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Bachelor Thesis

FamilyFlower

An artificial flower to foster distant family connections

submitted by
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Abstract

Physical separation of family members is an inevitable part of life, as children leave home to attend university or take a job in another city. Such separation may have adverse effects on the family members psychological well-being. Both the family member moving away and those who remain in the previous household will experience changes to their daily routines and modes and frequency of communication. This can decrease feelings of connectedness, and lead to loneliness. The FamilyFlower system offers a novel way of connecting people living in different households through two identical FamilyFlower devices. Each device is placed in one of the homes to be connected. They consist of a common houseplant and an artificial flower, placed side by side in a flower pot. The flower collects data about certain conditions in the first household and mirrors the conditions in the second household, and vice versa. Each of the measured conditions, which are recognition of human presence, movement, sound level and touch of the leaf, are mapped to an action of the other flower. The petals and the stem can move, the flower's center can glow in different colors and fragrance can be sprayed. These functions should help convey closeness of the users and enable them to include each other into their daily routines. Hence, the system is supposed to decrease the feeling of distance through an increase of emotional connectivity and a strengthened family bond.
A user evaluation was conducted in a real situation. Two households were connected for two weeks via the FamilyFlower. The results showed that the participants felt more connected to each other and established shared routines. Furthermore they reported an increased mood. The FamilyFlower device integrated well into daily routines and was perceived as an ordinary object of the interior design.

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Chapter 1
Introduction

This chapter gives a short introduction of the work. First of all, the motivation is presented for which the role of family in everyday life is explained and the properties of houseplants are pointed out. Then, the research goals of the work are stated.

1.1 Motivation

1.1.1 The meaning of family

The bond of family is encouraged by spending time together, especially through experiencing joint activities. [1] This includes sharing the little deeds of everyday life like taking communal meals, playing board games, conducting conversations or watching movies. For different reasons it can happen that one of the associated members has to live completely or partly in a remote location by which this person has less opportunity to participate in the daily life of the family. Thereby exists the danger of losing the family bond and feeling excluded or lonely. This can have far-reaching consequences as family is of great importance of most people's lives.
The meaning of family goes far beyond being a collection of people somehow bound together through birth, marriage or free choice. It rather describes a group of people with a strong emotional and social bond who assure each other personal safety and protection from loneliness, so that even close friends can be seen as

[1] "The Importance of Spending Time Together" https://www.parentingni.org/blog/time-together-importance/ (accessed: July 19, 2019)

family. [2] In the course of development and age every individual goes through various roles and generations and thereby experiences different living conditions. Throughout their childhood, it is common children share a household with their parents and siblings, which turns into starting an own household and family. Even when living in different places a strong bond between parents and children remains, shown by regular mutual contact.
The living place of a family, especially the living room and the kitchen, can be seen as a central meeting point, where the family spends time together and exchanges about the events of a day. The everyday life is structured by family members leaving and entering this room in order to pursue their activities. However, while spending time in the same household, people are aware of information about each other's presence, which creates a feeling of not being alone and always having a contact person to have fun with, discuss worries or ask for advice. Leaving the family home can lead to loneliness, since when living in one's own apartment the connection to the everyday life of the family is threatened as parts of family activities could be missed. Phone calls and messages can maintain the communication, but are not even capable of reflecting the small impressions in life animating everyday life.
FamilyFlower is supposed to counteract losing these important small acts and lets the distant person participate in family life. This should reduce the feeling of loneliness and being separated and encourage building further contact.

1.1.2 The use of plants in living rooms

Plants are wide spread and often encounter our daily life. For instance, they are integrated in a lot of our homes as houseplants, especially in urban regions.
For many reasons people value their characteristics which bring along a positive effect on body and soul. One of it is the calm and sovereign charisma, they spread and the resulting improvement of a person's well-being. Furthermore, several people enjoy taking responsibility for the plants since an emotional attachment arises while observing how the plants develop under their care. [3]
A more functional reason is that plants improve the indoor climate, while binding CO_2 and producing oxygen, which reduces people's stress level and lifts their mood. [4]
Another advantage of plants is that they have a natural way of subtly indicating information through their slowly and unobtrusively changing appearance. Therefore, they offer to use them as model for ambient displays. Moreover, if they were expanded with some technology they could be transformed into ubiquitous

[2] "Wer und was ist eigentlich Familie?" https://www.urbia.de/magazin/familienleben/politik-und-gesellschaft/wer-und-was-ist-eigentlich-familie (accessed: June 14, 2019)
[3] "Zimmerpflanzen und ihre Bedeutung für den Mensch". https://www.pflanzenfreunde.com/bedeutung-der-zimmerpflanzen.htm (accessed: June 14, 2019)
[4] "Why Indoor Plants Make You Feel Better". https://www.nbcnews.com/better/health/indoor-plants-can-instantly-boost-your-health-happiness-ncna781806 (accessed: July 25, 2019)

devices. Plants are the ideal representative for the concept of calm technology which many designers have taken advantage of. According to this concept, defined by Weiser, it is desirable to present information in the periphery, which means noticing actions in the field of view without claiming the user's focus of attention [15].
The above stated properties of plants are aimed to be transferred to FamilyFlower through integrating a representative in the construct. It is supposed to be received more positive by the users and to integrate easy into the living space. To profit from the way plants communicate with people, the signaling is aimed to be copied from their natural behavior like the blooming of a flower or the wiggling of a branch (movements in the wind). Furthermore, as they are living beings that need regularly attention to stay healthy, they can be seen in a superior sense as symbol for a social bond that must be striven to preserve.

1.2 Goal

The intention of the thesis is to develop and implement a system called FamilyFlower to counteract the problems of distant living persons. Therefore, the target is to construct prototypes which are placed into the households of the belonging people and reciprocal integrate them into each others' everyday lives. To make use of the positive properties of plants, the system should be based on a common houseplant.

FamilyFlower aims to foster a tie over distance while reflecting the everyday actions in a household to a remote one by symbolizing them through an artificial flower that augments a common houseplant. This is a bidirectional process which is why two identical flowers are each placed in one of the homes to be connected and exchange information via the internet. The flower is designed to assume several functions ensuring the detection of the events taking place in the local apartment and the display of those in the distant household.
One functionality is that the system should be capable of recognizing the presence and motions of people being near the plant. This is presented by a corresponding flower while opening the blossom to bloom to indicate the appearance of persons and a wobbling stem to show motions. An additional service is that the flower should be able to measure the current volume level in its surrounding which is displayed to the remote home by a colored glowing flower in which the color illustrates the sound level. Furthermore, a touch of the flower's leaf is supposed to trigger the counterpart to distribute pleasant fragrance.
All these operations should provide cues that help to infer what is happening in the other household. The appearance of persons close to the flower could indicate whether anyone is in the common areas of the family. In that case, the absence or presence of movements such as the volume level would additionally help to infer which action is currently pursued. For example the presence of people in a quiet surrounding without any movements suggests that it is resting

time whereas a higher volume with movements announce that some activity is going on. Additionally, the spreading of scent offers the opportunity to affect the ongoing events. At this point it is up to the users to create own application scenarios for this function. Examples would be to indicate desired contact or to symbolize thoughts of the family. All this enables the separated persons to participate in the daily life of each other and offers opportunity to create common routines over distance, which should help to strengthen the family unity and cause a comfortable feeling in all included members.
The signaling concepts of the flower are adapted from the natural behavior of plants like the opening and closing of the blossom or the distribution of scent. Moreover, the light in the center of the flower could symbolize a pistil.

After the implementation of the final prototypes, it is intended to conduct a short user evaluation with the system. For that, the objective of the work is concluded to the following four research goals that should be examined:

- Support building a connection over distance.
- Enable a feeling of closeness to a person.
- Providing functionality to encourage shared routines.
- Facilitate integration into the living environment.

1.3 Outline

In the following chapter related works of different areas - connecting remote people, using plants in technological context and IoT devices - are discussed. Afterwards, the concept of the FamilyFlower system and its corresponding FamilyFlower devices is explained. This is followed by a detailed description of the implemented system in which all the hardware and software that was used to create the system is depicted. Then, in the next chapter the research goals, the evaluation method and the gained results are presented and discussed. At the end of the thesis, a conclusion is drawn as well as the limitations mentioned and an outlook to the future work given.

Chapter 2
Related Work

In this chapter, some related projects an their meaning for FamilyFlower are investigated.
The first section focuses on the connection of remote living people. The next part deals with the use of plants in a technological context, once as ambient displays and once as interaction devices. The last point of this chapter investigates related IoT devices.

2.1 Connecting remote people

Communication is a crucial part in human cohabitation, without which our everyday life would be impossible to manage. It facilitates to set up a connection with each other and is essential in interpersonal relationships. A distinction is made between verbal and nonverbal communication, which represents information exchange with and without the use of language. In the process acoustic, optic or tactile channels become active. [5] Being in the same place, it is easy for people to recognize and interpret the subtle signs which initiate contact whereas staying in different locations requires supplementary equipment. In addition to ordinary communication mediums such as phone or short messages, some designers developed novel devices to overcome the distance for private as well as office purposes.

One example is Blossom [12], a project of Patrick Olivier and Jayne Wallace, who designed jewelry to emotionally connect family members living apart. It is a jewel which is matched to the personal conditions of a young woman who left her homeland Cyprus to live in the UK. The design enables her to maintain a

[5] "Was ist Kommunikation?" https://www.studienkreis.de/deutsch/kommunikation-ueberblick/ (accessed: June 19, 2019)

connection to her roots, the place where she grew up and her grandmother lived. As figure 2.1 shows, the device is made out of a wooden branch decorated with a small glass bowl containing postage stamps coming from the years the woman's grandmother lived in Cyprus. They were stamped in an exchange of letters between Cyprus and the UK to symbolize the past communication of the family across the countries. In the beginning, they are arranged like a closed blossom (Figure 2.1a) but as soon as enough rain has fallen on the property in Cyprus they mechanically position like a blooming flower (Figure 2.1b). The extent of rain is measured by a sensor placed on the family land and the mechanism of the jewelry triggered when crossing a certain threshold. In order to emphasize the transience of life the invigoration of flower only works once. The time of this process can not be determined exactly, but months or years are expected.

(a) closed flower

(b) open flower

Figure 2.1: Blossom

After testing the object for a month, a reflecting session pointed out that the jewel utterly fulfills the expectations of creating an emotional connection to loved ones, even beyond death. Being near the object invites taking a few moments to think of shared experiences and creates anticipation on the awakening of the flower if not happened yet. In both manifestations the blossom enriches the user's life, because of its simple communication, which is easy to understand and react to.

Another work is Tsungari [7], a communication concept to foster connection between family members living apart. To take into account the tendency that emotional information are likely to be exchanged with much influence of nonverbal communication, Itoh et al. designed a model which includes the transmission of this soundless cues like a person's mood or the social context. In this way, the everyday life of distant relatives should be improved by supporting them in maintaining a close relationship and giving them a sense of belonging.
Based on this concept, they developed a system named FamilyPlanter [7] which consists of identical terminals connected to the internet and exchanging information via a server (Figure 2.2). Therefore, one of these devices must be placed in each of the two affiliated households. Each terminal is topped with a planter

that contains optical fibers. Furthermore, an infrared sensor in order to detect the presence of a person, as well as an ultrasonic sensor to capture motions in front of the device are integrated into the planter. The attendance of a person is shown to the remote home through glowing optical fibers, whereas recognizing a motion is displayed by rotating fibers. In addition, there are three buttons installed into the terminal playing each a different sound in the distant home.
A field test has shown that the system has adapted pleasantly to the daily routines of the participants and moreover incorporated many thoughts of family into their day, whereby both sides felt strengthened in their bond.

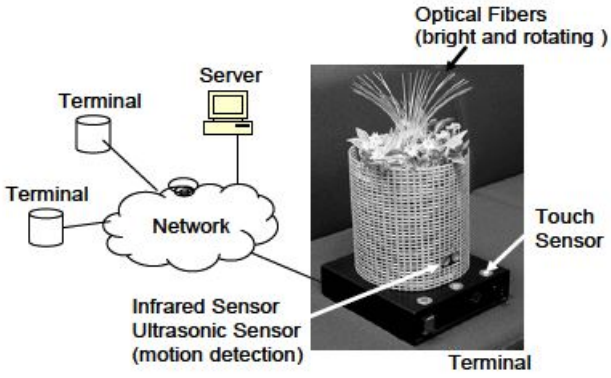


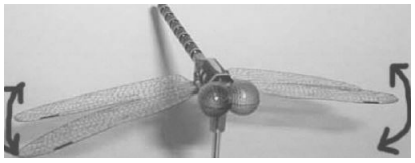
Figure 2.2: FamilyPlanter system

The ASTRA Awareness system [10] distinguishes itself from the previously named works since it represents a more explicit way of exchanging information. It enables the remote family members to experience the special moments of the day on a monitor instead of only sharing the inconspicuous signs of it.
The system consists of an LCD screen installed into the family's living place to receive information and a portable mobile device to send them. In order to find meaningful content, the developers converted the principle of a ToDo list into a ToTell list, containing daily activities instead of tasks. They embedded this concept into their application on the mobile device, which supports the user in creating list items with input methods like taking pictures, freehand drawing and handwriting.
A field experiment was conducted, approving that the system helps users to feel more connected and that they enjoyed learning more about each other's daily life.

A further approach that deals with distance communication, but to promote information exchange in office situations, is a project of Greenberg and Kuzukova [3]. It investigates the use of awareness systems in form of physical surrogates (Figure 2.3) which should facilitate the processes in office life by providing information about the coworkers' actions and intentions.

