Dumbo, Design Process Report

Honors Academy Professional Development Report

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ABSTRACT

This report contains the overview of the design process for the user interface of Dumbo, an intelligent device which labels human activities based on ambient sound. The software of the device is programmed to adapt to each of the user's household, and the interactions are designed accordingly. Dumbo is composed by two parts: a physical device and a mobile application. The overview describes the design process from after the concept report, to the final prototype with insights from: content strategy explorations, interaction design explorations (for the physical device), visual design and final execution. The last part of the report contains a reflection in relation to the initial learning goals.

Authors Keywords

Interactive intelligent system; physical user interface; digital user interface; rich interaction; smart textiles;

PROBLEM

In this phase, the brief was analyzed and broken down into requirements in order to understand what exactly was needed for the user interface.

The system that needed to be designed aims at providing real-time, local ambient sound recognition for the smart home with the help of machine learning algorithms. The system was a research prototype and the software would be integrated into a physical design. It would use a standalone microphone and a Raspberry Pi 3 single-board computer. The device needed to communicate feed forward and feedback to the user through a user interface, and it also needed to collect user input for continuous learning. In this way, the system would be able to adapt to any household it is placed in. The system is not connected to the Internet and does not upload any data to the cloud.

The device would be designed with the Internet of Things in mind and it would be open for further connectivity.

CONTENT STRATEGY

In this phase, the rationale behind the type of device and the content of the product was designed based on the decided functionalities. The user scenario was simple: the device can label activities by analyzing ambient sound and output the label to the user. The user can decide whether the label is correct or not, and, if not, re-label it with an existing label or a new one.

However, because this was a sensing system, close attention had to paid to Belotti's 5A's [1] - Address, Attention, Action,

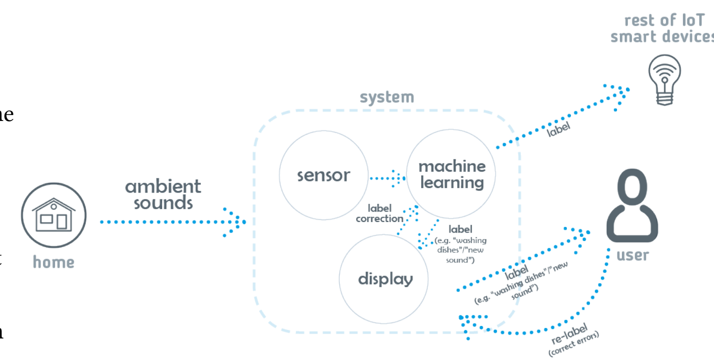


Fig. 1 - Our system's input-output dynamics

Alignment, Accident. These principles were created with regard to the following questions which had to be answered when designing the interface of our system:

- When I address a system, how does it know I am addressing it?
- When I ask a system to do something how do I know it is attending?
- When I issue a command (such as save, execute or delete), how does the system know what it relates to?
- How do I know the system understands my command and is correctly executing my intended action?
- How do I recover from mistakes?

Therefore, the functions of the device were: signaling it is listening, signaling it detected something, communicating the current activity. The capabilities of the user could be: ignoring or denying a label, (in case of ignoring) re-labeling an activity, listening to daily activity snippets, reviewing a daily list of the activities, modifying a list of labels (re-naming or adding labels). The following definitions were decided upon:

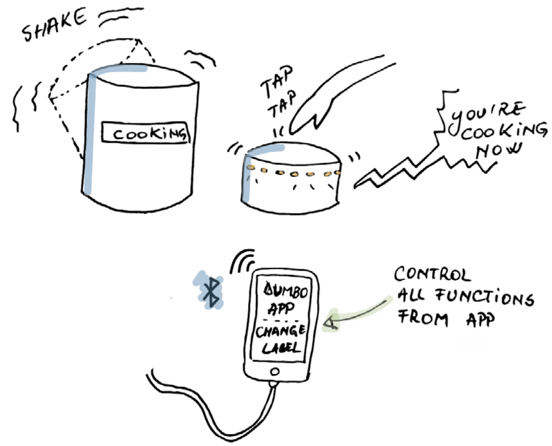
Activity = a snippet of sound detected once by the system

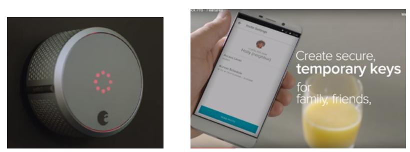
Label = a name given to a group of activities ("Shower" is the label of all the samples of sound from when the user has showered).

The initial design includes a centralized system (i.e. one locus of interaction) because of time limitations and also the scope of the project (quality not quantity). [10].

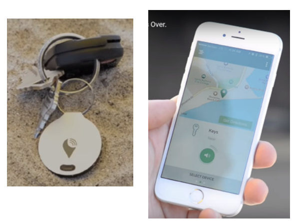
The next step constituted of an exploration of forms of UI and PROs and CONs for each form with corresponding examples from the industry of smart systems. Our system was given the name of "Dumbo".

A. Physical UI & touchscreen GUI - Dumbo with limitted interaction & mobile application

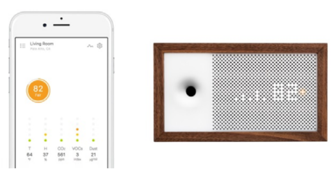




August smart lock & app [2]



TrackR bravo - tracking device & app [3]

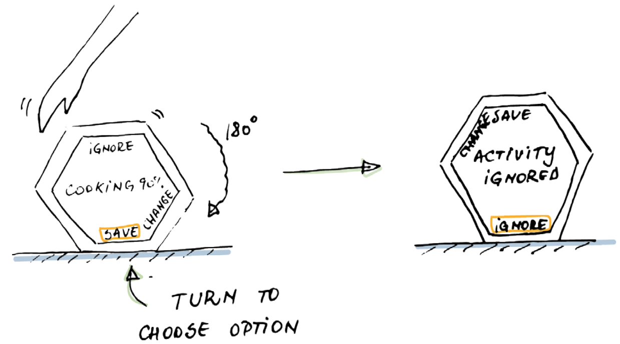


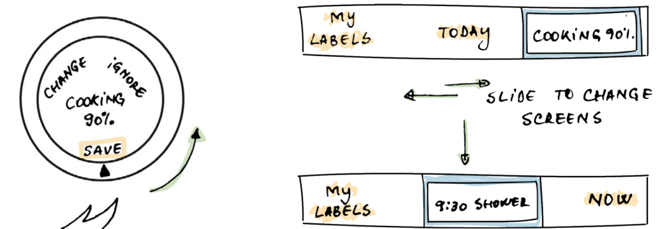
Awair - Smart Air quality monitor [4]

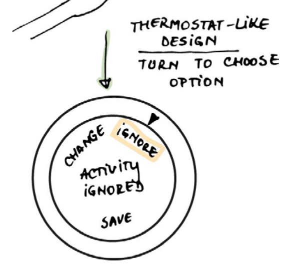
PROs: the app gives privacy - only the owner can view past activities and change labels.

