Introduction to Innovation

Apartment

Group 9

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Introduction

This document describes the process of designing and evaluating a smart home system called "SmartFlat" for a family apartment. First, in *Section 1* and *Section 2*, we will introduce our newly designed accessories for controlling the water and electricity consumption. We will then give an overview on the design process of the main central monitor in *Section 3*, and its main feature "Family-Reporting" in *Section 4*. Finally, we will present our guideline for using the system in *Section 5*, give some examples how the system could be used by different persons in *Section 6* and a "Code of Ethics" in *Section 7*.

1. Water faucet

1.1. Problems with conventional water faucets

There are two widespread types of water faucets. The first type are the classic water faucets with one lever or two knobs which have to be rotated manually to turn the water on or off. This type of faucet is more common in private households. Since faucets have to be touched to be operated, sanitariness can be a problem. Another problem is resource-saving. While soaping up hands water wouldn't be needed, but in many cases the faucet will not be turned off because it would be inconvenient to wet your hands, put soap on and now turn the faucet off with soaped up hands, just to turn it on again some moments later.

The second type are motion sensor based water faucets which detect if hands are approximately under the tap and automatically turn water on or off. This type of faucet is more common in public buildings or shopping malls. It solves the problem of turning water on and off with soaped up hands, but takes some control away from the user. In most cases the pressure of the water can not be controlled with such faucets, its input modality was reduced to an on/off-type of input. Temperature, if possible to control at all, is still controlled via levers or other mechanical means.

Summarized, we try to tackle two kinds of problems. For one, we want to increase sanitarity by making direct physical contact between faucet and user optional. We still want to keep traditional control options, if users simply do not want to use a more modern approach and as a fallback option, so the faucet is still operable even if parts like sensors are defective. Two, we want to decrease resource wasting by giving the user comfortable control options, while not reducing the amount of control the user has compared to common water faucets (e.g. water pressure).

1.2. Interface: structure and components

The faucet needs a microprocessor and a Wi-Fi module (BW12 RTL8710BX) to gather all sensor inputs and send them to the central monitor over Wi-Fi. If the central monitor is used to control the faucet, the logged in user counts as a consumer for the resource and can control the faucet.

Otherwise, the conditions to operate the faucet are:

1.) The user is checked in, i.e. the RFID chip (bracelet) is detected in range of the faucet.

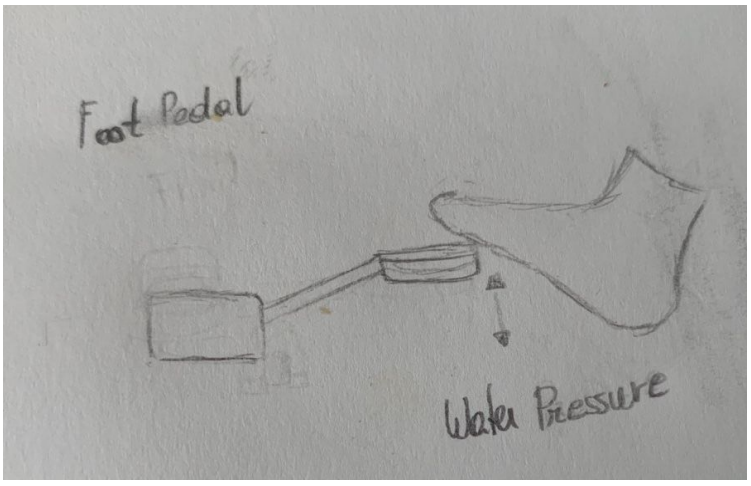
2.) The Control Stick is rotated slightly to the back, depending on wanted water pressure. This condition can either be fulfilled by manually rotating the ball by moving the control stick or by using the foot pedal.

For safety measures manual control (rotating the control stick) also works when a user is not detected as registered. If, for example, a person suffers burns while cooking and the bracelet gets damaged, the user should still be able to use the faucet to cool the wound, without needing to get the central monitor or another user. Such use is tracked as an unregistered user by the central monitor.

To allow checking in into the water faucet an RFID-module (IdTronic RFID UHF M800) is built into the faucet to detect the RFID device (bracelet) used for check-in. The reach of the module has to be tuned to detect RFID devices which are approximately in the sink. Thus, checking in happens automatically and should not trouble users. The faucet sends the check in to the central monitor, where the logic for checking in is actually handled. If two or more users are detected in range, the resources count as shared.

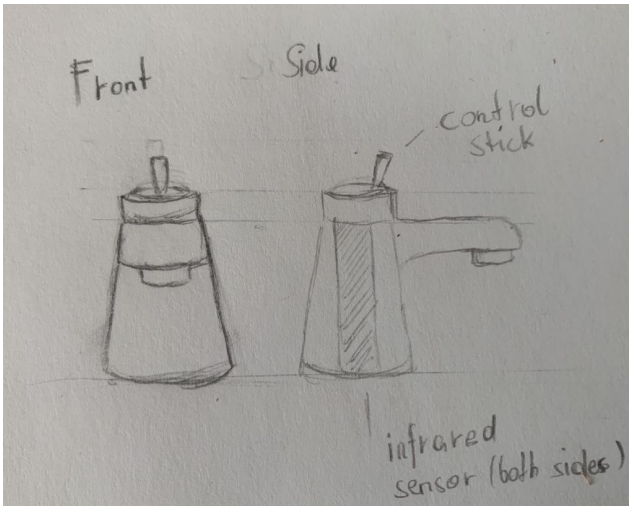
1.2.1. Faucet controls

A foot pedal mounted on the floor is used to turn the faucet on and for controlling the pressure without hands. The foot pedal needs to be long enough to be easily reachable under the sink. Since the pedal may be used barefoot or wearing only socks, the material of the pedal and strength needed to operate the pedal needs to be considered as well. For the top we use a rubber like material, as metal may feel uncomfortable on the bare foot. If no pressure is applied to the pedal, the pedal rises automatically back to its origin. Additionally, the central monitor can be used to turn the faucet on or off (*Section 3.4.3.*).



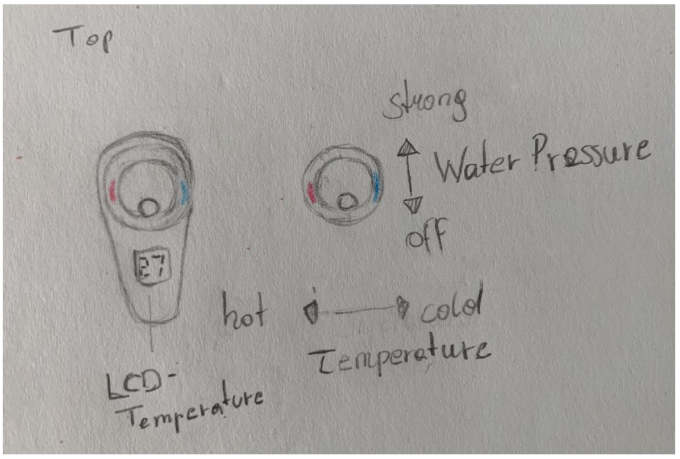
Sketch of foot pedal. Pushing the foot pedal down turns the water on. The water pressure can be raised by pushing it farther.

