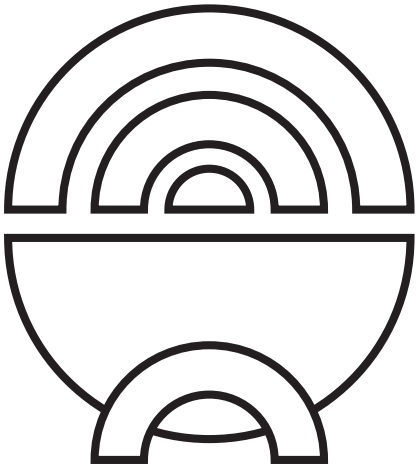
Graduation Report / Master Thesis

Sietse Taams



Designing a connected barbecue

The Internet of Things and the barbecue experience

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Master thesis / Sietse Taams
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Info.nl / LABS

Sietse Taams - Master Thesis

Acknowledgments

TU Delft

Henk Kuipers	***Chair***
Ianus Keller	***Mentor***
Tomasz Jaskiewicz	*Iterative design processes*
Martin Havranek	*Technical consultancy*
Holly Robbins	*Designing for mutual praxis*

Info.nl

Iskander Smit	***Mentor***
Marlon Doomen	*Visual designer*
Martijn Krenn	*UX designer*
Jeroen Langendam	*Extern*
Stefan Mirck	*Front-end developer*

Others

Charmé Munter
Maurice Taams
Peter Taams
Marianne Helms
Peter Kalkman
Dioni Schoop
Tjeerd Stamhuis

Preface

Internet is no longer just about connecting the computers that are operated by humans. The number of devices has outgrown the number of humans and these devices will get more and more intelligent, demanding new ways of interconnection and networking.

When some of these demands are met, a system can be created that involves several devices working together. Combining their strengths and making it possible to communicate with humans, the devices offer new ways of accessing information that was not known before.

Being a relative new domain, the Internet of Things currently is under a lot of investigation by all kinds of interested parties.

A lot is going on in the agricultural sector for example. Growing plants and vegetables demands large amount of real time local data. The Internet of Things offers precise measurements with efficient sensor systems, providing ways of control and optimization.

In my vision, the Internet of Things will also provide opportunities on a smaller scale, making the lives of people just a bit more interesting. Looking into information processing and optimization, strengths that can be attributed to the Internet of Things, I want to support people at the barbecue: an environment with a lot of guessing, trial and of course: error.

Abstract

Through emerging technologies, it is possible to efficiently extend everyday objects with wireless communication and sensing-/actuating functionality. The objects can communicate with each other as well as with humans. The movement that is concerned with applying and investigating these technologies is called The Internet of Things.

What the Internet of Things (IoT) can do for the barbecue was analyzed in this project by research through design. At the beginning one of the opportunities from the initial brief was confirmed by existing research: user performance in barbecuing.

Looking at IoT from a perspective where products can be agents, human-product relations are easier to understand and the dialogue between the two became a point of focus.

From a technical point of view the challenges of technology in an extreme environment were tackled with IoT features. The relevant variables such as temperature and food type were investigated. Controlling these variables became something that should be the combined effort of user and technology (dialogue). It should reward the user for his efforts since the main problem is that he likes to be at the barbecue but doesn't think well of his performance.

This division of labor was investigated further with design research and philosophy. The new question became how a designer can give meaning to this user-product relation. A tangible user interface (TUI) was found to be able to contribute to the relation since there is a lot of freedom to interact with it.

By integrating the opportunities from some of the iterations, Pitmaster was created. It is a barbecue support toolkit that consists of temperature sensors, sensor tongs, timers and a base station.

Key features include: timers that become points of focus where a user can see and remember the cooking progress for any type of food. Its accuracy comes from combining the measurement of temperature and food height with guesses from the user that become more educated after his adjustments of parameters and collection of data by the system.

During and after the concept evolution the design decisions were generalized and this resulted in more insights that could be interesting for future IoT projects. Lastly, the product's potential impact was predicted and reflected upon.

Visit the blog to see more!
(http://www.sietsetaams.com/bbq/)

Reading guide

To improve the readability of this report it has got a couple of layers that contain specific types of information. It offers a more structurized way of convey information instead of mixing it all up. The layers will either dive deeper (Zooming in), generalize (Zooming out) or reflect.

Zooming in

In these sections there will be extra attention for an aspect of the background information. It might help understand the process better and offers advanced knowledge about the subject.

Zooming out

It can be useful to see some design aspects in a broader perspective. Zooming out will emphasize on one of these aspects and take them out of the barbecue context. This also supports the idea of the barbecue being a showcase and can generalize an IoT solution.

Reflection

Here there is room for a personal twist that supports the main story. Some design decisions have a personal component and this will be highlighted in a section like this.

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Integration

About the project

This report contains the graduation project of a 'Design for Interaction' master student. In this project, a connected barbecue will be designed in order to make barbecuing more rewarding for the people involved. The project was initiated in collaboration with team LABS: an Internet of Things innovation lab facilitated by the digital service company Info.nl.

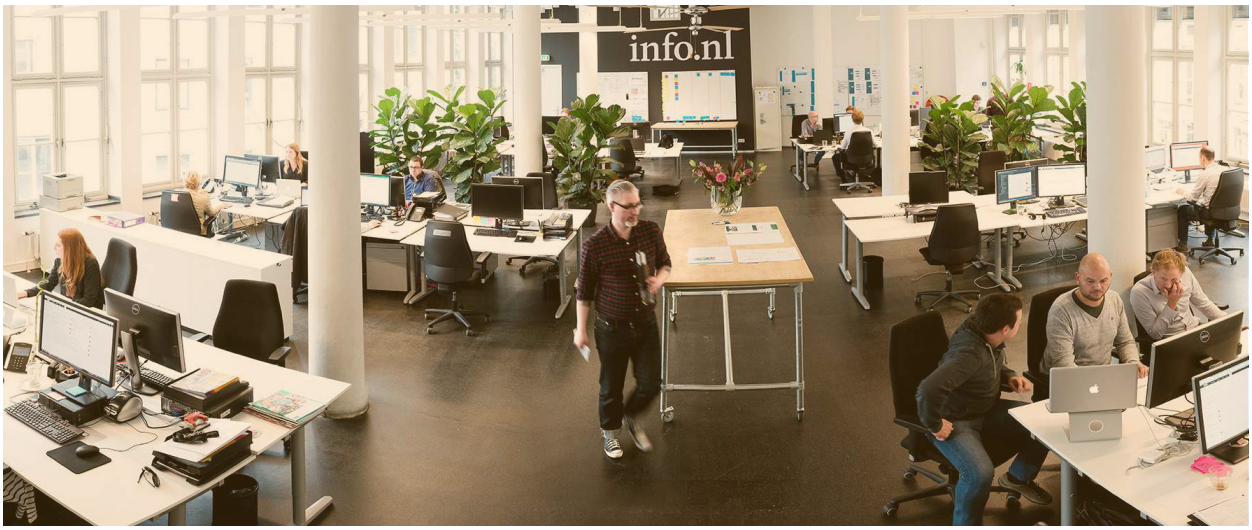


Figure 1. Creative technology agency Info.nl located in Amsterdam

1.1 The company

Info.nl

Info.nl is a creative technology agency that is dedicated to crafting digital products and services. In this field, they have over 20 years of experience and currently the number of employees is approximately 70. These people are distributed over several teams in a so-called 'agile' working environment. This means that the teams are essentially self-driven and multidisciplinary. A team works closely together with one or more clients and the composition of team members is specifically directed towards these clients.

Since 2017 a dedicated team is set up for the development of Internet of Things projects: team Connectable. This team is trying to combine the strength of info.nl, service design, with a new category: tangible products. These product-service combinations fit the Internet of Things (IoT) domain. An example here is Growficient; a way of using sensors in greenhouses for optimal results in the agricultural sector.

Info.nl is active in thinking on and experimenting with IoT within the dedicated innovation lab (LABS) for a long time already.

LABS

LABS is a space for in-depth research and analysis of the digital innovations of the near future. Labs commissions projects to research with internal resources and external cooperations, especially with several universities, but also with other agencies like product designers.
Sharing the knowledge is an important aspect. Next to publications, LABS is co-initiator of the Behavior Design AMS meet-up and initiated and co-oganises the Amsterdam edition of a Berlin conference on the design and making of the new things: ThingsCon Amsterdam.

1.2 The domains

Internet of Things (IoT)

Being a relatively new domain, IoT refers to an interconnection of everyday objects. Because these objects are able to communicate with each other or with the Internet, a kind of intelligence can be perceived by the user. These 'intelligent' products, often referred to as 'smart products' are opening a lot of opportunities to improve the quality of people's lives.

Barbecue

A way of innovating in the IoT domain is trying to connect an everyday object to the Internet or to other objects. The LABS team from Info.nl has recently been looking into a cooking device that matched the interest of the student who came up with the idea of connecting a barbecue.

1.3 Problem definition

Skill

Because the frequency of using the barbecue is not that high and the cooking process is complex, learning by doing is hard and can be discouraging. In terms of food, there are some risks such as burning it, overcooking it or under-cooking it. This will either cause health risks, be wasted or will not be enjoyed by the users.

Social

Barbecuing is often a social occasion and the relation between the one that is handling the barbecue and the rest can look very different over the course of a meal. Next to that, the main user spends a lot of time at the barbecue and is often separated from the group. Also, especially men seem to get some kind of pride out of doing it and feel responsible for the result. This result therefore often has an impact on one's self-esteem or masculinity.

Combining the skill and social aspect leads to potentially contradicting demands: the result should be good but if this result is caused by something other than the user (e.g. a smart device), is it possible for the user to still feel proud?

1.4 Design brief

Redesign the barbecue experience using modern communication technologies. From the barbecue as stand-alone device a product-service will be created. Depending on the user demands that will be prioritized during the project, one or more of the challenges or opportunities from the problem definition will be addressed.

1.5 Method

The method that was used in this project is an iterative design process, currently described as 'design tornadoes'. The strengths of this approach are being able to evaluate technologies and getting user input early. These results will either be included in the final design or 'fail fast and fail cheap', resulting in more insights overall. Because of the intended use of relative new technologies, the method seems to fit the project well. Also the early user insights are important in order to design the intended interaction qualities.

For more information regarding the method, see Appendix A.

1.6 Structure

To have an overview of the structure of the project, a visual is shown in Figure 2. It is based on the iterative approach and related to the pillars of Industrial Design Engineering: Business, Human Interaction and Technology. This report will work towards two deliverables: the IoT barbecue concept and the overlapping review of what the Internet of Things is capable of.

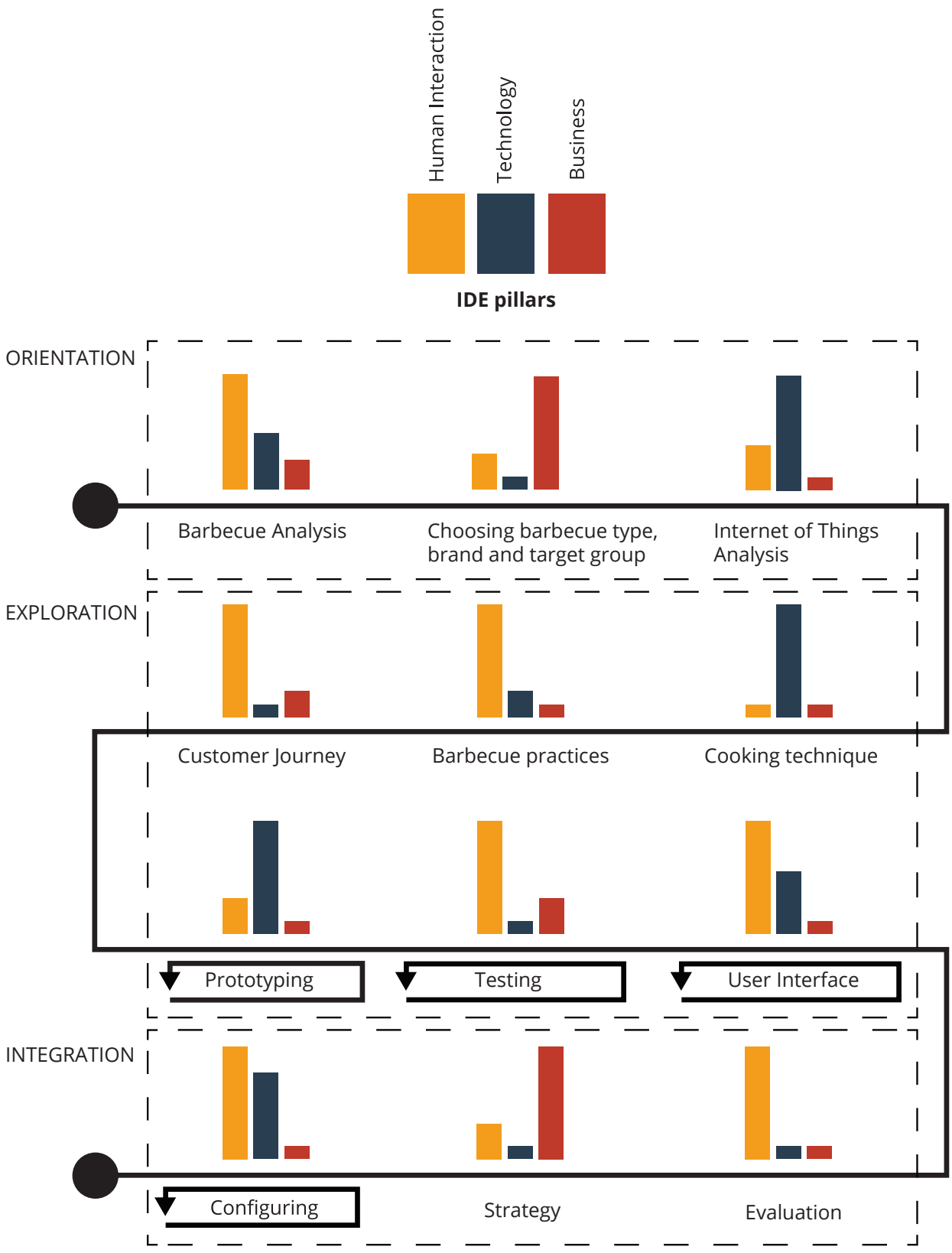


Figure 2. Process overview of the approach and relevant domains.

The orientation phase is the beginning and foundation for the rest of the project. The two main domains, barbecue and Internet of Things, were analyzed here. Introducing the key elements and taxonomy, it gives shape and direction to 'the playing field' that will be explored further in the second phase.

2. Internet of Things

3. Barbecue analysis

4. Existing solutions

2 Internet of Things

Being a relatively new domain, IoT refers to an interconnection of everyday objects. Because these objects are able to communicate with each other or with the Internet, a kind of intelligence can be perceived by the user.

'Internet of Things' has become an umbrella keyword that roughly describes the changing and extending role of the Internet. The Internet usually refers to the web: a digital information network that can be accessed by users through a computer. But in the last two decades, the extension of the Internet has led to the new term: Internet of Things. So what does this extension include? (Also, see Appendix B)

2.1 Things

The things that are so often refer to are meant to be 'smart objects'. Through emerging technologies, it is now possible to efficiently extend everyday objects with wireless communication and sensing-/ actuating functionality. These everyday objects can then be perceived as 'smart' because they have properties that match the following characteristics: (Miorandi et al. 2012)

1. Anything communicates: smart things have the ability to communicate wireless among themselves, and form ad hoc networks of interconnected objects.
2. Anything is identified: smart things are identified with a digital name: relationships among things can be specified in the digital domain whenever physical connection cannot be established.
3. Anything interacts: smart things can interact with the local environment through sensing and actuation capabilities whenever present.

2.2 Value creation

Next to the technology being available like the miniaturizing of chips, increased memory and efficient power management; it is also relatively cheap and therefore suitable for everyday products.
The nature of IoT is to combine physical things with hardware and software. This results in something that has additional functionality next to the physical functions it already possesses. Also the new layer can be a digital service that is not only accessible locally but at a global level. To illustrate this we can look at a light bulb, its primary function being to provide light in a specific direction. When enhanced with IoT technology however, it could additionally detect human presence and serve as a low-cost security system (Wortmann & Flüchter, 2015). The value that is created by a product like a smart light bulb is not limited to the value of that individual product. A product can be connected to related products and becomes part of a bigger system (system in system). To continue the example of the light bulb, it could be connected to other light bulbs around the house that track the presence of humans. This information could then be used to reduce energy use by turn off the lights when they aren't needed.

2.3 Interaction

A user can either interact directly with the physical or smart components of the product but can also access the product cloud. Because the smart layer or cloud is able to compute and visualize data, the user can start to understand product performance and properties that would be hidden otherwise. To get back to the light example once more: using the system of connected light bulbs around the house, the energy consumption could be computed in 'the cloud'. The result can be visualized in a graph that is interesting for the user to get more insight in the use of the lights, whether it is to reduce energy usage or discover lamps that are rarely used.

2.4 Agency

The interaction of a user with an IoT product goes both ways. The user has an effect on the product and vice versa. Also both the user and the product can interact with their environment. Because of the enhanced functionality, the product can also act on its own behalf and does not directly need its user. The product becomes an agent.
In the paper 'Products as Agents: Metaphors for designing the products of the IoT age', Nazli Cila proposes new taxonomy regarding Internet of Things products. These products are put into three categories depending on their level of agency: Collector, Actor

and Creator. These categories can be seen as roles that a product can take.

Collector

A Collector product is able to measure factors in the environment that cannot be perceived by humans. It can visualize this data in order to provide insight and mold the users' behavior and social practices.

Actor

Actor products require coordination and negotiation with the user. They could nudge users to change their behavior or can make dramatic interventions.

Creator

A creator product can act autonomously. It can have some degree of self-awareness or self-improvement. Also it is able to 'talk' with other types of products, often in order for its own good.

These agent roles overlap with the more conventional way of describing agency of IoT products (Figure 6):

- Monitoring: using sensors and external data sources to get the products' condition or external environment.
- Control: embedded software enables control of the product functions and personalization of the user experience.
- Optimization: algorithms use monitoring and control capabilities to enhance product performance and allow predictive diagnosis.
- Autonomy: combines monitoring, control and optimization to have autonomous product operation, coordinating with other products and systems.

Figure 3. Actor: The addicted toaster Brad acts like it really wants someone to use it. It tweets about how bad it wants to toast bread (Rebaudengo, 2012).

Figure 4. Collector: Fitbit can collect data about workouts. It is able to visualize this data to provide insight.

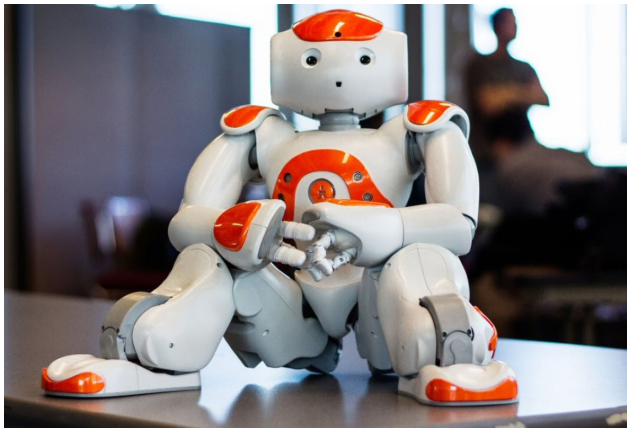


Figure 5. Creator: Recently, robots were made that had some degree of self-awareness (RAIR Lab, 2015).

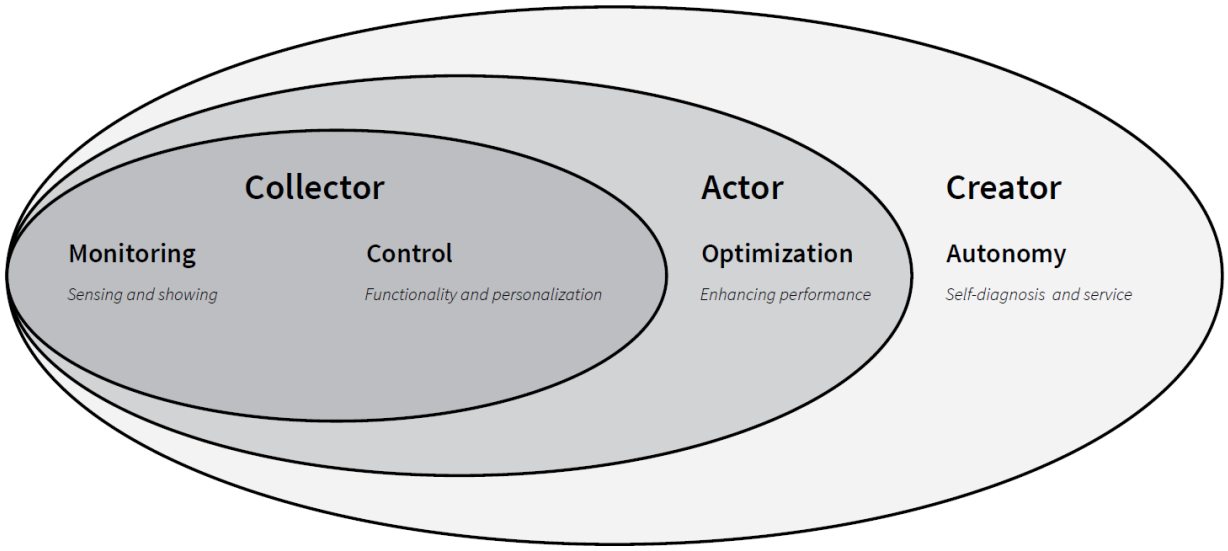


Figure 6. Smart product agency

2.5 Dialogue

When we look at the products as agents, the way of interacting with them has a different perspective. The product no longer has a 'slave' role in which it just accepts orders from its user and doesn't do anything else. The interaction is more similar to a dialogue in which both parties have something to say. This is only natural if we consider that some parts of the system can outclass the human ability, like sensing temperature for example. In other words, there are things the system can do better than its user and there are things the user can do better than the system. If we appreciate both, there will be opportunities in which we can use the best of these both worlds.

