Cashasa

Exploring the use of automation goals incorporated into the 3D-model home representation to facilitate smart home planning

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Abstract

Given that any smart home will ultimately be inhabited by end users, involving them into the planning phase is indispensable to spread the understanding and acceptance of intelligent solutions. However, from users' perspective understanding the complex landscape comprises navigating through the quantity of available solutions, as well as identifying needed hardware. Moreover, suppliers often concentrate on technologies, and not on people. Such a non-user-centric, but technology focused organisation does not support users in achieving their automation goals. Thus, we propose a more user-centric approach to build a cognitive bridge between goals and technologies. Additionally, given that users often experience difficulties in imagining future effects of domestic technologies, we are introducing a 3D visualisation integrating the goal-focused approach. We implemented the two approaches in one prototype and performed an evaluation study. The results for the goal-based approach were very positive whereas the 3D visualisation has to be further refined to exploit its opportunities. In particular, each user should be provided with an exact representation of his or her home. This extension would enhance users more in putting themselves into the context of their domestic space.

Überblick

Benutzer, welche sich für die Automatisierung ihrer Wohnsituation entscheiden, können sich online oder offline über die Vielzahl von Lösungsen informieren. Allerdings erleben sie oft Schwierigkeiten ihre Automatisierungsideen umzusetzen, da sich Anbieter eher auf Technologien als auf die Benutzer konzentrieren. Dabei ist der Endkunde oft mit einer komplexen Darstellung der möglichen Hardware Komponenten konfrontiert. Basierend auf diesen Informationen können sich Bewohner häufig keine möglichen Einsatzszenarien von Smart Home Technologien vorstellen. Um kein Kundeninteresse in diesem unübersichtlichen Sortiment zu verlieren und eine verbesserte Kundenorientierung zu erreichen, stellen wir hier einen Ansatz vor, der die Kundenbedürnise in den Fokus setzt. Dabei konzentrieren wir uns zuerst auf die Formulierung der Ziele, die durch die Automatisierung erreicht werden können. Im zweiten Schritt werden anschliessend die jeweiligen Technologien aufgezeigt. Nicht alle potentiellen Nutzer haben ein gutes Vorstellungsvermögen für räumliche Konstellationen. Dieses ist aber wichtig für die Planung von Smart Home Installationen und zukünftigen Wirkungen dieser Technologien. Um die räumliche Vorstellungskraft zu unterstützen, stellen wir eine dreidimensionale Representation des Hauses vor. Darin visualisieren wir mögliche intelligente Lösungen, die in der kundenfreundlichen Form dargestellt werden. Die beiden Ansätze haben wir mittels einer Studie ausgewertet. Der kundennahe Ansatz, implementiert in einem Prototypen, erzeugte positive Ergebnisse. Die dreidimensionale Visualisierung zeigte sich als ein guter Ansatz für weitere Forschung in der Benutzerunterstützung der Smart Home Planung. Allerdings müsste in der Zukunft die Genauigkeit der Representation verbessert werden. Dabei verstehen wir, jedem User ein individuelles Interface mit der genauen Abbildung der Wohnung oder des Hauses zu bieten.

Acknowledgements

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This thesis would not have been possible as it is without the local startup, Archilogic, who provided me with the 3D framework to use as a visualisation in the study. I would like to thank the entire Archilogic team for the trust and support, and especially Tomas Polach and Martin Naumann for their time and creative ideas to integrate the Archilogic framework via an iFrame within my work.

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Chapter 1

Introduction

"The most important thing in communication is hearing what isn't being said. The art of reading between the lines is a life long quest of the wise." - Shannon L. Alder

1.1 Context

During the 20th century, domestic technology changed dramatically, as discussed by [Aldrich, 2003]. The first quarter introduced electricity into homes, spurring new appliances and equipment to be developed, such as washer, refrigerator and vacuum. The last quarter brought information technology into domestic spaces, enabling appliances, systems and networks to exchange information. Lastly, the 20th century ended introducing the previously hardly imaginable concept of *smart home*, opening up a multitude of possibilities. In his book [Aldrich, 2003] further explains that the term *smart house* was officially first used in 1984 by the American Association of House Builders. However, already in the early 1960s hobbyist built *wired homes*, a concept that set the headstones for the meaning of smart homes of today.

the 20th century ended introducing the previously hardly imaginable concept of *smart home*, opening up a multitude of possibilities

The definition of *smart* in smart homes differs depending on the context, whether it is used in the description of

commercial products or in academic research. In industry, homes that can be controlled via a remote access are seen as smart homes, whereas in academics, a lot of researchers see a smart home *smart* when some aspects include automation and machine learning.[Mennicken et al., 2014a] In their research, they added more flexibility to the research term, defining smart homes as houses that offer increased comfort with aid of computation. Becoming more and more widespread, a lot of research has looked into how people are using the various options that exist in the context of smart homes.

smart homes: houses that offer increased comfort with the aid of computation

1.2 Problem and Motivation

Given that every smart home will eventually be inhabited by end users, it is indispensable to integrate the user into the planning phase. It is crucial to have users participating and understanding smart home solutions, setup, control and the affect they have on their domestic spaces. Without it, they are unlikely to accept the intrusion of ubiquitous computing into their privacy of domestic lives, such as sensors or robotic machines.

every smart home will eventually be inhabited by end users

Currently there is a multitude of commercial players customers can choose from to purchase automation technologies, ranging from specialised technicians to conventional online technology stores. Thereby, the way smart home solutions are shown to users has not been standardised and depends heavily on the type of the supplier. Every seller presents their assortment in a different way. Some highlight possible problems or repetitive tasks in the household and provide a solutions. Others advertise abstract categories or specific solutions. Given that a lot of suppliers are simply technology provider stores, they will most likely have home automation and the so-called Internet-of-Things[1] hardware components listed in their assortment. Sometimes, these are grouped into themes, categories or another similar label. Yet, online and offline technology stores do not have the time or capacity to interpret each

sources informing users about home automation technologies are often very much focused on devices and technology

[1] http://www.theinternetofthings.eu/

device they are providing.

Related work by [Mennicken et al., 2014a] highlighted that researchers and product designers should further support inhabitants of smart homes in navigating through the quantity of available solutions, applications, or services, as well as identifying potentially needed hardware. Nowadays, people who would like to automate parts of their domestic spaces or who are interested in starting to use smart home technologies, need to navigate through various websites or catalogues. As mentioned, these sources are often focused on technology and product specifications as they are structured based on different devices and hardware components. However, being presented with hardware or software components and their specifications only does not support most people in achieving their automation goals, or in being inspired by browsing through home automation possibilities. People mostly do not think in terms of hardware, but in terms of their interests or needs for automation and the problems they strive to solve within their home, for instance *When I come home, I want it to be warm*. Hence, a more user-centred approach would be to structure the information towards a human-driven mindset by specifying automation goals first and then revealing the technology to achieve these objectives in a subsequent step. This goal-focused perspective might further inspire people because they are curious to see what automation ideas and home technologies worked for others [Mennicken et al., 2014b].

simply being presented with hardware or software components is not intuitive for users

people mostly do not think in terms of hardware, but in terms of their interests or needs for automation

We would like to take an approach that supports people in the context of their goal to automate a certain task. Thus, the aim of this thesis is to answer the following question:

*How can we shift the focus from currently rather technology-driven communication of smart home solutions to a more people-driven focus (**RQ1**)?*

Furthermore, we aim to focus on the people-driven perspective in the context of presenting smart home solutions. We envisioned to portray home automation goals in a joint interface with a visualisation of the home model and to integrate visualised goals within the 3D model. Thereby, the second research question we are focusing on is:

*How does the 3D representation of a users' home affect the interaction with the goal-based approach of smart home solutions? (**RQ2**)*

users often have difficulties imagining automation configurations and their implications

More precisely, we are evaluating how an integration of a 3D home model visualisation in the user interface, presenting various smart home solutions, supports people to better understand the offerings. Amongst other arguments, the reasoning behind this research question was based on the work by [Lertlakkhanakul et al., 2008]. Their research states that users often have difficulties imagining automation configurations and their implications. With a metaphor of their home, our aim is to support people into putting themselves in the context of their own domestic space when viewing and evaluating various possibilities of home automation.

academia and industry often focused on a technology push rather than on design, usability and use of technology

The motivation to the second research questions builds upon further arguments identified by related work. [Borodulkin et al., 2002] state that in contrary to the increased attention to home automation equipment and smart home technologies' capabilities, less importance was laid on developing understandable, usable and easy to use interfaces. Additionally, [Harper, 2006] explains that *little effort has been put into understanding what is needed* and that academia and industry often focused on a technology push rather than on design, usability and use of technology. However, [Borodulkin et al., 2002] argue that a comprehensive and usable interface is crucial for spreading ideas and accepting smart home concepts. They highlight that in particular, *the Man-Machine-Interface*, nowadays mostly called the Human-Computer-Interface, *is often acknowledged to be the most sensitive area for the acceptance of home automation systems*. This implies that designers of smart home solutions should not only focus on the detailed technical implementation, but should invest a substantial amount of time and effort in providing usable, appealing and understandable user interfaces to increase the acceptance of these systems.

a comprehensive and usable interface is crucial for spreading ideas and accepting smart home concepts

1.3 Scope and Contribution

This work is the first step into the long term goal of enhancing users to be more capable of understanding their future smart home by introducing a goal-based approach in an individually customisable and usable 3D house floor interface. Ultimately, we envision that this approach would enable them to participate more in the smart home planning process, as well as the later device configuration, control and supervision phases. The aspect of visualisation builds upon the following approaches from related work: PyViz [Lertlakkhanakul et al., 2008], V-PlaceSims [Thomas and Crandall, 2011] and Smart Blueprints [Lu and Whitehouse, 2012]. We are integrating their ideas and objectives, but extending the features space and the details of the visualisation (see more in related work, 2). The aspect of goal-based approach and categorisation of the current product landscape builds upon works of [Takayama et al., 2012], [Brush et al., 2011], [Lee et al., 2008] and others (see in Sec. 3.4).

enhancing users to be more capable of understanding their future smart home

introducing a goal-based approach in an individually customisable and usable 3D house floor interface

This thesis firstly aims to contribute to the understanding how to use a goal-based approach of presenting home automation goals primarily, and the needed devices subsequently. Thereby, we aspire to bridge the gap between user automation goals and technical solutions available on the market. To achieve this, we need to rearrange the steps in the process how users browse for smart home technologies. Secondly, this work contributes the concept and first prototype of a 3D visualisation representation to make users relate to their domestic spaces. This sets the initial step to consecutive integration of 3D usage in goal-based approaches. Thirdly, it combines the two directions and an evaluation study in a joint prototype. Ultimately, synthesised study results and this thesis are contributed.

we need to rearrange the steps in the process how users browse for smart home technologies

1.4 Structure

Chapter 2 describes previous works that inspired our approaches or methods, and that we built upon. Further, in chapter 3, we address the RQ1 and create the lifestyle ma-

trix to bridge the gap between technologies and people. In this chapter we describe our conducted market analysis and provide the mapping from goals to devices. Chapter 4 describes how we integrated four different parts into the final prototype Cashasa, the lifestyle matrix, the 3D visualisation, the questionnaire required for the study and the user interface aspects. Subsequently, chapter 5 follows the chosen iterative approach and takes the user on the journey from the first prototype to the final implementation. Having all details implemented, chapter 6 discusses study results we gathered from 82 participants. The following chapter, 7, explores limitations in our method, technical feasibility and general setup. Ultimately, chapter 8 discusses future directions and possibilities we would like to contribute whereas chapter 9 provides a conclusion to this work.

Chapter 2

Related work

This chapter analyses and discusses aspects of related work with respect to the following topics. Firstly, we reflect upon user-centred approaches in equipping smart homes. Secondly, we explore how 2D and 3D visualisations were used in earlier researches. Lastly, we discuss motivation for smart home technologies identified by related work.

2.1 User-Centred Approach in Equipping Smart Homes

as any smart home will eventually be inhabited by end users, it is indispensable to integrate the user into the planning phase

Given that any smart home will eventually be inhabited by end users, it is important to integrate the user into the planning and setup process. It is indispensable to have them participating and understanding on how smart home solutions are operating. Nonetheless, only few research contributions applied the user-centred approach for the planning phase.

A commercial player, the Institute for Building Technologies, supports users to plan their smart home with steps described in the video [1]. It presents four different stages to achieve the end installations. In the first step users have

[1] https://www.youtube.com/watch?v=H4yZ57OOT5k

to ask themselves what they really want based on the provided questionnaire[2]. It comprises automation possibilities categorised into abstract goals. The next phase is called *material planning*. It transforms requirements from the first step into required functionalities. In addition, the needed sensors and actuators are sketched into the floor plan. The third phase is setting up the device concept, followed by the last where users choose the product partners. We are taking a similar approach by showing users automation possibilities and necessary hardware and software components.

One of the first academic contributions is the work by [Lertlakkhanakul et al., 2008]. They focused on letting the user participate in the smart home equipment configuration process by creating a simulation of virtual space using virtual reality technology. Their argument states that users have difficulties imagining automation configurations and respective implications. Hence, researchers address this issue by proposing an interface that connects smart home users to their smart environment by letting them configure spatial interaction during the first phase, the design phase. This enables inhabitants to experience their environment through a virtual place before they see it in reality.

users have difficulties imagining automation configurations and their implications

It has been further discussed by [Lertlakkhanakul et al., 2008] that users cannot imagine how the final design of a house or an apartment will look like when only being briefed on architect's design ideas. The previous mainly occurs because they are not trained to have a full imagination of three-dimensional spaces or are not able to translate discussed ideas into a 3D model in their mind. This might result in a considerable expectation disjoint between the two parties after the domestic space has been built. Users might find some unexpected elements emerge in the final outcome that are unsatisfiable or incomplete. Thus, there exists a communication gap between architects' design imaginations and users being unable to process the ideas given.

there exists a communication gap between architects' ides and users being unable to process the ideas given

This difficulty in communicating has also been identified by commercial players. A Zurich based startup, Archilogic[3], is building a 3D technology that will allow archi-

[2] http://igt-institut.de/smarthome/fragebogen/#
[3] http://about.archilogic.com/

tects to better describe ideas to customers and future inhabitants. Archilogic says their mission is to rebuild the reality in a 3D model to let people experience working and living spaces not only how they are, but also how they could be. This phenomenon of misunderstanding user needs does not only happen in architecture, where adjustments after construction produce costly processes [Palmon et al., 2006], but also in software development that can be seen as an analogue activity. Understanding software user needs is a complex process, especially when customers cannot communicate - or even imagine - what new functionalities and products they would like to have. To address this, the field of Requirements Engineering aims to define and elicit adequate requirements [van Lamsweerde, 2009] prior to start developing new products in order to anchor what kind of system will be developed [Nuseibeh and Easterbrook, 2000]. Likewise, such problems of disjoint expectations will become more considerable in case of smart homes where a lot of interconnected equipments and complicated services are installed. Based on the argument that simulating spatial reality is essential to duplicate the experience of real world [Oxman et al., 2004], we would like to introduce a 3D representation of users homes. By visualising their home in form of a 3D virtual space and thus creating a context-aware model, we aim that smart home users will be more likely to accept and emerge into technological possibilities.

a 3D representation aims to support people to recall their domestic spaces

simulating spatial reality is essential to duplicate the experience of real world

Additionally, we took inspiration on the approach integrated into the Reality Editor by [Heun et al., 2013]. They point out that presenting for example a light control in a user interface traditionally results as as a list of numbers or symbols, but is never mapped to the actual position in user's homes. This brings an increased abstraction for users that have to memorise the mental relationship between objects and virtual interfaces. On contrary, their approach removes complex abstractions displaying objects in user interface as they are in real world (see Fig. 2.1). This results in a simplification of the above mentioned lights control. It further transforms the complex tasks into intuitive ones.

Reality Editor reduces abstractions by presenting objects in interfaces as they are in real world

Based on the researchers' argument *"A minimum amount of abstraction and mental demand is achieved when a user has a direct view of the object of interest ..."* [Heun et al., 2013] we

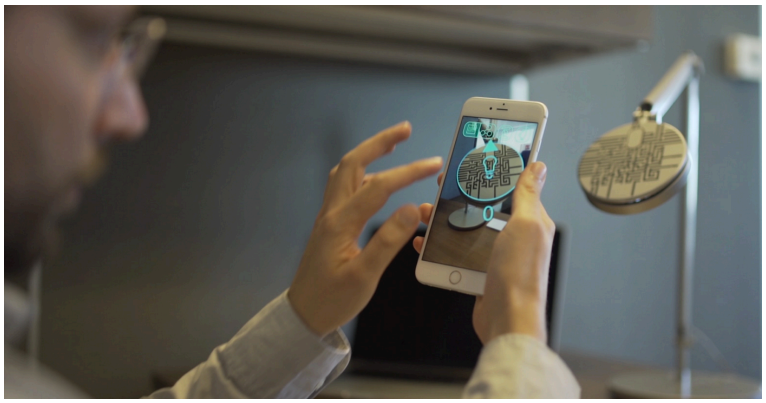


Figure 2.1: The Reality Editor providing direct mapping, source: Reality Editor[4]

our work removes some abstractions, revealing a closer representation by the 3D model than by presenting scenario-based descriptions

argue for our 3D visualisation of users' homes. For the scope of our thesis we are technically limited to remove all abstractions when providing the 3D model. Hence, it still acts as a representation of user's home. Nonetheless, it removes a couple of layers of abstractions, revealing a closer representation by the 3D model than by presenting a list or scenario-based descriptions. The long term goal will be technically feasible in the nearer future: Users will provide us with an image of the 2D floor plan, upon which we will generate an exact 3D model (see Future Work in Sec. 8.1), when possible also considering furniture and colours customers have in their actual homes.

2.1.1 Visualising Ideas in the Smart Home Context

By providing a 3D model interface we do not only aim to support inhabitants correlate the imaginary spatial interaction into the real world. We also aim to introduce a goal-based approach that focuses users' mindset more to their homes and away from technology when they think and talk about smart home contexts. Furthermore, based on the discussion by [Takayama et al., 2012] that home and automation do no go together as one is homey and the other cold, we are aiming our prototype to be considered more *homey* than cold by letting people's mindsets focus to the context

of their home.

Project SmartLive by University of Siegen
During the last stage of our thesis, we encountered a similar project with slightly different priorities. Unfortunately, their digital showroom was published on 18th December 2015 on their website, SmartLive[5], only a couple of weeks after we finalised our prototype. If we have had known about their work before, we could have contacted their group to explore synergies of both approaches. Nevertheless, our work extends the research project *Was ist SmartHome*[6]. They created a digital showroom of smart home solutions in order to inform beginners and prospective users about it. Their ultimate goal was to make the smart home topic more understandable. Thereby, researchers categorised solutions in three categories, safety, energy saving and comfort. Each category is broken down into specific activities such as *"Lightning control: in case you forgot to turn off the lights in the bedroom, your smart home will do it for you"* or based on the sensors *"motion sensor camera: with the installed camera on your garage door, you always have everything in control"*. However, they are heavily concentrating on the device level, and do not follow the entirely goal-based approach we are focusing on, but are presenting a combination of a goal-based and device-focused descriptions, see Fig. 2.2. Hardware components are directly mapped to each automation goal and users can download a pdf of the device specification. We believe this approach tended to be quite hardware focused because their research partner was the supplier of most of the sensors mentioned in the work. Each solution (either goal-based or device-focused) is displayed as a badge in an image of a house that provides a direct interaction (see Fig. 2.2). When the user clicks on the badge, a pop-up showing required devices is displayed. Our work takes this analogy of the house, displaying possible solutions within and the digital showroom. However, we are not displaying one general image of a house, but are customising a 3D model visualisation based on different users. Thereby, we aim to put users more into the context of their domestic spaces.

[5]http://smart-live.info/
[6]http://www.was-ist-smarthome.de/#Forschungsprojekt

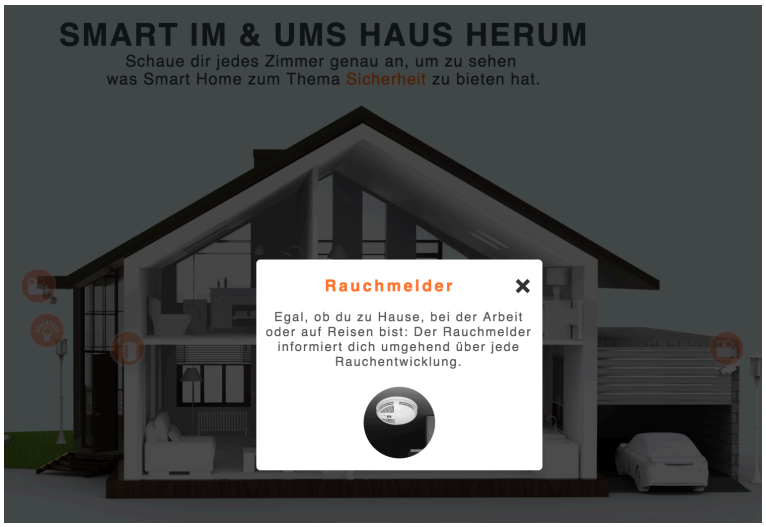


Figure 2.2

Design Principles by Norman: Visibility
An additional argument for the visualisation is based on the design principles about visibility by Norman. He states that usability is improved when the user sees different command and options that exist. Functionalities that are not visually represented are difficult to be discovered [Norman, 2013]. In our work we are not doing a usability research. However, we need to create a sufficiently usable prototype to be able to gather more and better data to answer our research questions. Consequently, providing a visualisation supports in reminding people what elements they have in their domestic spaces by showing them a floor model similar to their homes.

Metaphoric design
use of metaphors in interfaces helps communicate more effectively and to a more diverse and heterogeneous group of viewers

Furthermore, metaphoric design goes into the similar direction. Metaphors can be seen as fundamental concepts, terms or images that aid to recognise, understand and remember information easily. The use of metaphors in user interfaces helps communicate more effectively and to a more diverse and heterogeneous group of viewers or users [Marcus, 1998]. For the scope of the project we introduced metaphoric design to improve the understanding and usability of our mental model. Metaphors such as terms, concepts or images might be representing data, tasks, functions

or people [Marcus, 1998]. Hence, metaphors are used in the way people's homes are visualised, how different symbols for specific actions are chosen as we are aiming to trigger an association to real world elements.

Visual vs. scenario-based communication
These are similar reasons why we preferred a visual to a scenario-based communication. A scenario-described mapping between goals and technologies might be more complex to understand as including more words calls for incorporating more complex structures and thus, misunderstandings. According to previous literature, in current times visual communication brings added value in communicating information on a global scale [Berger, 1988], [Horn, 1998]. Given that we wanted to create as usable requirements elicitation tool as possible that is open for all countries, it is essential to make sure we design the study as understandable as possible for the global context.

Future audience is visual
An additional argument to it is that future audience is visual. People who reacted to the pre-survey we mention in 4.3 were mainly young people between 20-35, with a median age of 26 and mean age of 28.36. This age range represents our main target group for the study. Market research found out that in the still quite early stages of smart house advances, early adopters are mainly younger people in multi tenant households with a higher than averaged net income and a higher education [CapgeminiConsulting, 2011]. According to previous works, visual communication brings added value in the information age of the current time [Berger, 1988], [Horn, 1998]. Hence, we decided to address this young audience by communicating as visually as possible for the scope of the project without adding relevant risks to influence the results of the study due to visual components.

visual communication brings added value in the information age

2.2 2D and 3D Visualisations

Previous works have focused on visualising data, inhabitants' space or building entire house labs to display users

meaningful interpretations. We explored in particular works that used 2D and 3D visualisations to integrated their ideas and learnings into our prototype. The need for giving meaning to raw data arouse with the spread of home automation solutions and smart home appliances producing more and more data. In particular, [Thomas and Crandall, 2011] argue there is *"continuous need for quality visualisation"*. The rising complexity of data output is increasingly making it more difficult for inhabitants to comprehend the systems in their own domestic spaces. To display that data, previous works presented various visualisation tools focusing on different aspects. One work [Ivanov et al., 2007] proposed a 2D visualisation as an intuitive way to display a large number of multidimensional data, including both spatial and temporal components. The data was gathered from a high number of motion sensors and video cameras monitoring a large office space. Others have visualised statistical history data of single sensors such as [Muller and Schumann, 2003] and [Rantz et al., 2008]. Further, 3D renderings were used by [Szewcyzk et al., 2009] who focused on visualising and evaluating data for systems *"providing health monitoring and assistance to people experiencing difficulties living independently at home"*.

the complexity of data output makes it more difficult for inhabitants to comprehend their domestic spaces

A user-centric approach, V-PlaceSims [Lertlakkhanakul et al., 2008], focused on integrating the user in the design stage of planning, in particular the configuration part. Their work aimed to introduce a novel framework supporting smart home users to *"configure spatial interaction caused by context-aware services"*. Briefly, they tried to simulate configuration of how the inhabitants' space will look like by using virtual reality to create a virtual space platform (see Fig. 2.3). We were inspired by the ideas behind V-PlaceSim. They are taking a user-focused approach to allow users imagine how their home will finally look like in order to *"avoid the considerable gap between the architect and the user in smart home design process"*. For the scope of this thesis, we are simulating abstractions of smart home solutions within the domestic contextes. The concrete analogy to V-PlaceSims is our long term goal to illustrate specific devices that are needed to achieve automation goals and their effect within the 3D visualisations (see Sec. 8.4).

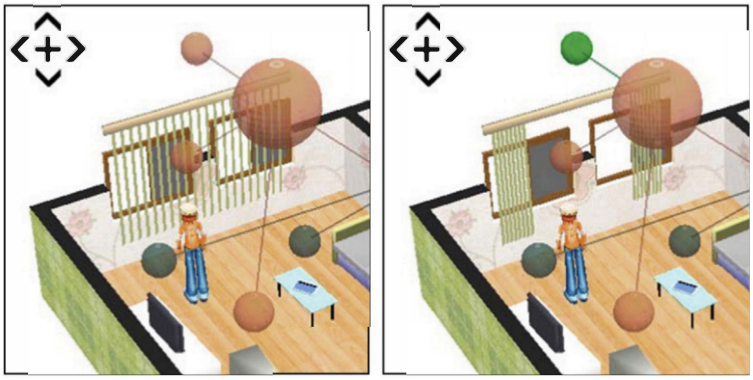


Figure 2.3: V-Place Sim work: Stimulating configuration of the blinds, by [Lertlakkhanakul et al., 2008]

PyViz [Thomas and Crandall, 2011], demonstrated at the Center for Advanced Studies in Adaptive Systems (CASAS) at Washington State University[7], is a visualiser that allows viewing the smart home system in real-time and giving access to historical data and trends (). PyViz serves as the basis for the CASAS smart home research, being using during all stages of smart home deployment, from planning and installation to live and historical data visualisation.

Some projects have focused on building physical houses acting as labs to test and explore smart home concepts, technologies and implications. For instance, the Aware Home from Georgia Tech [Kidd et al., 1999] inhabited by people to be monitored by researchers, the MavHome project [Cook and Youngblood, 2003], the Gator Tech Smart House [Helal et al., 2005] where ubiquitous computing was applied for everyday activities focusing mostly on smart home appliances, and the Toyota Dream House Papi [Sakamura, 2005] that was designed to be an environment friendly and energy saving house. Although we are not building physical lab houses, we are trying to provide the closest possible representation of users homes in a 3D model. In the mentioned works researchers were able to recreate some of the home experiences to let their study participants relate to their homes. Hence, lab houses, de-

we are trying to provide the closest possible representation of users homes in a 3D model

[7] http://casas.wsu.edu/

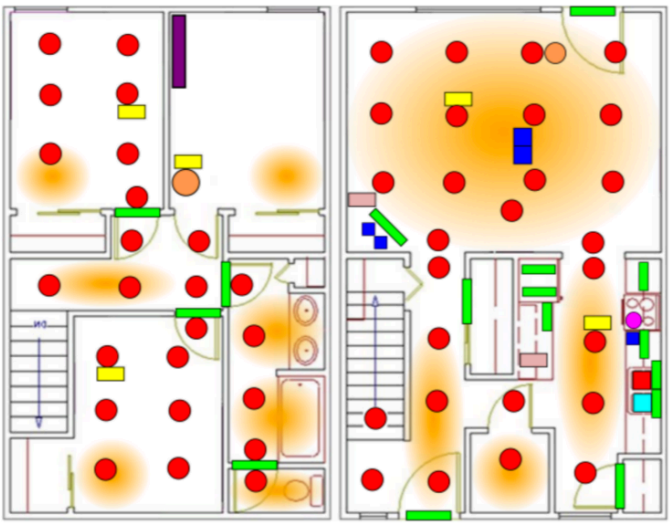


Figure 2.4: PyViz Work: Configuration file of sensors by [Thomas and Crandall, 2011]

spite the fact that they generally do not feel like home, were used to investigate smart home concepts. With our 3D representation we are aiming to achieve this effect.

2.3 Motivation for Home Automation

Amongst other focuses, through the evaluation study our work explored motivations for setting up or using home automation technologies. Others before have researched what thrives people to install, integrate and further use home automation technologies. [Takayama et al., 2012] discuss about values inhabitants with home automation systems found or created and summarised them as:

1. *have peace of mind by knowing that everything is ok at home*
2. *optimise: being ecologically conscious, saving money, notice things about yourself, family, home (see progress)*
3. *experiment by tinkering to learn and teach*

4. *entertain and impress others, be a welcoming and gracious host for family and friends*

5. *personalise the home*

Another work, by [Brush et al., 2011], describes convenience, peace of mind and centralised control as people's favourite aspects of home automation.

In their study [Mennicken and Huang, 2012] conducted a *"in-the-wild study of smart homes"*, exploring people's motivations to equip their homes with smart technology. They identified 4 main motivations.

1. *Modern homes are smart homes*. Researchers describe participants in their study expressed this opinion even though smart technologies did not have major impacts on their daily lives.

2. *Experiencing benefits increases interest in upgrades.* Their study revealed that the more people were confronted with automation possibilities, the more they felt comfortable with and trusted the smart home technology.

3. *Hacking the home is a hobby.* This aspect was especially mentioned by participants with a technical background who are interested in modern technologies, amongst which smart home technologies.

4. *Smart homes save energy.* Some participants aimed to save energy with the installation of smart home technologies.

Chapter 3

From Market Analysis to Lifestyle Matrix

In the past years, there has been an increased interest in autonomous systems and smart homes - in 2012 it was estimated that by 2015 smart home market will grow to $11.8 billions in the USA [Mennicken and Huang, 2012]. Currently, although early in 2016, we have not yet found published numbers for the market size for 2015. However, Statista[1] reported that in 2014, the revenue was at $20.38 billion. They further describe that until 2020 it will grow to $58.68. Another source, MarketsAndMarkets[2], estimates the same market size for 2020. This would mean a 17% grow rate between the years 2015 and 2020.

there is a multitude of commercial products available aiming to support people in automating their homes

The market answered to the leveraged demand, and currently there is a multitude of commercial products available aiming to support people in automating their homes (see Automated Home[3]). Thus, from a technical point of view, there are plenty of options and a large variety of home automation solutions and components that people can choose from. However, simply being presented with

[1] http://www.statista.com/statistics/420755/global-smart-homes-market-value/

[2] http://www.marketsandmarkets.com/PressReleases/global-smart-homes-market.asp

[3] http://www.automatedhome.co.uk/home-automation-technology-choices

simply being presented with hardware and software components is not intuitive for users

hardware and software components and their specifications only does not support most people in achieving their automation goals. Neither is it an inspiration for exploring intelligent possibilities around the home, in particular not for smart home novices. Related work has stated that researchers and product designers need to support inhabitants of smart homes more in navigating through the quantity of available solutions, and in identifying potentially needed hardware [Mennicken et al., 2014a]. There is a multitude of technical solutions available and there is a multitude of users having ideas of what they want to automate. In order to succeed with their ideas for automation, users have to navigate through hardware and software components that might help them to achieve their automation task. However, there is an understanding gap between the focus on technology and users expressing their needs in natural language. In order to minimise misunderstandings and frustrations, we would like to bridge the gap between user goals and technical solutions available and support users with a more intuitive way to browse for smart home ideas (see Fig. 3.1). The main focus lies in giving people a possibility to find what they want first, and letting them explore needed technology to this goal second. Thereby, we are following a people's driven approach based on current user desires, on contrary to laying the focus on technology or hardware.

there is an understanding gap between the focus on technology and users expressing their needs in natural language

Steps and overview
The following sections describe the steps taken (see Fig. 3.2) to describe the final lifestyle matrix based on the product landscape and related work on categorisation (see more in Sec 3.4).

