cloud closet

Product Opportunity Document

Cloud Closet

This document presents a design concept developed in the ELEC-E9900 - Networked partnering and product innovation – NEPPI course at the Aalto University.

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1. DESIGN CONCEPT

We wanted to design a concept that helps people to be more aware of the clothes they own. Simultaneously, it seemed quite evident to us that most people own many clothes that they do not actively use and would prefer to sell, if there was a simple way to do it. That is why we came up with Cloud Closet – the best solution for personal fashion management, as well as selling and buying second-hand clothes. This is the value proposition in a nutshell:

- With Cloud Closet, users are able to digitalize the contents of their wardrobes with an easy-to-use IoT camera and a web app;
- Cloud Closet helps its users to be more aware of the clothes they own and provides easy access to their wardrobes;
- Cloud Closet aims to match people with similar clothing-styles and facilitates the selling, buying and borrowing of clothes, peer-to-peer;
- Cloud Closet builds a community around the app and enables social sharing of fashion.

Cloud Closet consists of two parts, an IoT camera and a web app. In other words, there is both a physical and a digital aspect to it. Users can take photos of their outfits using the IoT-camera, whereafter the photos are sent to the cloud to be analyzed by sophisticated machine learning algorithms. Once the photos are analyzed, the clothes can be browsed through the web app. This allows users to maintain a digital wardrobe, be more aware of all the clothes they own and utilize them more effectively.

The concept is especially useful for users who are frequent sellers or buyers of second-hand clothing. We noticed that the best sellers on digital second-hand market platforms, tend to use mannequins to display their clothes in a more demonstrative way. However, mannequins can cost 100-200 euros and they do not really provide any other additional value to the user. Cloud Closet allows users to conveniently take really illustrative photos of their clothes, which increases the likelihood of the clothes getting sold for a higher price.

The physical form of the camera is designed to be very undetectable and flat (see Figure 1) so that users would not mind keeping the device in the same place for longer periods of time. The camera's stand is foldable and therefore, its size is remarkably small when not being used. We kept in mind that the device's design must be visually pleasing to users, since it would be a continuously visible object in their homes.

Figure 1: The Cloud Closet Camera

The camera can easily be attached to basically any surface. However, the ideal location for the camera is on top of a full body mirror (see Figure 2). Whenever the user is inspecting his or her own appearance, it is convenient to spend a few seconds to take a picture of the outfit. We believe this is the most likely situation people would use the camera.

Figure 2: One suitable location for the camera

1.1 Overall architecture

The overall architecture is depicted below (see Figure 3) and it consists of the following core components:

1. Camera unit (more details are given in Embedded Design section);
2. Web application (more details are given in Progressive Web App Design section);
3. Backend infrastructure (more details are given in Web application and backend architecture section) with Computer Vision (CV) logic running in the cloud (more details are given in Computer vision system and data analysis section).

The connection patterns, media and protocols are described in detail in the above-mentioned chapters accordingly. To summarize, all of the system components are communicating using internet protocol suite (TCP/IP) as a conceptual model over which different protocols are running.

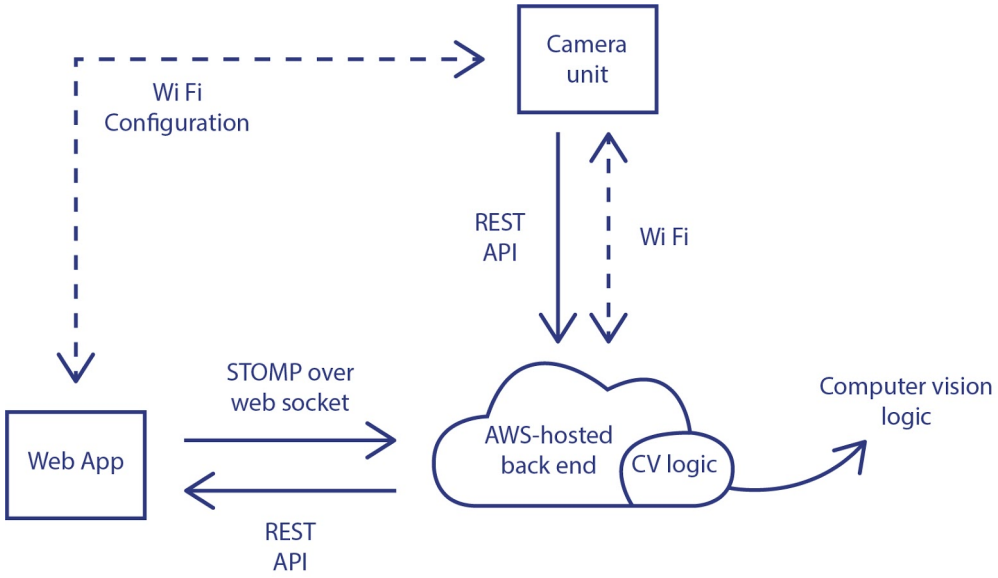

Figure 3: Overall architecture of the Cloud Closet

1.2 Interaction design

There are multiple ways in which users can interact with Cloud Closet, but it is important to note that not all of them include using the physical part of the product, the camera. Important use-cases for using the system include:

- Adding new items to Cloud Closet;
- Browsing one's personal clothing-library and deciding on what to wear for certain occasions;
- Selling and buying second-hand clothes through Cloud Closet's marketplace;
- Following other people's fashion collections.

The first imperative use-case for Cloud Closet is taking photos with the camera and adding new pieces of clothing to your own Cloud Closet (see figure 4.). Users can take the photo by clicking a button in the web app. The photo could also be taken with the aid of voice recognition technology/gestures, but this feature is not yet included in the prototype. Once taken, the photo is analyzed in the cloud by an algorithm that can detach different garments from a person in the photo. The user can then add different pieces of clothing to the personal library through the web app, where the user can name items and add details about them, such as brand, size, color and condition. Over time, machine learning algorithms will learn to fill in these details automatically. If the user is wearing a piece of clothing that is already stored in the digital wardrobe, this is automatically detected and the app does not suggest adding it as a new item.