There are two active infrared sensors, one on each side (left and right) of the faucet. The infrared sensors are used to control the temperature of the water. If the sensor on the left side detects a hand, the temperature rises. If the sensor on the right side detects a hand the temperature sinks. Additionally, the central monitor can be used to change the temperature (*Section 3.*).



Front and side view of control mechanisms of the water faucet. On top is the control stick used as manual fallback for controlling water pressure and temperature. On the left and right side of the faucet are infrared sensors.

The stick on top serves as a fallback solution for manual control, should the other means of input not be used either because of discomfort or defect. The part on the top also serves as visual feedback for the user, should other means of input be used. If the foot pedal is pressed, the ball rotates to the back, depending on the strength the pedal is operated with. If the sensors are used to change the temperature the ball rotates to the left or right, depending if the water is set to be cooler or warmer. Additionally there are colour markings on the top, to allow easier understanding of the direction in which the stick has to be put to make the temperature warmer or colder.



Detailed view of the control stick and the LCD for temperature. Turning the stick left or right raises or lowers the temperature of the water respectively. Turning the stick back turns the faucet on and controls the water pressure.

1.3. Tracking water consumption

For tracking how much water flows through the faucet we use two YF-S201 Hall-Effect Water Flow sensors. One for the cold water pipe and one for the hot water pipe. This allows us to have a more precise hot water consumption for the family-reporting (*Section 4.*). Additionally we use a temperature sensor to measure the actual temperature of the water. The measured temperature is shown on a small display on top of the faucet.

When a user is checked in and the sensor recognizes flowing water the liters used per second (seperated in hot and cold water) are then sent to the central monitor over Wi-Fi together with the measured temperature of the water.

2. Light switch

2.1. Problems with conventional light switches

Conventional light switches are an established possibility to turn lights on or off. For room lights the switches are often already positioned at room entrances and exits. For smaller lights like bedside lamps switches are usually part of the lamp or at least very close to the lamp. What seems to be lacking is flexibility and consequently comfort. For operating the lights the user has to move to the light switch. For example, if the user goes to bed and realizes he or she has forgotten to turn off the lights in the bathroom it is necessary to go back to the bathroom to turn off the lights. This lack of comfort is what we want to tackle with our solution.

2.2. Interface: structure and components

The touch panel module (ATMXT144U-UU) has an integrated microcontroller and is connected to Wi-Fi (BW12 RTL8710BX) and an RFID module. If the central monitor is used

to control the lights, the logged in user counts as a consumer for the resources, even if this person is not in the room. Additionally each person in the room of the turned on room light, that is registered to the light source counts as a consumer as well.

Otherwise, the conditions to operate the lights are:

1.) The user is checked in, i.e. the RFID chip (bracelet or ring) is detected in range of the light. For light rooms the whole room is scanned, for smaller lights like bedside lamps only a smaller range is scanned (see Checking In).

2.) The light is turned on via the touch panel.

For room light switches Ultra High Frequency RFID modules (IdTronic RFID UHF M950) are used which have a range up to 10 meters and should cover the whole room. If needed, the range can be extended with additional antennas. For smaller lights like bedside lamps or mirror lights Ultra High Frequency RFID modules (IdTronic RFID UHF M800) with a range of around 1.5 meters are used. If a person enters or exits the room (or the reach of a small light) a notification is sent to the central monitor with the user ID. The calculation of the resource consumption is handled by the central monitor. If two or more persons are in a room the resource counts as shared and the central monitor calculates the individual consumption.

A disadvantage of this approach is that the RFID range of the module has to be tested for each room and may need additional antennas depending on partitioning of the room etc. Additionally, the walls may need a strengthened insulation to make sure the RFID signal is not traveling through walls, as this would allow users to be registered in multiple rooms simultaneously and could possibly skew resource consumption.

When a person exits the room and no other person is left in the room (i.e. not registered by the light source in the room) the light is turned off by the central monitor automatically. The automation can be fine-tuned via the central monitor, e.g. only for certain rooms or only at certain time ranges or even turned off completely. This automatic functionality is a measure to increase comfortability compared to conventional light switches.

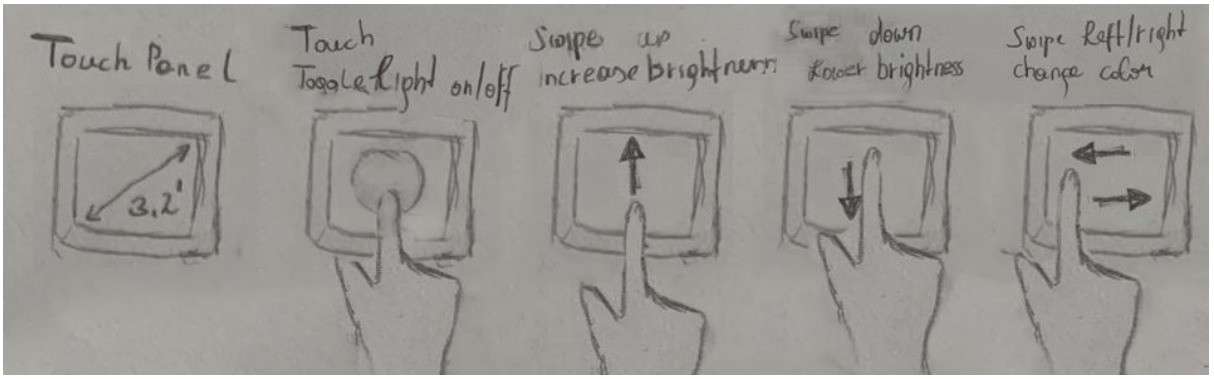
2.2.1. Light controls

3.2 inch touch panels are positioned besides entrances/exits of every room. Touch panels for smaller lights, like bedside lights or bathroom mirror lights, are positioned close to the light source. Those types of lights are often turned on because they are usually needed in specific situations, where the user is close to the light source, e.g. if additional light is needed in front of the mirror because the room light is not bright enough, or turning on a bedside lamp to read a book or find something in the bedside table. A simple touch toggles the light on or off.

For dimmable lights the brightness is divided in discrete steps from 0 to 5, where 0 is completely off and 5 is the brightest setting. Dimmable lights can either be turned on by a

simple touch (starts at brightness 3) or swiping up (raising the brightness from 0 to 1). Swiping down decreases the current level of brightness or turns it off (when decreased from 1 to 0). Swiping up or down for non-dimmable lights is interpreted as a simple touch. If the lights support color changing, color can be changed by swiping either left or right. This information is also sent via WLAN to the central monitor.

Additionally, the portable central monitor can be used to control the lights in the rooms with the same functionalities as the touch panel: Turning light on or off, changing brightness or color. This allows for example to decrease the brightness of the room while sitting on the couch and watching a movie, without the need to stand up and move to the switch. This is an additional functionality to increase comfortability compared to conventional light switches.



Sketch of the touch panel and touch controls. A touch toggles the light on or off, swiping up or down increases or decreases the brightness respectively, swiping left or right changes the light color.