CONs: harder to design emergent functionalities, user dependent on the phone

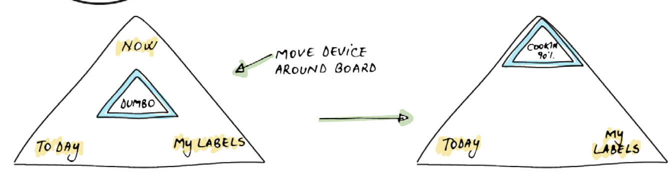
B. Touchscreen GUI with physical controls for menu options







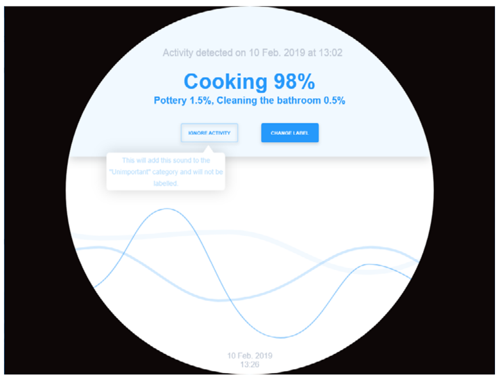
Skydrop - Sprinkler Controller [5]

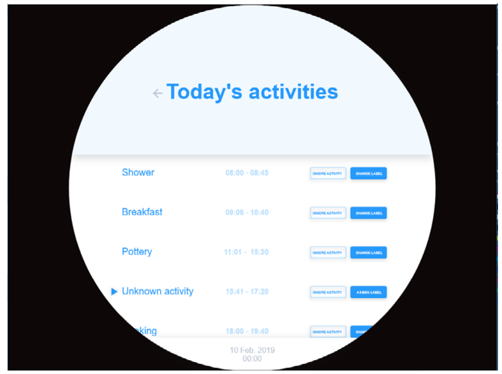


PROs: more interactive and intuitive, better user experience than a simple screen

CONs: more difficult to design emergent functionalities because of the limitation of the physicality, privacy is gone unless the owner has a token

C. Touchscreen GUI only (an initial mock-up was executed for this form as an initial exploration into Dumbo's functionalities - see below, please check [this link](#) for full videos)





Honeywell -smart thermostat [6]

Hydrawise - Smart Irrigation Controller [7]

Amazon Echo Spot - Smart Alarm Clock [8]

PROs: easy to implement future emergent functionalities

CONs: less exciting interaction, privacy is lost, unless the user has a token

In the end, the first form was chosen (physical UI + mobile application). This form offered the best of all worlds: an opportunity for designing an intuitive exciting user experience within the physical device, a higher level of privacy for the user's data within the app (because the smartphone is a personal device), a more innovative design compared to a simple screen, and, since the physical device would perform the listening, a more convenient system - the physical device can be moved wherever the activity is while the screen is always accessible from any location since it is on the phone.

Next, the functionalities of the physical device versus the digital interface were divided.

Physical device:

- Signaling it is listening
- Signaling it has detected something
- Communicating the current activity (with highest confidence)
- Saving/Denying a label

Mobile application - same as the physical device plus:

- Changing a denied label
- Listening to daily activity snippets
- Reviewing a daily list of activities
- Modifying a list of existing labels (adding/renaming)

In this way, the physical Dumbo would contain less private information, allows for peripheral attention [9] from the user (listening and detecting an activity) so the user does not have to consciously access the device to see whether it is listening or detecting and, last but not least, allows for on-the-spot interaction which is convenient. On the other hand, the application contains more private information (i.e. the daily overview and list of labels), requires the user's central attention , allows for personalization and can remotely control the system from any spot in the house.

INTERACTION AND VISUAL DESIGN (PHYSICAL DEVICE)

In this step, the manner in which the content structure would interact with the target audience had to be thought of. Since the physical device offered the most exciting design opportunity and the one with which I had experience the least, it was the first one I started with.

- **Listening and detecting**

As mentioned above, in order to not bother the user and require her full attention, the listening and detection of activities had to signaled in a non-intrusive way. For this, an LED strip was chosen. The LEDs would have three states: off if Dumbo would be off, constantly on if Dumbo would be listening, and animated if Dumbo would have detected an activity at the current moment. It was decided for movement to be used instead of lights so that the user's perceptual and not cognitive skills would be atoned [11].

- **Asking what the current label is**

For the user to ask Dumbo what action it thinks is performed at the current moment, an open-close functionality was chosen. When the user "opens" Dumbo up, then the label would be revealed by audio (speakers) - this was done in order to avoid screens in the physical device. Then, two options - deny and accept - would also be made available. Once a choice is made (or not), and Dumbo is closed, it can go back to its normal state. There are many reasons for this design decision, among which the following can be found:

1. The action of opening is a metaphor for revealing something - in this case, the detected label.
2. As listening and detection were in the periphery, opening the Dumbo up requires the user's central attention - in this way, the user's full attention is shifted to making a decision whether the detected label is correct or not [9]. The user is fully aware of using the device for this functionality.
3. The two options of accepting and denying a label are only available in the "open" mode, after the system had communicated to the user the label "in question" - in this way, we create layers for modes-of-use. Therefore, mode-switching becomes physical, making the interface less confusing than if the buttons would always be available to the user [12].
4. It is solving the problem of activity interruption: if Dumbo is open, then the system knows that the user has taken a break from the performed activity (and, therefore, the activity might not be over). After the user makes a choice, then Dumbo can go back to listening and it does not mark the "break" as an ending to the activity in the back-end.

