FlowFrame

ITPDP 2025 - Group 3

FlowFrame

Jakob Skøt Nielsen 202407223
Mikkel Friis Lassen 202408084
Robin Højland Hansen 202409877

June 2025

Final Report in IT-Product Design Project 2025

Supervised by Clemens Nylandsted Klokmose, Minna Pakanen & Simon Hoggan Christensen

In this assignment we have used generative AI to search for academic papers, setup Latex, make improvements to the text and to setup references.

Department of Computer Science
Aarhus University
Denmark

Abstract

In this project, we used a contextual design process, including ethnographic field research methods, like semi-structured interviews and observations. This led us to identify the filming of skate tricks as a monumental part of the skate community. Based on our findings, we created a prototype called FlowFrame that helps unaccompanied skaters film dynamic videos that fit the style of skate videos. Using GPS waypoints, the skater creates a path FlowFrame drives during the skater's run. This simulates a cameraman following the skater, which is typical for filming skate videos. Placed on top of the FlowFrame, a gimbal camera with object tracking keeps the skater in frame.

In this paper, we present our technical prototype, interaction design, and GUI for the accompanying app. We evaluate these prototypes with users and analyze and reflect on the resulting feedback. Having a robot following the skater conflicts with their established and more old school identity and culture. Tripods are an accepted technology, so for future work we suggest splitting the product into two – a static tripod with a gimbal camera and an add-on of the path following car.

1 Introduction

Skateboarding was first popularized in the 1950's but had its golden age from 1993 to 2006 [22]. A time that we found still influences skateboarding's culture with its use of decommissioned filming equipment and late 90's aesthetics in clothes and art. Through ethnographic field research we delved into the rich culture and strong identity surrounding skateboarding, and we found that filming skate videos is an integral part of it. The most popular technique for filming these videos is having a skateboarding camera man closely follow the skater while filming from a low angle. This requires a skater who has the time, equipment, and skills to film. Another common way to film is by placing a phone on the ground and then skating while attempting to stay in frame. This results in a static video far from the action, which is undesired in skate videos.

We saw an opportunity for a tangible IT product that would make good quality skate videos more accessible for unaccompanied skaters. A consequential aspect of this product was ensuring it was still culturally acceptable in the skater community. This created another dimension for the design, which we found quite intriguing. Our problem statement therefore is:

> *How do we create a product that assists skaters in filming their tricks, when they are skating alone or their friends are occupied? Since the skate community has a strong sense of identity and culture, the product also needs to conform to these conventions.*

In this paper, we present our solution with the design of FlowFrame. FlowFrame is a wheeled robot that follows a path created by the skater. Placed on top of it is a gimbal[1] camera with object tracking that keeps the skater in frame. In the following chapters we introduce the technical and GUI prototype and its design rationale based on the ethnographic field research we have conducted. We then evaluate the concept and GUI through AUX evaluations.

This project is related to the subtheme: *Outdoor exploration for the very particular.*

[1] A device that electronically stabilizes the camera around three axes.

2 Presentation of FlowFrame

Figure 1: *FlowFrame in it's intended context*

FlowFrame is a compact, wheeled camera assistant for skateboarders (see figure 1). Built-in cameras enable object tracking and video recordings. FlowFrame can be used in two modes. Tripod mode, which keeps skaters in frame while the FlowFrame remains stationary. Path mode lets skaters set up a path by placing waypoints determined by the users' phone GPS location and see them on a map view. FlowFrame drives along this path while keeping the skater in frame using a pan/tilt module.

The skaters use the accompanying app to control FlowFrame including choosing a mode, setting up tracking targets, accessing video recordings, and creating and testing paths (see figure 2). The full flow can be seen in this YouTube video.

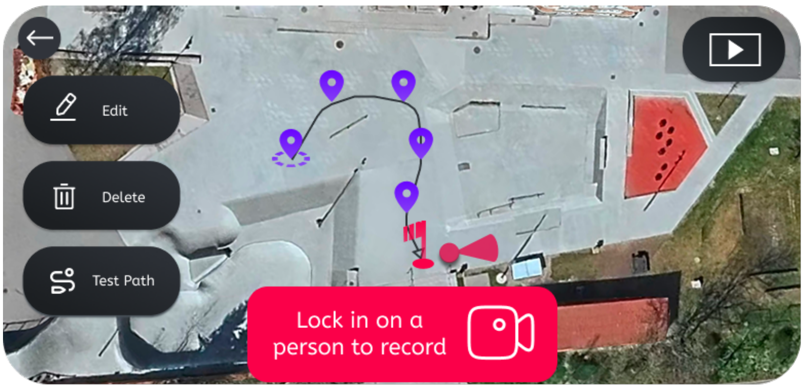

Figure 2: *FlowFrame's path creation screen*

2.1 Design philosophy

The whole of our ITPDP project is rooted in the contextual design process from Holtzblatz & Beyer [28]. This means that the whole product development process is based on findings from ethnographic fieldwork within our actual user group. Contextual design is shaped from five principles, of which one sounds:

> *"System design must support and extend users' work practice" [28]*

Work practice refers to users' behaviour, attitudes, goals and intents. These work practises is part of a larger context which also includes technology. Since our introduction of a product into their context, will influence their work practise, it is our goals as designers to influence it positively. To do this we first need to understand the context and work practises. [28]
In practice this was done by actively postponing idea generation until the contextual inquiry phase was done, to make sure the ideas and concepts developed were harmonious with our users' work practises.

Another of the five principles highlights the fact that *"People are experts at what they do – but are unable to articulate their own work practice"* [28]. Our users cannot necessarily communicate their needs and wishes. It is our job as designers to discover this and help deliver them their desiderata. This is a description used by Nelson and Stolerman that covers not only what the client is saying, but also their latent needs and what isn't said out loud - a representation of what the client dreams about. We approach the users as equals and aren't *just* the facilitator for a specific design idea. Because of that, we engage in a *serving* relationship instead of one of *helping*, playing into each other like the yin-yang concept. [43]

Through multiple methods of field research can we begin to understand our users' work practises [28]. We have done this by using multiple ethnographic field research methods like semi structured interviews, contextual interviews and observations. As it is stated by Nelson and Stolterman, you must let empathy lead the way [43].

2.2 Scenarios

Below on figure 3, we have illustrated three use scenarios for FlowFrame. These are use cases which our users have mentioned they could see themselves in during our field research or evaluations.