3. Central Monitor

3.1. Description

The main component of SmartFlat is the central monitoring system. This component looks similar to an ordinary tablet, but loaded with powerful features. The central monitor system serves as a bridge between the accessories, which makes it mandatory for the whole system.

The target group for which this monitor is intended are the household owners. For example, in a family household it will be more often used by the parents than the children. The central monitor offers them the possibility to control the accessories from a single place in the house. Users will have the possibilities to set separate settings for each accessory (for example: no lights while on vacation or lights once a day while on vacation to prevent break-ins). It gives an overview of the consumption of water/electricity/gas per household and per person in detail (for example: hot/cold water consumption per person). All features will be described in the following subsections. The central monitor will be equipped with a voice control system, for the ease of use.

The accessories are connected to the central monitor by Wi-Fi. The pairing to the central monitor is done by simply turning the accessories on. The central monitor automatically detects that a new accessory is in range and prompts the user to confirm the pairing. After the pairing the user needs to set the default settings for the accessories, for example name, room, etc.

A user profile will be created for each person in the household. The RFID technology on the accessories will track the consumption data for each user, and send the data to the central monitor. This data is then displayed for each user on his user profile. Usually one or two users will be given the admin role, so they can get insights into the data and analysis, add new users/guests or restrict the usage of the accessories per user.

One application that will be included on the central monitor is an associated social media platform for people who use the same system. Here they can communicate with each other and exchange information on how to deal with certain tasks and problems.

3.2. Ideas

1. The article „The Solution of Smart Home Indoor Positioning Based on Wi-Fi" [1] deals with the development of smart home systems based on Wi-Fi Technology, to monitor and control the home environment. Traditional pairing methods, including passkeys, QR code, Bluetooth, RFID often require specific user interfaces. Wi-Fi is one of the key technologies that enable connectivity for smart home services. Wi-Fi signals have now been widely leveraged for various sensing tasks, due to its sensitivity to environmental dynamics. A smart home system, where accessories are connected with Wi-Fi technology is cost-effective, non-invasive, and enjoys convenient deployment. No further interfaces are required, because the connectivity is done over Wi-Fi Protected Setup which is activated over a simple push on a button. The extensive application of the Internet will make home control more automated, intelligent and humane. Based on this article, the usage of Wi-Fi connectivity between the control monitor and the accessories are the best solution, because of its reliability, cost-effectiveness, and ease of use.
2. The article "Smart home management with online power measurement" [2] points out how important monitoring energy consumption is becoming very necessary for optimal use of generated power. With the increase in local generation at household level and increase in rooftop solar panel installations, a proper monitoring system is required to assess and calculate energy consumption. While our system by the time of writing includes a water faucet and light switch, the paper mainly concentrates on power sockets. The information collected from the power socket is then sent to a "Central Host" system which monitors and manages the load connected. In the study the central system is controlled by a mobile application creating an option for remote access. Because the calculation of voltages and current at every socket needs a microcontroller or a microprocessor, installing one at every socket increases the cost of the entire system and results in additional power loss in order to supply voltage to respective microcontrollers.

In order to avoid this, a central system has been developed, with higher capacity to handle the arithmetics of all the data from the accessories.

3. The article “Design and Implementation of User Interactive Wireless Smart Home Energy Management System” [3] handles the decision making by the system to reduce the monthly bills of a household. The pattern developed in the study learns about previous user behavior and usage patterns of appliances, collects real time power consumption of appliances and creates efficient reports based on the collected information. The proposed power management system works with a wireless mesh network with WEEMAN (Wireless Enabled Electricity Manager) as a node. WEEMAN stays close to the user and learns the common behavioral patterns inside the house. The user also has the opportunity to set the upper limit of energy consumption per person in the household (expressed in monthly bill percentages). Our control monitor will use a similar approach to decrease the user monthly bills in water/electricity consumption.

3.3. Use case

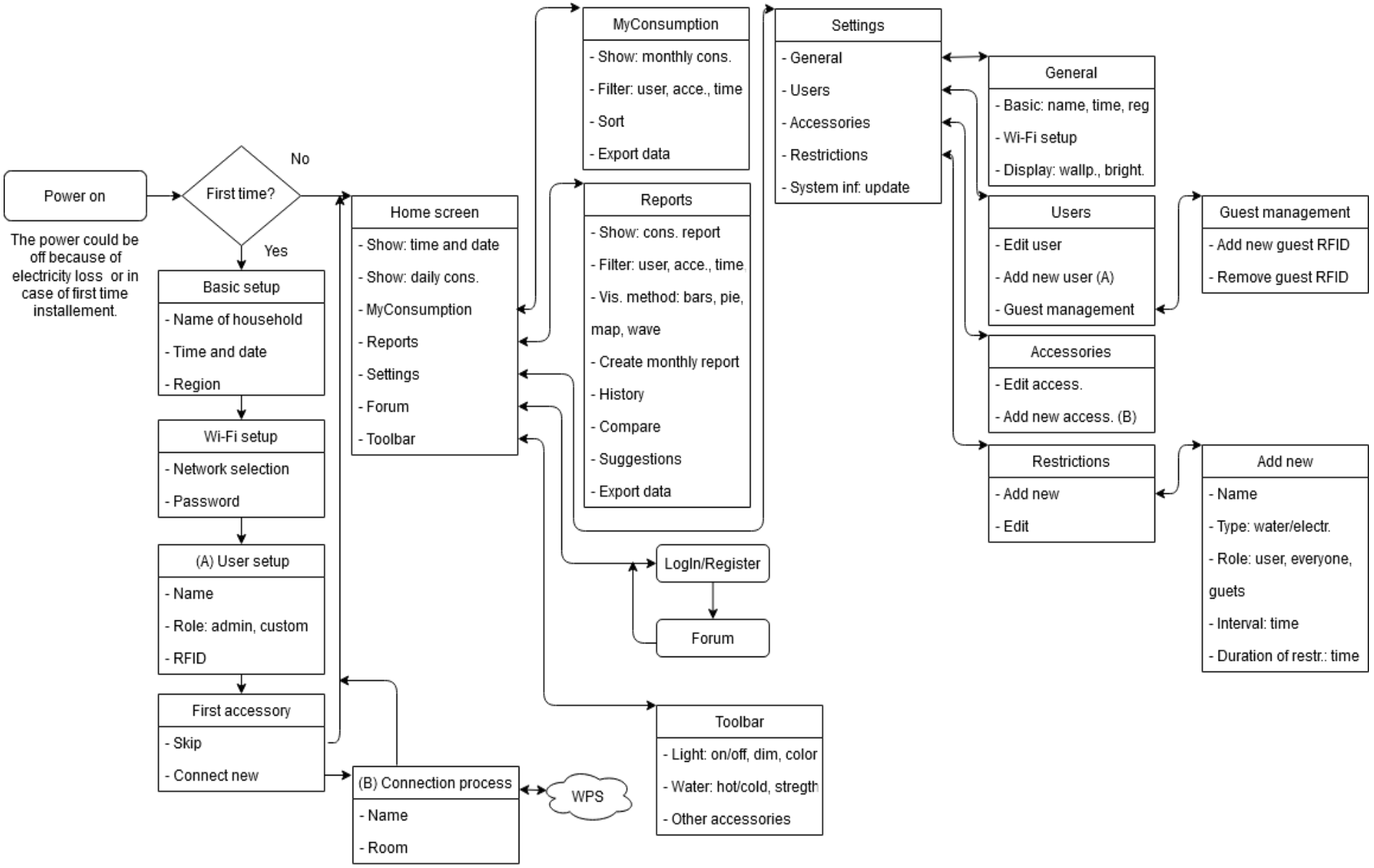
After turning on the central monitor for the first time, the user needs to configure the basic settings, clock, time zone, date, region, etc. Then the Wi-FI setup is initiated. After connection to the local network, an admin user account needs to be set. Usually, the admin user is the “head” of the house, but in some cases the admin user can be pre-set by the system provider. In addition, the user can, if he/she wishes, add more persons to the household. For example, adding a child or husband/spouse. In this step, the admin just needs to enter the basics about the new user, name, household role and RFID tag number. More detailed settings can be later edited from the profile menu. After successfully configuring the user profile, it is time to add the first accessories. Of course this step can also be skipped, in cases no accessories are yet acquired. If the user already has an accessory, he/she just needs to push the button on the central monitor that states WPS (Wi-Fi Protected Setup). The same button needs to be pushed on the accessories and the connection is going to be established. The accessories then pops up on the monitor and the user can set a custom accessory name and a room where it is located. The setup of the central monitor is now fully completed and the user is taken to the home screen.