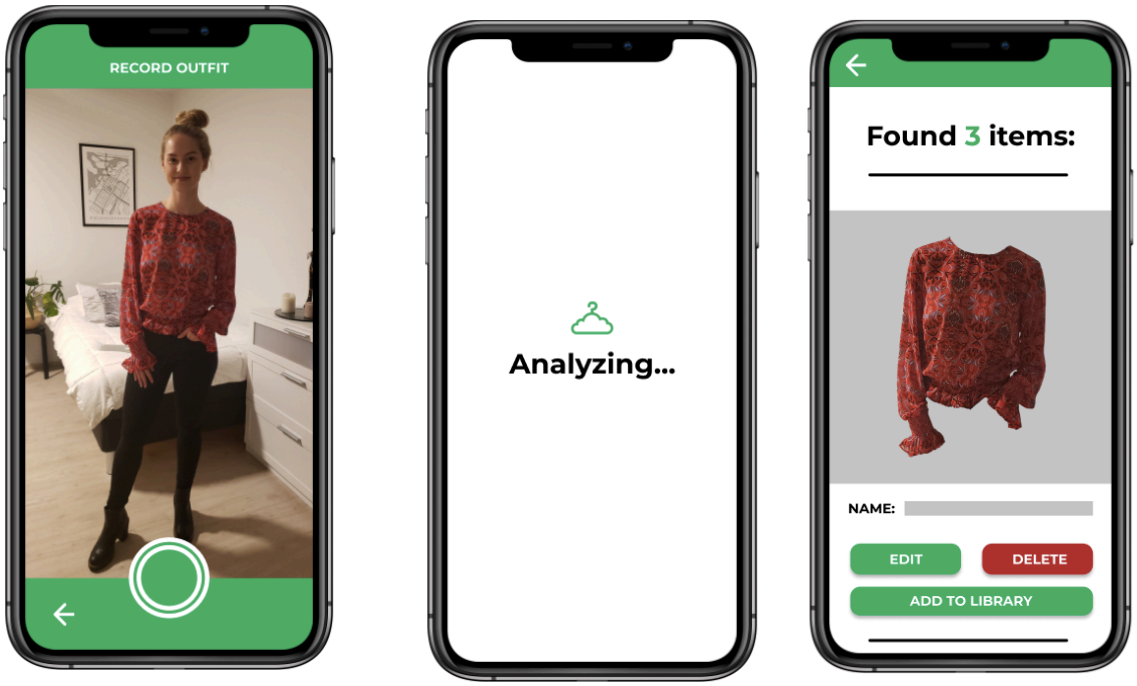

Figure 4: Adding items to the digital wardrobe

Secondly, the user can browse their digital wardrobe conveniently with the web app once the clothes have been added (see figure 5.). Different items are divided into categories such as tops, bottoms, shoes or hats, to make browsing more convenient. This is a lot easier compared to going through all the clothes of a physical wardrobe and users can do this at any time, in any place. The feature of browsing one's own digital wardrobe has two useful use cases: it makes considering what to wear for a certain occasion easier and it enables users to be more aware of all the clothes they own. A piece of clothing is not forgotten since it's not just lying somewhere in the depths of a wardrobe, but easily visible through the Cloud Closet app.

Also, it has been made easy for users to put unused pieces of clothing on sale through the platform. Once the page of an individual clothing is opened, it can be listed for sale with just a few clicks. The platform gives price recommendations based on the price points of similar items, but users can freely decide on the price by themselves. Other Cloud Closet users will see the item through the web app's marketplace and they can contact the seller by sending messages through the app.

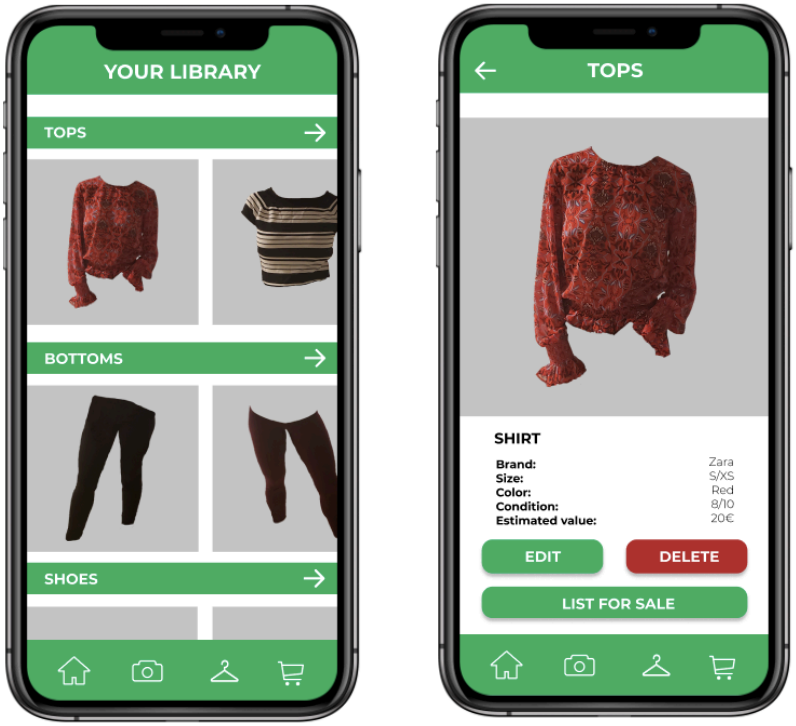

Figure 5: Browsing the digital wardrobe

Thirdly, the marketplace of the web app provides a handy way to buy second-hand clothes from other Cloud Closet users (see figure 6.). Users can find suitable clothes through a search feature and recommendations provided by the web app. The recommendations are personified for users based on their own digital wardrobes as well as previous purchases. The goal is to make people only buy things that they will actually use in the future. The marketplace also highlights the items that are being sold in users' areas, as the trading is initially done via face-to-face meetings.

Cloud Closet is also a social platform in which you can follow other users' fashion collections through their profiles. Once users open an item's page on the marketplace, they can find its seller's profile and with the option to follow them. This social aspect of the concept further

facilitates matching people with similar taste for fashion and helps facilitating the trade of second-hand clothing.