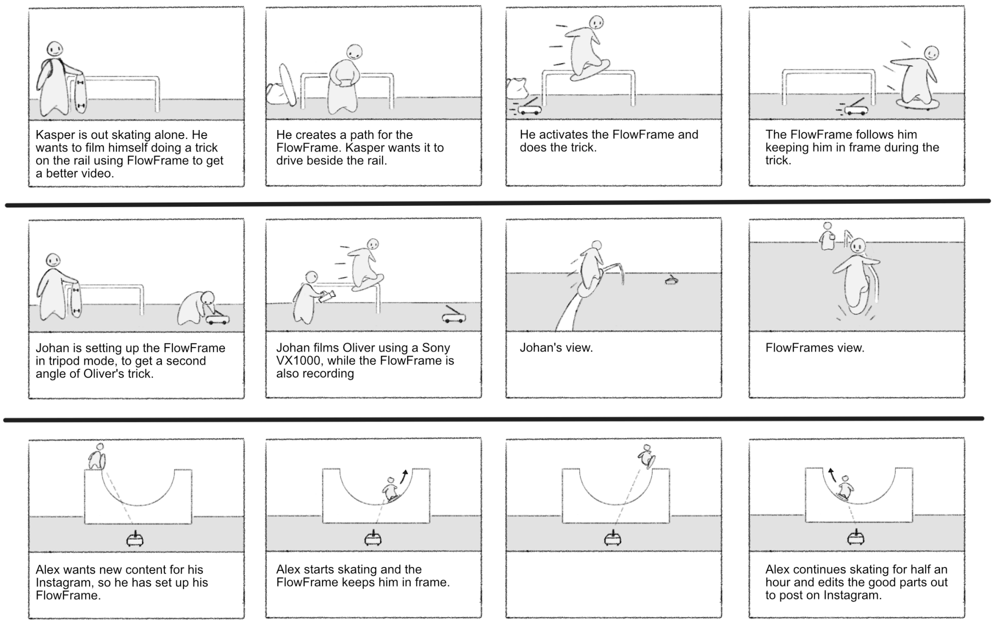

Figure 3: *Storyboard of three use scenarios with FlowFrame*

2.3 Business potential

FlowFrame fills a clear gap in the market by replacing or assisting the camera man, by offering low-angle tracking tailored to skaters filming alone, which drones and handhelds can't do. It taps into the creator economy, helping skaters produce high quality content solo. Starting with skateboarding, the tech can expand into other markets like gymnastics, track and field, and ground-level parkour.

We have created a business model canvas to illustrate these and other aspects (see figure 4). It can be seen in larger scale in Appendix 1

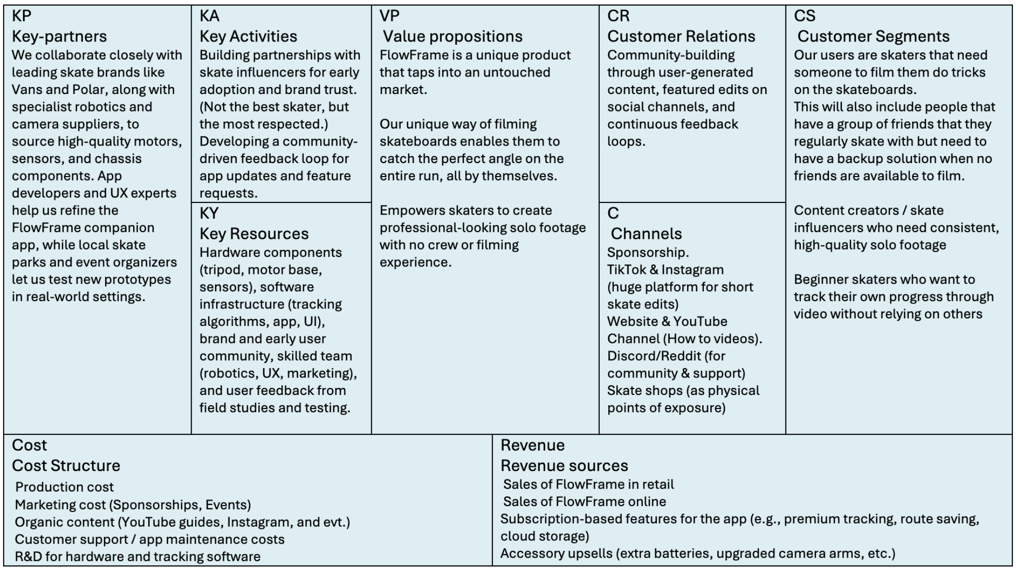

Figure 4: *BMC of FlowFrame*

3 Related work

In the following section, we review key academic studies and commercial products and relate them to FlowFrame.

DJI Flip

Despite weighing under 249 grams, the DJI Flip includes a 4K camera and built-in vision processor for autonomous subject following. It locks onto people and keeps them framed smoothly, even if the target briefly moves out of view. Its tight integration of camera, compute, and stabilization in a tiny package gives us a clear model for choosing sensors and processors on our ground-based tracker. [15]

The DJI Flip supports our claim that the market needs a product for light and cheap dynamic filming. Furthermore, it helped us come up with an educated guess on the price of our project in future work.

DJI Pocket 2

The Pocket 2 is a small, pocket-sized gimbal camera that uses ActiveTrack 3.0 to follow subjects without any markers. It performs real-time pose estimation on its built-in chip, keeping shots steady even when the camera shakes or the subject briefly disappears from view. With very low tracking lag and efficient power use it shows us that the technology for small compact gimbal with a relatively good battery life existed and was possible. [14]

This allowed us to think towards a small and lightweight gimbal, impacting multiple design decisions.

DJI Osmo Mobile 7

The DJI Osmo Mobile 7 series is very similar to the other DJI products in size and object tracking aspects. However, in this series of products, an extension rod and tripod are built in [16]. This is essentially the same product that we intended to prototype. Since the product already exists, we will need to create novelty in a different way – by wheeled movement.

LEGO Mindstorms with Raspberry Pi Vision

Otto et al. extend a LEGO Mindstorms EV3 [33] kit by offloading vision processing to a Raspberry Pi 4 (RPi4)[55] and USB webcam, which he uses to make the robot follow a line on the floor. The RPi4 handles real-time line following and object detection – using simple color filtering and shape recognition – while the LEGO motors [32] drive the chassis. This split lets you swap or upgrade either part without affecting the other. [49]

This connection between the EV3 and the RPi4 inspired us with our own project. We added a pan-tilt camera gimbal instead of the line follow camera.

Raspberry Pi + OpenCV Real-Time Tracking

Al-Juraidan and colleagues built a Raspberry Pi–based system that uses OpenCV [46] to spot a colored object at 15–20 FPS and steer a small robot so the object stays centered in view. They combine simple color-thresholding with a PID controller to keep tracking accurately at modest speeds, showing that low-cost hardware can handle both video analysis and motion on the same board. [4] This shows that FlowFrame can use a Raspberry Pi with OpenCV in combination with a more powerful tracking algorithm, to track skaters.