On the home screen the user gets presented with basic information about his household. Besides the clock and date, the user gets displayed the current daily consumption of each accessory in the household. Under the information the user has access to the central monitor applications. Four apps are provided to the user: MyConsumption, Reports, Forum and Settings. Furthermore the user can access a quick toolbar by sweeping from the top of the screen. Here the user can manually turn on/off lights and water sources for each room. The “MyConsumption” app provides information about the current monthly consumption in real time. From here the user has different possibilities to filter the view. The consumption could be displayed for example in voltages/amperes/watts for electricity, liters/gallons for water or euros (or any other currency depending where the user lives). Filtering is possible by user,

day or accessory. In the Reports app the user can create detailed reports and comparisons for each month and year. These reports could then be sent via email, printed or shared on the forum. The information could be displayed by different visualization methods, like charts, pies, bars etc. Before visiting the forum app, the user needs to enter his email address to gain access. The user can use the forum platform to call up experiences from other users. In this way, he/she can avoid certain problems that could occur with the system.

In the Settings app the user has access to edit the basic settings of the system, to add/edit accessories or users, to set restrictions per user and to get the system info. The basic setting and the adding/editing of accessories are handled similar as mentioned above, with few additional settings that could be edited (for example user icon, birthday, etc..). Guest handling is also done from the user profile section. Here the admin could register the wearables used by guests. The guest is a single profile, that can contain multiple RFID numbers. All guests' activities are saved under this profile, independent of who the guests are. More information about guests' profiles will be given in *Section 5*. The restrictions section of the Setting aspp the admin can set restrictions for individual users. For example, he/she could restrict “Child 1” to use electricity in the “Child 1 Room” between 21:00 and 06:00, because of sleep time. Finally the system info gives information about current firmware, failures, connectivity issues, updates etc..

The central monitor also handles basic voice input, for example, to turn on/off lights. A detailed voice input guide is presented in *Section 3.4.3.*. The diagram below shows all functionalities of the central monitor system.


Power on
First time?
No
Yes
The power could be off because of electricity loss or in case of first time installement.
Basic setup
- Name of household
- Time and date
- Region
Wi-Fi setup
- Network selection
- Password
(A) User setup
- Name
- Role: admin, custom
- RFID
First accessory
- Skip
- Connect new
(B) Connection process
- Name
- Room
WPS
Home screen
- Show: time and date
- Show: daily cons.
- MyConsumption
- Reports
- Settings
- Forum
- Toolbar
MyConsumption
- Show: monthly cons.
- Filter: user, acce., time
- Sort
- Export data
Reports
- Show: cons. report
- Filter: user, acce., time
- Vis. method: bars, pie, map, wave
- Create monthly report
- History
- Compare
- Suggestions
- Export data
LogIn/Register
Forum
Toolbar
- Light: on/off, dim, color
- Water: hot/cold, stregth
- Other accessories
Settings
- General
- Users
- Accessories
- Restrictions
- System inf: update
General
- Basic: name, time, reg
- Wi-Fi setup
- Display: wallp., bright.
Users
- Edit user
- Add new user (A)
- Guest management
Guest management
- Add new guest RFID
- Remove guest RFID
Accessories
- Edit access.
- Add new access. (B)
Restrictions
- Add new
- Edit
Add new
- Name
- Type: water/electr.
- Role: user, everyone, guets
- Interval: time
- Duration of restr.: time

3.4. Technologies

Two different main components are used for the central monitor system. One is a tablet, which contains all the hardware which makes the controlling process possible. This tablet is driven by an application which is at the same time powerful and user friendly. Some basic functionalities of the application could be controlled via voice input.

3.4.1. Tablet as a monitor bridge

The tablet consists of a touchscreen that presents the results to the user, but the other main components are the RFID module and WPS module. The RFID module is responsible for logging the user, which for example, controls the lights through the monitor. The consumption of the electricity is then added to his/her user profile. The WPS module with Wi-Fi standard is used for connectivity. The whole system is driven by a processor, which also handles the arithmetical and logical functionalities. For the voice input, the monitor is equipped with an array of 6 microphones and a speaker for the responses. The monitor uses a Lithium-Polymer battery for power. The total weight of the monitor is 450g. The technologies used to build the monitor are affordable for normal consumers by cheap mass production.

The touchscreen built into the monitor is the LP101WH4-SLA6 developed by LG. It is a 10.1-inch IPS capacitive touchscreen with an 1366x768 resolution, offers 16.7M colors, 60 Hz refresh rate and a brightness of 400 nits.

An MT8173 developed by MediaTek is used as a SOC. It is a quad core processor (2x1.8 GHz Cortex-A72 & 2x1.4 GHz Cortex-A53) with integrated PowerVR G6250 graphic unit. This processor is mostly used by tablet manufacturers to build high performance multimedia tablets. The system uses a 1 GB DDR2 RAM developed by Elpida (*B8164B3PF-1D-F)*.

For the Wi-Fi connectivity with the WPS standard the system uses an BW12 RTL8710BX wireless module. It is mainly developed for Smart Home purposes. The BW12 supports WPA-, WPA2-, WEP- and WPS 802.11b/g/n security standards.

The RFID module is the M950 4 channel embedded UHF RFID Module developed by iDTRONIC. It features a power of max 30dBm up to 10m read range and aTTL or RS232 interface.

Power to the system is provided by the Lithium-Polymer 6200mAh battery (BTC-ABD101SL) which is charged with a charging cable or via the provided dock. Because the system is in no need for large memory capacities, it only uses 4 GB eMMC flash memory module developed by Swissbit (SFEM4096B1EA1TO-I-GE-121-STD).

