BBeacon, Connecting Bees to the Internet of Things

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Abstract
In this pictorial we summarized and reflected on the process of developing the idea of a product & service system called BBeacon. BBeacon aims at ceasing the decline of bees and raising people's awareness of how crucial bees are to the human being the environment, by means of bringing three groups of stakeholders together (beekeepers, customers and municipalities). Experts including beekeepers and entrepreneurs in the agriculture domain were involved during the process of research, ideation and prototyping. Two physical prototypes and two online platform models were designed to set up a core structure for future research and iterations.

Authors Keywords
Bees; Internet of Things; Bioinformatics; Prototyping.

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Introduction

Bees are amazing creatures; they cooperate and communicate with each other in an efficient network to produce food for raising their larvae and to organise their own communities. All these activities have great value for the environment and also bring enormous benefits for us human beings. Recently, bees are disappearing from earth in a rapid rate, which is known as the Colony Collapse Disorder. Clear reasons have not been found yet, but human activities like pesticide abuse are found to be the possible culprits (Neumann, Peter; Carreck, Norman L. 2010). The decrease of bees is absolutely a bad sign for living beings because bees pollinate most of the crops that are being eaten as food to survive. As Albert Einstein once quoted: "If the bee disappears from the surface of the earth, man would have no more than four years to live".

BBeacon envisions an "internet of bees" product & service system combining Internet of Things (IoT) technologies and beekeeping in the urban city areas. Involving three groups of stakeholders (i.e. professional beekeepers, government officials and common citizens) and offering different value propositions to them. The idea is to create communities where a better environment for the bees can be established by the efforts of all the members, as to maintain a more eco-friendly and healthier urban environment.

A sensor kit that can be integrated in the hive has been develped for the professional beekeepers. This kit, which is an addition to the hive, is able to measure weight, humidity and temperature inside the hives. Combined with an online application, beekeepers are offered a smarter way of tracking the data and parameters that are crucial for beekeeping. Bees from one hive cover a range of three kilometers around their home.

Together with the artificial flowers containing the integrated sensors and "bee attractor" (i.e. sugar water) spread over the city in citizens' gardens, bees will be attracted to pollinate the garden. The amount of bees will be counted and sent to local IoT servers to have a representation of the eco-friendliness of a specific area. People with the artificial flowers in their gardens can view the data of their gardens and different cities through a phone app. Profiles of the beekeepers are shown as well, to create connections between citizens and beekeepers. Finally, government officials also will have an insight in these "bee hotspots" of their cities. They can use this to make comparisons among different regions and cities and use this references in making plans to develop the urban city environment.

With BBeacon, the aim is to raise the people's awareness of the functions and importances of bees and offer new possibilities of having bees in the urban city areas.

Objective

Bees are, next to a large group of other insects, extremely important for the growth and development of life. By pollinating crops and flowers, these plants can grow fruit, vegetables and seeds. If there are no bees, there is no pollination, there will be no crops and thus people will have a problem in getting enough food. Bees colonies are dying out rapidly, in the US, even up to 44% from April 2015 till April 2016 (The Bee Informed Team, 2016). Because the exact cause of this is not known yet, this project tries to get a clear overview of the health of bee colonies and the environment around them.

By observing how well a colony in a hive is doing, detecting changes and intervening in time, the loss of bees might be prevented. According to Wietse van Dijk, beekeeper at St. Ambrosius Eindhoven, beehives can increase around 400 gram a day and each honeycomb frame can weigh 2.5 kg. When measuring this, growth can be detected and actions can be taken when it is less than the average weight of a season.

Humidity and temperature are also important. When a queen is within a colony, the average temperature should be around 36 degrees Celsius. If she is not, the temperature can become much lower, around 26 degrees Celsius. If a colony doesn't have a queen, their chances of survival will decrease drastically. Besides, a low temperature or high humidity means that bees won't fly out often, which causes they can gather less food.

The sensor attached to the flower can detect how many bees are active in specific areas, like gardens. By counting these and compare them to an average combined with the statistics of a certain day, it is possible to create an overview of the activities of the bees. When there are not enough bees in a specific garden, it will be likely to change the range of the plants and flowers to attract more biodiversity. Furthermore, the product will make people aware about the importance of pollinating insects. This can cause the users will take care of the health of their own garden.

The data from the hive combined with the data of the flower sensors, gives an idea about how bees behave in a certain environment or area. By comparing these data with numbers from hives in other areas, conclusions improvements can be proposed. This information can be shared with municipalities who have the possibility to undertake actions to change or improve the local environments.

Research

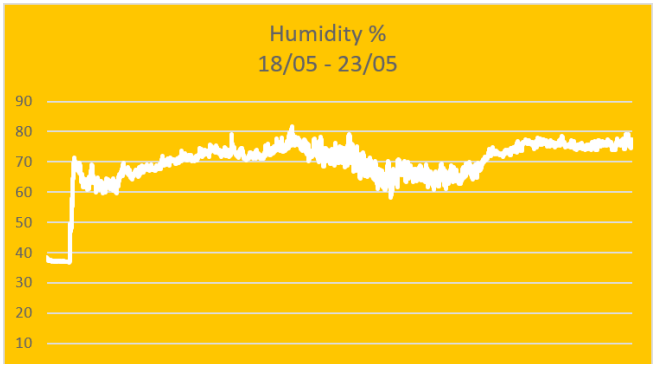
Beekeepers

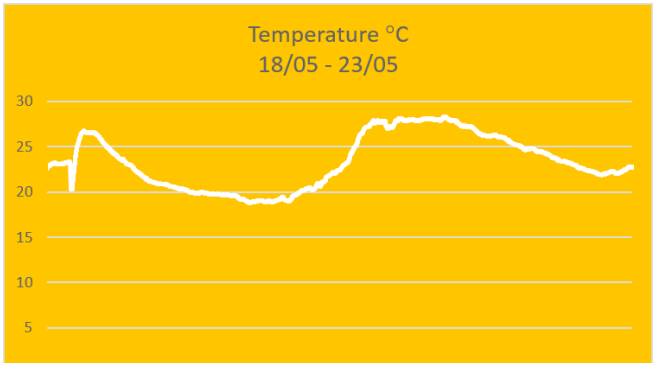
The important target group of the BBeacon project is, of course, beekeepers. The intention was to allow them to get more information about their hives and colonies. Beekeepers were consulted to get better insights in what information can be meaningful. The first ones that have been consulted were Ruud Korteling, of "de Walhut" and Yuri Kasyanyuk and Wietse van Dijk of beekeeper association "St. Ambrosius". Questionnaires have been send out to a number of beekeepers around the Netherlands as well, the results of which can be found later in this chapter.