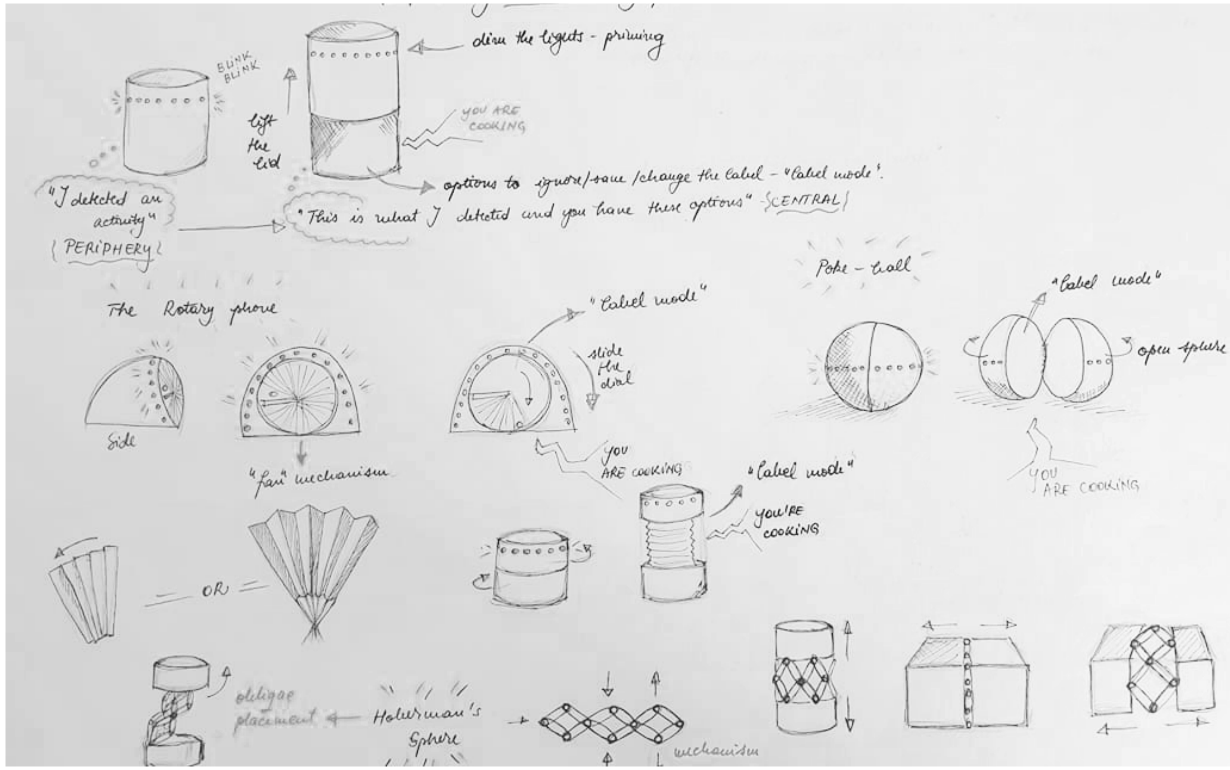


Fig. 2 - Ideation for open-close mechanism

Above, one can observe the initial sketches for different open-close mechanism.

- **Accepting or denying the label**

In the "open-mode", the user would have two options: accepting or denying the label. Again, I wanted to make use of the perceptual skills of the user and introduce haptics or texture into the interface. I opted for textures since in my research project, "Black textures", I researched the effect of colorless (black) textiles with different contrasting properties into physical user interfaces [13]. It proved to be a good alternative to flat materials (plastics/wood) and gave a new dimension to the interaction. Therefore, I decided to use this by making it interactive this time - i.e. using electronics to provide feedback once touched, therefore, using smart textiles. The different properties of fabric would be: harsh, soft, in between harsh and soft, smooth.

The way the user would interact with the two options could be: tapping, stroking, sliding, pulling or pushing the control.

With all these options in mind, an online survey was created for users to choose between what they would prefer. The results were used in the creation of the first paper prototypes of Dumbo.

The questionnaire explained what the system is about and asked users to choose:

1. for the shape of Dumbo between: spheric, cubic (box), or cylinder
2. for the open-close mechanism (independent of the shape) between: sliding, hinge, extendable or fan
3. for the deny and accept between: harsh (laser engraved felt), soft (suede), inbetween harsh and soft (felt), smooth (latex).
4. for the control of the accept/deny functionality between: sliding, tapping, pushing, pulling, stroking

The survey had 42 respondents the the top two results for shape were spherical (45.2%) and cubic (33.3%). The top three open-close mechanisms were sliding (36.6%), fan (24.4%) and extendable (22%). The top two interactions preferred were tapping (42.9%) and sliding (31%). For the smart textiles, the soft fabric won for accepting (45.2%) and the harsh one was chosen for denying (57.5%). The inbetween soft and harsh was on the second place for both.

The top two shapes and top three open-close mechanisms were combined in six paper prototypes, while the buttons were created with harsh material for denying and soft material for accepting.