The designers divided the surrogates into different classes according to the application areas. The two most interesting ones regarding FamilyFlower are the indication of coworkers' activity and the displaying of interest in colleagues.
The first class aims to derive a person's accessibility by displaying their activity level. This is intended to facilitate getting in contact with each other, since it provides employees with similar interpersonal cues as if they were located in the same building. Various representatives of this category were developed, whereby two identical surrogates are connected to each other to enable a mutual exchange. The activity level is detected by a video based motion sensor. One example is the Peek-a-boo surrogate (Figure 2.3a) which shows the activity level in form of a changing position. As long as a person's movement is detected, the puppet turns its face forward to indicate availability and conversely points to the wall when the user is inactive to illustrate absence. Another representative of this class is the dragonfly surrogate (Figure 2.3b) which begins to flap it wings intensely for a few seconds when an activity outbreak of a person is captured and then continues for a minute with slow movements.

(a) Peek-a-boo surrogate



(b) Dragonfly surrogate

(c) Mutant ninja surrogate

Figure 2.3: Surrogates

The second class is intended to facilitate direct contact by indicating an interest in another person. One example is the Mutant ninja surrogate (Figure 2.3c) which is associated to one of the surrogates of the first category to represent a connection between two particular employees. The person owning the ninja figure is able to inform his remote colleague in whose office the other surrogate is standing about a desired contact by lifting up the figure. If, for example, the peek-a-boo surrogate were to represent the first category, the puppet would start to rotate back and forward to catch the users attention and display the other's interest.
The advantages of these examples are that they use the attention of the periphery to make their purposes visible without attracting too much attention while working. Moreover, their intentions and the way they communicate them are easy to understand and to apply. They support to reach colleagues at a good time and prevent failed contact attempts, which cost time and nerves.

The above drafts point out some ways to foster communication over distance by serving the intense urge of being connected to physically separated loved ones or being informed about the coworkers' actions. Just like FamilyFlower, they all support to share meaningful moments taking place in the day, though in different manners. But the individual designs have further commonalities with FamilyFlower.
The jewelry Blossoms uses a similar kind of communication with their users while symbolizing the emotional attachment to a beloved person in form of a blooming flower. However, FamilyFlower offers more interaction possibilities since it frequently repeats this process, whereas the flower in Blossoms only blooms once. Furthermore, FamilyFlower makes use of bidirectional instead of unidirectional communication, which aims to foster a feeling of togetherness on both sides.
Comparable to the Astra Awareness system, the FamilyPlanter system and the surrogates, FamilyFlower is intended to offer ability to provide information about the whereabouts of a person which allows conclusions on their current activity and accessibility. There, the Astra Awareness system uses more concrete ways of messaging than FamilyFlower by exchanging the obvious happenings of the day in form of pictures and text notes instead of subtly showing the hidden communication signals. Moreover, the FamilyPlanter system and the Surrogates have more in common with FamilyFlower, since they all demonstrate the presence and motions of people occurring in front of the device. As is also planned for FamilyFlower, the FamilyPlanter system uses an infrared sensor to detect a person's presence, whereas the surrogates take a video based approach.
In contrast to all above presented projects, FamilyFlower is the only one making use of a well-established domestic object, which targets to simplify the integration and encourage the common use.

2.2 Using plants in technological context

2.2.1 Using plants as ambient displays

There are several approaches of turning plants into ambient displays. In the process, designers not only fall back on living plants but try to make use of their benefits by copying their appearance as basis for technical devices.

One example of a plant-like display is LaughingLily [2], a prototype of an artificial lily, constructed to mediate group meetings. Standing in the middle of a conference table, it is capable of measuring the volume in a room and giving direct feedback to the people around. Therefore, the lily can indicate two different states, shown in figure 2.4, by automatically changing the position of its petals. Thereby, the positive state, revealing a pleasant working atmosphere, is shown by lifting the petals up to full bloom and an undesirable surrounding is

demonstrated by drooping petals. On the one hand, in order to have a successful meeting, it is helpful when the group exchanges with intermediate volume which triggers the artificial lily's positive state. The negative one, on the other hand, is caused if a discussion is too lively or if there is silence in the room because then no quality exchange is happening.
Informal opinions were collected, confirmed the clarity and easy integration of the artificial plant object. Additionally, the different states of the flower, as they are associated with happy and sad moods, seem to trigger an emotional reaction, increasing the chance of changing people's behavior.

Figure 2.4: LaugingLily

Figure 2.5: Laughter Blossom

Yoon et al. [16] designed a similar prototype, the Laughter Blossom (Figure 2.5.), which as well reacts on auditory stimuli by changing the shape of its blossom. However, with the goal of encouraging laughter it is supposed to increase the happiness of the employees. This leads to a satisfying working environment and by that to people, who obtain superior results. In order to identify people's laughing, a microphone is integrated into the prototype. As soon as a laughter is recognized the flower opens to bloom for a few seconds and closes again, when not recognizing any more laughter.
An evaluation revealed the flower left an appealing first impression, which the participants would like to pursue further. However, they criticized the small number of interaction options that the flower provides resulting into a fast loss of interest.

The two projects described above show that using the appearance of flowers as ambient displays finds high acceptance among the users. The way the artificial reproductions communicate by changing the shape of its blossoms is easily understood and the unobtrusive display of information perceived as pleasant. The aim of FamilyFlower is to reach similar effects in terms of integration and legibility, since its communication is as well based on an interactive flower. Moreover, in all projects described in this section the mechanism of the flower is triggered by a servo motor. A further commonality is the reaction to current auditory stimulus. Laughter Blossom can filter and indicate a certain sound, here laughing.

FamilyFlower and LaughingLily are both capable of measuring and displaying the current sound level in a room, one by varying light colors and the other by differently positioned petals.

A different approach of turning a plant into a functional display is given by Infotropism [6]. Holstius et al. worked out a system based on corn seedlings as shown in figure 2.6a, which align through controlled illumination, thrown by integrated daylight lamps. The plant pot is placed between two containers, which are equipped with motion sensors. As soon as someone throws something into one of the containers, the light will be activated on the corresponding side for a few seconds. Since plants always grow in the direction with the highest incident of light, the seedlings will lean throughout time towards the frequently used container. Moreover, Holstius and colleagues built a robotic replica of the system imitating the living one.
The motivation behind this work was to encourage people to care for the environment more consciously by using recyclable packaging. Hence, the systems with living and artificial seedlings were tested for two weeks in a university cafeteria to display the differences in use of trash and recycling containers (Figure 2.6b) and confront visitors with the impact of their consumption. As a control condition, simple containers with no technical features were additionally placed in the cafeteria. The feedback the systems gave to indicate the more used container was well understood, so that over time a light positive change persons' behavior was seen in the frequency the recycling container was used. The effect was more evident on the model with the living plants, but also the robotic system encouraged the people to recycle more than the usual containers.
This work shows that plant displays can be easily integrated into people's daily life to create awareness, since they are quickly accepted and understood. The emotions which evoke in the desire to care for a living being are strong and motivates us to adapt our behaviour. FamilyFlower is as well based on a plant and in this way aims to reach same acceptance. The emerging feelings arising in the interaction should encourage people to care for their relatives and foster the bond of family.

In contrast to the above listed projects the main component of InfoPlant [5] is a living houseplant instead of an artificial plant or food crop (Figure 2.7). However, it is also technically equipped to allow feedback in many ways. The required augmentations can be subdivided in three categories: in the first one the plant's appearance is briefly altered by taking direct influence on its shape, e.g. changing the orientation by rotating the plant pot, rustling the leaves through the use of a fan or pulling a twig. The second category comprises mechanism which change the exterior of the plant over a period of time. For this the major factors that are necessary for the growth of the plant are controlled like the watering or the illumination. The last one provides features by adding additional apparatus to the plant, like LEDs or loudspeakers.

(a) Core component of Infotropism

(b) Plant display in cafeteria

Figure 2.6: Infotropism

These diverse functions led the designers to implement two application scenarios. The first one displays the electricity, heating energy and water consumption in a household. Both the current need, and the course over a longer period are demonstrated. The current state is shown while directly changing the shape of the houseplant whereas the long-term use is displayed by taking influence on the plant's growth, which affects the appearance of the plant only in the course of time. In addition, transgressions of a given threshold bring the LEDs to light up and the leaves to rustle.
The other application makes use of InfoPlant to inform its user about the current status of his email and twitter accounts. If a new tweet is posted on the user's wall or a new email is received, the LEDs start to blink and the leaves to rustle. Additionally, the more unread emails are contained in the user's incoming mail folder, the stronger the plant's branches are pulled to the bottom.
Results of a user study demonstrate that people felt like InfoPlant fits well in their homes and the implemented applications could influence their everyday life positively. Similar to the above studies, participants mentioned a kind of emotional affection which is created by dealing with a living being. In other aspects the opinions diverged. Some users perceived the system as unobtrusive whereas others felt distracted in what they were doing at that moment.

A similar construction is the PlantDisplay [9], which as well consists of a houseplant widened in their existence while displaying information in form of its changing condition.
In a first step, data of a certain type are collected from several input devices and uploaded on a database server. Next, they are filtered and transferred into actions

Figure 2.7: Infoplant

Figure 2.8: PlantDisplay

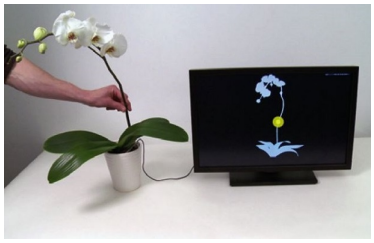
which influence the plant's growth. That means, the more information is found, the more water and light the plant receives. In order to avoid damage, an upper limit of each application is set for every day.
Kuribayashi and Wakita tested their system with human relationship as input type. For this they filtered collected data by the time shared with friends while meetings, phone calls and text messaging. Dependent on the findings, the light was turned on or the water pump activated. After two months, a change in the plant's condition was clearly recognizable as shown in figure 2.8, in which each plant visualizes the relationship to another friend. According to their own statements, the users were influenced by the changing condition of the plant and adapted their behaviour correspondingly.

With regard to FamilyFlower it is to say that too many actions of a ubiquitous device can be overwhelming so that it makes more sense to concentrate on just a few actions to use a plant properly as an ambient display. To maintain a positive feeling in the use of FamilyFlower it should be taken distance from transferring the plant's condition to display a desired behavior. Feeling the urge to help the plant creates a pressure for the user to act appropriately, which is beneficial to trigger a change in behavior but not to foster an emotional bond. FamilyFlower should rather accompany gently throughout the day to encourage the feeling of family closeness. However, the benefits of the two above designs like the high acceptance in a family home, the clear understanding and the potential to improve the users well-being by feeling supported are desired to achieve with FamilyFlower too.

2.2.2 Human-plant interaction

Plants are not only suitable as ambient displays, they can also be technically equipped for use in various other areas.

One example is given by Bontanicus Interacticus [13], in which a living plant or an artificial replica is transformed into a high precision input device. To this end, it is capable of recognizing several forms of touch interaction which includes being able to determine the exact location as well as the amount and strength of touch. An example is shown in figure 2.9a. In order to offer these functions, an electrode is plugged into the soil to enable the capacitive sensing technology, which is only possible to apply because a plant is an electrical circuit by nature. In this technique the plant is stimulated with multiple frequencies and then the reply to touch is measured. Accordingly, the obtained feedback is classified into different interaction methods with the help of machine learning techniques. Every plant or plant like structure has unique electrical and physical properties, since shape and structure vary. Thus, each offers different possibilities of touch interaction and fields of use like for example as musical instrument in which each touch position triggers a different sound.



(a) Interaction with a living plant

(b) In an exhibition presented plants.

Figure 2.9: Botanicus Interacticus

The range of applications is wide, however the designers' intention is to get people in touch with their surrounding. So they presented several living and artificial plant species (Figure 2.9b) in an exhibition which reacted with visual and audio responses on touch.

From the category everyday helper is EmotiPlant [1]. It is designed specifically for older adults to support them in plant nurturing. Additionally, it should offer a fellow to keep them company and reduce the feeling of loneliness.
Equipped by several sensors (Figure 2.10a), the plant is capable of monitoring the most important parameters necessary to maintain a good condition which are light intensity, ambient temperature and soil moisture. These values are demonstrated to the user on a small panel in front of the pot by bars in a histogram. Depending on them an emoticon in happy, neutral or angry mood is presented

(Figure 2.10b). This process facilitates to infer the current condition of the plant. In case one parameter is not within acceptable range it is highlighted to achieve countermeasures. However, the histogram is only visible when touching the plant to encourage interaction. Additionally, it then shows a happy smiley to foster the feeling of having a companion which liked to be cared for.

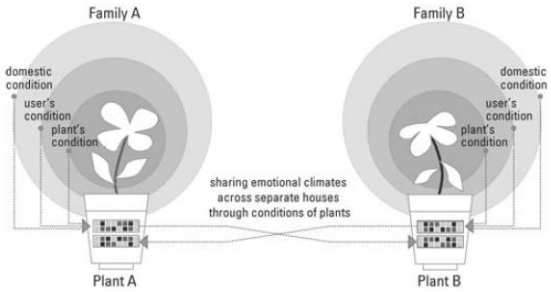
(a) Prototype

(b) The five displayable emoticons.

Figure 2.10: EmotiPlant

Dealing with a related issue is the AmbientPlantPot [8], which connects older people with their separated family members as relief from loneliness by displaying the current condition of its contained plant to the household it is located and to a remote one.
The system consists of two plant pots, which are installed in the homes to be connected. Both are equipped with three displays, one to inform the user about the state of its own planty roommate, one to show the plant's condition to the remote family and the last one to give hints about the ongoing happenings in front of the planter. This functionality supports to infer the user's, the plant's and the domestic condition which is explained in figure 2.11a.
To allow conclusions of the plant's status, the moisture level of soil is determined with help of a weight sensor and displayed through showing a series of colors running over the screens in both households. The attendance of a person is detected with an infrared sensor and lights up the third display in the distant household, which is arranged in form of a happy smiley (Figure 2.11b). This enables the users to mutually recognize ongoing happenings and encourages establishing shared routines.