3.1 Observed Market Categorisation

We analysed the link between people's goals and technology reflected in the current product market landscape by understanding how companies are marketing and categorising product solutions. The analysis included sections on automated homes in online stores such as Amazon, BestBuy or BadgetFlow, IFTTT recipes, forums' discussion cate-

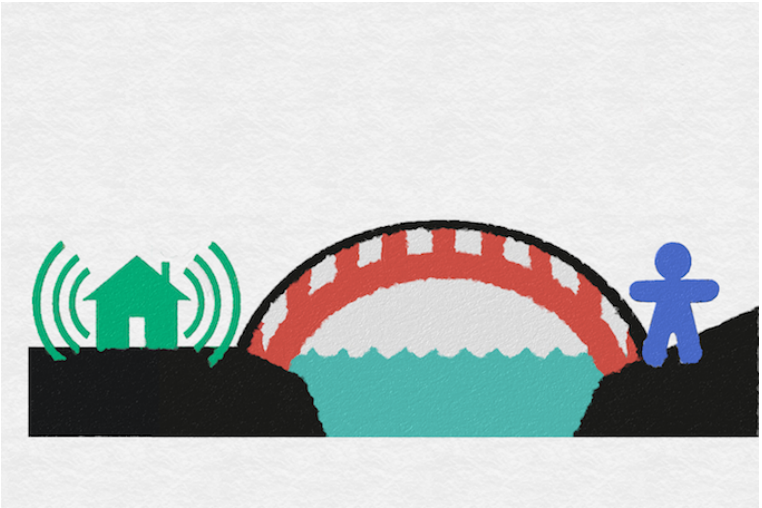


Figure 3.1: Sketch: bridging the gap between smart home technologies' supply and user's demand

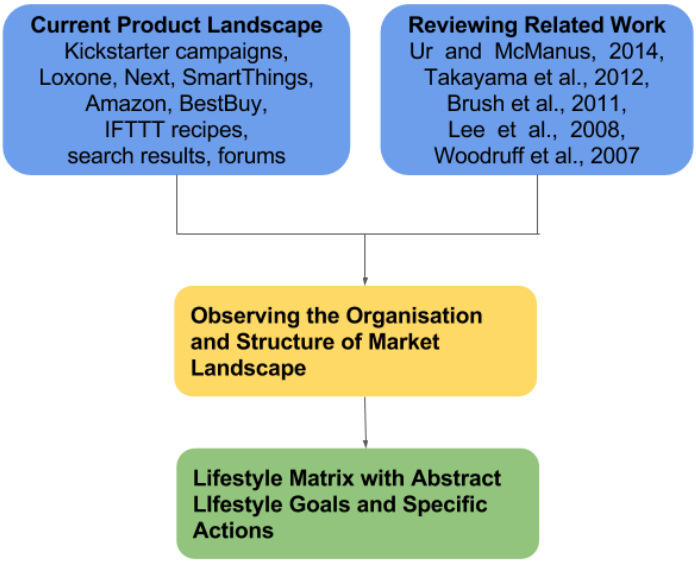


Figure 3.2: Based on the current product landscape and related work, steps taken to create the Lifestyle Matrix

gories, Kickstarter smart and automated homes campaigns, results from search engines when looking for *smart homes* and *automated homes*, and products that act as a hub integrating a lot of devices such as Loxone, Nest, SmartThings.

every supplier chooses a different product presentation

Each solution provider chooses a different way to categorise products, making the listings on product sites very heterogeneously organised. We identified five different types of categorisation elements in the product landscape:

- abstract goals
- specific goals
- general devices
- specific devices → controller (hardware components)
- topics of interest

Table 3.1 presents examples to each of the five categorisation type.

Categorisation	Example
abstract goals	security, energy saver
specific goals	hear when the baby wakes up
general devices	lights, blinds
controllers	Mi Casa Verde, Leviton
topics of interest	gardening, pets, remote control

Table 3.1: Concrete examples to the categorisation types

Organisation in different abstraction layers
These five types of categorisation are combined in various ways, mixing different abstractions layers. We summarised the combinations as patterns A, B and C (see classification in Appendix F).

Pattern A

Any of the five components is put on the same abstraction layer resulting in 1 layer sorting, see table 3.2.

abstract goals	specific goals	general devices	controllers	topics of interest

Table 3.2: Pattern A: 1 layer sorting, observed during market analysis and categorisation

Example Pattern A
Enjoyliving: The offerings are listed by a mixture of general devices (light, blinds, heating, alarm, intercom, ...), abstract goals (surveillence, ...) and general terms (garden, weather, access, ...) [source: EnjoyLiving] [4].

Pattern B

In some product offerings specific goals are not put on the same abstraction layer like other four terms, but act as broken down actions of abstract goals or general devices resulting in a 2 layer sorting (table 3.3).

abstract goals	general devices	topics of interest
specific goals	specific goals	

Table 3.3: Pattern B: 2 layer sorting, observed during market analysis and categorisation

Example Pattern B
SmartThings: Listed by devices (lightning, thermostat, motion sensors, locks), broken down into actions. For the device *lock*, the actions are *lock up doors when you leave*, *lock up doors when closed*, *unlock when someone arrives*. [source: SmartThings][5]

Pattern C

Specific devices, such as hardware components are the driving force of product listings, making it quite technology focused. We called it sorting by the controller, in 3.4.

[4] http://www.enjoyliving.ch/home/?L=1
[5] http://www.smartthings.com/product/

controller

Table 3.4: Pattern C: sorting by controller, observed during market analysis and categorisation

Example Pattern C
Amazon provides three different sorting options. A user can shop by solution, by specific devices or by new products. The pattern C rises during shopping by specific devices (controllers) such as Mi Casa Verde, Wink Hub, Leviton or Nexia. [source: Amazon][6].

3.2 Goal-Based Approach Categorisation

we aim to achieve an easier navigation through all the product landscape

Aiming to achieve a better overview and easier navigation through all these options, the idea of pattern B separating different abstractions into two layers (see table 3.3) was followed. Thus, the structure of abstract categories that can be broken down into specific actions was pursued. The other structure from the pattern B, displaying solutions based on *general devices*, was not further elaborated because as per *RQ1* we aimed to take out the technological focus to concentrate on what people want and not what is feasible with technology. Thereby, we concentrate only on abstract lifestyle goals and specific actions from observed pattern B. In a second step we mapped hardware components to specific actions. This mapping should leverage people to understand how to reach automation goals.

Pattern B As described above, the pattern B was characterised as follows. Specific goals are not put on the same abstraction layer like other terms, but act as broken down actions of abstract goals or general devices resulting in a 2 layer sorting.

[6] http://www.amazon.com/

abstract goals	general devices	topics of interest
specific goals	specific goals	

Table 3.5: Chosen Pattern (B): 2 layer sorting

3.3 Categorisation Process

As can be seen as a first step in Fig. 3.2, we analysed 30 different product sites and when applicable their respective mobile applications and 4 forums (englisch and german). We recorded every descriptive categorisation, resulting in 480 entries from websites (supply side), and 54 entries from forums (demand side). Thus, the analysis corpus included 34 different sources with a total of 534 entries (see Appendix F). The entries ranged within the above mentioned components (abstract goals, specific goals, general devices, controllers and topics of interest, see 3.1). Further, we investigated how often each of the components was mentioned and summarised it into a cluster with abstract and corresponding specific goals, considering and integrating all components.

analysis corpus included 34 different sources with a total of 534 entries

Two layer structure: lifestyle goals and actions
The structure after categorisation consists of an abstraction layer and a specific layer resulting in having a two layer classification similar to pattern B market categorisation (see table 3.3). Our categorisation process resulted in two main terms, the top layer with *lifestyle goals* and the lower layer with specific *actions*. Each lifestyle goal can be broken down in multiple actions (see in Fig. 3.3). The next step in our categorisation process was to validate our classification with a card sorting method (more about the card sorting evaluation and results can be found in Section 3.5). But first, we provide further explanations on the two terms, lifestyle goals and actions, in the next section.

the categorisation process resulted in two main terms, the top layer with *lifestyle goals* and the lower layer with specific *actions*

Defining the wording: Lifestyle goal
The term *lifestyle goal* is a mixture of abstract goals like *healthy lifestyle* or *energy saving* and *topics of interest* like *pets* or *child care*. Some wordings might seem to belong to both, for instance the *topic of interest child care* due to the positive

intonation might be argued to be following the *lifestyle goal* of *being good parents*. Given that it does not bring further value for the scope of this project to differentiate between an abstract goal and topics of interest, we summarised both terms under lifestyle goals. Naming of lifestyle goals implies a positive tendency in the context of daily life routines at home or topics of interests linked to the home. However, for the scope of this work we will not discuss philosophical questions around the positivity aspect considered during the naming. Thereby, topics around what is a choice, what is a positive choice and if people were inclined to choose some elements only because they were expressed more positively will not be further elaborated.

naming of lifestyle goals implies a positive tendency; however, we will not discuss philosophical questions around the positivity aspect

Defining the wording: Actions

People relate better to concrete activities then to abstraction. Thus, abstract lifestyle goals are broken down into specific actions (see Fig. 3.3 and Fig. 3.4). These *actions* are clustered to belong to thematically matching lifestyle goals. For instance, lifestyle goal *energy saving* is broken down into actions such as *house can store solar power and coordinate the usage between solar and energy usage* and *water monitoring allows you to know about your daily / monthly usages*. During our work we use *household activities* as a synonym to actions. In particular when interacting with users during our study.

people relate better to concrete activities then to abstraction

3.4 Exploring Product Categorisation in Related Work

In our work, we contribute by conducting an analysis between people's goals and technology reflected in the current product market landscape, and categorising observed elements. Thereby, we tried to understand how companies are marketing and grouping product solutions. We got inspired by related work and built upon previous attempts to cluster smart home solutions.

In the need finding study by [Takayama et al., 2012] participants specified various automation activities they implemented themselves. Researchers gathered all the stories

and categorised them in six main areas, security, lighting, energy, climate control, irrigation and entertainment.

Work by [Brush et al., 2011] proposed long-term home automation inhabitants a Home Application Store from which they could choose 17 different applications with the corresponding hardware, categorised in four categories, media, security/monitoring, environment and control such as set scenes or to have a centralised control of the automation system. For each application they asked them if they already have it and if they would buy it. Despite the same interest in home automation, Brush et al. found that installations and desires about the 17 applications were quite heterogeneous.

In their work, [Lee et al., 2008], produced one hundred and one smart home concepts that addressed identified user needs. They further clustered the concepts into seventeen themes including activity monitoring and scheduling, home security, and enhancing family relationships. The seventeen themes were then abstracted into the five high-level application areas activity management, logistical backup, opportunistic reminders, health and meal support, and family awareness.

[Woodruff et al., 2007] conducted research with 20 Orthodox Jewish families as long-term users of home automation. Due to their religious reasons and constraints activities like cooking and turning lights or appliances on and off are forbidden during Sabbath. In their case, during Sabbath when work in general is forbidden, automation supports lifestyle and long-term goals of spirituality, and to some extent slow living.

A [CapgeminiConsulting, 2011] study grouped product solutions into categories while trying to answer the question how well enterprises are understanding (potential) customers, respectively to what degree the demand and supply side coincide. Thereby, following terms have been categorised, security, building and equipment safety, energy efficiency, health / emergency, and comfort and entertainment.

A research project *Was ist Smarthome*[7] by the University of Siegen created a digital showroom of smart home solutions in order to inform beginners and prospective users about it. Their ultimate goal was to explore techniques how to make the topic of smart homes more understandable for the end users. During this process, they categorised solutions in three categories, safety, energy saving and comfort.

The Institute for Building Technologies composed a questionnaire[8] in order to support users in planning their smart home. End consumers are presented with the following abstract categories, that are further broken down into specific activities: heating, ventilation, lighting, shading, cooling, safety and other ideas.

3.5 Card Sorting as Evaluation

We used the Card Sorting Method [Soegaard and Dam, 2012] to verify the categorisation of the smart home solutions market landscape. The following section describes steps of this evaluation.

As mentioned above we firstly analysed the link between people's goals and technology that was found in the current product market landscape. We investigated how often each of the components was mentioned and summarised it into a cluster with abstract and corresponding specific goals. The first categorisation resulted in the following high level abstraction of lifestyle goals. (The complete synthesis with abstractions and actions can be seen on the right hand side in Fig. 3.3).

- safety / security / surveillence
- family
- elder care
- child care / parenting

[7] http://www.was-ist-smarthome.de/#Forschungsprojekt
[8] http://igt-institut.de/smarthome/fragebogen/#

- pets
- energy saving
- climate control
- entertainment / comfort / relaxing
- convenience
- healthy lifestyle

Identified lifestyle goals are building upon categorisation performed by [Ur and McManus, 2014]. They classified user needs elicited over Mechanical Turk[9] into the following labels, *security, lighting, energy, climate control, irrigation and entertainment*. These identified categories were further refined in our analysis.

In order to verify and evaluate the understanding of categorised actions and lifestyle goals, we performed a Card Sorting [Soegaard and Dam, 2012] with six participants (see table 3.5). The age of the participants ranged from 25 to 51, with a mean age of 31, and a median age of 26. Two people, representing one third were female. All six participants had or were pursuing a tertiary education (university) in a technical field. In addition, three of them had a user-centred Design Thinking education, and one worked as a teacher. We acknowledge the limitations connected to the sample of the participants and the generalisation of the lifestyle matrix, see Sec. 7.1.2.

3.5.1 Results of Card Sorting

Five out of six participants performed the categorisation similar to like we did, clustering themes of actions together and giving them a label. These results could directly be compared and taken into account while checking the validation of our classifying process.

[9] https://www.mturk.com/mturk/welcome, "a crowdsourcing Internet marketplace that enables individuals and businesses to coordinate the use of human intelligence to perform tasks that computers are currently unable to do"

Person	Profession	Age	Gender
A	Mechanical Engineer	51	male
B	Design Thinking, Information Technology Student	26	female
C	Design Thinking, Information Technology Student	25	female
D	Information Technology Student	25	male
E	Teacher and IT Student	33	male
F	Design Thinking, Information Technology Student	26	male

Table 3.6: Participants of the cardsorting evaluation

One participant decided to take an alternative route by categorising into three groups. Each consisted of a trigger and reaction, with the difference who performed the trigger and the following reaction. Options are whether it is a human or a technology. With this participant's approach three categories were formed. Firstly *Automagicallysation*, a combination of the word *magic* and *automatisation*. He understood this abstraction as having a perceived *magical* trigger and a reaction by technology. Second category consists of a technical trigger and a reaction by people. Last category was called *daily life support* and has people as both, trigger and reaction.

Based on the feedback from the participants we adjusted our lifestyle matrix. The comparison between the classification before and after Card Sorting can be seen in Fig. 3.3. Concrete changes are discussed in the following parts of the section. We photographed the respective Card Sorting results of participants and included the sources to the Appendix F.

Category Security Actions we clustered into this category were considered as fitting. However, one action is added to complement the range. We identified that some actions should also be put in Security that we had put in another category. In particular, *panic button - share your emergency and location* and *keeping track of your doors: lock and unlock up doors when appropriate (when you leave, when everybody leaves, unlock when a guest comes)*. One participant found that the former *panic button* belonged to the Family-Category, the same like we labelled the action. However, the remaining four participants found it more logical to have it ordered under the category Security, as it implies having some sort

lifestyle goal	#	actions	lifestyle goals before card sorting	actions before card sorting
Safety			**safety / security / surveillence**	
	1	smoke alarm and fire detector make sure the air in the house is not contaminated		smoke alarm / fire detector makes sure the air is in the house is not contaminated
	2	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video		see what is going on around the house: if wanted, take pictures / vidoes periodically or for instance if unusual motion is detected, if doors / windows open when they should not. The goal is to support to detect break-ins, and even help police detect the intruder
	3	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe		turn off burgulars alarm when ou arrive home / start it when ou leave home
	4	holiday mode: home appears occupied by randomly turning on/off lights & other media		holiday mode, make the house appear occupied by randomly turn on / off the lights
	5	panic button to share your emergency and location to friends, family	**family**	
	6	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)		panic button - share your emergency and location
Family			**elder care**	
	7	monitor bed- and bathroom during the night to detect if occupant does not return back		monitors motion sensors in bedroom and bathroom during the night, and detects if occupant does not return from the bathroom after a specific period of time
	8	get notified if loved ones depart from their expected daily patterns and behavior		get notified if elderly loved ones depart from their expected daily patterns and behavior
	9	track your children when they leave school zone, get notified when they come home	**child care / parenting**	track your children when they leave school zone
	10	baby monitor when you are not in the same room		baby monitor
	11	by turning off all lights in the home send a signal to the children that it is time for bed		turn off all lights in the house, at the same time a signal is sent to the children that it is time to go to bed
	12	get updates or check the pet when away	**pets**	check the cat / dog / other pet when away
	13	nearly home? automatically message the person who should know		
Energy Saving			**energy saver**	
	14	home stores solar power and coordinates between solar and energy usage		the house can store solar power, and coordinate the usage between solar and energy usage
	15	know your daily power usage, manage appliances to turn on & off when not needed		Through power monitoring you know your daily / monthly usage, and can manage your appliances to turn on and off and thus live more ecological, and simultaneously save money
	16	get notified about water leakage & shut it off remotely; monitor your water usage		In case of water leakage you get notified about it. Furthermore, the water monitoring allows you to know about your daily / monthly usages
Weather Control			**climate control**	Turn on your irrigation system when there is no rain, and turn it off when there is enough rain (smart irrigation system with integrated weather predictions and moisture sensors)
	17	irrigation system turns on when there is no rain, and turns off when there is enough rain		Monitors temperature, and does an action when a certain temperature is reached, or temperature drops below certain value.
	18	Monitors temperature, adjusts it by learning your activities; change temperature remotely		blinds / windows / doors opening & closing according to wheather and thermostat adjusting when doors / windows are opened
	19	blinds opening & closing according to weather and sunlight		
Atmosphere & Relaxing			**entertainment / comfort / relaxing**	
	20	set the right atmosphere, music, TV program and temperature		Set the right atmosphere, the music, TV program, temperature, ligthning
	21	set up the lightning according to your current mood or turn it on / off remotely		Turn on / off the lightning remotely, or set up the lightning according to your current mood
	22	wake up with customized dimmed lights, or when it is optimal to be woken up		Smart alarm: Wake up with the customized lightning that you wish, you can start with dimmed lights, or wake up when your sleeping activitiy (tracked by a fitness tracker) is in an optimal mode to be waken up
Convenience			**convenience**	
	23	your simple coffee-maker automatically turns on in the morning when you wake up		Connect your simple coffee-maker to a controllable outlet, and automatically turn it on in the morning when it senses motion in the bedroom or via smart phone
	24	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc		Set up an automated alarm to remind you to water your flowers, take out your trash, feed your pet, etc
	25	turns devices on/off according to arrival / departure; remotely turn off all appliances		Keeping track of your doors: lock and unlock up doors when appropriate (when you leave, when everybody leaves, unlock when a guest comes)
	26	floors will be vacuum cleaned automatically and the device will recharge itself		automatically turn devices on / off according to people's arrival / departure or remotely, for instance turn all kitchen (oven, toaster) appliances off when you leave home
				nearly home? direct message the person who should know
			healthy lifestyle	

Figure 3.3: Comparison of lifestyle matrix before card sorting (right side) and after (left side)

of emergency and threat one can try to avoid. The latter *keeping track of your doors* also makes more sense in Security then in Convenience as it addresses some safety concerns. In particular as the doors can be seen as the main entrance to one's home people strive to protect it as best as possible. Also, after the Card Sorting process the name of the category was decided to be labelled as Safety. Thereby, we eliminated the names security and surveillance from the category label.

Category Family Participants clustered all actions about family, pets, elder care and children under one category *family*. One participant concluded *it doesn't matter if it is a baby I watch or a pet, i would put that together into the same category*. The other two said *Family is all that because pets are family*. Further, the action we firstly thought was better fitting into the category of Convenience (*nearly home? direct message the person who should know*), was often placed into family, a decision we included into our model.

Categories Energy Saving and Weather Control Actions we grouped into these two categories coincided with actions participants clustered together. The difference was that two participants labelled all actions together under one bigger category in comparison to us who still separated them into two distinct labels. Nonetheless, we decided to keep the two categories separated considering there is still a major difference between the two. Energy Saving focuses more on a sustainable lifestyle whereas Weather Control implies more people are getting a convenient solution to their daily lives. Additionally, in the future each category will comprise a larger number of actions. Hence, it makes sense to provide a clear distinction although currently providing a relatively small number of actions under the labels.

Category Atmosphere and Convenience The contents of these two categories were clustered similar to our grouping. However, they were often put into one group by our participants. One participant labelled both groups together as *cosier living*. We were considering to take over that label name (cosiness). However, taking in account that in the future we will need to reconsider separating the categories back again into Atmosphere and Convenience, in particu-

lar when we add more actions, we kept the categories separated.

Category Healthy Lifestyle Healthy Lifestyle as a further category was not mentioned, nor missed by the participants. They responded they see healthy living more as a personal choice (by eating well and doing sports), rather than as solution they would look for under smart home products. Thus, currently, we decided not to include healthy living solutions into the model. However, we need to keep in mind that in the future healthy options might be considered as part of smart home solutions by the users, given the current continuous rise of wearables, Internet of Things and other connectivity devices.

3.5.2 Final Thoughts on Card Sorting Results

The categories are not to be considered final, because an action often might thematically belong to multiple lifestyle goals. In addition, every user or customer might find different actions sorted under different categories as more or less intuitive (see Limitations in Sec. 7.1.2). Due to future evolution of user needs or technical progress, the boundaries of the categories might become more or less strict. It all depends on the future direction of the mentioned two aspects.

3.6 Lifestyle Matrix

Having a classification of lifestyle goals and actions, we mapped needed controllers (hardware and software components) to each action. Thereby, in order to minimise people's association with companies, general controllers are listed (f.ex. *motion sensor*) without specifying brands. This neutrality is essential to elicit user needs and requirements without having brand preferences interfere with their choices (see the lifestyle matrix with mapped devices in Fig. 3.4). During the mapping process we differentiated between an *app* and *proprietary app*. Under *proprietary app*

the neutrality towards devices should minimise the influence on elicited user needs

we understand a mobile application that was developed specifically for the purposes of the hardware devices. In comparison, an *app* can be downloaded from the conventional store of the respective operating system.

Lifestyle matrix as the basis of the interactive prototype is the first step to narrowing the gap between technical solutions available and a users having ideas of what they could automate. It supports them in navigating through hardware and software components by rearranging the steps in the process. The first step for users will be to think about what they want to automate. Further, the prototype will give them a possibility to find the right technologies that support their goal, bridging the two worlds. The lifestyle matrix and the interactive prototype as a basis are concentrating on a people's driven approach based on current user needs. We do not aim to follow the technology driven approach or created new needs solely based on technology. On contrary, we have the vision that user needs and requirements should trigger the development of technology.

Lifestyle Matrix - Mapping Actions to Areas in the Home Given that most automation goals need hardware devices to be achieved and that these devices will have to be installed into users' homes, we mapped each automation to the area in the home where the installation could be setup. The mapping of actions to the areas in the home can be seen in Appendix, A. Furthermore, when we visually integrated actions as badges into the 3D models (see 5.7), we relied on the mapping of actions into the areas of the home to represent the location where the setup would be installed in people's homes. Lastly, this mapping will be valuable for subsequent implementations (see Sec. 5.7 and 5.9).

Lifestyle Matrix - Adding Estimated Complexity to Actions In order to learn more about the complexity of automation possibilities, we analysed how to achieve each of the intelligent solution and estimated its difficulty in terms of setup and needed adjustments to the home. We added our estimated complexity to the lifestyle matrix, see in Appendix, A. This estimation has not been practically proven, but gives some overview based on the results from search engines, forums and product sides.

lifestyle goals	#	actions	mapping to devices
Safety			
	1	smoke alarm and fire detector make sure the air in the house is not contaminated	smoke sensor (detects smoke particles, carbon monoxide, checks Air Pollution Index), proprietary app
	2	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video	door & window contact sensors, motion sensors, wireless sirens, video cameras, proprietary app
	3	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe	motion sensor, glass break sensor, door & window contact sensor, smart door system, burgular system (proprietary) app
	4	holiday mode: home appears occupied by randomly turning on/off lights & other media	light bulbs, media system, proprietary app
	5	panic button to share your emergency and location to friends, family	phone with gps or gps-device, app from store
	6	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)	smart door lock, door sensor (tells you if doors open), proprietary app
Family			
	7	monitor bed- and bathroom during the night to detect if occupant does not return back	motion sensors, proprietary app
	8	get notified if loved ones depart from their expected daily patterns and behavior	monitoring system, proprietary app
	9	track your children when they leave school zone, get notified when they come home	phone with gps or gps-device, app from store
	10	baby monitor when you are not in the same room	baby monitor with audio and video sensors, proprietar
	11	by turning off all lights in the home send a signal to the children that it is time for bed	light bulbs, proprietary app
	12	get updates or check on the pet when away	video, audio, motion sensors, proprietary app
	13	nearly home? automatically message the person who should know	smart phone (with gps), app from store
Energy Saving			
	14	home stores solar power and coordinates between solar and energy usage	solar panels, home solar battery, power grid-tie inverter, power meter
	15	know your daily power usage, manage appliances to turn on & off when not needed	power monitor sensors, proprietary app
	16	get notified about water leakage & shut it off remotely; monitor your water usage	moisture sensors, proprietary app
Weather Control			
	17	irrigation system turns on when there is no rain, and turns off when there is enough rain	sprinklers, garden hose, hose connectors, watercontrol system, soil moisture sensor, temperature sensore, access to weather predictions, proprietary app
	18	Monitors temperature, adjusts it by learning your activities; change temperature remotely	thermostat, open data readings from weather stations through app, heater / air conditioning, proprietary app
	19	blinds opening & closing according to weather and sunlight	smart blinds or blind opener, open data readings from weather stations through app, proprietary app
Atmosphere & Relaxing			
	20	set the right atmosphere, music, TV program and temperature	light bulbs, media system (audio, video), thermostat, proprietary app
	21	set up the lightning according to your current mood or turn it on / off remotely	light bulbs, proprietary app
	22	wake up with customized dimmed lights, or when it is optimal to be woken up	light bulbs, fitness tracker, proprietary app
Convenience			
	23	your simple coffee-maker automatically turns on in the morning when you wake up	smart power outlet, motion sensors, proprietary app
	24	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc	app from store
	25	turns devices on/off according to arrival / departure; remotely turn off all appliances	smart power outlet, motion sensors, proprietary app
	26	floors will be vacuum cleaned automatically and the device will recharge itself	robot that vacum cleans

Figure 3.4: Lifestyle matrix as the final outcome of the categorisation and mapping process

Chapter 4

Interactive Prototype Cashasa

The contribution of this work consists in bridging the gap between user automation goals and technical solutions available on the market. We aim to support people in the context of their goals to automate a certain task. Thereby, we are rearranging the steps in the process how users inform themselves about and browse for smart home ideas. One possibility to achieve this is to show goals first and needed technical devices second, the principle of our lifestyle matrix. Hence, the lifestyle matrix as the core of the interactive prototype is the first step to narrowing the gap between a multitude of technical solutions available and a multitude of users having and not having ideas of what they want or could automate. Our work aims to support users in navigating through hardware and software components by rethinking the steps. Firstly, users will think about what they would like to automate. Secondly, the prototype will give them a possibility to find the right technologies that support their goal.

we are rearranging the steps in the process how users browse for smart home technologies

In order to achieve this, the lifestyle matrix (see Fig. 3.4 and Sec. 3.6) connects these two distinct worlds, people's needs with technologies. It supports users in navigating through the heterogeneous market landscape. We have analysed various ways how to present the lifestyle matrix and simultaneously implement a visually appealing proof of concept.

lifestyle matrix connects these two worlds, people's needs with technologies

online web application with a visualisation brings scalability as it can reach more and more diverse groups of people

Our aim was to create a sufficiently usable prototype in order to collect more and better data to help answer the research questions. The choice fell upon a web application with an additional visualisation. The need for creating a visual online prototype has been critically analysed in 4.3. An online web application brings scalability as it can reach more and more diverse groups of people than traditional in-person or phone interviews. Hence, an automatic and scalable user elicitation method was preferred to manual elicitation techniques. Limitations upon this choice are discussed in Sec. 7.4.

Four main parts combined together result in the final prototype Cashasa (see Fig. 4.1). The upper left image in Fig. 4.1 represents the first part to Cashasa, the lifestyle matrix (see 3.6). The second part is the visualisation of a floor plan with integrated actions from the lifestyle matrix into the 3D model. This part will be discussed on a deeper level in chapter 5. Further, the questionnaire builds the basis for the elicitation of user opinions and is described in 4.4. Lastly, the User Interface (UI) brings all these parts together enabling a web application to be developed. We see branding as one UI part, discussed in 4.1. Other UI elements are mentioned in chapter 5.

4.1 UI part: Branding

One part of the UI mentioned above is the branding described in the following sections. The other part of the UI will be discussed in chapter 5 that illustrates the path from the first wireframe to the end prototype.

Name

Cashasa: **C**ustomer-centric **A**utomation-goals **S**cheme of **H**ousehold **A**ctivities in **S**patial **A**reas

Ultimately, after several iterations on the idea for a name, we found Cashasa. We decided upon a combination of the Spanish and Italian word *la casa* meaning home / house, and the German word Haus meaning house. Further, Cashasa officially stands for customer-centric automation-goals scheme of household activities in spatial areas. This is exactly what we are trying to achieve. We aspire to introduce a people-centric approach when displaying various

Figure 4.1: The four parts to the interactive prototype

options of possible household automation goals. Hence, our work proposes a scheme how to present these diversified solutions. In addition, we are integrating a 3D visualisation of a floor model to achieve a spatial metaphor for participants by triggering a ressemblance of the shown floor model and the participant's home.

Logo

When designing a logo we chose a house's outline as it symbolises a metaphor of a home. Although many people live in an apartment, the symbol of a house is often used to represent homes. Therefore, it can be

Figure 4.2: The Cashasa logo and name

logo symbolises a metaphor of a home

seen as a widespread understanding we made usage of.

Colours

Figure 4.3: Green (#57b682), redish pink (#FF5252)

Green as the main colour prevailed from the beginning. We tried a couple of other colours such as different shades of red, purple, orange and blue, but rather quickly decided on the shade of green with the hex code #57b682. We did not perform a deeper academic research on what colours represent what attributes in scientific literature, but relied on some widespread marketing studies. Green is often associated with balance, tranquility, nature, alleviating depression and growth (see [Zammitto, 2005] and FastCompany[1]). We evaluated the chosen shade of green to be fitting for the purposes and scope of our prototype radiating a calmness and tranquility. In order to find an accent colour to the primary colour green, we advised the material palette[2] provided by Google Material Design Guidelines. Here, we chose the accent colour to be a redish pink, with the hex code #FF5252.

4.2 3D Model as a Technique to Let People Relate More to Their Own Homes

3D floor plan should support users thinking in the context of their home when envisioning possible home automation scenarios

Once the choice of designing a web application as a proof-of-concept was decided, several iterations of possible prototypes were designed. Already early in the process, visualisation of a floor model with household activities was preferred to displaying only scenario-based user stories. We aimed to show actions from the lifestyle matrix (3.6) in a 3D floor plan to support thinking in the context of their home when envisioning possible home automation scenarios. [Takayama et al., 2012] discussed that home and automation do not go together as one is homey and the other

[1] http://www.fastcompany.com/3028378/leadership-now/what-your-logos-color-says-about-your-company-infographic

[2] https://www.materialpalette.com/

Figure 4.4: Example of Archilogic's spatial homes

cold. However, by displaying a 3D floor model to put people in the context of their home, we are hoping our prototype to be considered more *homey* than cold.

In order to achieve a more tangible visualisation we integrated a 3D framework designed and developed by a Swiss based spin off from ETH architects, Archilogic [3]. Their company's goal is to *rebuild the world in the web and in 3D - a city by city, house by house, room by room, wall by wall, chair by chair*. Shortly, Archilogic's motivation is to enable architects to describe and illustrate their ideas better to customers and future inhabitants.

Archilogic's goal is to *rebuild the world in the web and in 3D - a city by city, house by house, room by room, wall by wall, chair by chair*

4.3 Arguments for the 3D Visualisation

Archilogic framework [4] as a visualisation was chosen in order to let people think in terms of their homes when interacting with possible options of home automation. In the following sections we discuss the importance of such a visualisation on a more deeper level, adding to the arguments mentioned in Sec. 2.1.1 such as making automation more homey, applying design principle *Visibility* by Norman, using metaphoric design, discussing the visual vs. scenario-based communication and being aware that future audience is visual. Firstly, we will present the initial survey we

[3] http://about.archilogic.com/
[4] http://about.archilogic.com/

conducted to evaluate the choice of providing a visualised representation of people's homes. Secondly, we argue for the visualisation.

4.3.1 Initial Study Results

The survey we conducted addressed the question whether people needed a visualisation similar to their home in order to better relate to it (further details can be seen in Appendix, F). In total 99 people participated in the survey, 63,3% male and 36.7% female, with an average age of 28.36 and a median age 26. We spread the study over social media groups of local people and expats in Switzerland, Chile, USA and Australia and received answers from 21 different countries.