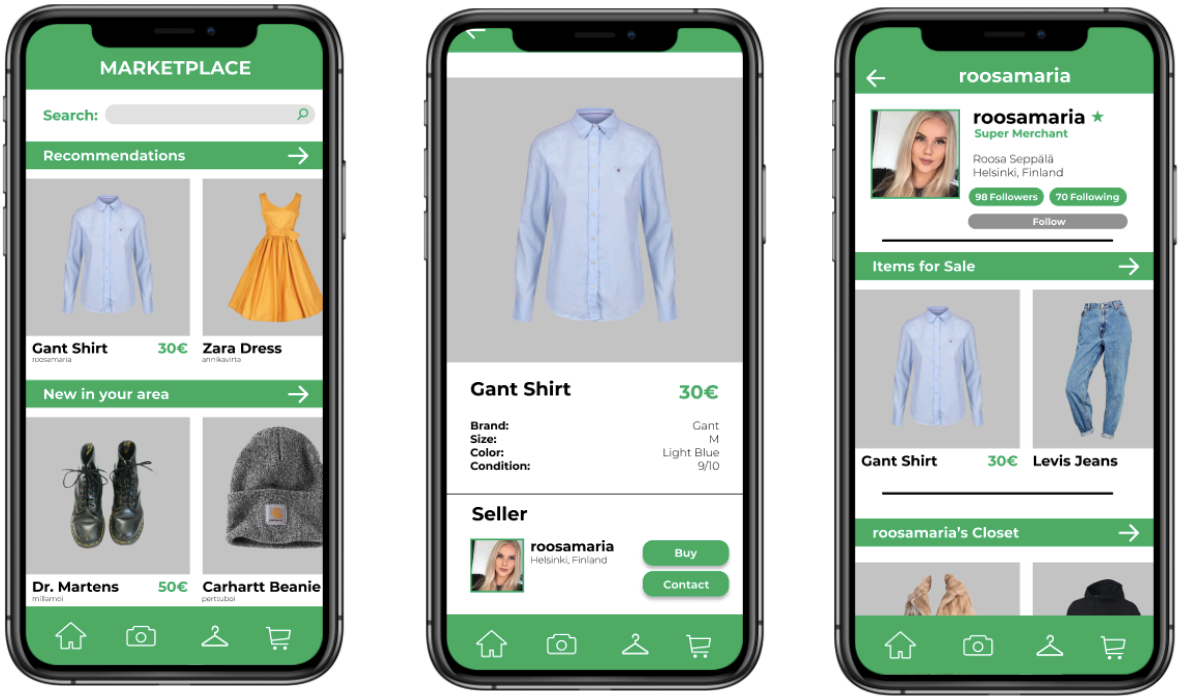

Figure 6: Using the marketplace and social features

2. BACKGROUND RESEARCH

2.1 Inspiration and reflection, the quest of a relevant context

The first step of our process was to think about issues to tackle on our own, where a solution including the use of an IoT-product or service could be relevant. Our first brainstorming was then a mix of many different perspectives on how to exploit the benefits of an IoT system. Each member of the team came with very diverse problems and contexts in mind. However, we agreed on developing a solution aiming to tackle a real societal problem, not just building a system as a 'gadget'-alternative to an already existing solution.

Indeed, many examples of IoT-products or services nowadays reveal to be simply 'gadgets' and rather useless, since not every aspect of the problem is taken into consideration or simply because the problem aimed to be solved is not relevant enough to focus on. To cite an example, the start-up 'Solu machines', presented during a lecture given by Pekka Nikander, which developed a user interface aiming to be an alternative to PC:s, was revealed to be an IoT failure because of many reasons; one being too weak a consideration of the other alternatives on the market, including tablets. This observation became even more obvious when going through the many facets of IoT solutions detailed in the book "Designing connected products" by Rowland, Goodman, Charlier, Light, and Lui (2015), thanks to which we became aware of the complexity to design a relevant and successful IoT system.

In addition to solve a real problem, we wanted our solution to be innovative in one way or another. This innovation could lie on many different points, like the technology used, the device, the mobile application, or even the user experience. After having explored and discussed on a variety of different societal issues of the 21st century, we thought that focusing on the problem of materialism was interesting and challenging enough. Indeed, the indirect waste caused by the relationship we maintain with the objects we own as consumers and households, is definitely a major and wicked issue of today's world. With this theme of materialism being very wide, we decided to focus our attention on the context of homes; this is where we found the largest amount of problems.

Our definition of indirect waste when talking about objects and things people own, differs from the definition of waste as thrown away. It is more related to waste in the sense of not being used. Objects or things that are not used are a waste of money for the buyer, a waste of material and energy that was needed to produce them, and a waste of space to store them. This is what drove and convinced us to pursue this direction.

Before the field study, we laid out some issues we were already familiar with:

- Losing objects at home;
- Not remembering what one owns;
- Organizing and storing objects, clothes etc.;
- Saving things that should be thrown away;
- Cleaning and maintenance work;
- Recycling trash.

At this stage of the project it was still too early to design solutions, even though the majority of the team had potential ideas in mind. Instead, it was the perfect time to undertake our field study, to dig deeper into our topic and directly question the potential end-users of our future product. The goal of the field study was not only to confirm or contradict our own assumptions on potential problems, but also to find surprising facts and insights we did not foresee – allowing us to find a relevant direction and to target aspects of the context where a solution would be most needed.

2.2 Field study, empathizing with the context

As stated above, our field study was aimed to open our eyes on the topic of materialism in the context of homes. Many different ways could have been relevant to get information and insights. However, we chose interviews. Considering the short amount of time, we had for our development, it seemed like the quickest and most efficient way to get relevant information. The challenge at this point was to design the questions of the survey, in order to get as fruitful insights as possible.

The core aspects we decided to cover during our interviews are as follows:

- Demographics and general information about the person;
- General relation between the person and his/her objects;
- Experience in losing things or not finding things at home;
- Emotional attachment to objects;
- Process when getting rid of or selling objects.

We conducted seven interviews in total, as each member of the team was involved in this field study. The people we interviewed responded to these criteria:

- A 30-year-old female, working and living with her husband in a 60m2 flat for 2 years;
- A 23-year-old male, studying and working, living with his girlfriend in a 68m2 flat for 1.5 years;
- A 28-year-old female, studying, living alone in a 45m2 flat for 3 months;
- A 23-year-old male, studying, living with his roommate in a 60m2 flat for 3 years;
- A 23-year-old female, studying, living with her roommate in a 46m2 flat for 1 week only;
- A 28-year-old female, working, living with her partner in a 50m2 flat for 1 year;
- A 57-year-old male, working, living with her wife in a 77m2 for 5 years.

In addition to getting insights, the goal of the study was also to help us to target a user group in particular. Nevertheless, we ended up interviewing mostly young people and/or students, because we wanted our team to be related as closely as possible to the problem.

Figure 7: An interviewee's closet

2.3 Findings, detecting and defining the issues

After having conducted our respective field studies, each of us made a summary to highlight the most important points of the exchange with the potential end-user. We were quite surprised by the variety and quality of the insights we got through the survey.