NEEWER DL400

The NEEWER DL400 is a compact, app-controlled dolly that rolls on motorized wheels and follows straight or curved paths. Weighing about 1.7 kg, it fits easily into a backpack. Users set speed via a smartphone app and rotation is set manually on the dolly, making it handy for smooth product shots or timelapses. However, its motion is limited to either a straight path or a pre-specified curvature. The fastest it can go is 1 meter in 15 seconds, which isn't fast enough for the sudden turns and rapid movement in skateboarding. [42]

4 Design process

In this chapter we define the design process of FlowFrame. This includes methods and results from the ethnographic fieldwork and how we have used it. We then illustrate the idea generation and the selection of the resulting concepts. Lastly, we show the development of our prototype, where we present the results in the following chapter.

4.1 Ethnographic field work

We have used multiple ethnographic field research methods to gather data on our users, as understanding them is the core of the contextual design philosophy [28]. We have used improvised, contextual, semi-structured, and focus group interviews as well as observations.

The collected data is in many diverse formats. Transcriptions of interviews provide personal and specific data, but artifacts like the Aarhus Local challenge book[2] (see Appendix 2) provide more of a cultural and aesthetic understanding. Here are the types of data we have collected:

- Notes and transcriptions[3] of audio recordings from interviews
- Notes and sketches from observations
- Pictures. Both photos we have taken, and inspirational/technical pictures from the internet
- YouTube and Instagram videos of skateboarding and the VX1000 camera for inspiration
- Aarhus Local challenge book and two resulting videos

Improvised Interview

We conducted two improvised interviews before completing our interview guide, to take advantage of sudden opportunities. Improvisation often arises in unforeseen situations where there is a need for quick action [30]. One interview took place at an Aarhus SkateScene event, where one group member engaged two skaters (P8, P9) in conversation about culture, motivation, and routines. P8 was around 30 and P9 was around 20. They had both skated for around four years. The second improvised interview occurred during an unplanned encounter with a skater (P1), who had 20 years of experience. P1 provided valuable insights and led to contact with new participants (P4, P5, P6, P7). These improvised interviews resulted in three semi-structured interviews and one focus group interview.

Contextual Interview

Contextual interviews are a way to bring to light users' tacit knowledge. They are experts at what they do, but their work becomes habitual, so they have a hard time describing why and what they do. Contextual interviews are one-on-one field interviews, where the researcher observes the user during their work, and asks ad hoc questions to understand the users' motivations and strategies [28].

During an Aarhus SkateScene event one group member engaged six skaters (aged between 20 and 40) in contextual interviews. The group member observed and asked elaborative questions as the participants were skating and resting/socializing between skate sessions. They were mostly interacting in groups, so the group member switched between them instead of just following one skater as one would normally do during contextual interviews [28].

[2] A book with a list of tricks to complete for local skate crews.
[3] The transcriptions were made using the GoodTape AI tool [24] and corrected manually afterwards.

Semi-Structured Interview

We conducted four semi-structured interviews. Two of them took place at Godsbanen (P2 aged 27 and P10 aged 22), another was scheduled beforehand (P3 aged 36) while the other occurred spontaneously when we had an opportunity to speak with an experienced skater (P4 aged 23, 10 years of experience). Although spontaneous, we maintained a semi-structured approach to adapt questions to the interviews' answers while maintaining a structure and a focus on our interview guide. We allowed the interviewees to go a bit deeper into specific self-chosen topics, without moving away from the semi-structured approach.

Throughout the process we used open-ended and object identification question types such as Grand Tour, Native Language, and Case-Focused questions, which allowed the participants to describe their sport and context in their own terms [67]. This flexibility helped us uncover both "skater" terminology and tacit knowledge embedded in their daily routines.

Group Interviews (Focus Group)

We conducted a focus group interview with three young skaters (P5, P6, P7, aged between 10 and 13) at a local skatepark. Due to the participants' age, we chose this method to help reduce the power imbalance often found in one-on-one interviews. Focus groups are particularly well-suited for research with children, as they create a more relaxed, peer-based environment. Conducting the session in a familiar environment further supported openness [3].

The group interaction allowed participants to build on each other's responses, creating a richer picture of the skateboarding culture. This aligns with the definition of focus groups to generate data through group interaction on researcher-defined topics. Here the group effect is highlighted as a key strength—where dialogue between participants leads to deeper insight [40].

Observations

We conducted non-participatory observations at both Godsbanen and Læssøesgades Skole. Our observations were covert, meaning the participants did not know they were being observed. This was done to avoid influencing participants' behavior. We justify the ethics of this approach by only observing in a public skate park and sketching and writing notes instead of recording. [17]

At Godsbanen, we observed how skaters interacted with each other and the space—not only while skating, but also during conversations and other interactions with the board. This aligns with the concept of observed experience, which emphasizes how tacit knowledge can be accessed through watching what people do and how they use objects and spaces [59].

At Læssøesgades Skole, we observed while a *Ung i Aarhus* event was being held outside regular school hours. This allowed us to see how the skate area was used in a more open, youth-driven context. In both cases, the observations complemented our interviews by providing a broader understanding of the users' relationship with their environment.

4.1.1 Methods of data analysis

The data collected is naturally individual, but we are designing for the whole customer population [28]. Therefore, we need to consolidate the data to clarify common patterns, which represent more general needs and wants of skaters. We have done this by creating affinity diagrams.

Affinity diagram

Affinity Diagrams structure data from all participants, to reveal overarching problems and the scope of them [28]. We gathered all our data – pictures, sketches, notes, and quotes from interviews in the middle of a table. Then we went through all the data and categorized it. If a piece of data didn't fit an already existing category, a new one would be created. The categories were: (see figure 5)

S.K.A.T.E	Area	Newcommers
Social	Film	Culture
Idle	Filming with phones	Cheering
Why skate?	Filming with old cameras	Board
Envorinment	Event	Gadgets
Tricks		

Figure 5: *Affinity Diagram categories*

During the revision of all the categories and their data, we sometimes created or renamed subcategories, to consider different problem areas. When we were done, we documented the diagram and remade it, now with themes that we wanted to explore further, instead of general categories. The three themes were: *Gamification and board, Embedded in track and enhanced feedback* and *Strengthen community and identity.*

4.1.2 Empirical presentation

From the affinity diagrams, we categorized multiple themes. *Filming, Community, Culture and Identity* and *Tricks* we felt were the most prominent and interesting themes, which is why we focused on them.

Filming

A huge part of skating is filming the tricks. It's often longer videos with many parts or vertically short form videos. Of course, professionals post skate content online, but many others also film themselves – either to post on (primarily) Instagram, or for themselves and friends to watch later:

> *"It's a lot of fun to look back on or post it on Instagram and other social media."* (P2)

We noticed two different approaches to filming. Some wanted high quality and clean videos, while others wanted more of a retro and *trashed* aesthetic. For both styles a fisheye lens is very popular, both for cameras and phones. It makes the movement seem faster and the skater seem closer. P2 also described it as *"just a skater thing"*.