We gave participants three floor plan choices and asked them which one reminded them the most of their home. The answers they could give were the three floor plans, *A*, *B*, *C*, *all* and *none*. Out of all participants, 16.3% said that none of the floor plans reminded them of their home. 1% said all options reminded them, and the rest was distributed between the three: A with 13.3%, B with 29.6% and C with 39.8% (see results in Fig. 4.5). People who chose none said they lived on two floors, so the layout was different, the room sizes and numbers did not match or they found the style of the models too distinct from their homes. For the scope of our thesis, we aim to achieve a closer representation to people's homes. By doing so, we strive to let people identify themselves more with one of the suggested choices.

only 6.1% stated that they could imagine their home anyways

We further asked what elements people needed to be reminded of their homes. Out of 99 participants, only 6 people, meaning 6.1% stated that they could imagine their home anyways as it is in their mental model and therefore do not need any of the listed elements (number of rooms, existence of rooms, furniture, doors & windows or everything). The 6.1% consisted of 6 people:

- Hungary, 25, F

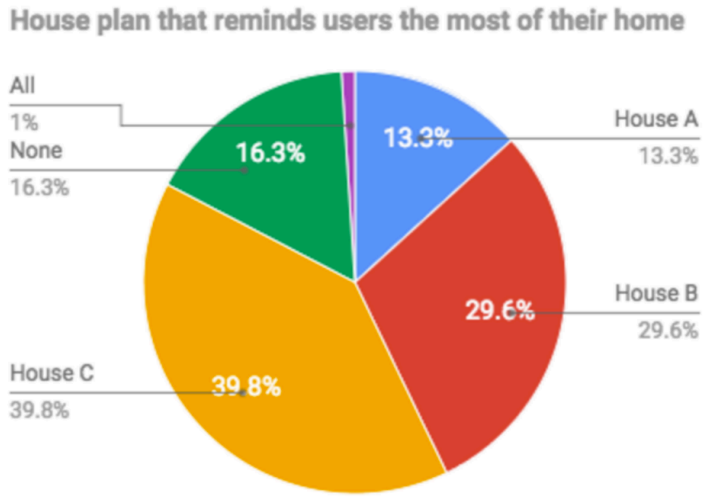


Figure 4.5: Survey feedback to what floor plan reminded them the most of their home

- Germany, unknown, M
- Switzerland, 25, M
- Sweden, 27, M
- Switzerland, 38, M
- Germany, 59, F

These 6.1% who chose *nothing, I can imagine my home anyways* appears to be very diverse such that we cannot draw a specific correlation between people who said they do not need a visualisation and their cultural, country or age. The other 93.9% stated they need some floor plan elements to relate to their home (see results in Fig. 4.6). Elements that supported people relate better to their home were in particular the number of rooms (34.6%) and the existence of rooms (28.4%). Some mentioned furniture (15.4%), doors and windows (14.2%). The remaining few said similar colours and cultural traits.

What this means for our prototype

Consequently, the goal for the interactive prototype is to customise homes of participants as much as possible and

customise 3D models as much as possible to provide as much similarity to their domestic spaces as possible

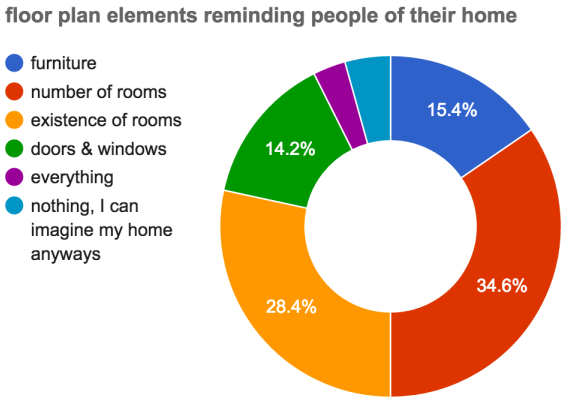


Figure 4.6: Survey feedback to what elements participants needed to imagine their home

provide them with as much similarity to their domestic spaces as possible. In general, we focused on providing different floor plan options in terms of number of rooms and existence of rooms, but did not consider very much furniture and colour decorations or cultural traits. Hence, our prototype takes into account whether participants have a balcony or a garden and how many rooms they have. Thus, users can choose between a range of houses with different layouts, bedroom number, and to some extent diverse furniture and colour tones. According to some user input in this survey, the aspect of colour shades in the floor plan might be important to feel related to one's home and will be considered in future work (8.1). Furthermore, in subsequent work users will be able to upload their own 2D floor plan that will be generated into the corresponding 3D model to provide a representation as similar it can be to their own home. As a long term goal, they will be able to add furniture by themselves, see their home either as a house, a flat in a building that is on upper, lower or multiple floors, and get their domestic environments illustrated such as village, suburban or urban (see Future Work in 8.1).

the aspect of colour shades in the floor plan might be important

4.3.2 Realising a Tangible Online Study

Furthermore, we argue that the 3D visualisation is going to make an online study more tangible. User interfaces build the basis for a product's usability and eventually its success [Marcus, 1998]. By providing a visualisation of actions in a 3D model resembling the domestic spaces of the participants rather than only a questionnaire form, we aimed to design our study as tangible as possible. A questionnaire displayed in a gamified version is less formal than a traditional survey. The informality makes it appear as a game, and stimulates the creative thinking more when thinking about elements they would like to automate in their homes, a strategy also used by previous works in [Gaver et al., 1999]. Gaver used informal postcards with questions instead of a typical questionnaire to trigger a communication with the elders' about their lives and cultural environment. Postcards were seen as a more attractive and friendly medium to ask elders about their personal lives. In return, they felt more encouraged to provide answers then they would have with a traditional questionnaire. As to some extent we are intruding into people's personal spaces - their homes - we believe that this informality yields more and better results.

informality makes it appear as a game, and stimulates the creative thinking

4.3.3 Design as Research

The term *design as research* has been brought up by works around experimental design who try to approach research from a more artist-designer site rather them from the traditional science- and engineering approach. [Gaver et al., 1999]. We took an inspiration in Gaver and thus are not looking to design solutions for specific user needs, but to reveal opportunities to discover new interests in the already existing products and ideas. With the focus on the visual questionnaire, we aim to provoke their thinking about what they would really fancy having in their home.

experimental design tries to approach research from a more artist-designer site

4.3.4 Economic Simulation Games

Incorporating the visualisation aspect, our usable interface can be viewed as an economic simulation game for several reasons. It is a system that represents and models the reality [Feinstein et al., 2013]. Further, it supports in decision making and teaching, which are defined as characteristics of simulations [Feinstein et al., 2013]. There is a motivational interest in simulations because of the game-like atmosphere the user is emerged in [Hyman, 1978]. With the implemented visual and gamification elements we aimed to motivate people to invest time getting to know, emerging themselves fully and completing the study. Through the game we are revealing options on the market to users, thus enabling them to achieve their goals.

4.4 Questionnaire as Part of Cashasa

As shown in Fig. 4.1 the questionnaire is one main part of Cashasa. The role of the questionnaire in the prototype is to elicit value for our study. Throughout various iterations on the questionnaire, we got feedback from HCI researchers, computer science students, professionals focusing on the Design Thinking methods and ultimately a couple of test participants on the content and wording. The final wording version can be seen in Appendix, B and the implemented version in Appendix, D. In chapter 6 we analyse the received results.

4.5 Architecture and Chosen Technologies

Cashasa was deployed to cashasa.com[5]

Cashasa was deployed on a DigitalOcean server that is physically situated in Frankfurt, Germany. The URL we deployed[6] Cashasa to is cashasa.com[7].

[6] we will only keep the survey online for a couple of weeks
[7] http://cashasa.com/

The web application Cashasa is implemented with the state of the art client side AngularJS[8] which provides some amazing features like the two-way data binding that automatically synchronises information between models and views and results in an extraordinary, expressive, readable environment. Thereby, HTML5 and CSS3 are extended by AngularJS to better fit to the dynamic content. We further integrated Angular Material [9], an implementation of Google's Material Design Specifications, to make usage of reusable, tested and visually modern UI components on the client side. The server-side runs on Node.js [10] that helps building highly scalable and concurrent applications rapidly.

HTML5 and CSS3 are extended by AngularJS to better fit to the dynamic content

We used a Firebase[11] service to store our data in the non-relational cloud database. Firebase is a document based, e.g. a nonSQL, database that on high level is used in almost the same way you would use a MySQL database. All data is stored as JSON in the cloud and can be syncronised to all connected clients in real time. The communication between our application and the Firebase instance happens through the exchange of JSON objects. Firebase further provides a *Security Rules* featuers to ensure quality of data updates.

Firebase as the nonSQL database in the cloud was the best fitting for the needs of our application

The Archilogic's framework that is mostly implemented in JavaScript provides us with the 3D floor model visualisations. We were given access to the code of Archilogic and the right to modify branches of code needed for the purposes of our project. Howeer, due to confidentiality reasons we are not allowed to share many details about it. The integration of Archilogic's framework into our application was done through an iFrame. This enabled us to establish a one-way communication through RPC (Remote Procedure Call) from our application to the iFrame (see one example in Snippet 4.1).

Listing 4.1: RPC code example

```
var message = {
        rpc: '2.0',
```

[8] https://angularjs.org/
[9] https://material.angularjs.org
[10] http://nodejs.org/
[11] https://www.firebase.com/

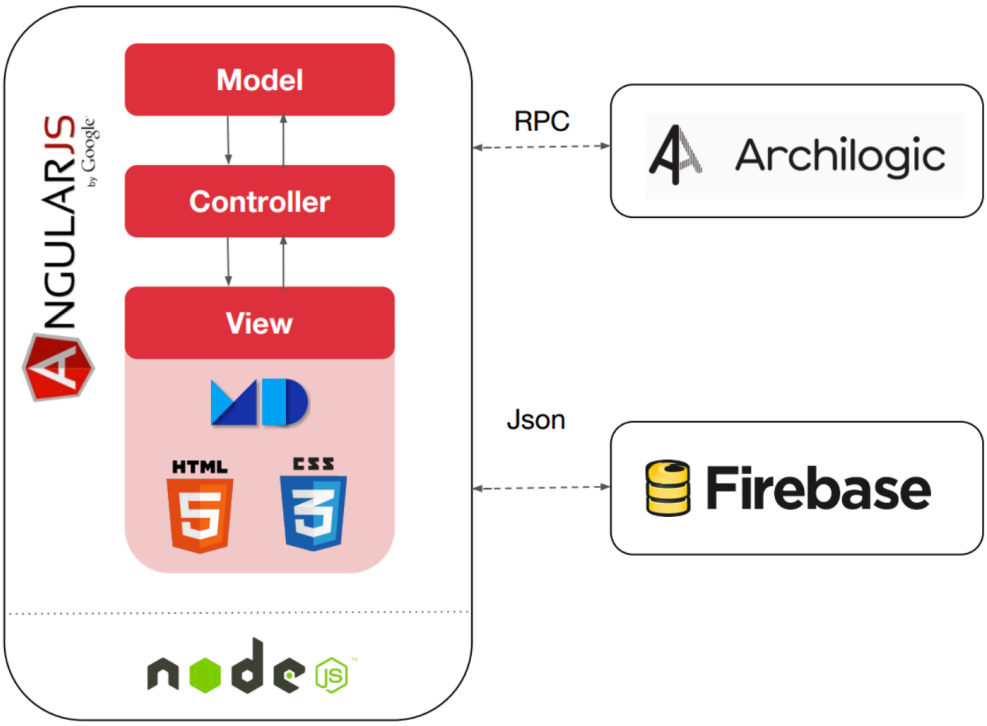


Figure 4.7: Architecture and chosen technologies for Cashasa

```
      method: 'script.run',
      params: {
        code: '(' + goToCamBookmark +')
        ('+\$scope.preference1[0].name+')'
      };
    };
```

A bidirectional communication was lamentably not technically feasible for the scope of the project and will be discussed in the Limitations, sections 7.2.2 and 7.2.2.

same objects are used throughout the entire stack

By using JavaScript language throughout the entire technology stack objects are all stored in the same format, JSON, meaning that the server and client always see identical objects. Using the same syntax improves readability of the code, database querying and displaying the objects on the client side.

Example: Randomisation of actions and lifestyle goals
As mentioned in Sec. 5.4, we completely randomised both, the order we show abstract lifestyle goals and the sequence of household activities within lifestyle goals. The randomisation minimises the influence we would have on participants' preferred activities when always displaying the same arrangement of actions and lifestyle goals.

Listing 4.2: randomisation of lifestyle goals and actions

```
for(var i = 0; i<categories.length; i++) {
  var category = categories[i];
  var actions = [];
  for(var j = category.start; j<=
      category.end; j++) {
    actions.push({
      url: "/images/actions/action" + j
          +".png",
      name: j,
      drag: true,
      mapping: mapping[j-1].devices
    });
  }

  randomInput.push({categoryname:
      category.name, randomAction :
      shuffle(actions)});
}

\$scope.shuffledCategories =
    shuffle(randomInput);

/*
shuffle array: for categories and for
    actions within categories
*/
function shuffle(array) {
  var currentIndex = array.length,
      temporaryValue, randomIndex ;

  // While there remain elements to shuffle...
  while (0 !== currentIndex) {

    // Pick a remaining element...
    randomIndex = Math.floor(Math.random() *
        currentIndex);
    currentIndex -= 1;
```

```
    // And swap it with the current element.
    temporaryValue = array[currentIndex];
    array[currentIndex] = array[randomIndex];
    array[randomIndex] = temporaryValue;
  }
  return array;
}
```

Chapter 5

The Road to Cashasa, The Final Prototype

This chapter discusses the evolution of an idea from the first wireframe to the end prototype. We are illustrating the main thoughts and choices we pursued on the way. As mentioned in chapter 4, the interactive prototype Cashasa consists of four main parts. This chapter will focus mostly on the UI part (see 4) that combines all other elements, the lifestyle matrix (3.6), the 3D model visualisation (4.3) and the questionnaire (4.4). Each section describes a different prototype iteration. Prototypes are discussed by generally describing the ideas. When applicable we further discuss implemented features and reveal received feedback and learnings we accumulated during the respective iteration. We understand and use the term *wireframe* for a not yet technically implemented prototype, but a sketch or drawing consisting of some vital elements.

5.1 First Prototype - A Wireframe

We visualised the initial ideas relating to Cashasa in the wireframe in Fig. 5.1. The flow of the prototype is the following: the user comes to the landing page (I in Fig. 5.1) and finds out that this application's aim is to make their

Figure 5.1: Wireframe of the first prototype

home smarter. The next screen (II in Fig.5.1) shows the same floor plan model for everybody and asks users how they would like to make their home smarter. All users see a certain amount of money they have available to later *buy* automated household activities. Further, they see two buttons with options on how to browse for smart home solutions. One button displays solutions *by rooms* and the other *by lifestyles*. If the user clicks on the button *by lifestyles*, he or she see a list of different abstract lifestyle goals (III in Fig. 5.1). Specifying one of the lifestyle goals (IV in Fig. 5.1), a detailed list will be revealed of household activities that could be automated in the home.

5.1.1 Implemented Features

Design of the icons for household activities

When starting the first prototype iteration we already finalised the market analysis and created the lifestyle matrix (in 3.6). Given that lifestyle goals and respective household

activities serve as the core for the interactive prototype, we aimed to use metaphors when talking about household activities. As discussed in Sec. 2.1.1, the use of metaphors in user interfaces helps communicate more effectively and aids to recognise, understand and remember information more easily [Marcus, 1998]. Thereby, having one specific icon representing each household activity would increase the recognisability and understanding of the latter. In next iterations we will discuss further design elements of household activities with all other design aspects integrated. Final designs with the respective icons for each household activity can be seen in a later section in Fig. 5.9.

as lifestyle goals and household activities serve as the core for Cashasa, we designed recognizable icons for each action

5.1.2 Feedback and Learnings

General vs. customizable floor plan models
After testing this wireframe with a couple of students and simultaneously conducting a survey described in Sec. 4.3 we concluded that we should not provide one general floor plan, but should offer a selection of various 3D models to participants. We focused on the feedback from the study (in Sec. 4.3) to providing different 3D model options in terms of rooms and existence of rooms, but did not consider very much furniture, colour decorations or cultural traits. Hence, in the next prototype (see Sec. 5.2) we aimed to constitute whether participants have a balcony or a garden, how many rooms they have, and in what area they live. From this parameters we will conclude what model fits the users best.

we should customise 3D models as much as possible

Aspect of money in the prototype
The first idea integrated the aspect of money by giving each user the same amount of funds. Each smart home solution (called *household activity*, see definition in Sec. 3.3) would have their own prise. After reevaluating the aspect of money, we decided that all household activities should *cost the same* such that participants do not choose the ones they could or could not afford in real life. Among others, our goal during this work is to elicit user needs and what household activities participants prefer. Therefore, we wanted to minimise the risk that users would be dis-

tracted from choosing their preferred household activities by being given a certain amount of money. The aspect of money is therefore completely excluded from our prototype.

Sorting by rooms in the prototype
The first wireframe followed the idea that the interaction with the 3D floor plan will be bidirectional such that users will be able to specify elements within the model. However, due to a technical limitation (see Sec. 7.2.2) we were not able to completely interact with the 3D model. Thus, the feature where a click by the user within a certain area of the 3D model would reveal household activities could not be implemented. Therefore, the feature mentioned here in the first prototype (III in Fig. 5.1) *show by rooms* was not further implemented for the scope of this thesis. However, lifestyle matrix 3.6 was mapped to the areas of the house such that this feature can be reimplemented once it's technically feasible (see future work in 8.3).

5.2 Second Prototype - Customisable Floor Plan Models

In the second prototype we expended our first wireframe with adding further questions relevant for the study and the aspect of customisable layouts. We ask participants to specify on which floor they live, whether they have a balcony or a garden, and to choose the number of rooms. The created flow to the second prototype is illustrated in Fig. 5.2. At this point we assumed people who live on upper floors might have a balcony, and people who live on a lower floor might have a garden. In this iteration we did not consider that people living in lower floors could have both. However, later we included this possibility.

we modelled multiple floor plans suggestions depending on the input factors

The wireframe to the second prototype
The second wireframe extended the first one by the questions about age and home automation (I and II in Fig. 5.3), the aspect of specifying where one lives (urban or suburban, see III and IV in Fig. 5.3), whether they live on lower or

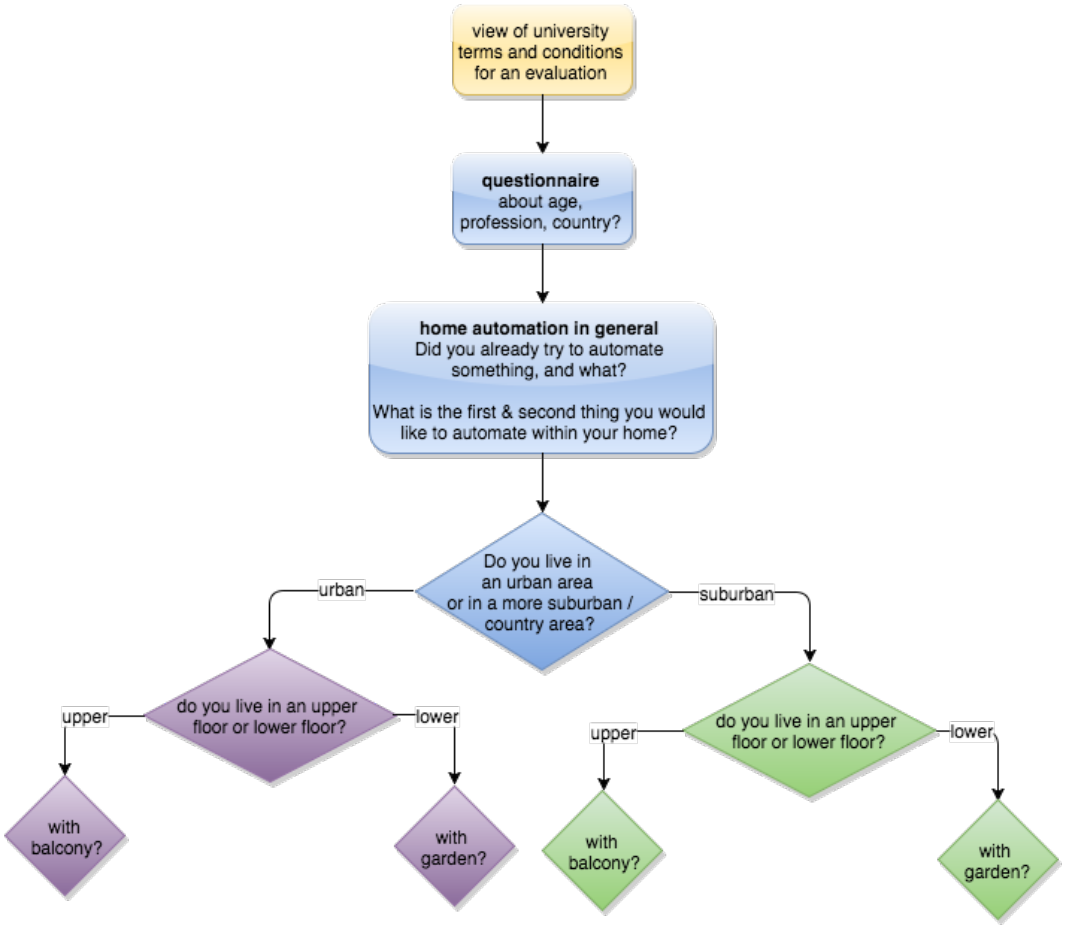


Figure 5.2: User flow of the second prototype

upper floor and if they have a balcony or a garden (V, VIa and VIb). Further, we modelled multiple floor plan suggestions (VII), depending on the input factors that can be chosen depending on the number of rooms. After the user has chosen a floor plan model that resembles their home the most, we provide them this 3D model in the application with all the features described in the previous prototype iteration (see 5.1).

5.2.1 Feedback and Learnings

The option of choosing variations of 3D models to resemble peopel's homes better received a highly positive feedback

Figure 5.3: Wireframe of the second prototype

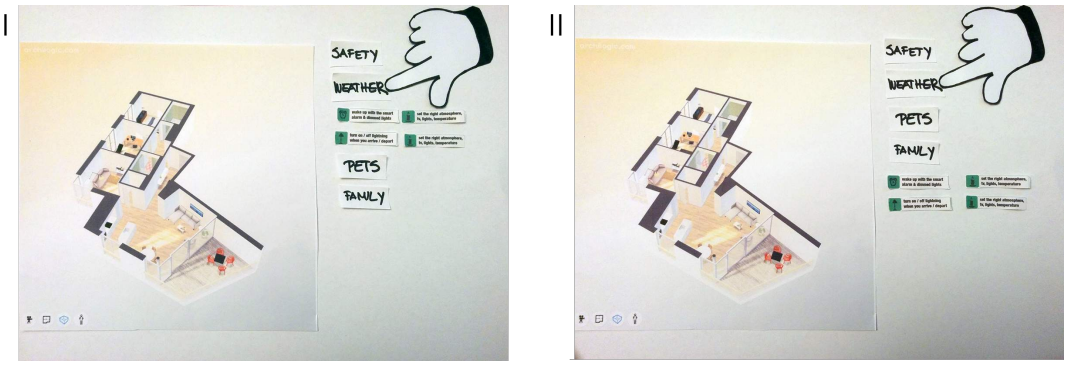


Figure 5.4: Sketch of first design around household activities

from our test users. Thereby, the flow and order of different views was considered logically designed.

5.3 Third Prototype - Arrangement of Household Activities

The goal of this prototype was to perform an analysis how to organise all household activities defined in the lifestyle matrix (see 3.6) such that the user sees them in a logical way. Having a fixed screen size as a restriction we designed possible arrangements discussed below. Further, in a next step we analysed how to best ask people to pick their favourite five household activities.

5.3.1 Implemented Features

Design of the view due to screen limitation
Given that a large proportion of the screen space will be taken by the 3D floor model, we have a rather limited space to design the arrangement of the household activities. Here we discuss a couple of iterations we prototyped.

there is a rather limited space to design the arrangement of the household activities

First draft (see Fig. 5.4): user clicks on abstract lifestyle goals, and the household activities are shown on click. They are either shown below all categories as in I, Fig. 5.4 or directly below the clicked lifestyle goal as in II, 5.4.

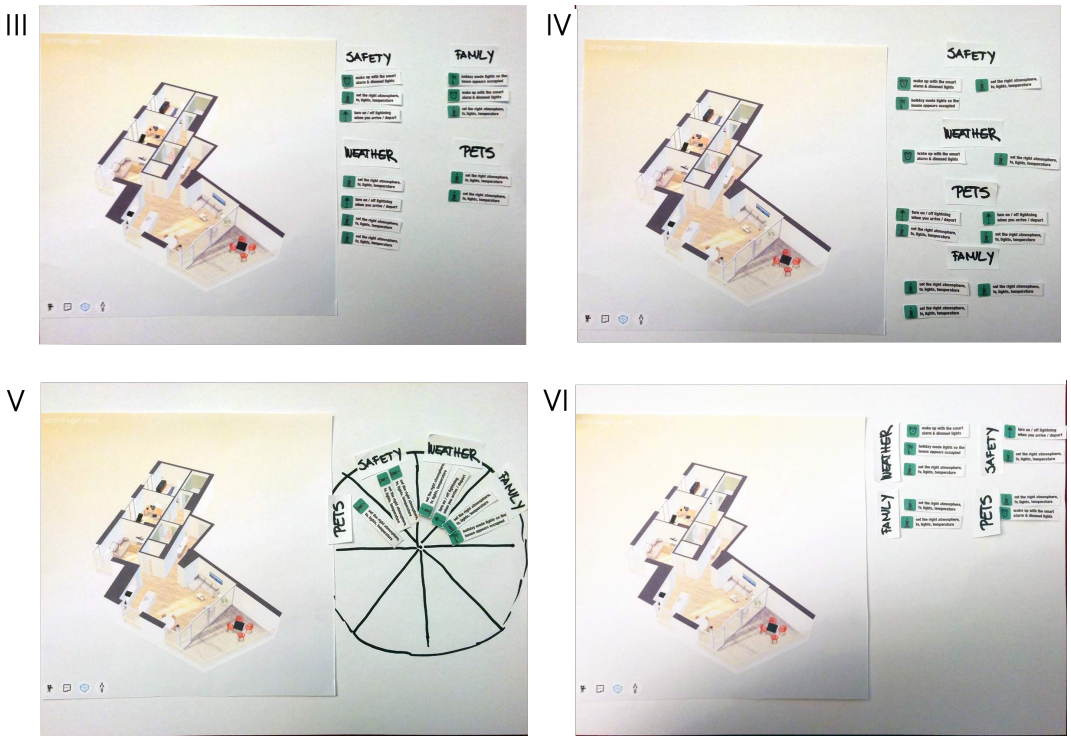


Figure 5.5: Sketch of second design iteration around household activities

all household activities should be shown easily

Second draft (see Fig. 5.5): In the previous two sketches (I and II in Fig. 5.4) we only show household activities when the user clicks on the abstract lifestyle goal. However, in order to give a full overview of all household activities and to minimise the risk that users will not go through all household activities, we need to show all without the need to click. Hence, during this iteration we improvised different groupings of abstract lifestyle goals and household activities. Finally, we went with the design of IV in Fig. 5.5, making sure we have space for at least two household activities in a row.

how to ask which household activities participants prefer the most

Designing the feature 'pick your five favourite household activities'

One of the main aims of our research is to elicit user preferences in the context of smart homes. Thereby, we evaluated how best to ask which household activities they prefer best. We have prototyped three fundamental designs (see Fig. 5.6). Sketch I in Fig. 5.6 shows all household activities listed without showing the user the abstract category.

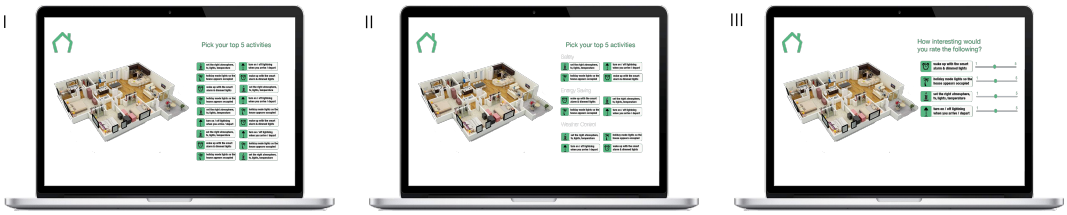


Figure 5.6: Drafts of feature 'pick your favourite household activity'

Sketch II extends the design described in the last section (see IV in Fig. 5.5) where we show all household activities listed below the belonging abstract lifestyle goal. The last sketch III in Fig. 5.6 experimented with showing users all household activities separately with the aim to get each of them ranked on a scale between one to five.

5.3.2 Feedback and Learnings

Pick up to five household activities

we reassessed whether we should oblige all participants to choose exactly 5 preferences

After testing iterations II and III shown in Fig. 5.6 it resulted in the feedback to reassess whether we should oblige all participants to choose exactly five household activities, thereby risking to get incorrect answers when people feel obligated they should specify that many. Alternatively, we could make this question more flexible and let users choose up to five preferences. Further, we were made aware of the time issue in surveys, and that people might not want to go through all of the household activities to rank them all as in III of Fig. 5.6. Hence, in future designs, we will not ask them to rank all household activities. Furthermore, we designed an *up to five* possibility in order to elicit people's preferences only rather than get false preferences as they might feel obliged they need to specify exactly five.

5.4 Fourth Prototype - Design of Household Activities as Badges

After prototyping the arrangement of lifestyle goals and household activities to show (in Sec. 5.3), we investigated how to best design these elements. We called this visual

badges is used as term for the visual representation of household activities

representation of household activities *badges* and will use the term in the future. Figure 5.7 shows a couple of designs, starting with the draft used since the beginning as in I, and seven further designs in II and III. Lastly, from the eight different designs we decided to pursue the middle one in sketch III because it is the closest to Material Design Specifications[1], design guidelines we used in our architecture described in Sec. 4.5.

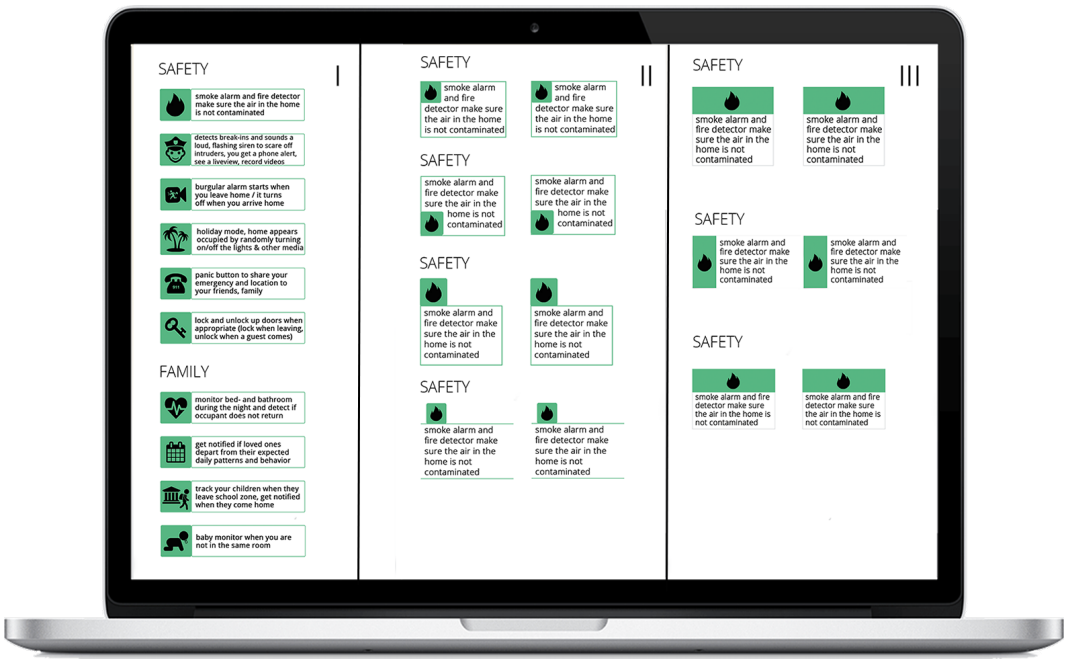


Figure 5.7: Drafts of household activities' badges

5.4.1 Feedback and Learnings

Based on the feedback the middle design from sketch III Fig. 5.7 was considered as the best design. Hence, we created a wireframe with all household activities defined, see Fig. 5.8 showwing one extract. Given that we have 26 different household activities, it will not be possible to show them within one glance, but we will create a scrollable area to reveal all.

[1] http://www.google.ch/design/spec/material-design/introduction.html

Figure 5.8: Wireframe with final household activities' badges

5.4.2 Implemented Features

Randomisation of shown top level lifestyle goals and household activities

The view of lifestyle matrix' goals and household activities (see 3.6) shown in the application is completely randomised. Each top level lifestyle goal is shown in a randomised order as well as each household activity within. By it, we aim to minimise the risk of influencing participants on their choice of preferences by the display order of lifestyle goals or the according household activities.

we completely randomised both, the order we show abstract lifestyle goals and household activities within lifestyle goals

Presentation of household activities in 2D

At this point we integrated all aspects discussed around top level lifestyle goals and household activities, from the lifestyle matrix (Sec. 3.6), such as the icon design for household activities in Sec. 5.1, the arrangement discussion given the screen size limitation in Sec. 5.3 and the design of badges in this section. This visuals to the implementation can be seen in Fig. 5.9.