Like all the projects of this section, FamilyFlower invites interacting with the given device, what should on the one hand encourage getting in closer contact with the plant to judge its condition and on the other hand inspire to contact remote family. Similar to Botanicus Interacticus, our system provides touch interaction, however restricted to the leaf and with the difference that the reaction



(a) Conceptual diagram

(b) Prototype with glowing display

Figure 2.11: Ambient Plant Pot

is triggered in a remote location instead of directly on site. A commonality of FamilyFlower and the Ambient Plant Pot is that they aim to connect two households by presenting information about the local events. Moreover, both are able to display the presence of people in front of the plant with help of an infrared sensor, which inspires the users to establish shared routines, like simultaneously watering or relaxing nearby to feel closeness. Furthermore, EmotiPlant as well as FamilyFlower make use of scales to demonstrate certain values, EmotiPlant through displaying the plants condition with emoticons and FamilyFlower by adjusting the light color depending on the volume level.

2.3 IoT devices

The internet of things builds an intersection of internet, users and things which are augmented in their existence "with sensing, computing, and communication capabilities, connecting them to form a network and making use of the collective effect of networked objects" [4]. The data gained out of this ubiquitous devices can be perfectly used to simplify users' daily lives by intelligently supporting them in their actions.

One project using this concept is the Messaging Kettle [14]. It creates a connection to remote family members while informing each other about preparing water for tea time. Thereby, it is possible to build shared habits over distance and different time zones strengthening the bond to family.
In order to enable connected water heater, each of two households has to be equipped with a Messaging Kettle system. It consists of two devices, a Kettle Mate and a Tea Box, augmenting a freely selectable boiler. The Kettle Mate is a board, shaped like a kettle, consisting of an Arduino Microcontroller with a contact-less infrared temperature sensor, a microphone, a loud speaker and an indicator light and the tea box a usual model made of wood with a tablet integrated into the cover. The apparatus in the same household are connected

with each other via Bluetooth and the ones in different households over internet. The actual boiler has to be placed near the kettle Mate, by which the infrared sensor is able to detect a change in water temperature as soon as someone is in the process of putting water on or it cools down again. That is presented to the remote home with a glowing light on the Kettle Mate in orange or red, dependent on the water temperature. An additional function of the augmenting device is that the user is able to transmit and listen to short voice records. Moreover, with help of the tablet in the tea box he can send and access small notes or sketches. The enclosed data can be recalled asynchronously to enable communication over different time zones and living habits.

Figure 2.12: Messaging Kettle

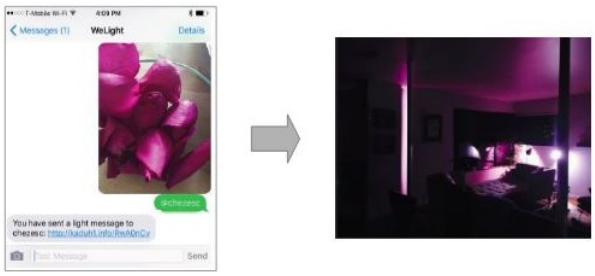


Figure 2.13: Scene creation of WeLight

Another IoT system is WeLight [11] which aims to foster emotionally communication of family members living apart by enabling them to control the lighting in the distant household.
The prototype is based on a common light management system that provides the control over color and brightness of various lamps in a local household. To allow the regulation over distance Morris et al. designed a chatbot application running on a server which creates and implements an illumination concept according to received text messages and pictures. Images are filtered and the results converted into light color and brightness of predetermined lamps by certain algorithms. Text messages are searched by keywords, the five top Google Images selected, the outcome of the image analyzes combined and the light affected accordingly. To guarantee security every user has to sign up previously with his phone number. In addition, the bot provides opportunities like accepting or rejecting received messages or defining the influenced lamps.

Like the two approaches above, FamilyFlower forms an IoT gadget since it fosters a connection between remote households by exchanging information over the internet. Additionally, all designs are based on transformed everyday objects which are a plant, a kettle and lamps. As well as the tea kettle and WeLight, FamilyFlower encourages sharing small personal cues of everyday life.

2.4 Conclusion

The FamilyFlower system is based on a combination of various areas designed to form a device that integrates easily into everyday life and helps separated family members feel an emotional bond through spatial separation.
Firstly, it is created to foster connection building over distance. Similar to projects described above, it aims to facilitate communication across homes by providing functionality which supports the reflection of the current events in the distant household. This includes the indication of presence and motions of people being near the system and the display of the current volume level in a room.
The second area comprises the plant kingdom. Like other systems named before, FamilyFlower represents an ambient plant display with behavior copied from its living models. The artificial flower is able to adopt several states by the mechanically opening and closing of the blossom, which imitates a natural process. The wobbling of the branch is reminiscent of the wind that sets the plant in motion. Furthermore, the user can trigger the distribution of pleasant fragrance in the distant apartment by a touch sensor integrated into the leave which is intended to encourage human-plant interaction. Additionally, plant augmenting functions are given such as the flower shining in different colors to indicate the volume level in the distance.
The last related field, is the IoT world. In our system two communicating flowers are connected via internet. Like the projects of the IoT section, FamilyFlower is based on a domestic object augmented in its original existence. Every stable houseplant can be extended in its decorative and well-being purposes by adding the flower device, with the goal to support the users in their communication and obtain the family bond over distance.

Chapter 3
Concept

In the following chapter, the concept of the work is explained. The first part presents the FamilyFlower system as a whole and elaborates the accessibility of the research goals. The second part describes the structure and functionality of the FamilyFlower devices.

3.1 The FamilyFlower system

Sometimes changing life circumstances require a close family member or friend to unintentionally leave the shared household temporarily or in long term in order to move to a new place of residence.
The associated loss of personal contact and familiarity can have far reaching consequences. One of them is that clues about certain features of relationships guiding communication when living together can no longer be experienced. This information can be of physical nature such as the presence or activity of a person but also concern the interpersonal human level such as the current emotional state. The lack of these can result in changed routines and social dynamics of daily life of all parties involved. Over a longer period of time the situation can lead to a shift in relationship and cause negative feelings, e.g. loneliness.
Sharing the little deeds of everyday life poses an important point to maintain a sense of belonging and closeness over distance that may strengthen the family bond. They are supposed to fill the inner gap that can arise if one is prevented from spending time in person together.

Living plants have a multitude of pleasant properties such as their pleasant appearance and their positive effects on people's body and soul. This was already described in in chapter 1.1.2. They are an integral part of many of our homes

which give reason to believe in a favourable integration of flowery devices into the living space. Furthermore, their appearance offers a good basis to be transformed into an ambient display.

The FamilyFlower system is supposed to integrate the benefits of houseplants into two identical FamilyFlower devices that support to counteract the problems of spatial separated persons which were described above. It aims to offer a novel form of communication to connect people living in distant households. The idea is to provide information that support the detection of actions taking place in an apartment. The information are collected in Household 1 with sensors which are integrated into the device and then mirrored by a controllable artificial flower to the Household 2, vice versa. This process is illustrated in figure 3.1. As the devices stay active during the entire day, the functionality should include the user into each others' the daily events. Moreover, by that the opportunity is given to establish shared routines. The negative feelings such as loneliness and dejection, that may arise, should be prevented by simulating closeness of the remote person. Every signal from the flower device triggered by the connected user should result in positive emotions and contribute to a better mood in the long term.
To enhance the overall appearance and increase user acceptance of the devices, living plants are included in the design. Thereby, the users are wanted to behave naturally in the vicinity of the devices, which results in meaningful results. Moreover, the daily activities the user must carry out to meet the requirements of the plant, such as watering or checking the condition, lead to regular encounters with the tool. This supports on the one hand the inclusion of the device into the users' daily routines and on the other hand symbolically represents the effort the users need to contribute in order to maintain the family bond.

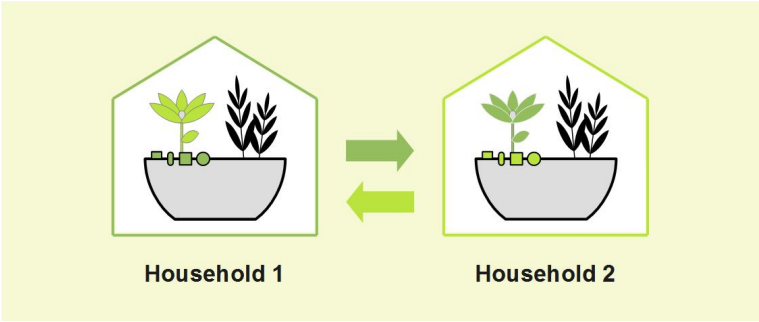


Figure 3.1: FamilyFlower system

In contrast to other common communication tools used to overcome spatial distance as texting, phoning or video calls which are usually used for shorter time periods the FamilyFlower devices stay always active. A further difference is that they do not require any expenditure to initiate the contact and by that offer the users an easy and casual way of communication, which adapts smoothly to their own daily actions. Moreover the devices' signals help to infer when time is

right to deepen the contact through other media and consequently prevent from frustration when not reaching the other person.

3.2 The FamilyFlower device

3.2.1 Structure

The FamilyFlower device is supposed to manage the communication between two separate households. Therefore, it is the component of the system which is placed in the users' living spaces.
It consists of a customary plant pot which is divided in two parts: one side offers space for a living plant, the other one is technically equipped and containing a controllable artificial flower. Furthermore, the device has the ability to establish internet access to exchange gained data with its linked FamilyFlower device. In figure 3.2 you can see the construction of the FamilyFlower device, which is described in more detail below.

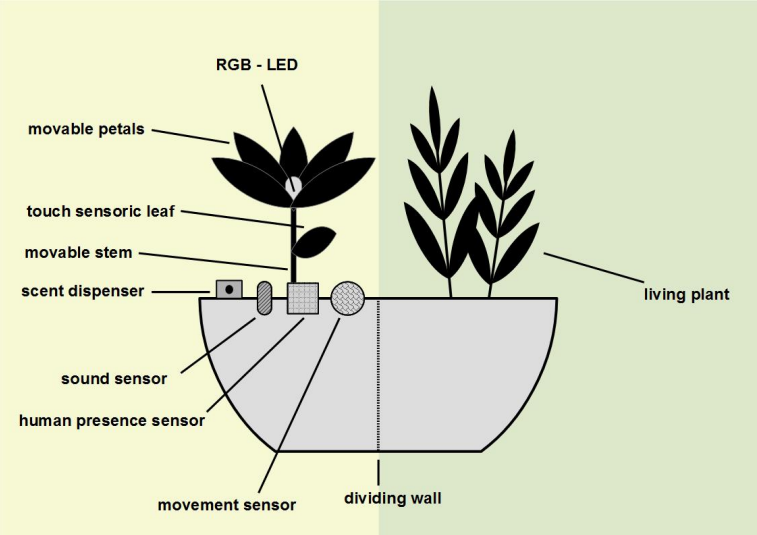


Figure 3.2: Structure of FamilyFlower device

The meaning of the integrated living plant in one half of the pot is explained in detail in the section above. The technical part of the FamilyFlower is meant to provide the information exchange. It performs the main tasks of the apparatus: the sensory acquisition of certain data in its surrounding, the signaling of the connected device's data and the sharing of the collected measured values.
In order to detect information in its surrounding, the device is equipped with several sensors which enable motion, human presence, sound level and touch detection. The recognition of these functions can originate from conscious or

unconscious actions of the users. In one case the users are detected during their common actions incidentally causing changes to the readings. However, they can also trigger them by deliberately approaching the FamilyFlower device. Motion, human presence and sound level detection can emerge both ways, whereas the touch gesture rather requires an intentional action.
In addition, the artificial flower mirrors the data which is collected in the connected household. The stem can move back and forth, the flower leaves can open and close, the blossom's inside is able to glow in different colors and fragrance can be distributed. All of these actions are inspired from natural characteristics of living flower except for the glowing center of the flower. The derivation of these familiar practices should help the user to intuitively decipher the message conveyed. Furthermore, flowers are well suited as ambient display as they offer a way to show information in the peripheral field of vision. That allows the users to bring the device into focus of view and attention when it performs an action, but does not distract them if the flower remains motionless. Hence, the FamilyFlower device can be smoothly integrated into the living area without being perceived as a nuisance.
A further point is that the flowery gadget meets all characteristics to be categorized as an invention from the field of the Internet of Things. Plant pot and flower are common objects which are technically equipped with the ability to connect to the internet. The standard house plant in its pot has turned from an object for observation into an smart ubiquitous communication tool. Thereby, the extra features provided to the plant do not interfere the original ones however increase the users' utility. They can now interact and communicate over the flowery device with their remote loved ones.

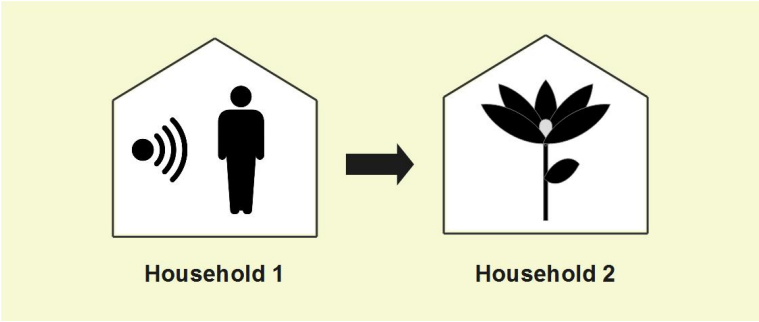
3.2.2 Functionality

The FamilyFlower device can perform four main functions. Each connects a measurement variable of one household to a display operation portrayed in the connected home. This is a reciprocal process which means that each device collects readings of its surrounding and displays those of the connected one.
Through the combination of all functions and additional conditions as the daytime, conclusions can be drawn which help to infer the actions in the remote home. Furthermore, they indicate proximity to those who live far away and are thus intended to reduce loneliness.
In the following the individual functions of the flower device are explained.