The six prototypes (see next page for pictures) were tested in a focus group consisting of three participants where qualitative feedback was gathered. The participants were first presented with what the concept is about and what the functionalities are. Then, they were asked to handle the prototypes and express their opinions about the shape, the open-close mechanisms. The users were asked to express their feedback in the following way :

- I like... (the users had to tell first what they liked about the prototype)
- I wish...(the users could express things they would have liked to change about the prototype)
- What if...(the users could express their suggestions about what they would have done in this case)

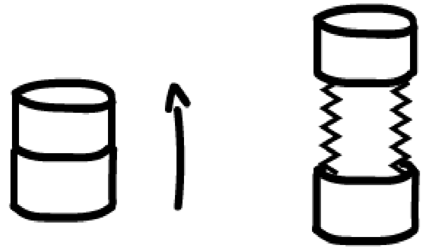


Fig. 3 - Extendable mechanism

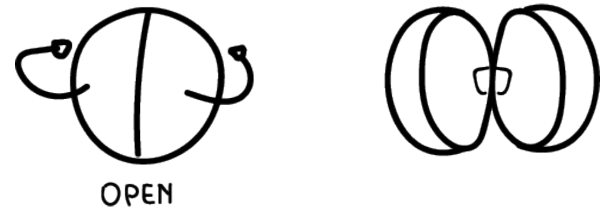


Fig. 4 - Hinge mechanism

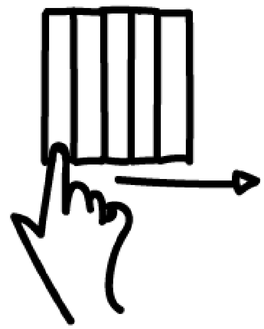


Fig. 5 - Sliding mechanism

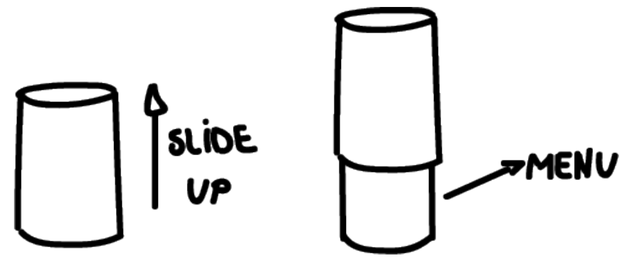


Fig. 6 - Sliding mechanism

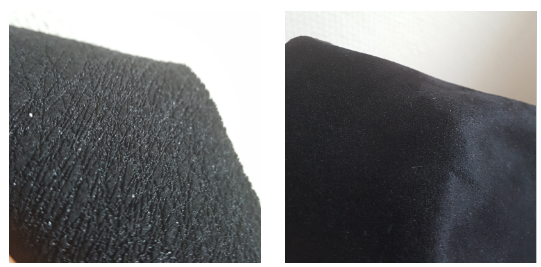


Fig. 7 - Harsh (laser engraved felt) vs. soft (suede)

Fig. 8 - Inbtetween soft and harsh (felt) vs. smooth (latex)