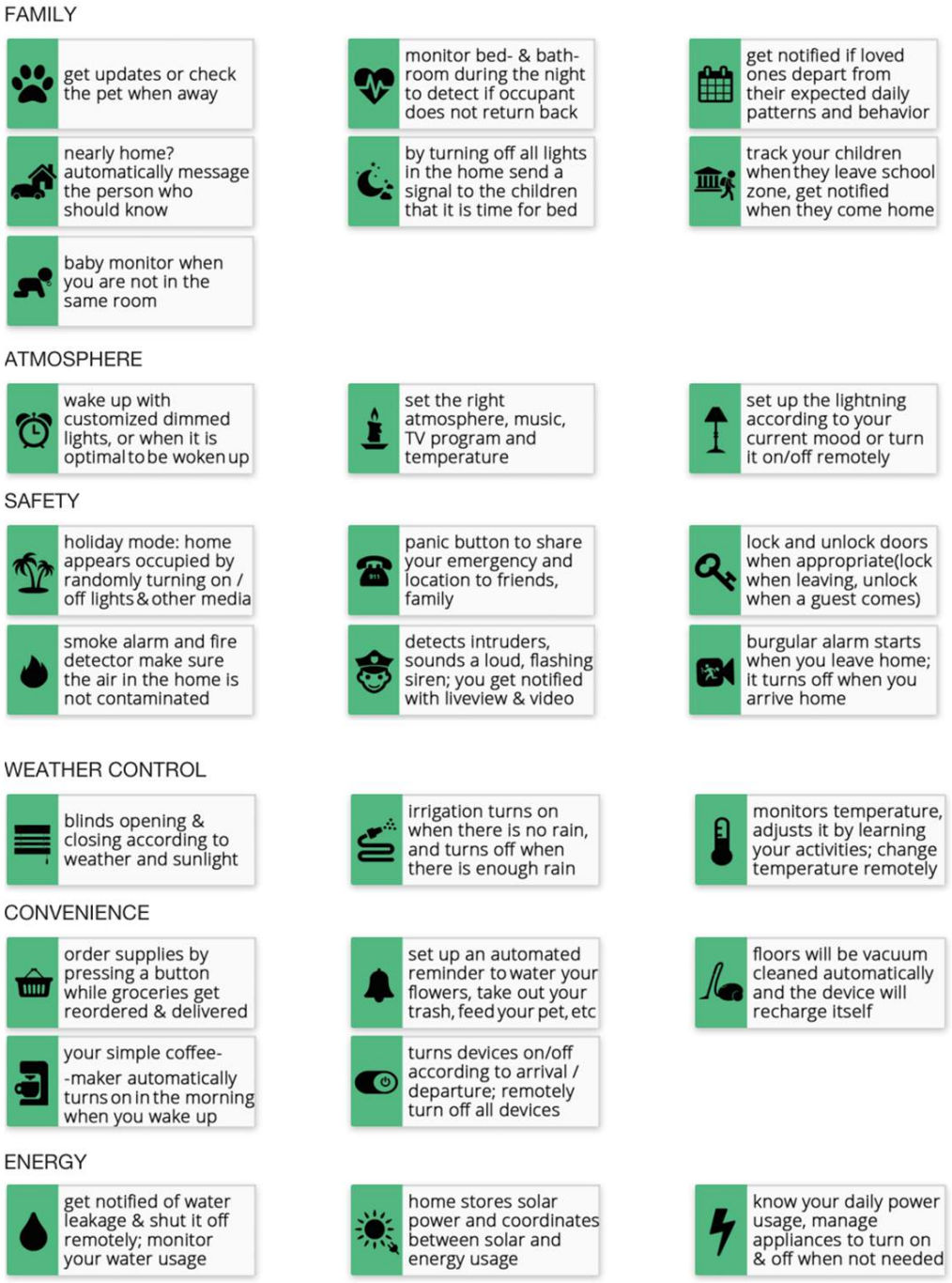


Figure 5.9: All household activities elaborated

5.5 Fifth Prototype - Different Floor Plan Layouts

During this prototype we focused on implementing the customisation of the floor model (as discussed above in Sec. 5.2) and designing the user flow such that it is as easy and understandable as possible for the user to choose the floor model that most resembles their home. Hence, we included questions about user's living situation (see Fig. 5.10). The relevant questions for us to later provide suitable floor models are the one about the number of bedrooms and about balcony or garden existence. Based on this user input we will show them up to three floor models that fit to the criteria as can be seen in Fig. 5.10. Hence, the user can decide upon one of them. Subsequently, in the remaining part of the study we will use the model chosen by the user.

decide which floor plan is most suitable for the user

5.5.1 Implemented Features

Customisation of the shown 3D model
We customised the 3D floor model shown to the user such that it resembles their home as much as possible. Hence, we prepared 18 different layouts of 3D home models considering the aspects of the number of rooms and the existence of balcony or garden.

To achieve this we adapted existing 3D home models from Archilogic[2] database such that they fit our needs. For some of the models we had to add a room, balcony, garden or change furniture. These were mostly only minor changes in comparison to the time and effort put by 3D graphic designers in the already available models.

Table 5.1 illustrates the number of models we prepared for the scope of our prototype: We set up 18 diverse 3D floor plans for the customisation purposes, 9 with a garden and 9 with a balcony (see all models in Appendix C). If a user

we modelled 18 different 3D floor plans, 9 with a garden, 9 with a balcony

[2] http://about.archilogic.com/

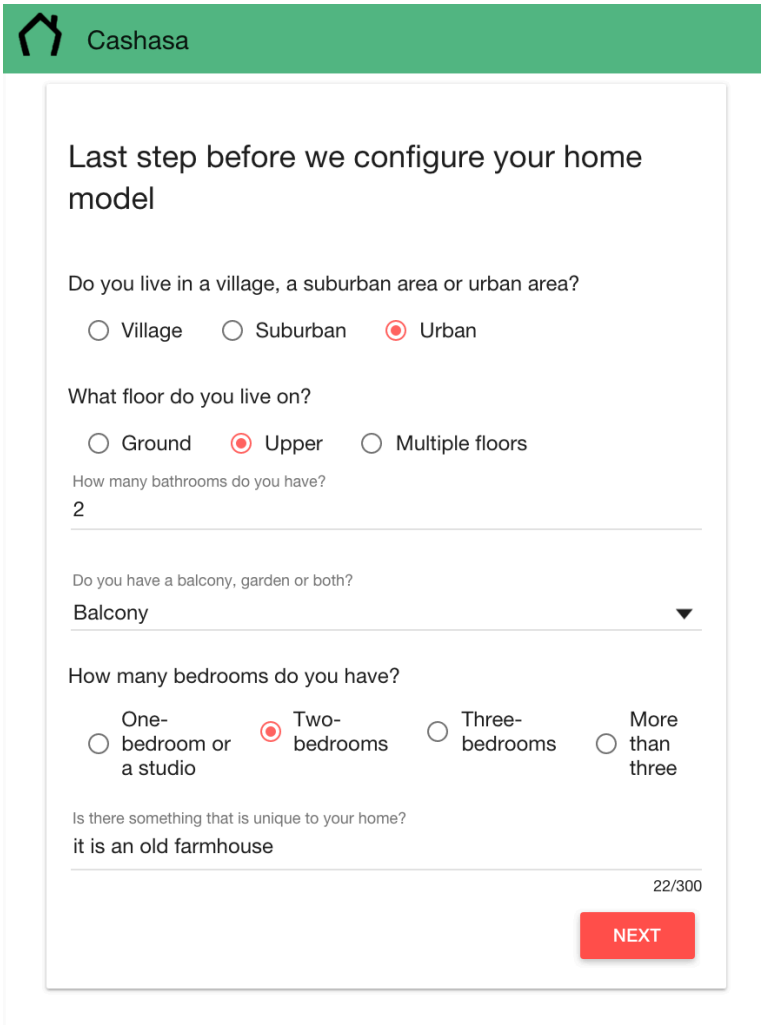


Figure 5.10: Screen of the last questionnaire step before configuring the model

	1 bedroom studio	1 bedroom	2 bedrooms	3 bedrooms
with garden	1	2	3	3
with balcony	1	2	3	3

Table 5.1: Number of different 3D models used in Cashasa

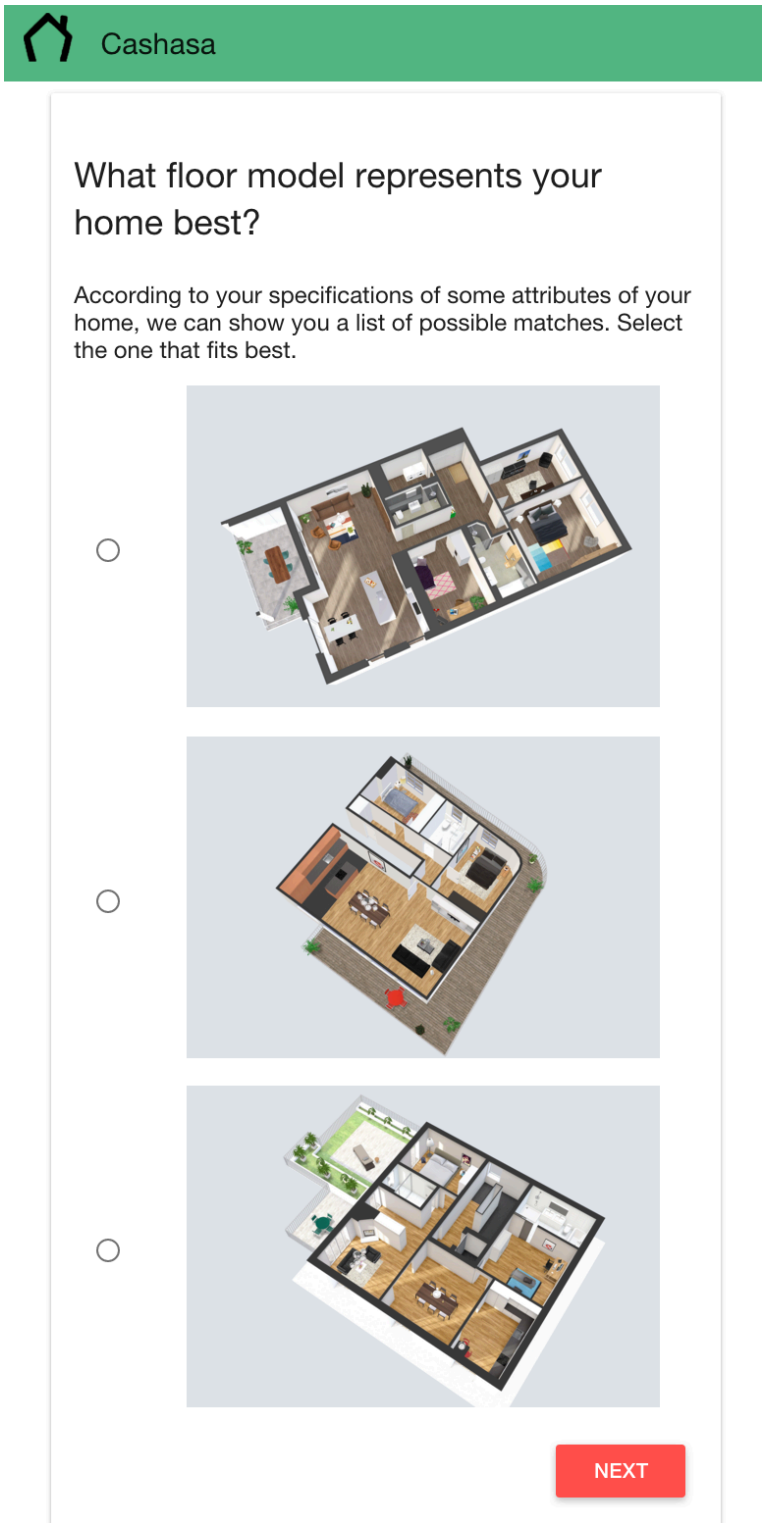


Figure 5.11: Choice of different floor model layouts screen

specifies to have both we will show them options of models with a garden only. If they specify they have none, we will show them models with a balcony. Each user will be presented with 3 models to choose from based on the two factors number of bedrooms and existence of the balcony or garden (see example in Fig. 5.11).

5.5.2 Feedback and Learnings

Our initial test users, in particular Computer Science students from the University of Zurich, stated they like to see a more personalised 3D model. One stated that she liked the 3D model had some details she also owns, like the red bicycle and similar IKEA furniture. Given that we cannot take all factors into account, the representation of the 3D models will not entirely correspond for all participants.

Further, we experimented with how many different model options participants will ultimately get to see and choose from (view in Fig. 5.11). Firstly, we showed 5-7 different houses, but received the feedback that this was too much as users might not be able to decide between this rather large amount. Ultimately, we provided only three different models to choose from.

Lastly, we experienced some ambiguity about the question *how many bedrooms do you have* and pre-offered answers *One, Two, Three, More than three*. Among the issues were, where does a studio belong, whether a living room counts as a bedroom and what exactly is counted as a room. Ultimately, we provided more specific answers such as *One-bedroom or a studio, Two-bedrooms, Three-bedrooms* and *More than three*.

5.6 Sixth Prototype - Drag & Drop Preferred Household Activities and Mapping to Devices

We laid most focus on the screen of our prototype where the user sees all household activities and the 3D model. On this screen we aspire to elicit what users prefer the most. Thereby, a drag and drop feature should support the elicitation of the most preferred household activities. Figure. 5.12 summarises most of the previously discussed features. Furthermore, on this screen users are made aware of the devices needed to achieve each respective automation.

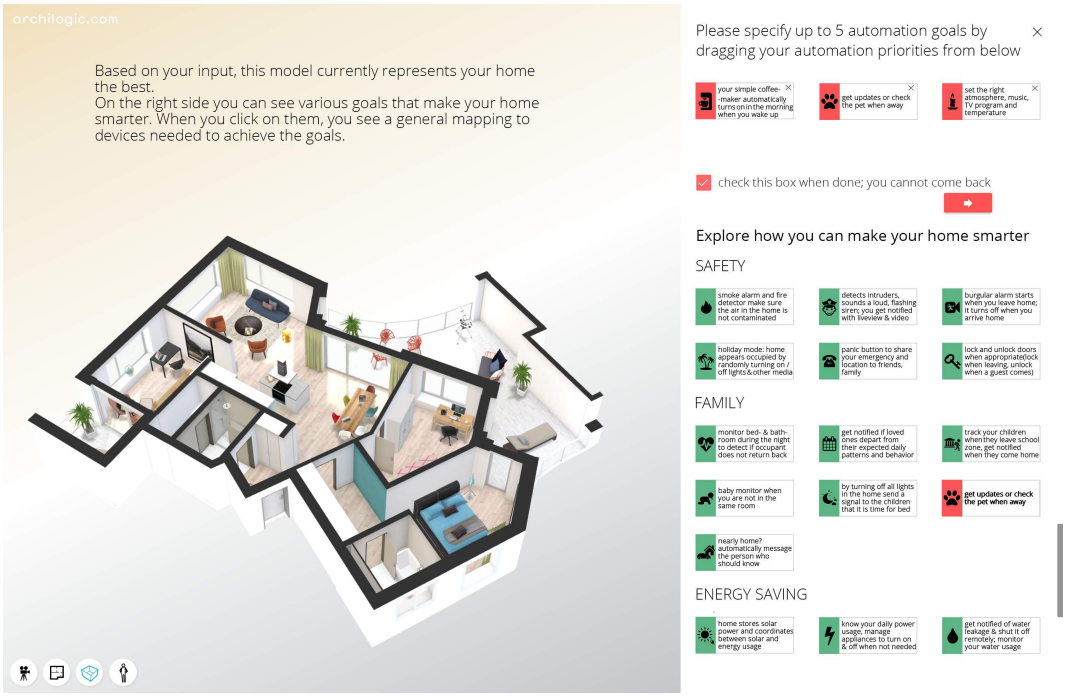


Figure 5.12: Wireframe of the sixth prototype iteration, screen 1

5.6.1 Implemented Features

Drag and drop preferred household activities
The aim of the view showing all household activities and the 3D model is to let the participant drag and drop up

once a household activity is drag and dropped, it triggers a colour change in the prototype

to five preferred intelligent home improvements. Once a household activity is drag and dropped, it triggers a colour change in the prototype such that users know which ones they have already chosen. When done interacting with this page, the user can go to the next view (see Fig. 5.13), where they see chosen household activities. On this page we will further ask questions why they had chosen these household activities and try to elicit how the floor plan model supported them in their selection.

Figure 5.13: Wireframe of the sixth prototype iteration, screen 2

this work maps general devices to household activities rather than specific products

Implementing *mapping to devices* based on the lifestyle matrix

In the lifestyle matrix (3.6) we mapped each specific household activity to a range of general devices needed to achieve the respective automation. To integrate this mapping within the prototype we thought of multiple ways to visualise the mapping: it could appear as a pop-up, a slided window from the right, a tooltip or a new tab opening. For the scope of this thesis we decided to implement the mapping to devices via the tooltip. This has several rea-

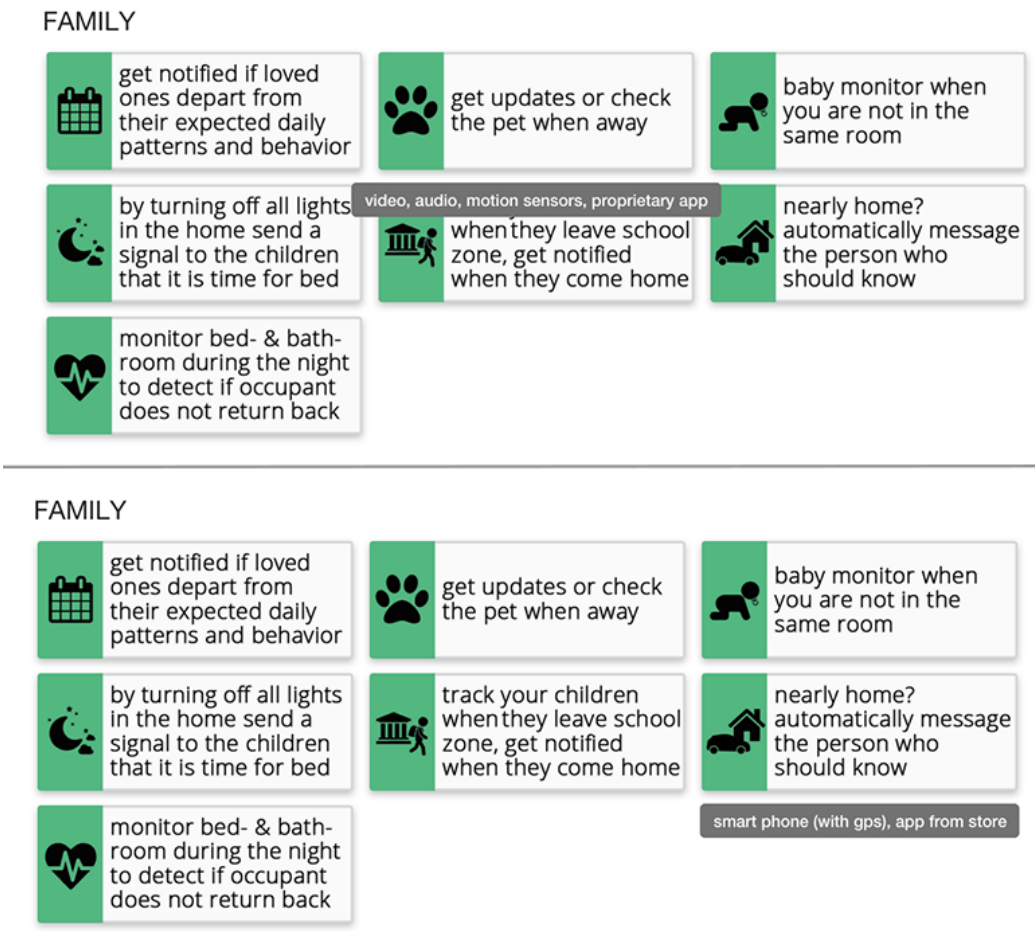


Figure 5.14: Implemented *mapping to devices* feature

sons. Firstly, in this work we concentrated on showing general devices only rather than specific products. Secondly, we did not want to break the clean design by introducing another pop-up window or a slider given that we will not present specific devices but the generalised versions. Hence, by having the limitation of the prototype that did not allow us to design these devices as 3D models and integrate them into the 3D floor plan view, implementing the mapping as tooltips was the best method. An implementation example can be seen in Fig. 5.14 with isolated household activities, and in Fig. 5.15 embedded into the entire screen design.

mapping household activities to devices was implemented via tooltips

The choice of visualisation method for the feature *mapping to devices* faces one major limitation on touch devices (see in Limitations, 7.5.3). However, the prototype was implemented and optimised as a web application to work on a desktop machine.

5.6.2 Feedback and Learnings

Badges of household activities decoupled from the 3D model
At this stage of the prototype the household activity badges in 2D were still decoupled from the 3D floor plan. Without having a representation of the badges within the prototype, it is difficult of the user to interact with it. This aspect is addressed in the next iteration (in Sec. 5.7) where we integrated the badges as 3D boxes into all 18 models.

Areas of the elements within the screen
Based on the feedback we identified a lower usability due to the arrangement of the screen as in Fig. 5.12. Thereby, we swapped the sides of the elements to improve usability and implemented the new version as in Fig. 5.15. In this figure, the implementation of the mapping to devices is visible. We further tested the arrangement of elements as in Fig. 5.15, and still received mixed feedback. In the next Section (5.7), we redesigned the screen based on the testing results.

5.7 Seventh Prototype - 3D Badges Interact with 2D Badges

Here we integrated the *iFrame* with the 3D model and established *RPC (Remote Procedure Calls)* between our application and the provided 3D model by Archilogic.

As mentioned in the previous section, the organisation of the areas within the screen with the 3D model and household activities was not completely logically usable. Thus, we rearranged it taking out the drag and drop area from the left side and put to the top as full width. Further, we swapped the floor plan area from the left side back to the

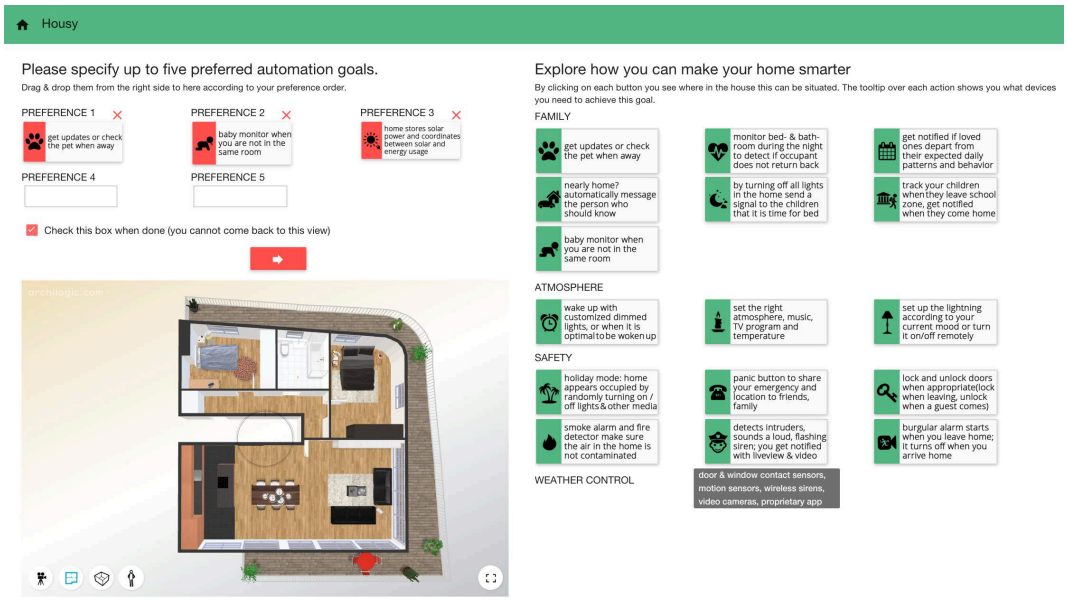


Figure 5.15: Implemented screen of the sixth prototype iteration

right side. The area with household activities was swapped back to the left side of the screen because we would like people to focus on the this area first, and on the 3D model second. The changes are reflected in Fig. 5.16. Given that western countries read from left to right, this order will more likely match western standards.

5.7.1 Implemented Features

3D badges within the 3D models

We created 3D badges to represent household activities within the 3D models and integrated them into all 18 different floor plans. The location of the household activities within the 3D floor plans was based on the *Lifestyle Matrix - Mapping household activities to Areas in the Home* (see mapping in Appendix, A, and discussion in 3.6). As can be seen in the Fig. 5.16, each household activity is represented as a box with the action's icon on top, and the combination of its icon and description on the sides. This feature was technically feasible due to the fact that we could reuse predefined boxes created in the Archilogic's framework.

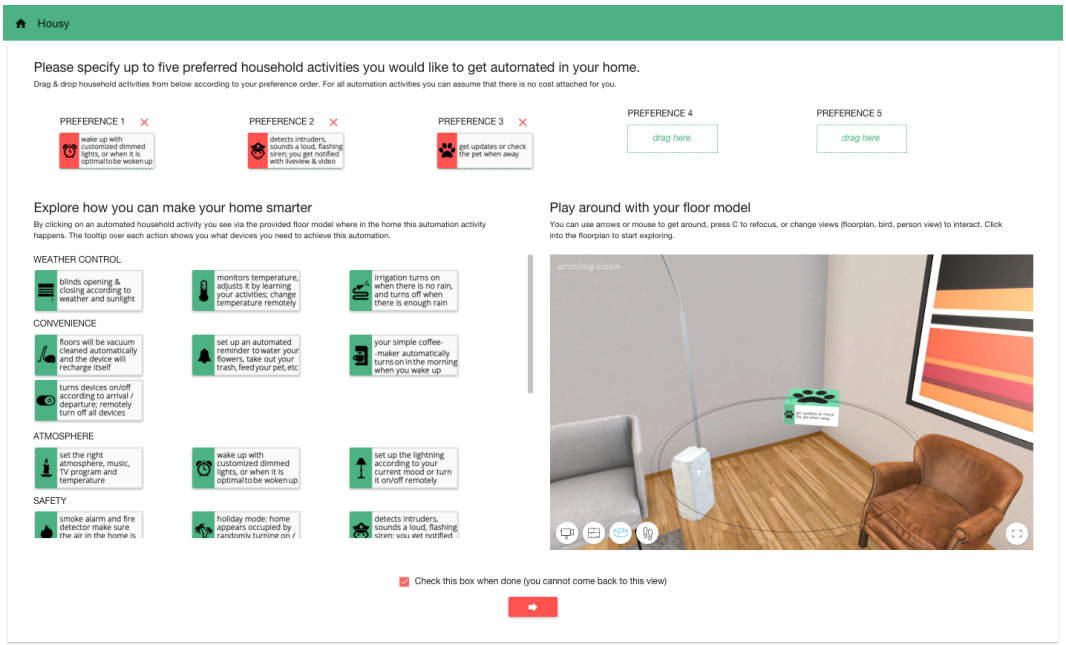


Figure 5.16: Badges of household activities in the 3D floor model

Interaction between household activities' buttons and 3D floor models was implemented

Interaction between 2D and 3D badges
A further implemented feature in this iteration was the interaction between household activities and the floor model, more specifically, the unidirectional communication between the application and the iFrame provided by Archilogic, as described in 4.5. When the user clicks on an action within the application, the 3D model will be zoomed in to reveal where the automation of this household activity could be situated in the home. The same happens when the user drag & drops an action into the designated preference field. In the figure, it can be seen that after the user specified 'get updates or check on the pet when away' as preference 3, the floor model is zooming into the spatial area where this could be automated.

5.7.2 Feedback and Learnings

Badges within the 3D floor model representing household activities received a really positive feedback. However, people found it difficult to distinguish between various top level goal just by a glance. In order to address this issue we

gave each lifestyle goal another colour (see Sec. 5.8).

5.8 Eighth Prototype - Multi-Coloured Badges and Video Walk-Through

This prototype's focus was to decrease the technical limitation that emerged in the usage of the Archilogic framework. Given that the iFrame only supports a unidirectional communication, we tried to increase the interactivity differently. We used colours to differentiate between various lifestyle goals and created video walk through for each of the 18 different 3D models using Archilogic technology.

5.8.1 Implemented Features

Colours added as distinction between lifestyle goals
Based on the feedback from several test persons, in order to increase the interaction between the floor model and the 2D badges, we gave each lifestyle goal another colour (see Fig. 5.18). This helps to improve the visibility of different household activities badges within the 3D floor model. As we already used two main colours, we decided to keep those, and to add four further Fig. 5.17). Each colour represents household activities from one lifestyle goal. Hence, the resulting colouring of household activities was implemented into the prototype Cashasa, see Fig. 5.19).

giving each lifestyle goal another colour increases visibility and interaction between the rest of the application and the 3D model

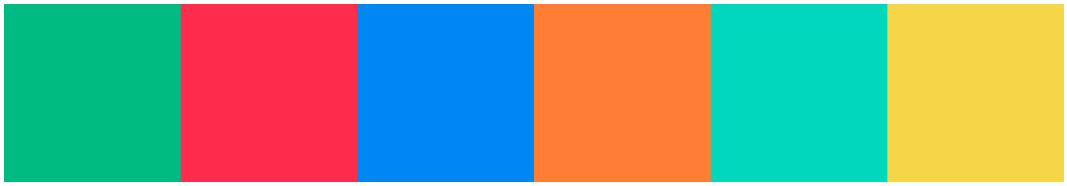


Figure 5.17: Colours used to differentiate lifestyle goals

One change leads to another one - in previous prototypes selected household activities became magenta in the drag & drop area and in the household activities area, see Fig. 5.12. Still, due to the increased number of colours, we did not

aspire to integrate this change on selection because this would mean introducing yet another colour which tends to become too colourful for an effective differentiation.

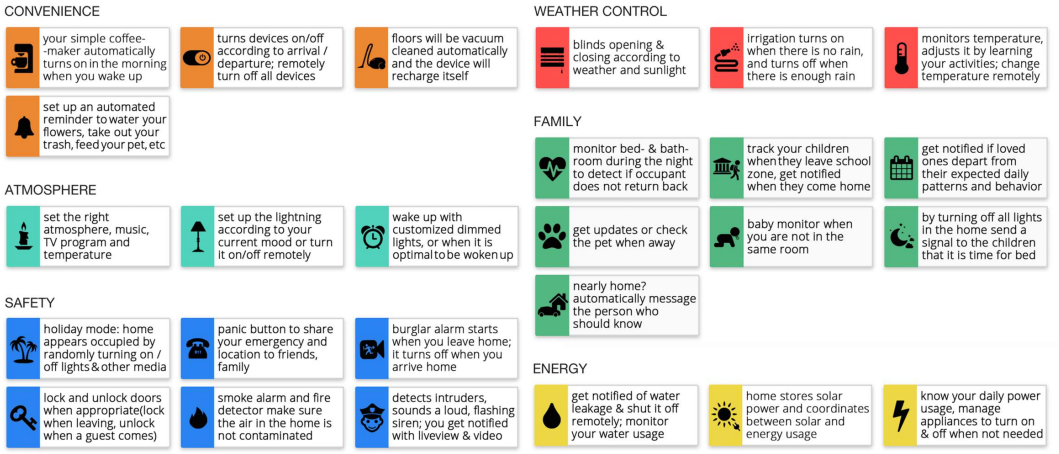


Figure 5.18: Implemented coloured household activities to differentiate lifestyle goals

A video walk-through of the 3D floor model
Before coming to this most discussed view of the prototype we aim to let people gain an understanding of household activities within the floor model. To achieve this, we included one view showing a video of the 3D floor model (see Fig. 5.20). In the video, users will see all 26 household activities and where they are situated. We adjusted the speed of the video such that users can read through the household activities and have a couple of seconds to think about them. Furthermore, we randomised the order in which household activities are shown in the videos to our various 3D models such that we minimise the risk to influence people's choices of preferred household activities by the order when they are displayed. Each of the 18 floor models' videos starts with a different lifestyle goal revealing the respective range of household activities. However, being a video, the randomisation process will not happen on each reload, but was randomised once by us, and will remain constant throughout the study.

Questionnaire design within the prototype
The content of the questionnaire is discussed in 4.4. The

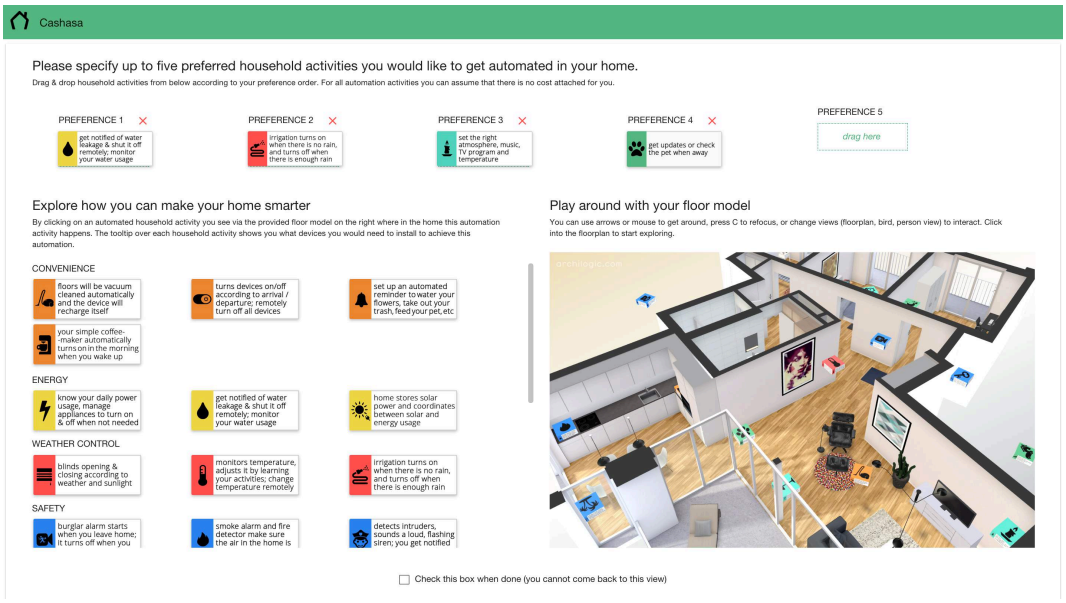


Figure 5.19: Implemented floor model with coloured feedback

design how this questionnaire is integrated into the interactive prototype follows Material Design Guidelines[3] such that the visual representation remains the same throughout the entire prototype. An example of how we asked questions can be seen in Fig. 5.10 and 5.11.

5.8.2 Feedback and Learnings

The coloured distinction between different categories of household activities was regarded as a good solution to increase the interaction between the main application and the 3D model within the iFrame. Given the limitation of only unidirectional communication between the two components, the main application and the iFrame, colours might slightly minimise this decoupling.