3.4.2. The App

The tablet is a compatible device that isn't only mounted at the docking station, but also offers the user to be carried around. It provides a permanent connection to all accessories via WPS. A permanent Internet connection is not necessary to run the system, but it is needed to access the forum or updates for the devices.

The application on the central monitor system is somewhat more limited than the application available for the usual multimedia tablet. The reason for the functionally weaker application is the intended usage of the monitor. The monitor and its application are only licensed to be used in the original smart home system and the provider constrain every third party usage. The central monitor is not developed for multimedia usage.

Since the accessories don’t have space for extra hardware, the central monitor provide all high-level functionalities. The central monitor system will receive data from the accessories as long as the WPS connection between the two is active. The application on the monitor then uses the advantage of the strong hardware performance to conduct all needed arithmetical and logical operations. All back-end operations are presented to the user in a simple visualized form. The interactivity of the data should give benefits to the user, but also provide feedback for future energy consumption.

3.4.3. Voice control

Voice control in smart homes is the fastest and easiest way to control your accessories. The Amazon Alexa Voice Service was used to implement the control module within SmartFlat. One of the biggest advantages of this service is the ability to create an application, which is called when saying certain commands and then provides desired functionalities adapted to the system. In order to create an application for the Alexa service, it is first necessary to create an Amazon AWS account, and then it is necessary to specify the name and title of the application, as well as the trigger keyword. SmartFlat uses the keyword “Flat” to trigger the voice control. Furthermore, when configuring the application, it is necessary to define user intents and command patterns that are mapped to a specific functionality. The phrases are predefined in order for Amazon to recognize speech precisely, because in that way the service expects to do tasks when triggered. If they are not specified, recognition is possible, but it is quite difficult and the system works stochastically. This feature is also one of the biggest shortcomings of the application because user behavior is often unpredictable, and it is not always possible to list all possible words, phrases and combinations. The voice control of SmartFlat is very limited and offers the user basic functionalities by controlling lights (on/off, brightness and luminance) and faucets (on/off, strength, colder/warmer). If the system doesn't recognize a certain command, first it asks the user to repeat the command, if the second attempt fails, a fallback response is triggered. All possible commands and the system responses are listed below.

Phrases	Alternative	Function	Response
“Flat, turn on all lights.”	“Flat, lights on.”	Turns on all lights in the system.	“All lights are on.”
“Flat, turn off all lights.”	“Flat, lights off.”	Turns off all lights in the system.	“All lights are off.”
“Flat, turn on the lights in ROOM_NAME.”	“Flat, ROOM_NAME on.”	Turns on the light in a specific room.	“ROOM_NAME is on.”
“Flat, turn off the lights in ROOM_NAME.”	“Flat, ROOM_NAME off. “	Turns off the light in a specific room.	“ROOM_NAME is off.”
“Flat, set ROOM_NAME to NUM%.”	“Flat, ROOM_NAME NUM%. “	Sets the brightness of the light in a specific room.	“ROOM_NAME is set to NUM%.”
“Flat, set ROOM_NAME to COLOR.”	“Flat, ROOM_NAME COLOR.”	Sets the color of the light in a specific room.	“ROOM_NAME is set to COLOR.”
“Flat, water on FAUCET_NAME.”	“Flat, FAUCET_NAME on.”	Turns on a specific faucet.	“FAUCET_NAME is on.”
“Flat, water off FAUCET_NAME.”	“Flat, FAUCET_NAME off.”	Turns off a specific faucet.	“FAUCET_NAME is off.”
“Flat, set FAUCET_NAME to NUM%.”	“Flat, FAUCET_NAME NUM%.”	Sets the strength of a specific faucet.	“Strength of FAUCET_NAME is set to NUM%.”
“Flat, set FAUCET_NAME to TEMPERATURE.”	“Flat, FAUCET_NAME TEMPERATURE.”	Sets the temperature of a specific faucet.	“Temperature of FAUCET_NAME is set to TEMPERATURE.”
“Flat, set turn on timer for TIME for ROOM_NAME/FAUCET_NAME. ”	/	Turns on the specific light/water after a specific amount of time.	“Timer set.”
“Flat, set turn off timer for TIME for ROOM_NAME/FAUCET_NAME. ”	/	Turns off the specific light/water after a specific amount of time.	“Timer set.”
“1: Flat, NON-UNDERSTANDABLE or NON-IMPLEMENTED”	/	Voice control doesn't understand the user, and asks for a repeat.	“Can you repeat that?”
“2: Flat, NON-UNDERSTANDABLE or NON-IMPLEMENTED”	/	Voice control repeats with a fallback phrase.	“Sorry, can't help you with that.”

Voice control commands, alternatives and responses

The voice control also allows nested commands, for example: “*Flat, turn on the lights in ROOM_NAME and set to NUM% and to COLOR*”. Also the response from the voice control can be nested, for example: “*ROOM_NAME is on and set to NUM%.*”.

3.5. Requirements

3.5.1. Functional requirements

The central monitor offers the user many functions that improve the quality of life. The user has the possibility to track his energy consumption via the monitor and to change his behavior to live more efficiently. The accessories are connected via Wi-Fi WPS to the central monitor. A requirement here is that the data is displayed in real-time. It is very important to protect the user data, so it is stored in encrypted form. The access to the data is protected by the RFID login. The reports need to be simple and understandable to every single user. The filters can be combined, to gain more insights. Restriction overlaps must be prevented automatically, so the user does not get confused.

Functions that the user may be familiar from his/her multimedia tablet are also found on the central monitor. The central monitor provides a social media kind of forum that allows the user to retrieve experiences from other users. The forum allows the user to create their own threads and to post to other threads to improve the community. Also a private messaging system to other forum users is implemented. This makes communication between users easier.

3.5.2. Non-functional requirements

Like many tablets, the central monitor has the functions of a conventional multimedia tablet, so it offers the user a time display that can be changed between 12/24 hour displays. Different time zones also offer the user the possibility to see the time in other cities. The central monitor comes with a built-in calendar, which allows the user to track the date.

A simple interface allows any age group to use the central monitor, the size of the text is readable and the language selection includes several foreign languages. So the central monitor is adapted to the user and offers easy handling for everyone. The central monitor comes with a user manual, which can also be found online. A regular software update will keep the central monitor up to date in different time periods, so the user will be protected for the future.