Fig. 9 - Focus group session with paper prototypes

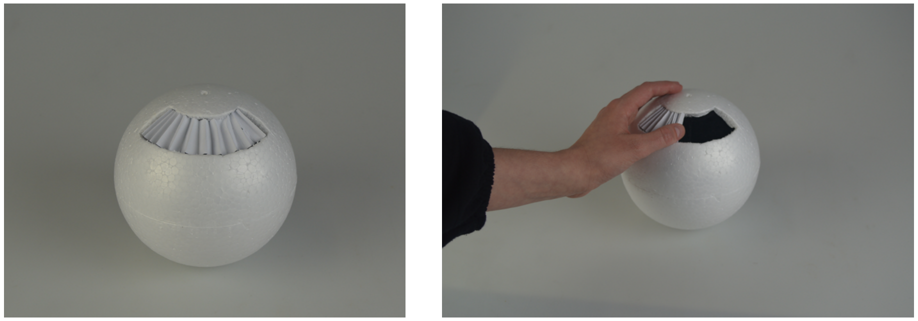


Fig. 10 - Sphere with fan mechanism

Fig. 11 - Sphere with extendable mechanism

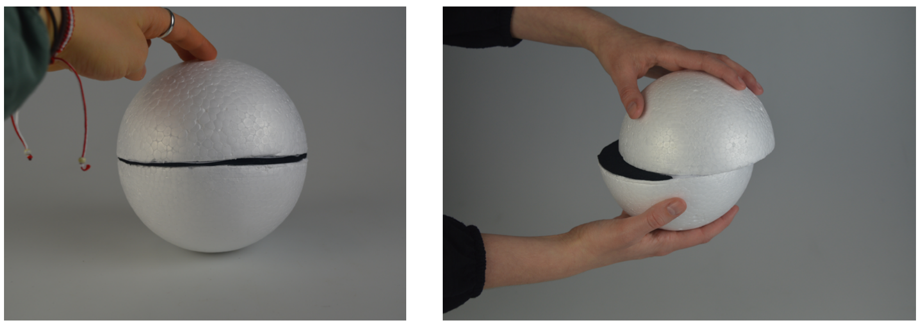


Fig. 12 - Sphere with sliding mechanism

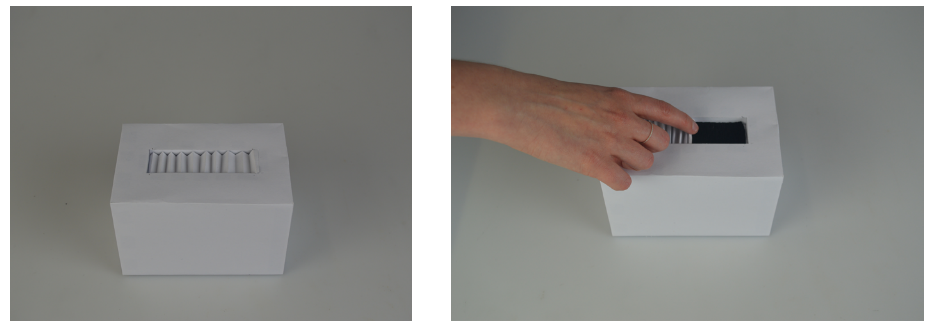


Fig. 13 - Box with fan mechanism

Fig. 14 - Box with extendable mechanism

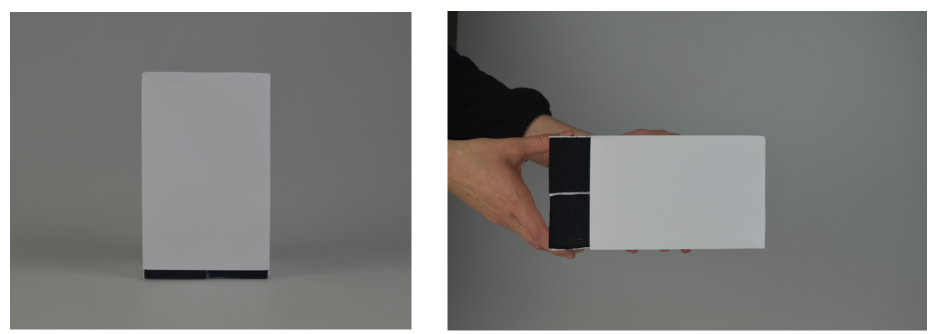


Fig. 15 - Box with sliding mechanism

Overall, the users managed to figure out which functionalities belonged to which interaction quite easily. They immediately identified the hash material with denying and the soft one with accepting. There was a slight preference towards the cubic shape: “I like its symmetry and sharp corners“ - User 1. The spherical shape elicited a little confusion especially when having to open the mechanism in the extendable and in the sliding forms: “I have the feeling it should turn somehow“ - User 2. The users liked the sliding mechanism the most - the looks of it when open, especially in the spherical shape. However, they expressed their concern that when sliding it back, the device should guide the hands as well having some kind of finger support.

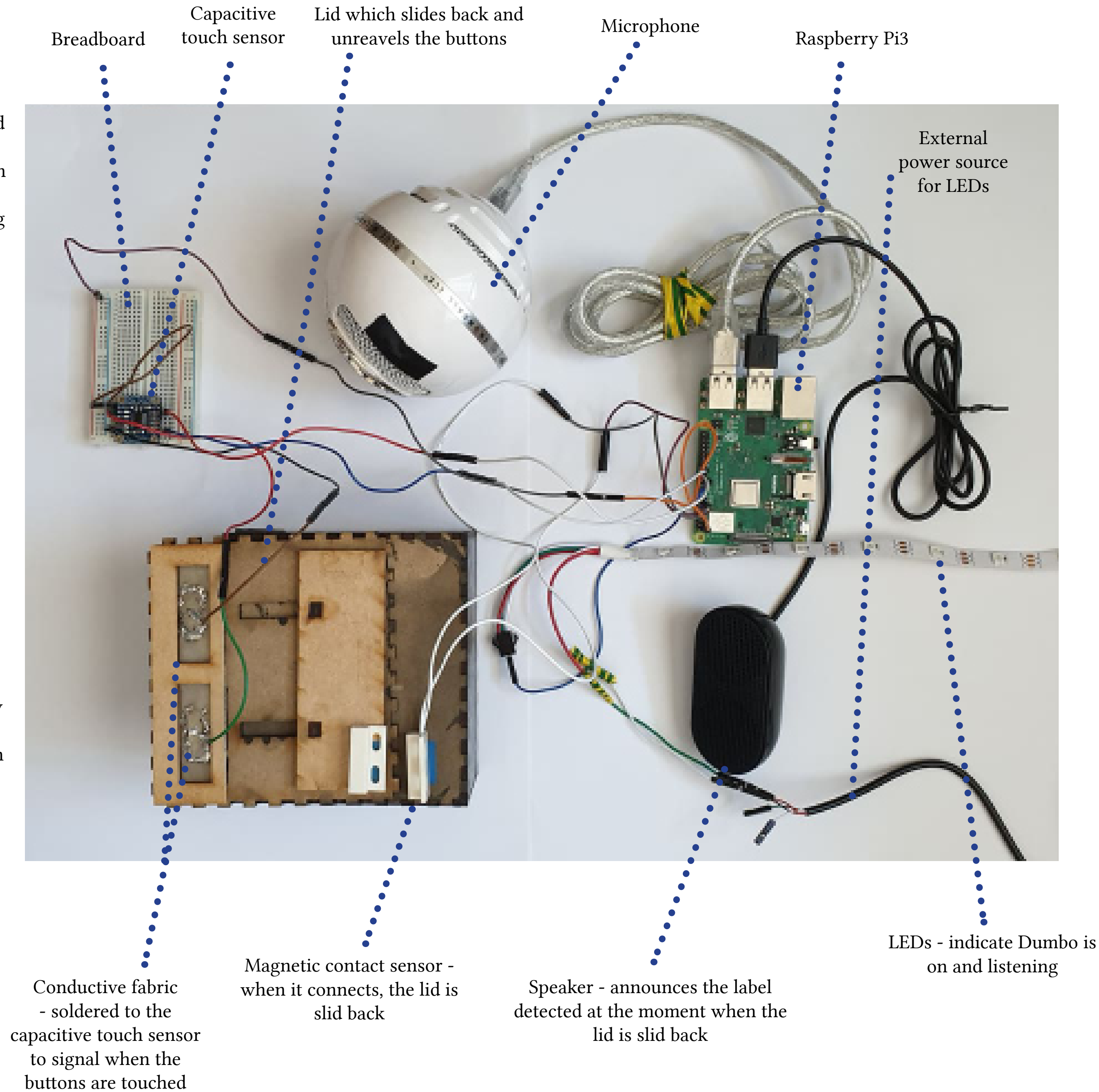
FINAL PROTOTYPE EXECUTION

Therefore, it was decided: the cubic shape with the sliding mechanism as in the spherical prototype would be built for the physical Dumbo.

In the meantime, the hardware components were ordered and the circuit put together. The hardware inside the physical Dumbo is composed by: the Raspberry Pi 3, a USB speaker [14] (for communicating the label and the chosen option - accepted or denied), a USB microphone [15] (for listening), a magnetic contact switch [16] (for knowing when the lid is slid back or not), WS2812B digital LEDs [17] (for showing Dumbo is on and listening) and a standalone 5-pad capacitive sensor [18] attached to a breadboard, from which wires are connected to woven conductive fabric [19] layered by the soft and harsh fabric (for the accept and deny options). The LEDs are connected to an external power source - a USB with a ground and a 5V wire connected to an adapter [20].

The case of the Dumbo was laser cut and spray painted. White interrupted lines were added around the harsh material for distinction of the denying function, while a smooth line was added around the accept function. Handles for the user’s fingers were added for sliding back, according to the focus group feedback.

The functionalities of the switches and sensors were programmed in Python with the help of the gpiozero library [21]. The wiring for the capacitive sensor was the most complex and can be found here.