[3] Http://www.google.ch/design/spec/material-design/introduction.html

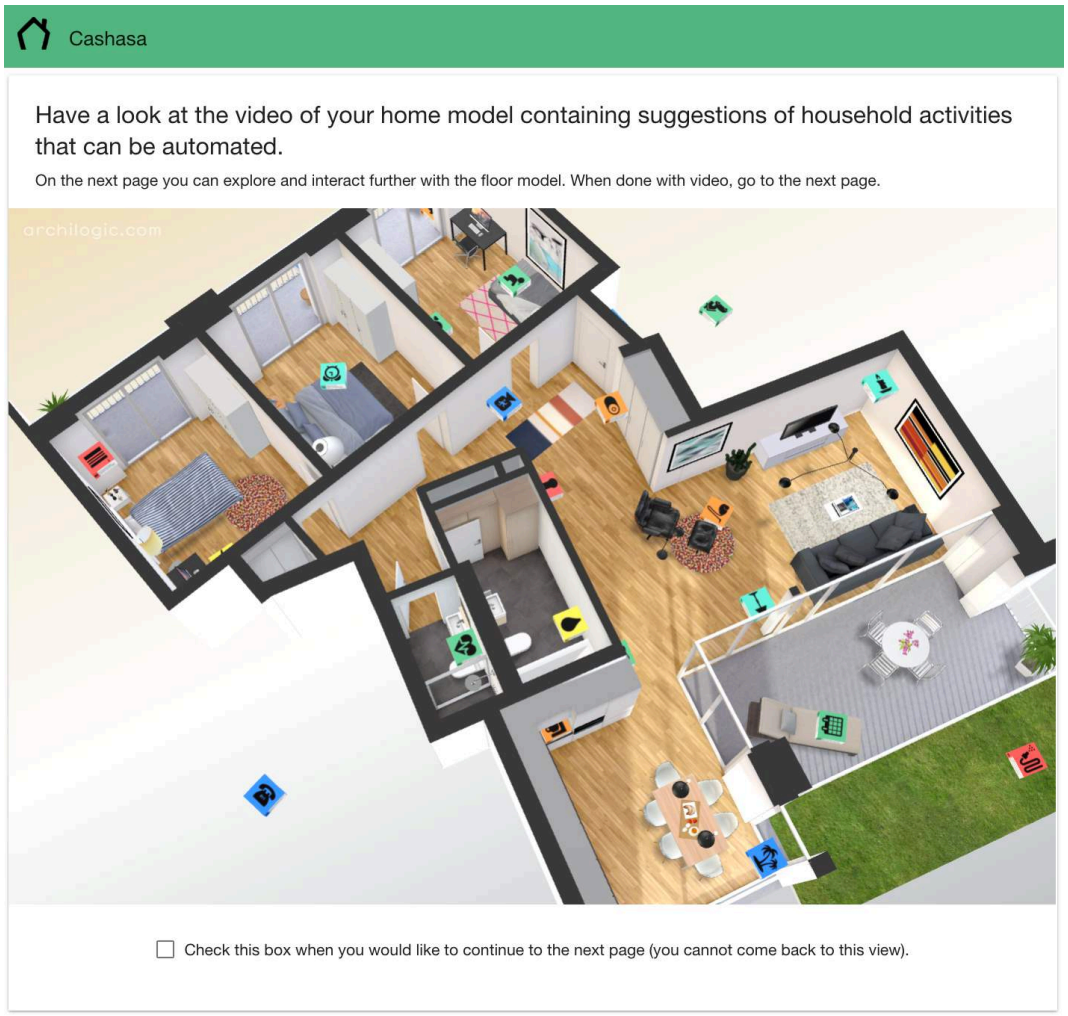


Figure 5.20: Walk-through view of Cashasa

5.9 End Prototype Cashasa - All Features

With an iterative design throughout our work, we could integrate valuable feedback from test users and experts into the final prototype. The flow and screens to the implemented end prototype can be seen in Appendix, D. This section briefly reflects on implemented features to give a summarised overview of the functionalities. Some were already discussed in the previous sections of this chapter.

Survey as web application
We designed and developed a survey in the form of a web application that integrates questions from the questionnaire, the lifestyle matrix and the 3D floor models as a visual representation of participant's homes.

5.9.1 Displaying the Lifestyle Matrix Features

Randomisation of shown lifestyle goals and actions
The view of lifestyle matrix' goals and actions (see Sec. 3.6) shown in the application is completely randomised. Each lifestyle goal is shown in a randomised order as well as each action within every lifestyle goal appears. By it, we aim to minimise the risk of insignificant study results by minimising the influence on participants.

Mapping actions to devices
Mapping between actions and respectively needed devices to reach automation (see 3.6) is visually presented in the prototype via tooltips for each action.

Combined the lifestyle matrix with a 3D visualisation
We visually displayed the lifestyle matrix (see 3.6) in a web application in combination with the 3D framework developed by Archilogic to address the RQ2.

Pick up to five favourite smart home solutions
Study participants are asked to choose up to five most preferred actions. We designed an *up to five* possibility in order to elicit people's preferences only rather than get false

preferences as they might feel obliged they need to specify exactly five (as described in Sec. 5.3).

Presentation of only chosen actions
Actions chosen by the participant as preferred are redisplayed in a next view within the 3D floor model and as action buttons. We aimed to elicit some further information about the smart home solution preferences.

5.9.2 3D Model Features

Customisation of the shown 3D model
We customised the 3D floor model shown to the user such that it resembles their home as much as possible. Hence, we prepared 18 different layouts of 3D home models considering the aspects of the number of rooms and the existence of balcony or garden.

3D models cannot be edited by users
Furniture or elements within the 3D model are not changeable by the participants because we aimed to make users focus on the provided smart home solutions, the location of them within the floor model and their interaction to trigger the resemblance to their home.

Presentation of 2D actions to spatially mapped locations in 3D models
We displayed actions from the lifestyle matrix (see 3.6) as buttons in the application, and modelled them as 3D badges in the 3D floor plan models. Each action's 3D badge was integrated into the room or area within the 3D floor model such that it fits to the spatial location where it would be installed in the real home, based on the *Lifestyle Matrix - Mapping Actions to Areas in the Home* in 3.6 (see the mapping to areas in Appendix A).

Interaction between action buttons and the 3D model
The interaction was implemented as a one-directional communication. When the user clicks on an action outside the framework's area, the 3D model reacts and zooms into where the the action's 3D flag is located .

Exploration of 3D floor models via videos
In order to let participants explore the entire automation space within the 3D floor model and relate it to their own homes, we are showing a video of the respectively chosen floor model with all the actions within it. Each of the 18 videos starts with exploration of another lifestyle goal and its respective action to minimise the risk of getting insignificant study result by influencing participants too much.

5.9.3 User Experience

Selectively responsive design
We implemented a responsive design, but fully optimised the user experience for the desktop user having their browser window size set to at least 960 pixels. However, we let participants with a fewer browser width know we did not optimise the application and their user experience would be reduced.

Design of the questions forms and input fields
We embedded the questionnaire within the visual prototype using Material Design Guidelines[4] to display input fields and forms as visually appealing as possible and to follow a clean design throughout the entire prototype.

Real-time validation and user feedback in UI
For a multitude of user input forms, we integrated a real-time user feedback when participants provided answers into the UI forms; for instance, we validate in real-time if somebody stated they are over 102 years old and let them be aware of the possibly mistaken input. When users want to proceed to the next page without completing all the information, we warn them about it.

General usability
Throughout our design and implementation iterations we evaluated different prototypes with some test users. As far as we got the feedback from students and professionals in that field, our prototype was considered usable.

[4] http://www.google.ch/design/spec/material-design/introduction.html

Notify user when they click the *Back* or *Close* button
We disabled the back button during the study to minimise the risk of adapting provided input in retrospective as this might influence the results. In addition, we disabled the navigation via the url. We decided that as per default a back button or reload deletes all user's answers. However, we are reminding users they are leaving the study and everything will be deleted when they (accidentally or non-accidentally) click on the back, refresh or close button. Regarding this design decision, we got feedback from a couple of participants and described the limitation in Sec. 7.4.

Optimised devices browsers for the study
The study was fully optimised for the browser Chrome. Browsers, Safari and Edge get the same quality of user experience whereas we have not extensively tested it on further browsers such as Firefox, Windows Explorer or others. Additionally, we optimised the user experience for the desktop or laptop users. Hence, our responsive design is *responsive* for screens with at least 960 pixels in width. Although all questionnaire views are mobile friendly with some minor design drawbacks, the core of the application is not due to the application architecture. Therefore, we notify mobile users to complete the study on a larger screen.

Logging participants screen width
In order to address the previously mentioned drawback, we logged the participants' device screen to be able to conclude the study drop numbers. 2 out of 82 valid inputs completed the entire study with a screen between 960 pixel and 1200 pixel. The other 80 participants were in a browser larger than 1200 pixel. 6 people started the study on a mobile screen (less than 600 pixel) and 1 on a screen between 600 pixel und 960 pixel. None of the 7 completed the study.

Chapter 6

Evaluation

The online survey consisted of 54 questions: 11 on the participants' age, background and experience, 8 on the household, 14 on home automation, 6 on their home's attributes specifically, 6 on the preferred household activities and 9 on the 3D visualisation. 29 out of 54 questions were open-ended to elicit qualitative data while 25 had a closed selection set of answers from which participants chose. The close-ended, quantitative questions were evaluated based on the dichotomous alternative, nominal, interval or Likert 5-point scale. The qualitative analysis was performed by one person using grounded theory techniques. The final version of the survey questionnaire can be seen in Appendix, B. Depending on participant's input some questions were not shown to avoid asking unnecessary elements.

29 out of 54 questions were open-ended to elicit qualitative data

We distributed the survey over one German online forum on home automation and over Facebook in expat groups, various university groups, of both technical and non-technical fields (in Switzerland, Chile and Australia) and in the Design Thinking groups. By spreading the study over the Internet, we did not consider the sections of the population without the access to the Internet. However, given that home automation requires certain technical knowledge and accessibility, we made a trade-off by choosing this distribution strategy.

online survey does not consider all parts of the population; however, this is the trade-off we made by choosing this strategy

To provide external incentives, participants were informed beforehand that we are holding a raffle to win one of five 50$ Amazon gift certificates. A participant was allowed to break the study at any time. The study results were kept completely anonymous.

Collected Valid Study Data
We collected 82 valid user feedback. Given that leaving some questions unanswered and dropping out of the study was allowed, 15 participants have not provided all answers but left the last couple of questions, in particular the feedback about the 3D model, unanswered. Hence, we will consider all participants' input to answer RQ1 and for RQ2 we will focus on the entirely provided feedback. In the following sections we will specify which sample we used. The link to the raw results can be found in F.

6.1 Addressing RQ1

To address *RQ1* we created the lifestyle matrix by rearranging how people browse for or inform themselves about smart home solutions and technologies. We displayed this people-focused sequence in our prototype Cashasa to evaluate the approach. We explored people's ideas on smart homes, what they would like to automate, what the already have automated and what activities from the lifestyle matrix they preferred most. In our analysis we considered whether aspects like profession, personal situation or comfort with technology influenced the above mentioned.

Demographics of study participants

*How can we shift the focus from currently technology driven communication of smart home solutions to a more people-driven focus (**RQ1**)?*

To answer the RQ1 we used the sample with 82 entries. The mean age of all participants was 28.4 (± 8.94 SD) and the median 26.0. 24.4% of the participants were female, 76.6% male. More than half of the participants live in Switzerland (58.5%). Further, 13.4% in Chile, 8.5% in Germany and 6.1% in United States (see Fig. 6.1). In addition, we had participants who live in Australia, Canada, France, Italy, Japan, Mexico, Netherlands and United Kingdom.

Background and profession

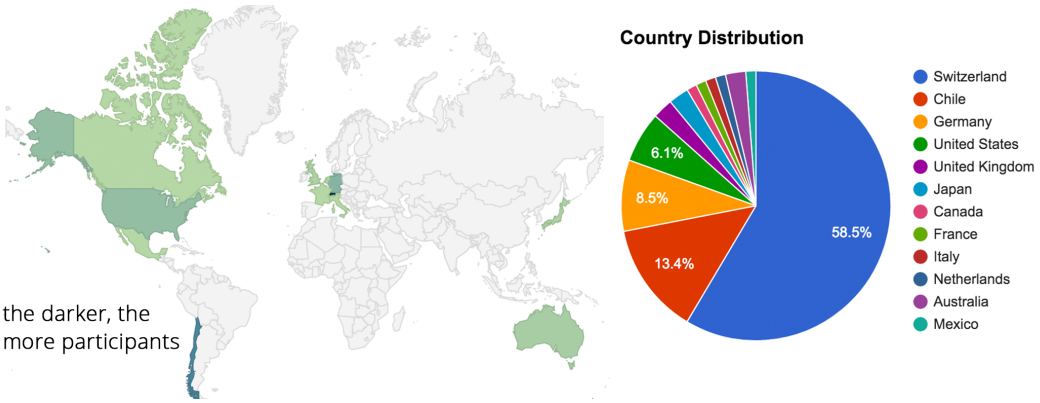


Figure 6.1: Distribution of countries participants live in

Most of the participants have or are pursuing a tertiary education, 53.7% a Master degree, 25.6% a Bachelor degree, 11.0% a Doctor and 6.1% a Postdoctor. The other 3.6% has a degree of or is in high school or technical school.

The majority of people are working or studying in a technical field (63.4%), such as computer science (software engineers, IT-Architects, ..), HCI (students / researchers) or engineers. We used ground theory to code the open question about participants' profession (see Fig. 6.2). Under technical field we understand professions from computer science, computer science related and engineering.

we summarised engineering, computer science and CS related into technical fields, business and other into non-technical fields

Among participants who had a non-technical position were scientists, designers, students in medicine, history, biomedical and pharmaceutical sciences. One participant was a housewife and another a project evaluator in housing development. Under non-technical field we summarised coded results (see Fig. 6.2) business and other.

6.1.1 Analysis if Profession Influenced Home Automation Aspects

We compared to what extent profession influenced aspects such as being comfortable with technology, interest and likelihood in home automation and whether they have already done automation.

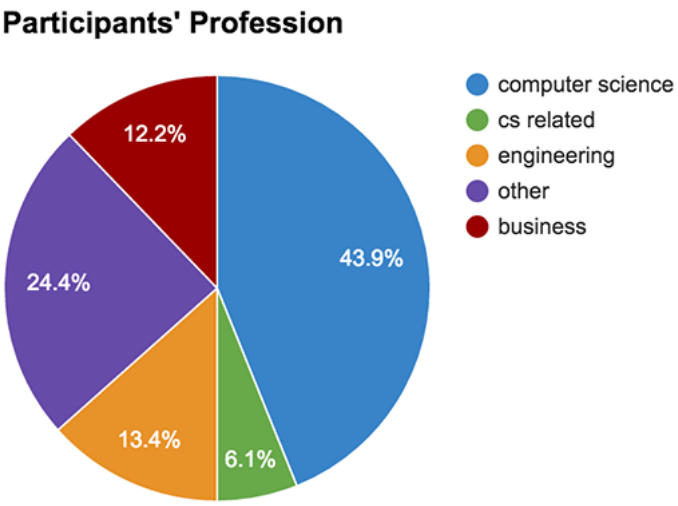


Figure 6.2: Participants' profession

Profession and its influence whether participants have already done automation
For this analysis we grouped professions business and other as the non-technical fields, and computer science, engineering and computer science related into technical fields. There was no evident correlation between the fields and the previously done automation (see Fig. 6.3). Moreover, participants with a non-technical profession seemed to have done slightly more automation before (36.7% for non-technical vs. 34.6% for technical). Being surprised by the result, we further broke technical fields into computer science and computer science related professions only. This group has done slightly more automation than non-technical professions, namely 38.9%.

Comfort with technology considering profession
The technology comfort depended slightly on the profession. People in technical fields specified they were more comfortable with technology such as smart phones, laptops than people in non-technical fields (see Fig. 6.4).

Interest in home automation considering profession
The interest in home automation can be considered con-

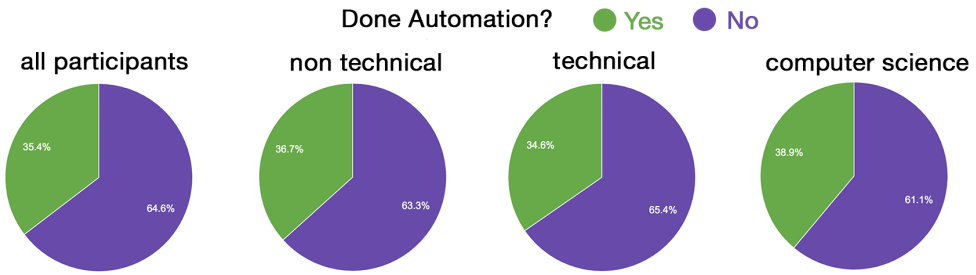


Figure 6.3: Profession influencing whether participants have already done automation

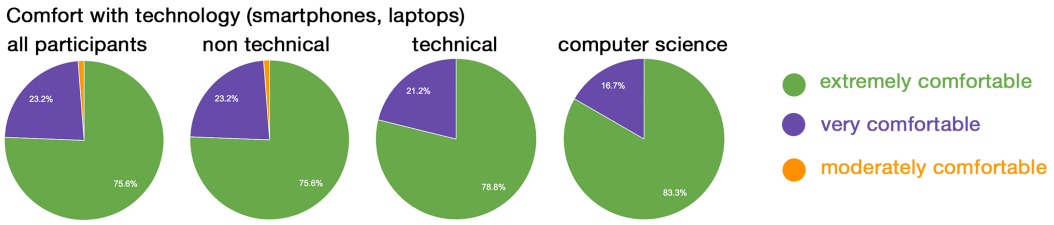


Figure 6.4: Tech comfort compared to professions

stant regardless of the fact that some participants are in technical and other in non-technical fields. Surprisingly, participants from a non-technical field yielded a slightly higher interest in home automation (see aggregated results in Fig. 6.5). This surprise might arise from the fact that non-technical participants have a different understanding of what exactly home automation is, imagining more sophisticated solutions to be possible. Simultaneously, participants with a rather technical background might be more aware of what is feasible. For instance, several participants from non-technical fields said they were extremely interested in home automation whereas the only three participants who specified they were *not at all interested* were a scientist, a PhD student in HCI and a social researcher. Deeper research is needed to explore these tendencies.

surprisingly, participants from a non-technical field yielded a slightly higher interest in home automation

Likelihood home automation based on profession
We computed the likelihood to home automation based on participants' profession. As for the interest in home automation, the likelihood to automate certain tasks in their home seemed higher for non-technical fields (see Fig. 6.6).

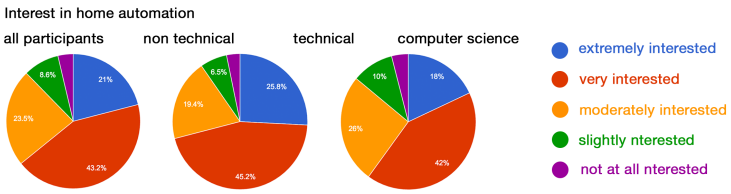


Figure 6.5: Interest in home automation considering profession

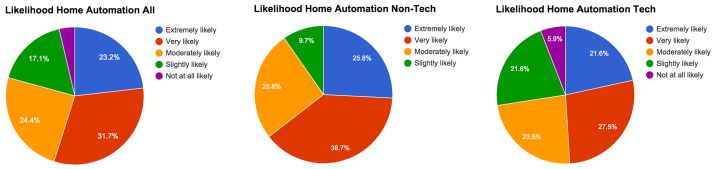


Figure 6.6: Likelihood home automation based on profession

Both options they could specify, *extremely likely* and *very likely* yielded a higher result for non-technical professions, with a total of 64.5% aggregated on the two likelihoods. In contrary, only 49.1% (aggregated) of participants in technical fields specified they are *extremely likely* or *very likely* to automate something. Furthermore, nobody from non-technical fields said they are *not at all likely* to automate something compared to 5.9% from technical fields. As mentioned in the previous paragraph, this tendency has to be further explored, but might be influenced by the knowledge of technologies and the perception what could effectively be done.

6.1.2 Interest in Home Automation

We analysed how interested participants were in home automation given they already automated something in their home before.

Interest in home automation if they have already automated tasks before
There is a difference in home automation interest between

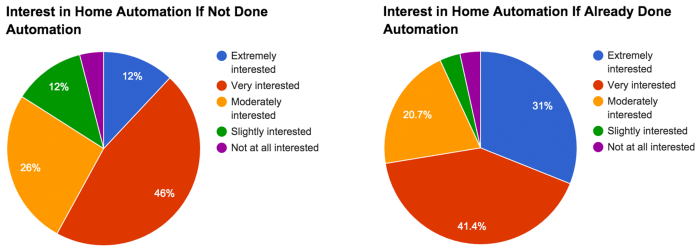


Figure 6.7: Interest in home automation when already automated things

people who have already done automation before and those who have not done automation any (see Fig. 6.7). The first yielded an aggregated 72.4% of being *extremely interested* and *very interested*. The latter yielded 58.0% for the same two categories.

Interest in home automation, but reluctant to use it

7 out of 82 people (8.6%) claimed they were very or extremely interested in home automation but unlikely to use it. The reasons were lack of knowledge, cost and time. Some mentioned the problem was that their domestic spaces were rented and not owned. Two participants said the devices are useless: *Most devices are useless, not secure or are not available in my country* and *I like to play with the gadgets but they tend to be expensive, installing them requires making modifications to the apartment, and I think in general they are not that useful*.

main reasons were lack of knowledge, cost and time

6.2 Insights about User Automation Needs

This section explores previous, current and future automation ideas of participants.

6.2.1 Previous Home Automation of Participants

A third of the 82 study participants said they automated something in their home. Mostly, it concerned lights or heating. Other activities included automated doors, irrigation of the plants, lawn mowing and vacuum cleaning. A few participants automated the coffee machine. Another participant made an emergency watering system for the roof garden: *It waters my plants only if I forget to water them and the ground becomes too dry for too long*. Although there exist heating automation solutions, one participant is using a self-made system with a customised script.

Owning further devices
16 out of 82 said they own further devices that could be automated or used for home automation, thereby 14 people specified what they own specifically. Mostly, the devices were Arduino and sensors, Raspberry Pi 2, and various light bulbs. One participant owns a Nest smoke detector, but has not found time to install it yet.

6.2.2 Automation Desires

At the beginning of the study we asked participants what they would like to automate first. Subsequently, we coded the open-ended question and got the subsequent results. The number in brackets signals how many time the item was mentioned.

- **cleaning / vacuum / trash** (22)
  Participants mentioned they would like to automate cleaning activities such as monitoring the level of dirt, floor and vacuum cleaning, cleaning the dust and windows, and emptying the trash.

- **lights** (22)
  Management of lights depending on arrival and departure, controlling every power outlet, controlling it wirelessly and configuring lights themes (e.g. movie night).

- **laundry** (11)
  The entire process of washing the clothes, folding and ironing it should be automated.
- **temperature** (9)
  Controlling the temperature via air conditioning or heating: the home should adjust the temperature based on whether it is occupied and on multiple indoor and outdoor temperature predictions.
- **windows / shutters opening and closing** (8)
- **everything** (4)
  One mentioned a smart and aware home is what he needs: *Not sure if it helps to select one single task - what I would like is a smart integrated home that is "aware" of its environment.*
- **cooking** (4)
- **keyless doors and automatic door opener** (4)
- **kitchen / coffee** (4)
  In particular washing the dishes, heating the kitchen floor, automatic management of kitchen devices and coffee machine was mentioned.
- **grocery shopping** (3)
  The fridge should reorder milk and other food automatically and the groceries list should generate itself based on the missing items.
- **safety** (3)
  The security issue was mentioned 3 times. An idea was to program the lights to turn on / off at regular or random intervals in order to prevent theft.
- **music** (3)
  An automated sound system and one that is the same in multiple rooms were desired.
- **save energy** (2)
  Two participants found it important to save resources such as electricity, for instance lighting or refrigerator.
- **comfort** (2)
  Experiencing a better sleep schedule by automating the lights and opening / closing the blinds

"not sure if it helps to select one single task - what I would like is a smart integrated home that is "aware" of its environment and can react automatically"

- **mixed automations** (7)
  One participant wishes that the washing machine and dish washer would fix themselves. Another would like to automate lawn mowing. Bath being ready, heating of the oven and stove, automatically turning on the computer, sun protection and dog feeding were other mentioned activities.

one participant said he already has everything automated

- **already has everything automated** (1)
- **nothing** (1)

To summarise, the three mostly desired activities were management of lights, cleaning activities such as general cleaning, vacuum cleaning or taking out trash and laundry. The latter two are currently not yet possible, but according to [Cakmak and Takayama, 2013] dusting, wiping, picking up things, doing laundry, etc. will be supported by technology in the future.

Reasons for the provided automation wish

participant's motivation for automation was that some activities are *painful* and *time consuming*

We coded the answers to the question why participants wanted to automated the previously specified (previous Sec. 6.2.2). The provided reasons are visualised in Fig. 6.8. In particular, they found some activities painful and time consuming. Other reasons were convenience, energy or money saving, laziness, sefety, the ability to control the home from remotely and lastly health.

One participant often forgets to feed the dogs, *Sometimes I forget and end up feeding them at 1 am*, and thus would like an automated dog feeding solution. Another is forgetful about laundry, *I'm super lazy, and if you forget about the laundry overnight it will smell and you have to start again*. Automating the laundry activity was further considered as a painful and time-consuming activity: *Ironing takes a lot of time and isn't interesting. I don't see a personal benefit of doing it myself* and *Folding and storing my clothes after I wash them - It is the household activity that takes me most time.* Two other participants who preferred keyless doors said: *Keys*

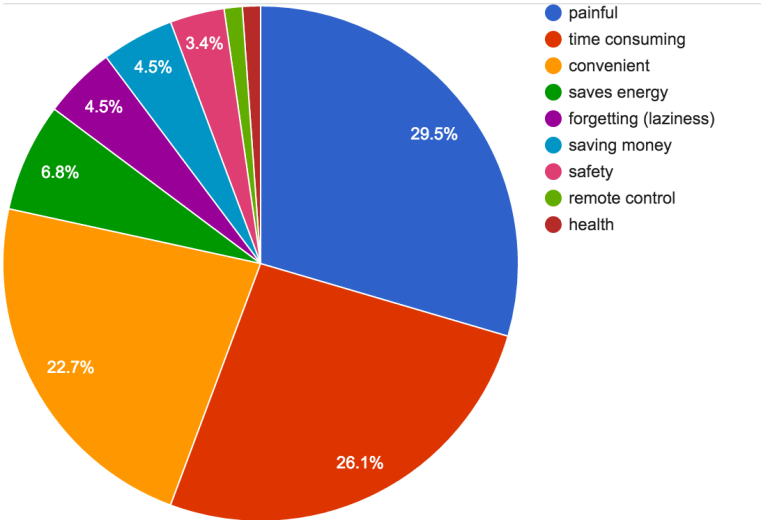


Figure 6.8: Reasons for automation, as specified in the study

are a weird thing to have, I'd rather open if with my phone. Also, I could easily share access. and *Because people like me tend to lose their key but never their smart phone*. Another participant claimed *a clean and tidy home would raise the standard of living*.

Moneterisation of the Automation Wish

After participants specified what they would like to have automated we asked them how much they would be willing to pay for it. One participant said he would pay a daily fee and seven said they would pay a monthly fee, for instance 10$ per day or 100$ per month; expenses per month ranged from 50$ to 200$. Others said they would be willing to pay a one time amount. These digits ranged up to five thousand US dollar (see Fig. 6.9). Only few would not want to pay for the home automation solution at all.

Some mentioned the solution needs be portable to the new apartment, for instance this participant: *Let's say 800 EUR, assuming I could take it with me when moving*. Another said *Could range from a few hundred bucks to 6-digits. In my rented home, I would certainly only go for small cost solutions*. This supplements findings from Sec. 6.3.3 where we write about

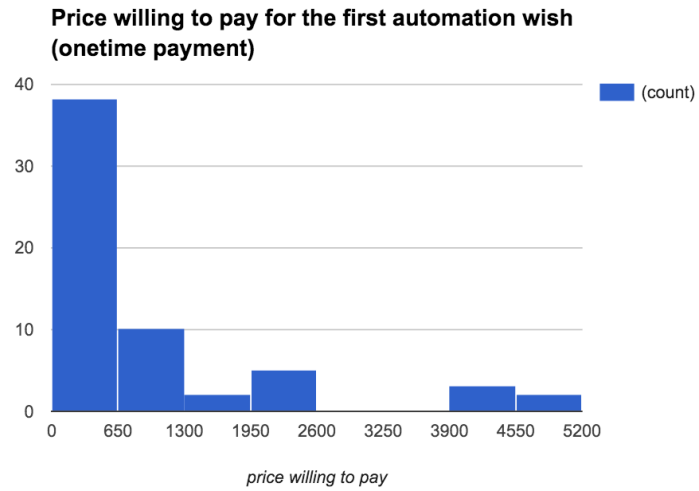


Figure 6.9: Price willing to pay for the first automation wish

expressed concerns of renters about what happens when they move. Few others said it is vital to consider the sophistication of a solution to determine the price. A couple of people compared the current solution's cost to the future one and said they are willing to pay the same as now or a bit more.

6.3 Analysis of Chosen Preferences

We asked study participants to choose up to five preferred activities. In total 397 activities were chosen by 82 people. Thereby, 75 people indicated all five preferences, 3 people chose four, 3 participants decided only on three, and 1 person only specified one preference.

We analysed the frequency each preference was chosen and compared it to the expected value of 3.85%. Exactly half, namely 13 actions were chosen more often then the expected value (marked light-green in E(x) column in Fig. 6.10).

The most popular activity, chosen in 12.34% of the cases, was #26 *floors will be vacuum cleaned automatically and the device will recharge itself*. The second most chosen activity

		in total	397	E(x) =	3.85%
lifestyle goals	#	rank	counts	percent	actions
Convenience	26	1	49	12.34%	floors will be vacuum cleaned automatically and the device will recharge itself
Convenience	25	2	36	9.07%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Energy Saving	15	3	35	8.82%	know your daily power usage, manage appliances to turn on & off when not needed
Weather Control	18	4	27	6.80%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Energy Saving	14	5	26	6.55%	home stores solar power and coordinates between solar and energy usage
Weather Control	19	6	26	6.55%	blinds opening & closing according to weather and sunlight
Atmosphere & Relaxing	22	7	24	6.05%	wake up with customized dimmed lights, or when it is optimal to be woken up
Atmosphere & Relaxing	20	8	19	4.79%	set the right atmosphere, music, TV program and temperature
Safety	4	9	18	4.53%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Safety	6	10	18	4.53%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Weather Control	17	11	16	4.03%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Atmosphere & Relaxing	21	12	16	4.03%	set up the lightning according to your current mood or turn it on / off remotely
Energy Saving	16	13	15	3.78%	get notified about water leakage & shut it off remotely; monitor your water usage
Convenience	23	14	13	3.27%	your simple coffee-maker automatically turns on in the morning when you wake up
Safety	2	15	12	3.02%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Convenience	24	16	12	3.02%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
Safety	1	17	10	2.52%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	3	18	9	2.27%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Family	13	19	4	1.01%	nearly home? automatically message the person who should know
Family	11	20	3	0.76%	by turning off all lights in the home send a signal to the children that it is time for bed
Safety	5	21	2	0.50%	panic button to share your emergency and location to friends, family
Family	7	22	2	0.50%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	8	23	2	0.50%	get notified if loved ones depart from their expected daily patterns and behavior
Family	12	24	2	0.50%	get updates or check the pet when away
Family	10	25	1	0.25%	baby monitor when you are not in the same room
Family	9	26	0	0.00%	track your children when they leave school zone, get notified when they come home

Figure 6.10: Preferred activities: Results of the study

(9.07%) was #25 *turns devices on/off according to arrival / departure; remotely turn off all appliances*. Chosen in 8.82% of the cases, the third activity is #15 *know your daily power usage, manage appliances to turn on & off when not needed*.

As can be seen in Fig. 6.10, lifestyle goals Convenience, Energy Saving, Weather Control and Atmosphere & Relaxing were among the more popular ones. The remaining two, Safety goals were in the middle range, whereas lifestyle goals around Family were only rarely chosen as preferred. In Sec. 6.3.1 we analysed only participants with children, respectively in Sec. 6.3.2 only with pets, to understand the low prevalence of the lifestyle goal *Family*. Further investigation is needed to elicit their needs.

6.3.1 Preferences of Participants With Children

8 out of 82 participants have or live with children under 16. These 8 participants chose 34 preferences in total (see results in Appendix, E.2). Only one of the 34 chosen activities

was related to children, namely #11 *by turning off all lights in the home send a signal to the children that it is time for bed*. For the overall study, this activity was chosen twice more, in total three times. One participant (female, 28 years) said she chose this activity because of trouble with her sleeping. The other (male, 32 years) said it was easy and without discussion. Hence, the reason participants without children chose this activity is that they want to signal to other members or to themselves that it is time to bed - not necessarily only to their children. For future consideration, we should rephrase this description, as it can be used for both groups, and we should take out ambiguity of what children are. Some parents might be living with children major that this age that we did not consider as children.

None of these participants chose #10 *baby monitor when you are not in the same room*. However, this activity was chosen once by a 25-year old Japanese sharing the home with family. He gave the explanation that *You never know what these babes do*. Possibly, this participant lived with a baby before, was working as a babysitter in the past or a family member might be expecting a child soon.

Lastly, nobody chose #9 *track your children when they leave school zone, get notified when they come home*. This activity might go too far concerning the privacy discussions. As it was never chosen, we will consider it not being a current user need.