Adapting product

Assuming that a user is able to learn from what the product will tell or teach him, it is likely that the skill of the user will improve, probably faster than without the product. This will create the following problem: Having a product that is doing the same every time but having a user with an improved skill level. It could be like following a tutorial over and over again while you are able to understand what is going on yourself. An IoT opportunity here is to be able to adapt to the user's skill. For a novice user, the product might have to do more and it could have an acting role. For an experienced user, the product might take a collectors role to just reassure the user of what is going on. In theory, it could even mimic the user's skill and act on its own when it is not acted upon by the user.

Barbecue analysis

Barbecues come in all sizes and shapes. For the project a specific type was chosen in order to limit the amount of possibilities later on, keeping things manageable within the chosen time scope. The barbecue experience is a typical one and has a lot of history to it. Why is it a thing that often men do?

3.1 Barbecue types

The most popular barbecues out there are:
1. Regular barbecue using charcoal and a steel casing, the heat can fluctuate, which can either be positive or negative.

Figure 7. A charcoal fueled barbecue

2. Barbecue that uses propane gas that allows for easy temperature control but wood chips should be added in order for the food to taste smoky.

Figure 8. A typical gas barbecue

3. A ceramic barbecue that stays warm more easily but is expensive and hard to handle. All three can be used with or without a lid and this has a lot of impact on the functionality.

3.2 Experience

"Barbecuing is pure and connects people, but the pit master's performance disappoints"

Figure 9. The expensive one: a ceramic barbecue

An interesting title from a research company that investigated the barbecue experience in the Netherlands (Hielkema, 2015). They found that a lot of people are into barbecuing (91%) and there usually is a man that handles the grill (pit master). This man however, is not too happy with his barbecue performance, scoring himself a 6.4 mark average.

Statements like 'The grill is my castle' and more subtle; 'I grill, but someone else can try' were popular amongst men. It is interesting to see the feeling of pride and responsibility taking into account that they don't even appreciate their own performance.

The type of barbecue is also important for the experience. Charcoal is not only popular because of the price (cheaper than gas and ceramic types) but it is also associated with the most authentic flavor and masculinity (Appendix F).

An interesting brand here is Weber. It is famous for their charcoal barbecue design and take up the most space in a lot of stores with their extended product portfolio. Most barbecues are placed in the mid-range segment and they sell a lot of accessories as well.

3.3 History

So why is it often men that barbecue? A paper about the role of the father stated that after WW2, there was a demand for fathers to be more involved with their family. During that time, the roles of men and women were classically divided and men did not do a lot of household chores. Advertising played a big role in getting men to do the cooking: barbecuing was stated as 'fun'. Ads often showed men that looked like cooking men that were already accepted, like chefs (apron and chefs hat). Next to that, the properties of the barbecue were described more technically and in contrast to a stove, safety and usability were not really addressed. (see Appendix C for advertisements)

Another range of ads from around WW2 could also play a role in the barbecue popularity: meat advertisement. Meat was said to be very healthy and it was not unusual to eat very much of it. In war time, meat would be the thing soldiers needed to fight better. It could be that this association helped people, especially men, to crave more and bigger meat. The barbecue was a good place to cook this since it had a lot of grilling surface.

3.4 Target group

An interesting target group is the men that score themselves relatively low on performance even though they like to handle the barbecue. It makes them responsible for the result and their efforts should be rewarded. For now it is assumed that their lack of skill is a combination of little experience with cooking in general and the Dutch food culture: simple and straight forward. Because the weber barbecues aren't high end but relatively expensive and the average barbecue party is a group of around 7-8 people the project aims at families with a medium income.
The target pit master will therefore be 28-65 years old, doesn't spend a lot of money on a high end barbecue but wants to own a brand that is perceived as decent. Also he doesn't cook at home that often and therefore lacks cooking skills.

3.5 Conclusion

The exact origin of the barbecue ritual is hard to trace back. The historical view on the role of men in barbecuing caused by marketing is interesting and plausible. For this project, the truth behind the ritual however is not that relevant since a lot of interesting things are happening already. The direction of skill improvement is viable and has been confirmed by existing research.

Figure 10. A typical use case

Existing solutions

Even though the domain of the smart barbecue is small, some companies have tried to create one or made tools that go well with it. The solutions that exist or have existed today were analyzed.

BrightGrill

A failed Kickstarter called: bright grill. It is an electric grill (has a power plug) and is connected to the Internet. An app can be used to control it but it is based on using predetermined times for certain food. Also it uses the temperature in the grill, outside of the food and it is not accurate. (Figure 13)

General Electric smoker

A project where a barbecue is hooked up with sensors for humidity, smoke velocity and temperature. The values are monitored and a skilled chef can use the live data to optimize the cooking process. It is not market ready, just a prototype. (Figure 11)

Lynx Smart Grill

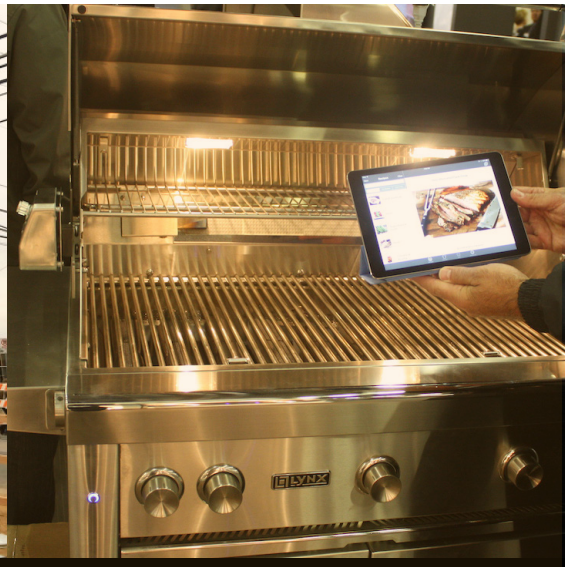
A high-end smart grill that can be controlled with an app. It is expensive ($6000) and has a temperature sensor at the cooking surface. It has limited options and works only with android/IOS (Figure 12)

Weber Tools

The Weber company offers some smart tools at the moment. The newest one is a Bluetooth enabled thermometer set. It comes with a base station that is connected to up to four thermometer pins. The pins are color coded so the temperatures are liked to the right pieces of food. (Figure 14)

Figure 11. GE smoker hooked up with sensors

Figure 12. High end 'smart' grill from Lynx



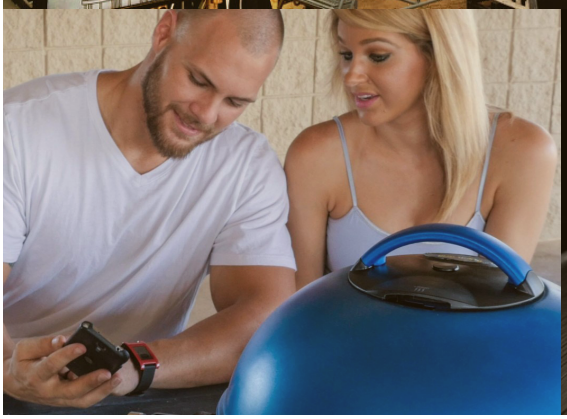


Figure 13. Brightgrill

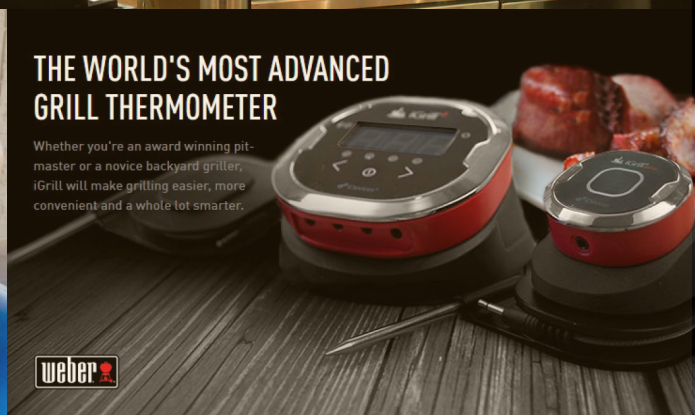


Figure 14. Weber temperature kit that measures the inside temperature of meat

In the exploration phase, the (sub-) problems and opportunities around the barbecue were addressed. The solutions that were found, are to be developed further and have to be integrated eventually. This way, a system is formed that has the functionality of combining the barbecue data and user input into a final solution that will be able to efficiently support a user during barbecuing.

5. Barbecue skill
6. Customer Journey
7. The cooking process
8. Temperature
9. In control
10. Input
11. Interface
12. A basic system
13. Barbecue dynamics
14. Design Principles

Barbecue skill

Aiming at performance, one of the first challenges is finding out what people know. What is the difference between an expert and a novice user? And how does this influence the design direction of barbecue performance?

5.1 Expert

In order to learn more about the skill involved in barbecuing, chef Edwin van der Slot was asked to participate in a barbecue (see Appendix G for pictures).

He was also asked to be in charge of doing the shopping, this way the type and quality of the meat and vegetables could be taken into account in for example assessing the end result. He pointed out several times that from his experience he knew that people often don't really know how to handle relatively big pieces of meat. The result often being tough and dry.

In cooking meat, he explained, three important stages can be identified that each require different kinds of temperatures. In the first stage, the meat should be seared so that it would 'close'. This way, the juices will be trapped inside and the meat has the potential to stay moist and tender. In the second stage, the meat will be cooked further, the cooking time will be determined (rare, medium, well done or anything in between). This stage is already hard for a lot of people since it requires experience and skill.

The last stage is said to be one that a lot of people seem to forget: resting. Meat should rest for about 15 minutes in order to reabsorb the juices. If it is cut right away, a lot of juice is lost and the meat will still end up dry.

The expert role

The chef's family would always ask him first to come to a barbecue because they feel they need him. He will be there to help out when they are struggling. Important here is that they do like being at the barbecue but they want the reassurance and help of someone who is an expert.

Extra tips and tricks

- The meat should be out of the refrigerator in time so that it will be around room temperature before cooking. This way, the temperature difference is lower and the meat will be more tender since it will not lose that much juice
- When cooking fish, use oil and citric acid. The acid will already start curing the food if it is marinated in time.
- Cleaning the grill should be done right on the barbecue on a high temperature. The dirt will come off much easier and no metal-affecting soap is required. It can be done before and after using the barbecue but cleaning in between cooking is also a good idea since it reduces the chance of flavors mixing up or burning.
- Use a chimney starter! The charcoal or briquettes will burn evenly and therefore the temperature will be distributed better as well. Also, one does not have to put a lot of effort in stoking up the fire this way.

Edwin van der Slot
Professional chef

Over 20 years experience with grilling on various types of barbecues

Current barbecue:
Big Green Egg

“Certain family members usually invite me to their barbecue first. Only when I say that I’ll be there they feel safe to invite others. Even though they like to be at the barbecue themselves, me being around gives them the reassurance they need.”

- Edwin van der Slot
Chef

5.2 Novice

Accessing information

When barbecuing, a lot of action from the user is required. This can also be seen in the customer journey (link). For starters, it can be hard to keep everything under control. The dominating factor in grilling is the temperature. For food to be ready to eat, it should have reached a certain temperature where it has acquired more taste and killed dangerous bacteria.

This temperature is usually hidden from the user, whether it is the temperature of the meat, the grill or the charcoal. Sometimes a barbecue does have a temperature sensor and this often measures the temperature of the air inside the barbecue (with the lid closed).

So what if a relatively unexperienced user is able to measure more temperatures? The meat temperature for example. Could this help him to have more control?
This was explored with a small intervention where a novice user was given a meat thermometer while barbecuing. He was given the assignment to use the thermometer and figure out the rest himself with any resources possible.

From the start, the user did not feel comfortable with the temperature device. He even started questioning whether it would work, given the other external factors such as grill temperature and the cold wind.
The next problem was that there were a couple of relatively smaller pieces of meat where he felt that it would be even less accurate.

The thermometer did already have some information on it. There were indications of several pieces of meat next to different temperatures. This was clear to the user. The meter however only had indications for 5 types of meat. One of the meat types that was on the barbecue was not on there: deer. The user chose to make a guess about this meat type and determined that the desired temperature should be somewhere between beef and lamb.

Figure 15. A novice user that is not sure of how to use the meat thermometer.

Figure 16. A novice user trying out an advanced technique of determining the meat's doneness.

What was even more interesting that at one point he decided not to use the thermometer at all. Using his phone, he found a step-by-step guide that made him use his fingers to feel the resistance of the meat. This way he would determine how far the meat was cooked. The goal of the user was to end up with a medium deer steak. The result was a steak that was almost 'well done'.

Eventually, he said that he would feel that sometimes the temperature could come in handy such as following a certain recipe or using large pieces of meat. But for him part of the fun is not knowing everything and this, combined with the fact that he does not think the temperature is measured accurately results in not directly wanting to use a thermometer.

Conclusion

Seeing that a novice user looks for a guide not directly using temperature, a few things can be concluded. Whether temperature is the decisive factor in cooking meat, on its own it will not matter too much to this novice user. Instead, he trusts more on direct contact with the food, feeling its resistance. Noticing that the goal was not accomplished, the method is not free of error and training will be needed, even though the guide was step-by-step. On the other hand, one could say that the judgment of the user was wrong and he could also learn to use the temperature measurement accordingly. Above all, it is clear that the meat thermometer is not perceived as the right method.

5.3 Conclusion

Product as an expert

The expert user had the experience of other people wanting him to help them while barbecuing. They would still be handling the barbecue but take his advice while doing it. His role would be passive/active advice giving, which is a role that would be suitable for an IoT product. The 'product as an agent' perspective strengthens this image of a user-product relationship with room for dialogue.

Learning curve

Another reason for discovering the difference in skill level from a novice and expert user was to determine the 'learning material'. In other words: is there room for a product that can help a novice user to become a better pit master? From the barbecuing expert it was observed that his experience allowed him to perceive a lot of real time information about the food on the barbecue. This information was hard to obtain for the novice user, even with a documented plan. This kind of information about temperatures and cooking times could be obtained by a smart product-system and would be suitable in supporting users who lack experience.

System of systems

To take it even further, if the barbecue would be a system that is connected to other systems it could share data with other barbecues. This way it could be possible for a novice user to learn from an expert. The barbecue would be able to take over certain preferences and timings, resulting in a so-called 'expert system'.

Reproducing

Having the barbecue with the chef as an expert, I felt inspired to have a barbecue and try to reproduce the result. Since I worked in a restaurant kitchen for over six years I was pretty confident as well. Together with my dad we tried out the techniques the chef used. It did not work and however I was dissapointed with my own skills, I felt that it did help me realize i was on to something. There is just too much trial and error for me and others to get the most out of the food.

Information sharing

The strength of shared information across systems is enabled by the software layer of an IoT product. It can be remotely adjusted because of its connectivity properties. This software can modify the way the hardware (physical parts) behaves. An example: the functionality of Tesla cars is mostly made up by software. The software can collect information from thousands of cars in order to optimize their behavior on the road, like the way they use their brakes. The new software can be uploaded when the car is idle and the user can have a car with improved functionality overnight. (https://www.tesla.com/nl_NL/support/software-updates)

6 Customer journey

To have a good overview of what a user goes through before and during barbecuing, several insights are combined in one graph: the customer journey. The 'things' that people use and data that they user and generate can be seen in the graph as well. It highlights the interesting areas for IoT touch points.

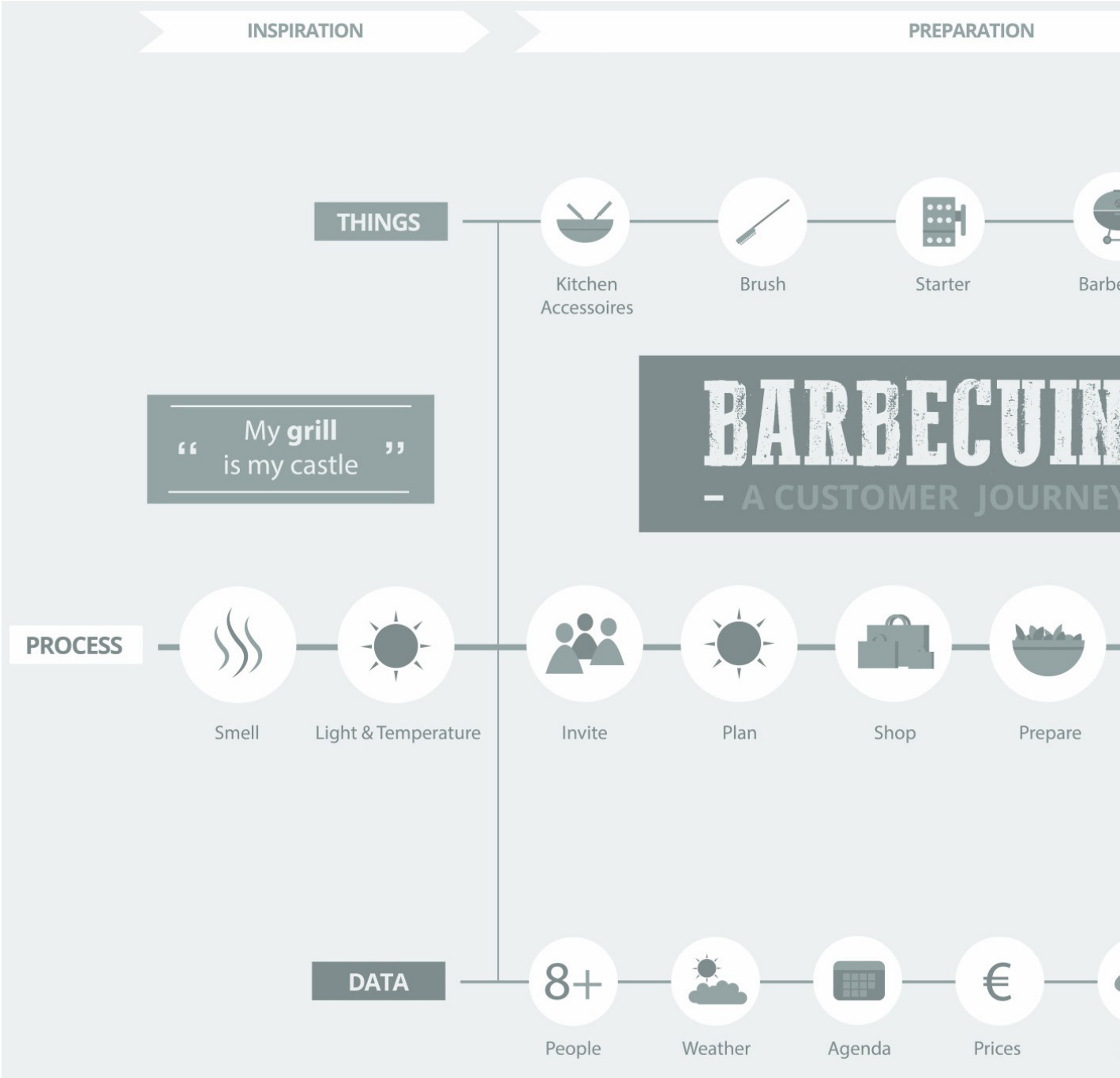


Figure 17. A Customer Journey that shows the user's barbecue journey with associated tools and data.