For old cameras the SONY VX1000, which runs on tape, is the popular choice (see figure 6 and 7). It's what was used when skateboarding was at its peak in the 90's and it has a very particular picture and sound, which has been described as *"it just sounds like skateboarding"* in public videos featuring this camera [57].

Figure 6: *The Sony VX1000 Camera*

Figure 7: *Screenshot of a recording with a VX1000 and a fisheye lens[66]*

The editing also matters a great deal in these videos. A song usually plays in the background. Sometimes the video becomes so well known in the skateboarding community that the song itself gets associated with the video. There are many different styles and aspects of these videos which skaters care about:

> *"Crazy many people care a lot about editing. You typically skate over a song. There are also some who cares a lot about making these sort of skits and funny bits. Some also make all kinds of graphics in the videos."* (P3)

Community

The skateboarding community is strong and very welcoming, both locally and internationally. Cheering and recognition is also a big part of the social aspect:

> *"No matter where you are in the world, I always think that if you go to a skatepark, you'll always have a chat with someone. And there is space for everyone. I don't think there is any other sport, where you can chat with someone who is fifty and on the other side is one who is ten, and everyone cheers for each other."* (P3)

During a skating session there are a lot of breaks, where they often sit together and talk, drinks beers/sodas and/or smoke. During these breaks and other idle times, they often interact with their skateboard in some way (see figure 8).
There are multiple initiatives to strengthen the community. For example, the Aarhus Local Challenge book, where crews (a group of skaters) filmed and sent in a video of them doing predefined challenges, to be shown at an open party (see figure 9).

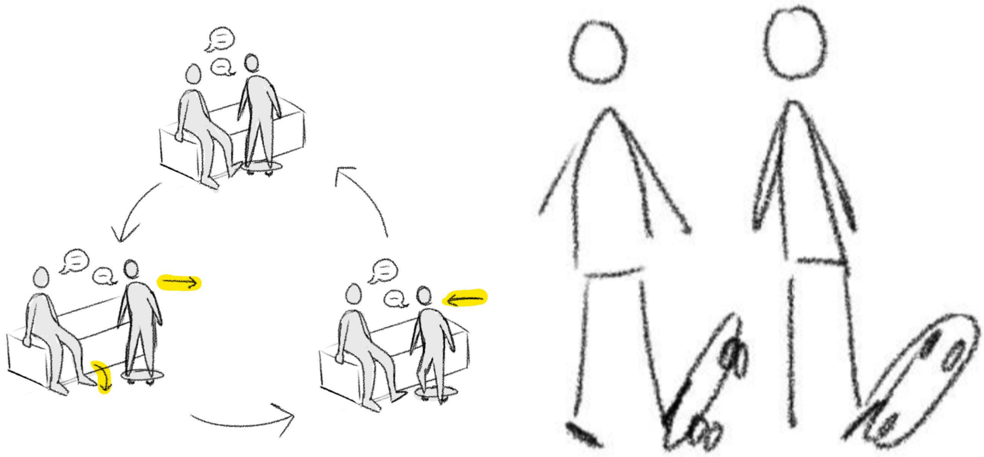

Figure 8: *Two examples of skaters talking while mindlessly interacting with the board.*

Figure 9: *Screenshots from contributions to the challenge book. [45]*

Culture and identity

We observed a strong sense of identity connected with skateboarding. There were certain clothes, shoes, boards, art styles, customs and technology they had embraced. Graffiti (see figure 10), the VX1000, fisheye lenses, Thrasher[4] shirts, VANS[5] shoes and fist bumps are just some examples we observed.

> *"You can really 'nerd out' a lot. In all kinds of different directions. That is why I think this is so cool. Like, I can sit and 'nerd out' on some cameras and obsess over technical pictures and books. Also, just tricks, film, wood [i.e. board] and clothes."* (P3)

They present the skater identity and their artifacts as very established:

> *"I just think that the skateboard by itself, is altogether very established. That is how it looks, and that is how it feels, and that's how it's always felt, and it just works."* (P2)

[4] American skateboarding magazine
[5] American apparel, accessories, and skateboarding shoes brand

Figure 10: *Graffiti at Godsbanen Aarhus*

Tricks

When it comes to actually doing the tricks, we also found some interesting aspects. There were two elements that made a trick cool – bravery and skill. The skaters we talked to values skill more, but they can still appreciate a jump from a big ledge - known as a *just“gap”*. A few tricks are also just uncool. A double kickflip is uncool, even though it’s technically more advanced than a normal kickflip. When questioned on this the interviewee just answered, *just“that’s just how it is”* (P8).

Another thing that made a trick cool was novelty. I.e. making a new trick or doing a trick at a place or context nobody else has done (see figure 11).

Figure 11: *Clive Dixon jumping out of a helicopter in KING OF THE ROAD [65]*

All in all, there are a lot of different aspects of skating. Both the actual skating and a strong community with a rich culture and interesting technology.

4.1.3 Work Models

We used the work models to deepen our understanding of the skateboarding community and find possible breakdowns - both in terms of significant cultural aspects and the artifacts used.

Artifact models

We have created 3 artifact models on the skateboard, the VX1000 and fisheye-lenses. These three technologies are very important to skaters. Either because they themselves use it, or because they're a significant cultural artifact. We have noted both technical details, the skaters' use of them and possible breakdowns concerning these artifacts. They give an insight into the user's thoughts about their activity (i.e. filming or skating in our case) and highlight breakdowns [28]. The models can be seen in a better resolution in appendix 3.