6.3.2 Chosen Activities by Participants With Pets

A total of 18 out of 82 participants have pets. However, out of 86 chosen activities by these 18 people, the activity #12 *check on the pet when away* was chosen only twice. This represents 2.3% of all chosen cases which is below the expected value of 3.85%. Results can be seen in Appendix, E.3.

However, in addition, two participants who did not choose #12 said in the next question of generating further automation ideas they would like to automate *dog feeding in particular* and *Windows open when cats go out, food regulation re-*

motely.

In order to draw relevant conclusion concerning the automation around pets, we should conduct a study with pet owners only to elicit exact needs.

6.3.3 Planned Time of Staying at the Same House or Appartment

From the 82 participants, 23 are planning to stay less than 1 year, 22 between 1 and 2 years, 24 between 2 and 5 years. On contrary, 13 participants are planning to staying longer than that, 8 between 5 and 10 years and 5 more than 10 years. The lifestyle goal *Energy Saving* seems to be slightly more popular amongst participants who are planning to stay longer in the current place they live, whereas *Atmosphere & Relaxing* and *Convenience* appear to be slightly less popular (see comparison in E.4). Some participants expressed concerns about renting issues, for instance whether their landlord would allow them to use some home automation technologies and if so, what happens when they move. We described this phenomenon as limitation in Sec. 7.4 because it might influences the choice of chosen preferences in our study.

some participants expressed concerns about renting issues

6.3.4 Preference Rank Analysis

As people ranked the activities, we have the information which activities were preferred on each preference level (see analysis in Appendix, E.1). The most preferred activity overall, *vacuum cleaning the floors*, was also mostly preferred in both, preference rank 1 with 23.17% of cases and preference rank 2 in 8.54% (note, that 3.85% is the expected value). For the third and forth preferences rank, this activity was chosen second most often, 7.40% for third, and 8.97% for the fourth rank. For the fifth rank, it was the fifth most chosen one, yielding 6.67%.

For each preference rank, the first five most preferred ac-

tions ranged within the lifestyle goals *convenience*, *safety*, *energy saving*, *atmosphere & relaxing* and *weather control*. The lifestyle goal *family* was never chosen within the top five. Aggregated results in Fig. 6.10 reveal that the top five activities in the aggregated results were lifestyle goals *convenience*, *energy saving* and *weather control*.

6.3.5 Perceived Safety and Chosen Safety Actions

safety actions seem to correlate with the participants' perceived safety of where they live

Most people perceived their current country as *Extremely safe* or *Very safe*. However, 9 participants stated they feel *Moderately or slightly safe*, 5 living in Chile, 2 in United Kingdom, 1 in Germany and 1 in France. We grouped the participants in the two groups, *Low Safety* and *High Safety*, and analysed how often they chose *Safety* actions (see Table 6.1 and see descriptions of actions in Table 6.2). Actions, #2, #4 and #5 yielded a higher interest from participants perceiving their safety as low, respectively action #2 160%, #4 57% and #5 693% higher interest. This indicates that safety perception might correlate with the interest in home automation around security.

Safety Nr.	Low Safety (%)	High Safety (%)	ALL (%)
#1	2.22	2.56	2.52
#2	6.67	2.56	3.02
#3	2.22	2.27	2.27
#4	6.67	4.26	4.53
#5	2.22	0.28	0.50
#6	4.44	4.55	4.53

Table 6.1: Perceived safety and chosen activities from the category safety

6.3.6 Activities Around the Goal of Saving Energy

In Sec. 2.3 we listed motivations found by related work. In their works, [Takayama et al., 2012] and [Mennicken and Huang, 2012] named the goal *saving energy*. We aimed to analyse how this correlated with our study results. Out of the three lifestyle goals *Saving Energy*, two were chosen

Nr.	Description
#1	smoke alarm and fire detector make sure the air in the house is not contaminated
#2	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
#3	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
#4	holiday mode: home appears occupied by randomly turning on/off lights & other media
#5	panic button to share your emergency and location to friends, family
#6	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)

Table 6.2: Lifestyle goal safety, numbered actions

more than the expected value, whereas one was chosen less: *know your daily power usage, manage appliances to turn on & off when not needed* was chosen in 8.82% of the cases, *home stores solar power and coordinates between solar and energy usage* in 6.55% and *get notified about water leakage & shut it off remotely; monitor your water usage* in 3.78%. Thereby, the expected value is 3.85%. Goals related to saving energy seem to be within the preferred home automation options. However, this was only the case when participants were given a list of possible activities to choose from. When prompted to describe what they would like to automate (see Sec. 6.2.2), the aspect to save energy was mentioned only twice. This is an interesting finding.

interestingly, energy saving actions were only chosen when provided in a list; when prompted for what they would like to automate, these goals did not appear

6.3.7 Participants Getting Household Support

Out of 82 participants 17 are getting some household support, seven from Switzerland, six from Chile, two from the United States, one from Germany and one from Mexico. Surprisingly, all six Chilean households were getting extensive assistance. Three have a housekeeper who spends 30, 35 or 40 hours a week managing and cleaning the home. The forth has a housekeeper for 15 hours and a gardener for additional 5 hours. Another participant has a babysitter

helping out for 40 hours and lastly one has a cook for 25 hours per week. The participant from Mexico receives help by the housekeeper for 15 hours a week and the American for 18 hours a week by the babysitter. Other participants receive fewer assistance, from one to three hours per week by the housekeeper or gardener. We compared different automation needs of people getting a higher help at home versus people getting lower support. We examined what they specified as preferred automation wishes when prompted at the beginning of the survey and what activities they chose later in the study. Although receiving more help at home, the first group prefers activities such as *vacuum cleaning*, *a supermarket-list generator* or *cooking*. Similar preferences were chosen by the other group. Hence, people receiving extensive support are not averse to automate activities related to this external assistance.

Although receiving more help at home in these areas, participants would still like to automate *vacuum cleaning*, *cooking*, ...

6.3.8 Further Automation Ideas

27 out of 82 had further ideas after choosing their preferences. Air quality was mentioned by two people. The home should automatically air the home and ensure optimal environment (humidity, temperature, CO2 concentration etc.). Automation around laundry and cleaning, e.g. via household helpers or robots, were further desired.

Some ideas were quite wider. One participants said to prefer an artificial intelligence system, similar to Amazon Echo, that is interacting with humans and connected to all systems from our list. Another does not want reminders to perform tasks, but the house to take care of everything directly. There was a suggestion to provide *extreme burglary protection*. That would be a firewall preventing hackers and automatically alerting authorities.

"the house should take care of everything directly"

Two additional ideas were around pets, namely *pet feeding that is remotely controllable* and *windows open when cats (pets) go out*. Three people wished for cooking automation, one in particular mentioned heating the food before arrival: *Sometimes I don't have much time to prepare food before I have to go out again*. Another three mentioned a need for an au-

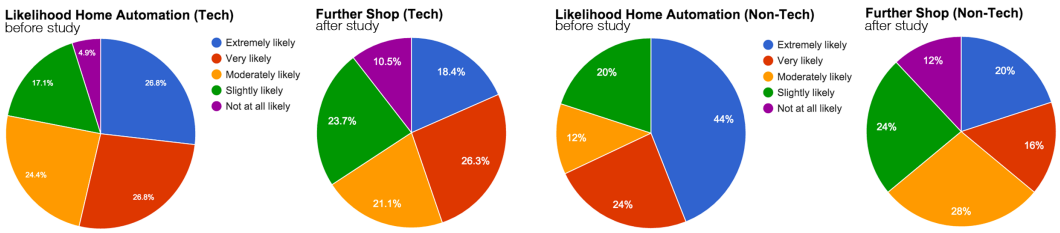


Figure 6.11: Comparison of the two likelihoods, before and after the study

tomated food ordering. A participant's need is to improve the quality of living in small spaces (e.g. quickly changing a bedroom into a living room). A smart music system to follow the users, modular houses, automation bill payment, automatic furniture building and replacing were among further ideas.

6.3.9 Probability of Further Browsing

Participants rated their likelihood to use home technologies in their home at the beginning of the survey. In the end they answered the question whether they are likely to browse or shop for automated solutions in the future. For this analysis we considered the 67 participants who completed all questions. We noticed that for both fields, technical and non-technical, the likelihood for further browsing lowered in comparison to their estimated likelihood to use home technologies at the beginning of the study (see Fig. 6.11). Particularly surprising was the positively estimated likelihood by non technical participants in terms of usage of home automation. The explanation to this manifestation could be a difficulty of understanding what smart homes and home automation are when not being confronted with it before. In the end of the study all participants gained more insights of what is possible and how to achieve it. Hence, some might have found the functionalities were not sophisticated enough, some they were too complex and others that they would hire a specialist for this kind of setups.

for both fields, technical and non-technical, the likelihood for further browsing lowered in comparison to their estimated likelihood to use home technologies at the beginning of the study

As for the other two correlations with the likelihood to further shop or browse, the specified interest towards home automation and the fact whether participants have done

automation before yielded different results. As expected people who are more interested in home automation will be more likely to further browse or shop for home automation technologies. The same applies for participants who have previously done automation, who are in technical fields and for male participants in general.

6.3.10 Final Thoughts on the Preferences Choice

We can conclude that actions that on average were chosen less frequently then 2% should not be considered as current user needs. We compared these least popular activities with participants' input about what they have automated before in Sec. 6.2 and what they would like to automate in Sec. 6.2.2. In addition, all activities that yielded a percentage higher then 2%, but lower then the expected value of 3.85% (yellow in Fig. 6.10) should be further reanalysed in a larger scale study to determine whether these user needs are relevant on the demand side.

People with previously low interest in smart homes and home automation are in general not changing their mind. Moreover, people are perceiving their interest towards home automation as larger than the probability to further browse or shop solutions. As already mentioned above, the reasons to this phenomenon might be that people not familiar with the field have rather utopian ideas of what is possible or prefer to hire a specialist to automate their homes if necessary.

people not familiar with the field might have rather utopian ideas of what is possible

We were surprised the lifestyle goal *Family* was not mentioned very often in the entire study. However, as only a small percentage of the study participants had children or pets, further studies with pet owners and respectively parents should be conducted to avoid a wrongly excluding actions #9, #10, #12 and #11 from the lifestyle matrix.

Lifestyle goals concerning *Energy Saving* were chosen when we suggested all possible activities. When prompted to describe what they would like to automate (see Sec. 6.2.2), activities around the aspect to save energy was mentioned

only twice. This is an interesting finding we would like to further explore.

6.4 Evaluating People-Based Approach

By letting people choose their preferences, we were able to elict user needs. Further, we aimed to explore whether our goal-based approach has future opportunities to be followed. The question about the understandability of action descriptions was answered by 77 out of 82 participants. 75% perceived the descriptions *not at all difficult*, 13% *slightly difficult*, 2.9% *moderately difficult*, 7.2% very difficult and 1.4% *extremely difficult*. We analysed how this perception changed based on the field of profession. Participants in technical fields found the descriptions 10.26% less difficult compared to non-technical fields. Nobody from the technical field specified them to be *very or extremely difficult* whereas 11.6% non-technical participants perceived them likewise.

Further open-ended feedback on that question revealed two contrary opinions by a couple of participants. One stated that the descriptions might be even shorter, e.g. less detailed. One participant raised the concern that *people unfamiliar with the proposed ideas might have hard time to grasp the full scale of the vision by only being presented with these brief words*. This opinion was shared by four further participants (one from a non-technical field, and three from technical fields) who commented that some more details or concrete examples might have been useful.

I liked that you displayed which devices are involved, because it gives you the cognitive bridge to the "home automation stores" like Amazon

Additionally, one participant gave us explicit feedback on bridging the gap between hardware and user needs: *In an earlier visualisation you displayed which devices are involved in such an activity/scenario, I liked this because it gives you the cognitive bridge to the "home automation stores" like Amazon or elv.ch*. One participant expressed the concern that household activities vary between continents and that this is hard to deal with.

Conclusions on the people-based approach

goal-based description of automation activities was considered not at all difficult to understand

The goal-based descriptions of household activities that could be automated were considered not at all difficult to understand by the sample set of our study. Even when considering only non-technical participants who beforehand had less touch points with automation ideas and technologies, the results yielded a positive understanding. Consequently, we were able to elicit information on participants' needs with the suggested people-based approach. As mentioned above, one participant gave direct feedback to the rearranged process of browsing for smart home solutions highlighting that displaying needed devices for an activity provides the cognitive bridge to the online home automation stores.

6.5 Addressing RQ2

How does the 3D representation of a users' home affect the interaction with the goal-based approach of smart home solutions? (**RQ2**)

To address *RQ2* we firstly had to find out more about participants' home attributes to represent it as a 3D model. Furthermore, we were interested in what they consider unique about their home, how well the 3D model represented the context of their home and ultimately how they used the model.

Most of the participants live in urban parts (67.1%) compared to 19.5% who live in suburban parts and 13.4% in a village. 68.3% live in an apartment, 30.5% in a house and one person (1.2%) in another arrangement. Furthermore, 64.6% rents, 11% owns and 24.4% live with their parents or in housing owned by their parents. In average, one and two people per household are most common, namely both in 26.8% of the cases. One person said 1.5 people live in the apartment, meaning that the second person does not live there all the time. In 22% there are three people, in 14.6% four and in 7.4% five people per household. Only one person (1.2%) lives with 6 people.

About household layouts

36.6% of the participants have a garden, 31.7% a balcony, 18.3% both and 13.4% has none. The majority of people chose the model type 3 because they have 3 or more bedrooms, namely 58.5%. Another 24.4% chose the 2-bedroom

Figure 6.12: Mostly chosen 3D model

and 17.1% the one-bedroom model. One 3D model (see Fig. 6.12) was chosen in 23.7% of the cases.

6.5.1 Home Uniqueness

We aimed to find out what details and attributes people found unique to their home. These insights are in particular valuable to know more about what might be important for participants. These details might be the key to provide a closer model as the home representation to users in future work (see discussion about closer representation in future work, 8.1).

One third of participants gave us insights about something they consider unique and special to their home. One participant lives in an extremely old building, from the 15th century. Some others in a loft. One household has a keyless (button press) lock for the doors. On contrary, one participant can't buzz people up from the apartment, but has to run down to the door to let them in manually.

a third of participants find something about their homes unique

A couple of people referred to the uniqueness of their floors. One floor is Japanese tatamie, another made of

stone. One has a floor that creaks when you walk on it.Two households have special rooms. One a wardrobe, another has an extra room, not connected to the house directly. It is in the garden with the size of about 30 square meters.

Some found their thick walls to be unique, some their glass front, others their connected or large rooms. Finally, one household reveals that it is very close to the beach, on a steep hill overlooking the heads.

6.5.2 How Fitting Was the 3D Representation

We explored how well the 3D model represented participants' homes. We got mixed feedback from a total of 67 participants and noticed the tendency toward a rather wide gap of matching of the model to participants homes This limitation has been acknowledged in Sec. 7.2.1 and addressed in future work, Sec. 8.1.

9.0% said it matched it *Very well* in particular because it included similar furniture, for instance same chairs or details like the *Mac computer*, and similar space distribution. 37.3% stated the 3D model represented their home *Moderately well* because the layouts are not the same as for their home. For instance, the kitchen and living room are separated in the 3D model while in the real home they are not, or vice versa. One participant stated *It's not the same layout. But it gets the idea across.* 31.3% people considered the model a *Slightly well* match. In particular the aspect of not representing two-floors was criticised by the participants. Additionally, the distribution of rooms, room sizes and ratios, furniture and the plan of the floor mismatched the actual homes. One participant said their balcony/garden is on the roof top, an aspect we did not consider. Another 22.4% rated the fitting of models as *Not at all well* giving similar reasons as described above.

In retrospective, we could have provided models with 2 floors, but were reluctant that the navigation in a model with 2 floors would be even more complex. Given that due to the technical limitation of the used technology, the nav-

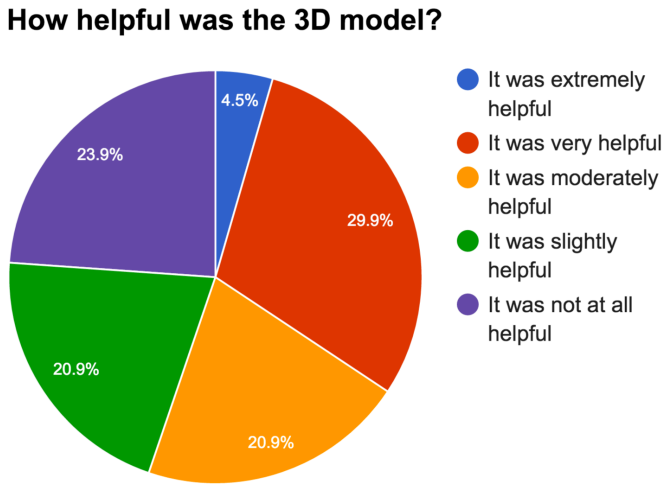


Figure 6.13: How well did the 3D model represent the actual home

igation within the model was challenging for a couple of participants, we made the trade-off of a larger mismatch between the models and the actual homes. As mentioned above, Sec. 7.2.1 describes this limitation and Sec. 8.1 addresses it as future work.

6.5.3 How Helpful Was the Provided 3D Model

Out of 67 participants providing us with this feedback, three (4.5%) answered the 3D model was *extremely helpful* because the visuals helped to understand the ideas and the space where the technologies would be installed. Further 29.9% claimed the model was *very helpful* as one can associate a room with an activity and it helps to visualise the ideas. 20.9% considered it *moderately helpful*, stating that although the visualisation helps by showing the activities in a context, the context was not that a close representation to the actual flat. On contrary, one participant said that any smaller model would have helped and that there is no need for such a customisation. Nonetheless, during this study this opinion was rather in a minority. 20.9% did find the

visualisation *slightly helpful* and a further 23.9% considered it *not at all helpful*, see in Fig. 6.13. A couple of participants explained that the descriptions were simple enough to understand what was going on, no 3D visualisation is needed. Another few said they already knew what their apartment is like, and can easily bring it to mind. In addition, the mental model of some participants is more accurate and detailed that the provided representation. The argument of a not close enough representation further arouse. Lastly, two participants stated they already had automation activities in their mind and knew what they would like to automate. In general participants from technical fields found the 3D model more helpful than non technical users rated it.

6.5.4 Usage of the 3D Model

participants used the model to learn about activities via the video, to be inspired, to explore activities and to relate to the home because of some details in the model

We asked people whether they used the provided model and if so, how exactly they used it. 48.6% of 67 participants stated they used it, further 10.6% reported they could not use it as they wished due to navigation problems. One person described it as follows: (*It was difficult to navigate so I went around as best I could do read about the automation, but I didn't do it as much as I would have liked*). 3% said the model was not representative enough as an explanation they did not use it, whereas 37.9% claimed not to have used it at all.

We coded the open-ended answers to analyse how people used the model into main reasons inspiration, exploring activities, similarity to the home, video and navigation problems (see Fig. 6.14). The latter was already mentioned in the above paragraph. Under inspiration we summarised the following statements. One participant wanted to emerge into the atmosphere: *Mostly to recreate the atmosphere and feel like I was inside the model*. Another to explore rooms: *I watched it run by itself, and then I used the mouse to go to the rooms I was interested on*. Several mentioned it inspired and made them think about additional home automation. The next coded category was exploring activities, as the feedback *I used it to further explore the house and understand the differences*. The similarity to their home was mentioned by a couple of participants: *I used the model to remind myself of*

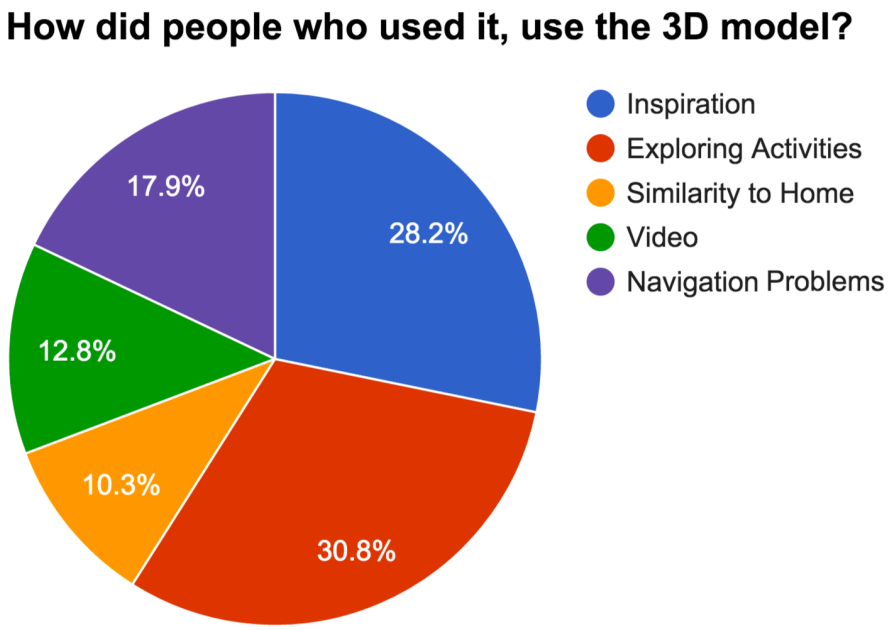


Figure 6.14: Usage of 3D model

our flat, by having the spot shown where the particular activity would take place worked as a reminder of what the activity could include or what boundaries it should have. Additionally, *it helps to give more realistic approach to how a smart house might be.*

6.5.5 Feedback on the Provided 3D Model

We got valuable feedback on the 3D visualisation and some ideas how to proceed. Five people suggested to visualise needed devices and their effect on the homes (this coincides with our long-term goal, see in future work, Sec. 8.4). For instance, showing devices in action, such as robot cleaning the room, blinds opening and closing or burglar alarm starting. Alternatively, it was proposed to show the difference between automated and current state. This would make the prototype more interactive and tangible.

Another round of feedback revealed to provide a more accurate representation of people's homes. In particular, to

introduce a two-floor visualisation and add the garage *that is crucial to include a wider range of automation possibilities*. Further, the ability to switch to the 2D mode was suggested. These aspects are addressed in Sec. 8.1 of future work. Moreover, one participant suggested a conceptual model instead of a physical model to help ensure thorough consideration of all aspects and avoid the problem of mismatch in the floor plan and furnishing.

Further participant's idea was to introduce a modularity to be able to drag and drop some parts in and out. While we find this approach interesting, we have already considered it at the beginning of our work. However, due to the technical limitations to the framework we are using, Archilogic[1], we could not implement it likewise.

We got several feedback about a complex navigation within the provided 3D model. This issue has to be addressed to facilitate navigation within.

6.6 Conclusion on the 3D Visualisation

As discussed in Sec. 6.5.2, a closer representation of the 3D model is vital to enhance the support of the visualisation for the purposes of exploring home automation technologies. We aim to remove all abstractions and mismatches between the models and the actual homes (see future work in Sec. 8.1). Nevertheless, although the representation was not identical to their homes, the perceived help by the 3D model during the process yielded a more positive feedback, see Sec. 6.5.3. People mostly used the visualisation (Sec. 6.5.4) for the reasons such as inspiration, exploring activities, similarity to the home and getting ideas from the video (see Fig. 6.14). Given that some users reported navigation problems when trying to explore the 3D model, we will firstly address this difficulty. In a next step, we would like to conduct a lab walk-through study with participants to observe their interaction with the visualisation. We will prompt users to provide us with their 2D floor plan before-

[1] http://about.archilogic.com/

hand, such that we can present them with the exact representation of their homes. When possible, we will additionally ask them to send us some photos on the furniture and colours they have in their homes. This observation will help us generate insights for the next step, described in future work, Sec. 8.1.

Concluding, we see opportunities in using the 3D visualisation in the user interface to enhance users explore, install and later manage their home automation technologies. However, this approach firstly has to remove abstractions and provide an exact representation to let users fully emerge into the context of their domestic spaces.

6.7 Threats On Validity

The small number of participants in our survey, the use of personal social media profile for inviting them, the prevalent technical background of the participants and the larger amount of detailed questions might limit the generalisability of the results of the study. We tried to minimise this threat by spreading the survey over a large variety of social media groups where only few people were associated with us. Additionally, we did not ask all questions to everybody, but adapted them based on previous answers to avoid asking unnecessary elements. The process of categorisation, analysis and presentation of data and information in all steps throughout our work brings another threat to validity. This process is not straight forward and unambiguous and the market landscape analysis, the lifestyle matrix, the prototype and lastly, the analysis of both, quantitative and qualitative survey results, pose another threats to validity.

To minimise these risks, all categorisation, analysis and presentation work was done by the same researcher, who gathered feedback from experts, test users and smart home users. Lastly, the qualitative analysis was performed by one person using grounded theory techniques, such as open, axial and selective coding. In a next step, to avoid observer bias in the qualitative analysis, all parts should be open coded by at least one more researcher. Further and more

detailed description of limitations is described in the chapter 7.

Chapter 7

Limitations

This chapter discusses limitations not mentioned in the general *Threats on validity* section in 6.7.

7.1 Lifestyle Matrix

This sections reflects on the limitations concerning the lifestyle matrix, from the market analysis that might not be people-focused, the intuitiveness of the categorisation to the future process of curation and keeping the matrix up to date.

7.1.1 Market Analysis Based on the Market Side Might Not be People-Focused

Throughout our work we argue that we are trying to shift the technology-focused listing of smart home solutions to a more people-focused approach. Yet, during our market analysis to formulate the lifestyle matrix we heavily focused on the market side reflecting the current product market landscape, and only slightly considering the user side. We clustered 480 solutions from 30 different supplier sources and 54 entries from forums (demand side) to include the most meaningful points. Nevertheless, the mar-

we heavily focused on the market side reflecting the current product market landscape

ket is a combination of supply and demand views, creating opportunities for the supply side to exist when there is a need for it. Given that the supply can be seen as an indirect measure of the entire market, we relied on these more accessible data. During the evaluation survey we got insights into the accuracy of the market in the demand side. Some actions were were more preferred whereas other were less preferred, see Fig. 6.10 in 6.3.

the supply can be seen as an indirect measure of the entire market

7.1.2 Intuitiveness and Generalisation of the Lifestyle Matrix

As mentioned in Sec. 3.5.2 categories of the lifestyle matrix are not to be considered final. An action categorised under one lifestyle goal might belong to another or multiple ones. Our classification might not be intuitive for everybody: Every person has their perception of what they consider logical and intuitive. Although we gathered feedback on a couple of occasions, we verified it with a rather heterogeneous group in the Card Sorting process. The six participants might slightly differ in age, gender and education. However, they all have or are pursuing a tertiary education in a technical field. Based on these aspects our lifestyle matrix might not be generalisable for the purposes and needs of the entire user spectrum.

everybody has their perception of what they consider intuitive; our categorisation might not be intuitive for everyone

7.1.3 Low Number of Items in the Lifestyle Matrix

The lifestyle matrix (in 3.6) comprises 6 lifestyle goals, each ranging from three to seven actions, adding up to 26 actions in total. The smaller sample of actions might be criticised with the argument that we did not include all relevant household activities that could be automated. We might have missed some relevant household activities that are important user needs, or trend. The chapter Evaluation, 6, discusses the study results and which actions were more or less preferred.

7.1.4 Curation of the Newly Upcoming Needs

Given that the current technology market is moving fast, people's environments and needs adapt quickly to new possibilities. Future technological innovations might make our lifestyle matrix' goals or respective actions inaccurate or obsolete. Additionally, new user needs might arise that need to be input and reflected into the lifestyle matrix. The future challenge is to keep the lifestyle matrix relevant. It should be validated against people's changing needs based on technology effects on a regular basis to keep our prototype up-to-date constantly.

7.2 3D Model Representation

This section addresses limitations connected to the 3D representation such as its mismatch, the problem connected to leaving the physical space context and the possible distraction to answer the first research question.

7.2.1 3D models are not Representative Enough

In our prototype Cashasa we showed different individualised floor models to users that varied in the number of rooms, balcony or garden existence and to some extent furniture (we prepared a choice of 18 various visualisations). Based on the user input, we filtered them and ultimately showed only three to each participant. Given that our questions might be ambiguous, users' answers might imply this ambiguity. As we are later using 3D apartments based on these answers, this problematic might increase the mismatch between the models and the participants' homes. Study results show the perceived mismatch between the model and participants' homes in Sec. 6.5.2.

Furthermore, during the conducted pre-survey (4.3) and the final study, we received the feedback that some people, besides the existence of rooms and same amount of rooms

in the model, require furniture, colours or specific cultural traits to be similar. Only than can they relate to their home based on the floor model. Yet, for the scope of work we did not focus on a variation of furniture, colours or cultural traits in the floor models. This aspect influences the perceived match of the 3D representation. Both limitations are addressed in future work (in Sec. 8.1).

7.2.2 Users Need to Leave the Physical Space of the 3D Model

a bidirectional interaction between the 3D floor model and our application was technically not feasible

We integrated the Archilogic's framework[1] as an iFrame (see 4.5) into our application. However, due to this architecture decision it was not possible to implement a bidirectional interaction between the 3D floor model and our application. The model within the iFrame cannot send any information back to the parenting application. Hence, users have to leave the physical space of the 3D model and switch the context. It is currently not feasible to click on a badge (an action) within the model and by doing so trigger a reaction of the application outside the iFrame. Only the other direction of communication is technically feasible in a reasonable time and thereby implemented. By triggering an activity inside the application, for instance clicking on one of the action buttons, a reaction inside the 3D floor plan would happen. Automatically, the floor model zooms into the area where the badge is situated.

Due to this technical limitation, we could not implement the prototype to sort actions by rooms. One-directional sorting would have been technically feasible: users could specify the rooms kitchen, living room or bathroom to be zoomed into the respective area within the 3D floor plan. However, the other direction would have not be technically feasible: Users could not click on an area within the floor model to reveal only the respective actions within the application.

[1] http://about.archilogic.com/

User's interaction with the floor model cannot be logged via number of clicks and location of the mouse cannot be reconstructed

As described, the architecture of our application does not allow a bidirectional communication. Given that the 3D floor plan was integrated as an iFrame, it cannot communicate any information back to the parenting application. Hence, trying to track the position of the mouse within that spatial area leaves us with an unknown mouse path. The same happens for the number of clicks within the iFrame. Due to this technical difficulty, everything that happens within the iFrame appears as a blackbox to our application, and we cannot elicit further information for the scope of our study.

the 3D model integrated as an iFrame cannot communicate any information back to the parenting application

7.2.3 3D Model Might be a Distraction

Reviewers who are HCI or smart home experts pointed out that the representation of the home as a 3D model might distract from the first research question (*RQ1*), that we are addressing in the study, *How can we shift the focus from currently rather technology-driven communication of smart home solutions to a more people-driven focus*. Acknowledging this possible distraction, we cannot certify that our results were not influenced by it. A next step into this direction would be to separate the study into two different studies; one that focuses only on RQ1 and the second concentrating only on RQ2, *How does the 3D representation of a users' home affect the interaction with the goal-based approach of smart home solutions?*

7.3 Mapping to General Devices Rather Than to Specific (Brand) Devices

As we aimed to minimise people's association with companies we mapped actions with general devices only. This design choice was to elicit as neutral results regarding brand preferences as possible. Therefore, we mapped actions to

general devices in our lifestyle matrix (3.6) and not to specific brands. However, a general mapping might not be detailed enough to setup an automation goal. Users are more likely to prefer a step-by-step recipe with specific devices linked to a website shop to know how to achieve an automation for a household activity. Future work in Sec. 8.2 addresses this potential limitation.

7.4 General Setup of the Study

A limitation pointed out by reviewers is that *"people care a lot less about the survey than we do"*. They reminded us that in general participants are going to click through as fast as possible. Thereby, the more questions we ask, the less accurate the survey results are going to be. We cannot estimate how much more or less precise the study results would have been if we had designed the study more briefly or differently. This limitation influences in particular the accuracy and generalisation of our study results.

the more questions we ask, the less accurate the survey results are going to be

Owner of the home might influence the choice of actions
The factor who owns the building / apartment, and who needs to pay for electricity and power usage affects energy consumption [Dillahunt et al., 2009], [Dillahunt and Mankoff, 2014]. Thus, for the purposes of our study, this aspect affects the demand of automation products that impact energy savings and might not reflect the actual demand on the market.

Accessibility & reachability of the study
Our study was implemented as a web application. This implies those who do not have the access to the Internet will not be able to be recruited for the study or participating in it. However, home automation solutions are rather targeting early adopters and to some extent early majority. Rather technically savvy people will be interested in smart home solutions, or at least people who how some basic modern technologies' setup in their home like internet connection. [CapgeminiConsulting, 2011]

Disabled back button considered as limitation by some

participants
Some participants did not have a positive perception of the disabled back button. The respective users felt that in case the 3D model did not represent their home the best, they would like to go back and change it. However, due to the disabled back button (see Sec. 5.9.3), they were not able to do so. One participant contacted us asking if we could implement the *Save Button* to be able to stop the survey and continue it at a later point. We will consider this feedback for the future iterations to ensure participants feel they were provided with the model that represents their home best.

7.5 Further Technical Limitations

In this section we discuss further limitations connected to technical choices, implementations and feasibility.

7.5.1 Order of Shown Actions in the Video is Not Randomised on Each Reload

In 5.8 we described that we included a video as a walk through the 3D floor plan before letting users interact with the model themselves. Each of the 18 different floor models' videos starts with another lifestyle goal, as we randomised this while creating the videos. However, given that a video cannot be dynamically created for each user, this recording is static. As we cannot provide a randomisation of the order of shown actions and lifestyle goals, we are risking to slightly influence the choice of actions based on the order in the video.

