interview jederzeit unterbrechen falls Sie eine Pause wünschen.
- Sie können das Interview jederzeit ohne Erklärung und folgenlos abbrechen.
- Sollten Sie uns nach dem Interview etwas mitteilen wollen, können Sie uns gerne telefonisch kontaktieren.
- Wenn Sie es möchten, können wir Ihnen eine Zusammenfassung der Interviews zukommen lassen.

Für weitere Fragen stehen folgende Personen zur Verfügung:

Johannes Herrnegger
0650/8423148
johannes.herrnegger@gmail.com

Einverständniserklärung

für ein Interview im Rahmen der Forschungsgruppe COMPASS

Name:

Ich habe alle Punkte gelesen, verstanden und stimme dem Interview zu.	JA □	NEIN □
Ich stimme zu, dass das Interview mit einem Audioaufnahemgerät aufgezeichnet wird.	JA □	NEIN □

_____ _____

Datum Unterschrift des Interviewleitenden

_____

Unterschrift des Interviewpartners / der Interviewpartnerin

Diet-COMPASS Interviewleitfaden

1. Formalitäten

- Info-Sheet durchgehen – „Haben Sie dazu noch Fragen?"
- Einverständniserklärung durchgehen, unterzeichnen lassen
  - Auf Aufzeichnung hinweisen
- DSGVO-Einverständniserklärung unterzeichnen lassen, DSGVO-Info-Sheet mitgeben
- Aufzeichnung starten

2. Einführungsinfos

Expertenmeinung zu Innovations- und Entwicklungsprozessen, Werten und verknüpften Themen. Es geht uns ausschließlich um Ihre **persönliche Expertenmeinung**. Es gibt **keine richtigen oder falschen Antworten**.

Wir werden die Diskussion auf Band aufnehmen, so dass wir uns daran erinnern können, was gesagt wurde. Bitte laut reden, so dass wir Sie auf dem Band hören können. **[dies bitte betonen]**

---

3. Allgemeines

„Wir starten nun mit ein **paar Basisinformationen** um Ihren Hintergrund etwas besser einordnen zu können!"

- **Ihr Name?**
- **Ihre Rolle im Unternehmen?**
- **Beschreiben Sie bitte kurz in eigenen Worten Ihr Unternehmen, was es tut und welchen IoT-Bezug es hat!**
- **Wo würden Sie Ihr Unternehmen einordnen?**

□ Industry
□ SME
□ _____

- **In welcher/n Branche/n ist Ihr Unternehmen tätig?**
- **Welche Produkte hat Ihr Unternehmen im IoT-Bereich?**

Konzentrieren wir uns in weiterer Folge auf <Produkt X>, ein aktuell bei Ihnen wichtiges mit dem modernsten Entwicklungsprozess. Bitte beantworten Sie die Fragen, so es um ein einzelnes Produkt geht, bezüglich dieses Produkts und sonst bezüglich Ihres Unternehmens im Allgemeinen."

- **Bitte beschreiben Sie dieses Produkt:**
- **„Welches Geschäftsmodell oder welche unternehmerischen Ziele verfolgen Sie mit Ihrer IoT-Lösung / Ihrem IoT-Service / Ihrer IoT-Technologie?"**
- **„Was ist die grundlegende Absicht hinter Ihrem Geschäftsmodell?"**

□	***Marktdurchdringung*** *(Wachstum, bestehender Markt)*	*Aufwertung bestehender Produkte durch ein digitales Offering ohne direkte oder zusätzliche Monetarisierung, z.B. auch um Daten zu sammeln*
Anmerkungen:		
□	***Marktentwicklung*** *(neue Märkte)*	*Primäres Ziel ist es mit dem Produkt eine neue Zielgruppe zu adressieren oder einen neuen regionalen Markt erobern zu können*
Anmerkungen:		
□	***Angebotsentwicklung*** *(Wachstum mit neuen Services in best. Märkten)*	*Smart Services werden als Add-On zu bestehenden Produkten verkauft, um weitere Erlösquellen zu erschließen*
Anmerkungen:		
□	***Diversifikation*** *(Neues Produkt in zusätzl. Marktsegment):*	*Ziel ist es das Unternehmen durch innovative Technologien breiter aufzustellen und separate neue Erlösquellen zu erschließen*
Anmerkungen:		

- **Erlösmodell: Aus welchen Quellen und auf welche Weise wird Erlös / Umsatz / Revenue generiert?**