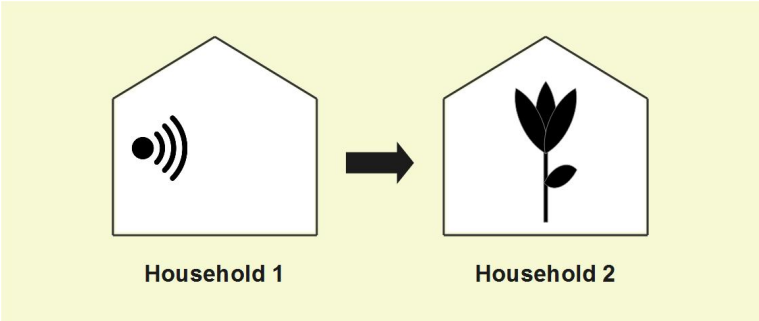
Recognition and display of physical presence

The first function is that the presence of people in front of the device can be detected. The recognition of human presence in Household 1 is linked to the petals' position of the flower in Household 2, vice versa, which is visualized in figure 3.3. If no person is identified in the area in front of the plant pot the blossom

stays closed (see figure 3.3a). As soon as an individual is discovered, whether moving or standing still, the flower will open to bloom (see figure 3.3b) and close again if the person leaves the flower. This function should enable the user to recognize when someone is present in the connected apartment. The pattern of the opening and closing in Household 1 can help to infer the actions in Household 2, vice versa. If the flower is always open, an action is being performed in a constant place. However, if it opens and closes at regular intervals, the user will probably be doing something more intense. From the emotional point of view, the opening of the flower is aimed to create a good feeling in the users as they enjoy the virtual appearance of a loved person.



(a) If a person is detected in Household 1, the flower in Household 2 is open, vice versa.



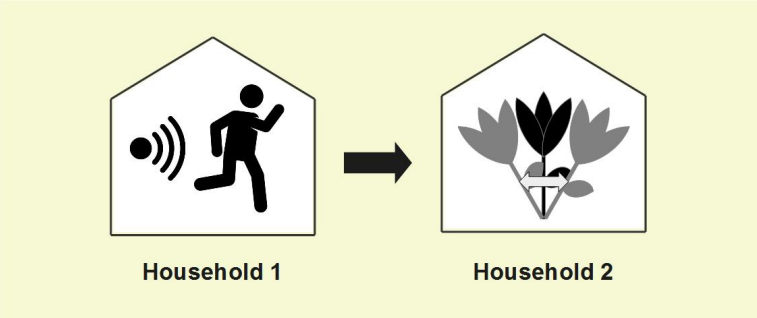
(b) If no person is detected in Household 1, the flower in Household 2 is closed, vice versa.

Figure 3.3: Recognition and display of human presence

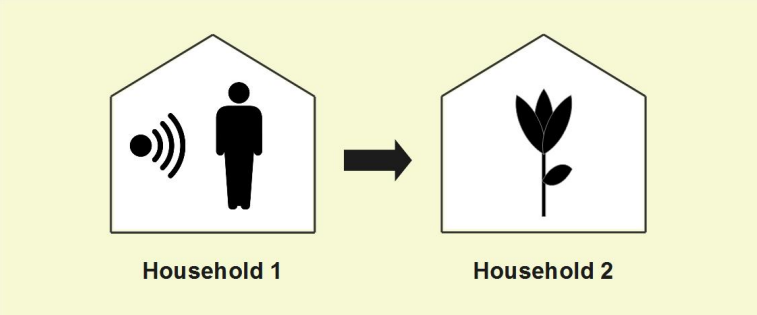
Recognition and display of motions

A further function of the flower is the recognition of movements in front of it. The discovery of movement in Household 1 is shown through the moving stem of the flower device in Household 2, vice versa. If a movement is detected the stem starts to wiggle for a short time. If no movement is detected, the stem will not budge. The features are shown in figure 3.4a and 3.4b.

The frequency of movement in a given period of time can help to identify what is happening in the other apartment. If the stem shakes only once and not for a long time, the user has probably just walked past the device. If it moves several times in a row, the user is likely to be performing an activity in front of the plant pot.



(a) If a motion is detected in Household 1, the stem of the flower in Houshold 2 moves, vice versa.



(b) If no motion is detected in Household 1, the stem of the flower in Household 2 stays motionless, vice versa.

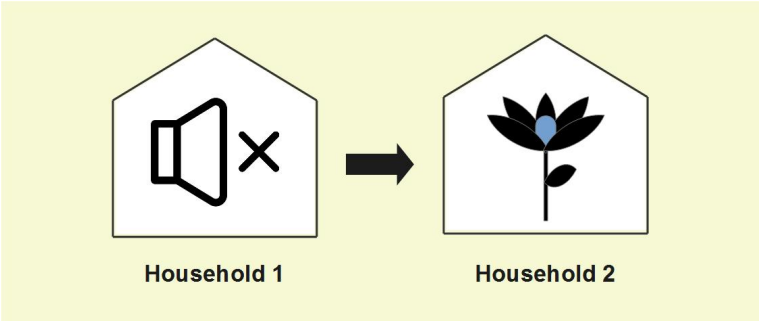
Figure 3.4: Recognition and display of movement

Recognition and display of volume level

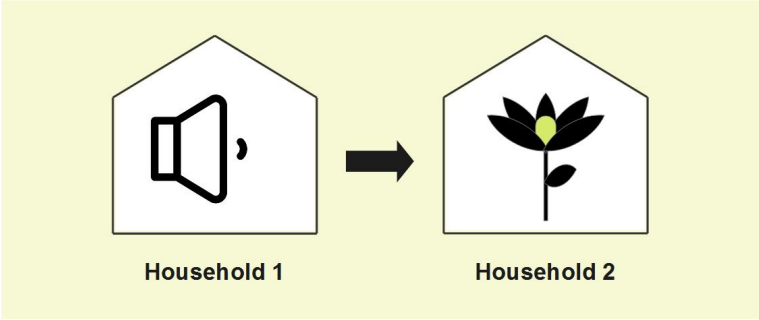
Furthermore, the flower is capable of recognizing different sound levels in its closer surrounding. If in Household 1 the sound level changes, an integrated Led in the center of the blossom of Household 2 switches the color, vice versa. The sound is measured continuously and divided into three categories: silence, medium volume and loud volume. Each category is assigned to a specific light color which changes as soon as a modification is detected. As can be seen in figure 3.5 [6] the color blue displays silence, green intermediate volume and red a loud atmosphere.

[6] loudspeaker icons are copied from: https://www.flaticon.com/ [accessed: 22.07.2020]

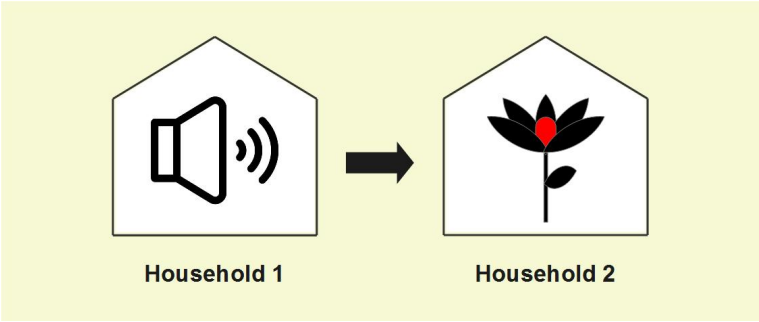
An interpretation of silence in one household is that there is a quiet activity going on or nobody is there. Medium volume could stand for normal everyday sounds and the detection of loud noises could refer to a lot of ongoing activity. A further indicator for the events in the remote home, is the frequency of changing colors. Many shifts in a short time could also indicate a lot of activeness.
However, there is another way of making use of this function, while using it as interaction method. The user can try to emit specific signals by intentionally influencing the volume. The meaning of the transmitted message can then be freely interpreted.



(a) If there is silence in Household 1, the led in Household 2 glows blue, vice versa.



(b) If there is ambient volume in Household 1, the led in Household 2 glows green, vice versa.

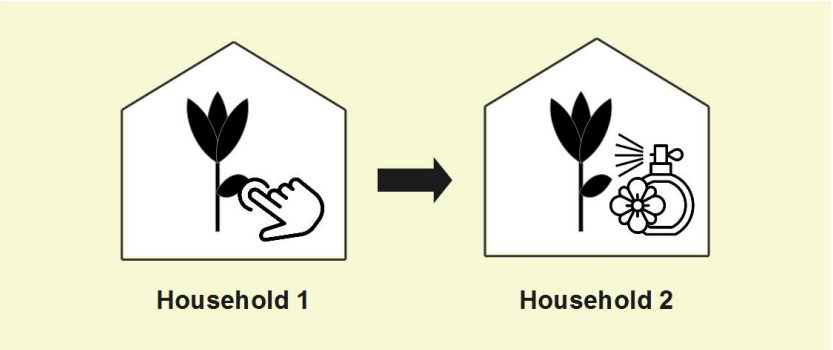


(c) If there is a loud atmosphere in Household 1, the led in Household 2 glows red, vice versa.

Figure 3.5: Recognition and display of volume level

Recognition and display of touch interaction

The last function is the touch of the flower's leaf. If the flower's leaf in Household 1 is touched, the FamilyFlower device in Household 2 releases a pleasant fragrance, vice versa. Figure 3.6 [7] illustrates, that as soon as the touch of the leaf is measured, the other flower sprays scent. This function offers the users a possibility to interact consciously with the remote person.
The exact meaning of the reception of perfume is up to the remote person. For instance it could be used to attract the attention of the user, if no one is in the closer surrounding of the gadget. Another possibility would be to send a message through the scent like "I am thinking of you" or symbolizing a hug.
Moreover, it is intended to offer some opportunity to build shared routines. For example, the release of the fragrance could be a morning or evening ritual or used to signal the arrival or leaving of the apartment.



(a) If the leaf of the flower in Household 1 is touched, the flower in Household 2 spreads fragrance, vice versa.

Figure 3.6: Recognition and display of touch

[7] the touch icon and the fragrance icon are copied from: https://www.flaticon.com/ [accessed: 22.07.2020]

Chapter 4
Implementation

In this chapter the implementation of the prototypes for the FamilyFlower devices that realize the FamilyFlower system is explained.
The first section describes the hardware used for the FamilyFlower devices. This includes the description of the non-technical and the technical components.
In the second section the applied software is examined. One part explains the connection of the two FamilyFlower devices and the way their communication works. The other part illustrates how data is obtained using the *Arduino IDE*.

4.1 Hardware

The FamilyFlower system consists of two identical FamilyFlower devices which are shown in figure 4.13. Each of them is composed of common construction material and technical equipment which is described in the following section.

4.1.1 Non-technical components

Plant pot

The foundation of the FamilyFlower device consists of household objects and building materials. The core element forms a standard oval shaped plant pot. It is subdivided in the middle into two parts by an adjusted plastic plate which is hot glued so that no water can pass from one side to the other (see figure 4.2a). This setup is necessary to place a living plant into one side of the pot without destroying the sensitive technology on the other side through watering the plant. In order to position all necessary technical components appropriately in the other

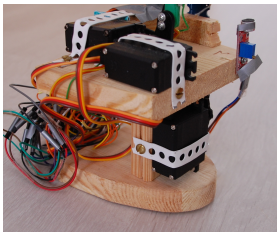
(a) Prototype 1 of the FamilyFlower devices

(b) Prototype 2 of the FamilyFlower devices

Figure 4.1: The two FamilyFlower device prototypes

half of the plant pot a wooden base was built which is pictured in figure 4.2b. It fits into the pot and conforms smoothly to its shape. The construct consists of two horizontal levels which are connected through a vertical side wall. Thus, it is formed to fix all components in their suitable places. The exact arrangement will be explained in section 4.1.2. At the bottom the wooden frame is screwed to the plant pot which fixes it into its place, however it stays removable for maintenance purposes. Furthermore, a holder for a fragrance spray is integrated to the edge of this half of the plant pot, which contains a bottle of scent.

(a) The divided plant pot



(b) The wooden construct

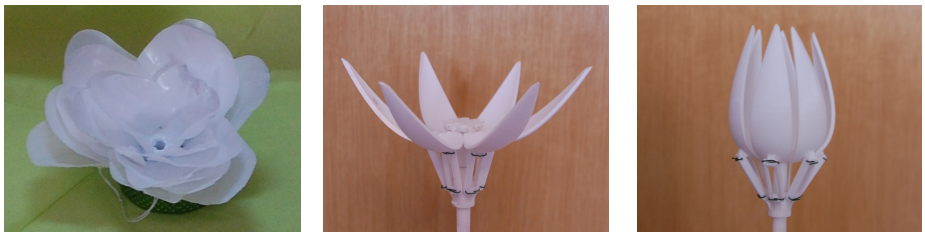
Figure 4.2: Non-technical parts of the FamilyFlower devices

Artificial flower

The artificial flower consists of 3D printed and handcrafted parts. The stem and the substructure of the petals are 3D printed (*Prusa i3 MK3S Multi Material printer* with green PET material). Petals and leaf are constructed by hand out of a malleable foil. The construction of the final artificial flower took several steps of development.
In a first step the mechanism to move the flower leaves was created. Based on a template of an already established project [8], several petals were built with the 3D

[8] https://hackaday.io/project/163866-christines-blooming-rose#menu-description. [20.07.2020]

printer and composed to a rose (see figure 4.3a). A pull mechanism was supposed to control the opening and closing of the blossom. After the completion a big disadvantage of the flower was discovered, which made it unsuitable for the FamilyFlower project. The difference between the opened and the closed blossom was too marginal to enable an identification of the different states properly.