7.5.2 Colours in the UI Might Influence Choices

In the end prototype each lifestyle goal has its respective actions coloured in one pre-chosen tone, as in Fig. 5.18. The

colours are not randomised and do not change on each reload

colours are not randomised and do not change for different floor models or different users. Hence, there exists a probability that the choice of colours for actions of a specific lifestyle goal might have influenced the final choice of preferred household activities.

Coloured feedback to signal what actions have already been chosen is not implemented
Up until the iteration of the seventh prototype (5.7) we planned to implemented a visual feedback to let users know which action they already selected. As you can see in Sec. 5.6, Fig. 5.12, it was planned to have all actions in green, and the selected ones in the redish-pink. Nonetheless, after user feedback during the iteration of the eighth prototype, we decided to colour each lifestyle goal in a different colour, extending the amount of colours to six. With this increased number of colours we did not introduce a further colour to signal the user which action they have already chosen. This non-signaling might make our prototype less usable. In future work (see Sec. 8.3.1) we discuss a possible implementation to address this.

7.5.3 Complex Navigation Within the 3D Model

Several users experienced difficulties while trying to navigate and interact with provided models. This issue reduced the accuracy of the results we wanted to elicit around the 3D visualisations. While exploring the source of these issues, we found out that it depended on the operating system and the browser vendor.

Touch screen support is not implemented
We focused on optimising our study for the desktop user and warned them when they were accessing it via a mobile phone. When we implemented the feature *mapping to devices* via tooltips (see Sec. 5.6), we made a trade-off that these are not shown on touch screens.

Chapter 8

Future Work

This chapter discusses future research directions or opportunities we have encountered through our work. Some of the described aspects are directly addressed limitations we summarised in the previous chapter, or features we could not implement.

8.1 Closer Representation of 3D Models

Based on the gathered feedback, an accurate representation of users' homes is indispensable and therefore the long term goal. In the future, users should be able to upload their own 2D floor plan as an image. The sketches should be generated into a 3D model to provide the same layout as that of their home. Through this extension, a more precise representation of people's homes is possible. This feature is already technically feasible with the Archilogic[1] framework, but the process to generate a 3D model out of the 2D image takes a couple of hours to be completed.

user should see an exact spatial layout of their homes as a 3D visualisation based on the uploaded plan image

Switching between 2D and 3D views
Additionally, the possibility to be able to switch between the 2D and 3D model views should be evaluated. Given that some participants said they preferred a 2D view, this

[1] http://about.archilogic.com/

aspects have to be taken into account. To achieve this, the sketch of their domestic layout uploaded by users should be rendered to represent the 2D view in a similar style like the 3D version.

Furniture, Colours and Cultural Traits
Additionally, users need to be able to add furniture to the floor model by themselves and see their home either as a house or as an apartment in a building. By adding customised furniture and thereby diverse colours and cultural traits, this functionality will address elements people sometimes saw as key elements to relate to their home. Moreover, the prototype becomes even more representative when visually displaying if a user's apartment is on upper, lower or multiple floors, and illustrating their home environments such as village, suburban or urban.

8.2 Mapping to Specific Devices

specific devices needed for the chosen activity could be shown

As described in the limitation Sec. 7.3 we did not want specific brands to influence people's choices of actions. Hence, we created the lifestyle matrix (Sec. 3.6) with general devices. However, in the future, we need to find a way to provide a more detailed mapping to specific devices. A possible idea to this implementation is to firstly show general devices (as we did now in Cashasa), and in a second step provide users with a step-by-step recipe what specific devices they would need to achieve an automation of their chosen household activity. We created a possible visualisation in Fig. 8.1. Even when displaying specific devices, it is essential to follow the people-driven rather than technology-driven approach.

8.3 Implementing Fully Interactive Application

As described in Sec. 7.2.2, we experienced a limitation in the technical feasibility since we used the framework devel-

Figure 8.1: Possible visualisation of specific devices (wireframe), source of device figures from iRobot[a]

[a]http://homesupport.irobot.com/

oped by the local startup Archilogic[2]. Due to this issue, we were not able to develop a fully interactive and integrated application. Instead, the user has to leave the context of the representation of their home to choose preferred household activities. Archilogic plans to prioritise and address the involved limitation and implement the respective feature within two quarters after we finish with our project. Hence, in the future a bidirectional communication with the 3D models will be possible. This additional capability leads to addressing several limitations. Users should interact completely with and within the 3D model without leaving the spatial context and choose their preferred au-

users should be staying the context of the representation of their home to choose preferred household activities

[2]http://about.archilogic.com/

tomated activities within the same 3D application. Additionally, sorting various actions per room has not be implemented. However, we consider it vital to add this functionality such that participants will be able to click on a room, e.g. *kitchen*, and the prototype will display all intelligent activities possible in the kitchen.

8.3.1 Coloured Feedback to Better Signal Chosen Activities

As mentioned in the limitation 7.5.2 in the final prototype we have not implemented a feature to signal users what actions they have already chosen because of the already high multitude of colours. In some previous iterations of the final prototype we had only one colour for all the actions (green), and signaled the selected actions in redish-pink. Subsequent work should rethink the indication of already chosen actions. We suggest not to introduce a further colour, but display chosen actions' colours darker grey and make these buttons unclickable and undraggable, see a possible implementation Fig. 8.2, being inspired by the video gaming industry to darken the items. Gaming interfaces often have a large amount of colours without appearing too overloaded and are often using neatly chosen colours and grey tones. [Zammitto, 2005] describes: *"In digital games visual information is the most used input medium, and colours are useful coded messages"*.

"in digital games visual information is the most used input medium, and colours are useful coded messages"

8.4 Augmented Reality to Show Devices and Their Impact Within the 3D model

augmented reality increases the sense of being involved into an action and provides a more visualised way to tell stories

New ways of communication emerged since the very first conversations via paintings on the cave walls. Examples such as sculptures, modern theatres, language, books, images, photography, movies, storytelling, augmented and virtual reality show that people strive to express themselves in various manners. The last ones both increase the sense of being involved into an action providing a more vi-

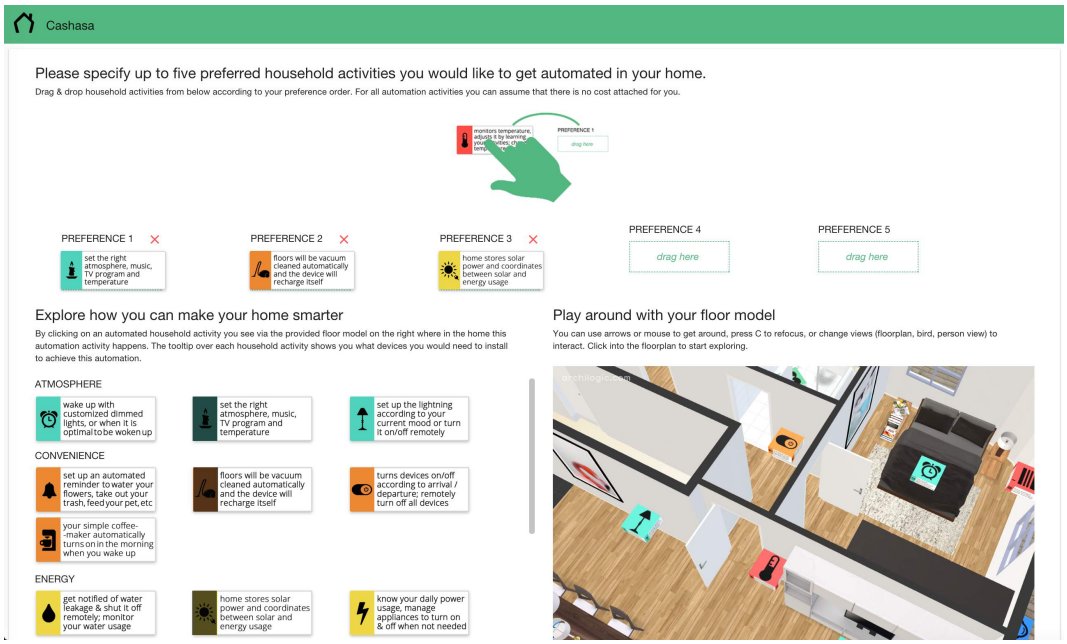


Figure 8.2: Coloured Feedback for Chosen Activities

sualised way to tell stories. Virtual reality creates a completely synthetic world and lets people emerge into the virtual environment. In comparison, augmented reality also provides insights into created synthetic information, but integrates virtual worlds into into the real world. [Bimber and Raskar, 2005]

Figure 8.3 displays how virtual worlds are embedded into real environments. With augmented technologies, people can see what furniture might fit into their homes. This connection between virtual and physical worlds could extend the features of our prototype Cashasa. We started our approach by displaying smart home possibilities as goals and finally visualised spacial layouts to represent user's homes. However, we did not visualise further aspects that happen in the home, as for instance people or the effect of the smart home solutions once they are installed.

A functionality could be implemented, where people see devices needed for an automation action via pointing their tablet or phone to the areas within their home (Fig. 8.4 visualises our ideas). This would show the people the ef-

Figure 8.3: Augmented reality is embedded into real environments, source: Noah Falstein, the Chief Game Designer at Google on Project Tango[a]

[a]https://www.google.com/atap/project-tango/

showing the effect of the smart home solutions once they are installed

fect certain devices have on their home. Given that adding this functionality in reality might be complex, the feature should first be available within the provided 3D floor plan by pointing a tablet in the model. Hence, not only a mapping with specific devices needs to be contributed (as reflected in 8.2), but also extending these devices with augmented reality possibilities. This implies illustrating how different devices would look like inside the homes, and what impact such as space needed, light or shadow they might have on domestic spaces. We envisioned our idea with the example of the specific device, Nest[3], see Fig. 8.4.

Furthermore, one could visualise inhabitants in the 3D model to illustrate how they would be interacting with new devices. However, it should be evaluated how realistic content can be display given the risk of the *Uncanny Valley*. The work by [Mori et al., 2012] researches about this risk and implies that the more realistic characters are in augmented reality, the less accepted and believed they end up being.

[3]https://nest.com/

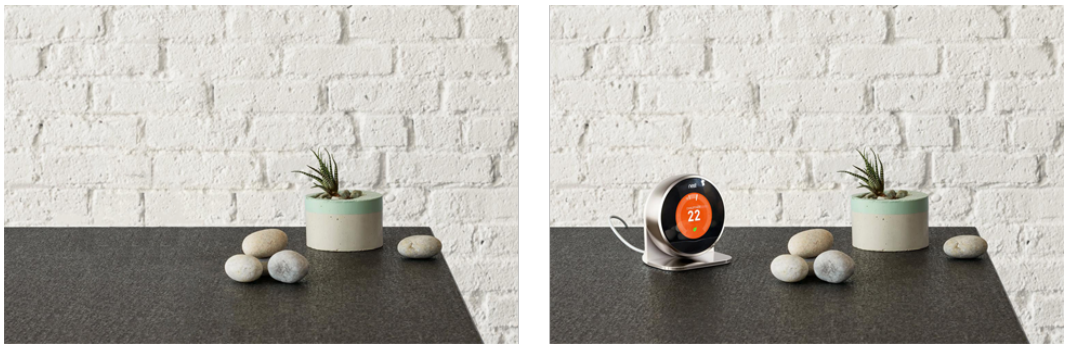


Figure 8.4: Prototype of what could be done as a feature of Cashasa with augmented technology, based on the visual from Nest (source: second visual from Racemap[a], first visual created based on the second one.

[a]https-//racemap.de/img/about/tablet.png

8.5 Going Beyond Home Visualisation

During the entire work we only focused on visualising the home of the participants. However, by concentrating on these couple of square meters surrounded by walls, we neglected all smart home technologies inhabitants might be using in their holiday homes, office or other facilities, car or public transportation. By integrating various aspects of someone's daily life, researchers could provide a more complete and connected smart environment going beyond the spacial layouts. For the users this would mean a personal digital bubble controllable remotely from anywhere and anytime. Following this approach, the community would face the even greater challenge of dealing with privacy and cyber security than smart homes are already facing today. However, it is worth exploring limitations of how far we can go in digitalising people's homes and lives.

concentrating only on homes, we neglected all smart home technologies inhabitants might be using in their holiday homes, office, cars or trains

8.6 Virtual Reality with Cardboards

Users often cannot imagine how the final design of a house or an apartment will look based on the briefing of architect's design ideas [Lertlakkhanakul et al., 2008]. They are not trained to fully understand three-dimensional spaces

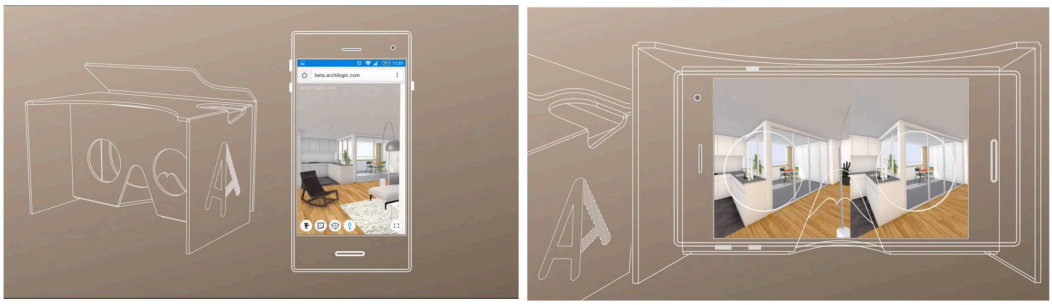


Figure 8.5: Virtual Reality Feature of Archilogic, source from Archilogic[a]

[a]http://about.archilogic.com/vr-support-for-google-cardboard-v2/

Cashasa could let users explore spatial layouts via virtual reality using cardboards

or to translate discussed ideas into a 3D model in their mind. This was one of the reasons (see 2.1) we introduced the approach to display a 3D floor model in our prototype Cashasa. In the future, Cashasa could be extended to let users explore spatial layouts via virtual reality using cardboards. As mentioned in the previous section (8.4), virtual reality creates a completely synthetic world and lets people emerge into the virtual environment [Bimber and Raskar, 2005]. Given that Archilogic[4] already supports the VR cardboard technology (see Fig. 8.5), this feature should be discussed more thoroughly.

8.7 Addressing All Stages of Smart Home

Cashasa could support the stages of smart home planning, installation and configuration

Due to the scope of the master thesis, we focused in particular on the planning phase of smart homes. However, the long term goal is that future smart home users will be able to use the goal-based approach tool, Cashasa, for the stages of smart home planning, installation and configuration. The following components were not addressed in the scope for this project but could be considered in future works:

[4]http://about.archilogic.com/

8.7.1 Controlling Installed Devices From Within a Unified Controller Interface

a multitude of heterogeneous solutions, standards and interfaces brings added complexity for users

Once devices are installed in their homes, users could be provided with a unified interface to control all solutions being setup. During this work we identified a multitude of heterogeneous and individual home automation solutions and devices. From the user's point of view this makes the choice and usage of smart home technologies extremely complex. Every automation goal brings a multitude of devices to be installed and every device brings their own standards and interfaces to the daily lives. As already described in previous works, [Mennicken et al., 2014b], an ongoing challenge is to standardise and integrate these different technologies into *"a more unified access"*. We further highlight the need for standardisation of this heterogeneous landscape as a crucial challenge to deliver a people-focused user experience. As described in [CapgeminiConsulting, 2011], providing a single point of contact to customers reduces complexity and brings added value.

we highlight the need for standardisation of this heterogeneous landscape as a crucial challenge to deliver a people-focused user experience

Once the challenge of standardised automation technologies control and interface has been addressed and a single point of contact has been provided, we could envision two different ways to provide this functionality as en extension to Cashasa.

Virtually over a 3D model interface
Current smart home users could see all installed devices - once they are installed - in the virtual home model and be able to control and supervise them via the 3D model interface.

By combining digital and virtual worlds
Reality Editor by MIT Research [Heun et al., 2013] supports adding behaviour to *"smarter objects"*. They define these as *"objects or devices that have an embedded processor and communication capability"*. The Reality Editor system combines augmented reality techniques to map digital interfaces on top of physically tangible elements, such as buttons, lights or knobs (see Fig. 8.6). After the mapping, the user can add or edit the behaviour or change functionalities of physical

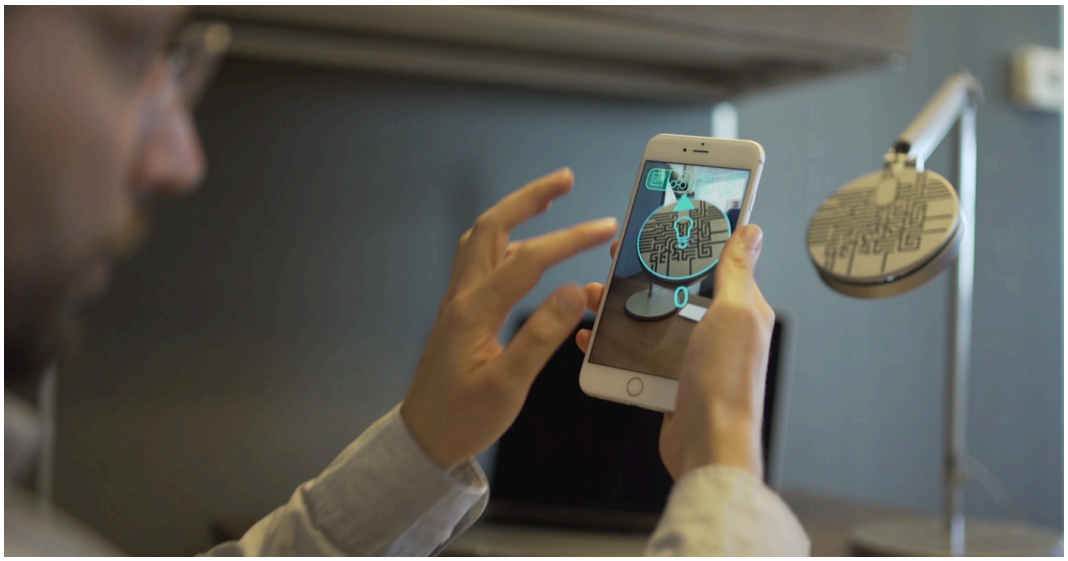


Figure 8.6: The Reality Editor, a visual showing the combination of physical objects and digital world, source: Valentin Heun, Pattie Maes from MIT Media Lab[a]

[a]http://fluid.media.mit.edu/projects/reality-editor-programming-smarter-objects

objects via a smart device.

Similarly, Cashasa could be extended to resemble the functionalities of the *Reality Editor*. By doing so, not only would users be able to control their intelligent installations via a virtual interface only, but they would be able to interact with physical objects, that later trigger a change in the behaviour (this extends the previous described section about Augmented Reality, Sec. 8.4).

8.7.2 Curation of the Offerings Listed in Cashasa

in the fast moving market we face the challenge to keep the offerings of the lifestyle matrix up to date

As described in Sec. 7.1.4 a limitation to our prototype is the currently fast moving market. The challenge of the future work consists in finding a way to keep the offerings of the prototype reflecting the needs and requirements from the user side. To achieve this, content providers could be appointed to keep the tool up to date. The curated offering should extend the number of actions per lifestyle goal in order to portray the full range of smart home possibilities.

8.7.3 Predictive Analytics

The envisioned long-term goal of Cashasa is to be deployed in homes with installed smart home technologies. In that case, the tool would gather data collected by homes in use. Further, it would be able to analyse data and provide suggestions to users and researchers by performing cluster analysis to determine which preferences were chosen with which. Users are interested into seeing what worked for other people (as per [Mennicken et al., 2014a]) and to get recommendations based on their current setup and interests. On the other hand, researchers and solution providers aim to elicit user needs, requirements and get feedback on the setups. For instance when solutions presented on the platform do not coincide with user needs, or when users search for goals that do not exist on the platform, researchers would get informed that there is a mismatch between the supply and demand.

recommender systems support users to explore possible solutions and researchers to elicit user needs

8.8 Future Study Design

Having received reviews that the 3D visualisation might be a distraction for the questions we are trying to address (see 7.2.3), a potential next step would be to separate the two studies. Concerning the visualisation part, a think-aloud lab study focusing explicitly on the effects of the 3D models could be conducted. Through observation of participants' interaction with the visualisation in the interface, their thoughts and opinions could be elicited more accurately. This exploration would reveal deeper insights into the patterns of interaction with the model, people's opinions and mental models they have of their home.

A further possibility for a subsequent study could be to randomly show participants either a visualisation with the floor model or without. We already implemented the interface with the two random conditions as prior to the study we were evaluating to use the comparison test but decided against it.

8.9 Shift in More House Owners and Less Renters

As described in the limitations, Sec. 7.4, only a small percentage of our study participants owned their home. Others rent. The article on FastCoExist[5] describes that the so called *millenials* can currently only rarely afford their own homes. However, some wish to rent but cannot bear the cost. To address this issue, the concept of the suggested sustainable and tech-aware house should help solve this problem by lowering costs. They mentioned features such as a totally solar run system and rain sensors controlling the irrigation system when it detects rain. We believe these and similar concepts will be gaining popularity in the near future in the US, and to some extent in other parts of the world. This trend would mean that more people will be willing to live in equipped smart homes, because they will be more affordable. When the shift to a higher percentage of home ownership happens, smart home providers will have to address arising needs of the new landlords. We believe this will shed a new light in user needs concerning smart technologies.

[5] http://www.fastcoexist.com/3055319/is-this-the-house-that-will-turn-millennials-into-homeowners

Chapter 9

Conclusion

"If you go anywhere, even paradise, you will miss your home." - Malala Yousafzai

User involvement into the process of smart home planning is vital to trigger their interest and let them understand their future domestic spaces. However, from user's perspective navigating through the complex product landscape is not straightforward. Suppliers often focus on hardware components, and not on people. Such a concentration on technologies does not support users in achieving their automation goals.

Thus, our work addressed this aspect and suggested a user-centred goal-based approach in structuring information about home automation technologies. We aimed to bridge the gap between user goals and technology. To achieve this and to address the RQ1, we created the lifestyle matrix in chapter 3.6 by rearranging the steps in the process. After performing a product market analysis, we firstly displayed exemplary goals of what could be automated and secondly mapped required devices to each goal. In order to evaluate our approach, we implemented an interactive prototype (see chapter 4 and 5) and conducted an online study (see results in chapter 6).The suggested goal-based method in presenting home automation examples yielded positive feedback. During the distributed online study users had to choose five preferred household activi-

ties from a larger list. Throughout this process, they were confronted with the goal-incorporated approach. Firstly, we were successful in eliciting their preferences and needs (see chapter 6). Secondly, by applying this method, we made the smart homes topic more understandable, even for people who previously had few touch points with the area. Descriptions of household activities that could be automated were in general considered *not at all difficult* to understand by both, technical and non-technical fields. In addition, we got one explicit feedback on providing the cognitive bridge between automation goals and online home automation stores by device mapping.

Furthermore, our work focused on visualising the goal-based approach in a 3D model to let people's mind models incorporate their domestic spaces when thinking about home automation solutions. The incentives in this representation of user's homes lie in arguments presented by related work. On the one hand, [Lertlakkhanakul et al., 2008] explain that users are often confronted with difficulties when imagining home automation configurations. On the other hand, [Harper, 2006] state that academia and industry are often concentrating on a technology push driven research and development, rather than on design, usability and use of technology. Furthermore, [Borodulkin et al., 2002] imply that although an extensive attention has been laid to home automation equipment and technologies' capabilities, less importance was given on implementing understandable, usable and easy to use interfaces. We addressed these arguments with our research question, *How does the 3D representation of a users' home affect the interaction with the goal-based approach of smart home solutions? (**RQ2**)*

We presented goal-based automation solutions within the 3D model that we customised based on several factors to resemble user's domestic spaces as much as possible within the scope of the thesis. Given that the 3D model was considered helpful despite the fact it was not the exact representation of people's homes, we see future opportunities in following this approach. However, subsequent research should display 3D representations without any abstractions, it should show the exact model representation of the actual home. We would like to highlight that the closer

representation is vital to enhance users to completely relate with the model and let them fully emerge into the spatial context of their homes. Nevertheless this limitation of a mismatch in the provided model, study participants used the visualisation for inspiration, exploring goal-based activities, getting ideas from the video or to relate to their homes through found similarities in the model. Therefore, we imagine that with a much closer representation, more opportunities could be explored.

To summarise, we evaluated an integration of a semi-customised 3D visualisation in the user interface with the incorporated goal-based approach to present smart home solutions. Whereas the goal-based approach yielded positive results, the visualisation has to be further refined to enhance users in putting themselves in the context of their domestic spaces. Having explored this opportunity, we would like to imply the long term goal of Cashasa to combine these two approaches in order to provide users with a usable, interactive and representative interface in the stages of getting ideas about ubiquitous computing, planning the smart home and controlling configuration of intelligent solutions from within the interface. Additionally, we provided directions for future work in chapter 8.

Appendix A

Lifestyle Matrix - Area Mapping & Estimated Complexity

lifestyle goals	#	actions	mapping to area in the home	mapping to devices	estimated complexity
Safety					
	1	smoke alarm and fire detector make sure the air in the house is not contaminated	kitchen, bedroom, children's room, living room	smoke sensor (detects smoke particles, carbon monoxide, checks Air Pollution Index), proprietary app	easy
	2	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video	all house (doors & windows)	door & window contact sensors, motion sensors, wireless sirens, video cameras, proprietary app	medium
	3	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe	entry / hallway / close to windows	motion sensor, glass break sensor, door & window contact sensor, smart door system, burgular system (proprietary) app	medium
	4	holiday mode: home appears occupied by randomly turning on/off lights & other media	kitchen, bedroom, children's room, living room	light bulbs, media system, proprietary app	easy
	5	panic button to share your emergency and location to friends, family	outside of the house	phone with gps or gps-device, app from store	easy
	6	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)	all house entry / hallway, balcony/garden	smart door lock, door sensor (tells you if doors open), proprietary app	complex
Family					
	7	monitor bed- and bathroom during the night to detect if occupant does not return back	bedroom, children's room, bat	motion sensors, proprietary app	medium
	8	get notified if loved ones depart from their expected daily patterns and behavior	all house	monitoring system, proprietary app	medium
	9	track your children when they leave school zone, get notified when they come home	outside of the house	phone with gps or gps-device, app from store	easy
	10	baby monitor when you are not in the same room	children's room, bedroom, livi	baby monitor with audio and video sensors, proprietar	easy
	11	by turning off all lights in the home send a signal to the children that it is time for bed	all house	light bulbs, proprietary app	medium
	12	get updates or check on the pet when away	all house	video, audio, motion sensors, proprietary app	medium
	13	nearly home? automatically message the person who should know	outside of the house	smart phone (with gps), app from store	easy
Energy Saving					
	14	home stores solar power and coordinates between solar and energy usage	balcony, garden / all house	solar panels, home solar battery, power grid-tie inverter, power meter	complex
	15	know your daily power usage, manage appliances to turn on & off when not needed	all house	power monitor sensors, proprietary app	complex
	16	get notified about water leakage & shut it off remotely; monitor your water usage	kitchen, bathroom	moisture sensors, proprietary app	complex
Weather Control					
	17	irrigation system turns on when there is no rain, and turns off when there is enough rain	balcony / garden	sprinklers, garden hose, hose connectors, watercontrol system, soil moisture sensor, temperature sensore, access to weather predictions, proprietary app	complex
	18	Monitors temperature, adjusts it by learning your activities; change temperature remotely	all house bedroom, children's room, living room	thermostat, open data readings from weather stations through app, heater / air conditioning, proprietary app	medium
	19	blinds opening & closing according to weather and sunlight	all house bedroom, children's room, living room, kitchen, bathroom	smart blinds or blind opener, open data readings from weather stations through app, proprietary app	complex
Atmosphere & Relaxing					
	20	set the right atmosphere, music, TV program and temperature	bedroom, children's room, living room	light bulbs, media system (audio, video), thermostat, proprietary app	easy
	21	set up the lightning according to your current mood or turn it on / off remotely	bedroom, children's room, living room	light bulbs, proprietary app	easy
	22	wake up with customized dimmed lights, or when it is optimal to be woken up	bedroom, children's room	light bulbs, fitness tracker, proprietary app	easy
Convenience					
	23	your simple coffee-maker automatically turns on in the morning when you wake up	bedroom, kitchen	smart power outlet, motion sensors, proprietary app	medium
	24	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc	all house	app from store	easy
	25	turns devices on/off according to arrival / departure; remotely turn off all appliances	all house	smart power outlet, motion sensors, proprietary app	medium
	26	floors will be vacuum cleaned automatically and the device will recharge itself	all house	robot that vacum cleans	easy

Figure A.1: Lifestyle matrix with mapping to areas in the home

Appendix B

Questionnaire

Main View
We are researching different techniques to present various smart home technologies to users, to elicit their preferences and to explore what factors influence these choices. Thereby, we are introducing a goal-based approach in an individually customisable 3D model interface. The name Cashasa stands for customer-centric automation-goals scheme of household activities in spatial areas.

Tell us something about yourself

1. Have you taken this survey before? (yes, no)
   Dichotomous alternative
2. What is your gender? (male, female, n/a)
   Nominal scale
3. What is your age?
   Ordinal scale
4. What country do you currently live?
   Grounded theory / open coding, axial coding
5. How safe would you say is the place you live in?
   (Extremely safe, Very safe, Moderately safe, Slightly safe, Not at all safe)
   Likert-scale
6. How long have you already lived in the same house / apartment you currently live?
   (less than 1 year, between 1 and 2 years, between 2 and 5 years, between 5 and 10 years, more than 10 years)
   Interval scale
7. How much longer are you planning on living in the same house / apartment you currently live?

(less than 1 year, between 1 and 2 years, between 2 and 5 years, between 5 and 10 years, more than 10 years)

Interval scale

8. Are there other countries you lived in for an extended period of time (i.e. more than a year)? Please list (country & how long).

   Grounded theory / open coding, axial coding

9. What is the highest level of education you completed including the one you're currently pursuing?

   (Primary school, High school or equivalent, Technical school, Bachelor's degree, Master's degree, Doctoral's degree, Postdoctoral, Other (please specify))

   Nominal scale

10. What is your occupation? (give es detailed as possible - if student, provide student in biology)

    Grounded theory / open coding, axial coding

11. How comfortable do you feel with technology such as computers, smart phones, tablets?

    (Extremely comfortable, Very comfortable, Moderately comfortable, Slightly comfortable, Not at all comfortable

    Likert-scale

Questions around your home

12. Do you live in a house or an apartment? (house / apartment / other (please specify))

    Nominal scale

13. Do you rent your home or do you own it? (rent / own / other (please specify, e.g. you live in a home own by your parents))

    Nominal scale

14. How many people live in your household (including you)?

    Ordinal scale

15. Who do you share your household with? (family, partner, friends, alone, other (please specify))?

    Nominal scale

16. Do you live with kids younger than 16? (yes / no)

    Dichotomous alternative

17. Do you have a babysitter / gardener / cook / person taking care of your home or someone helping you out regularly with your home? (yes / no)

    Dichotomous alternative

18. (*if 17 yes*) Who is helping you out, and how many hours in average does he/she spend weekly in your home?

    Grounded theory / open coding, axial coding

19. Do you have pets? (yes / no)

    Dichotomous alternative

Devices and Home Automation

20. How interested are you in home automation technologies?

    (Extremely interested, Very interested, Moderately interested, Slightly interested, Not at all interested)

    Likert scale

21. Have you already searched for or informed yourself about home automation technologies online? (yes / no)

    Dichotomous alternative

22. How likely are you to use some home automation technologies in your home? (Extremely likely, Very likely, Moderately likely, Slightly likely, Not at all likely)

    Likert scale

23. (*if 20 is Extremely interested or Very interested and 22 is Slightly likely or Not at all likely*) You seem interested in home automation, but reluctant to use these technologies at home. Can you please give reasons why?

    Grounded theory / open coding, axial coding

24. Have you already automated some household activities in your home? (yes / no)

    Dichotomous alternative

25. (*if 24 is yes*) What did you automate and how?

    Grounded theory / open coding, axial coding

26. (*if 24 is yes*) How well does the automation perform the household activities it is supposed to support? (Extremely well, Very well, Moderately well, Slightly well, Not at all well)

    Likert scale

27. (*if 24 is yes and 26 specified*) Do you want to share details on your last answer, "..."?

    Grounded theory / open coding, axial coding

28. Do you own further devices or sensors that have automation or remote control capabilities, that you haven't configured yet? (yes / no)

    Dichotomous alternative

29. (*if 28 is yes*) Please specify devices or sensors you own.
    Grounded theory / open coding, axial coding

The following question might be a little bit abstract - there is no right or wrong answer. Just provide your initial thoughts or best estimate

30. Which household activity would you like to be automated the most (assuming that it would work perfectly)?
    Grounded theory / open coding, axial coding
31. Why?
    Grounded theory / open coding, axial coding
32. How much (in USD) would you pay for it (assuming that it works perfectly)?
    Grounded theory / open coding, axial coding
33. What are further household activities in your home that you'd like to have automated?
    Grounded theory / open coding, axial coding

To create a 3D model representing your home, just a few last questions ...

34. Do you live in a village, an urban area or suburban area? (village, urban area, suburban area)
    Nominal scale
35. What floor do you live on? (ground, upper, multiple floors)
    Nominal scale
36. How many bathrooms do you have?
    Ordinal scale
37. Do you have a balcony, a garden or both? (balcony, garden, both, none)
    Nominal scale
38. How many bedrooms do you have? (One-bedroom or studio, Two-bedrooms, Three-bedrooms, More than three)
    Nominal scale
39. Is there something that is unique to your home? Please explain...
    Grounded theory / open coding, axial coding

[VIEW]
What floor model represents your home best? According to your specifications of

some attributes of your home, we can show you a list of possible matches. Select the one that fits best.