6.1 The journey

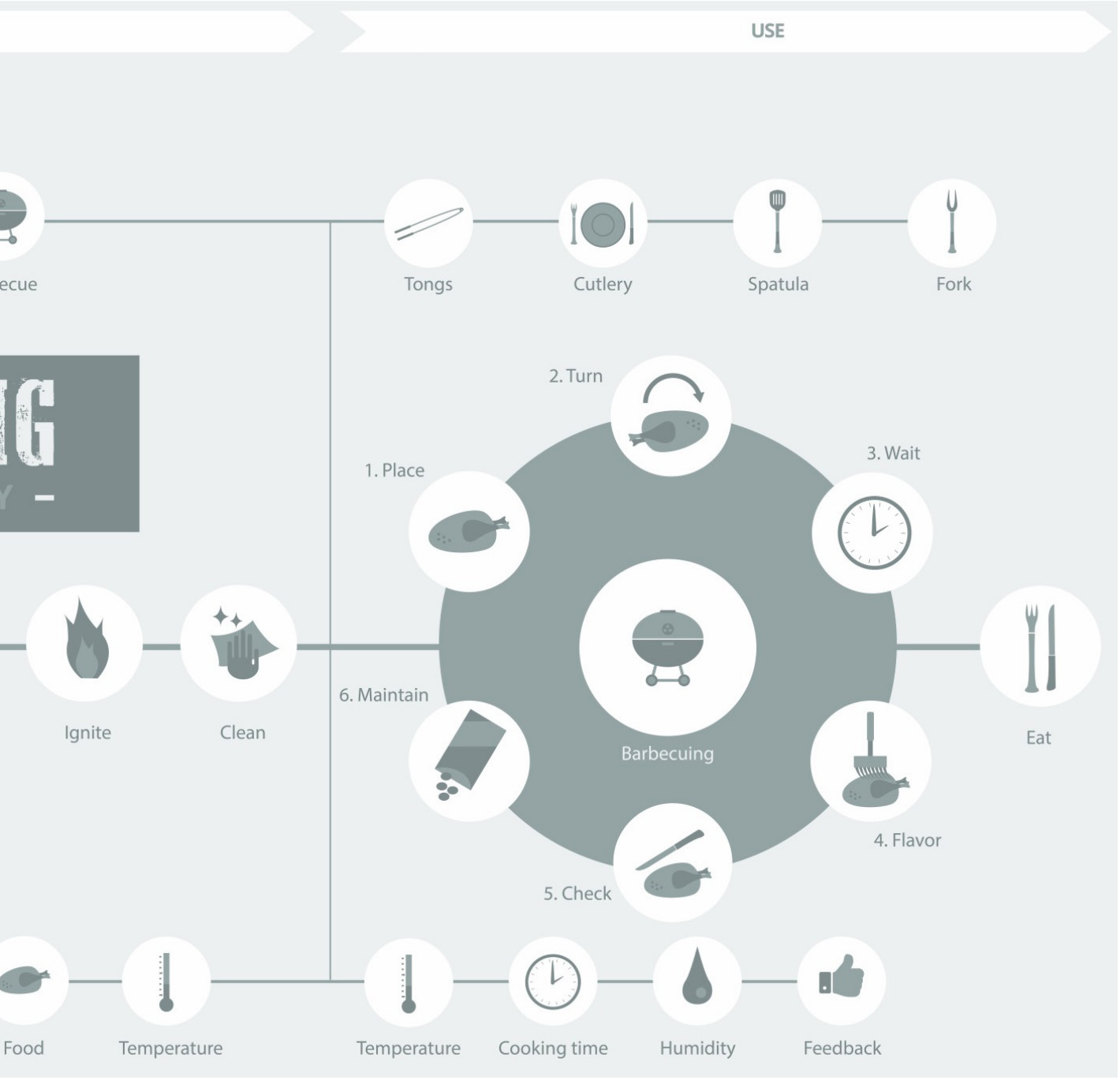
Overall, the line in the middle represents the process that most users go through. Next to that, two lines were added that represent Things and Data. Also the process is divided into three phases: Inspiration, Preparation and Use.

Things

Because the solution space consists of Internet of Things solutions, the things that are used in a regular barbecue were considered. This was done to be able to spot any opportunities for functionality that something that already exists can fulfill (with adjustments). It has the potential to being able to avoid the creation of additional products for functionality that can be integrated.

Data

Next to that, IoT solutions are often complex in the sense that they can compute and 'see' data that humans cannot do.
For processing this information and making it available at the right time, a service is often the right solution. When a service like that is



created it might be valuable to add other data as well. It would have the potential to integrate multiple solutions in the same service.
Even without the service, it is interesting to see what the relevant data is that is being considered or generated by the user or barbecue. It might be an important factor in the quality of the result from barbecuing (food and experience).

The three phases Inspiration, Preparation and Use will be described and discussed next.

6.2 Inspiration

In the inspiration phase the barbecue trigger occurs. It is often the smell that brings back the feelings of summer, good food and being together.

Process

- Smell: The smell of the barbecue is typical and inviting. It can trigger people to barbecue.
- Light & Temperature: Evenings are 'long', the temperatures are comfortable and the light is practical: summer is the most popular barbecue season.

Relevance

The processes in this phase are not relevant to this project. They work fine the way they work now, over 90% of the people like to barbecue anyway.
The IoT domain also has limited options here. A smell is hard to convey with a product and again: there is no problem with motivating people.

6.3 Preparation

The preparation phase contains the actions that take place before the actual barbecue event. It can be exciting to anticipate on the fun that is to come but also stressful because it takes effort to prepare well.

Things

- Kitchen accessoires: Several kitchen accessoires can be used for marinating, cutting and other food preparation purposes.
- Brush: A steel brush can quickly get rid of the dirt that is sticking to the grill.
- Starter: A starter is a nice way to evenly ignite the charcoal. It required less effort from the user as well.
- **Barbecue: The type of barbecue determines the length of the preparation phase. Charcoal takes more time than gas.**

Process

- Invite: Barbecuing is a social event organized together with family or friends.
- Plan: Most people associate barbecuing with nice weather and will check the weather forecast in advance.
- Shop: Depending on the amount of people and their wishes, the food and drinks have to be bought.
- Prepare: Food that goes on the barbecue has to be seasoned or prepared in another way. Also side dishes are made.
- **Ignite: The charcoal has to be ignited and it requires time for it to be hot enough to start grilling.**
- Clean: Once the grill is hot, it can be cleaned more easily. Using cleaning agents should be avoided to prevent corrosion .

Data

- People: The amount of people and their food preferences are important.
- Weather: Warm and dry weather is often preferred. Weather data is used.
- Agenda: In order to plan a date, people's agendas are consulted.
- Prices: Food, especially meat can be expensive. Information about products and prices is required.
- Food: The availability of certain food can vary. Also some food types go better with other food or drinks
- **Temperature: To start grilling, a certain temperature has to be reached.**

Relevance

Inviting, planning and shopping are things that work very well using a smartphone. There is an interesting link however: the wishes of people could be communicated as input for shopping. Also, these wishes can be useful in barbecuing later: giving the meat the right 'doneness' for example. But the wishes for cooking can also be conveyed during barbecuing. The link with shopping is still interesting but for now it doesn't fit the direction of barbecue performance.
The temperature is interesting because it is relatively easy to measure with a sensor. The result can be used to communicate whether the charcoal is hot enough to grill over (timing).
Most of the things involved dont have that many touchpoints with the user except for the barbecue. This is the product center and will definitely be involved in designing.

6.4 Use

During the use phase, the barbecue and accessoiries are used to cook or heat up food.

Things

- **Tongs: Barbecue tongs are a tool that allows picking up food without penetrating it.**
- Cutlery: Several food types require different kinds of cutlery. Also the plates are cleaned more often or even replaced.
- Spatula: A spatula is used to pick up fragile food types and is also a tool for scraping of grill residue.
- **Fork: For heavy pieces of food that can withstand penetration, a fork is used.**

Process

1. **Placing meat can be done differently for aestetic reasons (grill stripes) or cooking performance (heat).**
2. **Most heat comes from the bottom, food should be turned before it burns but nog before it is seared.**
3. **The meat should be given enough time to eather sear, cook or rest.**
4. Extra flavor can be added, especially on big pieces of food.
5. **Checking the food can be done by feeling its resistance, measuring temperature or by sight after cutting it.**
6. **The barbecue fuel also needs to be considered: it should be refilled in time and heat up again.**

- Eating: Eating will be done during and after barbecuing but this can be different for the main user.

Data

- **Temperature: The temperatures on the grilling surface, inside the meat and around the meat determine the result.**
- **Cooking time: There are different cooking times for different kinds of meat and personal preferences.**
- Humidity: Sometimes water is added because the humidity can influence the meat's succulence.
- **Feedback: The result is eaten by people who might have a different taste. Their feedback could be useful.**

Relevance

Also in the use phase, temperature is important. The impact is huge but the values are often not clear to the user. This is an excellent opportunity for IoT that has the capability of sensing and communicating the data in a clear way.
The things that are used to handle the meat are interesting directions because there are a lot of touch points. They could have sensors or actuators that support the user in his decisions during the barbecue process. The option to save information locally or globally makes it an interesting opportunity to keep track of preferences and user feedback.
Next to the strong relation between the food and temperature, the fire itself could also be managed, refueled for example, using IoT sensors.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The cooking process

The cooking process is complicated and cooking on the barbecue makes it even more complex. It adds several ways of influencing the flavor and texture of the food. For meat, the cooking process probably is the most difficult. Three stages can be identified in grilling meat: searing, cooking and resting.

7.1 Searing

During searing, the meat is grilled on high temperature in a short amount of time. The outside of the meat reacts to the heat and the color changes. This is called the Maillard reaction and during this process the color and taste of the product will permanently change.

Because of the barbecue grill, the taste caused by the Maillard reaction is often more pronounced than pan grilling because the intensity of caramelization varies across the piece of meat (grill stripes).

Contrary to popular belief, the searing process does not prevent the meat from losing juices (drying out). Actually, it even loses a bit more weight compared to cooking without searing. But the increase in taste and texture make it worth doing.

7.2 Cooking

In the cooking process, the proteins in the meat or fish are denaturalized. This process is irreversible and means that the texture and taste change permanently. The heat during cooking also makes the food lose its juices which can have a negative impact on the tenderness. In order to have food that is tender, safe and tasty, a balance is

Figure 18. The Maillard reaction adds color and flavor

to be found in the length of the cooking process and the temperatures involved. Some types of meat and fish are safe to eat raw while having a tenderness that makes it still pleasant to chew: beef and salmon for example. These kinds of food can be grilled for added flavor and texture (Maillard). The extent to which it is cooked from raw to 'cooked all the way' is called 'doneness'. It can be personal, some people just prefer meat that is more red, or situational: pregnant women avoid eating raw meat and fish.

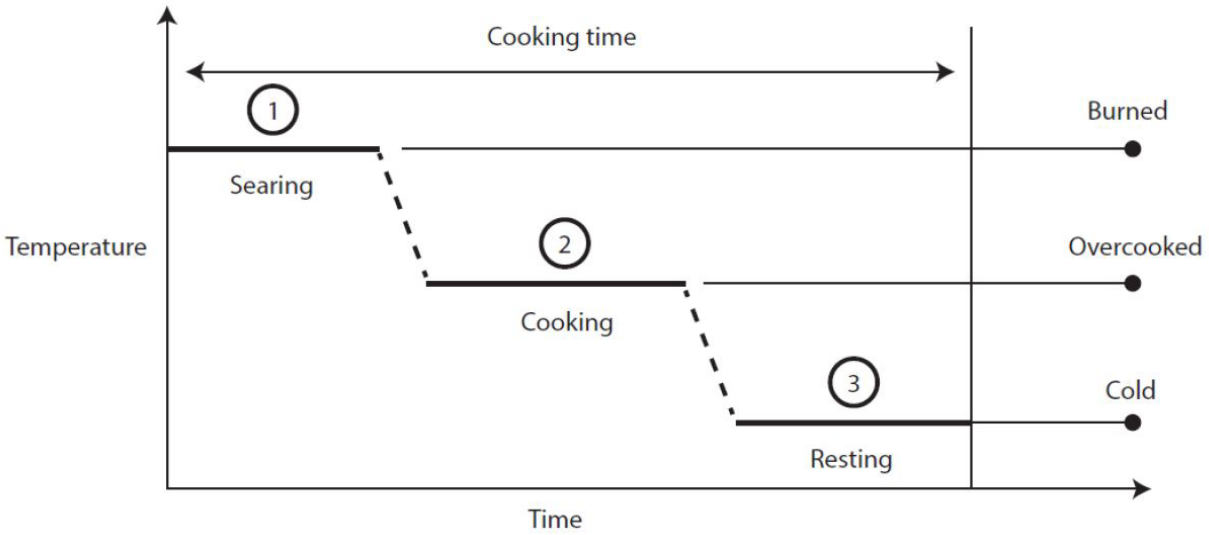


Figure 19. Barbecue cooking process (also referred to as barbecue flow)

7.3 Resting

For the types of meat that aren't cooked all the way and still have a degree of doneness, the resting phase is important. A lot of fibers in the meat are stressed by the high temperature and lose their juices. When the meat has reach the desired doneness and is cut immediately, a lot of the juices will be lost. In the resting phase, the temperature will stabilize and the fibers start relaxing and reabsorb most of the juices. The resting phase therefore has a positive impact on the tenderness of the meat, under the condition that it is not overcooked.

7.4 The barbecue flavor

Cooking with the barbecue does bring something extra to the food next to just the experience. The flavor is different and this is caused by the key features of grilling mentioned before.

7.5 Smoke

The smoke from burning charcoal gives the grilled food a smoky flavor. It is one of the reasons why barbecuing with charcoal is still popular next to electric grilling and gas barbecues, which are more easy to control. Since heat will go up, the smoke reaches the bottom of the meat first. This means that for food that is grilled on only one side the smoky flavor will be less pronounced than grilling it on both (or more) sides. Also, for large pieces of food, the smoke needs time to really get through and give more flavor to the inside. In some cases therefore, the lid is closed in order to keep more smoke inside as well as to enable the smoke to enter the food from all sides. Besides the smoke from charcoal, other material can be added to enhance the flavor by smoke. Natural wood chips for example, or wood chips that have been flavored with whiskey or beer. Also some (dried) herbs are suitable for putting directly on the charcoal, enhancing the grill flavor.

7.6 Heat

The source of the heat in a barbecue is smoldering charcoal. It can exceed 260 degrees Celsius and therefore it is very suitable for the Maillard reaction mentioned before.

Through the combination of radiant heat and direct conduction (contact heat) the Maillard reaction has different intensities and these levels increase the 'depth' of the flavor. Next to appearance, this is a reason why people like food with grill stripes.

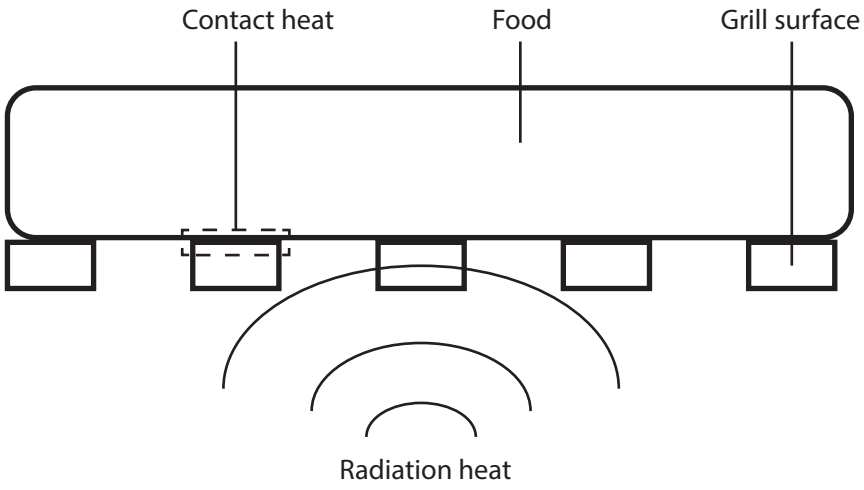


Figure 20. Heat and cooking food

8 Temperature

Whether one is cooking meat, vegetables or fish, the temperature of the barbecue will determine the end result. This temperature can be adjusted by controlling parts of the barbecue. How this can be done is described here.

8.1 Measuring temperature

For the measurement of the temperature a regular thermometer won't do. There are often sensitive electronic parts that can not withstand the hot barbecue environment.

Thermocouple

A thermocouple is a simple, robust and cost-effective temperature sensor used in a wide range of temperature measurement processes. It consists of two dissimilar metal wires, joined at one end. When properly configured, thermocouples can provide measurements over a wide range of temperatures. (http://www.omega.com/prodinfo/thermocouples.html)

Testing

In order to read the values of a thermocouple, additional hardware is needed that is able to translate the signal.
An arduino board was used to connect the hardware and display the values. (see Appendix D for Arduino code) At room temperature, the thermocouple was tested for reaction time. Because the temperature will be relevant for the cooking time on the barbecue, this reaction time is important for accuracy.

While heating up seemed to go fast (within seconds), cooling down was a problem. It took way to long for the values to return to normal. After a technical consult the problem became clear: heat will apply a current on the thermocouple and this will result in the temperature value. When the device can't easily lose the heat, the value won't drop as fast either.

In the case of room temperature, active cooling would help the cooling down reaction time. On the barbecue however, there is a big difference in temperature inside and outside of the barbecue. This effect can help the thermocouple to lose heat and be more accurate.

Conclusion

The type of thermometers that were tested are suitable for the relevant areas in the barbecue. Their position however, should be carefully considered. In order to be accurate they need to be cooled effectively. Using the temperature difference between the inside and outside of the barbecue, this can be achieved with a significant effect.

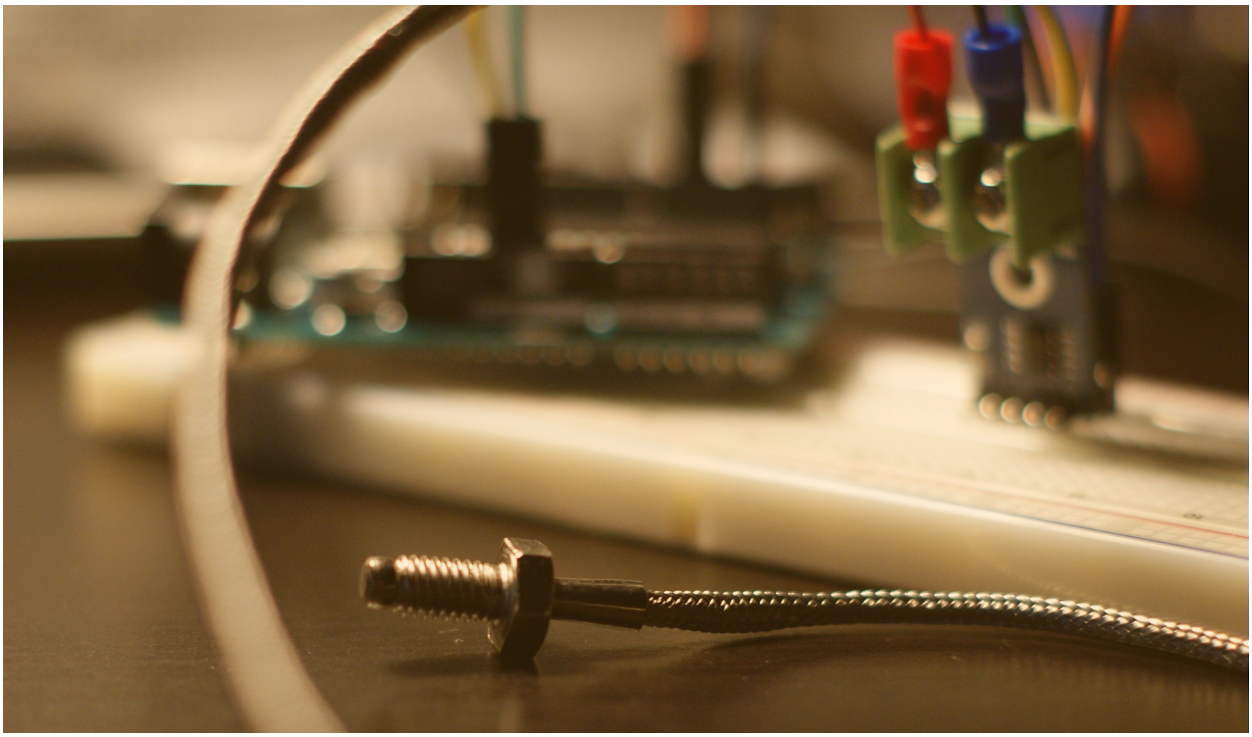


Figure 21. Arduino monitored thermocouple that measures up to around 1000 degrees Celsius

8.2 Temperature control

The dominant factor in barbecuing

There are a couple of ways of changing the cooking temperature of the food that is being grilled.

1. Changing the distance between food and heat source
2. Changing the amount of fuel that is being burned
3. Block the direct heat and use indirect heat
4. Adjust the oxygen supply
5. Use the lid

Changing the distance between food and heat source

Heat is radiated from the smoldering charcoal in the barbecue. In most barbecues, this heat is not contained very well and therefore it is easily lost. Because most of the heat 'travels up' the heat source is located below the grill: the heat will reach the meat from below. The properties of heat makes it decrease when the distance between the heat source and grill increases. Using this phenomenon, heat can be increased or decreased by either changing the position of the heat source or changing the grill position.