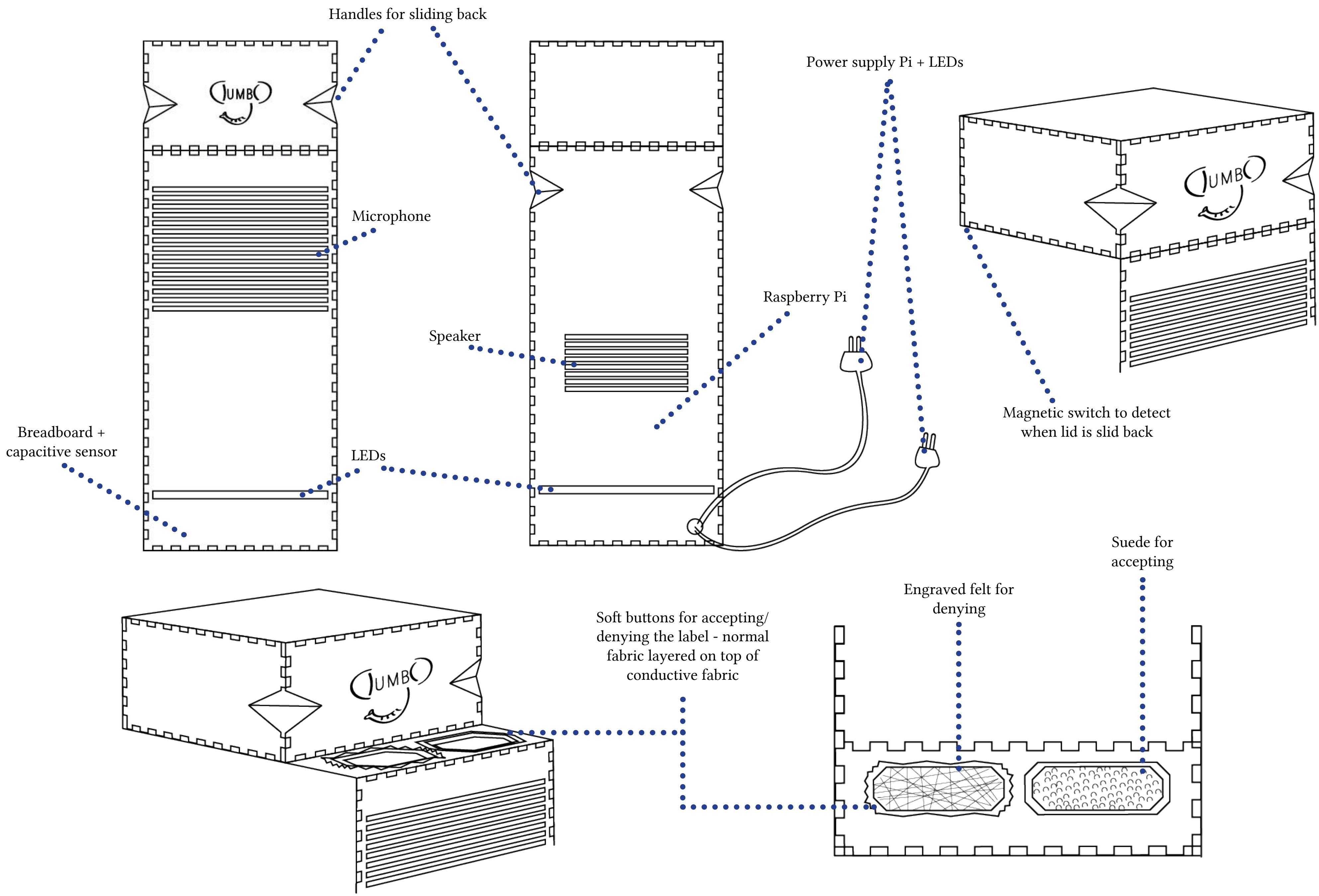


Fig. 16 - How the hardware is placed inside Dumbo; above row, from left to right: front view, back view, top side view when closed; bottom row, from left to right: top side view when open, above view when open

Fig. 17 - Dumbo from front

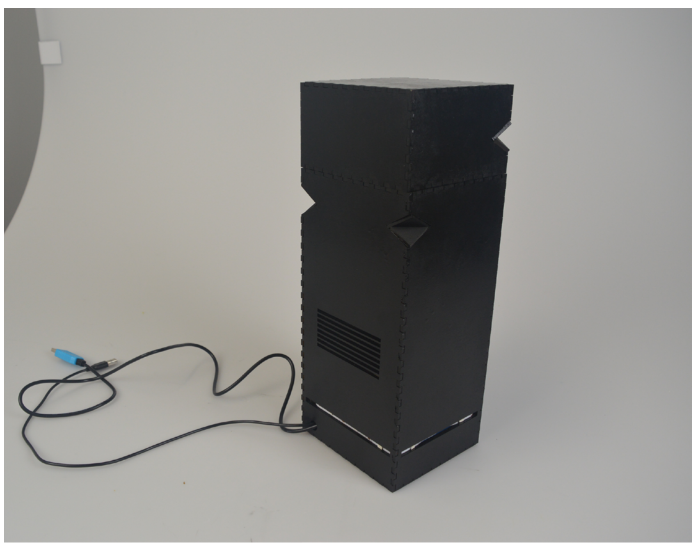


Fig. 18 - Dumbo from back

Fig. 19 - Dumbo top side view closed

Fig. 20 - Dumbo top side view open

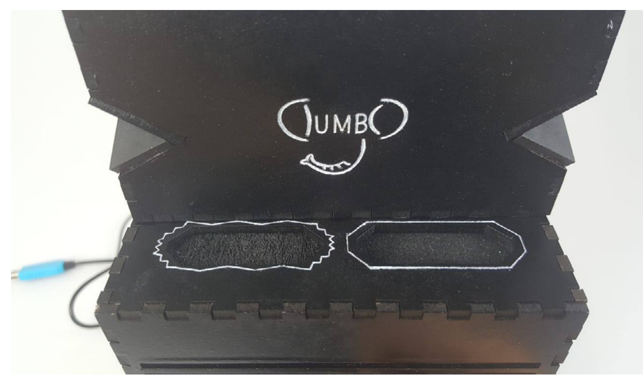


Fig. 21 - Dumbo top view open

For the mobile application, the prototype was directly programmed with HTML, Materialize CSS [22] and JavaScript for interactivity. The link structure of the app is flat - it does not have depth, but breadth for less confusion. Pop-ups and drop-down menus were used to avoid using too many screens.