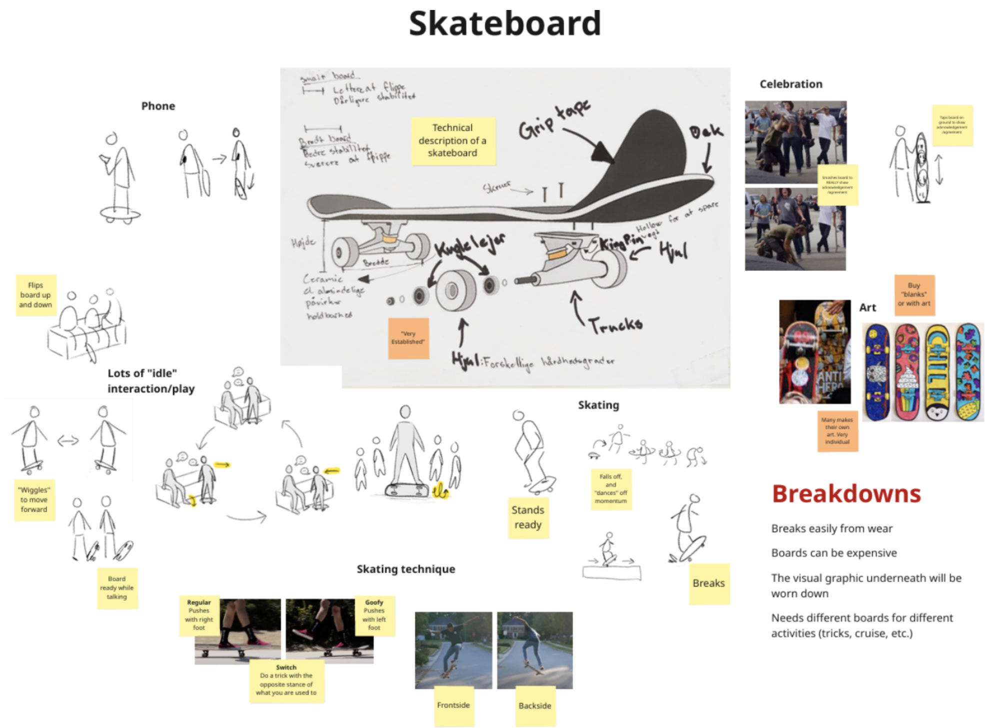

Figure 12: *Artifact model of a skateboard*

This model does not highlight a lot of breakdowns (see figure 12). The board is very established, so we didn't expect to find many problems. The model instead gives a great overview of the technical and cultural aspects as well as the different uses of the board.

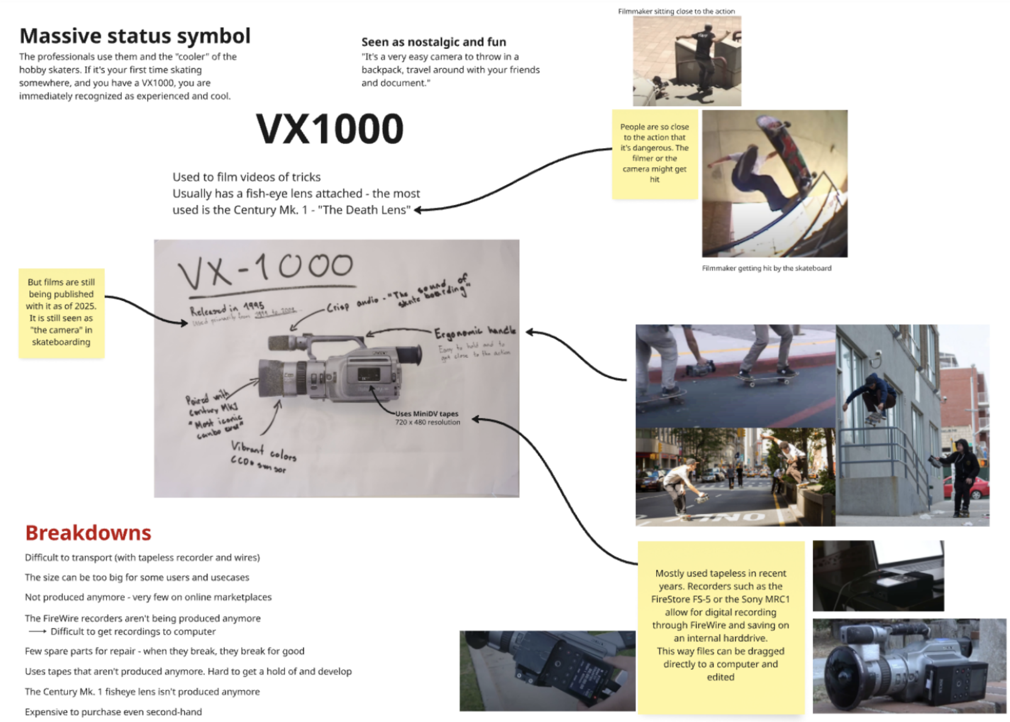

Figure 13: *Artifact model of VX1000 camera*

This model has a lot of breakdowns (see figure 13). It's an old camera with outdated technology and from that there appear a lot of problems. It's also discontinued, so some breakdowns also remark the distribution of the camera. Despite the problems, it is still a huge status symbol in the skateboarding community and is therefore still very relevant.

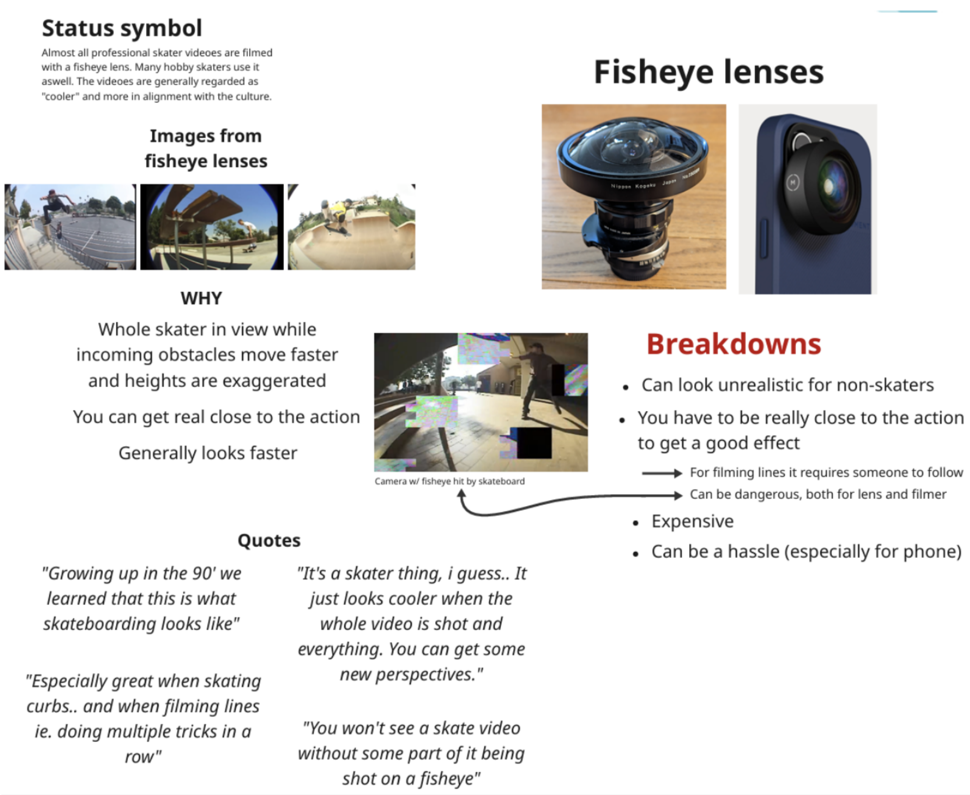

Figure 14: *Artifact model of FishEye lens*

This model (see figure 14) highlights the risks during filming - both for the camera man and the lens. Furthermore, it highlights the cultural value of the fisheye lens and the impact it has on the community.