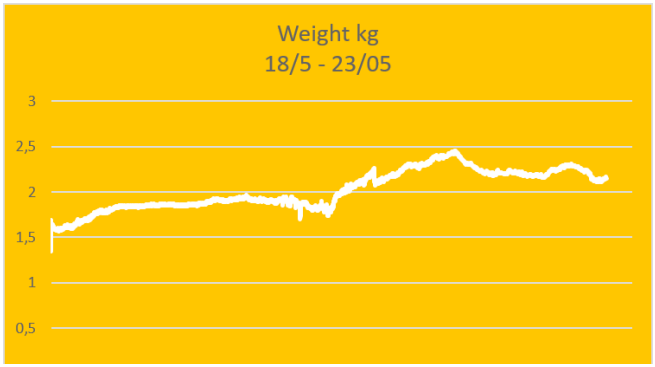
De Walhut

De Walhut is an apiary in a forest near Nuenen and is run by Ruud Korteling. It is a paradise for every insect, plant and animal around and includes accommodation for birds, bugs, toads, mushrooms, trees and of course: bees, both solitary and in colonies. The goal of visiting this place was to find out what troubles beekeepers currently experience and how bee life in a city is different from bee life in rural environments.

There are a number of things that have been done to benefit the bees near Nuenen. There are flowers and trees around that provide a lot of food to the bees, hives are covered with a roof, and even places for solitary bees to live and breed. Though, about a hundred meters away, there is nothing but grass and crops with little food to provide to the bees. According to Ruud, this is basically a desert to his bees, while a city might have a very diverse range of food, from trees placed in parks to flowers in gardens and on balconies. Bees are very capable of survival in the city, even when habitats are fragmented (Cane, J. H. 2006).







St. Ambrosius
As opposed to De Walhut, St. Ambrosius is a group of experienced and inexperienced beekeepers, all beekeepers have their own hives and take care of them using advice from other beekeepers. They also give classes in beekeeping and try to spread the word as much as possible to inspire other to also start keeping bees or at least considering them.

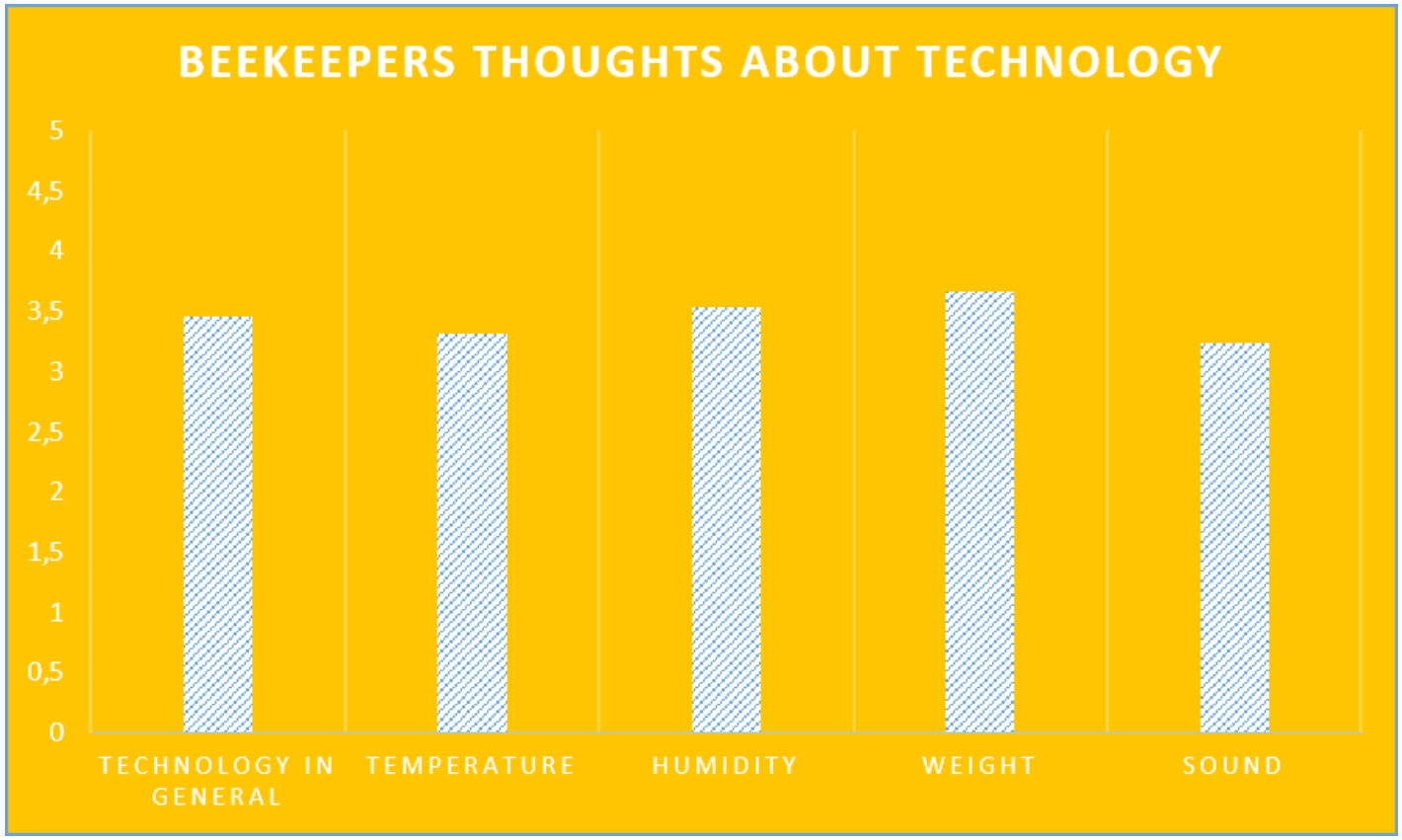
The apiary is located right next to a garden center and filled with nectar-rich plants and trees. A great place for bees to live, but no exception to the problems that bees face today, like the unexplained Colony Collapse Disorder (Evans, J. D. 2009) and the Varroa mite epidemic (Wilfert, L. 2016). It is therefore essential for the beekeepers to find new ways to protect their colonies. The community at St. Ambrosius is very open to try new technologies, like testing the BBeacon in two of their hives. The first iteration of the sensor was put into a single level hive with a new colony that did not yet choose a queen. The second iteration of the sensor was placed into a shallow two level hive with a newly caught swarm of bees. The first iteration proved to be the most reliable, graphs of a week's worth of data can be found to the left.
At the time of writing there is too little data from the BBeacon Hive to draw conclusions from, but development of the relatively colony is perceivable without the need for a completely new, proprietary, "smart hive".