The core findings of the field study are as follows:

- Finding the right piece of clothing and knowing what is inside the wardrobe is often inconvenient;
- Objects related to self-expression or objects with an emotional connection seem to be less disturbing to keep, even if they are not used;
- People have too many clothes, and managing them is demanding;
- Small objects are sometimes hard to find and easy to lose;
- Plants' needs are hard to understand, so communicating with them could be a nice idea;
- Selling or throwing away objects is both time- and energy consuming. It is easier to do no;
- It seems easy to misplace objects that are not often used;
- Tracking some belongings could be appealing;
- Objects are sometimes hard to install and/or harmonize with the rest of the space;
- Couples sometimes have problems waking up to their partner's alarm clock;
- Some technical objects are hard to understand;
- Communicating with the objects is a very split perspective;
- Many objects or garments are not used at all.

Some of the outcomes of the interviews joined our original team insights, e.g. the idea that losing small objects can easily happen, or that it is hard to remember every single object that we own. The challenge was then to combine all the different outcomes, to interpret the results in a meaningful way, and to detect the most interesting points on which our future IoT project could lie. After several debates and discussions, we agreed on narrowing down our scope to clothing because it was a recurring problem in our interviews. Clothing was also a topic we discussed before our research. The field study provided us with a wider perspective on how people manage their wardrobe and what relation, habits, tricks or difficulties they have with their clothes.

2.4 Ideation and secondary research

Here are the outcomes of the field study related to clothes that drove our ideation process:

- Searching for the right piece of clothing to wear can be demanding;
- Browsing a wardrobe is not convenient;
- Managing and maintaining a big amount of clothes is demanding;
- Many clothes are not often used or not used at all;
- Selling or giving away clothes is demanding;
- It is possible to forget owning some clothes.

The challenge was then to decide which aspects of the collected information would be the most interesting to focus on. Should we try to cover as many aspects as possible? Should we focus only on one of them? Which issue could be the most relevant to tackle with an IoT system? What is the most wicked problem among the ones we found?

To help us to find some answers to those questions and ideate the best solution, we undertook some secondary research. Here are some facts that we found very relevant and inspiring:

- The second-hand clothing market is growing and becoming bigger every year.
- More than 70% of the world's population uses secondhand clothing.
- The average lifetime of a piece of clothing is approximately three years.
- Nearly 100% of textiles and clothing are recyclable."
- The recycled textile industry has great potential to expand

  (Leblanc, 2019);
- People on average do not wear 50% of their wardrobes (a study with 18 000 heads of households in 20 countries). (Van Elven, 2018);

The secondary research also comprised an analysis of existing actors, solutions or companies related to the domain of clothes, or that include relevant aspects to look at for our concept. We studied the second-hand market by looking at retailers like UFF and Fida, and online platforms like Vinted, where we perceived some pain points in the way it demands time to use them properly. We checked some online applications that already propose a digital closet solution, like Verify and Cladwell. Although they seem to bring a solution to better organize clothing, the platforms do not integrate the aspect of selling or sharing clothes at all. We also had a look at

selling-platforms like Tori.fi, and found that most of the items sold are very badly presented, with pictures of bad quality and prices that sometimes are not really justified. Finally, we put an eye on social networks like Instagram, Pinterest, Tumblr and Facebook and noticed that the idea of sharing lifestyles and fashion are rather popular nowadays.

Following both the field study and secondary research, we were then able to draw the core aspects that our final design concept should integrate:

- Easy-access to browse one's closet (An IoT-app could be a good solution);
- Facilitate the selling and/or sharing of clothes (the App and camera UX could solve this);
- An idea of a second-hand market community centered on sharing styles (Thinking our system as a platform should be the right way to do it).

2.5 User feedback

We presented our final concept and visualizations to a selection of potential final users, to get to know what their opinion was and if they would use our platform and how. This feedback collection can be considered as an initial test and a base for future potential research and development of our solution. Here is what we collected:

Male, 24 y.o.:
"Funny concept! Especially the marketplace idea is really good. I would use it to sell my clothes and I would also want to buy clothes from my friends. I never sell my clothes in traditional flea markets since it's too much of a hassle with the table booking and everything. Selling clothes at Tori.fi is also complicated since you need to separately take pictures of all your garments and it takes time to post them on sale. I believe I would also benefit from the social aspect of the "Cloud closet" platform/app. Maybe people could ask if I wanted to sell something I had not thought about selling before and then I might realize I don't need it anymore and sell it."

Female, 24 y.o.:
"It would be fun to see my roommate's wardrobe on the app so I could easily ask to borrow some of her clothes. It would be nice to see also my other friend's wardrobes because then we could easily swap clothes together and we would not need to always buy new garments for different occasions."

Male, 23 y.o.:
"Selling within the app has to be easy, just a couple of clicks away. Also taking the pictures has to be easy. I would not want to use the mobile app to take the picture maybe instead of pressing the "take a photo" button on the app the camera could recognize a specific gesture and take the pictures when I make that gesture (e.g. raising one hand)."

Male and Female, 24 y.o.:
"Seeing our own clothes in the app would not really help us since we don't own many clothes. We are aware of the clothes we own, but maybe shopaholics could use the app to remember what they own and that could also help them to reduce shopping."

We can synthesize and cluster the outcomes of the feedback as following:

- Positive feedback:
    - The marketplace idea is appealing, seems like an easy way to buy/sell used clothes;
    - More convenient solution compared to competitors, e.g. Tori.fi;
    - Especially the social aspect of the app sounds interesting, seeing friends' wardrobes;
- Criticism/suggestions:
    - Selling and taking pictures has to be really easy;
    - Not very useful for people who don't own a lot of clothes.

2.6 Next steps for potential further research

The next step of the research would be to make a physical prototype of the IoT device, to connect it to the application mock-up and then undertake field tests. By combining these tests with the feedback we collected, we could better refine, develop and modify some aspects of the user experience, user interface and aspects of the concept itself. Prototyping would also allow us to test the technical components and evaluate them, and to eventually try other options. A more detailed research on the market and a deeper analysis on different ways to fund the project would also be crucial to implement the project in the real world.

3. EMBEDDED DESIGN

The platform includes an indoor IoT-device as a core data collection unit. It is a network-attached camera, capable of creating high resolution images (1920x1080), which is constantly connected to a power-outlet. The camera is normally hibernated, when the ON-button is pressed, it is activated to take a picture. The role of the camera is to capture an image on request and transfer it to backend in RAW-format without any processing.