Sequence models

We have also created 3 sequence models (see figure 15). The models can be seen in a better resolution in appendix 4.

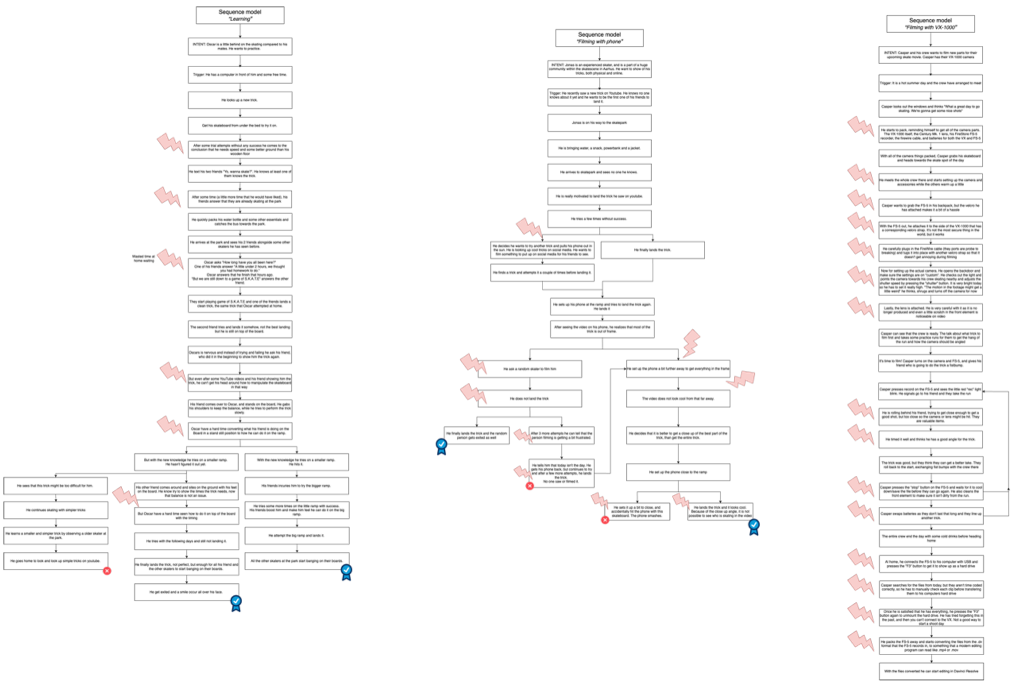

Figure 15: *Sequence Model*

These sequences and the identified breakdown points create a good foundation for the possibilities for improvement within our subtheme and user group. The *Filming with VX1000* sequence is particularly littered with breakdowns, which is a problem for such a culturally important artefact.

The *Filming with a phone* sequence highlights the challenges of capturing skate tricks using a mobile phone. While it is more convenient than using a professional camera, the difference in video quality is significant.

The *Learning* sequence illustrates the different skill levels among skaters and how they support each other in the learning process. It also emphasizes that both teaching and being taught can be difficult in the context of skateboarding.

We are aware that most of our work models focus on artifacts or the technical aspects of skating, but this was the direction our field research led us to.

4.1.4 Personas

Personas must be based on field data of the users [44]. In our case we took characters from the scenarios we had already created and made personas out of them. The scenarios and therefore also the personas were based on our empirical work. The personas were based on a mix of different people and not just a single skater (see figure 16).

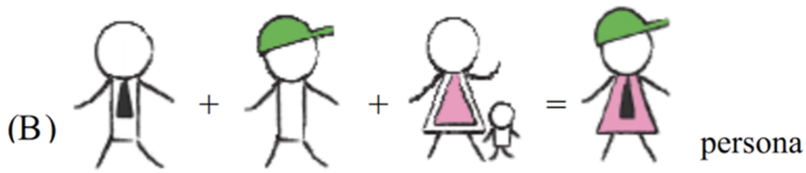

Figure 16: *Persona as a person or as a mash up of people [44]*

To create the personas, we identified recurring themes, motivations, and behaviors across our empirical material. This included things like how often people skate, what gear they use, how they film and share their content, and what social dynamics they're part of. We then grouped these patterns into three distinct personas that each highlight different types of users within the skateboarding environment - from younger beginners to older hobbyists. The personas were also enriched through visual presentation, including personality sliders, quotes, and platform preferences, to ensure they communicate not just user needs but also the emotional and cultural context around skating. See figure 17 for a presentation of one of our personas. All three created personas can be seen in high resolution in appendix 5

Figure 17: *Persona of Michael from the scenario filming tricks with phone at the Frederiksbjergskole*

4.1.5 Scenarios

Scenarios are stories about users and how they interact with a system/product. They explicitly envision and document user activities. They evoke reflection and they keep the focus on the users. [11]

We have created four different scenarios and three personas. We have selected one of each to present in the assignment. The rest is in appendix 5 with the personas.

Filming tricks with phone at the Frederiksbjergskole

Michael (25) is meeting up with his crew black dogs at the Frederiksbjerg skole in central Aarhus after work. Most of the crew are already jumping stairs and grinding on rails. Sasha (26) spots him, smiles and shouts "Yo Michael!" in greeting. He takes a round and fist bumps those of his friends that are not busy with a trick. Michael walks over to Anton (23) who is standing at the top of the stairs in front of a red rail (see figure 18). Anton makes puppy dog eyes, hands out his phone and asks if Michael can film his trick. Michael laughs while nodding and then takes Anton's phone. He unlocks it using face recognition by turning it back to Anton's face. Then he opens the camera app. He uses a minute to change the camera settings to match the outside lighting. There is a setting he cannot find on Anton's phone, so he gives up. He presses the record button and signals for Anton to start with a thumbs up.

Antons face changes to complete focus. He takes a deep breath and takes off on his board. With the skateboard under his feet, he jumps the rail and grinds on it all the way down. Michael follows the movement with his body and camera. The friction from rail to skateboards makes a familiar screeching sound and then a satisfying "plonk" when Anton lands on the pavement. Michael and a few of the others cheer and fist bumps Anton when he skates back to the group. Michael stops recording and gives the phone to Anton, who excitedly takes it to review the footage. The sound from the video plays out loud, and when the "plonk" comes, Anton laughs and woos. Later that day, Michael is on Instagram and sees a new post from Anton. Together with other short clips, Michael sees the video he made. It has been shortened and has been overlayed with a filter, that makes the colors pop a bit more. When Anton is grinding on the rail, it's in slow motion, but goes back to normal when he lands. Michael likes the video and continues with his Instagram feed.