It is important for the bees to have an amount of honey at the end of summer that is big enough to last them through the winter. Right now beekeepers basically have to lift the hive and estimate if there is enough honey inside. This could be solved by weighing the hive which is much more accurate. By weighing at specific times during summer, when honey production is the highest , it can

be indicated what plants and flowers benefit them the most in the environment, as a lot of plants bloom at a different times.

Humidity and temperature can also tell a lot about the bee population. Bees prefer to keep these variables pretty constant (Oertel, E. 1949). During brood for example, the temperature around the queen should be around 36 °C. This temperature can drop lower during winter, and can show when the colony becomes active again in the summer, possibly indicating when food is starting to run out.

Questionnaire
The beekeepers that had been payed a visit, shared ideas of values to measure and how to display this to beekeepers in a relevant way. To collect more data a questionnaire has been created that was sent to beekeeper associations related to St. Ambrosius (the complete questionnaire can be found the the appendix). Questions that are asked are about what values they'd like to see measured and how much the proposed BBeacon Hive and BBeacon Flower would be worth to them. Results were collected on the 5th of June 2016. Their interest in the different proposed data sources can be found to the right.



Competitor Analysis
To find out where this product is placed best in the market, a competitor analysis has been done. It is important to know what kind of products and services are already existing, how well they are working and how much people are being interested.

There are a lot of similar projects and products found on the internet, but almost none of them appear to be very active. Some are just hobby projects that have been performed once or twice, others look like professional companies but don't seem to be on the market just yet.

Bee Smart Technologies
A good example for this is Beesmart Technologies (Beesmart Technologies, 2012). This startup company offers a comple smart hive system that basically measures the same things. They aim to offer 3 products which are similar to our 3 products. First of all, they offer a smart beehive which contain the sensors. Together with this hive comes a platform where you can see all the activities of your own hives, but now other people's hives. The last product is a bee counter that you can place in from of your own hive. The company seems to specify its targeted group towards commercial beekeepers or hobbyist with multiple hives.

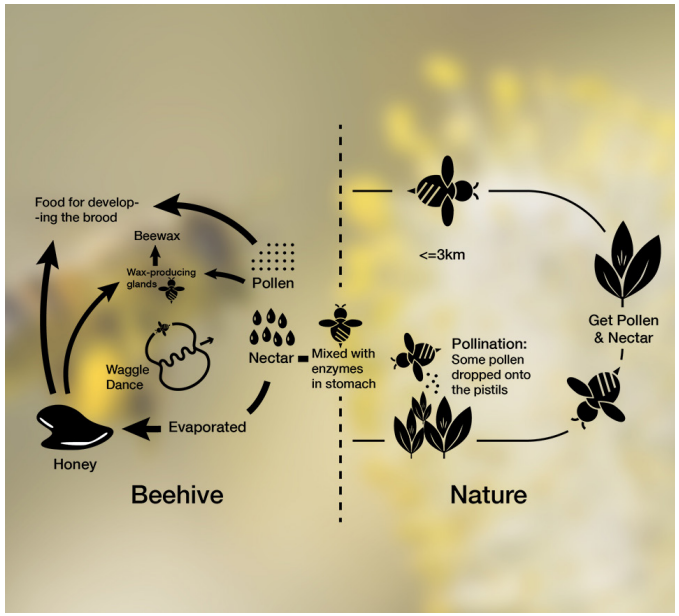
Flow Hive
Almost all of the competitors products focus either on an open source project for electronic fanatics that want to help the bee problem or on beekeepers with multiple hives. Our projects takes the best of both worlds, combining the open data for tech freaks and an understandable product for beekeepers. Our product has the potential to gain a lot of data, using the bee counter, that can be analysed by researchers or by an open call . It seems like this is the unique product for the normal consument, that can enable to get insights in the bee decrease problem. The flow hive shows that there is a interested from non beekeepers in order to solve the problem. by using the power of communities.

Flower

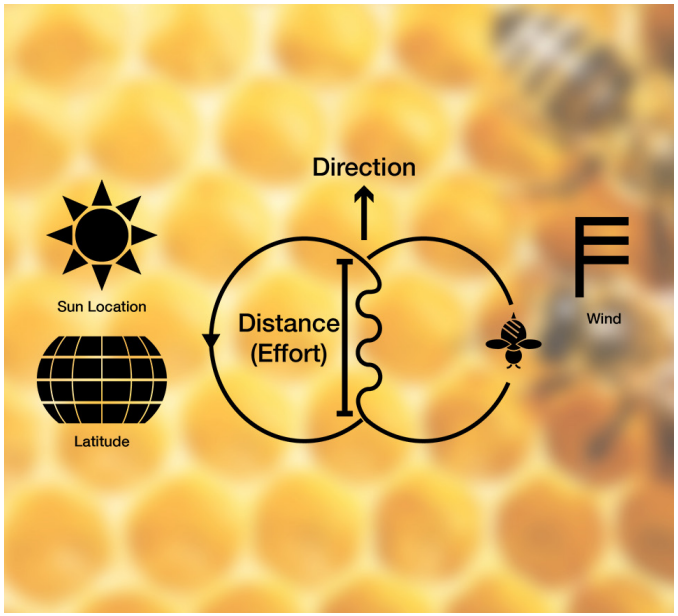
To make the BBeacon Flower sensor as attractive as possible, research has been done in finding out what makes plants and flowers attractive to bees. For flowers, there are some important criteria that define the perfect one (Kathy LaLiberte, 2014). For example colour; petals in white, yellow, blue or purple attract much more bees than orange, pink or red petals. Especially red petals, because bees are not able to see red (L. Schoonhoven, Niet Zonder Elkaar, 2014), but this all depends on how well petals reflect UV-light. Also, the amount of petals does matter, while a flower with a single row of petals will attract more bees than multiple rows of petals; bees cannot enter them so easily.