3.1 Design, housing and physical parameters

A visual research on existing cameras and webcams has been made before the design of our device. We looked at security-camera brands like Somfy, Arlo, Wyze, YI, as well as webcam brands like Logitech and Microsoft. Our camera had to be small and minimalistic to fit in many environments and not to be visually annoying. We thought the camera should be put either on a surface or on a wall. This is the reason why we integrated an adjustable foot. A square module is a suitable solution to integrate the lens, LED light, power button and all the other electronic components. Moreover, the product has to communicate this idea of picture quality, and if the design is to weak or the size is too small, people will tend to connect it to cheapness. The color of the shell can be imagined in many different variants as well. Figure 8 depicts the camera wall installation.

Figure 8: Cloud Closet camera wall installation (with light turned on)

Here are the core values of the device:

- Quality and homogeneity of each image, despite different luminosities or environments;
- Suitable for many indoor environments with different requirements, thanks to the adjustable feet and the pure design;
- Great reactivity and network connectivity.

In a folded position, the camera unit has the following dimensions:

- Width - 65 mm;
- Length - 65 mm;
- Thickness - 14 mm

The camera can be deployed up to 50mm from the base and incline on a 360° direction. It weighs approximately 97 grams, including the electronic components. If we consider Ingress Protection (IP) rating, it is IP52, which is achieved by a mono-body architecture and silicone sealing for the openings and button, as well as glass cover to protect the camera lens and LED stripe. The camera is meant to be used indoors at room temperature (20 °C) and relative humidity parameters (45-55%). The device is powered by being plugged in to an EU-standard 220V (230V in Finland) electric socket.

In terms of material, the shell of the camera, as well as the feet are made from a plastic (polypropylene) injection, which is the ideal production process for big series of objects. This polypropylene can eventually be replaced by bioplastic to fit the device in a more sustainable spirit, which Cloud Closet aspires.

Possible further research and development to pursue on the IoT-device would be on the design, by making prototypes and testing if the different components work together, and on the user interaction, especially the way the user activates the picture shot (voice or gesture activation instead of pressing a button are considered).

3.2 Electronic components and modules

The camera-unit consists of the following components:

1) An ESP32-WROOM-32 microcontroller is selected as a general control unit, as it is an industry-verified option, capable of operating in versatile environments with a low power consumption and sufficiently enough computing power;
2) A power-management module and Rohm BP5723-33 AC/DC converter to allow the power connection via usual 220V (standard in the majority of European countries) socket. The parameters of the converter are the following:
    a) Output to fit the ESP32-WROOM-32 requirements - 10 Watt, 3.3 V, 3.3 A;
    b) Input - 220 V;
3) IEEE 802.11b/g/n wireless module (WiFi), which is an integrated part of the selected microcontroller. The network usage parameters are planned to be the following:
    a) Distance - up to 30 meters;
    b) Latency - up to 5-7 ms, what is actually covered by the approximate radio connection latency of 1-3 ms;
    c) Channel width required - 20 MHz over 2.4 GHz Wi-Fi frequency;
    d) Communication rate:
        i) Infrequent rate generated by sending images;

ii) Estimated average images count per 24 hours - 3-10 images;

iii) Estimated payload size (reading from the matrix) - up to 4 Mb, what means that WiFi network with MTU (Maximum Transmission Unit) of 2312 bytes per packet and fragmentation would be more than enough.

In general, distance, latency and channel-width are irrelevant parameters in terms of the particular system-use and WiFi capabilities, as this radio communication technology would definitely handle the transmission load. The system does not require any dynamic data update for user-feedback, however, device configuration is performed via the same wireless network, establishing a connection between the user's smartphone and the camera, which means that the wireless communication module should be capable of operating in the AP (access point) mode.

4) Camera module with vertically positioned matrix (1/1.8" CMOS Sensor) and wide angle lens (10mm focal length);

The camera does not include any other sensors or logic units, while it includes the following actuators:

1. Power button to activate the camera from the hibernation;
2. Flash LED lights ring, which is used to:
    a. Light up the low exposure environment on camera shutter activation;
    b. Act as a user feedback interface. Flash is an RGB LED stripe, so it provides users feedback in the following cases:
        i. Power on - running blue light to emulate the preloader and a consequent single green blink;
        ii. Power off - red double blinking;
        iii. Firmware update - running blue light to emulate the preloader;
        iv. Taking pictures and sending them - white flash and running green light to emulate the preloader for data sending procedure.

3.3 Network attachment procedure

As mentioned in the Electronic components and modules section, the camera is driven by ESP32-WROOM-32 microcontroller, which includes a Bluetooth module. In the first versions of the device the network attachment would be accomplished by the use of WiFi connection. It would allow to eliminate the software development for the Bluetooth module, increase the usability and allow the configuration via a web app. Simultaneously, it would decrease the PCB costs, as well as the logic development. The network attachment procedure is the following:

1. The user unpacks and powers on the camera;
2. The camera automatically initializes an access point (AP) on power on. The same WiFi module is used to run the AP as the one to send the images further. Camera has a default SSID and no authentication is required for the connection;
3. The user starts the connection process from the app and follows the instructions;
4. The user connects his/her smartphone to the AP initialized by the camera;
5. The user specifies a home network SSID and password (the web app also supports a manual entry for the subnet, IP and default gateway IP) in the web app for the camera (the user's smartphone and the camera are in the same network created by the Iot-device's AP);
6. The camera is rebooted (by means of the command from the web app) and connected to the home network.

The user may reconfigure the camera with the new network settings by connecting to the same network, as the camera was configured to. The web app would allocate and connect to the camera by means of the zero configuration protocols:

- Bonjour on the iOS devices;
- Zeroconf on the Android devices.

3.4 Integrations

In order to have full control of the camera unit and allow the post-purchase consumer support and over-the-air (OTA) firmware updates and deployment, following SDK integrations are considered:

- AWS IoT Core to control the devices and collect the user-analytics. In addition, Amazon S3 (object storage infrastructure for e-commerce networking) is considered to be used in the future, while AWS IoT Core simplifies the connection within its infrastructure;
- esp_https_ota SDK, which acts as an abstraction layer above the native ESP32 update component and provides APIs to perform OTA via HTTPS protocol.