☐ *Physisches Produkt (Hardware, auch als Add-on zu verkaufter Hardware)*
☐ *Traditioneller Service (z.B. Maintenance)*
☐ *Digitaler Service (z.B. eigene IoT-Plattform)*
☐ *Zugang zu einer Plattform (App Store, intermediary models, Marktplatz)*
☐ *Daten*
☐ Other: _____

- **Ist diese Absicht / das Geschäftsmodell transparent[1] für Endnutzer? Warum?**

- **Wie sieht der (typische) Erlösstrom aus?**

☐ Indirekt (z.B. über Daten)
☒ Einmalig
☐ Pro Zeit: _____
☐ Pro Nutzung: _____
☐ Pro Erfolg: _____

- **Welche Nutzergruppe / Zielgruppe wird adressiert?**

- **In welchem Bereich ist Ihrer IoT-Lösung / Ihrem IoT-Service / Ihrer IoT-Technologie angesiedelt?**

☐ Smart Home oder ähnlicher Kontext (Kontrolle durch einzelne Nutzer)
☐ Smart Office, Shared Spaces
☐ Public Spaces
☐ Anderes

- **Wo ist Ihre IoT-Lösung / Ihrem IoT-Service / Ihrer IoT-Technologie geschäftlich angesiedelt?**

  ☐ B2C
  ☐ B2B – Service / Industrial / Other
  ☐ B2B->C (Transitiver Verkauf an Consumers über Partner)

[1] Insbesondere bei datenbasierten Geschäftsmodellen werden Geschäftsabsichten teilweise nur in formaler Sprache an den Kunden kommuniziert. Bei Geschäftsmodellen, die bestehende Produktreihen augmentieren sollen, sind strategische Überlegung des Unternehmens eventuell im Vordergrund, die für den Endkunden nicht so relevant sind. Die transparenteste Darstellung ist die Verrechnung von klar kommunizierten Preisen ohne Verwendung von Kundendaten im kommerziellen Sinne oder größerer strategischer Zusatzerlöse.

- **Haben Sie zum Geschäftsmodell Ihres Unternehmens noch etwas anzufügen?**

4. Bestehende Diskursräume

„Nun möchten wir den Übergang zu wichtigen Diskursräumen machen, die aus Ihrer Sicht in Ihrem Kontext, aus Ihrer Erfahrung oder in Ihrer Einschätzung bestehen. Ein Diskursthema entsteht, wenn die Vorstellungen zur Nutzung oder zur Installation von IoT-Systemen oder deren Verwendung von Daten divergiert. Für diese Analyse sind sowohl implizite (nicht ausgetragene) also auch explizite Diskurse (ausgetragene) von Bedeutung. Diskursräume sind die Ort (physisch, digital, cyber-phyiscal) oder Settings in denen es zu Diskursthemen kommen kann oder typischerweise kommt.

Dimensionen z.B. Kontrolle, Präferenzen, Persönlichkeitsrechte, Freiheit, …

- **Gibt es Diskurse (Diskursräume/Diskursthemen) im Design oder der Nutzung des Produkts?**

- **Bitte beschreiben Sie diese Diskurse <u>jeweils</u> anhand folgender Eigenschaften:**

1. Worum geht es?
2. Welche „Player" sind involviert und welche Interessen bringen Sie in den Diskursraum mit? Z.B. User vs. Firma, User vs. andere User (bzw. Usergruppen), User vs. Gesellschaft, Produkt/Firma vs. Gesellschaft, Produkt/Firma vs. Politik / Policy making / …
3. Welche Rolle spielt die Technologie im jeweiligen Fall - wird dieser Diskurs durch Technologien z.B. aufgelöst, angefacht?
4. Wann wurde Ihnen klar, dass hier ein Diskurs besteht?
5. Wie haben Sie den Diskurs als solchen erkannt?
6. Wie verläuft der Diskurs / wie ist er verlaufen?

- **Haben Sie zum Thema Diskursräume noch etwas anzufügen?**

5. Unternehmenswerte

Einleitung: Im nächsten Schritt möchten wir Werte und Unternehmenswerte betrachten und einordnen, die Ihnen wichtig sind als Person, als Abteilung oder als Unternehmen. Sollten Sie bei einigen Punkten nicht offen sprechen können, können Sie gerne Ihre Einschätzung / Meinung zu diesen Unternehmenswerten darlegen.