Block the direct heat and use indirect heat

The grill supports food that is heated by the smoldering charcoal. Besides the grill bars, the only thing that separates the food from fire is air. Heat will pass through the air and directly cook the food.
When an object is placed between the heat source and food, the heat is no longer able to directly 'touch' the food. Cooking will either be slow or may not even happen at all. A common way of smoking food uses this method of blocking direct heat. What is important here though is that the heat is still able to somehow reach the food. This is often achieved by closing the lid to prevent the heat from escaping the barbecue before heating up the food.

Adjust the oxygen supply

A lot of the time, barbecues will be closed at the bottom and the oxygen that is needed to maintain the smoldering or fire is attracted from the top. When there is no lid, a lot of air, and therefore oxygen is available. When the lid is closed it is much harder for oxygen to reach the fire. This is why some barbecues have extra (closeable) holes. There are barbecues that have these holes at the bottom so that even without the lid, the fire can also attract oxygen from below. Another positive effect of these holes is that dust can fall through. This affords easier cleaning and cleaner combustion.

Use the lid

The lid can be placed on the barbecue in order to bring down the temperature. This takes away a big portion of the oxygen supply but it also makes it harder for heat and smoke to 'escape'. Heat is contained better and the barbecue becomes more like an oven. Depending on how much oxygen is still able to pass through, the temperature will start dropping and become relatively stable.

8.3 Combining

Temperature and cooking

Taking into account the cooking process described in the previous post, a way to use the methods above could be the following scenario:

1. In the searing step, the heat source and grill are close together resulting in high temperatures and a Maillard reaction.
2. For cooking, the distance between grill and heat source is increased, resulting in a lower temperature. This way the meat will have time to cook and the chance of burning or overcooking it is reduced.
3. In the resting phase, the temperature is lowered even more by increasing the distance even more and by closing the lid. The meat will be heated from all sides without cooking it any further, enabling it to reabsorb juices while preserving a pleasant temperature for consumption.

8.4 Fan prototype

Goal: getting more insight in how adding more air (oxygen) to the barbecue will influence the temperature.
Prototype: hacked barbecue with thermometer and Arduino controlled fan. (see Appendix D for code)

Idea

One of the ideas was to use a fan in order to add more oxygen to the barbecue while the lid is closed. This way the grilled food is heated from all sides while the temperature should be easier to control.

A regular barbecue was hacked, it was hooked up with a temperature sensor and an Arduino-controlled computer fan. The adjusted barbecue was tested by trying out different fan speeds and noticing what impact they have on the temperature in the barbecue (with the lid closed).

Temperature

From the barbecues that were done before, it was noticed that the temperature of the barbecue dropped when the lid was closed. The reason for it being that there is less oxygen directly available and the smoldering will therefore have a lower intensity. The temperature would be stable but there is no sense of control. By adding more oxygen it was anticipated that the temperature could be increased. This way by controlling the fan (while the lid is closed) the temperature can be controlled.

Result

What was anticipated beforehand was that the air that goes in cools down the barbecue a bit. The oxygen that is supplied however would make the smoldering more intense resulting in an overall increased temperature. In this test however this was not the case.

Different fan speeds were tested and they resulted in a decrease of temperature in the barbecue up to 30 degrees Celsius. Noticing however that the temperature without fan was around 200 degrees Celsius, the cooling effect does not have to be a negative thing. Cooling is also a way to control temperature and 200 degrees is actually too hot for most cooking and resting processes.

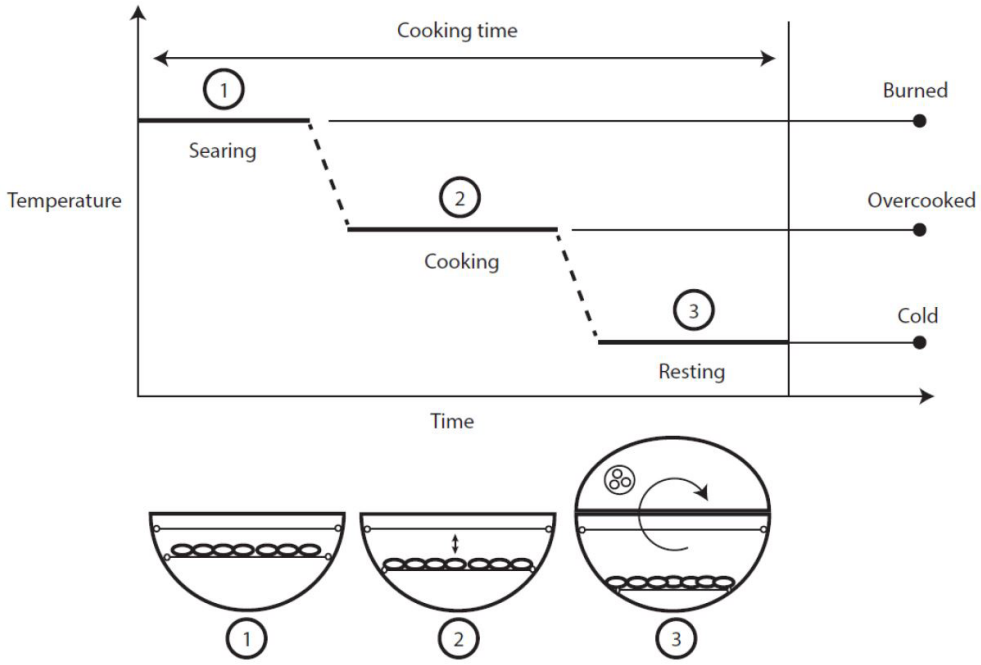


Figure 22. Combining heat control can be used to get the right cooking flow

Feasibility

The fan prototype tests have not been conclusive. The outside temperature during the tests was around 0 degrees Celsius. During the summer, the air temperature outside could be 30 degrees Celsius and up. The new effects could be significantly different from the ones that occured here. Also, there are more possible ways of adjusting the temperature.

Figure 23. Arduino powered fan that adds more oxygen to the barbecue but also cools it down

9 In control

In the customer journey some interesting opportunities for IoT were identified. Most of these opportunities are about controlling or sensing elements of the barbecue, temperature in particular. Even though technology can do a lot here it is important to notice that the user needs to feel in control. In this chapter the sense of control is further investigated.

In developing a product that has a form of agency, one thing to always have in mind is people's need to be in control. Even after using 'smart' devices for decades, the world does not seem ready for devices to take over too much of their decisions.

9.1 Lying buttons

One example of the need for people to have a sense of control is the traffic lights. For pedestrians there is always a button near the traffic light. When they push it, the system knows there is someone waiting and the queue for traffic lines is adjusted. At least sometimes. (http://www.mirror.co.uk/news/weird-news/traffic-light-buttons-dont-actually-9206633)

In a lot of cases, during busy times for example, the buttons don't work anymore. At least, they don't do anything for the system. They do work in keeping people from violating red light signals.

Placebo

The reason for this is the placebo effect. People that push the button feel that their action will take effect, even though they have to wait for a while. Because they feel 'heard', they are less likely to break the rule and cross the road while the light is still red. When the button would not be there, their trust in the system is lowered because they are not sure that the system knows they are there. Therefore they get more impatient and more likely to break any rules.

9.2 Trust

The traffic light example shows that people do not trust that the system knows they are there. They feel the need to reassure the system of their presence.

Figure 24. Does the button actually do anything?

Figure 25. Being in control doesn't exclude any help, this pan shows whether it is ready to fry or not

Because a product with agency takes over some actions from the user, it is important to realize that it automatically takes away some of the user's agency. In a case like the barbecue it might be better to leave more agency for the user so he/she really feels like having the control.

9.3 Information

Another factor in being in control is having the information to act upon. In barbecuing, there is a lot of ambiguity because the environment is often changing and the types of food vary. It takes a lot of effort in managing these dynamics. The barbecue is like a black box to most because it is just not clear what is happening inside, even more so when the lid is on.
An example of having information one can act upon is the Tefal pan. It lets you know when the pan is hot enough to effectively fry in (Figure 25).

9.4 Task flow

To have a better overview of what kind of problems arise when barbecuing and what information is needed to act upon, a task flow was created. It is an extension of the customer journey and zooms in on the cooking process and the actions that are currently required from the user.

From the task flow can be seen that there are a lot of routes towards the goal, which is to eat. The actions are in circular shapes and the diamond shapes are states that support going from one action to another. Going from one action to another, a decision is made. For example: after ignition, the user determines whether the charcoal is hot enough to start grilling. A decision like this can be based on the color of the charcoal or the heat felt by one's hand holding it near the fire.

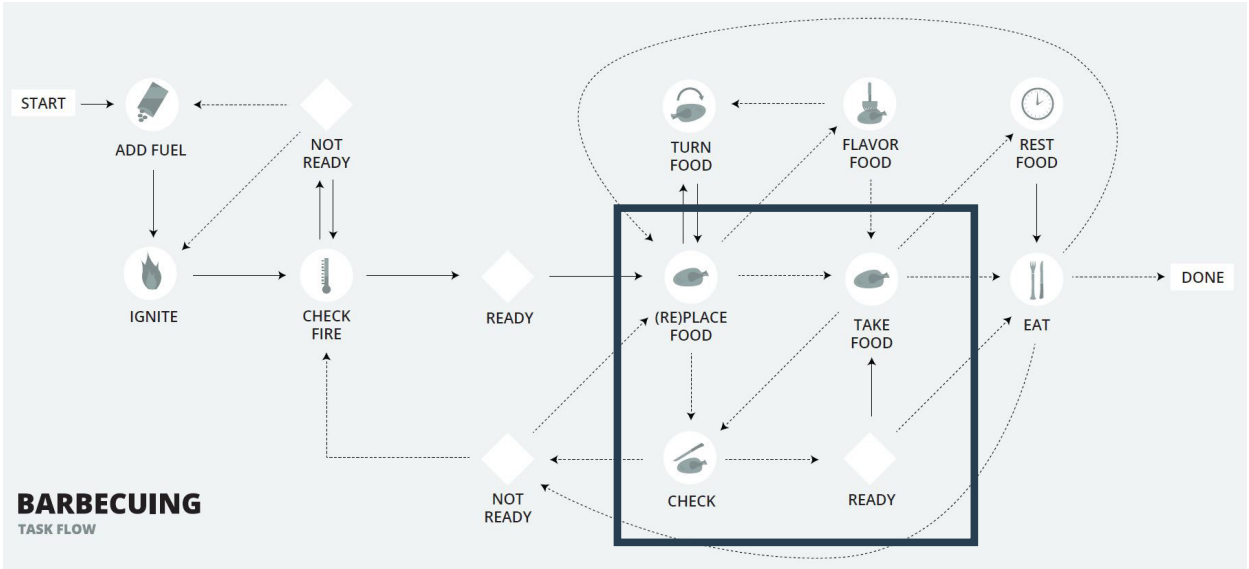


Figure 26. A task flow shows the routes that a user can take and the problem areas in these paths. An important bottleneck is highlighted.

These are types of information that support the actions, progressing through the task flow. Sometimes the information is unclear and the user can take extra actions to find the necessary information. For example, instead of going from 'take food' to 'eat', the readiness of the food is confirmed by 'check' first before progressing to 'eat'. These extra steps can occur multiple times and can be a source of frustration. By increasing the amount of information at certain points in the task flow, the decision making can be a lot more accurate.
During several barbecues the point mentioned above about determining the readiness of the food was found to be the biggest source of problems. It will be the main focus in further ideation and conceptualization.

9.5 Fun and control

The opposite of a lack of information would be: too much information. This opposite is also likely to exist in the barbecue experience. If the sensing capabilities of the product would be perfect, it could give precise timings and notifications and deliver the perfect result. In this case the division of labor would be one-sided and the user would not be required to take a lot of action. Without the interaction with the barbecue, the sense of control is more with the barbecue than with the user.

9.6 Conclusion

In this chapter it became clearer that a product with agency should carefully be considered. Users are not ready to rely on a system too much because they don't trust it well enough and they need a sense of control, making decisions themselves. Additionally, they require more information while barbecuing in order to make these decisions. This is information that a system could provide. Checking the readiness of food is the action that will be prioritized.

Temperature changes

According to chef Edwin (chapter X), meat is sensitive to sudden changes in temperature. Some loops therefore, like checking a piece of meat several times, can decrease the tenderness of the meat. Also, checking meat is often done by cutting it to see the color inside. This causes the meat to lose the juices inside at a higher rate and cook unevenly.

10 Input

In the cooking process, the temperature and time are both important factors and were discussed before. Other factors that have to be taken into consideration are: food type and food dimensions.

Time and temperature can be seen as energy input. Naturally, this would have a formula like this: time*temperature = x amount of energy. This energy is taken up by the food and the bigger a big piece of meat is for example, the more energy is required to cook it.

10.1 Size matters

If we look at the meat according to the three dimensions; length, width and height, we can see that one of the three is more decisive than the others.

On the barbecue, the highest temperature is the radiation heat from the smoldering charcoal (and the effect this has on the grill). This applies the biggest amount of energy to the meat. This radiation heat is applied to the surface of the meat: the length times the width.

As long as the meat surface does not exceed the charcoal surface, the entire surface is heated up by the radiation heat. During earlier measurements (chapter 8) this radiation heat was also found to be the highest one, sometimes by a factor two. This roughly means that there is not much difference in cooking times of two pieces of meat that have the same height but a different length and/or width (surface).

The height therefore contributes more to the cooking time. If there would be two pieces of meat with the same volume but a different height, it is likely that the piece with the smallest height will be cooked faster. (Figure 27)
This is one of the reasons why supermarkets are selling thin slices of meat that are meant for barbecuing.
Together with temperature and time, the meat volume determines the cooking time. With height being the dominant factor of the dimensions, this information is important to obtain.

Some of the current solutions in smart barbecuing make use of the weight of the meat. This is said to roughly indicate the cooking time, together with the type of meat and of course time and temperature. The weight has to be manually put in by the user, using an application on a smart phone or other device. There are some drawbacks to this:

- The weight is to be determined first, for every piece of meat
- Then an action is required to correctly fill in the information
- Weight does not say anything about the dimensions and loses accuracy

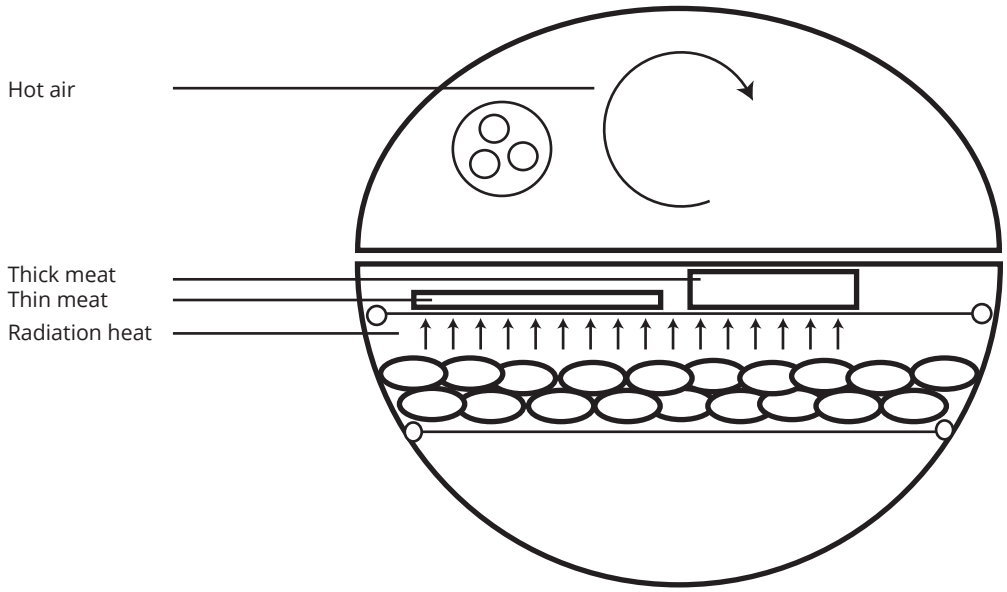


Figure 27: Food is heat up by radiation and hot air, radiation being the most dominant factor

10.2 Measuring food

To make the user input less prone to errors, there is an opportunity for IoT to sense and communicate this data. Also, sensing could take away some of the action that is required for the input (manually filling it in). Lastly, the dimensions could be taken into account, resulting in a possible increase in accuracy.

One of the ways to sense this information that is needed is measuring dimensions. If we take a look at some products that are already being used while barbecuing, some products have a lot of contact with the food and could be suitable for this job. One of these products is the barbecue tongs. It is used to pick up food, to (re)place it on the grill and to turn it around. This tool can be improved so that it will also be able to measure food dimensions. Several ideas were generated that had different sensors for measuring. One of the simplest ideas included using a potentiometer. Placed on the hinge, it can measure the operation angle. This angle then can be processed to calculate the distance between the tongs' ends.

10.3 Prototyping

The idea was shaped into a prototype using two aluminum tubes that were bent accordingly. The potentiometer was placed between the two moving parts and was calibrated using a ruler. The model was wired to an Arduino so its input could be used to determine the cooking time for a piece of meat in this case. That being said, it is obvious that this tong cannot distinct vegetables and meat for example, or anything else for that matter.

Next to that, another assumption was made about the meat: that it does not matter too much what type of meat it is. If the cooking time (for cooking it through all the way) could roughly be determined, one could also decide to stop it sooner, when the meat can be cooked medium for example. In the Arduino program, the tongs input was used to calculate the cooking time in a linear fashion: twice as high means a cooking time being twice as long.

10.4 Conclusion

The cooking circumstances of barbecuing result in a couple of dominant factors: food height, barbecue temperature and time. Time and temperature are already accounted for. Using an important 'thing' from the customer journey, also the food height can be measured. Barbecue tongs make an interesting opportunity for an IoT intervention.

Figure 28. Barbecue tongs prototype that can measure thickness of food

Heat capacity

The assumption that the type of meat does not vary too much in terms of cooking time is supported by looking into heat capacity. In Figure 29, the heat capacities of different meat types are shown in relation to temperature. It can be observed that they go through the same process. Having a maximum difference of 15%, this could mean a 15% accuracy loss. While this has to be looked into further, it should not be impossible to work with in the scope of this project.

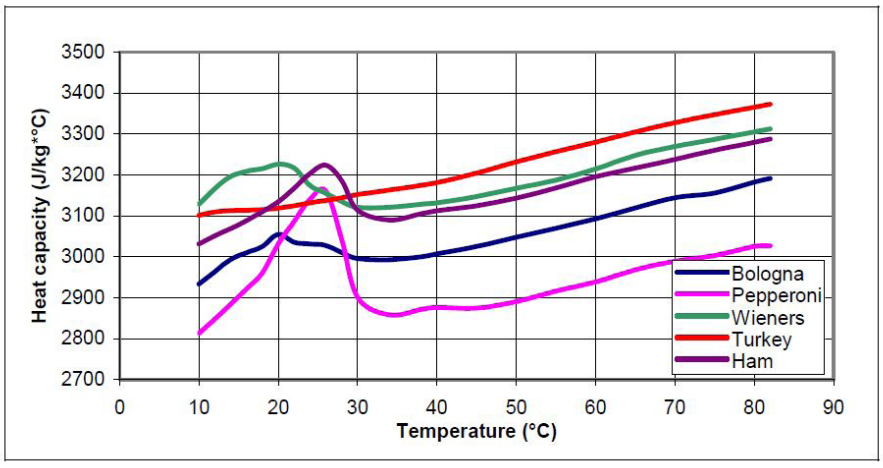


Figure 29. Heat capacities of several types of meat at different temperatures

11 Interface

The goal of an interface on the barbecue is to make it clearer to the user what is happening inside. It will help someone to perform better in the short term but the information feed can also help to learn how the barbecue works since the impact of one's actions could be visualized.

11.1 Barbecue flow

Currently, the barbecuing event consists of a lot of trial and error for most men. Not only do they often lack cooking experience, it can also be unclear how the barbecue should be controlled. Closing the lid for example, has several implications that they might not be aware of and they will use it for the wrong reasons.

One of the key factors here is temperature. Some barbecues nowadays have a temperature sensor on the lid. The temperature at the grill surface however is also important. If these two temperatures could be communicated clearly, the user could also see the results of his actions and have a better idea of how to control the barbecue.

Next to controlling the barbecue, that has to do with the opening and closing of the lid and oxygen supply, the food has to be handled. As stated before, there is an optimum flow in working with temperatures while grilling meat. If an interface can help with managing this flow, it can encourage the user to take action at the key steps in this flow. Also for other food types, it is often necessary to turn the food around or change the temperature. When the user knows how to control this, the only thing left is to know when to do the necessary actions.

11.2 Communication

Communicating the time is tricky here. Showing a simple countdown timer would work to the extent that one knows that action is required when it reaches zero. But sometimes it is also convenient to know how much time actually passed already.

For example: taking something off the barbecue one minute earlier has a different result when the total cooking time is 4 minutes than when it is 20 minutes (25% vs. 5%). So what is important here is feedback and feed forward: how much time has passed and how much time is left?