3.6. Design

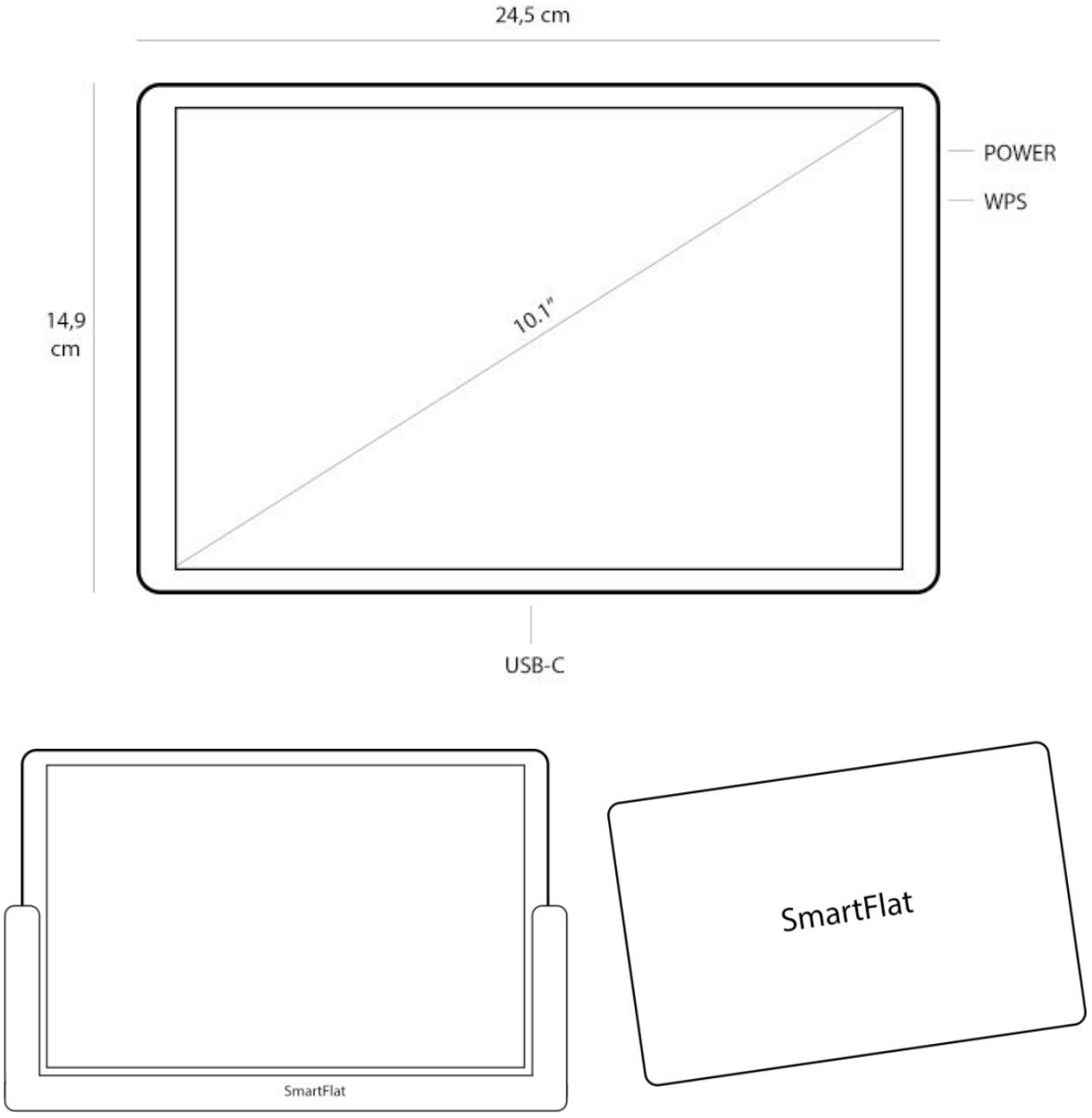
3.6.1. Look and Feel

The outer design of the central monitor is very similar to a multimedia tablet. It is designed in such a way that it cannot be distinguished from an everyday tablet. Only two buttons are found at the tablet's sides. The power on button and the WPS button. Other conventional options like, volume up/down are handled in the settings menu of the app. As mentioned

above a 10.1-inch touchscreen is installed to allow easier navigation through the app. Also an USB-C charging port is found at the bottom of the tablet.

The total dimensions of the tablet are 24.5 x 14.9 x 0.8 (cm), with a weight of 450g. This is very practical because it allows the user to carry the tablet around and do tasks without interfering with other things. Usually smart home monitors are larger and fixed on a wall of an apartment. For users who don't wish to carry the tablet around, a wall mount is provided which also acts like a charging dock. The wall mount is made of durable PVC.

The tablet case is mainly made of aluminum. It's bend, scratch and splash protected. It comes in only one color, black. The user has the possibilities to buy extra cases and covers for better protection. These accessories come in a large number of colors, combinations and materials.



Central monitor front side, back side and positioned in the charging dock

3.6.2. Application design

The app is simply designed to give the user a quick start in using the monitor.

After the setup of the tablet is successfully complete and a connection to the accessories established, the user is presented with a home screen. From there he/she can navigate through all features the tablet has to offer. A symbolic app and widget system is used so almost every user is familiar with.

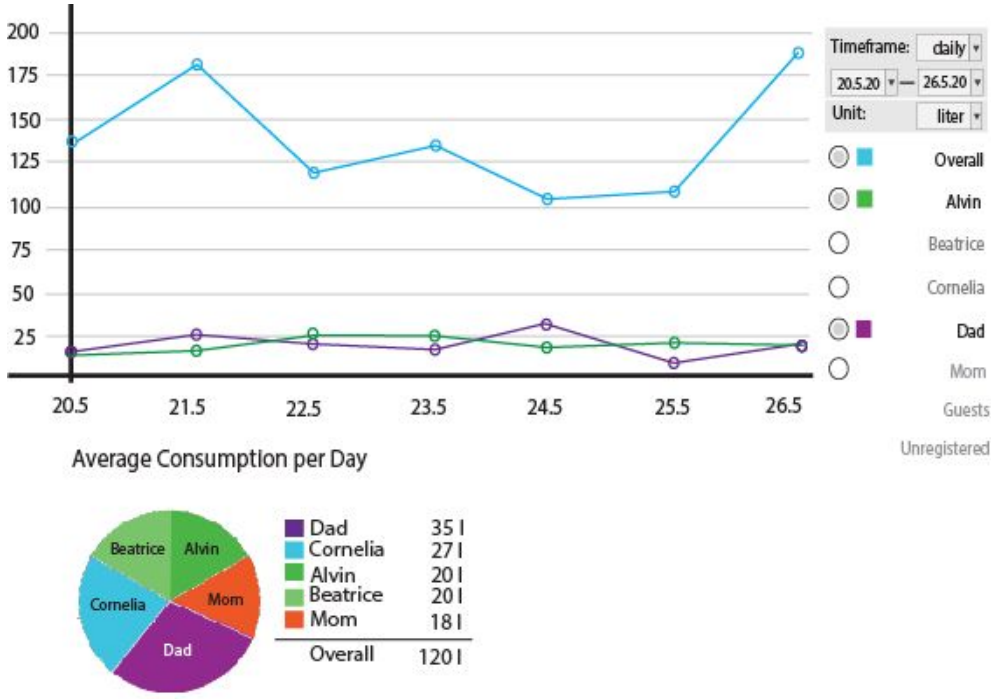
The application is based on the "Android Open Source Project" and all functionalities of the app are described in *Section 3.3*. The design is shown on the sketches below.

The home screen and the MyConsumption designs of the App

4. Hot water reporting

The faucet sends the checked in user, the consumed water in liters per seconds (seperated in hot and cold water) and the current water temperature to the central monitor. The central monitor handles all calculations and offers visualization of the data. The automatic check in system via RFID is described in detail in *Section 2*.