(a) First 3D flower model

(b) Second 3D flower model - opened

(c) Second 3D flower model - closed

Figure 4.3: Rejected 3D flower models

Hence, in a next step a different template [9] was used to create petals. Here, the flower uses another mechanism to move the petals than the previous one. The flower consists of a stem, six petals, a crown and twelve struts. The petals are attached to the top of the stem. Furthermore, their lower side is connected via struts to the crown which encloses the stem. Through moving the crown up and down, the petals move in a position that the flower appears closed, respectively opened. With this model, the difference between an opened and closed blossom is clearly recognizable as shown in figure 4.3b and 4.3c. However, the flower has an immense flaw as its petals look very unnatural and aren't visually appealing. Therefore, the 3D model was transformed in a last step. The ends of the petals was

(a) Final flower construct

(b) Uncolored petals

(c) Final artificial flower

Figure 4.4: Final artificial flower model

cut off. Only the construction for the opening and closing mechanism remained. The result is shown in figure 4.4a. Consequently, the petals had to be designed in a different way. They and also the leaf of the flower were made of a special material, called *Creaflexx*. It is a plastic foil malleable through heat which becomes solid

[9] https://sketchfab.com/circuito.io/collections/sunflower. [20.07.2020].

and stable after cooling down. After the material had been cut and formed (see figure 4.4b), the pieces were painted colorfully to create an optically appealing flower (figure 4.4c) and glued to the printed parts. Moreover, an aluminium foil was added to the bottom of the leaf. Its purpose will be explained in the next section. In the end all parts was glued to their places.

4.1.2 Technical components

The FamilyFlower device is provided with several technical equipment which enable to implement the functions that are described in chapter 3.2.2. The core component is a microcontroller board. The other engineering parts can be divided in actuators and sensors. The sensors collect data from the environment and the actuators cause visible changes of the artificial flower. Every function couples a sensor of FamilyFlower device 1 with an actuator of FamilyFlower device 2, vice versa. However, both plant devices have to fulfill both tasks, record and monitor actions. Hence, both devices require all here mentioned modules.
The following describes the individual technical components including the microcontroller as well as the sensors and actuators which are used to implement the respective function of the device. An overview about all applied parts can be found in table 4.5.

		Sensor (recognition)	Actuator (display)
Physical presence	C	Human presence sensor	Servo motor
	T	Detect persons in front of the device	Move the flower leaves
Movements	C	Motion sensor	Servo motor
	T	Detect motions in front of the device	Move the flower stem
Volume level	C	Sound sensor	RGB-LED
	T	Detect sound level around the device	Change color
Touch interaction	C	Touch sensor	Servo motor
	T	Detect touch of the flower leaf	Activate fragrance diffusor

C = Component
T = Task

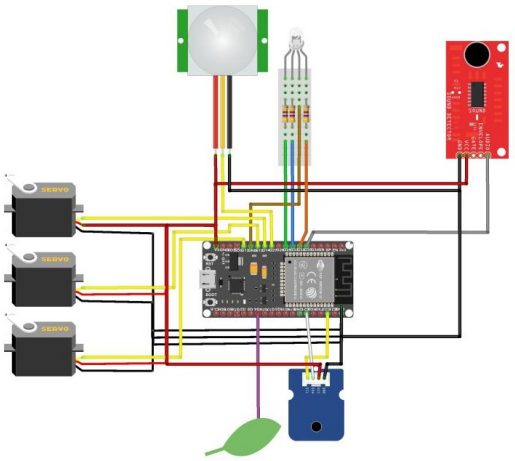
Figure 4.5: Table of technical components

Microcontroller

For the FamilyFlower device, the development board *AZDelivery ESP32 NodeMCU* with Wifi support is used as microcontroller. It is supposed to control the sensors and actuators. Therefore, they are linked with jumper wires to the board. Required intermediate parts within the construction as resistors are soldered in between the board and the technical equipment. All components are attached to the 5V connection, the grounding and to control pins of the board. In figure 4.6b the structure of the electronic circuit is shown (created with *Fritzing* [10]). Table 4.6a gives an overview about the pins that are used for the individual components. The board is driven using a 5V power supply unit with 1A, respectively 1.5A (small variation between the two FamilyFlower devices). The device will be activated to plugging into in a socket.

Component	Pins
Human presence sensor	G21, G22, 5V, GND
Motion sensor	G27, 5V, GND
Sound sensor	G35, 5V, GND
Touch sensor	G4
Servo motor stem	G12, 5V, GND
Servo motor petals	G13, 5V, GND
Servo motor fragrance	G14, 5V, GND
RGB-LED	G32, G33, G25, GND

(a) Table of used pins



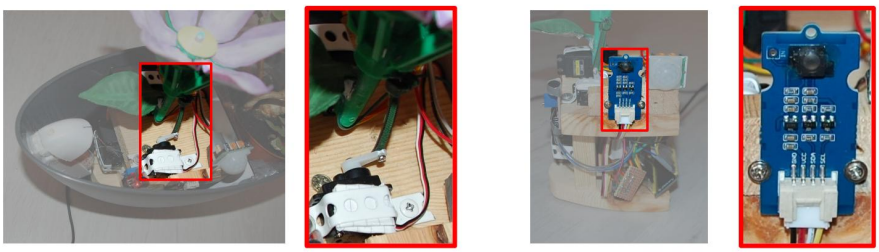
(b) Interconnection of technical components

Figure 4.6: Electronic circuit

Implementation of human presence function

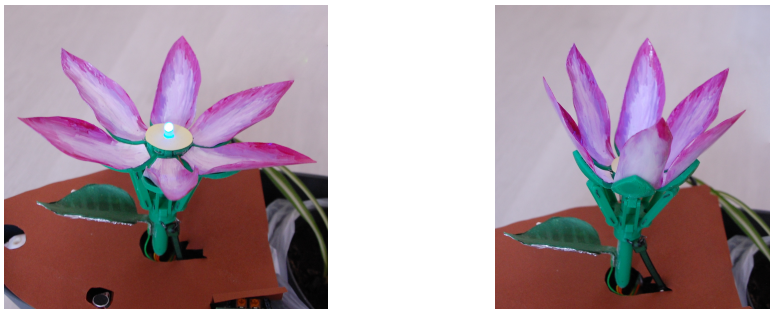
To perform the recognition and display of physical presence, the FamilyFlower device uses a human presence sensor to recognize the attendance of persons and a servo motor to control the opening and closing of the flower.
To recognize people in front of the flowery device it is equipped with the *Grove - Human Presence Sensor (AK9753)*. The human presence sensor is attached to the upper level of the wooden substructure, which is shown in figure 4.7a. It is able to detect persons who are located a few meters in front of the device.

[10] https://fritzing.org/download/. [20.07.2020].



(a) Human presence sensor

(b) Servo motor



(c) Opened blossom

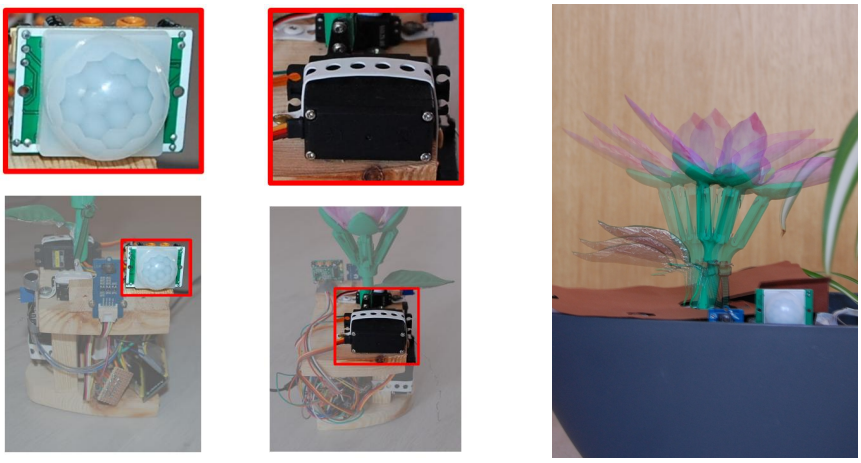
(d) Closed blossom

Figure 4.7: Implementation of human presence function

For the display of physical presence a servo motor is used to control the movement of the flowers' petals. One device uses the *MG995 RC Servo* which was a stopgap solution due to a defective servo, the other one uses the *micro servo sm s2390s*. The servo motor and the artificial flower are fixed on the top level of the wooden constructs. A cable tie serves as a pushing rod with which the opening and closing of the flower can be controlled. The construct is shown in figure 4.7b. Therefore, it is connected on one side to the servo motor and on the other side to the struts of the artificial flower. If the servo pushes the lever upwards the flower closes. If it pulls the lever downwards, the flower opens. The closed flower is figured in 4.7d and the opened flower in figure 4.7c.

Implementation of movement function

The implementation of the recognition and display of movement is executed by a motion sensor to recognize movement in the surrounding of the device and a servo motor to move the stem of the flower.
For the detection of movements in front of the device a *PIR Infrared motion sensor module* is attached to the wooden structure (see figure 4.8a). It can detect motions in a 180 degree area in front of the gadget.
To display movements the flowery device makes use of a *MG995 RC Servo*. It is

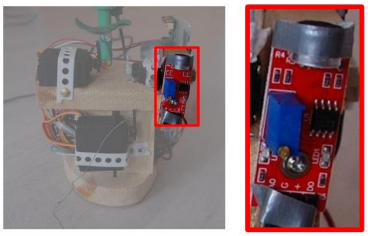


(a) Movement sensor (b) Servo motor (c) Movement of the stem

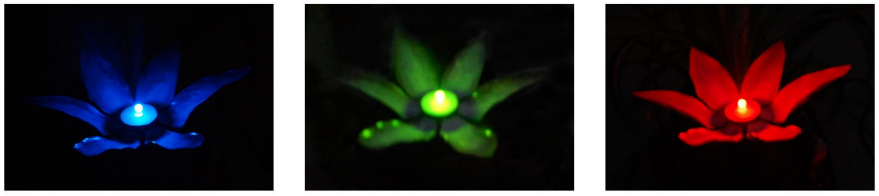
Figure 4.8: Implementation of movement function

attached to the upper level of the wooden structure, which is shown in figure 4.8b. The stem of the artificial flower is attached to the lever of the motor, so that the movement of the servo motor generates the motion of the stem. This is indicated in figure 4.8c. The flower is positioned so that it sticks out above the plant pot and its actions can be instantly realized.

Implementation of sound level function



(a) Sound sensor

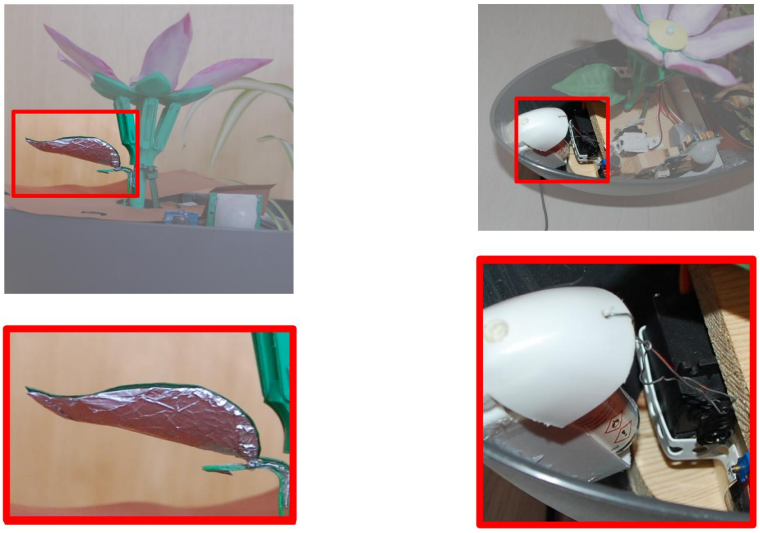


(b) RGB-LED glowing in different colors

Figure 4.9: Implementation of sound level function

Furthermore, the recognition and the display of the sound level is achieved through a sound sensor and an RGB-LED.
In order to detect different sound events in the closer surrounding of the device it is supplied with a *sound detection sensor module*. It is installed at the front of the wooden substructure (see figure 4.9a).
For the display of the different sound levels common RGB-LEDs are integrated in both devices. They are positioned in the center of the blossoms' inside where real flowers have their pistil. The inside of the stems are hollowed out so that the cabling runs through it to be connected to the development boards. Figure 4.9b shows the different colors of the LED.

Implementation of touch function



(a) Touch sensor (b) Servo motor

Figure 4.10: Implementation of touch function

The last function, the recognition and display of touch, is controlled by a touch sensitive leaf and a servo motor which triggers the spraying of fragrance.
The microcontroller board supports the use of touch recognition through special input pins. As described above, the bottom of the leaf is equipped with an aluminium foil. It is connected to the cable of the touch sensor pin (see figure 4.10a). In that way, a touch the leafs' bottom can be recognized.
To display the touch of the leaf a *MG995 RC Servo* is used which is shown in figure 4.10b. It is placed to the side wall of the wooden foundation. Between the servo motor and the trigger of the fragrance dispenser holder a wire is tightened.

4.2 Software

4.2.1 Data exchange

The internet platform *ThingSpeak* [11] offers the possibility to exchange data over the internet. IFor that, channels can be created that can contain up to eight field variables. They can be accessed to be written or read out while being identified through special IDs. If a channel is read out, always the latest value is returned. Furthermore, the course of every field can be graphically shown, which allows the comfortable inspection of the data. With a free account, fields can be written at most every 15 seconds. The course of all collected data in the channel can be downloaded at any time as a csv file.
To ensure an exchange of sensor data between the two FamilyFlower devices, the internet platform *ThingSpeak* is used. For each of the devices an own channel was created. Every channel contains four fields for the adjusted sensor data. Field 1 holds the data of human presence, Field 2 data of movement, Field 3 data of sound level and Field 4 the data of touch. To ensure a smooth running the channels are updated every 16 seconds. Channel 1 is written with the readings of Household 1 and read out by the device in Household 2. For Channel 2 it is the other way around. This is illustrated in figure 4.11 [12]. More detailed information about reading and writing the fields follows in the next section.