4. PROGRESSIVE WEB APP DESIGN

This section describes the web application architecture and its functionality, as well as the backend infrastructure and computer vision component requirements and features. The first application version is a cross-platform web-based application, which is distributed for two major mobile platforms, iOS and Android, via the Apple App Store and Google Play Market respectively. In the future, the mobile applications are planned to be rebuilt on native iOS and Android SDKs, using Swift and Java/Kotlin languages. It would enable native support, increased efficiency and functionality; possibility to perform computer vision calculations on device, which in turn would reduce the costs of cloud service computing power.

The estimated infrastructure development costs are the following:

- Infrastructure architecture and the technical spec - EUR 5K;
- Computer vision algorithm and analysis system - EUR 27K;
- Backend logic, external integrations and an API - EUR 10K;
- Web application design - EUR 6K;
- Web application development - EUR 20K;
- Other production costs - EUR 10K.

Total: EUR 78K

4.1 Design vision and application functionality

Overall App Design

When talking about the application in this section, it mainly refers to the mobile application instead of the web application. Although a web application is needed for the project, the mobile-version would be the most important one, since the majority of users would be using this platform.

The overall app-design is based on, and uses visual elements coherent with the Cloud Closet brand identity. The soft green color, (HEX-code: #2fac66), was chosen as a gender-neutral alternative, that is easy on the eye, making the UX pleasant. The goal was to make the app attractive to both male and female users. The typeface used in the app is 'Montserrat', both in 'Bold' and 'Light' weights.

Montserrat Bold

Montserrat Light

Figure 9: Cloud Closet Logo

Functionality

The main functions of the web app were presented in chapter 1.X – Interaction design. This section will dive slightly deeper into the app's functionality. Primarily, the app is divided into four main categories represented by the icons in the footer (Left to right): Home/Personal profile, Recording outfits, Clothing Library and Marketplace.

Figure 10: Cloud Closet app footer

Recording Outfits

The main function of the IoT-device is making it possible for users to record and add outfits to their personal cloud closet. The app is designed to help the user with setting up the camera for taking optimal pictures, in terms of camera placement etc. The users can control and set up how the pictures are taken in the app; if the user e.g. wants to use a certain gesture for taking pictures this can be defined in the app. The objective is to make recording outfit as seamless a process as possible for each user.

After a photo has been taken and the app has analyzed the clothes, the user has three choices for every item that was found:

1. Edit – Add information details to the piece of clothing, such as brand, condition etc.;
2. Delete – If the user does not want to add a piece of clothing to the library, they can choose to delete it;
3. Add to library – The piece of clothing is added directly to the user's library.

If the user wants to add all the items to their library, they can choose the option "Add all to library". If the user wants to take a new picture, that feature is also accessible from this page.

AI and machine learning are crucial for the app to work to record clothing as seamlessly as possible. An increasing amount of users will aid the machine learning, making the AI smarter and leading to better results in the long run.

Personal Profile

The personal profile is an essential component of Cloud Closet's social platform. Things visible on the profile include:

- Personal details (Name, location, followers, followed people);
- Friend's listed items;
- Personal listed items.

If the social platform was compared to Instagram, Friend's listed items would be the equivalent of the news feed, where users can see new pictures of the people they follow. The personal listed items would be the equivalent of the user's personal feed on their profile.

Settings are not included in the prototype, but this section would include managing privacy, notifications, payment setup, passwords etc.

Clothing Library

The personal clothing library works as a personal digital wardrobe for each user. In addition to being able to view all the items a user owns, they can also add and view detailed info for each piece of clothing. One planned feature is and estimated price for each item. Based on information from the picture, brand, condition and size, AI can be used to calculate an indicative price for the item. This information is not public however, and will only be visible to the user. Also, whenever an item is listed for sale, the user can determine the price themselves. The estimated price is simply there to help out the user with the hassle of pricing their items.

By default, every user's library is public and visible to their followers. However, users can choose which items are visible and to whom. Some users might want to share their style with others, while others want to keep it to themselves. Therefore, the app is designed to be flexible and meet different needs.

Marketplace

The marketplace is where users can browse and list items for sale. The 'homepage' for the marketplace includes three different categories: Recommendations, New in your area and People you follow. The recommendations-section show clothes that are recommended to the user, based on their own library and style of clothes. The new in your area-section shows items listed close to you (in a 3km radius). We believe people are more prone to buying items when they are close. Face-to-face sales naturally also do not require shipping, which is a quicker, more sustainable

option. The people you follow-section simply displays items listed by the user's friends. The marketplace also comes with a search bar, where users can search for specific brands, items and users.

Under every item displayed on the marketplace, the user can see who is selling the item. The seller is also displayed under the item being sold, once the link is opened. Here the user has the options to buy the item directly, contact the user (via an in-app-chat) or visit their profile.

When visiting other people's profiles, users can browse the profile owner's listed items and personal library. The personal library does not necessarily contain items that are listed. Instead, it opens up the possibility to easily check out other people's wardrobes for inspiration etc.

4.2 Web application and backend architecture

The web application is built with React Native, which allows seamless cross-platform development and natively distributed applications, utilizing HTML, CSS and JS, which is a cheaper solution compared to iOS and Android native applications. Flutter by Google is another option of a framework to be considered.

Backend infrastructure would consist of the following components:

- Nginx web server;
- Redis database;
- Memcached, as a memory caching system to speed up the operations, as our web app is going to be a dynamic database-driven web solution;
- Business logic created with PHP Symfony.

As for hosting service, AWS services (Amazon EC2, Amazon S3, AWS Backup) would be used because of scalability considerations and ease of support, as well as because of the huge infrastructure of neighbouring Amazon services useful for the future system advancement and growth. For example, AWS IoT Core, described in Embedded Design section.

The application is connected to the backend via RESTful API and STOMP over WebSocket:

- RESTful API is used as a major communication interface, so API methods cover all the application functionalities to exchange data with the cloud platform in the form of an HTTP request;
- Web sockets are an extension to RESTful API to allow dynamic data updates in the application. This interface is useful for dynamic closet updates, chat- and catalogue functionalities. The STOMP protocol is selected as it is a simple text messaging tool.