The data of spent water is presented in a line chart and can be filtered for specific time ranges. Additionally to the accumulated water spent, it is also possible to show the individual water spending of each user. The filter for time ranges and persons can be combined at will.



Visualization for the hot water consumption. On top is a line chart showing the resource usage of the selected persons for the selected timeframe. On the bottom is a pie chart showing the average consumption for the selected timeframe.

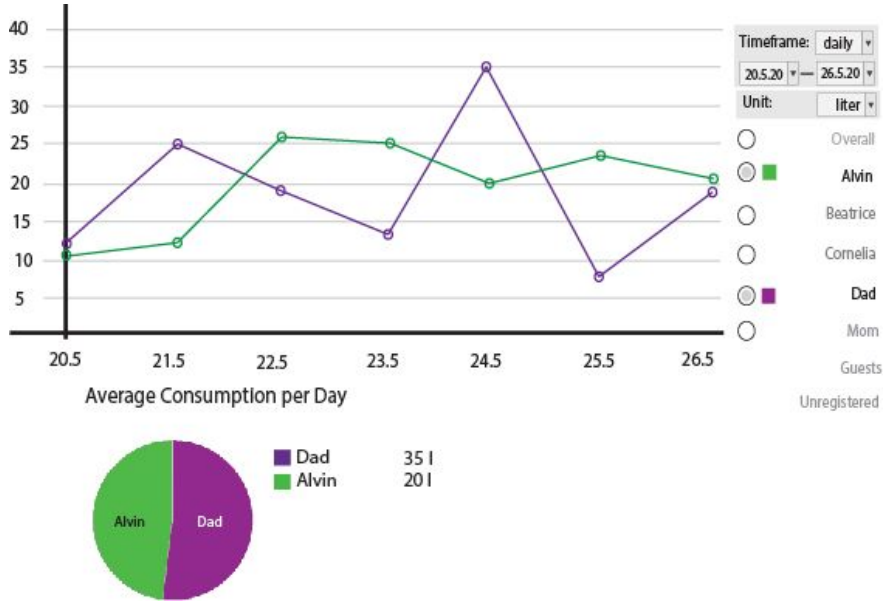
The time frame can be changed via the drop down menus in the top right. The drop down has the following entries: daily, monthly and yearly. Additionally the exact dates can be set, depending on the selection of the dropdown above. The average consumption pie chart also changes its contents depending on the settings.

If it is set to daily the exact range of days can be selected and the pie chart shows average consumption per day. If it is set to monthly the exact months can be selected (e.g 12.19 - 04.20) and the pie chart shows the average consumption per month. If it is set to years the years can be selected and the pie chart shows the average consumption per year. Only the first box is required to fill out, the second can be left empty (or set to empty if it is already filled), instead of a line chart only a pie chart is shown.

Below the timeframe dropdown box is the unit dropdown box, this changes the unit of the horizontal axis and also the unit in the average consumption pie chart. The entries for unit include: liters, gallons, percent and the currency of the set region e.g Euro. The currency is only available as an option if water consumption prices are set. Should they not be set when selecting currency a pop-up window opens and asks for current water prices. It is also possible to enter different prices for different times of the day.

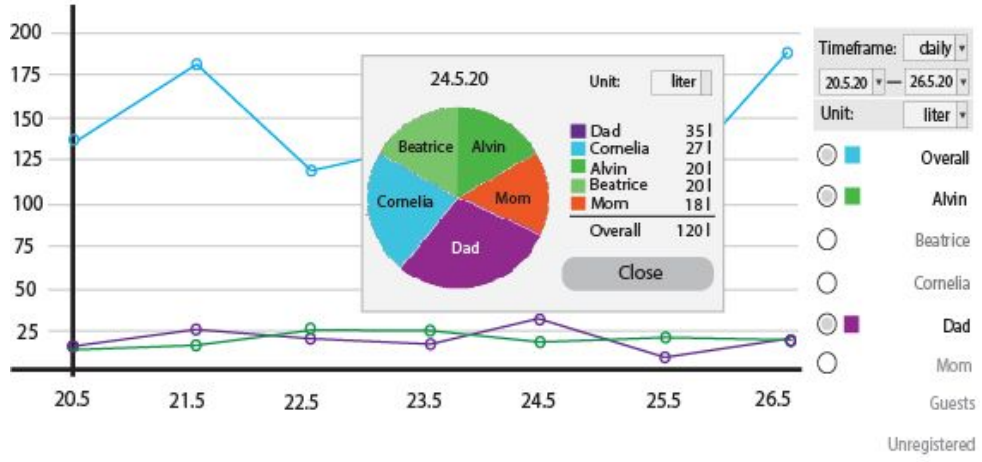
Below the unit dropdown box are touchable radio buttons for each user. Touching the radio button (or the user name) toggles its state between included and excluded. Users that have a consumption of 0 for the selected time frame have no radio button beside their name. The option Overall is always on top, followed by the members of the household in alphabetical order. The options Guests and Unregistered are always at the bottom. Individual guests are not separated in the visualization as we want to guarantee them some kind of anonymity, as it may feel uncomfortable to provide hosts such detailed insight about their own behaviour. Names of included users are shown in black and have a color assigned in the legend. Names of excluded users are shown in gray and have no color assigned in the legend. The overall option shows the accumulated water spent from all members. As long as the Overall option is selected the pie chart compares the usage of all people in the household. The legend of the pie is sorted by the amount of resource spending.

The y-axis of the line chart scales according to the highest value in the data. If the Overall option is deselected for example, the y-axis would automatically scale down, which allows for a more detailed comparison between data sets (see image below). Since the Overall Option was deselected, the pie chart also only compares data between the two selected members.



Visualization without Overall selected. The y-axis automatically scales depending on the selected user. The pie-chart also updates according to selection.

Additionally there's the possibility to touch one of the dates in the x-axis to get a detailed view for the selected date in a popup window. The popup window can be moved around by dragging the window and closed by touching the close button. It is also possible to open multiple of these detailed stats. The pop-up window also allows for changing the unit. When it first opens it takes the Unit setting from the main window, but can be changed individually without reflecting its change in the main window. In the mockup below the pop-up for the 24h of May was opened by clicking on the 24.5 entry on the y-axis. The detailed view also works for the monthly and yearly time-frame options.



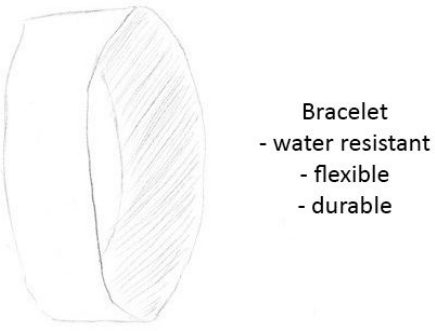
Detailed visualization of selected date. By touching a date on the bottom a pop-up window with detailed stats for the date opens.

5. Check-in accessories and guest guide

Welcome, Dear guest! This guide shows you how to use the appliances you will find in this SmartFlat home. We would like to make your stay as comfortable as it can possibly be!