11.3 LED prototype

An idea to do this is using LEDs. An example can be observed in the Amsterdam metro: every station has its own LED. When a station is on the route and is not visited yet, the LED is turned on (option 1). When a station has been visited, the LED is turned off (option 2). In the last case, the station is currently being visited and the LED will be blinking (option 3).

In this case the barbecue flow will resemble the metro trip. There are three stages: searing, cooking and resting. These stages are represented on the journey by different color LEDs. At the start, all LEDs are turned on. Then the journey begins and according to the appropriate cooking time, the LEDs will be turned off one by one.

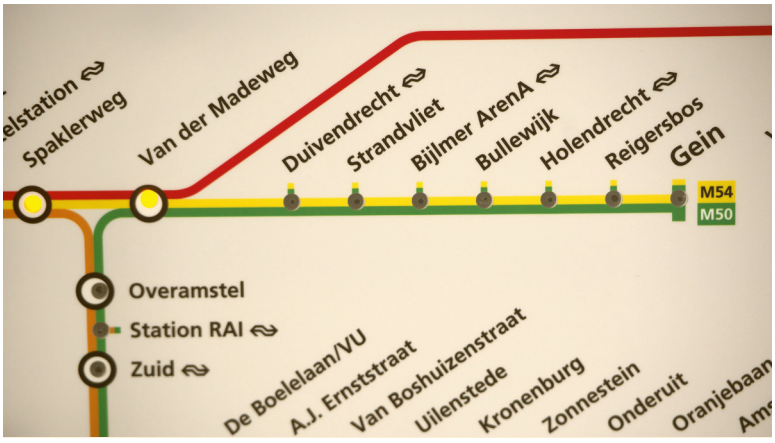


Figure 30. LED feed of metro information

With this solution it would be possible to have an idea about the time that has passed already and the time that is remaining. An important assumption here is that the abstract representation of (with LEDs) is enough to be understood by the user.

Next to the LED strip, two temperatures are shown. One represents the target temperature that is linked to the cooking stage. The other temperature is the live temperature at the grill surface. This way, the user is motivated to try and change the temperature (chapter 8) or is reassured that it is going well: there is information to act upon.

11.4 Conclusion

The LED feed enables the feeling of control since there is room for the user to determine when to intervene. The information is accurate enough to take an educated guess but not accurate enough to take the responsibility away from the user.

Educated guess

By giving information that the user can take into account in his decision, the feeling of being in control stays with the user. In products where a big part of the experience is to do things yourself the balance in agency between user and product is important. Giving too much information will make it too easy or require a high cognitive load. Providing little information may result in trial and error which can lead to frustration.

Figure 31. LED prototype that resembles the barbecue flow and associated temperatures

12

A basic system

The exploration approach has led to several design directions that should come together somehow. In a first attempt to combine the IoT opportunities, a basic system is created that shows the elements and their connection.

Combining the solutions regarding measurement, control and interface, a system is composed that enhances the barbecue in a way that it can boost the user's performance.

Opportunities

The IoT opportunties are:

1. Measuring temperature (Chapter 8)
2. Displaying information to the user (Chapters 9 & 11)
3. Measuring food height (Chapter 10)
4. Computation

Currently based on meat, the user input (3) and real-time temperature findings (1) are used to estimate (4) the outcome. A prediction is made based on the thickness of the meat and the temperature on the barbecue. The time it will take to cook the meat all the way through is estimated. Because of the nature of the interface (2), where the progress can be seen, the user can make a conscious decision about taking off the meat, whether it should be cooked all the way or not.

Testing

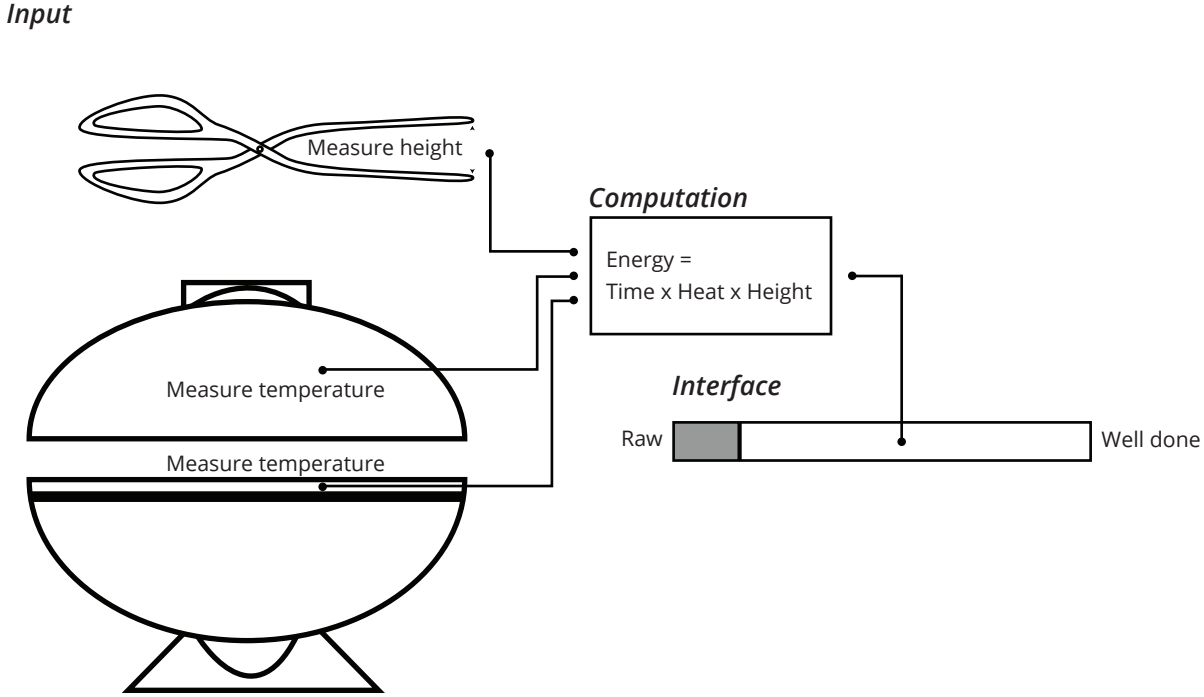
The system was tested with a user walk-through. The most important take-aways were:

- Hard to see it work in practise with more people and food
- From a distance, the different colors were not easy to seperate
- For a single piece of meat it worked quite well
- Feedback for moments of measuring are required
- Doubt about the functionality for vegetables and fish

Conclusion

Even though the different opportunities made up an interesting combination it did not seem to be a useful concept in practise. The main issue being that the system is limited to a single piece of food without an easy way to scale up. With further iteration the potential of this system will be investigated.

Figure 32. A basic system with temperature sensors, sensor tongs and a LED interface



13 Barbecue dynamics

With the previous prototypes, a basic system was composed that gave the user more control over the barbecue environment. The system was, however, limited to a single piece of meat. In reality, pieces of meat with a variety of dimensions can be placed on the grill. They might even be placed there at different intervals, so there has to be a way of managing these dynamics.

Note:

The focus will be on meat because this is the most difficult food to cook right and has the highest health risk when something goes wrong. Other food types will be discussed later on.

13.1 Tracking

The meat management comes down to being able to track every piece of meat separately in the following cases (not exclusive):

- The meat dimensions vary and require different cooking times
- The meat is placed on the grill at different time intervals
- The doneness of the meat has to deviate because of personal preferences

The tracking is needed because the memory of the user can't be under the load of having to remember which progress interface belongs to which piece of meat. Especially not over the course of barbecuing, a process that can take up a whole evening and already requires a lot of cognitive abilities from the user.

The problem becomes even clearer when it is visualized as in Figure 33. What can be noticed is that for every piece of food there would be an additional progress bar. On itself this might not be an information overload but visualizing it in an interface brings in some other problems.

13.2 Position based solutions

Tracking position

With the barbecue tongs available, there is a tool that will be near the meat very often. If its position can be tracked, it could be linked to the meat cooking process. This can provide the ability for the user to get the right information when pointing at a certain piece of meat for example. (Figure 33) Technically this is very difficult. There is not yet an accurate way to do this in the context of the barbecue. After a technical consult with Martin Havranek (TU Delft studiolab) the interesting options were found to be too hard to execute in the barbecue environment.

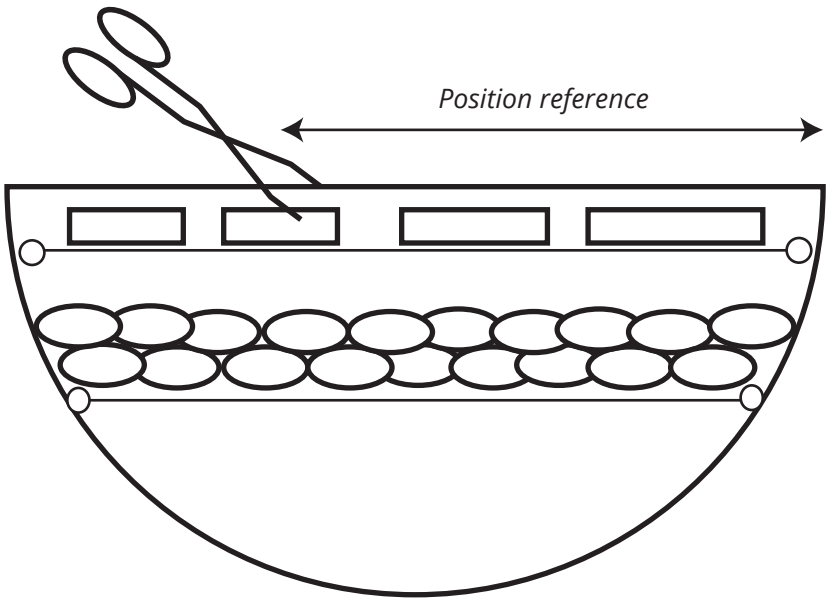


Figure 33: Keeping track of the tongs' position could help linking the food to the right information

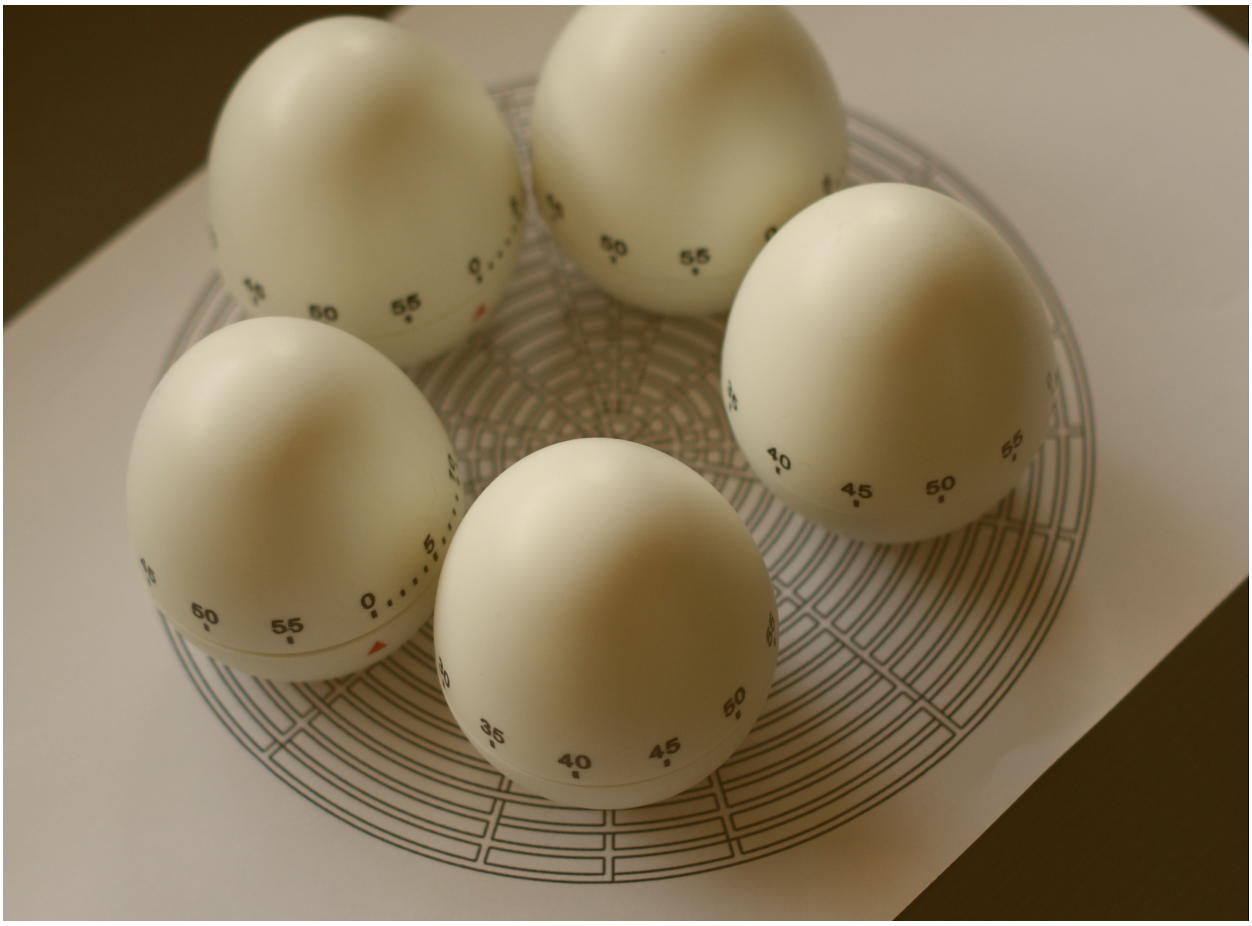


Figure 34. Problem simulation and solution: mapping the timers on a seperate interface.

Mapping example (mirroring)

If the food's position can't be sensed with the tongs for example, there could be a way for the user to determine the position. The order and number of pieces can be simulated or copied elsewhere. By keeping a reference, the link could be made between the food and its cooking progress. As can be seen in Figure 34, a user put a timer on a grill 'map'. When a timer went off, the food on the similar position on the real grill would be ready.

Predefined areas

A static solution can be to define a couple of 'zones' at the start of the barbecue event. Then each timer can be assigned to a zone and when the number is low, the zones are easy to keep track of. (Appendix E). It does require extra effort from the user in setting up the zones and in sorting meat by dimensions before adding it to a zone.

13.3 Label based solutions

Without explicitly keeping track of any positions, meat can also be tracked otherwise. If it is tagged with some kind of artifact, it can be traced back.

Weber thermometers

Weber's digital thermometer system uses a colored indicator to trace back the right temperature to the right piece of meat. (Figure 35) This is an example of a label that is represented by a color. Other options would be to add a number or other distinctive features like a specific pattern or symbol.

Figure 35. Weber color coded thermometers, base station and application

13.4 Conclusion

A dynamic solution like sensing the tongs' position is too much of a challenge in the barbecue environment. While the static solution of predefining areas puts too much cognitive load on the user. Using a seperate interface to map the food on the barbecue seems a nice balance between a static and dynamic solution.

Design Principles

The orientation- and exploration phases resulted in several insights in the user and potential concept. To make the concept meaningful, the insights were summarized into a couple of short design principles. Addressing these principles should be the main goal in the integration phase.

The grill is my castle

The responsibility and pride of being at the barbecue resonates with a lot of users. This should be respected in a way that the decisions and control should be in favor of them. The product has an advising role and should not let the user feel excluded.

Lower the pressure

Because of the rather complex cooking processes going on along with other events that require the user's attention, barbecuing can be overwhelming. One might not feel comfortable in leaving the barbecue at all because his attention is required constantly. The product should provide him a way of knowing when it is okay to relax.

Let me remember

Barbecuing is often seasonal and months can go by without doing it. It is hard to remember how to do something one doesn't do that often. The product should offer a way of saving results.

Improve me

By showing the impact of the user's actions the barbecue will be less of a 'black box'. Mastering the grill should therefore become more easier.

In the exploration phase, the (sub-) problems and opportunities around the barbecue were addressed. The solutions that were found, are to be developed further and have to be integrated eventually. This way, a system is formed that has the functionality of combining the barbecue data and user input into a final solution that will be able to efficiently support a user during barbecuing.

15 Ingredients

The important design directions are described here as the main ingredients. They will be composed into a final configuration. Getting to the final design will have an iterative nature, evolving the basic system (Chapter 12) using the insights from the barbecue dynamics (Chapter 13).

Temperature sensor

Thermocouples will be used to measure the heat at the grill surface and the heat of the air inside the barbecue when the lid is closed. They will be accurate enough for the barbecue purpose but therefore they need to be able to release heat as well. This is why a part of the conducting metal or wire from the thermocouples will have to be placed on a cooler spot, outside of the barbecue or in the bottom.

Sensor tongs

The tongs are still a great way of measuring the meat thickness. They are accurate under the condition that the user knows about how they work. For now, their function will mainly be measuring. Other options are sensing motions like turning food around or grabbing food. Eventually it might be convenient to be able to sense real time data about the food it holds.

Timer

Timing on the barbecue is key. Being closely related to the temperature, time has to be managed accordingly and its role will not be limited to determine when the food is ready. With the right notifications or visualization, it could also help the user maintain a more constant temperature.

Mapping tool

The food's cooking process will be tracked. Because the conditions may vary, it is key that the pieces of food can be tracked individually. To do this, a kind of mapping is required. Simulating the position of different pieces or tracking them with labels, the right progression can be associated with the right piece of food.

Interface

The interface is a special case because there will be multiple interfaces across the system. The parts of the barbecue that communicate together have an interconnection but also the user has a connection with parts of the system. The focus will be on the Human-computer interaction (HCI). The key factors here are whether the system is easy to learn and efficient enough, in a way that the result of using the system outweighs the effort of using it.
For the implementation of the interface there are two main directions. There is the Graphical User Interface and the Tangible User Interface.

GUI

A Graphical User Interface is based on the visualization of computational data. For example when temperature is measured digitally, it can be shown with an LED strip. Interacting with this data can be done in a physical way, like tracking the barbecue tongs position and linking it to several process indicators (chapter X). The data is being accessed and visualized.

Example: playing music on an MP3 device. The device has a screen that shows different songs that can be selected. Clicking on the song starts the song.

TUI

In a Tangible User Interface, the interaction with the digital world is still there. However, the way of accessing or manipulating data is through an object that represents the target object or action.

Example: playing music with a special device that has jars. Opening a jar 'releases' the music and the music will be played. The jar has the symbolic meaning of containing a song (representation).

Memory and optimization

The average person in the Netherlands barbecues around five times a year (Appendix F). Also these events are seasonal and often take place during summer. This has an important implication for using the barbecue: learning by doing is hard because it is not done that often and there can be long idle times in between. One might wait for up to a year to use the barbecue again. While the user's memory might not be effective when a year has gone by, the Internet of Things has the ability to manage this information very well. The information will consist of

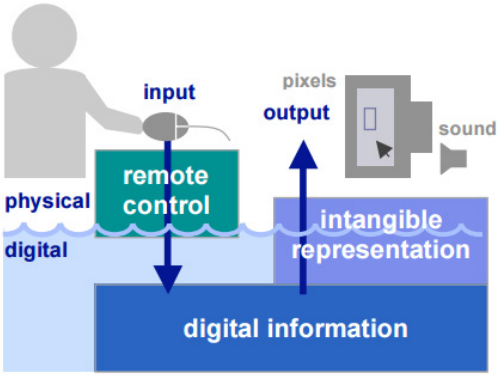


Figure 36. Graphical User Interface (GUI)

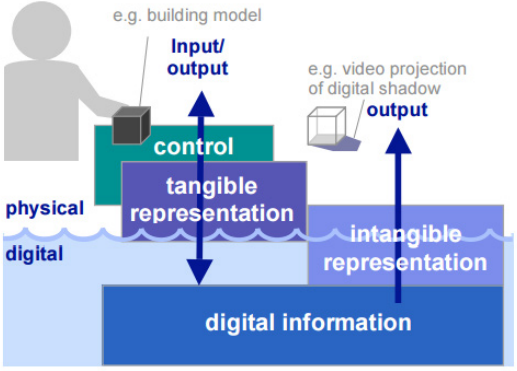


Figure 37. Tangible User Interface (TUI)

Evolution of the concept

The system functionality has taken shape in the form of a set of ingredients. These can still be composed in different ways and allow for a variety of configurations. Iterating over some of these configurations together with potential users should support the decision about the final concept.

From a basic system towards a concept that respects the design principles.

16.1 Positioning

To account for the barbecue dynamics, the mapping system should be able to simulate what is actually happening on the barbecue. The cooking process should be related to the position of the pieces of food on the grill.

By combining the TUI and GUI mentioned before, a solution to this problem was found by using separate cooking timers. These timers each resemble a piece of food or similar pieces of food. From the basic system, the progression bar can still be used.

Since the system now has an extended interface, it needs to be able to differentiate between the separate timers. It should know what cooking progression to show on a timer. As stated before, a lot of technology doesn't work in the hot environment around the grill and there is no easy way for the system to know how to distribute the data over the timers.