If we speak about other web application integrations, we are planning to incorporate enterprise tools to enable user analytics, online payments and scalability features. Following frameworks, instruments and SDKs are integrated:

- Firebase, which is used for deep linking (required for ads) and push notifications. Firebase is an optimal solution for notifications, as it allows us to eliminate the need for a personal push notification server and gateway development of our own;

- Fabric, as a parent system of Crashlytics, which is going to be used for malfunction and crashes detection;
- Segment, as a tool for user analytics. It allows to connect the collected data to Google Analytics, Firebase, Mixpanel, etc. via a single integration. User analytics and demographics data is essential for the product development and feature advancement and tuning;
- Payment gateway integration (Klarna SDK);
- Zendesk Support SDK as a tool for support automation.

4.3 Computer vision system and data analysis

The computer vision (CV) is a core component of the platform. It is used to detect and analyze the images from the camera and fetch the clothing items from them. The algorithm set should be capable of:

- Liveness detection to eliminate spoofing attacks. The system should understand from the picture that it is a real person, not a cardboard model or an image opened on a tablet, for example. It could be accomplished by a neural-network (NN) driven solution analyzing the materials' texture or human eyes. In addition, the camera could be configured to take a very short video instead of a single image. Such a method would allow to track the data points detected, which in turn results in a simpler recognition model;
- Clothing fetching, which means that the system should cut and grab the clothing image segment. It could be accomplished by the use of edge detection algorithms, using a geometric invariant moment, Canny, Hough transforms feature extraction and calculation techniques;
- Clothing matching, which will check the clothes in the database and the newly taken picture in order to avoid duplicate entries. It could be done with basic features used to compare and match colors, shapes and texture. Basic features derived from GLCM (Gray-Level Co-Occurrence Matrix) could be used, as well Kohonen Neural Network (type of SOM, so-called Self-organizing Map);
- Clothing mask creation and rendering to improve the image quality and allow the future in-device augmented reality trying of goods, which is not in the 1st version's scope.

In order to achieve the above-mentioned CV functionality, the following frameworks are used to build the model and run the recognition and matching calculations:

- OpenCV;
- Dlib;
- NVIDIA TensorRT;
- Caffe2 (PyTorch as it is a parental framework);
- Amazon SageMaker for model deployment.

4.4 Data handling and secure-by-design development issues

In accordance with GDPR, Cloud Closet would operate under the privacy-by-design approach. Only data that is necessary for the delivery of the core functionalities and features are to be processed or stored. Cloud closet will store user data in the cloud. This data is to be communicated with SSL or HTML protocols and encrypted with strong encryption algorithms provided as a part of the AWS database and content delivery services.

Cloud Closet aims to be as transparent as possible regarding data handling towards its users. This transparency also covers the use of the services provided by 3rd parties, such as advertising providers or analytics tools. Cloud Closet will have a Data Processing Agreement in place with all parties who Cloud Closet collaborates with. These agreements will be drafted with competent lawyers and the compliance of these parties with GDPR will be audited.

The users of Cloud Closet are required to explicitly consent to the storage and processing of their data in order to use the application. This data will be used for advertising, analytics and crash logging. As required in the GDPR, users will always have the option to opt out and prohibit the use of any data gathered from their use of the app. Cloud Closet users retain the right to be forgotten.

Cloud Closet will have a protocol in place on how a data breach or other data privacy issues will be handled. This protocol will always include communication to all users whose data has or might have been breached.

Finally, a member in the Cloud Closet staff will be assigned responsible for data protection.

5. VIABILITY AND POTENTIAL IMPACT

Our IoT-camera and web app will help its users to become more aware of the clothes they own, provides an easy access to, and convenient browsing of the users' wardrobes and facilitates the selling, buying and borrowing of second-hand clothing by building a community, matching people with similar styles and creating a simple-to-use marketplace.

Based on the research we conducted prior to the ideation stage of this project we found out that people would need a more convenient way to browse their wardrobes and sell or borrow their unused clothes. The first problem is currently solved the best by pulling out all of your clothes from the closet, going through them, and placing them back again. The second problem, selling unused clothes, has been tried to solve with many alternatives such as traditional flea markets, online second-hand platforms and social media platforms. However, these solutions continuously seem to fail delivering to the expectations of users since many of our interviewees addressed their need for an easy-to-use platform for selling needless garments.

5.1 Platform business model and the network effects

Our business model follows the principles of a platform. Instead of using the traditional value-chain model, we are creating a two-sided market in which all of the users generate value for each other (Van Alstyne, Parker & Choudary 2016). We bring together 15-35-year-old fashion-conscious people, creating a place for interaction and high-value exchanges.

Cloud Closet, as the owner of the platform, controls the intellectual property and governance of the platform (Van Alstyne et al., 2016). We want to sell the camera to the users in order to have some control over the quality of the pictures that end up on the platform, but otherwise, the users are the ones who generate the value by adding their clothes to the virtual closets. Actually, information and interaction within the platform will eventually become our main assets and possibilities of value-capture, as well as the source of a sustainable competitive advantage.

The overall value that Cloud Closet delivers to its users depends on the number of users that start using the application. Instead of focusing solely on the customer value, Cloud Closet will shift the focus to consider the value of the entire ecosystem. The more users that add clothes to their virtual closets, the more appealing it will be for other users to join the communities within the application. In other words, the value created and captured within Cloud Closet increases, respective to the increase in the number of participants, creating a cycle called 'network effects' (Van Alstyne et al., 2016 & Gawer, 2014). In order to facilitate the emergence of network effects and to leverage their power we are going to create an open environment by building interaction-supporting functionalities and enabling users to follow each other's closets. It's also important to understand that the participants of Cloud Closet can swap roles in ways that generate value to our platform. The same users that sell their clothes through our application today might buy clothes from other people tomorrow.

5.2 Costs of the design & manufacturing and web app development

Below we have estimated the costs of design, camera manufacturing and web app development.

The design costs are the following:

1. PCB design and manufacturing specification preparation - EUR 10K;
2. Firmware development - EUR 30K;
3. Camera housing design and manufacturing specification preparation - EUR 5K.

Total: EUR 45K

If we consider the manufacturing costs per single device, they are the following (estimated in the case of the 100 devices batch order):

1. Components
    a. Camera module - EUR 7;
    b. Microcontroller (ESP32-WROOM-32) - EUR 4;
    c. Power management module and AC/DC converter (Rohm BP5723-33) - EUR 2;
    d. Other components (button, LED stripe) - EUR 0.5;
2. Circuit production - EUR 2;
3. Body production - EUR 2;
4. Shipping, materials and all other costs - EUR 4.