Bracelet

Additionally to this handy booklet, you should have gotten a bracelet that you may now put on your wrist. This bracelet uses your position in the home to switch on the lights in whatever room you may be. But don't worry: Your tracking data can not be traced to you as a person. The family this smart home belongs to can see a statistic of their tracking data, but your actions will simply contribute to an anonymous data entry called 'Guest'.



If you want to wash your hands, use the foot pedal to control the water pressure. Hold your hand in front of the faucet sensor on your left to increase the temperature of the water or hold your hand in front of the right sensor to decrease the temperature. Don't worry about the bracelet while washing your hands. All of our bracelets are coated with a water resistant rubber shell.

NOTE: If the sensors are not functional, you can use the stick on top of the faucet to control the water flow. Move the stick up to increase the water pressure, or move it down to decrease it. Moving the stick to the left increases the water temperature, while moving the stick to the right decreases it. Each water faucet is equipped with a handy little LCD-screen that shows the current water temperature.

If the lights are not turning on or off automatically, you can use finger gestures at the light-switches. Find the light switch in the room you are currently in. It will be positioned near a door or a hallway. Touch the main panel of the light switch to turn it on or off. To increase the brightness, you can swipe up on the panel. Similarly, to decrease the brightness you can swipe down. Swipe left or right to change the color of the light.

If you are done visiting the smart home, please return this booklet and the bracelet to the homeowner. We hope you had a pleasant stay and we wish to be able to greet you in one of our smart homes again soon!

6. Scenarios

Scenarios illustratively show how the smart home application presented in this document could have a significantly positive impact on people's lives, while also presenting potential dangers that come with introducing such a technology to the general populace.

Positive scenario 1:
The states on the pacific coast of the US have been plagued by long and reoccurring droughts that make water a valuable resource. The Hendersons, a family of three live in the Los Angeles metropolitan area in a recently finished smart home. As the wages of Frank and Barbara, the adults of the family, are reasonably high compared to wages in other US-states or European countries, they could afford to install the new smart home technology into their home. They heard about the drought, that had started at the start of summer, on the news and want to, first of all, make sure that they themselves have enough clean water to wash their hands, shower and use the toilet, and furthermore, want to make sure that other people that are less unfortunate and cannot afford a big house can use clean water. They do not have to annoyingly turn off the water with their hands, while coating their hands with soap and even Timmy, their six-year-old son cannot absent-mindedly keep the water running due to having to remove his foot from the pedal controlling the water pressure. Even if Timmy starts to playfully activate the water sensor unnecessarily, his parents can even see that in the water consumption statistics and therefore do not have to be present every time he washes his

hands. They then have the opportunity to have a serious talk with Timmy about responsibility regarding limited natural resources.

Positive scenario 2:
In 2020 the whole world has been struck by a pandemic virus called Sars-Cov-2. The German married couple Dieter and Jutta Müller are both in their early forties and live in Munich. The regulations regarding contact to people other than the people you live with have gradually been lifted to a point where Dieter and Jutta can invite their best friends Hans and Irmgard to a nice Christmas dinner at the Müller family home. This dinner is vital to their wellbeing as Dieter and Jutta have been arguing more than usual due to being confined to the same apartment for two months due to the pandemic regulations and sharing an evening with friends would ease both of their minds.

Mindful as he is, Dieter asks Hans and Irmgard to wash their hands as soon as they arrive. Due to the Müller house being equipped with smart home technology; the guests do not have to touch light switches or faucet handles to go into the bathroom and wash their hands. The light sources in the rooms they must traverse turn on and off automatically when they are wearing their bracelets and the water pressure is controlled by their feet, which are significantly less likely to have traces of the virus on them. This reduces the potentially dangerous surfaces that the virus could cling to, to just their bracelets instead of multiple light switches in the rooms that they have to traverse through to get to the bathroom and the faucet handles.

Negative scenario 1:
Dieter Müller has been using his smart home system for quite some time. He is now staying at a hotel for a business trip. Dieter used the sink to shave, he turned the water on, but being used to the foot pedal, which he can never forget to ‘turn off’ as it moves into a neutral position when he leaves, he forgets to turn the faucet off. Unfortunately, the hotel room sink has no physical way of preventing overflow. When Dieter returns from his three course meal at the hotel restaurant, he finds the bathroom flooded, damaging the floor, resulting in a hefty repair bill.

Negative scenario 2:
Martha, a Dutch housewife, has become increasingly controlling regarding her family. Her teenage children must be home at 8 p.m. and she needs to control everything they do in their shared home. On the central unit, she notices that the children, in her eyes, use too much water to wash their hands and brush their teeth. She confronts her children and gives them punishment for, in her eyes, wasting water. She even uses the central unit to turn off the lights in the bedrooms of her children at 8 p.m. even though they wanted to read a book before going to bed.

7. Code of ethics

The code of ethics included with the SmartFlat design, details duties and rights that residents and guests have while using the smart parts of the home. Users are asked to abide by the code of ethics to guarantee usage that is enjoyable and advantageous to every user.

No identity theft:
Users may not share smart bracelets with each other without being aware of the repercussions on the water and energy consumption data that such behavior will have.

Consuming less water and power:
By using the smart home solution presented in this document, customers have the right to consume less water and power than they usually would. Faucets turn off when you do not need them, and lights can be turned off from anywhere. However, many customers may also feel like less consumption of water and power poses a duty due to the repercussions of man-made climate change. This duty becomes easily manageable using the presented system.

Maximizing comfort:
Users have the right to maximize their comfort by using the system to turn off lights in other rooms, without leaving their currently comfortable position.

Having data security and privacy:
All consumption data will be processed and presented without sending it to a remote server. This guarantees the users' rights to data security and privacy.

Being able to use fallback mechanisms:
Due to the system having multiple fallback mechanisms if some components may fail, users don't lose their rights to always being able to turn on their water or control their lights.

Not using a bracelet:
Guests or family members that wish to not wear the smart bracelets, can do so as all parts of the smart home solution provide means of being operated without the bracelets.

Guests have the right to anonymity:
Some guests may feel like their privacy is being breached, if the system collects data regarding their water or energy consumption. That is why the guest bracelets should be assigned to a profile such as "guest" to guarantee anonymity for guests regarding the smart home.

Using bracelets at other houses:
Extraordinarily ecologically aware users may use the same bracelet in different smart homes. By creating the same profile in another home, they visit, users can then sum up their water and power consumptions of the similar profiles of every home they went to.

Not selling personal data of family members:
Due to the data generated by the smart home system being related to hygiene and the home, the subject matter is very personal. Users should not sell the personal data of their family members to data companies or science experiments without their consent.

Inhumane conditions must not be created:
The central monitor can control the power supplies in the rooms. If a family member wants to keep their distance for a while, e.g., by locking themselves into a room, other family members must not use the central monitor to turn off all of the power supplies in that room.

8. Literature

[1] Zhang, S.; Qi, L., "*The Solution of Smart Home Indoor Positioning Based on Wi-Fi*". Lecture Notes in Computer Science, 2012, Vol.7530, pp. 279-284.

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[3] Aryadevi R. D.; Subeesh T.; Maneesha V.R., "*Design and Implementation of User Interactive Wireless Smart Home Energy Management System*". International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2013, pp. 626-631.