Figure 18: *Picture of Frederiksbjergskole with the red rail*

We have also created a storyboard to represent the scenario *"Skating with friends at Godsbanen"* (see figure 19).

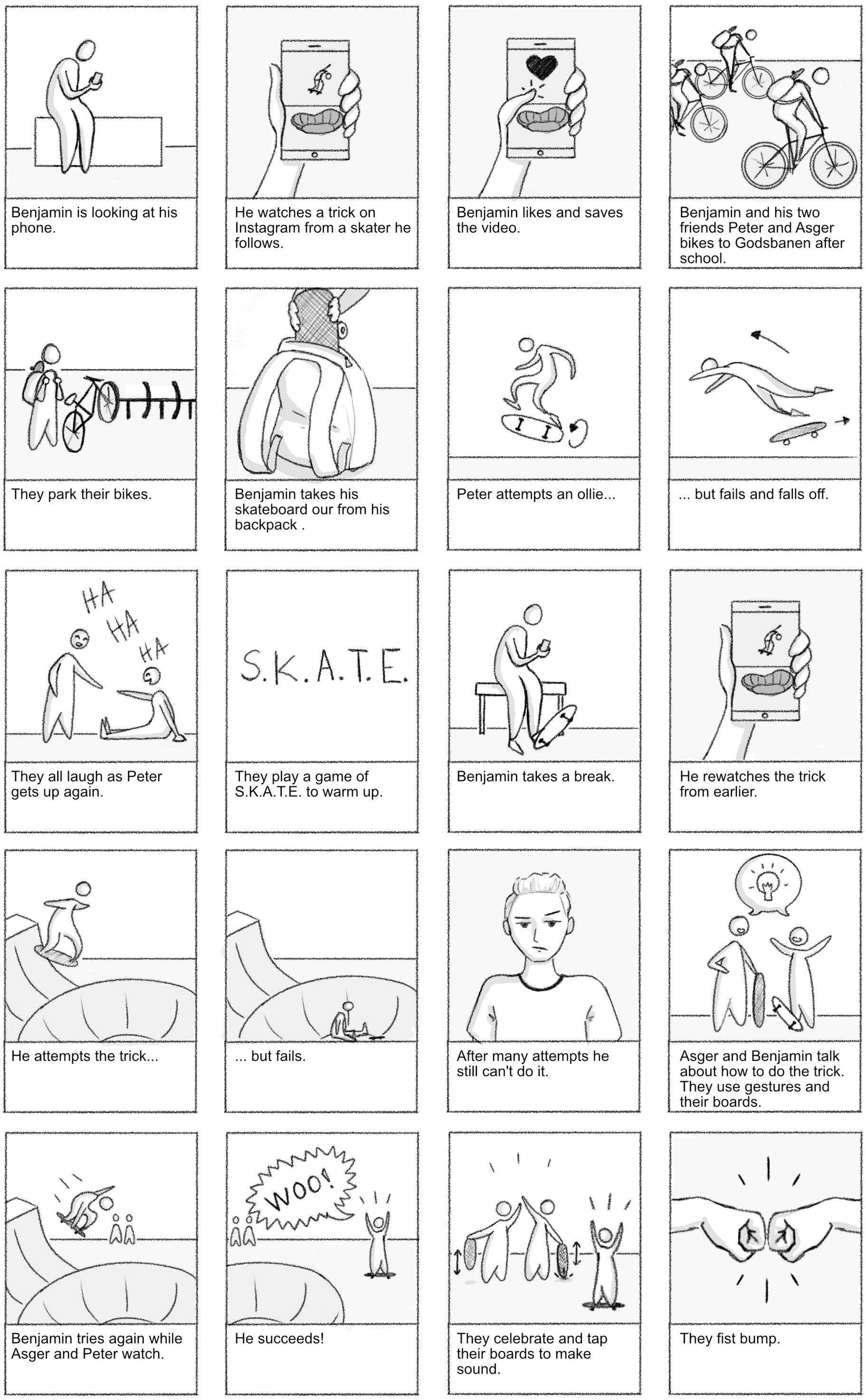

Figure 19: *Storyboard of Skating with friends at Godsbanen*

4.2 Idea generation

The idea generation phase was kicked off with a hybrid brainstorm as this was shown to be the most effective method by Girotra. Here we spend 15 minutes writing down ideas one-by-one after which we ranked our own ideas and presented them to the group. This was repeated 2 times to allow for input from others' ideas into our own ideas. Using the hybrid method also helped dissolve any hidden social structures in the group that could have hindered a traditional group brainstorm as documented by Girotra. [23].

We managed 100+ ideas but didn't stop there. To further increase the number of ideas generated, we conducted an inspiration card workshop with another group. This method is exceedingly good at breaking up norms and common conceptions [27]. Conducting the workshop with another group helped us create new connections between contextual domain cards and relevant technology which we otherwise would have overlooked or simply not thought about.

From an approach of divergent thinking, we switched to a converging view to narrow down the number of ideas. We used a simple place-a-dot technique for the first round of narrowing down. Each group member put a dot on the five ideas they liked the best and the ideas without any dots were eliminated. This was repeated twice and allowed us to quickly get down to a manageable number of ideas.

4.3 Concepts

We created 20 distinct concepts and used the place-a-dot method to quickly narrow the number of concepts down to nine. They were then rated in a matrix based on several factors, including how well they fit in the assignment, how well documented in our field work they were, how realistic they were to prototype along with our own excitement for them. Furthermore, it was important for us to rate them on cultural acceptance - an educated guess by us on whether the product would be accepted in the skate culture - as we learned from our field work that it was a particularly hard thing to pass. We also valued internal excitement as this would be a significant factor in our drive and motivation to put in the hours necessary for such a big project. The nine concepts and their ratings are shown in Appendix 6.

The four highest rated concepts were brought to a feedback session with the rest of the class. They will be explored in detail in the following sections along with reflections on the feedback on each. The two VX1000 variants are described as one concept with different directions.

4.3.1 Concept 1 - The VX2025

The first option for this concept was to create a shell for a phone that emulates the VX1000 look and feel while making it more convenient to film skate videos (see figure 20). We wanted to combine the best things from the 1995 design with the modern technologies of the 2020's. Specifically, we wanted to keep the handle, audio, and overall look of the video from the VX1000. It would also include attachment modules for different phone models. A usage scenario of this can be seen in figure 21.