- **Gibt es prägende Werte, die für Sie (als Person) wichtig in der Gestaltung neuer IoT-Lösungen sind? Welche und warum?**

- **Welchen Stellenwert haben Werte in Ihrem Unternehmen im Allgemeinen (wie wichtig/bestimmend sind diese)?**

- **Ist das gut / schlecht?**

- **Gibt es prägende Werte oder Unternehmenswerte, die in Ihrem Unternehmen zu beachten sind? Welche? (Liste, sortiert nach Wichtigkeit)**

- **Was prägt diese Werte? Warum?**

  □ Code of Conduct / Code of Ethics
  □ Interne Development Guidelines
  □ Visionsdokumente
  □ Andere Unternehmenskommunikation
  □ Andere: _____

- **Wie werden Ihre Unternehmenswerte im Entwicklungs- und Innovationsprozess beachtet?**

- **Dazu: Werden folgende Methoden in Ihrem Unternehmen dazu angewandt? Was sind jeweils Ihre Erfahrungen dazu?**

  □ Kontrolle / Enforcement/ Review
  □ Guidelines
  □ Support
  □ Innovationscontrolling ; Welches: _____
  □ Anderes Controlling; Welches: _____
  □ Standards; Welche: _____
  □ Fokusgruppen
  in welcher Phase: _____
  wie häufig: _____
  □ User Tests;
  in welcher Phase: _____
  wie häufig: _____
  □ Guidelines; Welche: _____
  □ Andere Maßnahmen:

- **Werden die in Ihrem Unternehmen wichtigen Werte eher „Top-Down" oder „Bottom-Up" gelebt? Warum?**

- **Sehen Sie Verbesserungspotentiale? Wie könnte dies umgesetzt werden?**

- **Wenn nein: Warum nicht?**

- **Gibt es positive Beispiel in denen besonders gut mit auflebenden Werten im Entwicklungsprozess umgegangen wurde? Wie hat man das umgesetzt?**

- **Haben Sie zum Thema Unternehmenswerte noch etwas anzufügen?**

6. Werte und Innovationen

- **Wie und durch wen wird Innovation in Ihrem Unternehmen gesteuert? Gibt es eine Rolle oder Person, die maßgeblich Innovationen in Ihrem Unternehmen treibt?**

- **Wie finden neue Technologien in Ihrem Unternehmen Einzug?**

- **Welche Erfahrungen haben Sie mit Innovationsprozessen in Ihrem Unternehmen gemacht? Waren sie erfolgreich (wie würden Sie Erfolg definieren)?**

„Innovationsprozesse können auch in Phasen eingeteilt werden. Zum Beispiel das Modell „Lead Management", das frühe Kreativ-/Ideenfindungsschritte, Entwicklungsschritte und letztlich Markteinführungs- und Perfektionsschritte in sechs aufeinanderfolgende Phasen einteilt."

	Modell Lead Mgmt
	Phasenbeschreibung
1	*Ideengenerierung*
2	Konzeptphase
3	Entwicklung
4	Konstruktion
5	*Markteinführung*
6	*Perfektionierung*

- **Haben Sie Erfahrungen mit diesem Modell? Wenn ja, welche? Gut/Schlecht? Haben Sie Erfahrungen mit solchen Modellen im Allgemeinen? Was ist Ihre Erfahrung damit und Meinung dazu?**

- **Welche Werte sind aus Ihrer Sicht und in Ihrem Kontext für wichtige Ebenen des IoT-Anwendungsdesign von Bedeutung?**

(Hier die COMPASS-Ebenen nicht hervorheben, darum geht es im nächsten Schritt ohnehin.)

Wert	Priorität (L/M/H)	Phase						Wie umgesetzt im Innovationsprozess?
		1	2	3	4	5	6	
		1	2	3	4	5	6	
		1	2	3	4	5	6	
		1	2	3	4	5	6	
		1	2	3	4	5	6	

7. Werte und Spannungsfelder

Im COMPASS-Projekt beschäftigen wir uns mit drei Spannungsfeldern rund um IoT-Entwicklung:

- Policy – EntscheiderInnen, z.B. aus der Politik
- Gesellschaft – Menschen im Zusammenleben
- NutzerInnen – Menschen als einzelne NutzerInnen
- Technologie – Ihre Möglichkeiten und gewollten sowie ungewollten Wirkungen und Eigenschaften
- **Welche Werte erscheinen Ihnen bei der Entwicklung von IoT-Technologien jeweils besonders wichtig?**

Policy	
Society	
User	
Technology	

Überleitung: Im Entwicklungsprozess gibt es oftmals ein Spannungsfeld zwischen verfügbaren Ressourcen und erwünschten Werten, die teilweise auch ideellen Charakter aufweisen. In anderen Situationen gibt es gute Visionen und Absichten, aber die operative Umsetzung bedarf mehr Klärung.