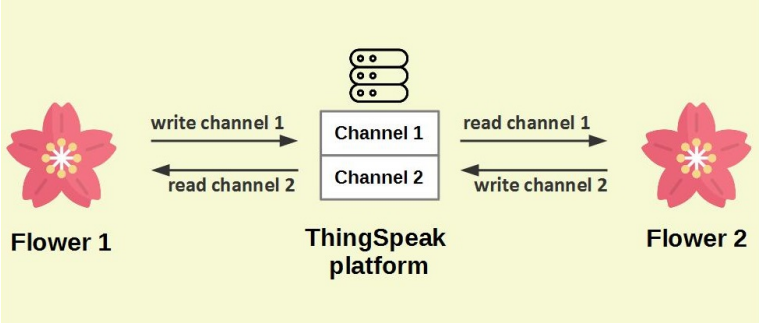


Figure 4.11: Data exchange over ThingSpeak

4.2.2 Control of components

In order to operate the technical components of the FamilyFlower devices the *Arduino software* [13] is used. The generated code is uploaded to the micro controller board to manage the processes of the technical parts. They can be divided in three categories: the communication with the server, the acquisition of data and the control of the actuators. For each of the required processes a method was

[11] https://thingspeak.com/. [20.07.2020].
[12] flower icon and server icon are copied from: https://www.flaticon.com/ [accessed: 22.07.2020]
[13] https://www.arduino.cc/en/Main/Software. [20.07.2020].

created in the code. Since the *Arduino software* only supports sequential programs, a virtual timer controls the procedure of the processes to imitate a parallel execution. Previously, all components are initially set up as the FamilyFlower device connects itself to the internet and brings the servos in the right start position. Each of the methods is executed in a certain time interval. An overview of the processes and the used time intervals are shown in 4.12.

	Component	Interval in ms
Server communication	Check Wifi	16000
	Update channel	16000
	Read channel	16000
Data acquisition	Human presence	100
	Movement	50
	Sound	20
	Touch	150
Actuator control	Servo flower	50
	Servo stem	100
	RGB-LED	16000
	Servo fragrance	50

Figure 4.12: Table of processing intervals

Server communication

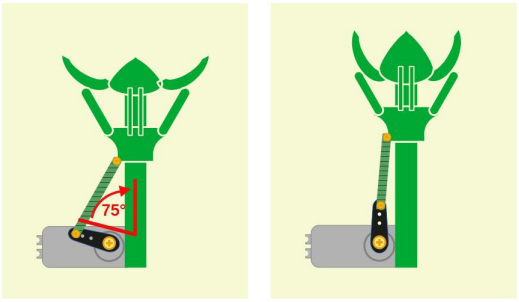
The first category of processes deals with the exchange of data with the server. All of this methods will be executed every 16 second at the end of an interval.
First of all the internet connection is checked. Should it be noticed that the internet connection is interrupted, the device will try to reconnect until it succeeds.
The second method is the update of the linked *ThingSpeak* channel's fields. For that, the data acquired during the whole 16 seconds long interval, which are stored in variables, are sent to the server.
The last process of this category is the reading of the data of the connected flower's channel. The requested data are saved in variables and will be proceeded further in the upcoming interval.

Data acquisition

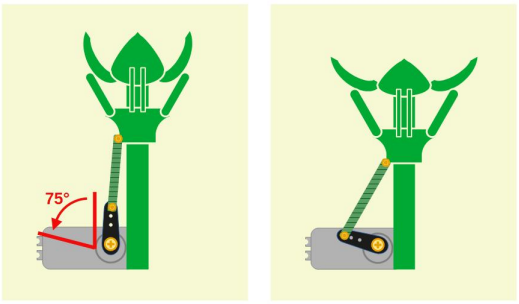
The second part of the methods includes the acquisition of sensor data. Since the ThingSpeak fields will be updated every 16 seconds, the measurements are collected in an equally long time interval.
The human presence sensor is at most read out 160 times per interval and returns a digital value. As soon as one of the measurements is recognized as true, the value for the whole interval will be labeled true. Then, the physical presence sensor will not be read out any longer for the rest of this interval. If all readings of the interval return false, the value for the whole interval will be labeled false.
The movement sensor works in the same way. The sensor reads up to 320 values per interval. It also returns a digital value. If true is measured once, the variable for movement recognition is set to true, otherwise it is false.
The collection of sound readings differs from the previously mentioned as the sensor returns analog values. To obtain data as accurate as possible the sensor is read out 800 times per interval. Therefore, during the 16 seconds interval a minimum and a maximum reading is updated and the difference is compared. The calculation was chosen to detect the loudest noise of the interval. Then, in a last step the measured difference is categorized through previously determined thresholds in one of the classes expressed through the values in the brackets: no sound(0), average sound(1) and loud sound(2).
The last section of code deals with the recognition of touch, which is requested up to 107 times per interval. It is additionally returned as analog value by the touch sensor. During the interval the amount of readings which lie in a certain range are counted. If a certain amount of touches is recognized the variable for the touch recognition is set to true and the sensor is not used anymore for the rest of the interval.

Actuator control

The last part of the methods are the executing methods. They control the displaying functions of the FamilyFlower device based on the data collected by the device in the other household, which were received at the end of the previous interval.
The movement of the petals and of the stem as well as the dispense of fragrance are all triggered by servo motors. These work in similar ways as they move parts of the flower in a time fixed interval for a certain angle until they are in the wanted position.
If the value for human presence of the connected flower is true, the desired state of the flower is open. If the value is false, the desired state is closed. When the actual and the desired state differ, the accountable servo motor will move to adapt the flower's appearance. If the state changes from true to false, the servo motor turns $75°$ up to push the crown upward via the cable tie which closes the flower (see figure 4.13a). If the state changes from close to open the servo motor turns $75°$ down to pull the crown which opens the flower (see figure 4.13b).



(a) Opening mechanism of the blossom



(b) Closing mechanism of the blossom

Figure 4.13: Opening and closing mechanism off the flower

If the received value for movement recognition is true the stem carries out a certain movement pattern for one time. The corresponding servo motor rotates from the start position $10°$ to the left, then $20°$ to the right and $10°$ back to the left (start position). This process is visualized in figure 4.14. If the received value is false, the servo motor will remain motionless.

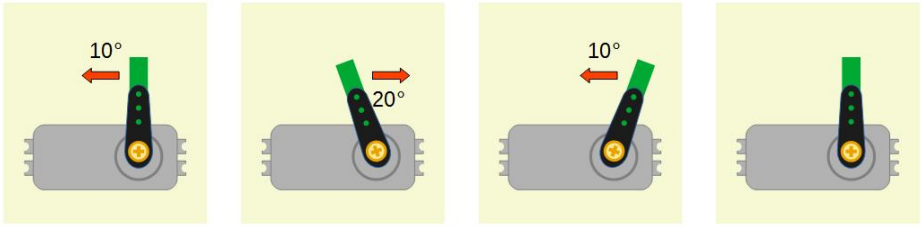


Figure 4.14: Movement mechanism of flower stem triggered

If the the touch reading of the connected flower says true, the corresponding servo motor will move to release fragrance. The attached lever of the servo motor will move $180°$ down to pull the cap of the scent distributor via the wire. This

triggers the contained scent bottle to release its perfume. Afterwards it will move back to its starting position. The process is shown in figure 4.15. If the reading is false, the servo will not move in this interval.

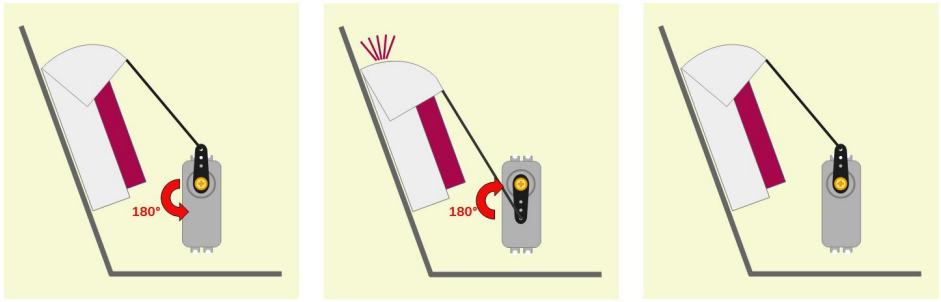


Figure 4.15: Scent distributor mechanism

When the incoming value for the sound level differs from the previous, the RGB-LED that is located in the center of the blossom adjusts its color. Value 0 is mirrored by the blue light, 1 by green and 2 by red.

Chapter 5
User Evaluation

This chapter is about the user evaluation that was carried out to investigate the usage of the FamilyFlower system. The first section, Research question, explains the objective of the evaluation. The second section, Method, includes information about the participants, design, data collection instruments and material and the process of the study. In the following two parts, the results of the evaluation are presented and discussed.

5.1 Research question

After designing and implementing the system, it was the objective to investigate the developed FamilyFlower system and its FamilyFlower device prototypes. Therefore, a small-scaled user evaluation was carried out. The question to be examined was if the system can fulfill the research goals.
In the following, the goals that have been already presented in section **??** are listed again as a reminder:

- Support building a connection over distance.
- Enable a feeling of closeness to a person.
- Providing functionality to encourage shared routines.
- Facilitate integration into the living environment.

5.2 Method

5.2.1 Participants

For the evaluation two participants were recruited (n=2) from the wider circle of acquaintances who have a bond with each other. They were both female. Their average age was 25.5.
The participants are in a close friendship and live in different households. Each of them shares the household with another person. Additionally, in one of the households lives a freely moving pet.
Both participants usually spend between 8-11 hours a day in their apartment during the week, on the weekend there are 4-5 hours more in average. The participants have contact with each other several times a week over media such as texting and phone calls.
As media to build a connection with remote living loved ones, they use in general texting, video and phone calls. None of them had prior experiences with devices, which are specially designed to establish a connection over spatial distance.

5.2.2 Design

In order to run the testing under realistic conditions the evaluation was carried out as field research. That means that the study took place in the households of the participants.
The actual testing phase took a period of two weeks. Beforehand, a time of approximately twelve minutes was required to prepare the testing. Afterwards about ten minutes were needed for post-processing.

5.2.3 Data collection instruments and material

The questionnaires and the further material can be found in the appendix.

Questionnaire - Demographics and living conditions

To receive detailed information about the participants a preparing questionnaire was created.
It collected data about their demographics, living conditions in the household and prior experiences with related devices. It contains a mixture of 12 open and closed questions.
For example it was questioned whether there live further persons or animals in the household because they could have an influence on the collected sensor data.

Questionnaire - Experience with FamilyFlower device

In order to gain data about the conditions in the testing phase a post-processing questionnaire was designed.
It gathered information about the usage of each function of the device by examining whether and how participants have recognized the functions of the device and which counteraction they have performed. This allows the use of the device to be investigated.
Furthermore, it asks the participants about their connection to each other during the testing phase. This survey should show whether the device fulfils its purpose of connecting people.
The last part consists of some general questions such as for instance: "What would you improve?"

Sensor data

During the whole testing phase technical data was measured. The extraction of the data is explained in detail in chapter Implementation. In the time in which the devices have been active, all data collected by them was sent to the linked ThingSpeak channels where they were stored. This includes the captured values for the recognition of human presence, movement, sound level and touch of the leaf. All of them are provided with a time stamp. At the end, they were exported in a csv file.

Further material

For the evaluation some further documents were created:

- **Study explanation:** It guided the participants through the evaluation process.
- **Declaration of user study consent:** The form is prepared for the participants to confirm their attendance in the user evaluation under the given conditions.
- **User guide:** It explains the requirements, the commissioning and the functionality of the FamilyFlower device.

5.2.4 Process

The evaluation process can be divided into three parts: the preparation, the actual testing and the post-processing.
At the beginning of the preparation phase, the FamilyFlower devices and the

required material were handed out to the participants. All further steps were clarified to them in the study explanation. They worked on them independently at home. First of all, the test subjects filled in the declaration of user study consent. Afterwards, they completed the demographic questionnaire. The next step was to get familiar with the device by reading the user manual.
The next part of the user evaluation was the actual test phase. The participants were asked in the user guide to place the device in a frequently used place in their household. At a previously verbally agreed time, the participants simultaneously activated the device. The participants were free to use the devices in a self-determined way without having to perform special tasks. They had to take care of the houseplant themselves. A contact person was available at any time for the possible occurrence of errors. At the end of the test phase the participants deactivated the gadget again.
The last step for the participants was to fill in the questionnaire about the experiences with the FamilyFlower system. Finally, the devices and the associated material were handed over to the person responsible.

5.3 Results

5.3.1 Sensor data

A review of the data has indicated that data are missing in some time periods which is probably caused by technical errors or influence of the user. In one data set two gaps showed up of about six and eight hours during the night. In the other data set, they were five gaps, each only several minutes long.
For the following section the usage of a function is defined as a corresponding positive return value of the interval (true for human presence, movement and touch; 1 or 2 for sound). The usage of the device is defined so that at least one function was used. Whether the user can triggered the function consciously or unconsciously is not differentiated.

Frequency of usage

The analysis of the collected readings indicates that all functions except the touch was used on a daily basis in both households during the entire testing phase. The touch function was triggered nine out of 14 days by one participant and by the other one ten out of 14. The average amount of usage per day of each function for both households is shown in table 5.1. In both households, the order of the function on the basis of frequency was identically in the following way: human presence, movement, loud sound, touch and average sound.

Furthermore, the usage of the device dependent on day time was considered. For each function and both households the amount of positive read values in a certain

		Household 1	Household 2
Human presence		315.14	138.57
Movement		463.86	571.57
Sound	middle	5.14	5.21
	loud	0.43	0.29
Touch		1.36	1.57

Figure 5.1: Table of the average amount of function usage per day

period was counted from the whole data sets. Then, the two results for each function and interval were added up and converted in a percentage separately for each function. The results are shown in figure 5.2. Between 6.00-21.59h the usage of the devices was higher than in the remaining day section. However, even in the night some usage was recognized. The recognition of human presence and movement was the highest in the interval between 6.00-8.00h with about 24% and 18%. The touch function was used more frequently in the afternoon and evening with approximately 22% at 14.00-15.59 and 27% at 18.00-19.59h. The sound function was used relatively even over the course of day.