Good examples for this are the blossoms of all the known fruit trees, like apple, cherry, plum and pear. They all have one single row of petals in a light white-pinkish colour and a bright yellow core with pollen that is easy to reach.

Bees also stay on one specific tree or area to harvest pollen. The trees benefit very well of this, because a apple tree cannot be pollinated with pollen from a pear tree. When the bees find this spot with food, they will remember this and when they enter the hive again, they will perform the so called beedance.



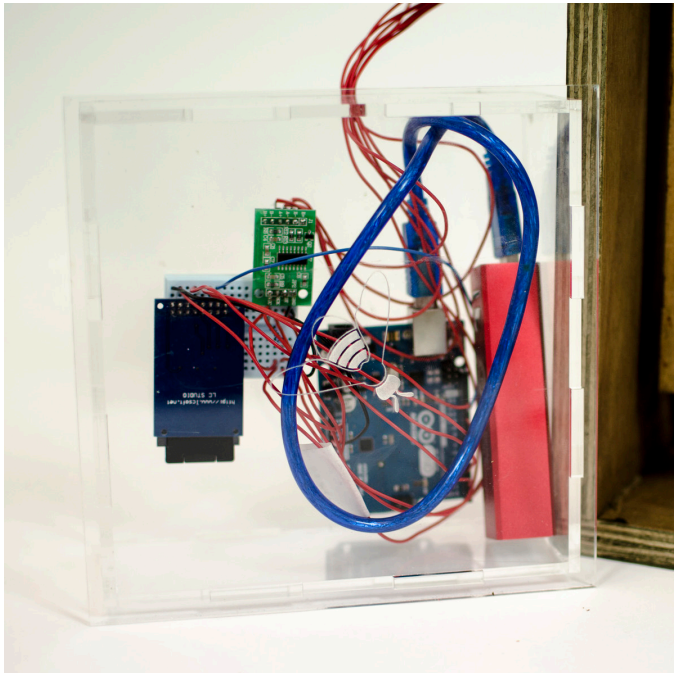
Behavior of Bees (Beehavior)
A healthy beehive consists of three kinds of bees: the queen, the drones and the workers. Each of them takes different tasks. The drones' primary role is to mate with the queen whose main job is to lay the eggs. The worker bees are most familiar to us and they undertake the heaviest load of jobs in a bee colony. They would fly around the hive within a circle of 3km's radius to collect pollens and nectar, during which they would accidently drop some pollens onto the pistils of other flowers of the same kind and complete the process of pollination. Inside the hive, they use the pollens as food to feed the broods. The nectar is mixed with the enzymes in their stomaches and then evaporated into honey in the wax which is also exuded by them to build up the honeycomb structure.



Bee Dance
There exists a common "language" among the bees allowing them to extract information about the food source, which is known as the bee dance (K. Rohrseitz, J.Tautz. 1999). Through this dance with certain behavior pattern, a lot of information is coded in it. The bees' ability to see the ultra-violet and polarized light allows them to spot the location of the sun, they can even sense the passing of time and the changing of seasons (or latitude) in order to always have a constant navigating reference. In the bee dance, the angle between the axis of the dance pattern and the sun location offers them the direction of the food source. The length of the axis represents the distance between the hive and destination. They can even take the wind into account to indicate the efforts it takes to get to the food source.

Design

For this project, two different products have been developed, both with their own sensors and intentions. The first one is BBeacon Hive, which are several sensors combined and placed into a beehive. The second one is BBeacon Flower, a device that is intended to place in people's gardens and is able to count bees.



BBeacon Hive
First iteration

The BBeacon Hive is a collections of sensors to be modularly implemented into a simplex hive conforming to the dutch standard NEN 1061:1975 nl.

The decision has been made to weight the hive by weighing the frames in it. This was achieved by embedding the humidity and weight sensors in a single frame that extended throughout the hive, with the other windows resting on it.

A portion of the windows the sensors were put into was reserved to accommodate the sensors, and protect them from being closed up with propolis by the bees. The rest of the window is to be filled up with wax, to encourage bees combs being built, but due to time constraints this was postponed in favour of running the test.

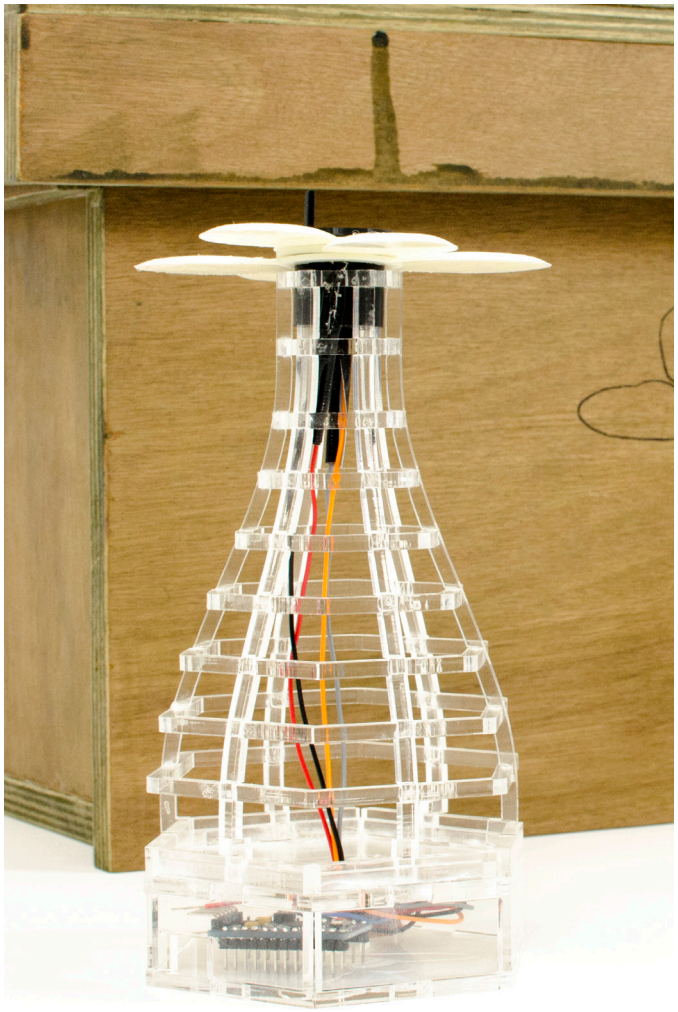
A box was made out of acrylic and waterproofed to hold the external electronics necessary to operate the sensors and save measurements.