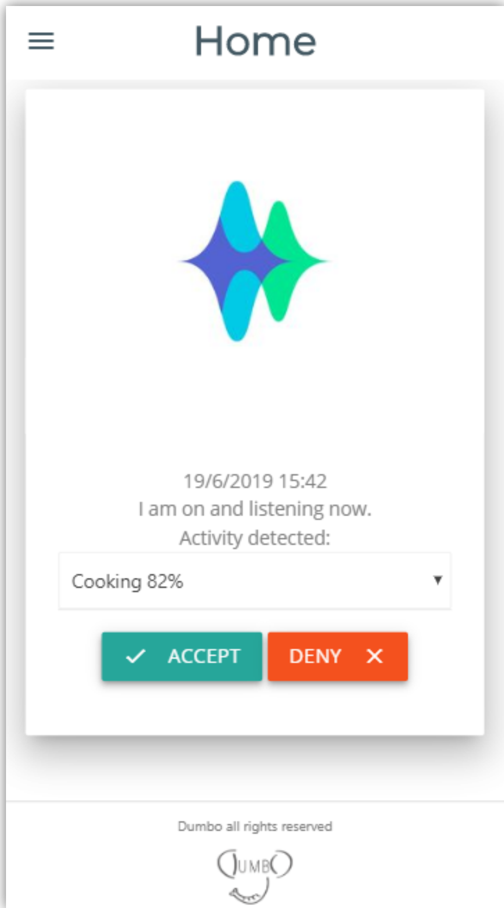


Fig. 22 - Dumbo app home screen; the user an see the current label with the highest confidence but she can choose two other different ones with lower confidences from the drop-down menu; she can also accept or deny the choice

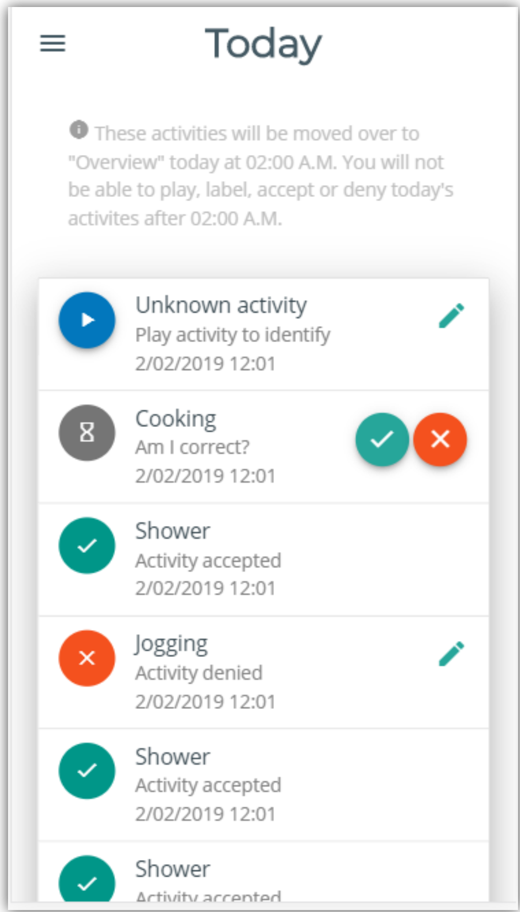


Fig. 23 - Today's list of activities; the user can view a list of all detected activities of the day; the user can play the unknown activities and re-label them; the user can accept or deny the ones that have not been accepted or denied yet (second example); if denied, the user can edit the label

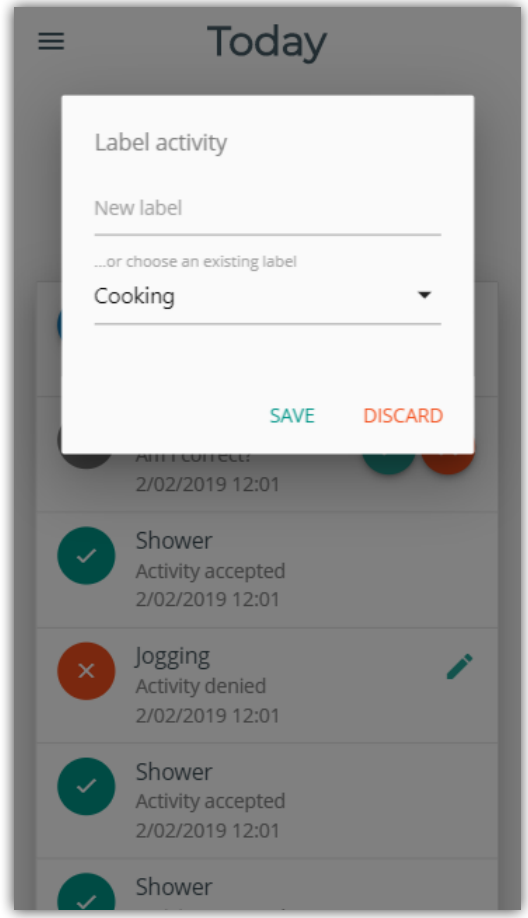


Fig. 24 - When denying, the user can re-label the activity by giving it a new label or choosing from the existing labels