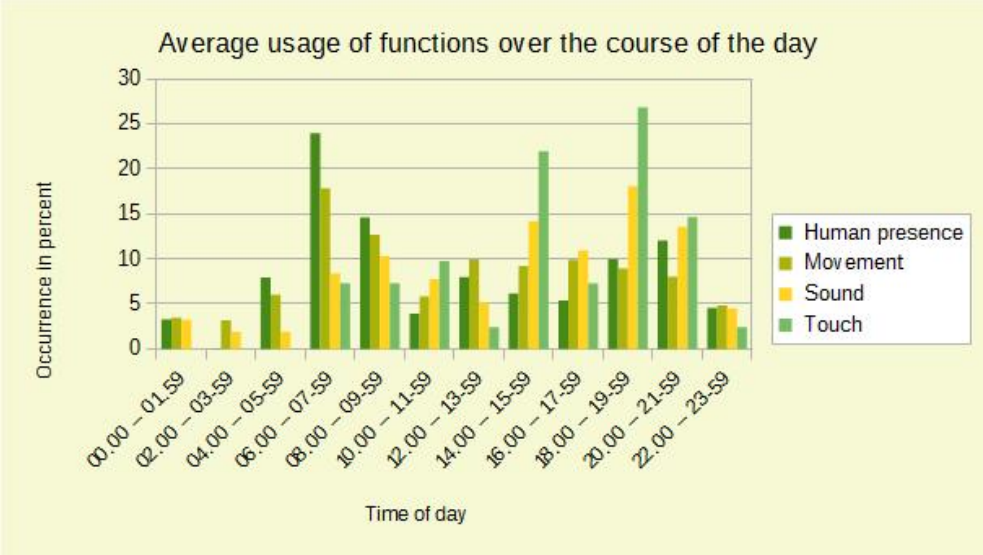


Figure 5.2: Function usage over the day throughout the complete testing period.

Shared usage

In figure 5.3 is shown how many minutes per day the devices was used at the same time. As soon as at least one action has taken place in a minute a user was assumed as active for this time section. The highest amount of time that was shared at one day with 77 minutes. The lowest amount is one minute. The average shared usage time amounted approximately 32 minutes per day.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
15	44	77	20	16	60	21	1	2	33	71	9	47	37

Figure 5.3: Table of amount of shared usage in minutes

Figure 5.4 shows the distribution of the time spent together in front of the device during the course of the day and entire testing phase. Therefore, all minute sections in which each device was used were added up. From 0.00-3.59h almost no time was shared together in front of the device. Afterwards, it increases dramatically and reaches its peak at 6.00-7.59 with approximately 140 shared minutes in this time interval. Then, it decreases sharply to about 10 minutes at 10.00-11.59h. In the further course of time, it increases slowly to around 60 shared minutes at 18.00-19.59h, followed by a soft decrease which approaches zero at 22.00-23.59h.

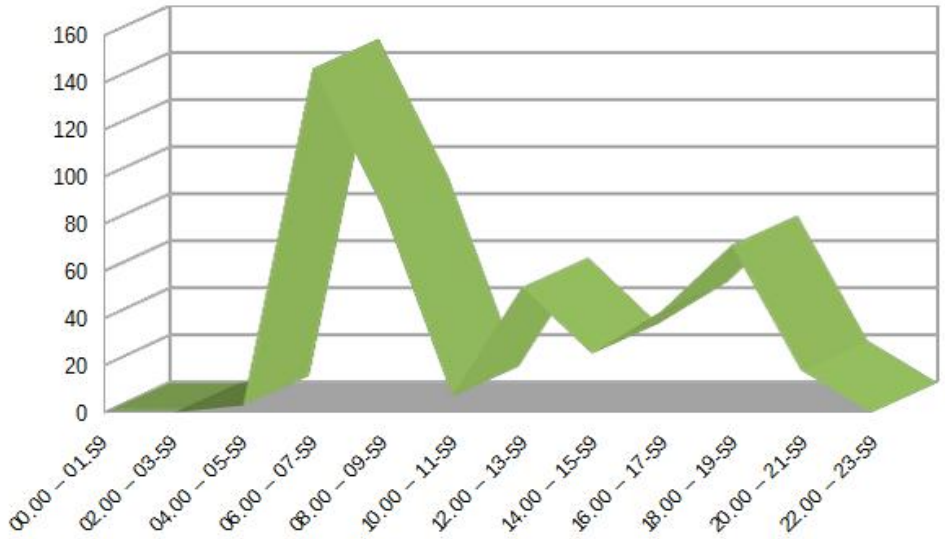


Figure 5.4: Course of shared usage

Interaction

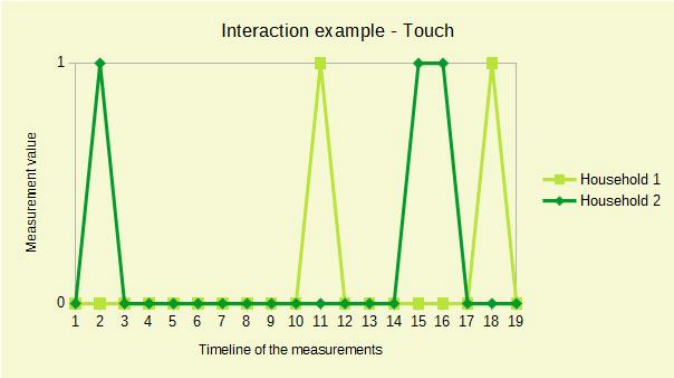
In figure 5.5 two interaction examples are presented. They refer to the values of the sound and touch functions. In figure 5.5a Household 2 triggers the touch function in time interval 2. Afterwards, Household 1 triggers the touch function in interval 11 (about two minutes later). In interval 15 and 16 Household 2 uses the touch function again (one minute later) and after 30 seconds in interval 18 Household 1.
In figure 5.5b a combination of the touch and sound functions are shown. Household 1 triggered the touch in time interval 4. In the next interval Household 2 used the medium sound and in interval 8 and 9 the touch function. Thereupon, Household 1 used the touch function in interval 11 again and Household 2 the medium sound in interval 12. Afterwards, Household 1 triggers the loud sound in interval 16.
The percentage of triggered sound and touch functions that could be allocated to an exchange was calculated. For each function was checked whether a of it in Household 1 could be mapped to a trigger in Household 2 within a time interval of five minutes were calculated. If it was the case, it was considered as part of an exchange. About 63% of all triggered touches and 21% of triggered sound events met this requirement.

5.3.2 Questionnaire data

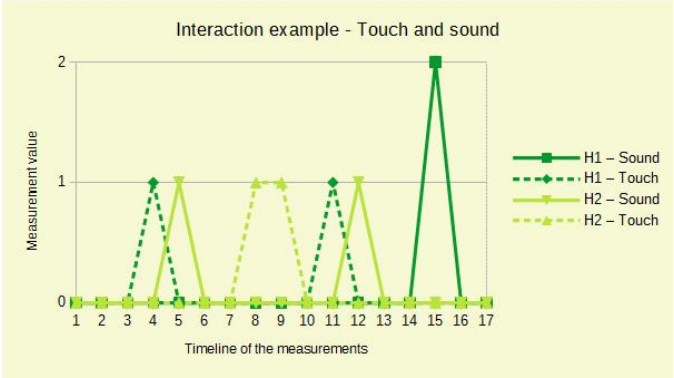
The results of the questionnaire "Demographics and living conditions" were already stated in the section 5.2.1. The analysis of the questionnaire "Experience with FamilyFlower device" are described in the following.

Usage of functions

In table 5.6 the reported results for the recognition and reaction to the displaying events of the artificial flower are shown. The change of petals and stem were recognized by both participants multiple times a day through the sound of the servo motors and the movement of the components. They respond to it with walking to the device and triggering a counteraction. The light and the fragrance events was recognized less frequently, only daily or a couple of times. The light event was recognized though an optical change, however was only notices when staying in front of the device or in a dark surrounding. They participants reacted to it, with tapping on or blowing into the microphone. The fragrance event was recognized by the sound of the engine and the smell of scent. Both participants indicated to have reacted with the touching of the leaf, one of them additionally blew into the microphone.



(a) Example 1



(b) Example 2

Figure 5.5: Interaction examples

Connectivity

With regard to the connection of the two participants, they reported to have felt a highly connected to each other. Furthermore, they reported about an positive change in their relationship. For the kind of changes, they listed: better knowledge of each others' routines, more contact and virtual meetings for coffee. Their subjective opinion was, that their mood has highly changed positively. As reasons they stated, the feeling of happiness when the flower was moving, the happiness about not being alone anymore and the motivation to see the other person getting up early. Moreover, the device was stimulated them to use further media as texting or phoning to establish further contact.

General information

Both participants placed the devices in common areas of the household which were at kitchen and a coffee table. They reported, that the device integrated well into their daily lives.
At a last point is the participants' opinions to the device. One of them liked

		Frequency of detection	Signals for detection	Counterreaction
Petals	H1	multiple times per day	sound and movement	walk to flower wave at flower
	H2	multiple times per day	sound and movement	wave at flower Touch leaf
Stem	H1	multiple times per day	sound and movement	walk to flower wave at flower touch leaf
	H2	multiple times per day	sound and movement	wave at flower blow in microsphone touch leaf
Light	H1	at least daily	change of color when sitting in front of device	tap on microphone blow in microphone
	H2	a couple of times	dark surrounding	tap on microphone blow in microphone
Fragrance	H1	at least daily	sound and smell	touch leaf
	H2	at least daily	sound and smell	touch leaf blow in microphone

H1 = Household 1
H2 = Household 2

Figure 5.6: Table of participants' function usage

the connection to a friend and sending of messages though waving to the plant and using the fragrance trigger. The other one liked the color of the petals, the variety of functions the device offers and the concept of mirroring the events in the connected household. Both participants criticized the unpleasant smell of the perfume. Furthermore, one of them wished for a more precise microphone.

5.4 Discussion

5.4.1 Sensor data

Frequency of usage

First of all, the frequency of function usages gives a rough insight about the suitability of the sensors. The fact that the usage of human presence is much higher than the movement although human presence is required for movement could be caused though a different measuring angle of the sensors (not possible to be influenced by programming). The fact that the sound level has changed only a few times per day could be due to an unsuitable sound sensor or code as higher values would be expected with the frequency of the other functions frequency. Probably sound is only detected in an very narrow surrounding.

The results of this part showed also that the devices were used everyday of the testing phase. Every usage of the device in Household 1 triggers a physical change of the flower in Household 2, vice versa. Therefore, it represents a form of communication. Since the device has been used for communication everyday and during the complete testing phase and course of the day, it can be suggested that the users were supported in building a connection over spatial distance by the device.
A further point is that for each function peaks are visible at which time in the course of the day they were used the most frequently. In the morning the amount of movement and human presence was higher. It can not undoubtedly be said if these actions were triggered consciously or unconsciously and by whom they were triggered (further persons and pets in household). However, the connected person still received a message. The touch which had to be triggered consciously was used more often at a later part of the day. This peaks indicate that a basis for developing shared routines was clearly given.
Furthermore, it can be suggested that the device integrated well in the everyday life. Without being appealing to the users, they would probably not have used it which definitely happened by the consciously triggering of touch.

Shared usage

The results for the time shared in front of the flower indicate that the participants were at each day of the evaluation active at the same time. During the course of the day peaks can be recognized. So the possibility was clearly given to establish shared action routines, since it can be assumed that a (virtual) encounter is necessary for this. Furthermore, it is a further point that the users were supported in connecting with each other with the device.

Interaction

For the following, the sound function is rated as interaction function as it was probably only triggered by the user if he operated it actively. The interaction examples presented above indicate that the participants developed a form of communication. They reacted mutually to the information received from the device in the connected household. For that, they used the same interaction method as touch or swapped to another one like the combination of touch and sound.
This shows that a form of connection is possible with the device as direct communication is part of it. Furthermore, the mutually triggering of the functions and developing of own ways of communicating with each other can be seen as a building of shared routines. This is only supported by the fact that a highly amount of all touch function were part of an exchange. Also the value for the touch function showed a tendency to be used for a mutual exchange.

5.4.2 Questionnaire data

Usage of functions

The fact that the participants reported to have recognized changes of the artificial flower on a daily basis on which they have reacted with a response indicates that they have developed a form of communication which supported them in building a connection with each other over the distance. The given variety of visible (movement of flower and change of LED), audible (sound of servo motors) and olfactory (fragrance) stimuli has encouraged them to trigger a response. The occurrence of these responses may also have helped the users to develop common routines.

Connectivity

The users reported that the device helped them to feel connected to each other which caused a change in their relationship that both participants recommended as highly positive. The connection level was also deepened while extending the communication for further media which was encouraged by the use of the FamilyFlower device.
A further point is, that the participants felt a happiness when receiving a message in form of a moving flower in which way their mood was lifted up. They connected the event with the presence of the familiar person which suggested them a feeling of closeness to each other.
Moreover, they confirmed to have established shared routines like drinking coffee in the morning. One of them also reported to have learned about the daily routines of the other person which which might have been an incentive to attend.

General information

The FamilyFlower devices were received as integrated well from the participants. Additionally, one of them especially liked the appearance of the artificial flower. Moreover, one participant was pleased by the established connection to the remote friend.

Chapter 6
Conclusion

This chapter contains a summary of the thesis. In the first section a concluding overview is presented. In the second section the limitations of the work are stated. In the last section an outlook on possible future work is given.

6.1 Overview

The goal of this thesis was to develop a system that connects people living apart. The prototype should be easy to integrate into a common household. In order to achieve the goal, two standard flower pots were equipped with the same hardware and software and connected via the internet. Each pot contains a living plant on one side and an artificial flower on the other side. Each device provides four functions which allow interaction with and observation of activity in the other household. For this purpose, detection of certain situations (such as noise) in one household can lead to a change in appearance of the artificial flower in the other household (such as a change in ambient lighting). It is also possible to directly interact, e. g. the touch of a leaf in one household triggering a scented spray in the other household.
In order to test the prototypes under real conditions, a small user evaluation was carried out in which the devices were placed in the households of the two participants for two weeks. The results showed that the use of the system had positive effects on the participants. They felt connected with the other person and their mood was positively influenced. Furthermore, they did not feel disturbed by the presence of the device in their homes. The evaluation of the collected technical data also showed that the devices were used daily. In addition, clear interaction sequences were shown in an exemplary manner. All of this provided a good basis for the joint development of routines across the spatial separation.