Second iteration
In the second iteration, the sensor needed to a little bit less unwieldy by removing the window and integrating the sensors in a set of risers to be put at the sides of the hive, as can be seen in the pictures. Hardware remained the same technically, but size was minimized, so the sensors could be stored under the roof of the hive instead of on top of it.

In this iteration removing the sensors for maintenance, doesn't require removing a comb that might contain valuable honey or egg cells.
However, this configuration proved to provide less reliable results. Because the temperature and humidity sensors were dangling loose there was a much higher chance of cables going loose, and because the load cells need to rest on a single point, the slats the other combs rested on were unstable.

BBeacon Flower
BBeacon Flower is a device meant for consumers, especially people who have a garden. It is designed to look like a flower and intended to put in a garden, among other flowers. It consists of four parts that fit together.

First iteration
The first pair of flowers, the pot was produced out of laser cut MDF and later on acrylic plate. It was a really quick and easy way to produce the pot and to find the best shape to use in the final prototype. The reservoir is 3D printed from black ABS and it is really easy to replace it. The petals are 3D printed as well, but from white rubber PLA. By printing them in rubber, they represent the flexibility of real petals better. The acrylic flower has been used to test in a garden with honey to attract the bees.



Second iteration
The second flower sensor is a further development of the first one, where better attention has been payed to the design. On top, inside the flower, a infrared LED and sensor is placed. There is a reservoir which can be filled with a substance to lure bees inside, for example honey or sugar water. Next to this, the petals have a specific colour to make them more attractive. The colours blue, white, yellow and purple are highly attractive to bees while red, orange and pink are less. Besides the colour, the petals are also have a UV-coating. Real petals also reflect or absorb UV-light, and that is how bees define flowers to fly to. By giving the pedals of BBeacon also a UV-coating, it will be easier to approach. The flower is connected to the pot.

The pot or vase is a 3D-printed object, on top of the housing for the electronics. The wires of the infrared LED and sensor are guided through this form into the electronics housing. The end of the form is angled at 45 degrees, to make it as easy as possible for bees to approach.

The third part is the housing for the electronics, where everything comes together. It is shaped hexagonal, just like the honeycomb frames. In here there is an Arduino Pro Mini and a Micro-SD card reader.

The last part of the product is a wooden block, also

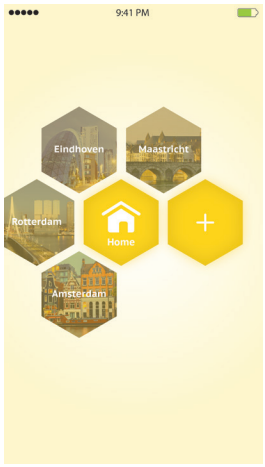
shaped hexagonal. In this block several holes are drilled, varying in size from 2mm to 12mm. Next to honeybees, there are also the so called solitary bees. They don't live in colonies and therefore also don't collect nectar to make honey. Instead, they lay eggs in these holes, wherever they will find them, and stuff them with pollen and nectar. They are extremely important for pollination and therefore it is also important to have them around in gardens.

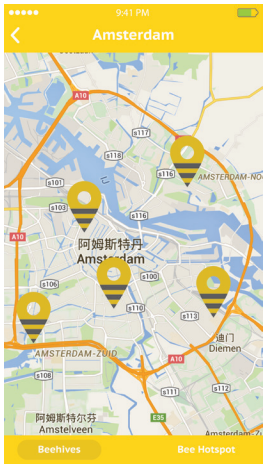
Web Application
The web application is designed for the professional beekeepers to keep track of the data that our sensors are gathering from the beehives.

The interface is designed in a way that beekeepers can easily view the data from three parameters (weight, temperature and humidity) in different time dimensions (day, month and year) and conveniently sync the data from different parameters to the same date (or time slot) to compare them.

The data is displayed in line charts, which gives a clear overview of the variations of the parameters during a period of time. In addition to the general tendency shown by the line charts, beekeepers can choose to display detailed information (i.e. average, increasement, highest and lowest points) on the charts.

For each parameter, beekeepers could add a line chart from another date to the current one to compare how the situation of one parameter could vary in different time slots.





Phone App

An app for mobile platforms was designed to let the customers who have the artificial flower sensors in garden view how many bees have entered their garden in a day/month/year. Users can also check how well is their garden doing comparing to the others. For example, the app would show within what range of area your garden has attracted most bees in a certain period of time.

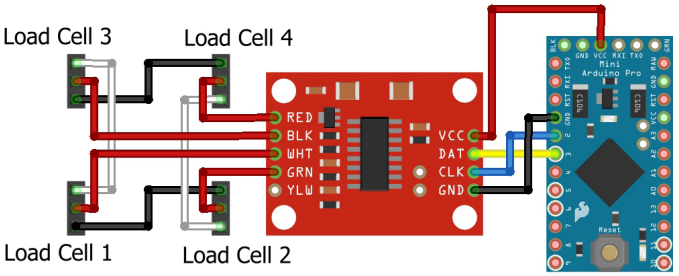
Besides the personal data, people can also look at the situations of other cities. In "Bee Hotspot", a city map would be shown and the size of the circles represent the amount of bees that are active in one certain area. Thus it's clear to see which region is doing best regarding to eco-friendliness within the area. The exact numbers would appear if users tap on the circles. By zooming in or out the map, more detailed or more general situations could be viewed by the users.

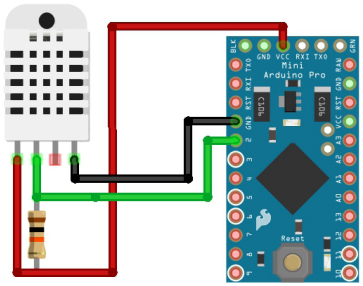
In "Beehives", locations of all the beekeepers in that region are shown on the map. Users could tap on the pins to view more detailed information of the beekeepers like their websites and pictures of their farms, through which we want to build a connection between citizens who are keen on bees and professional beekeepers. This will also encourage more beekeepers to use the system because it helps them to get more recognition of what they are doing and offers a powerful new channel to advertise their products.