[VIEW]
Have a look at the video of your home model containing suggestions of household activities that can be automated. On the next page you can explore and interact further with the floor model. When done with video, go to the next page.

[ARCHILOGIC-MODEL]
Please specify up to five preferred household activities you would like to get automated in your home.

Drag & drop household activities from below according to your preference order. For all automation activities you can assume that there is no cost attached for you.

Explore how you can make your home smarter. By clicking on an automated household activity you see via the provided floor model on the right where in the home this automation activity happens. The tooltip over each household activity shows you what devices you would need to install to achieve this automation.

40. Please specify up to five preferred household activities you would like to get automated in your home. (specify at least one, at most 5)
    Grounded theory / open coding, axial coding

Give us some more details on your chosen household activities.

40. Why did you chose this particular household activity? Specify how desirable this automation would be for you in your daily life.
    Grounded theory / open coding, axial coding
41. At the beginning of the survey you specified *automation wish* as the first household activity you would like to get automated. Rank this household activity in comparison to the above chosen ones. What ranking would you give it? (e.g, if you have activities ranked as A, B, C, and you think your own activity should be ranked between A and B, than input 2)
    Grounded theory / open coding, axial coding
42. What further household activity automation ideas should we add that we have not mentioned but are essential needs in your opinion. Please describe.
    Grounded theory / open coding, axial coding
43. How difficult was it to understand the descriptions of household activities? (Extremely difficult, Very difficult, Moderately difficult, Slightly difficult, Not at all difficult) *Likert scale*
44. Please further explain your answer in 43: how difficult you considered the descriptions of household activities. Do you have suggestions how to make these activities more understandable?

Grounded theory / open coding, axial coding

Give us some feedback on the provided 3D floor model

46. How well did the 3D model match your home? (Extremely well, Very well, Moderately well, Slightly well, Not at all well)

    Likert scale

47. Please explain why you specified that the 3D model matched see answer previous quesiton, 46?

    Grounded theory / open coding, axial coding

48. Please describe whether and if so how you used the provided 3D model when answering the questions?

    Grounded theory / open coding, axial coding

49. How helpful was the provided 3D floor model to putting yourself in the context of your home when thinking about household activities that could be automated?

    Grounded theory / open coding, axial coding

50. Did the provided 3D model help you to think about household activities that could be automated in your home? (It was extremely helpful, It was Very helpful, It was moderately helpful, It was slightly helpful, It was not at all helpful)

    Likert scale

51. Please describe why you think the provided model was as specified in 50?

    Grounded theory / open coding, axial coding

52. Is there anything that we could include in the floor model that would make it more helpful?

    Grounded theory / open coding, axial coding

53. How likely are you to do research, browse, or shop for home automation technologies in the future? (Extremely likely, Very likely, Moderately likely, Slightly likely, Not at all likely)

    Likert scale

54. Do you have any further comments or suggestions to add?

    Grounded theory / open coding, axial coding

Appendix C

Resources of 3D Models

Figure C.1: 1, 2 and 3 bedroom models with garden

1 bedroom with balcony

2 bedroom with balcony

3 bedroom with balcony

Figure C.2: 1, 2 and 3 bedroom models with balcony

Appendix D

Final Prototype

Smart Home 'Cashasa'

PAGE 1

About this study

We are researching different techniques to present various smart home technologies to users, to elicit their preferences and to explore what factors influence these choices. Thereby, we are introducing a goal-based approach in an individually customizable 3D model interface. The name Cashasa stands for customer-centric automation-goals scheme of household activities in spatial areas.

START!

Agreeing to research conditions

PAGE 2

KEY POINTS: Study about smart home solutions; 15 minutes needed; win one of five 50$ Amazon vouchers; use the Chrome browser (or Safari) on a desktop computer

You are about to participate in our study on home automation and smart homes. We'll ask you some general questions about yourself, technologies you use in your home and your preferences for household activities you would like to get automated. Your answers will enable us to gain a better understanding of the needs of inhabitants and the technique we chose to elicit those. We hope you learn more about home automation and get new inspirations and ideas what you could integrate into your home.

Why we are doing this research: We aim to understand what the best technique is to present various smart home technologies to the users, and what their preferences are.

Win one of five 50$ Amazon vouchers: All participants who complete the study may enter their e-mail in the end to participate in the raffle to win one of five Amazon vouchers. The participation in the raffle is recorded into a different database such that it is not possible to attribute answers to any particular participant.

What you will have to do: You will be asked some general survey questions, like general information about yourself, your housing situation and home automation. Then, you will specify your preferences of household activities you would like to have automated and finally we will ask you to give us some feedback.
Your participation in this study is completely voluntary and you may refuse to participate or withdraw without penalty or loss of benefits to which you may otherwise be entitled.

Time needed: Time needed to complete this study is around 15 minutes.

Recommended screen size and type: We recommend that you perform this study on a laptop or desktop computer, having the browser's width set to at least 1100px, and the browser's height to at least 700px.

Potential risks: There are no risks or cost anticipated in taking part in this study. You are free to leave at any time without penalty or loss of benefits to which you may otherwise be entitled.

Privacy and data results: Your responses will be kept anonymous. We do not collect any information that could be used to directly establish your identity and we will not attribute answers to any particular participant. The accumulated results of all users collected in this study might appear in both internal and external presentations and publications, as well as academic journals and conference proceedings.

To contact the researcher: If you have questions or concerns about this research, please contact Martina Rakaric, University of Zurich, Switzerland, martina.rakaric@gmail.com.

Please print or save a copy of this page for your records.

By ticking this check-box you confirm that you have read and understood the above and agree to take part in this research. Your participation is voluntary and you are free to leave the experiment at any time simply by closing the web browser.

☐ Yes, I agree.

You must check the box to continue

Tell us something about yourself

Have you taken this survey before?

- ○ Yes
- ◉ No

What is your gender?

- ○ Male
- ◉ Female
- ○ n/a

What is your age?

33

What country do you currently live in?

Switzerland ×

How safe do you feel in your country?

Extremely safe ▼

How long have you already lived in the same house / apartment you currently live?

between 5 and 10 years ▼

How much longer are you planning on living in the same house / apartment you currently live?

between 1 and 2 years ▼

Are there other countries you lived in for an extended period of time (i.e. more than a year)? Please list all countries and for how long you lived there.

Chile, 2years

13/300

Your highest level of education including the one you're currently pursuing?

Master's degree ▼

What is your occupation? (give es detailed as possible, eg. if student, provide student in biology)

software engineer

17/40

Comfort with technology such as computers, smartphones, tablets?

Extremely comfortable ▼

NEXT

Questions around your home

Do you live in a house or an apartment?

- ○ House
- ◉ Apartment
- ○ Other

Do you rent your home or own it?

- ◉ Rent
- ○ Own
- ○ Other (e.g. you live in a home owned by your parents)

How many people live in your household (including you)?

2

Who do you share your home with?

Partner ▼

Do you live with children younger than 16?

- ○ Yes
- ◉ No

Do you have a babysitter / gardener / cook / person taking care of your home or someone helping you out regularly with your home?

- ◉ Yes
- ○ No

Who is helping you out, and how many hours in average does he/she spend weekly in your home?

a cleaning lady, 4hours a week.

31/140

Do you have pets?

- ◉ Yes
- ○ No

NEXT

Devices and Home Automation

How interested are you in home automation?

Extremely interested

Have you already searched for or informed yourself about home automation technologies online?

- ○ Yes
- ◉ No

How likely are you to use some home automation technologies in your home?

Extremely likely

Have you already automated some household activities in your home?

- ◉ Yes
- ○ No

What did you automate and how?

I have a Philips Hue lamp.

26/300

How well does the automation perform the household activities it is supposed to support?

Very well

Do you want to share details on your last answer, "Very well"?

The interface is somewhat confusing, and the app crashes.

Do you own further devices or sensors that have automation or remote control capabilities, that you haven't configured yet?

- ○ Yes
- ◉ No

The following questions might be a little bit abstract - there is no right or wrong answer. Just provide your initial thoughts or best estimate.

Which household activity would you like most to be automated (assuming that it would work perfectly)?

Automatic temperature.

22/300

Why?

I want it to be warm when I come back home.

43/300

How much would you pay for it (assuming that it works perfectly)?

in winter months more, like 50USD per month.

44/300

What are further tasks in your home that you'd like to have automated?

cleaning

8/300

NEXT

PAGE 6

Last step before we configure your home model

Do you live in a village, a suburban area or urban area?

- ○ Village
- ○ Suburban
- ◉ Urban

What floor do you live on?

- ○ Ground
- ◉ Upper
- ○ Multiple floors

How many bathrooms do you have?

1

Do you have a balcony, garden or both?

Balcony

How many bedrooms do you have?

- ○ One-bedroom or a studio
- ◉ Two-bedrooms
- ○ Three-bedrooms
- ○ More than three

Is there something that is unique to your home?

it has a rooftop on top of the building.

40/300

NEXT

PAGE 7

What floor model represents your home best?

According to your specifications of some attributes of your home, we can show you a list of possible matches. Select the one that fits best.

○

Have a look at the video of your home model containing suggestions of household activities that can be automated.

On the next page you can explore and interact further with the floor model. When done with video, go to the next page.

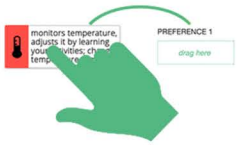
PAGE 8

☐ Check this box when you would like to continue to the next page (you cannot come back to this view).

PAGE 9

Please specify up to five preferred household activities you would like to get automated in your home.

Drag & drop household activities from below according to your preference order. For all automation activities you can assume that there is no cost attached for you.



PREFERENCE 1	PREFERENCE 2	PREFERENCE 3	PREFERENCE 4	PREFERENCE 5
wake up with customized dimmed lights, or when it is optimal to be woken up	monitors temperature, adjusts it by learning your activities; change temperature remotely	burglar alarm starts when you leave home; it turns off when you arrive home	drag here	drag here

Explore how you can make your home smarter

By clicking on an automated household activity you see via the provided floor model on the right where in the home this automation activity happens. The tooltip over each household activity shows you what devices you would need to install to achieve this automation.

WEATHER CONTROL

- blinds opening & closing according to weather and sunlight
- irrigation turns on when there is no rain, and turns off when there is enough rain
- monitors temperature, adjusts it by learning your activities; change temperature remotely

FAMILY

- track your children when they leave school zone, get notified when they come home
- get notified if loved ones depart from their expected daily patterns and behavior
- get updates or check the pet when away
- baby monitor when you are not in the same room
- nearly home? automatically message the person who should know
- by turning off all lights in the home send a signal to the children that it is time for bed
- monitor bed- & bath-room during the night to detect if occupant does not return back

SAFETY

- lock and unlock doors when appropriate(lock when leaving, unlock when a guest comes)
- smoke alarm and fire detector make sure the air in the home is not contaminated
- holiday mode: home appears occupied by randomly turning on / off lights & other media

Play around with your floor model

You can use arrows or mouse to get around, press C to refocus, or change views (floorplan, bird, person view) to interact. Click into the floorplan to start exploring.

Give us some more details on your chosen household activities.

wake up with customized dimmed lights, or when it is optimal to be woken up

Why did you chose this particular household activity? Specify how desirable this automation would be for you in your daily life.

because I have problems with waking up.

monitors temperature, adjusts it by learning your activities; change temperature remotely

Why did you chose this particular household activity? Specify how desirable this automation would be for you in your daily life.

because I want my house to be warm and cozy.

burglar alarm starts when you leave home; it turns off when you arrive home

Why did you chose this particular household activity? Specify how desirable this automation would be for you in your daily life.

To be more sure everything is ok.

At the beginning of the survey you specified "*Automatic temperature.*" as the first household activity you would like to get automated. Rank this household activity in comparison to the above chosen ones. What ranking would you give it? (e.g, if you have activities ranked as A, B, C, and you think your own activity should be ranked between A and B, then input 2. If it is the same as chosen above, explain it).

Specify the rank and share why.

same like B

11/140

What further household activity automation ideas should we add that we have not mentioned but are essential needs in your opinion. Please describe.

automatic cleaning

18/300

How difficult was it to understand the descriptions of household activities?

Not at all difficult

Please further explain your answer *Not at all difficult*. Do you have suggestions how to make these activities more understandable?

straight forward explanations.

30/300

NEXT

Give us some feedback on the provided 3D floor model

How well did the 3D model match your home?

Very well

Please explain why you specified the 3D model matched your home *Very well*?

It has the same amount of rooms and similar Ikea furniture.

59/300

Please describe whether and if so how you used the provided 3D floor model during the study.

To see where the devices could be installed

Did the provided 3D model help you to think about household activities that could be automated in your home?

Please specify

It was very helpful

Please describe why you think the provided model was *It was very helpful*?

Because it reminded me of my home.

35/300

Is there anything that we could include in the floor model that would make it more helpful?

option for specific devices.

28/300

How likely are you to do research, browse, or shop for home automation technologies in the future?

Extremely likely

Do you have further comments or suggestions you would like to add?

thank you for the study.

24/300

NEXT

Thank you for your time and participation!

If you wish to be informed about the study's results, input your email here. We are likely to have study results by April 2016. The email will not be associated with the data you just provided.

Input your email

sampleuser@cashasa.com

By having participated in this study, you have the chance to win one of the 5 Amazon vouchers à 50 USD. If you wish to enter the raffle, input your email here. We will inform you by mid February if you were amongst the lucky ones.

- (●) Yes, with the same email as above.
- ( ) Yes, with the following email.
- ( ) No, thank you.

SAVE

Thank you for your time and participation!

Appendix E

Some Chosen Study Results Visualisations

E.1 Analysis of Differently Ranked Preferences

PREFERENCE 1	E(x)	3.85%	82	in total
lifestyle goals	#	count	percent	actions
Convenience	26	19	23.17%	floors will be vacuum cleaned automatically and the device will recharge itself
Safety	6	7	8.54%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Energy Saving	15	7	8.54%	know your daily power usage, manage appliances to turn on & off when not needed
Atmosphere & Relaxing	22	7	8.54%	wake up with customized dimmed lights, or when it is optimal to be woken up
Energy Saving	14	6	7.32%	home stores solar power and coordinates between solar and energy usage
Atmosphere & Relaxing	20	6	7.32%	set the right atmosphere, music, TV program and temperature
Convenience	25	6	7.32%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Safety	1	5	6.10%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	2	3	3.66%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Weather Control	18	3	3.66%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Safety	4	2	2.44%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Family	13	2	2.44%	nearly home? automatically message the person who should know
Energy Saving	16	2	2.44%	get notified about water leakage & shut it off remotely; monitor your water usage
Atmosphere & Relaxing	21	2	2.44%	set up the lightning according to your current mood or turn it on / off remotely
Family	8	1	1.22%	get notified if loved ones depart from their expected daily patterns and behavior
Family	9	0	1.22%	track your children when they leave school zone, get notified when they come home
Weather Control	17	1	1.22%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Weather Control	19	1	1.22%	blinds opening & closing according to weather and sunlight
Convenience	23	1	1.22%	your simple coffee-maker automatically turns on in the morning when you wake up
Safety	3	0	0.00%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Safety	5	0	0.00%	panic button to share your emergency and location to friends, family
Family	7	0	0.00%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	10	0	0.00%	baby monitor when you are not in the same room
Family	11	0	0.00%	by turning off all lights in the home send a signal to the children that it is time for bed
Family	12	0	0.00%	get updates or check on the pet when away
Convenience	24	1	0.00%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc

Figure E.1: Preference 1: preferred activities

PREFERENCE 2	E(x)	3.85%	81	in total
lifestyle goals	#	count	percent	action
Convenience	26	12	14.81%	floors will be vacuum cleaned automatically and the device will recharge itself
Energy Saving	16	8	9.88%	get notified about water leakage & shut it off remotely; monitor your water usage
Weather Control	19	8	9.88%	blinds opening & closing according to weather and sunlight
Atmosphere & Relaxing	22	8	9.88%	wake up with customized dimmed lights, or when it is optimal to be woken up
Convenience	23	6	7.41%	your simple coffee-maker automatically turns on in the morning when you wake up
Convenience	25	6	7.41%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Weather Control	18	5	6.17%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Atmosphere & Relaxing	21	5	6.17%	set up the lightning according to your current mood or turn it on / off remotely
Safety	4	4	4.94%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Energy Saving	14	4	4.94%	home stores solar power and coordinates between solar and energy usage
Safety	5	2	2.47%	panic button to share your emergency and location to friends, family
Energy Saving	15	2	2.47%	know your daily power usage, manage appliances to turn on & off when not needed
Atmosphere & Relaxing	20	2	2.47%	set the right atmosphere, music, TV program and temperature
Convenience	24	2	2.47%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
Safety	1	1	1.23%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	2	1	1.23%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Safety	3	1	1.23%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Family	7	1	1.23%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	11	1	1.23%	by turning off all lights in the home send a signal to the children that it is time for bed
Family	12	1	1.23%	get updates or check on the pet when away
Weather Control	17	1	1.23%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Safety	6	0	0.00%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Family	8	0	0.00%	get notified if loved ones depart from their expected daily patterns and behavior
Family	9	0	0.00%	track your children when they leave school zone, get notified when they come home
Family	10	0	0.00%	baby monitor when you are not in the same room
Family	13	0	0.00%	nearly home? automatically message the person who should know

Figure E.2: Preference 2: preferred activities

PREFERENCE 3	E(x)	3.85%	81	in total
lifestyle goals	#	count	percent	action
Weather Control	19	10	12.35%	blinds opening & closing according to weather and sunlight
Convenience	25	10	12.35%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Energy Saving	16	6	7.41%	get notified about water leakage & shut it off remotely; monitor your water usage
Convenience	26	6	7.41%	floors will be vacuum cleaned automatically and the device will recharge itself
Safety	2	5	6.17%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Energy Saving	15	5	6.17%	know your daily power usage, manage appliances to turn on & off when not needed
Weather Control	18	5	6.17%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Safety	3	4	4.94%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Safety	4	4	4.94%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Energy Saving	14	4	4.94%	home stores solar power and coordinates between solar and energy usage
Atmosphere & Relaxing	22	4	4.94%	wake up with customized dimmed lights, or when it is optimal to be woken up
Safety	6	3	3.70%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Atmosphere & Relaxing	21	3	3.70%	set up the lightning according to your current mood or turn it on / off remotely
Weather Control	17	2	2.47%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Convenience	23	2	2.47%	your simple coffee-maker automatically turns on in the morning when you wake up
Convenience	24	2	2.47%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
Safety	1	1	1.23%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	5	1	1.23%	panic button to share your emergency and location to friends, family
Family	7	1	1.23%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	10	1	1.23%	baby monitor when you are not in the same room
Family	13	1	1.23%	nearly home? automatically message the person who should know
Atmosphere & Relaxing	20	1	1.23%	set the right atmosphere, music, TV program and temperature
Family	8	0	0.00%	get notified if loved ones depart from their expected daily patterns and behavior
Family	9	0	0.00%	track your children when they leave school zone, get notified when they come home
Family	11	0	0.00%	by turning off all lights in the home send a signal to the children that it is time for bed
Family	12	0	0.00%	get updates or check on the pet when away

Figure E.3: Preference 3: preferred activities

PREFERENCE 4	E(x)	3.85%	78	in total
lifestyle goals	#	count	percent	action
Weather Control	18	13	16.67%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Convenience	26	7	8.97%	floors will be vacuum cleaned automatically and the device will recharge itself
Energy Saving	15	6	7.69%	know your daily power usage, manage appliances to turn on & off when not needed
Atmosphere & Relaxing	20	6	7.69%	set the right atmosphere, music, TV program and temperature
Convenience	25	6	7.69%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Weather Control	17	5	6.41%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Safety	6	4	5.13%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Energy Saving	14	4	5.13%	home stores solar power and coordinates between solar and energy usage
Convenience	24	4	5.13%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
Safety	3	3	3.85%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Safety	4	3	3.85%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Energy Saving	16	3	3.85%	get notified about water leakage & shut it off remotely; monitor your water usage
Family	11	2	2.56%	by turning off all lights in the home send a signal to the children that it is time for bed
Weather Control	19	2	2.56%	blinds opening & closing according to weather and sunlight
Atmosphere & Relaxing	21	2	2.56%	set up the lightning according to your current mood or turn it on / off remotely
Atmosphere & Relaxing	22	2	2.56%	wake up with customized dimmed lights, or when it is optimal to be woken up
Convenience	23	2	2.56%	your simple coffee-maker automatically turns on in the morning when you wake up
Safety	1	1	1.28%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	5	1	1.28%	panic button to share your emergency and location to friends, family
Family	8	1	1.28%	get notified if loved ones depart from their expected daily patterns and behavior
Family	13	1	1.28%	nearly home? automatically message the person who should know
Safety	2	0	0.00%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Family	7	0	0.00%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	9	0	0.00%	track your children when they leave school zone, get notified when they come home
Family	10	0	0.00%	baby monitor when you are not in the same room
Family	12	0	0.00%	get updates or check on the pet when away

Figure E.4: Preference 4: preferred activities

PREFERENCE 5	E(x)	3.85%	75	in total
lifestyle goals	#	count	percent	action
Energy Saving	15	9	12.00%	know your daily power usage, manage appliances to turn on & off when not needed
Energy Saving	14	8	10.67%	home stores solar power and coordinates between solar and energy usage
Convenience	25	8	10.67%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Weather Control	17	7	9.33%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Safety	4	5	6.67%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Weather Control	19	5	6.67%	blinds opening & closing according to weather and sunlight
Convenience	26	5	6.67%	floors will be vacuum cleaned automatically and the device will recharge itself
Atmosphere & Relaxing	20	4	5.33%	set the right atmosphere, music, TV program and temperature
Safety	2	3	4.00%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Atmosphere & Relaxing	21	3	4.00%	set up the lightning according to your current mood or turn it on / off remotely
Atmosphere & Relaxing	22	3	4.00%	wake up with customized dimmed lights, or when it is optimal to be woken up
Convenience	23	3	4.00%	your simple coffee-maker automatically turns on in the morning when you wake up
Convenience	24	3	4.00%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
Safety	1	2	2.67%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	6	2	2.67%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Energy Saving	16	2	2.67%	get notified about water leakage & shut it off remotely; monitor your water usage
Safety	3	1	1.33%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Family	12	1	1.33%	get updates or check on the pet when away
Weather Control	18	1	1.33%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Safety	5	0	0.00%	panic button to share your emergency and location to friends, family
Family	7	0	0.00%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	8	0	0.00%	get notified if loved ones depart from their expected daily patterns and behavior
Family	9	0	0.00%	track your children when they leave school zone, get notified when they come home
Family	10	0	0.00%	baby monitor when you are not in the same room
Family	11	0	0.00%	by turning off all lights in the home send a signal to the children that it is time for bed
Family	13	0	0.00%	nearly home? automatically message the person who should know

Figure E.5: Preference 5: preferred activities

E.2 Participants with Children

PREFERENCE (with kids)		3.85%	34	in total
lifestyle goals	#	count	percent	action
Weather Control	19	4	11.76%	blinds opening & closing according to weather and sunlight
Weather Control	18	3	8.82%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Convenience	25	3	8.82%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Convenience	26	3	8.82%	floors will be vacuum cleaned automatically and the device will recharge itself
Safety	6	2	5.88%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Energy Saving	14	2	5.88%	home stores solar power and coordinates between solar and energy usage
Energy Saving	15	2	5.88%	know your daily power usage, manage appliances to turn on & off when not needed
Atmosphere & Relaxing	20	2	5.88%	set the right atmosphere, music, TV program and temperature
Atmosphere & Relaxing	21	2	5.88%	set up the lightning according to your current mood or turn it on / off remotely
Safety	1	1	2.94%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	3	1	2.94%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Safety	4	1	2.94%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Family	8	1	2.94%	get notified if loved ones depart from their expected daily patterns and behavior
Family	11	1	2.94%	by turning off all lights in the home send a signal to the children that it is time for bed
Family	13	1	2.94%	nearly home? automatically message the person who should know
Energy Saving	16	1	2.94%	get notified about water leakage & shut it off remotely; monitor your water usage
Weather Control	17	1	2.94%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Atmosphere & Relaxing	22	1	2.94%	wake up with customized dimmed lights, or when it is optimal to be woken up
Convenience	23	1	2.94%	your simple coffee-maker automatically turns on in the morning when you wake up
Convenience	24	1	2.94%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
Safety	2	0	0.00%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Safety	5	0	0.00%	panic button to share your emergency and location to friends, family
Family	7	0	0.00%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	9	0	0.00%	track your children when they leave school zone, get notified when they come home
Family	10	0	0.00%	baby monitor when you are not in the same room
Family	12	0	0.00%	get updates or check on the pet when away

Figure E.6: Participants with Children

E.3 Participants with Pets

PREFERENCE (with pets)		3.85%	86	in total
lifestyle goals	#	count	percent	action
Energy Saving	15	10	11.63%	know your daily power usage, manage appliances to turn on & off when not needed
Convenience	25	9	10.47%	turns devices on/off according to arrival / departure; remotely turn off all appliances
Convenience	26	9	10.47%	floors will be vacuum cleaned automatically and the device will recharge itself
Energy Saving	14	7	8.14%	home stores solar power and coordinates between solar and energy usage
Weather Control	19	7	8.14%	blinds opening & closing according to weather and sunlight
Safety	6	6	6.98%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
Atmosphere & Relaxing	20	5	5.81%	set the right atmosphere, music, TV program and temperature
Safety	4	4	4.65%	holiday mode: home appears occupied by randomly turning on/off lights & other media
Atmosphere & Relaxing	22	4	4.65%	wake up with customized dimmed lights, or when it is optimal to be woken up
Convenience	24	4	4.65%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
Safety	1	3	3.49%	smoke alarm and fire detector make sure the air in the house is not contaminated
Safety	2	3	3.49%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
Energy Saving	16	3	3.49%	get notified about water leakage & shut it off remotely; monitor your water usage
Safety	3	2	2.33%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
Family	12	2	2.33%	get updates or check on the pet when away
Weather Control	17	2	2.33%	irrigation system turns on when there is no rain, and turns off when there is enough rain
Weather Control	18	2	2.33%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
Family	11	1	1.16%	by turning off all lights in the home send a signal to the children that it is time for bed
Family	13	1	1.16%	nearly home? automatically message the person who should know
Atmosphere & Relaxing	21	1	1.16%	set up the lightning according to your current mood or turn it on / off remotely
Convenience	23	1	1.16%	your simple coffee-maker automatically turns on in the morning when you wake up
Safety	5	0	0.00%	panic button to share your emergency and location to friends, family
Family	7	0	0.00%	monitor bed- and bathroom during the night to detect if occupant does not return back
Family	8	0	0.00%	get notified if loved ones depart from their expected daily patterns and behavior
Family	9	0	0.00%	track your children when they leave school zone, get notified when they come home
Family	10	0	0.00%	baby monitor when you are not in the same room

Figure E.7: Participants with Pets

E.4 Planning Staying

participants planning staying longer (between 5 and 10 years or more than 10)

PREFERENCE		E(x)	3.85%	58	in total	
estimated complexity	lifestyle goals	#	rank	count	percent	action
complex	Energy Saving	15		6	10.34%	know your daily power usage, manage appliances to turn on & off when not needed
medium	Weather Control	18		6	10.34%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
easy	Convenience	26		6	10.34%	floors will be vacuum cleaned automatically and the device will recharge itself
complex	Energy Saving	14		5	8.62%	home stores solar power and coordinates between solar and energy usage
complex	Weather Control	19		5	8.62%	blinds opening & closing according to weather and sunlight
complex	Energy Saving	16		4	6.90%	get notified about water leakage & shut it off remotely; monitor your water usage
easy	Safety	1		3	5.17%	smoke alarm and fire detector make sure the air in the house is not contaminated
complex	Safety	6		3	5.17%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
easy	Atmosphere & Relaxing	22		3	5.17%	wake up with customized dimmed lights, or when it is optimal to be woken up
medium	Convenience	25		3	5.17%	turns devices on/off according to arrival / departure; remotely turn off all appliances
easy	Safety	4		2	3.45%	holiday mode: home appears occupied by randomly turning on/off lights & other media
easy	Family	13		2	3.45%	nearly home? automatically message the person who should know
complex	Weather Control	17		2	3.45%	irrigation system turns on when there is no rain, and turns off when there is enough rain
easy	Atmosphere & Relaxing	21		2	3.45%	set up the lightning according to your current mood or turn it on / off remotely
medium	Safety	3		1	1.72%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
medium	Family	7		1	1.72%	monitor bed- and bathroom during the night to detect if occupant does not return back
medium	Family	11		1	1.72%	by turning off all lights in the home send a signal to the children that it is time for bed
easy	Atmosphere & Relaxing	20		1	1.72%	set the right atmosphere, music, TV program and temperature
medium	Convenience	23		1	1.72%	your simple coffee-maker automatically turns on in the morning when you wake up
easy	Convenience	24		1	1.72%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
medium	Safety	2		0	0.00%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
easy	Safety	5		0	0.00%	panic button to share your emergency and location to friends, family
medium	Family	8		0	0.00%	get notified if loved ones depart from their expected daily patterns and behavior
easy	Family	9		0	0.00%	track your children when they leave school zone, get notified when they come home
easy	Family	10		0	0.00%	baby monitor when you are not in the same room
medium	Family	12		0	0.00%	get updates or check on the pet when away

participants planning staying less time (less than 5 years)

PREFERENCE		E(x)	3.85%	339	in total	
estimated complexity	lifestyle goals	#	rank	count	percent	action
easy	Convenience	26		43	12.68%	floors will be vacuum cleaned automatically and the device will recharge itself
medium	Convenience	25		33	9.73%	turns devices on/off according to arrival / departure; remotely turn off all appliances
complex	Energy Saving	15		29	8.55%	know your daily power usage, manage appliances to turn on & off when not needed
complex	Energy Saving	14		21	6.19%	home stores solar power and coordinates between solar and energy usage
medium	Weather Control	18		21	6.19%	Monitors temperature, adjusts it by learning your activities; change temperature remotely
complex	Weather Control	19		21	6.19%	blinds opening & closing according to weather and sunlight
easy	Atmosphere & Relaxing	22		21	6.19%	wake up with customized dimmed lights, or when it is optimal to be woken up
easy	Atmosphere & Relaxing	20		18	5.31%	set the right atmosphere, music, TV program and temperature
easy	Safety	4		16	4.72%	holiday mode: home appears occupied by randomly turning on/off lights & other media
complex	Safety	6		15	4.42%	lock and unlock up doors when appropriate (lock when leaving, unlock when a guest comes)
complex	Weather Control	17		14	4.13%	irrigation system turns on when there is no rain, and turns off when there is enough rain
easy	Atmosphere & Relaxing	21		14	4.13%	set up the lightning according to your current mood or turn it on / off remotely
medium	Safety	2		12	3.54%	detects intruders, sounds a loud, flashing siren; you get notified with liveview & video
medium	Convenience	23		12	3.54%	your simple coffee-maker automatically turns on in the morning when you wake up
complex	Energy Saving	16		11	3.24%	get notified about water leakage & shut it off remotely; monitor your water usage
easy	Convenience	24		11	3.24%	set up an automated reminder to water your flowers, take out your trash, feed your pet, etc
medium	Safety	3		8	2.36%	burglar alarm starts when you leave home / it turns off when you arrive home to keep your home safe
easy	Safety	1		7	2.06%	smoke alarm and fire detector make sure the air in the house is not contaminated
easy	Safety	5		2	0.59%	panic button to share your emergency and location to friends, family
medium	Family	8		2	0.59%	get notified if loved ones depart from their expected daily patterns and behavior
medium	Family	11		2	0.59%	by turning off all lights in the home send a signal to the children that it is time for bed
medium	Family	12		2	0.59%	get updates or check on the pet when away
easy	Family	13		2	0.59%	nearly home? automatically message the person who should know
medium	Family	7		1	0.29%	monitor bed- and bathroom during the night to detect if occupant does not return back
easy	Family	10		1	0.29%	baby monitor when you are not in the same room
easy	Family	9		0	0.00%	track your children when they leave school zone, get notified when they come home

Figure E.8: Comparison of participants planning to stay less and more in their current homes

Appendix F

Further Resources

Given that further Appendix Information takes a large amount of pages, out of ecological reasons we did not want to use more paper and decided to put all additional information on Google Drive, and enable everybody with the link[1] the access to them.

The shared Google Drive folder consists of

1. Market Analysis, the clustered product analysis including 34 different sources with a total of 534 entries. Additionally, each source's categorisation pattern is labelled (see analysis on this in 3.1.)
2. Card Sorting Images
3. Initial Survey
4. Research Conditions
5. Evaluation Results (in csv-format and spreadsheet)
6. Cashasa, the code of the prototype with installation indications in the README file. For the GitHub project, please contact the author of this thesis.

[1] https://drive.google.com/folderview?id=0ByUJSp3Tsmv3QnNCcUxFMm4wNTQ&usp=sharing

Appendix G

Content of the CD

The enclosed CD contains the following content:

- Zusfsg.txt: The abstract of the thesis in German
- Abstract.txt: The abstract of the thesis in English
- Masterarbeit.pdf: The written thesis document
- cashasa.zip: The code of the prototype
- MarketAnalysis.pdf: The clustered product analysis
- CardSortingImages.pdf: Images of the card sorting evaluation
- InitialSurvey.pdf: Design study and evluation results of the initial study
- ResearchConditions.pdf: Conditions for study participation
- EvaluationResultsCSV.csv: Raw evaluation results in the csv-format
- EvaluationResultsSpreadsheet.xlsx: Raw evaluation results in an Excel spreadsheet

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