This is why the user was considered again. He should be able to communicate the right information to the right timer.

Complexity

As we can see from the task flow (page), there is a lot of action required from the user at different times. On one hand the system will already mediate here in terms of giving more information to act upon. This way it will be easier for the user to navigate through this task flow. But by increasing the amount of actions for the user, currently by adding the timers, we want to be careful not to counter these positive effects. This is why the way of interacting with the timers should be effortless. The idea is to make them sensitive to input from the tongs. Because the tongs are an important touch point during the placement of food on the grill, they are an excellent opportunity for effortless use.

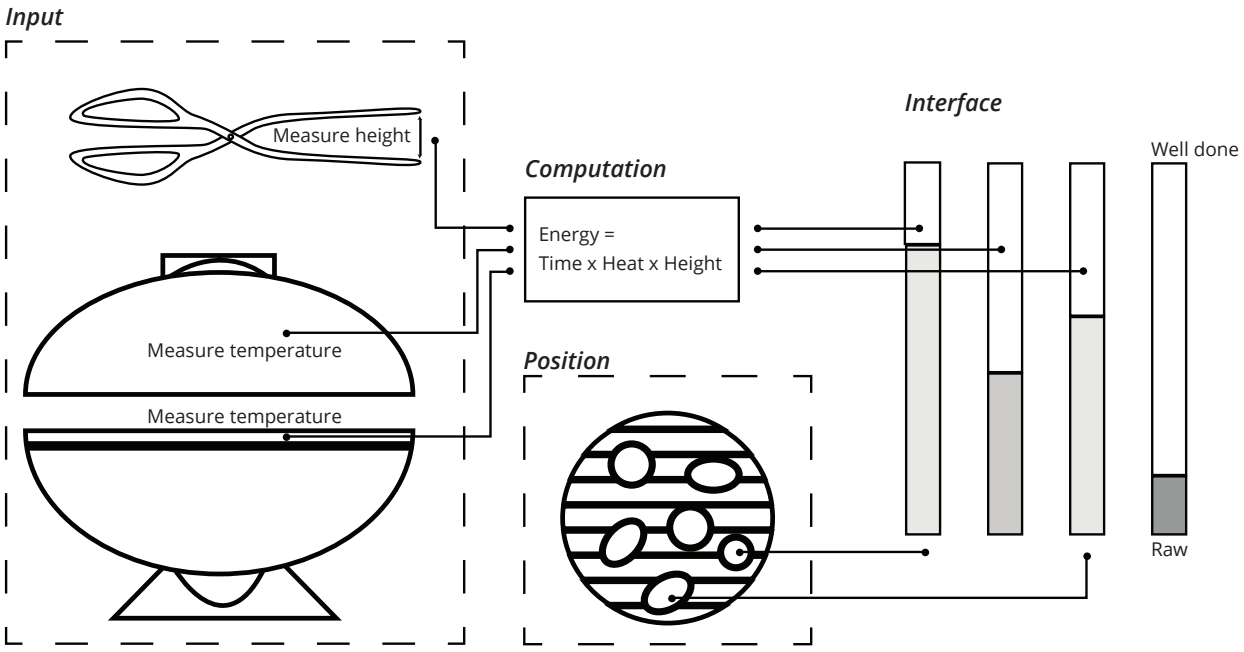
Tap & tell

The desired interaction will be referred to as 'Tap & Tell'. By holding the tongs close to the top part of the timer, information about the food will be transferred to the timer.

Feedback

Currently, the user should initiate measurements with a button. This is done for clarity and autonomy (Chapter 9).The tongs will give a vibration signal when a successful measurement is done. Also when the data is synchronized to the timer, the user will be reassured with a vibration signal.

Figure 38. Concept iteration with multiple timers that display cooking progression



16.2 Customization

Timer differentiation

Besides the problem of having several pieces of food on the grill, there is also the fact that these pieces often require various cooking times. While the difference of heat absorption amongst meat types does not vary too much, there is also fish or vegetables.

Dedicated timers

One of the options is to add an extra parameter to a timer. For example: a couple of different types of timers are made specifically for meat, fish or vegetables. These 'archetypes' should make it more easy for the user to handle the various food types. However, this has implications for the design as well: how many types will there be? How to communicate these types? It also leaves less room for interpretation and customization from the user.

White space

Another option is to leave some of the design decisions to the user. Introducing 'white space': seeing the product as a white canvas that the user can make changes to in order to improve its functionality. Looking at a refrigerator for example: its door has a lot of 'white space', a big surface with few information to display. Having an iron component, one of the unintended uses of the refrigerator became using it as a place to leave notes with magnets. The functionality was enhanced by the users themselves and it became a decorative object in the kitchen. Waiting for users to start customizing their feels like a process that should occur naturally and is hard to predict, however it can be kick started by marketing. Especially in these times of rising social media marketing, a lot of people can be inspired with very few resources.
To use and improve the timer, it can be marked at the right place on the progress bar.

'The grill is my castle'

The customization of the timers by the user contributes to the feeling of ownership. The user can have his own ways of labeling or interpreting the timers. It is an opportunity to impress others by showing off that one knows what he is doing. The portability of the timers also contribute to the freedom of using them by placing or ordering them in a certain way.

Referencing

The act of labeling the timers can also be a convenient way of matching the right food with the right timer. Originally this is based purely on position, which leaves some room for error since the food or timer can be moved independently of the other. By labeling another reference can be kept that makes it more obvious which piece(s) of food the timer represents.

Test

Using several timers at once could be overwhelming. Three timers were simulated on a laptop as a design intervention during a barbecue. They turned out to be a great tool to have an overview but the participant did have some trouble determining when to turn the food (some have 3 sides, others 2 or 4). The paper was there to see how the participant would mark the timer. (Figure 40)

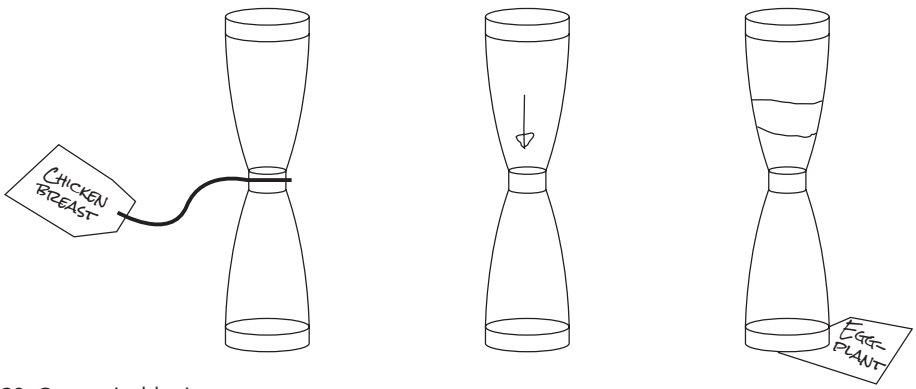


Figure 39. Customizable timers

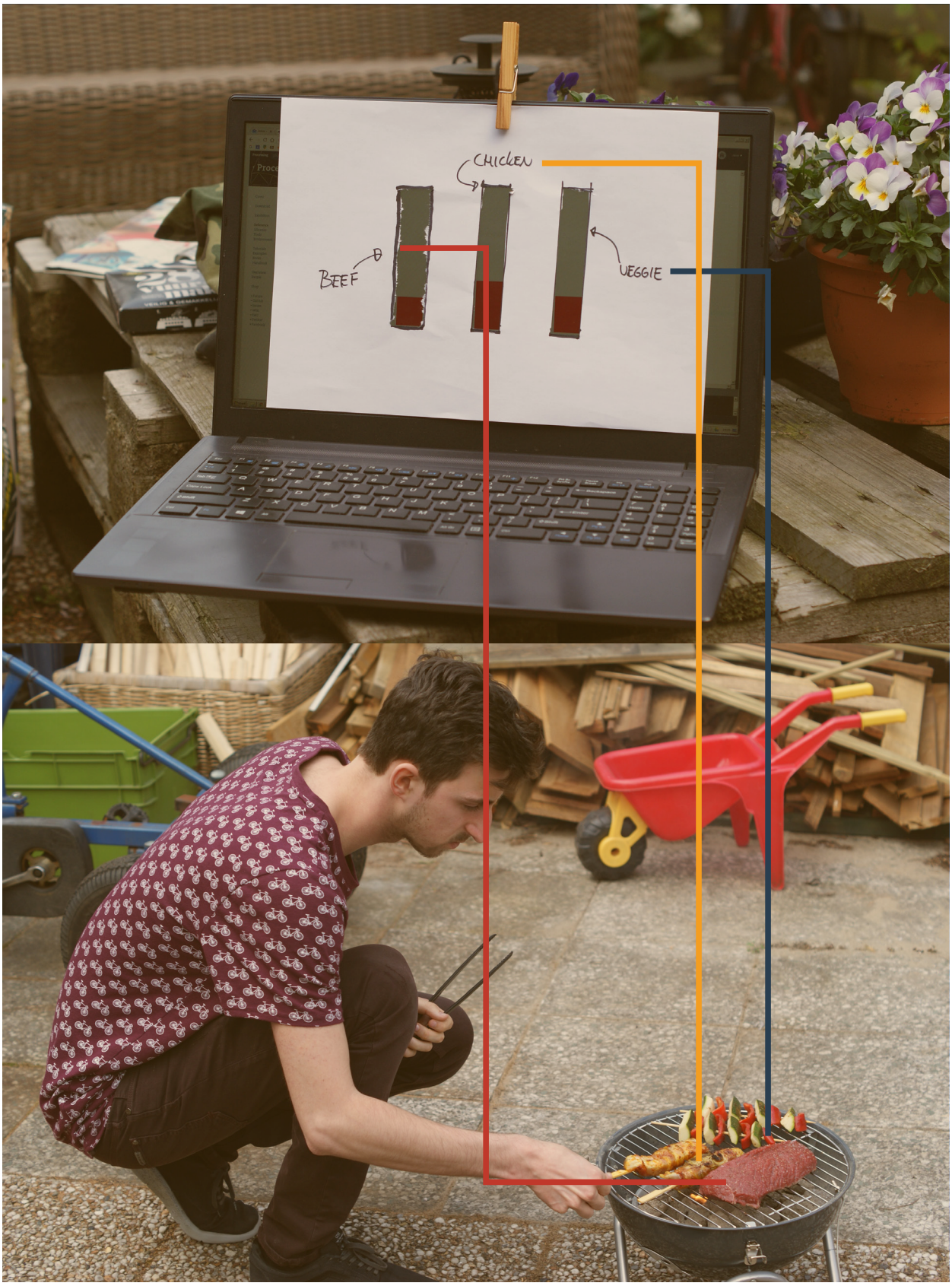


Figure 40. A timer simulation to test the use of multiple timers with associated food types on the barbecue.

Figure 41. Tea timer hourglass

16.3 Barbecue flow

From the barbecue flow (Chapter 7) three stages were identified: Searing, cooking and resting. The temperatures on the barbecue easily exceed 200 degrees Celsius which makes differentiating between searing and cooking hard (Chapter 8). Resting however, can be done by taking food off the barbecue. Therefore now the searing and cooking phase will be treated as one, cooking, and the resting phase will be the second important stage.

One of the processing in cooking that is often overlooked is the resting phase. An iteration on the previous timer concept resulted in a new idea about the shape and function of these timers.

Looking at other representations of progression, an hourglass has an interesting interaction. Turning it upside down starts or resets the 'countdown'.

The timer makes for a good opportunity here. By making it able to be turned around, it can display a different progression bar: the resting time. An hourglass timer was also seen around a tea drinking ritual (Figure 40). It shows the time that tea has to dissolve in the water for several types of tea.

By extending the functionality of the timers, not only the resting phase is accounted for but the flipping interaction also provides data about this action from the user.

Functional model

A working quick and dirty prototype was made to test the interaction with- and feasibility of the concept (Figure 42). It was able to be started with a magnet and to react on the flip action. The magnetic sensor did not respond very well but the rest worked great. (see Appendix D for code)

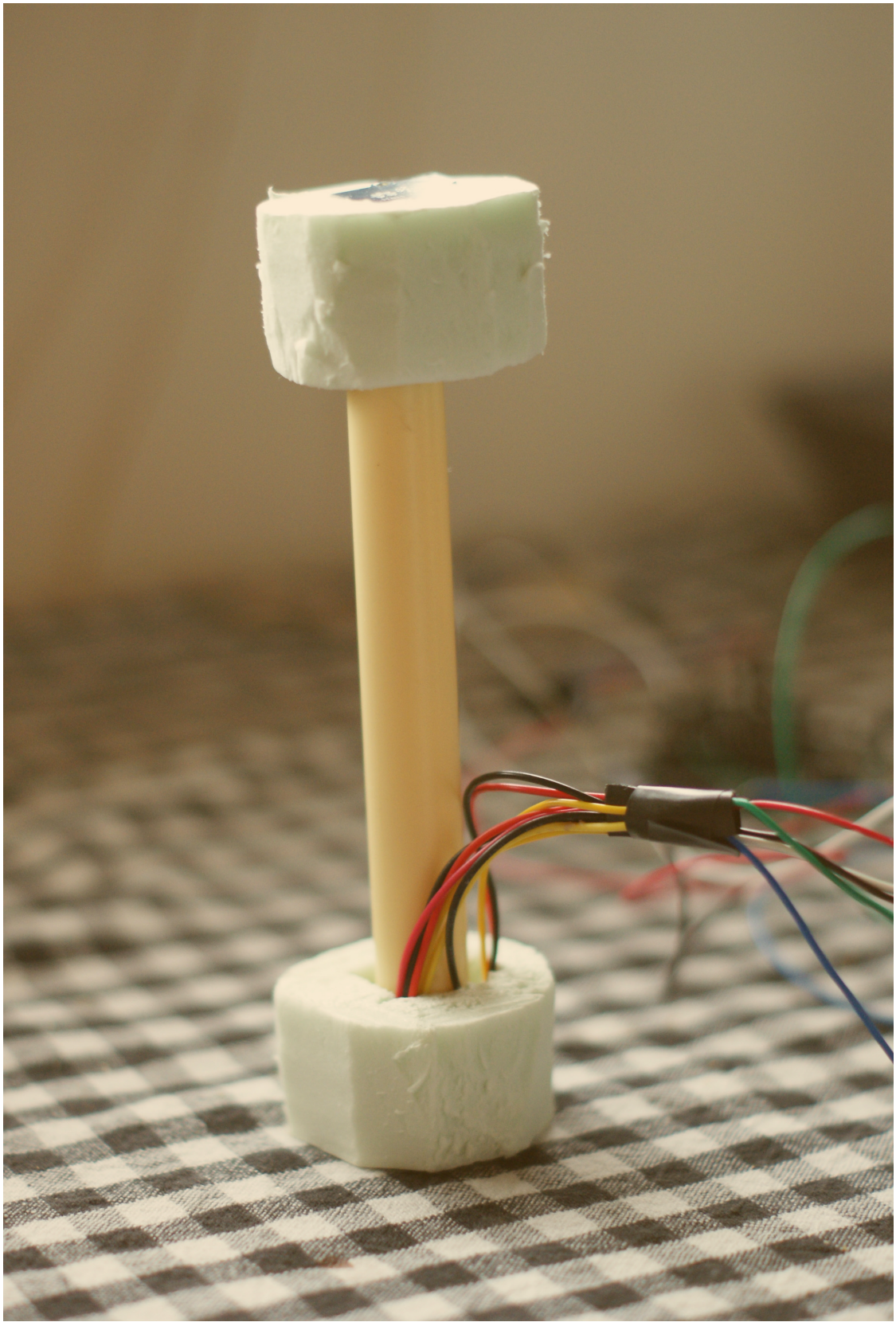


Figure 42. Functional timer prototype

16.4 Data generation

Having an action that resets a timer is important for the generation of useful data. It is a way for the system to know when food is taken off the barbecue.

Flip action

Every time a timer is being flipped, a sensor sends a message to the system whether to reset or start a resting timer. This message should also contain a kind of timestamp relative to the time that has elapsed. This way the point of preference is saved.

For example, the timer is used for medium rare beef and is often flipped relatively early in the cooking process. The data that is being generated by these actions is stored in the cloud. Because the timers have an own identity, the data can be used to predict actions or show how it is being used.

Growing relation and sharing

Every time the barbecue system is being used, new data will be generated. An interesting use of this data is sharing. For a novice user, it might be interesting to use a system that has been used by someone else already. Also experiences can be shared: if one has had a good barbecue at a friend's house, he could somehow get a hold on the data from the timers over there.

Another way is to transfer data from one system to another. Transferring data can be done to duplicate timers for example. The interface of sharing and transfering data is out of the scope of this project but will definately be possible with current technology and devices.

Optimization

Locally, the data can be used to optimize the barbecue process. The user will be able to see the results from previous actions and can use this to improve.

Visualization

So how does this data look like? The default color being red, the data trace will be a change in color towards yellow. It should however always stay a relative number in the sense that it is not possible for the whole timer to change color, only on the spot that is used most frequently.

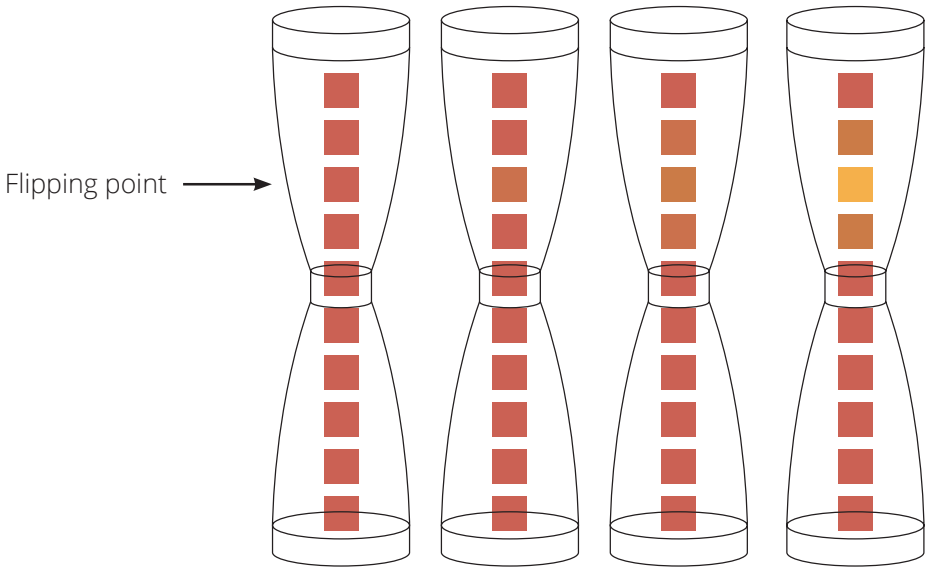
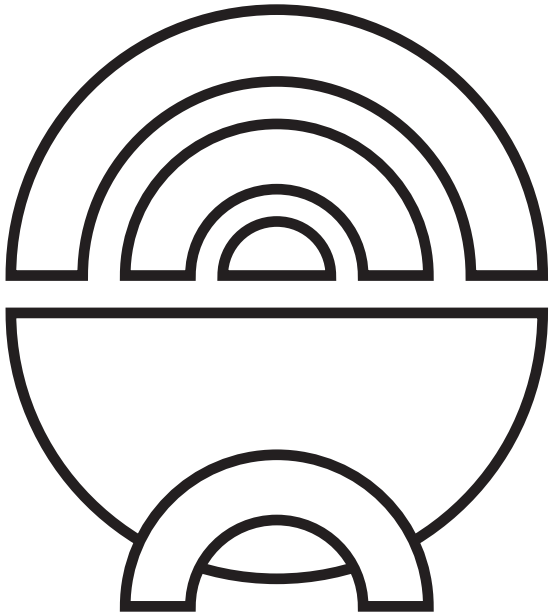


Figure 43. Data manifestation using color

Figure 44. Possibly, recipes could be synchronized to the timers

17 Final concept

The final configuration is based on a motivated decision after testing out different sets. The flow of information is shown together with the interaction- and prototype qualities.