Technology

BBeacon Hive

At the ground level the BBeacon Hive sensor consist out of five parts, Load cells, Temperature/Humidity sensor, a processor , data storage and a power source. This chapter discusses the choices made for BBeacon hive and plans that can help the sensor to better suit the needs of target groups.





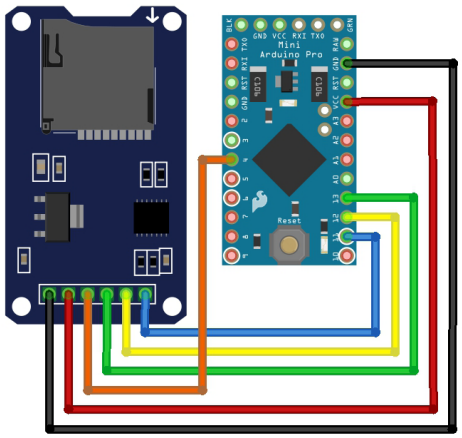
Load cells

The load cells for the BBeacon Hive have to be low profile, in order to not disturb the limited space inside of the hive too much. The first two iterations of BBeacon Hive used four 3-wire load cell extracted from a bathroom scale. These proved to be accurate to about 30 grams and can measure up to 180kg. Each window of a simplex beehive can weight up to 2.5kg according to beekeepers using them, each box in a hive holds up to 10 windows, and usually three of these boxes are stacked, bringing it to a total to about 75kg of just honey, leaving enough tolerance for the walls of the hive itself and accessories like extra food.

The four load cells are put into a wheatstone bridge configuration. Because of the fact that the load cells only cause a miniscule change in resistance the signal needs to be amplified by a high precision amp. We used a HX711 breakout. To connect to the processor

Temperature/Humidity sensor

These sensors can be considered together, as they will be in the same position and sometimes are combined in a single package. It does need to be accurate as changes of a few degrees can indicate important information, like the population moving further back through the hive in winter indicating the amount of food left. We used the DHT22 sensor. It works within the confines needed, is accurate to 0.5°C, affordable and easy to use with our microprocessor of choice.



Processor
BBeacon Hive needs a processor to process signals from the sensors into workable data and store or send it. We used an Arduino, at first an Arduino Uno R3 and eventually an Arduino pro mini to save space. In future prototype an arduino pro mini is most likely still the most convenient to use, but if BBeacon Hive reaches a product stage, an integrated processor will have to be chosen. The code we used to program the processor can be found in the appendix

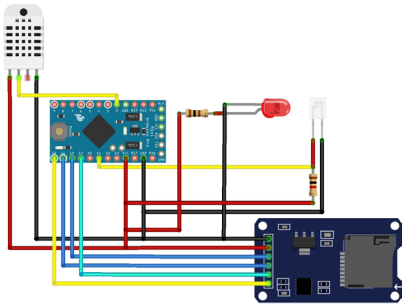
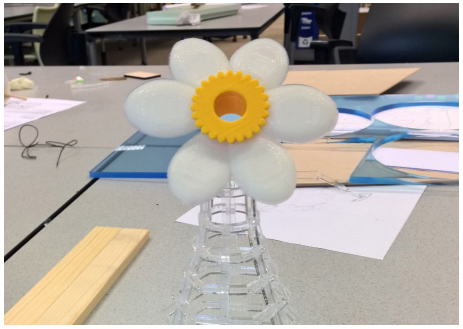
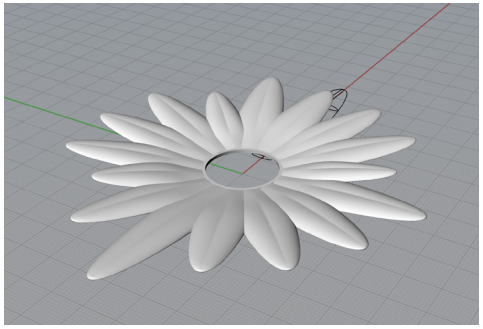
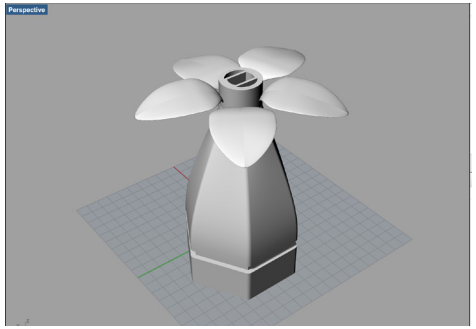
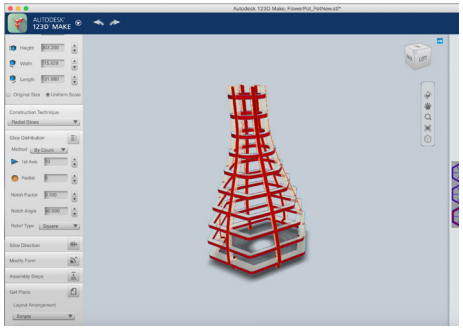
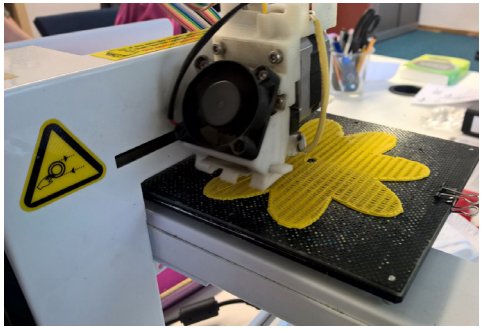
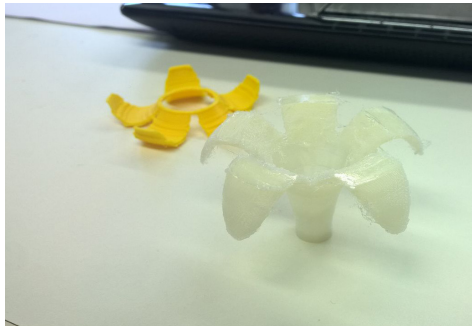
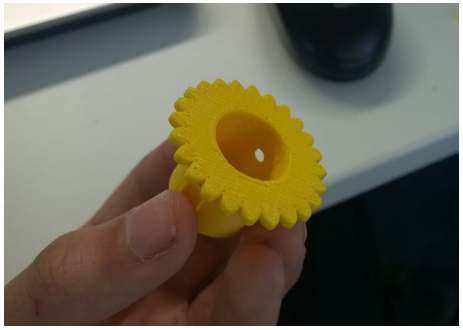
Data Storage
To effectively connect a network of beehives we plan to use the IoT. Eindhoven has the LoRa network (https://www.lora-alliance.org/) which we think has great potential to connect BBeacon to the internet. However at the moment of testing coverage just wasn't wide enough. The apiary we were testing at: St. Ambrosius did not have the lora network or a nearby WiFi network, this lead us to decide to store data locally for the test. We used a simple SD card breakout connected to the processor to store data and periodically read and empty the card.
In future versions we would like to use a chip such as the RN2483 to connect to a nearby LoRa gateway easily.