- **In diesem Licht, welche (zusätzliche) Unterstützung würden Sie für die Berücksichtigung dieser Werte, von Nutzerbedürfnissen im Innovationsprozess oder zum Umgang mit Diskursräumen im Entwicklungs- und Innovationsprozess, benötigen?**

- **Vielleicht z.B.:?**

  □ Guidance / Standards: _____
  □ Kontrollmechanismen: _____
  □ Ressourcen: _____
  □ Andere: _____

- **Wären diese für bestimmte Spannungsfelder (z.B. Society) besonders nötig? Welche und Warum?**

- **Haben Sie weitere Anmerkungen, die wir für werteorientierte Entwicklung von IoT-Lösungen berücksichtigen sollten? (Offene Abschlussphase)**

- **Haben Sie sonst noch etwas anzufügen? / Ist noch etwas offen geblieben?**

7. Verabschiedung

Vielen Dank für Ihre Teilnahme an diesem Experteninterview – wir werden in den nächsten Wochen Informationen aufarbeiten und zusammenführen, um in COMPASS eine Guidance für zukünftige Entwicklungs- und Innovationsprozesse im IoT-Kontext zu schaffen. Sofern wir dies dürfen, werden wir Sie gerne über Resultate (z.B. Deliverables oder Outreach Events) informieren.

Vielen Dank für Ihren wertvollen Beitrag zu unserem Forschungsprojekt und -vorhaben!

B.3 Interview Guide for Debriefing Interview

MA Debriefing Interview

Zusammenfassung meiner technical Probe. Results herzeigen.

Was haltet ihr davon?

Könnt ihr euch vorstellen, dass eure Perspektiven verändern könnte, was ihr in dem Bereich entwickeln könntet?

Verändern die Ergebnisse eure Sichtweise?

Wenn es das Startup noch gäbe, würdet ihr es ernsthaft in Betracht ziehen, die Methode der Technical Probe (vielleicht mit weniger Aufwand) zu verwenden?

Könnt ihr euch vorstellen, diese Methode in Zukunft in eurer weiteren Laufbahn zu verwenden?

Meeting Probe Survey

Hello!

Thank you so much for participating in this study! The survey is anonymous.

Feel free to answer the questions in English or German.

There is no right or wrong answer. Every opinion is valuable!

There are 12 questions in this survey.

General

Which meeting did you attend?

Please write your answer here:

On the screen, there was a 4-letter code provided (For example X1Y2). Please provide this code here.

Are you answering together or individually? *

Choose one of the following answers
Please choose **only one** of the following:

- ◯ Only me
- ◯ Group

Which experiences and/or thoughts did you have while using the probe? *

Please write your answer here:

Reaction

The device and the visualizations influenced the meeting in the following ways:

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
It made me/us more aware of our own speaking time	◯	◯	◯	◯	◯
It made me/us more aware of the speaking time of others	◯	◯	◯	◯	◯
It made me/us reflect on how the role within the company affects the speaking time	◯	◯	◯	◯	◯
It made me/us more aware of how age influences the speaking time	◯	◯	◯	◯	◯
It made me/us think about group dynamic	◯	◯	◯	◯	◯
It made me/us reflect on gender aspects in meetings	◯	◯	◯	◯	◯
It made me/us more aware of our role within the meetings	◯	◯	◯	◯	◯
It made me/us more aware of the air quality in the room	◯	◯	◯	◯	◯
It made me/us more aware of how air quality affects the meeting quality	◯	◯	◯	◯	◯

If you want to add notes to any of the above questions, please add them here

Please write your answer here:

How could...

How would it affect the meeting if the device would show the role of the attendees? *

Please write your answer here:

What do you think would be the impact on the meeting if the device would visualize the distribution on talking time of gender? *

Please write your answer here:

Which other measures could you imagine could influence what makes a good meeting? *

Please write your answer here:

4

Do you have any concerns about smart technology in meetings? *

ℹ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Not at all
- ◯ A little
- ◯ Moderately
- ◯ Very much
- ◯ Extremely

Which concerns do you have? *

Only answer this question if the following conditions are met:
Answer was 'A little' *or* 'Moderately' *or* 'Very much' *or* 'Extremely' at question '9 [G4Q00001]' (Do you have any concerns about smart technology in meetings?)

Please write your answer here:

Would you use a similar device frequently in your meetings? *

Choose one of the following answers
Please choose **only one** of the following:

- ◯ Definitely not
- ◯ Probably not
- ◯ Possibly
- ◯ Probably
- ◯ Definitely

Why? *

Please write your answer here:

Thank you!

Submit your survey.
Thank you for completing this survey.

List of Figures

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