Total: EUR 21.5

The estimated infrastructure web app development costs are the following:

1. Infrastructure architecture and the technical spec - EUR 5K;
2. Computer vision algorithm and analysis system - EUR 27K;
3. Backend logic, external integrations and an API - EUR 10K;
4. Web application design - EUR 6K;
5. Web application development - EUR 20K;
6. Other production costs - EUR 10K.

Total: EUR 78K

5.3 Revenue model

First of all, by accurate COGS calculations and deploying the economies of scale we can make sure to earn profits for each camera sold. We have estimated the cost of manufacturing and shipping per single camera to be 21,50 euros in the case of a 100 devices batch order. If we set the selling price at 50 euros we will have a 57 percent gross margin. The manufacturing costs can be expected to decrease to an even lower level when the order amount increases.

However, in addition to the camera manufacturing costs, we will also need to pay for designing of the product, the web app development and marketing especially at the beginning of our business. The following calculations will show how many cameras we would need to sell to break even when considering the manufacturing, design and web app development costs.

100* 21,5 (manufacturing/device) + 45K (design of the products) + 78K (web app development) = 125 150 e

Selling price/device 50e. Our gross profits per device 28,5e. How many do we need to sell to break even: 125 150e / 28.5e = 4392 cameras to break even.

Before and right after the launch of our application we need to direct our efforts to activities which will attract users to the platform. The price of the camera has to be kept relatively low so that it will not become a barrier for acquiring new platform users. At the very beginning we might need to distribute some cameras for free to our ideal platform advocates e.g. to some popular fashion bloggers in order to acquire the first users and spread the word, get some publishable testimonials and word-of-mouth support.

It is important to notice that the calculations above do not tell the whole truth about the viability of our product and the application. In fact, Cloud Closet will be able to generate revenues from multiple sources. A remarkable part of our revenues will be generated through the re-occurring transactions after the user has bought the camera. Our plan is to take a commission fee (10%) from every transaction that happens within Cloud Closet. Additionally, we are going to deploy the ad-based revenue model that will yield revenues from selling advertisement rights to third parties within our platform. Later on, we might also be able to monetize on the selling of data that we can gather from the app about the user's fashion consumption habits and preferred styles.

5.4 Competitor analysis and the strengths of our business

The main competitors of Cloud Closet in the second-hand markets include traditional flea markets, online second-hand marketplaces and social media platforms. Cloud Closet also faces competition posed by online and offline retail stores even though they do not aim at solving the same problems as the competitors in the first group. The development of information technology is something that backs us up in the competition against traditional flea markets and offline retail stores, since it has made it unnecessary to own physical infrastructure or assets, simultaneously simplifying and reducing the price of building and scaling up a platform business (Van Alstyne, Parker & Choudary, 2016). Additionally, since we are going to sell the solution to the same problem as many of the already established operators in the second-hand business, we need to make sure that what we offer is the most appealing option for the users to choose. In the table below, we have compared the cost of use for users and the functionalities between Cloud Closet and its competitors.

On the next page we present a competitor-table.

	Cloud Closet	Flea markets	Online second-hand market places (Zadaa and Vahankaytetty.fi)	Social media platforms
Cost of use	50€ one time purchase for the camera + commission fee on sold garments. Possible additional charges for delivery.	Clothing rack/table rent 30-65€ per each selling week + commission fee (normally between 5-10%).	Zadaa: commission fee 0-12% + a fixed fee of 1€/item. Delivery with a Zadaa package 4€. Vahankaytetty.fi: delivery fee 6,9€/package + commission fee 2,90e/item.	Social media platforms can be used to sell second-hand products without charges. However, they are clumsy and unreliable in this matter.
How does it work?	Wear the clothes you own and take pictures with the camera Some of the details of your clothing will be added automatically to your virtual closet Manage your virtual closet Join the virtual communities, follow other users and interact with them Buy/sell/borrow clothes with a couple of clicks Delivery options provided within the platform (A comprehensive option for managing your closet and sharing the passion for fashion)	Go through/clean up your closet and decide what to sell. Rent the rack/table Attach the price tags to garments Bring the garments to the flea market Organize the table during the selling period Pick up the remaining garments from the flea market (Some garments often disappear during the sales period due to the poor surveillance systems at flea markets)	Go through/clean up your closet and decide what to sell Take pictures of each of the clothing you want to sell Add item specifications, details and the price to the platform Zadaa: Get notified when someone has bought the item. Send the item using Zadaa package service. Vahankaytetty.fi: send your clothes to the warehouse. The items will remain on sale for up to 6 months after which they can be redeemed in exchange for an additional charge or donated to a charity. (Considers only the garments the person has already decided to sell, does not enable borrowing)	Go through/clean up your closet and decide what to sell Join groups that are created for second-hand selling purposes Take pictures of your clothes Add written details Arrange the transaction (Functionalities not optimized for second-hand selling, posting for sale and replying to messages is clumsy and time consuming, hassle of arranging the transaction)

Cloud Closet will differentiate itself from competitors by focusing on the social aspects of the application. We are building the value proposition not only around the easy selling, buying and borrowing of clothes between peers but also around the psychological and emotional value generated by allowing people to fulfill their intrinsic need of expressing themselves through clothes. Furthermore, the rise of social media platforms such as Facebook and Instagram have given evidence about peoples' desire towards building an extended virtual self and connecting with virtual communities. However, even though people post outfit pictures on social media and blogs, we see that there's still room for a platform that aims at bringing the fashion conscious people together to share their passion for fashion while simultaneously contributing to the building of sharing economies.

5.5 Web app and camera distribution plan

The web app will become available for free on the Apple App Store and Google Play Store. At first, we will sell the camera through our own website and the Kickstarter campaign. To follow up on our strategy that supports an easy access to the Cloud Closet platform, we should also soon start selling the cameras via e-commerce channels such as Amazon and eBay as well as in offline retail stores such as Gigantti, Clas Ohlson and Verkkokauppa.com (examples in Finland).

6. PUBLICITY & LICENSE

We firmly believe in sharing our work and looking for opportunities to develop this concept further. It is an attractive idea to work on this concept more concretely in the future, and perhaps get funded by investors. During the course we noticed that a critical element in improving ideas is to ask challenging questions. So having the chance to openly discuss our concept with others, would definitely aid the process of creating a better product.

Furthermore, we are not worried about anyone stealing our concept. We would be happy to see someone developing our concept further, even without us being involved. We believe it is not the idea itself that has marketable value. In virtually all cases, it is the execution that makes it real and monetizable. Also, sharing the concept early, will allow us to understand if it really is something other people would want.

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