Power Supply
To test the BBeacon Hive, we decided to keep it simple and use NiMH batteries commonly used to charge phones. Because of the low power consumption of the system these batteries could last over 3 days, the batteries were changed out when the data was read.

For future versions of BBeacon Hive, a solar panel on top of the apiary or the beehive combined with a battery to save emergency power could power the system. The system only need power to send a small packet of data every hour.

BBeacon Flower
For the prototype of the BBeacon Flower, we used a pair of transmitting infrared LED and infrared photo sensor on top of the flower to sense if bees are attracted into the flower. At the bottom, the DHT22 temperature&humidity sensor is applied and an arduino pro mini microcontroller board is used to process the programme. Since there is no LoRaWAN network coverage in our experiment spot, we decided to save the data locally to a micro-SD card. We used a powerbank to supply electricity to the circuit.

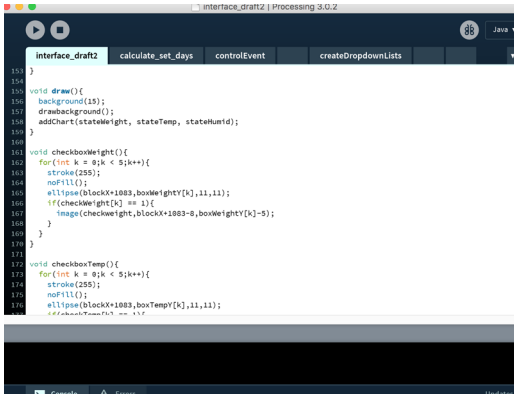
The first prototype was modeled in Rhinoceros. The petals and the container for IR emitter&sensor were made out from 3D printing and the body was imported to 123D Make (Autodesk) to be converted to pieces for lasercutting. The second prototype was made all out of 3D printing.

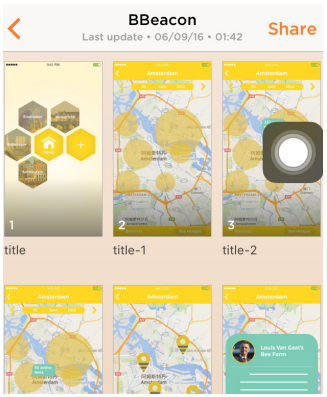










BBeacon Platform

The main function of the web application is that the beekeepers could easily check the data of a requested period of time and freely compare the data from different parameters (weight, temperature and humidity) in the same time dimension. Processing was selected to prototype it because it's powerful when it comes to the realization of relatively complicated interactivity. A GUI library ControlP5 was used.

For the prototyping of the mobile app for customers, the visual and function display are the priorities instead of interactivity, so we chose to use a handy mockup app on IOS platform - POP to demonstrate the functions of the app.





Current Issues & Future Goals

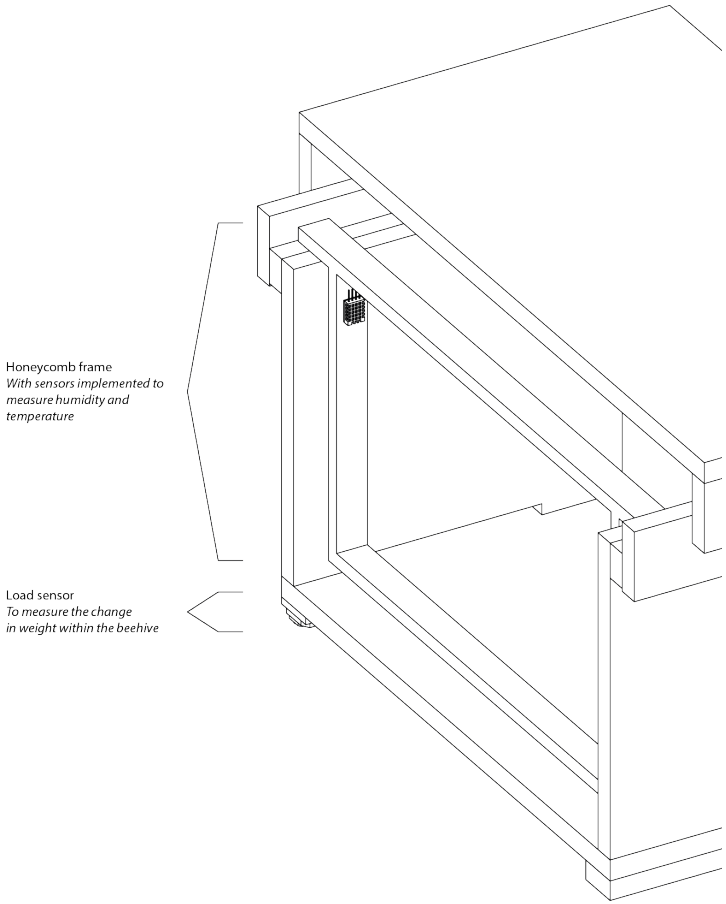
BBeacon Hive

3rd iteration

In cooperation with the beekeeper we decided that the best way to measure weight is to take the load cells outside of the hive, so they interfere less with the bee combs and are less likely to get clogged up with propolis or wax. Only a couple of wires have to enter the hive this way either under the lid or optionally through a tiny hole that won't interfere with the bee's entrance or exiting of the hive.
The diagram to the right shows how the newest iteration of the sensor will look. This sensor will run during the summer in order to collect data for analysis
Two load cells will be under one side of a beehive, the other side of an unmodified beehive will have to be raised to prevent the hive from being too unbalanced. A small box for the rest of the electronics will have to be included too, but can be attached to the underside of the beehive, close to the load cells. The actual components needed to run the sensors are very small and can be optimized to take a fraction of the space they're using in the second iteration.