6.2 Limitations

First of all, some of parts of the prototype showed limitations. Two of the used sensors were not optimally suited. The sound sensor was not able to detect changes of the sound level in further distances. Therefore it had to be used intentionally, and it was not even possible to detect a human voice if not speaking directly into it. Furthermore, the recognition of touch was not as precise as desired. To overcome fluctuations in sensor activation the threshold for detecting deliberate activation had to be set to two to three seconds. A further restrictive part was the fragrance spray. The design of the dispense holder limited the selection of brands whose spray bottles fit inside, and among those no satisfactory scent for the participants was found.
The second limitation is the size of the user evaluation. The system was only tested by one pair of participants. This gives a first impression but cannot provide a meaningful picture for a wider environment. What also needs to be mentioned about the study is that the use of a procedure that would have recognized by whom a function would be triggered and whether the triggering happened intentionally or unintentionally had been helpful. This would have made it possible to detect any sensor errors that might have occurred and would have allowed an extended evaluation of the data.
The last limitation are privacy concerns. The devices collect sensitive data about the users which were stored. For wider use, this method of data exchange would have to be reconsidered.

6.3 Future Work

One possibility for future work could be to revise the available functions of the device. One point is adapting the hardware. The sensors could be changed, especially those which showed some limitations, like the sound and the touch sensor. Also another fragrance dispenser with a more appealing scent would be good. A further point could be to add additional functionality. An example could be to send little voice memos with the device or install a display to share notes. Moreover, a possibility would be to indicate the history of received events. This could be either shown on a display integrated into the device or be linked to a smartphone app.
Another part of development could be to redesign the device. An early idea during development was to build a flower with the functionality that could be attached to every common houseplant. To achieve that goal the flower and the technical parts had to be much smaller or placed in different order.
One last part for future work would be to build more FamilyFlower devices that could be interconnected with each other to connect more complex living conditions. For instance if three households should be connected, every household would require two devices.

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Appendix

Questionnaire - Demographics and living conditions

Questionnaire - Experience with FamilyFlower device

Study explanation

Declaration of user study consent

User guide

FamilyFlower - Demographic questionnaire

This is the second part of the user study.
Please fill in the information before starting the testing phase.

Demographics

1. **What is your name?** _____
2. **How old are you?** _____
3. **What gender are you?**
   - ☐ female
   - ☐ male
   - ☐ diverse

About your household

4. **How many people live in your household?**
   - ☐ only me
   - ☐ 2
   - ☐ 3-4
   - ☐ more than 4
5. **How many hours do you usually spend at home per day during the week?**
   - ☐ less than 8
   - ☐ 8-11
   - ☐ 12-15
   - ☐ 16-19
   - ☐ 20-23
   - ☐ 24
6. **How many hours do you usually spend at home per day at the weekend?**
   - ☐ less than 8
   - ☐ 8-11
   - ☐ 12-15
   - ☐ 16-19
   - ☐ 20-23
   - ☐ 24
7. **Do pets live in your household that could be near the flower??**
   - ☐ no
   - ☐ yes, namely: _____
8. **What is your relationship with the connected person?**
   - ☐ family member
   - ☐ friend
   - ☐ other: _____
9. **How often do you usually see the connected person in real?**
   - ☐ several times a day
   - ☐ once a day
   - ☐ a few times a week

- ☐ only a few times a month

10. How often do you usually have contact over distance (texting, phoning etc.) with the connected person?

- ☐ several times a day
- ☐ once a day
- ☐ a few times a week
- ☐ only a few times a month

Prior Experience

11. Which media do you use to communicate with friends and family?

- ☐ phone call
- ☐ video call
- ☐ texting
- ☐ something different: _____

12. Have you ever used a device before which is specialized on connecting remote living people?

- ☐ no
- ☐ yes, namely: _____

FamilyFlower - Study questionnaire

This questionnaire will assess you impressions of the technology you have tested out during the user study.

Flower Leaves

In this section, please only consider the movement of the leaves on the flower.

1. **How often did you notice the flower leaves moving?**

☐ Never ☐ Once or twice ☐ A couple of times ☐ At least daily ☐ Multiple times per day

2. **If so, please describe when you became conscious of the movement.**

3. **Upon noticing the movement, did you undertake any special actions? If so, please describe which ones.**

Flower Stem

In this section, please only consider the movement of the stem of the flower.

4. **How often did you notice the stem of the flower move?**

☐ Never ☐ Once or twice ☐ A couple of times ☐ At least daily ☐ Multiple times per day

5. **If so, please describe when you became conscious of the movement.**

6. **Upon noticing the movement, did you undertake any special actions? If so, please describe which ones.**

Flower Light

In this section, please only consider the light inside the flower.

7. How often did you notice the light inside the flower change in color or intensity?

☐ Never ☐ Once or twice ☐ A couple of times ☐ At least daily ☐ Multiple times per day

8. If so, please describe when you became conscious of the behavior.

9. Upon noticing the behaviour, did you undertake any special actions? If so, please describe which ones.

Flower Fragrance

In this section, please only consider potential fragrance or smell coming from the flower.

10. How often did you notice a special fragrance to come from the flower?

☐ Never ☐ Once or twice ☐ A couple of times ☐ At least daily ☐ Multiple times per day

11. If so, please describe when you became conscious of the behavior.

12. Upon noticing the behaviour, did you undertake any special actions? If so, please describe which ones.

Connectedness

13. How connected would you say you felt to the other person during the study?

☐ Not at all ☐ Slightly connected ☐ Somewhat connected ☐ Moderately connected ☐ Highly connected

14. How aware were you of the connected person and their actions during the study?

☐ Not at all aware ☐ Slightly aware ☐ Somewhat aware ☐ Moderately aware ☐ Extremely aware

15. Do you feel the technology has influenced or changed your relationship with the connected person?

☐ Highly negative change ☐ Negative change ☐ No change ☐ Positive change ☐ Highly positive change

16. If so, please state how your relationship has changed?

17. Do you feel the technology has influenced or changed your mood during the study?

☐ Highly negative change ☐ Negative change ☐ No change ☐ Positive change ☐ Highly positive change

18. If so, please state how your mood has changed?

19. Has the flower encouraged you to use other means to get in contact with the connected person?

☐ Never ☐ Once or twice ☐ A couple of times ☐ At least daily ☐ Multiple times per day

20. If so, how did you get into contact with the connected person?

21. Please describe which behaviors of the technology have led you to take these actions?

General information

22. Where have you placed the flower during the testing period?

23. How many hours of the day did you use the flower?

24. What did you like about the flower?

25. What would you improve?

26. Do you feel that the setup integrated into your everyday life?

- ☐ Yes
- ☐ No, because: _____

Other remarks

Please state here any other remarks regarding the study or the technology you might have.

FamilyFlower – Study explanation

Welcome to the user study of my bachelor thesis "FamilyFlower – an artificial flower to foster distant connections". First, I want to thank you very much for participating :-)
In the following I will explain to you the course of the study. I will hand you out the necessary materials to the appropriate time.

1. Declaration of user study consent (2 min)

The first part of the study is to read the declaration of the user study carefully and sign it, if you accept all the terms.

2. Demographic questionnaire (5 min)

The next step is to fill in a short demographic questionnaire.

3. Read the user guide (5 min)

In this part you should read the user guide to get to know the functions and signals of FamilyFlower. If questions should arise here, I am available.

4. Testing phase (two weeks)

Then the flower will be put into operation. You will have two weeks to test the FamilyFlower. If there are unforeseen problems or malfunctions, you can contact me at any time.

5. Final questionnaire (10 min)

The last part of the study is to fill in a questionnaire about the experiences you have collected with FamilyFlower.

Declaration of User Study Consent

I hereby declare that I have been informed about the objectives of the investigation in which I am participating as a subject. I agree that the data collected and prepared about me in the following two weeks will be used for scientific purposes by employees and students of the Department of Computer Science at Saarland University and the German Research Center for Artificial Intelligence. This data will only be used for scientific purposes, e. g. for publications.

I am aware that participation in this study is voluntary and I can end the study at any given moment.

I am aware that during the study, the following sensor data are collected: human presence, movement, touch and sound level. This data will be properly anonymized.

This declaration is archived separately from the study data.

First name …….

Last name …….

Saarbrücken, …….

Signature ……

Family Flower – User guide

Requirements

In order to communicate with the connected flower a working Wifi connection is needed. The connection will be only used for exchanging data and no other purposes.
To supply the flower with electricity, a ususal socket is needed.

Activation

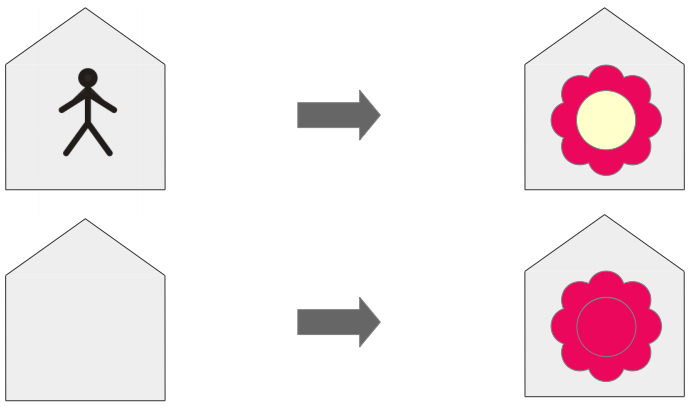
Please place the flower in a location where you spend a lot of time. The side with the sensors must be facing forward. To use the flower insert the plug in a socket.
If you feel the need to more privacy you can unplug the flower, but please make sure to plug it in again after.
If errors should occur, please unplug the flower and plug it in after a few seconds to reboot the device.
Futhermore the living plant should be watered every two days. Please make sure that no water runs into the side with the electronics.

Functions

FamilyFlower offers four different functions to display the current actions in your home to a connected household. At the same time, it acts as a display to show the other household`s events.

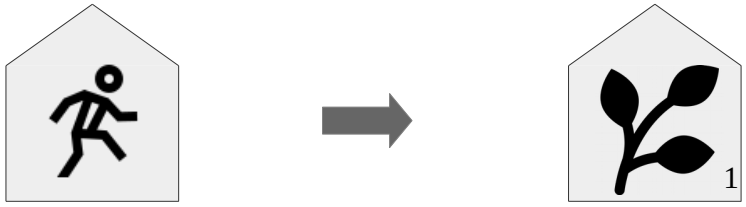
1. Recognition and display of physical presence – blossom

The flower recognizes the presence of people in front of the flower. This function is connected to the blossom. As soon the sensor of your flower recognizes a person, the connected flower will open to bloom. The other way round, if your flower is opened, someone in the distant home is staying near his flower.



2. Recognition and display of movement – stem

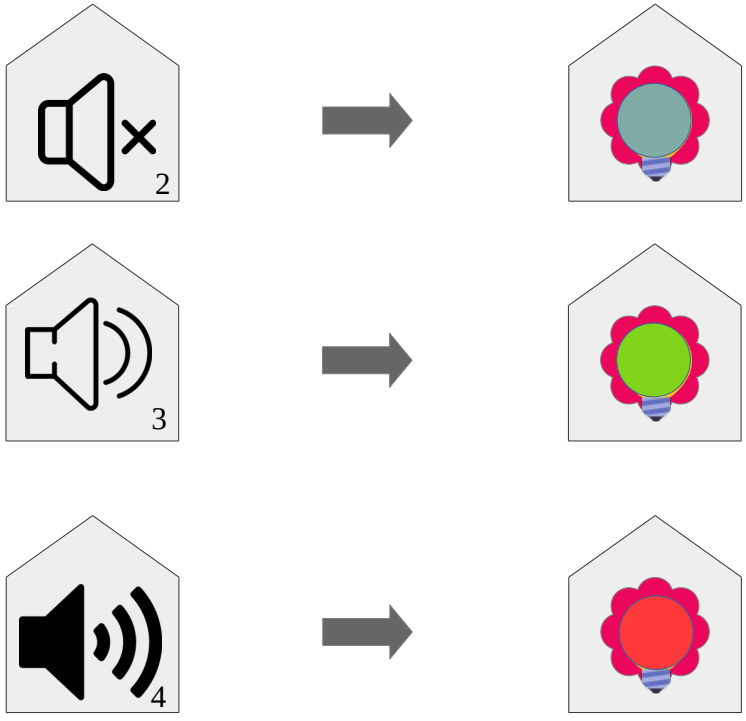
The flower recognizes movements in front of the flower. This function is connected to the stem. As soon there are movements in front of your flower, the connected flower will start to wiggle. The other way round, if your flower wiggles, there are movements in the connected home around the flower.



3. Recognition and display of sound level – LED

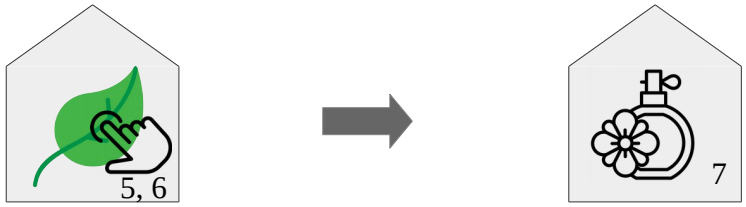
The flower recognizes different sound levels in its closer surrounding. This function is connected to the LED in the blossom. A blue light indicates silence, a green light a medium volume and the red light loud noise. The other way round the LED of your flower indicates the sound level in the connected home.

Hint: To influence the sound level you can speak and blow into the microphone or tap with your finger on it.



4. Distribution of fragrance

If you touch the bottom of the leaf for 3-5 sec the flower in the connected home sprays fragrance. In the other way if your flower sprays fragrance, someone in the connected home touched the leaf of its flower.



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