PITMASTER

a smart barbecue toolkit

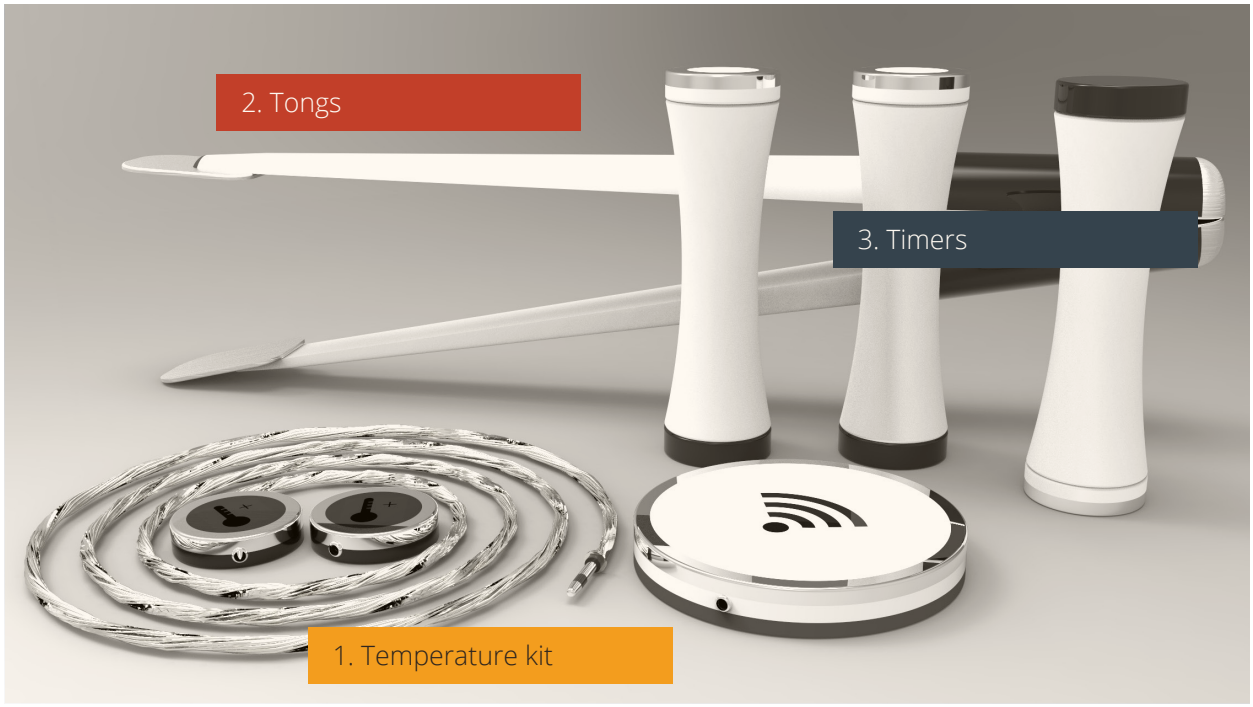


Figure 45. Conceptual prototype render.

17.1 The Pitmaster

The Pitmaster is a smart barbecue toolkit (Figure 45). It can be used to enhance the functionality of any regular barbecue. (see Appendix H for an overview sketch)

Magnetic temperature sensors (1) can be placed on the grill surface and in the lid. These will provide real time temperature measurements.

The base station (1) takes care of the communication of these temperatures since it's too hot inside the barbecue for some of the technology to work.

The barbecue tongs (2) can measure the thickness of food and together with the temperature a worst-case time estimation is calculated for the food to be cooked through. The shape of the tongs has evolved in order to incorporate the technology. With the new shape it is easier to place the battery and sensors without implications for ergonomy (Opposed to the old shape from Chapter 10).

The cooking progression can now rely on real time temperature measurement and will be shown on seperate timers (3) (Figure 46). Using the tongs, the food is linked to the right timer. Because the optimal cooking level varies with preference and food type, the user puts his mark on the timers and is able to remember and adjust after feedback.

When meat is not cooked all the way through it is important for it to rest. When the timer is reset by turning it over, its role changes from cooking timer to a timer that shows the right time for the meat to be cut and eaten. (see Figure 48)

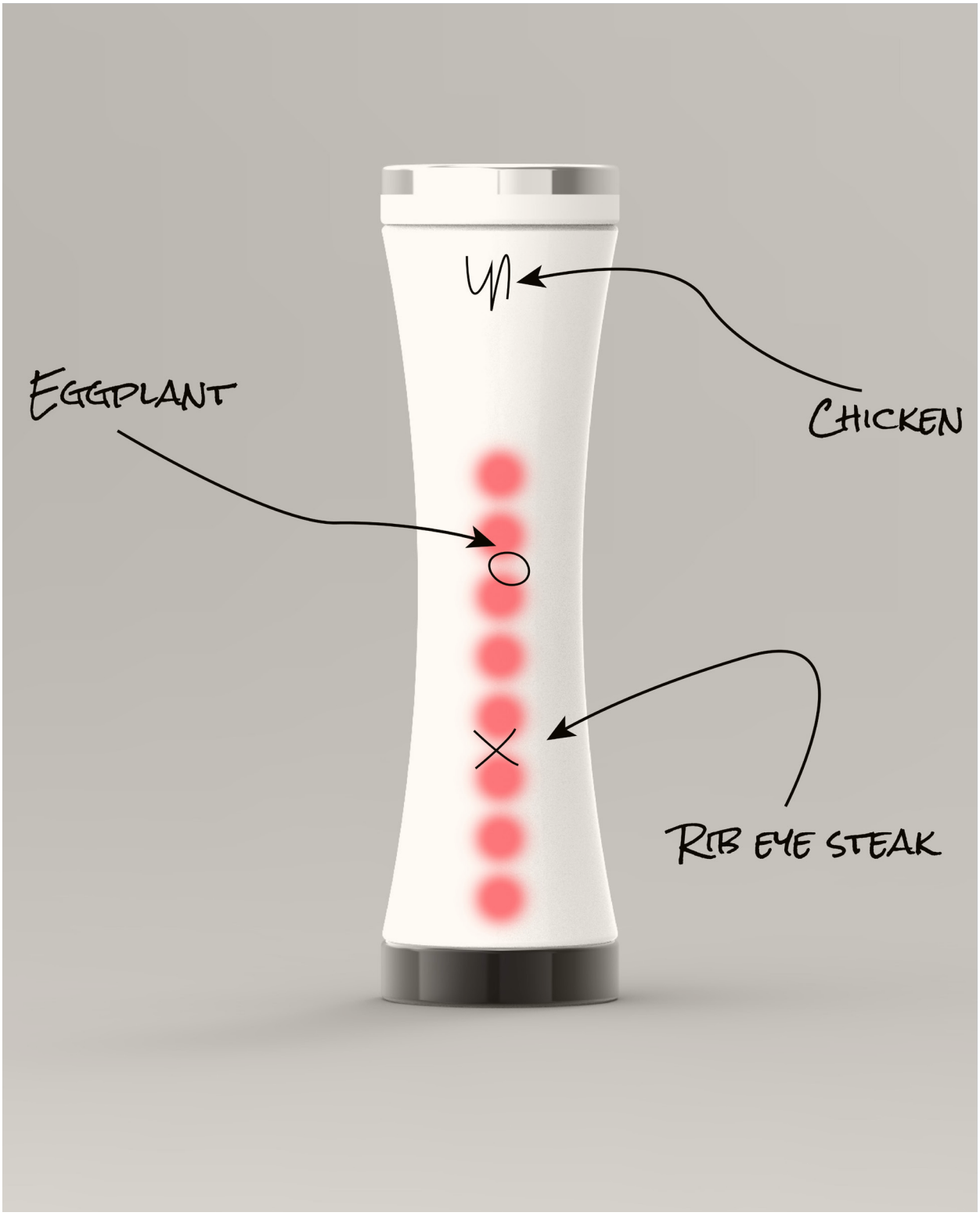


Figure 46: The cooking progress can be shown on the timer (together with analog cues)

17.2 Scenario

The usual scenario should be as follows:

1. Placing and measuring the meat with the tongs
2. Synchronizing the input with the right timer, vibration feedback confirms
3. Determining the level of cooking (doneness/bite/color), this happens at first use or when adjustment is required
4. Marking the spot on the timer, the user is free to do this whatever way he/she wants
5. The timer will show the cooking progression
6. When resting is required, turn the timer around, else the timer is reset by turning it back to its original position
7. The resting timer shows the time that the meat needs to rest, after it is done, the meat is at its best

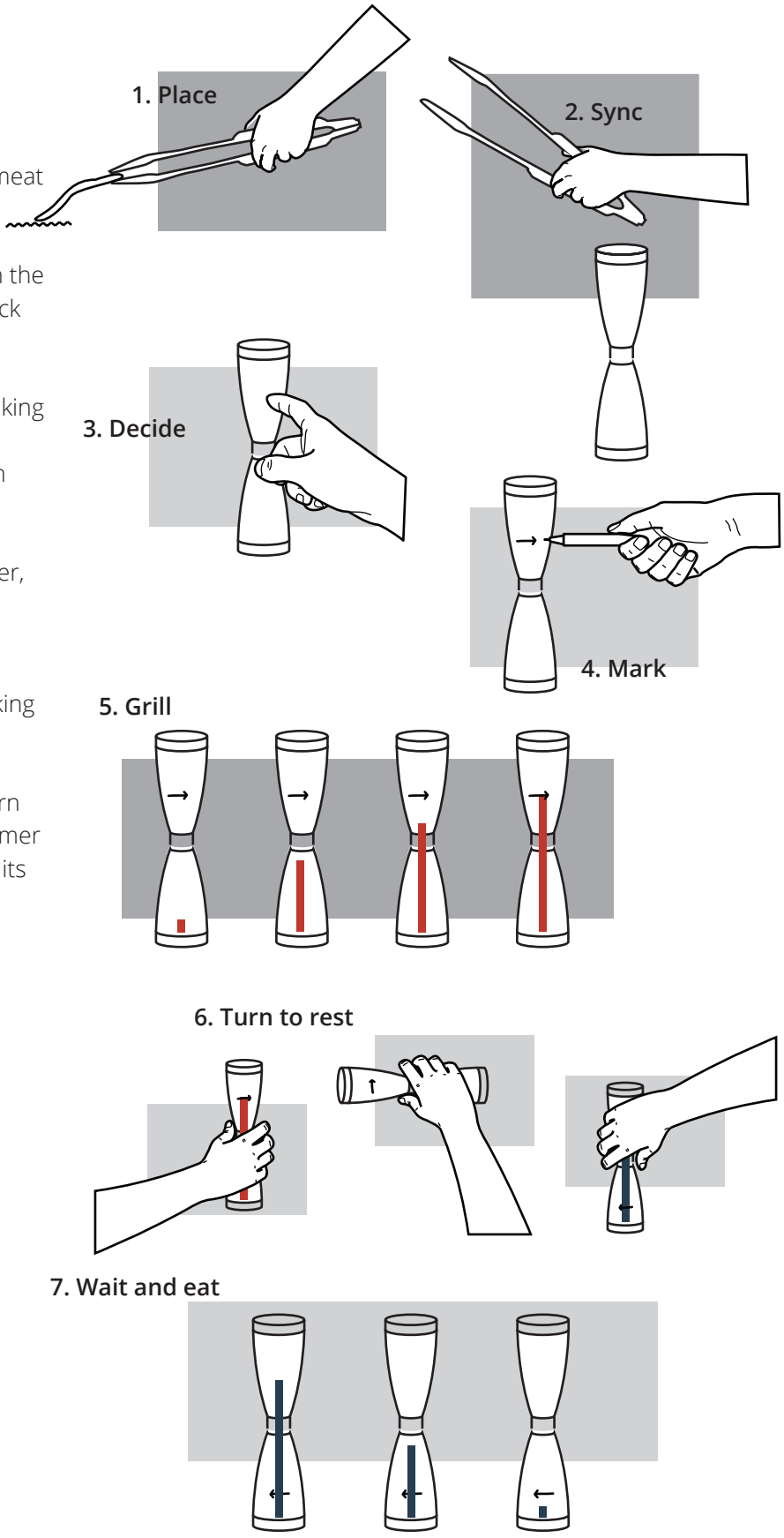


Figure 47. Pitmaster scenario.

Figure 48. A flipped timer can become a resting timer

17.3 Timer shape

The shape of the concept is based on the shape of an hourglass. What is should convey is a reference to time and pace. Since it affords flipping, it should somehow convey that as well. Also it has some features that are seen in salt- or pepper dispensers.

Next to the hourglass reference, the (vertical) symmetrical design does hint that it is possible to be flipped. A tradeoff of this shape is the height/width ratio. It should be high because then there is room for a bigger progress bar. This increases the amount of information that is visible to the user. The progress bar is made up of LEDs so more LEDs means a more accurate display of progress. For example: displaying five minutes with 5 LEDs has an accuracy of 1 minute whereas displaying the same amount of time with double the LEDs (10) has an accuracy of 30 seconds (half a minute).

While it is obvious here that higher is better, there is a limit. Under reasonable circumstances the cooking won't have a significant impact in terms of seconds. Taking into account short cooking times as well, e.g. one minute, for this concept 10 LEDs seems to be a good start.

The width is also a considerable factor here. Looking at the barbecue tongs, measurements are communicated through a tapping interaction. This means that there is a risk of tapping it too blunt, resulting in the timer falling over.

By creating more width at the top and bottom ends, the tipping point is reduced so it gets harder to push over the timers. Next to the shape, the risk of falling is also considered in configuring the positions of the technical elements. The battery will be the heaviest part of the product and therefore it is places at the bottom when the timer is in cooking mode. In cooling mode, the risk of pushing over a timer is reduced so then the tipping point is less relevant.

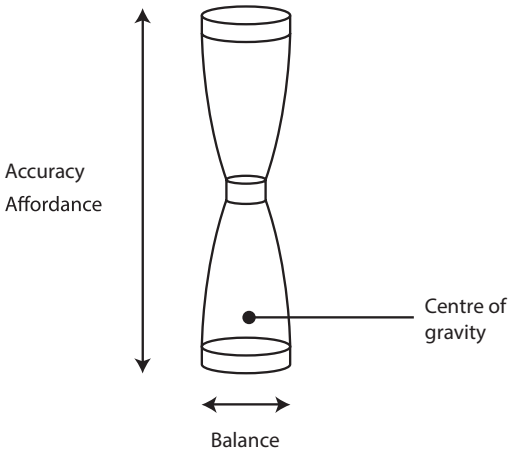


Figure 49: Timer shape features

17.4 Practices

The timers as a tangible user interface allow for multiple types of practice. Some of the potential ways of using the Pitmaster next to the already shown scenario:

1. Analog marks are great to use with the timer functionality. One could even copy them from a special cookbook (Figure 50).
2. The mobility of the timers can provide a way of monitoring food from a distance. It can be obvious and have a dominant place or it can be put in a pocket as a way to 'cheat'.
3. For a lazy chef the timers are an easy escape and he can hand them to the people who are eating (Figure 51).
4. They can be sold together with food or when buying meat from a butcher he might be able to advise or make the mark.

Figure 50. 'Analog' use of the timer

Figure 51: Use of the timers by a lazy or social chef: everyone is in charge of their own food

17.5 Evaluation

How does the design consider the established design principles?

The grill is my castle

Customized timers allow for personal interpretation of the progress bars. Doing things your own way and doing what other people might not be able to grasp immediately enhance feelings of identity and control. The system collects and affords educated guesses. The user still does the decision making and feels in control. Timers being focal things require the user's attention which contributes to feelings of being needed and not excluded.

Lower the pressure

By using the product the user's estimations about the food will become more accurate. This affords some degree of moving around and ease of mind because the user has an idea about the time he has before he has to interfere. The mobility of the timers also increase this effect since they can be seen from a distance or can be taken along by the user.

Let me remember

There are two ways of remembering information for future use.

Analog
The material and shape afford various ways of adjusting the progress bar. Also social media can be used to inspire people to do this. Labeling the timers can on one hand help to remember preferences for (repeated) use. On the other hand, it helps to remember the link of the timer with the associated piece of food on the grill.

Digital
The digital component collects the data and displays this after a certain number of times it has been used. This data can then be used to optimize or reflect on the grilling performance.

Improve me

For improvement, information is needed to act upon. The barbecue system provides more information. Impact from ones action around the barbecue is reflected in the timers. Rising temperature for example, can be seen in the acceleration of the progress bar. Next to that it is easier to improve because previous steps are not forgotten. The analog and digital data provide the information even when last use was a while ago.

Because of the iterative design approach a lot of the evaluation comes from intermediate interventions with the user. Because this is not the same as evaluating the system as a whole, Pitmaster will be evaluated during the final stage of this project.

17.6 Strategy

Two directions would be recommended for future product positioning:

Weber tool
The barbecue accessories from the Weber brand dominate the Dutch market. Chapter 4 shows one of the latest ones which comes with an app. It probably has given Weber some experience with digital services around the barbecue. The experience could be used in developing the Pitmaster to a market ready product.

Kickstarter
The Pitmaster seems the kind of product that the gadget-freaks of kickstarter would appreciate. Being able to remotely alter functionality provides the opportunity of launching the product early and developing it with peers. With the available sensors and actuators an interesting open source community could arise.

18 Barbecue as a showcase

The barbecue experience has been the subject of the research of Internet of Things potential. In order to grasp the underlaying system qualities, they are elaborated on in this chapter.

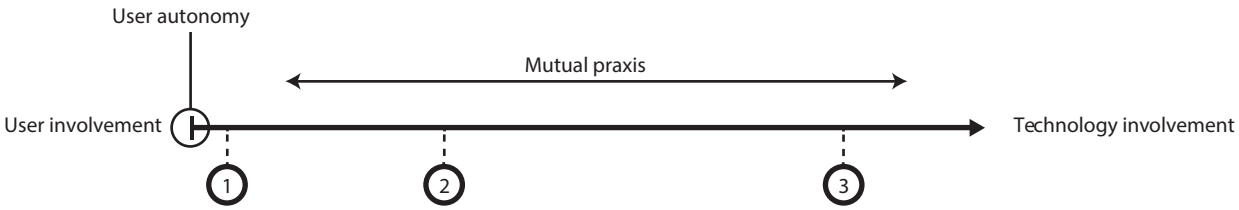


Figure 52. Division of labor scale of current practices

18.1 Focal things in practice

What are focal things?

According to Fallman (2011), the typical attribute of a focal thing is that it puts a number of demands on its user(s). These demands generally require presence, patience, endurance and skill. They are often true demands you cannot opt out of: things you have to do.

The focal thing is not an isolated entity, it is a material center in a complicated network of human relationships and the relations to their environment and cultural setting. It connects means and ends in a way of: 'I have to do this in order to get that.' The action of 'have to do' here does implicate a certain amount of effort because Borgmann puts the focal things at the opposite of 'regular' devices.

Devices

These 'devices' are designed with a limited purpose and can merely be consumed. For example: heating your house is now a matter of turning a knob. The means and ends are somehow connected but the ratio is different. This becomes obvious when it is compared to the old-fashioned way of making and maintaining fire in order to heat a house.

In IoT even more objects and contexts are hidden from the user which means less focal things and more ambiguity. An clear example being domotics where objects in and around the house are getting smarter and respond to the presence or absence of a person.

Implication

Now we don't want to condemn all technology and go back to having to do all kinds of effort in order to meet our basic needs. The goal here is to find a balance. A balance where using a product puts a set of demands on the user. For the barbecue experience that means: Enough demands to make the connection of means with ends; barbecuing and claiming the result. Not too many demands that will frustrate him like how currently barbecuing is an event full of trial and error.

Focal things in practice

Barbecuing as it is now, already is an example of focal things in practice. While grilling food, continuous attention is required to prevent it from burning and predictions have to be done about whether something is cooked well enough or not. This requires specific skills and experience.

To have an overview of how the barbecue experience relates to other ways of cooking we will look at different ways of focal things in practice and how these make up a scale of labor division (Figure 52).

The two extremes here are as follows: on the left the user is doing most of the work. It's the extreme version of hippie culture where most of the food is home grown and the way of preparing is a wood oven, natural acids or fermentation. (1)

On the right side the user is involved only a little. A pre-cooked meal is selected and heated in the microwave according to the description. (3)

The barbecue experience would intuitively seem to be placed somewhat left in between the extremes (2). Compared to an oven or pan it is somewhat less predictable in terms of temperature. Also: with the lid closed, the process is invisible. For these reasons, among other things, the barbecue requires more attention and skill than conventional cooking methods.

With the mapping of the barbecue related to labor division and cooking practices we can progress to the next stage. Since the product is being redesigned, it needs to find a new place on the scale. Choosing this new spot means taking into account the design principles and possible solutions.