Production

Moving even further into the future the system would of course benefit from a custom made PCB in which individual components can be used, to drive down price and size compared to the breakouts used now. A connection to internet also has to be included, our preferred solution is connecting it to a things network such as the LoRa network, alternatively an ESP module could be used to connect to a nearby WiFi network or ultimately a GPRS chip in combination with a SIM card could be used to send the data over a cellular connection. An added solar panel can make the system completely stand alone, but still has to be tested in depth to find out how much power is needed to drive the system and survive the dark night after every day.

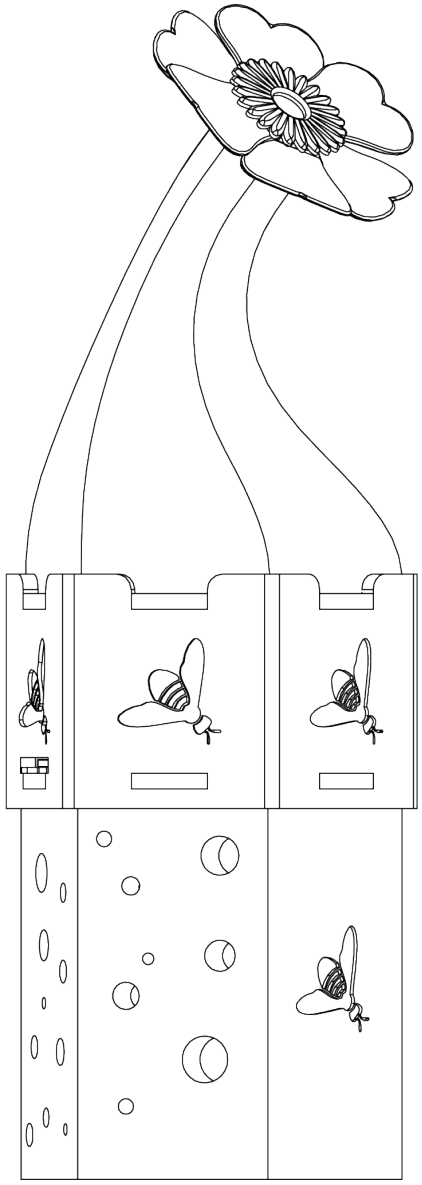


BBeacon Flower

The current issues that are being faced with the flower sensor, is that there hasn't been done enough testing to be sure if the bees are really being attracted to the flower. The first prototype did not have the right colours and also no UV coating. As a future goal, the new design needs to be tested, maybe even several flowers in a certain area, all with different coloured petals.

Another improvement is adding more sensors into the flower, to give the device more value for people to actually buy it. A good addition would be to make it like a weather station by adding a humidity and temperature sensor, just like the hive. Not only shows this what kind of day it will be, indirectly, it also tells more about the bee activity. When it is cold or raining, less bees are active which has direct influence on the numbers that will be counted. If the results show a link between the weather and the amount of counted bees, a low number can be explained by these conditions which makes more sense.

A second addition to this product would be a camera inside the flower, next to the infrared sensor. The infrared sensor detects perfectly if a bee has entered the flower, but besides bees, it will also count wasps, beetles and slugs. By adding a camera that shoots an image when the sensor detects a bug, it will be clarified when an actual bee is inside the hive.



BBeacon Platform

The web application enables beekeepers with interactivity to freely view and compare the data of their beehives in three different parameters (weight, temperature and humidity) and in different time dimensions. But there are some limitations for now as well. For instance, in the block for each parameter, only one another line (representing the data from another time slot) could be added to be compared with the current line. There is a possibility that the beekeepers want to view the data of several different time slots of one parameter at the same time. So in future iterations, we could allow beekeepers to zoom into one parameter to realize richer interactions and more possibilities within this single parameter.

So far the additional detailed information besides the lines representing the tendency of data in a certain period of time includes: average amount, increasement, highest and lowest points, but these data for now can only be viewed as attachments of the line charts, we could enable the beekeepers to view these data simply in form of numbers and compare these figures in the time dimension in our future iterations. And maybe more professional data analysis regarding specifically to beekeeping could be present in the interfaces, which should involve data analyse experts and beekeepers sitting together to work out possible plans.

Besides, the data outside the hive like the temperature and air pressure should be taken into consideration as well, because these parameters could influence the bees' performance inside the hive, which can be used by the beekeepers as a reference to better evaluate the data inside the hive and to more clearly figure out what goes wrong.

With the mobile phone app, we want to offer the customers who are using the BBeacon flower in their gardens with a fun and entertaining way to check how their garden is doing and to have a clear overview of the situations regarding to the activity of bees of different regions and cities. We want to keep this as simple as possible so we didn't put many functions like comparing data from different dates into this app, which we think is good.

However there could be improvements as well. For example, so far comparing bee activities of different cities and regions can only be done by swiping and zooming in & out the map, which might not be that clear and intuitive for the users. So in the future, we could add a ranking of bee activities of the cities and regions within a certain period of time to the app or change the way of how the cities are visually shown at the home page in accordance to their bee activity performances.

Conclusion and future vision
The sensors have been placed into the hives and the first results look promising, however, further data gathering is necessary to capture the greater image and make final conclusions. The responses from the beekeepers are positive. they are very interested in the further development and willing to test the devices inside their hives.

For the future, the product needs to be refined a bit, like the weight sensors and the connection to the internet of things. At this moment, most of the places where beehives are located, there is no access to the LoraWan Network. This most likely will increase, especially when providers like KPN or T-Mobile will use their network to increase the range. Cellular networks reach throughout the whole country and sounds promising.

The same rules apply to the flower sensor, but this one also needs more attention to position it in the market. The audience for the hive sensors is already clear and they are willing to use it, but to convince people to buy and use this flower takes a different approach. It needs to add some value to them so this is the next step. A good start is to send out a questionnaire and raise interest in the product. Finding out how people care about the bees, about their garden and in such a product to support both. But also if they are interested in the data or using this data for further purposes. Next to this, garden centers have been contacted to find out if they might be interested in offering these products to consumers.

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