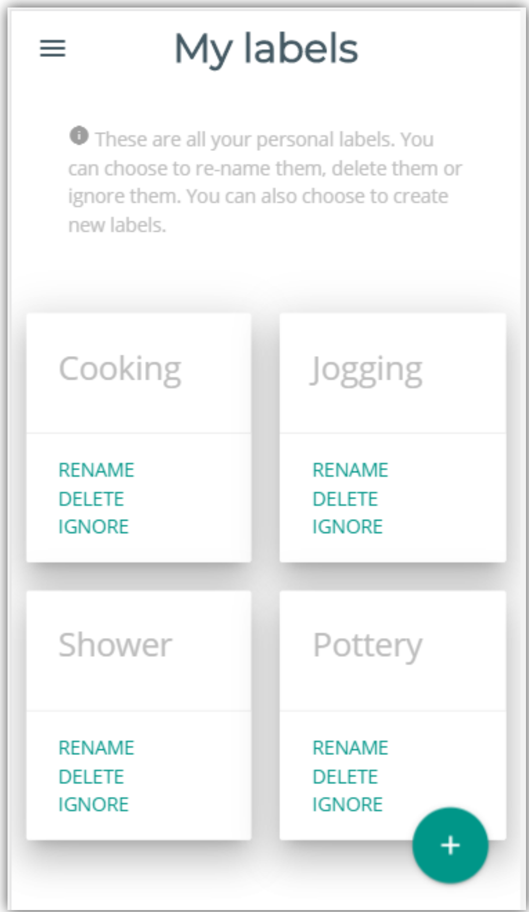


Fig. 25 -My labels page where the user can choose to add new labels, rename the existing ones or delete them, or ignore them (ignoring a label means that when the system detects that activity, it does not signal it, but it does add it to today's activities list in case it made a mistake)

REFLECTION

Learning goals before the project:

- Learning how to design a Graphical User Interface and a Physical User Interface for an autonomous, intelligent product which adapts to the behaviour of the user. Making design decisions in alignment with the back-end algorithm: how can the user give feedback to the system, so the system learns easily?
- Getting acquainted with Python, Raspberry Pi, sensors, AI models.
- Leading a team designing the AI product, working with AI specialists and helping them in the design and research process.
- Being involved in the planning and design of the validation session (focus group, criteria for experiment etc.).
- Analysing data (quantitative and qualitative) and writing paper.

Why did I pursue this project?

I took this project on in order to enrich the areas of expertise that the Master did not offer me the chance to practice. My Final Master Project (thesis) lacked in Technology and Realization and Creativity and Aesthetics in some places (Industrial Design areas of expertise) and, therefore, I decided to take this extra project on. Moreover, it was a way for me to branch out and work in a different area (UX design for intelligent products) to see whether this would be something I could pursue in a future job.

Learning goals and areas of expertise

The first learning goal consisted of designing a Graphical User Interface and a Physical User Interface for an autonomous, intelligent product which adapts to the behaviour of the user. This goal has been completed, by integrating "Creativity and Aesthetics" in the design method. I started with an ideation process from functionality to form by first researching the design opportunity and some similar products existing on the market. Afterwards, with the help of content strategy, I divided the concept into the physical one and the digital one based on the functions that the system had. For the design of the PUI (physical UI), I integrated different rich interaction techniques I learned during the course "A Designerly Perspective on IoT" given by Dr. Frens, assistant professor of the Industrial design Department, such as making mode-switching physical (creating layers for modes-of-use to make it less confusing), or principles from calm technology. Afterwards, I used surveys and a focus group to narrow down from a pool of design possibilities to one ideal design, touching upon "User and Society". However, hardware limitations came into the picture and I managed to think on my feet and compromise with the design accordingly. Moreover, I also used knowledge generated from my M2.1. research project regarding all-black soft interfaces by integrating smart black textiles into the prototype. For the GUI, I used simple design principles I "carried" from the human technology interaction courses I learned during my Bachelors.

Moving on to the second goal, I did manage to develop my "Technology and Realization" area in this project in the prototyping phase. I recalled web GUI prototyping by learning how to work with Materialize CSS and constructing the interface of the digital prototype. Moreover, I was in charge of identifying, purchasing and integrating the right switches and sensors into the physical device. I constructed the hardware structure of the prototype and the packaging. In this way, I learned how to work with a Raspberry Pi, Linux and program in Python 3. By designing the links between the back-end and the user feedback in the front-end, I managed to get acquainted and understand notions such as transfer learning, sound processing and classification, tapping into "Math, Data and Computing".

The third goal consisted of collaborating and leading the design team out of which two members were AI specialists. At the beginning, I lead the process quite frequently by showing them the way through the ideation and exploration phases, but also showing them how to document their development steps. Since I had more experience in research processes, I showed them how to define their research challenge and helped them with their academic writing. As the project went on, I started having difficulties with my own tasks and, therefore, started having more of a collaborative leading method rather than me leading them.

Limitations and challenges

The last two learning goals - conducting a validation phase with users and analysing the results in a research paper - were not completed, unfortunately. There are a few reasons which contributed to the fact that the process has been slower than initially planned.

One reason is that the task has been of high difficulty. Nor me or my colleagues from the Utrecht University had experience in designing or developing for sound-processing intelligent products. In my case, because of my lack of knowledge in almost every area I worked in this project, prototyping process slowed down immensely. I have never worked with a Raspberry Pi or built a circuit of any kind, therefore, the time it took me to learn was longer than expected. I am not a programmer and learning Python also took time from the advancement of the tasks. On top of that, this was the first web-development project I have worked hands-on in the last three years, therefore, my knowledge was a little rusty at this point.

Another problem was the fact that me and my teammates lived in different cities, had different ways of working and different expectations from our Universities but also from ourselves. Even though we had one face to face meeting per week, it still was not enough, in my view, for the difficulty of the task. Moreover, we had different values in work ethic: I valued more the trial-error-learn chain, while my teammates were programmed to find the most efficient and fast way to the destination. Also, the mixed requirements from both project coordinators were sometimes unclear and we found each other working towards different goals. Therefore, at many times, we had to sit and re-think common goals and strategies. In the end we managed to understand each other's ways of working and cooperate. However, I do feel like these differences slowed our process down.

All in all, I do feel like the final result, even though not validated in the right manner, is a successful one considering the size of the initial task. I do feel like we managed to contribute to the world of technology and design. Moreover, I am really happy with all the things I learned during this semester. It has definitely not been easy, sometimes spending hours on a problem that seemed like it would never get solved. At the end of the day, I managed to keep it realistic and prioritize the design activities. Also, I can say I gained both hard and soft skills out of this project that will help me in my future career and I am proud to attach this experience to my portfolio.

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