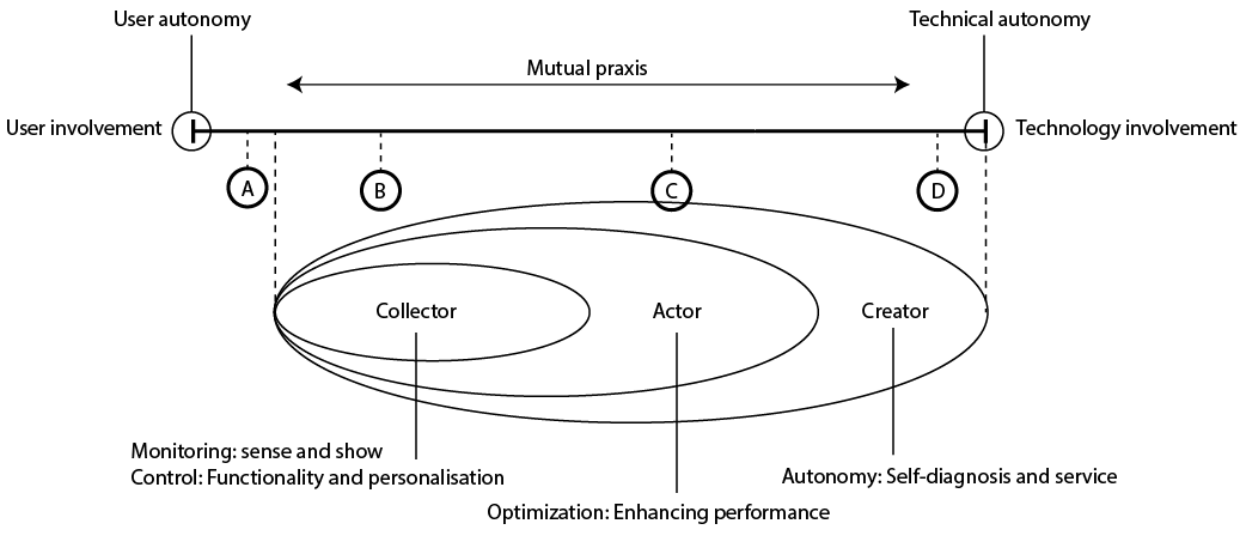
IoT

For a big part the solution space consisted of potential IoT technology. Naturally, incorporating IoT will often result in moving right on the scale. Whether there probably could be scenarios where IoT involves the user even more, for now the involvement of technology means to take over some of the labor from the user.

Using the graph from Chapter X about IoT products as agents, the different roles that the product can have are shown in a combined graph (Figure 53). Using the new technologies the graph could be extended towards technological autonomy. The old barbecue is on place A.

With the chosen target group and design- brief and principles, the current system does not allow for much technological autonomy. The product therefore has become a collector that supports the user in his decision making and predictions (B). The user still has to do a lot of the 'labor' and therefore the position of the concept on the scale will only move a bit to the right.

Figure 53. Division of labor scale of future practices



For a different target group there will be other cases in which there might be a lot of demand for this autonomy. If we would for example design for people who are severely limited in their physical capabilities, the concept could be shifted significantly more to the right into the Actor or even Creator role. (C)

Lastly, if we would want to design the most active machine possible with the least user interference we would end up somewhere near D. It could be a self-aware machine that optimizes every cooking process of the food it harvests. The user is simply there to eat.

Accuracy/investment

Next to demands from the user from an experience perspective for example, there is another potential incentive to keep the product relatively on the left side of the division of labor scale: money.
If the product starts to act independent of the user's skill, it has to somehow make more decisions on its own. This implicates a more dominant role for hardware and software and also an increase in accuracy since the user is less likely to intervene. The product will be in the 'Actor' range because it needs to optimize itself and make decisions. It will require more investment in hardware and (learning) algorithms. Whether investment was not on top of the priority list during this project, it can be important for other projects where there is a similar tradeoff.

18.2 Changing role

Improving

Using the product, there are a couple of things happening skill-wise. Actually, three learning activities will possibly be observed:

1. The user improves in using the product
2. The user improves in barbecuing
3. The barbecue improves in visualization: richer information

For any product that is acquired, there is a period of time where the user is getting used to it. When buying a new watch, the first couple of hours or days someone will be aware of its weight and maybe its way of displaying the time. After a while the product becomes an extension of the user and its use will come natural, more fluent (1).

The user's barbecuing skill is improved (2) by: seeing the impact of actions or phenomena on the timers. For example closing the lid and seeing how the timer responds (accelerating or warning). While this already provides more insight for decision making, customizing the timers provides references for comparison. This way it is easier to see whether you like it the current way or the previous way and eventually tweak it to perfection.

For example: the user makes a guess about when to take a burger off the grill and marks a spot on the timer. With the result he adjusts the mark for the next session.

The memory of the system provides data for comparison as well. (3)
It learns from the user's decisions and collects the timestamps. These are visualized as a change in color on that specific area on the progress bar.

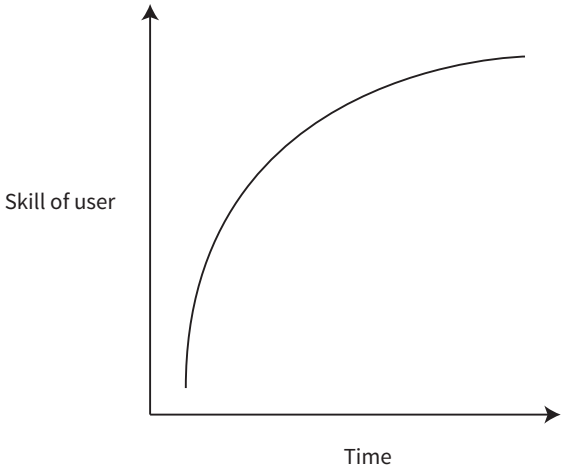
The improvement of the user will look something like this (Figure 54a). At first, most information is new and the learning progress is high. After a while, there are no new things to learn and the performance is just increased as the user will get more accurate. This can impact the user-product relationship in a couple of ways. The two most obvious being:

1. The user improves and does not even need the product anymore or is not challenged by it. The product becomes obsolete or boring.
2. After barbecuing a lot, the user is not really interested anymore in doing things himself. He trusts the system and feels comfortable in delegating tasks.

Delegation paradox

In relation to delegation, this can mean either that the product is going to have to do even less in order to challenge the user (1). Or the product has to start doing more to fulfill its role as a 'slave' to its owner (2). (Figure 54b)

Since these actions are opposites, somehow the product should know what the user wants. It might be necessary to get more input from the user: what his/her skill level is, for example, could be measured by reaction times. The way this input would be generated is interesting. What if the user would have a choice? If the user has the ability set a program where the system will do more it might be that this is going to be the default option for most users. Will this inevitably lead to a commodity-driven device again?



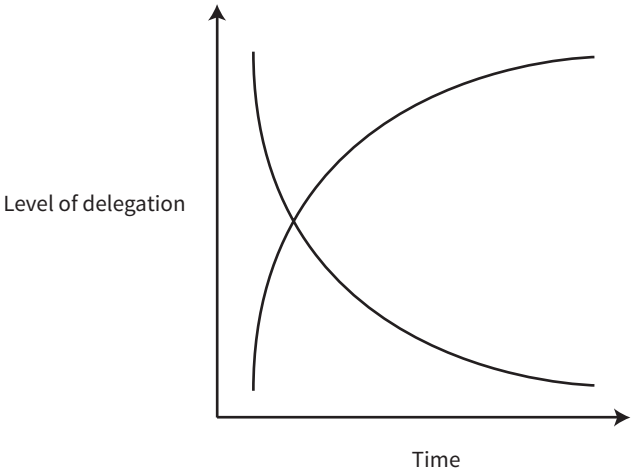


Figure 54a. Rough user skill level over time

Figure 54b. Delegation paradox

18.3 Interface

Mutual praxis means that the product and its user(s) have to cooperate. This means that two worlds will come together and both parties need to understand each other. The interface between these worlds can have all kinds of forms and often relies on interpretation.
In this report the most obvious distinction was made between different interfaces: a Graphical User Interface and Tangible User Interface. The new barbecue system has a combination of both.

Practises

TUI tangibles are persistent – they cannot be spontaneously called into or banished from existence. (Ullmer & Ishii, 2000)
This makes them very suitable to be focal things. Next to that, opposed to Graphical User Interfaces, tangibles allow for more degrees of freedom (Figure 55). They can be manipulated in free space by six degrees or less, depending on the design, whereas a GUI is often limited to a two-dimensional screen. Because of this freedom in using the tangibles and their persistent availability, they allow for more practices and this supports the mutual praxis in a way that the user has multiple ways of engaging with the product. The progress bars on the timers make up a GUI and show the information that has to be interpreted by the user in order to use the timer objects.

Generally, for some IoT products it might be interesting to take a look at the opportunities of a TUI, especially when the design has an important role for the user. This can be analyzed by using the division of labor scale and determining the position of the (re)design.

18.4 Iterating through things

Looking at the options and studying the many variables in designing for human-computer collaboration it is clear that things can get complex really fast. An iterative approach like the one during this project seems to work here because the mutual praxis can be determined early and provides directions for further development. The focal things and the 'things of the internet' can provide interesting combinations to iterate over.

Figure 55. A tangible user interface can allow for more freedom because it allows for manipulation in 3D space

“The expressive element of our actions is increasingly placed beyond our reach or influence as elements of action are fixed by, and incorporated in, the devices we adopt.”

Tatum (1994)

19 Thinking about technology

With the description and explanation of the product qualities as well as the underlaying system qualities, their impact will be analyzed further. Is there a way to predict how users are going to behave with the product?

19.1 Technology mediates

As Verbeek emphasizes in his book 'Op de vleugels van Icarus' (On the wings of Icarus), there is a need for new insights in designing with new technologies. He states this with a good analogy using the myth of Icarus: Icarus is imprisoned on the Island Crete and his father Daedalus wants to help him escape. Daedalus builds a set of wings using a wooden framework, feathers and wax. These wings are used by Icarus in an attempt to escape. His father however, warns him: if you get too confident and fly too high, the sun will melt the wax and you will crash. When you fly too low, the sea will make the wings too heavy and you will also crash. So try to fly in the middle.

This story is an analogy for the way we as humans should look at technology. We should not try to 'fly low' and deny the way that technology influences the way we think and act, even mediating our morals.
But if we get too confident (fly high) and say yes to every new development without a critical view, we might see the impact of technology as a fact instead of an opportunity for design.

Verbeek (2014) states that all technology has a mediating effect on the way how people behave as well as how other people perceive them. Verbeek also tries to reach out to designers with some guidelines about ethical reflection in designing persuasive technology (Figure 56).

Whether it is not clear that the concept meets the requirements to be a so-called persuasive design, the design does incorporate some intentions of 'persuasions' and at least an idea of how to use the product.

According to Don Ihde, one of the first philosophers that reflects on technology ("Prof.emir. Don Ihde," n.d.), technology is non-neutral and always mediates human experience. He suggests that even ubiquitous technologies have a mediating character that is not neutral, whether it is being used or not.

The digital camera makes for a good example here. When it is being used, one can imagine it takes up a lot of attention in order for the user to take the perfect picture. He can be looking at his camera more often than looking at the actual environment that is being photographed. It impacts the experience of being at a certain place. For a similar effect, it doesn't even have to be used. Having an expensive camera around can lead to behavior of avoiding to do activities that are potentially dangerous to the camera. Just by being there, it can influence the decision making of its user. Technology is also non-neutral related to fashion. It can be a way of self-expression to show off certain devices in front of other people (Fallman, 2010).

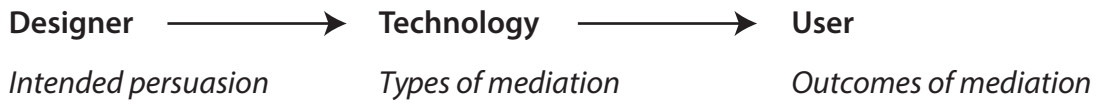


Figure 56. Guidelines for ethical reflection in design

As Ihde (1990) states: "For every revealing transformation there is a simultaneously concealing transformation of the world, which is given through a technological mediation. Technologies transform experience, however subtly, and that is one root of their non-neutrality."

19.2 Examples of mediation

It was attempted to somehow predict some of the Pitmaster's potential impact during the stages 'before use', 'during use' and 'after use'.

Before use

Taking a look at the barbecue system before it is being used, it is obvious that there is already a choice: whether to use it or not. Choosing not to use it could mean that a person is deliberately taking more risk while barbecuing. The other way around, choosing to use the system can also have an effect on the user that makes him feel 'weak' for choosing to be supported. A similar effect can be observed in discussions about driving a car manually versus automatic shifting.

It is an effect that probably always will be around but in this design it was considered by staying close to existing solutions (sensor tongs) in order to lower the threshold of using it and creating demands for the user to feel engaged and in control. Also providing ways for self-expression with the customizable timers.

A concrete action that can be taken here as well is to position the product with emphasis on it being something that helps the user to get better. Currently, there are numerous tools available in marketing that could help with the image of retaining masculinity and really taking ownership of the barbecue result: Influencers on social media or strong associations with other products that convey a similar image. The strength of these tools can be observed in the 'Man Tongs' for example (barbecue tongs, not to be confused with thongs..). These are a set of tongs that are relatively hard to squeeze, making them less practical but showing that you are capable of using it should show off some kind of masculinity. They were sold or given away for free with the famous beer brand Jupiler.

Figure 57. Masculine barbecue tongs branding

"Technologies transform experience, however subtly, and that is one root of their non-neutrality."

Ihde, D. (1996)

During use

Mobility

One of the features of the timers is that they are wirelessly connected to the 'system'. It means that their functionality exists partly outside of the product. In particular, the functionality of updating the timers according to live temperature measurements.
The impact of this design is that in theory, it is possible to check the cooking progress of the related piece(s) of food from anywhere. The idea behind this is the various ways of engagement and degrees of freedom for the user. However, there can be some downsides. Because of the availability of the timers, it can disconnect the user from the barbecue in a way that the timer has become the ultimate focal point. Instead of a tool for getting a better understanding of the barbecue process, it could become some kind of remote monitor.

Pace

A specific role of the timers is that they can be in resting mode. The function is changing from displaying a cooking progress bar to displaying a simple countdown. It was designed to increase the awareness and anticipation around the experience of eating. Since it applies to the user's patience, it can be tricky to design. Even though it is optional (you could just ignore it) it has some kind of dominance because there is a fixed time limit and there is no shortcut. However, looking back at the traffic light example (chapter X), there is a phenomenon that can show designs can work this way. With some of the newer traffic lights there is also a countdown timer. It reacts to the traffic light button

After use

Regarding the (subtle) transformation of experience by technology, it can be interesting to see the impact of this effect after using the product. From a positive angle, there might be an increase in use (more frequent barbecuing) because the barbecue experience is enhanced. The product's function is based on the user's inability of learning by doing because the doing doesn't occur that often. So when the frequency of use increases significantly, the user might progress faster and the product would become obsolete sooner. However, looking at the customer journey (Chapter X) it is obvious that there is a lot more going on around a barbecue event. The effort of preparing and shopping takes time and barbecuing still is something to do with a group of people. Therefore it is not expected that the frequency of barbecue will increase significantly.

Trends

In a society where trends are showing that skill and mastery are getting more important again on a smaller scale (bakeries, coffee places, beer breweries). It is important that people that use products to do something can take credits for the result. The Pitmaster does not take away too much of the agency and the result is the combined effort of human and technology.

Conclusion

The Pitmaster is a smart barbecue toolkit that evolved from an iterative design process. The goal from the beginning of the project has been to look into the potential of IoT for the barbecue experience. On the one hand Pitmaster shows that the potential is there, on the other hand also more questions came up during the project. The collaboration of user and technology was found to be interesting in this particular case. Analyzing and combining several theories and philosophies about Human-Computer interaction and ethics resulted in important insights and provide guidelines for future IoT projects.

As far as the product goes, it needs more development to be tested in depth but the foundation is there. It is built on the idea of the user working together with the technology. The user wants ownership of the result so the decision-making and effort are in favor of him/her. The role of the technology here is to provide information for the user to act upon. The Pitmaster has timers that can show the rough cooking progression of food. By marking the timers and learning from doing the user is able to improve. The product is targets men that were found to like being at the barbecue but criticised their own performance.

A lot of the technology is sensitive to the hot barbecue environment but IoT made sure that with wireless communication most risks could be avoided.

The combination of theories show that it is useful to map out the experience of a current product in terms of mutual praxis. This way a concious decision can be made about how the redesign schould relate to this. Making use of IoT, a redesign can be enhanced with technologies that will impact the mutual praxis. Looking at products as agents, it is easier to see what types of balance there are around this human-technology combination. In a time where a lot of technologies are made invisible, it can be interesting to look into new user-product relationships.

The type of user interface was found out to be an interesting opportunity to respond to the user-product dialogue. The persistent availability of the Pitmaster timers around the barbecue gives the user objects of focus and engagement. The way they are designed in combination with the function, the user is able to use them as a way of self-expression. Together with the performance enhancing features, it emphasizes on the user demands of ownership and skill.

Reflection

Process

In retrospect the project has followed an interesting course. In the first half of the process there was a lot of emphasis on the barbecue and technical opportunities. Then the project took more of an abstract turn. The division of labor, what was a factor from the beginning, seemed to resonate with theory about the mediation of technology, responsibility of designers and human-product relations. It did give the project more depth and this way is seems to be more valuable than a somewhat more market-ready concept. Because of the different perspectives and the time limit on the project, compromises had to be made. It seems that there is still more depth to it but with a concrete concept and relevant theory there appears to be a nice balance in the end.

Impact

University

Within the iterative design process there seems to be a great opportunity of experimenting with these mediations. An example: Steven Dorrestijn tested a new persuasive speed limiting system for cars. Depending on their location, the speed limit of the car was adjusted. The result was surprising. After a short period of getting used to the system, the drivers seem to appreciate the system instead of feeling annoyed by it (Dorrestijn, 2004). Because of the iterative nature of the project, multiple interventions can be done over a period of time in order to get a better feeling of a potentional change of behavior. Next to that, persuasive design deserves a more prominent role in IDE because it makes students aware of the fact that any product can influence the user's subjectivity.

Company

For info.nl, the company, the project is meant to be a source of inspiration as well as a showcase that appeals to a lot of people. The analysis of the showcase also provides interesting theory that is visualized in order to be able to see how other product would relate to this. Therefore it is suited to be used when designing a new IoT product.

Responsibility

Ethics is not a choice, to a designer it is an inevitability. While the effect of technology on experience might be subtle, designers should have the bigger picture in mind. What does the accumulation of all these subtle changes does to us? Technology itself does not only change our view on products but is even able to change our way of looking at ethics.

Personal

Future

What I found out is that the project has reassured me of the type of work I want to do post-graduation. I really like to make 'quick and dirty' prototypes and do a lot of research through designing. Additionally, the philosophy about technology I encountered during the project has gotten into my mind. I feel like there is a lot to explore and I hope to find myself in a position soon that will enable me to pursue this. The project feels like it is somehow still the 'tip of the iceberg' and I could definitely be working on it for another year.

Peace of mind

I did notice that I have a tendency to do a lot of work in parallel. A lot of ideas will just be in the back of my mind waiting for integration. With this experience I concluded that I should try and adopt the iterative design process even more in a way that my thought processes also get more iterative. In particular the closing part of these iterations are important: Drawing the line when something has been worked out to a sufficient level. It will probably help me to keep priorities and have some peace of mind.

Recommendations

Limitations

The first part of the project, especially the direction of designing for user performance, was based on quantitative research. The rest of the project however, qualitative types of research were done involving one or two participants (brainstorms, walkthroughs and interventions). Even though these resulted in useful insights, more in-depth research is needed to cover a larger spectrum of the target group.

The project started out somewhat practical, the redesign of the barbecue experience was the main focus. Later on it took a more abstract turn and there was more emphasis on the role of technology in the design. Within the time frame of this project there was not enough room to deepen both the concrete and abstract layer. The result is somewhere in between. It is a proof of concept of how technology can be integrated while respecting the autonomy of its user. The concept needs more evaluating in order to refine the exact shape, color and functionalities. A first step will be taken here in the last phase of the project after completing the prototype.

Opportunities

Integrating theory
Some interesting relations between different taxonomy and theory was observed during the project. Even though it might only be a first step towards a theoretical framework for IoT, there is something interesting going on between the ethics, technology, mutual praxis and interface types.

More projects like this should be executed and really create a common ground in order to make IoT meaningful.

Product
Features of the Pitmaster allow for the remote adjustment of its functionality. It is a delicate matter but it could be very useful to create a kind of dynamic behavior, further emphasizing on a potential adapting product. It requires more testing and new ideas of how to identify a user and make him/her trust whether this new user-product relationship can work.

Strategy
The connective properties of the product allow for updating the functionality remotely. This way existing users can contribute to the quality of the product. A kickstarter project would be a suitable strategy here since the buyers know about the beta stage of the product.

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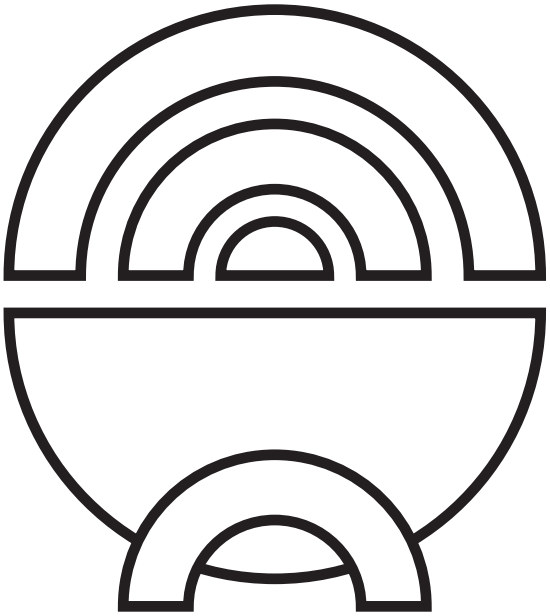

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