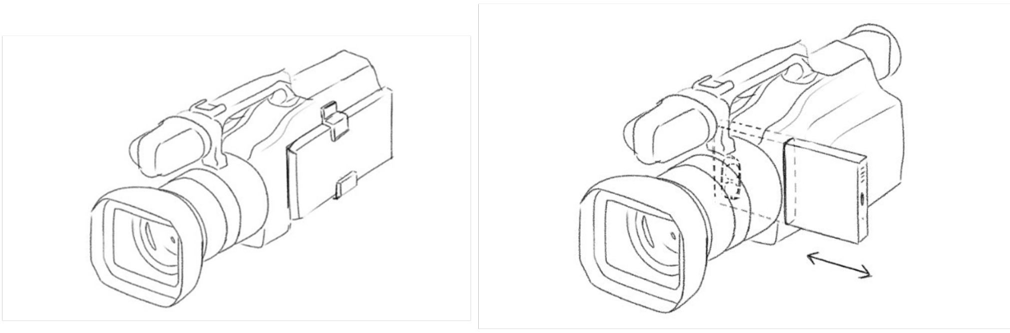

Figure 20: *Sketch of the VX2025 shell option*

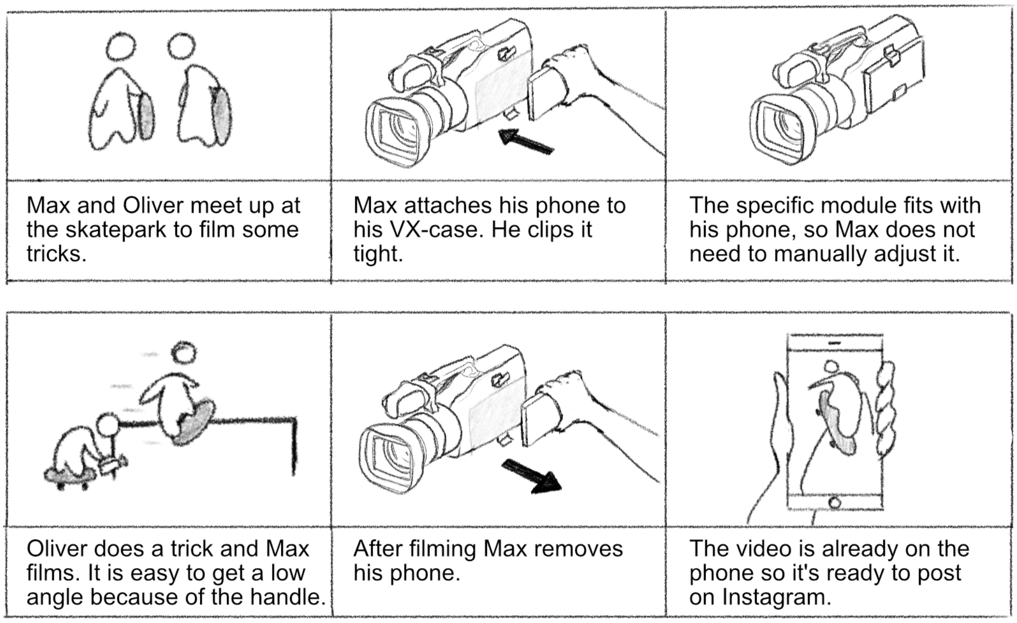

Figure 21: *Using VX2025 shell option*

The second option was a reimagined VX1000 built from the ground up, while retaining the qualities of the original design as seen in the scenario earlier. The qualities we would like to keep are the handling, audio, and video quality. We explored different form options for the camera (see figure 22) as well as usage scenarios (see figure 23).

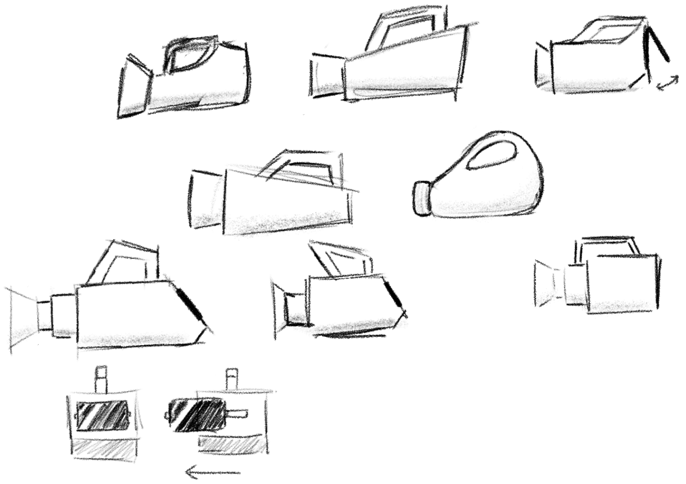

Figure 22: *Form exploration of VX2025*

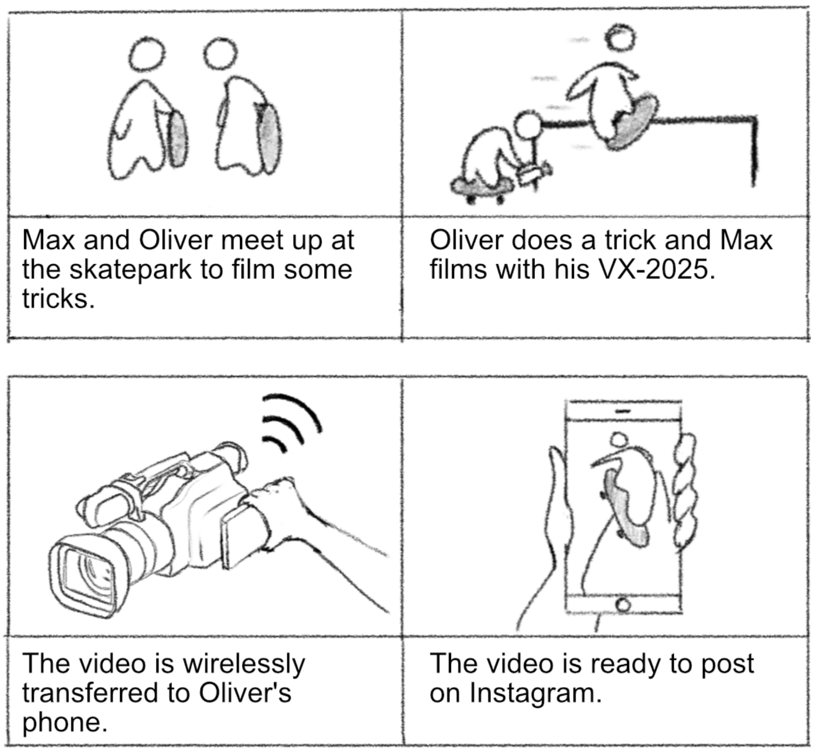

Figure 23: *Using the reimagined VX2025*

4.3.2 Concept 2 - The integrated filming system

The integrated filming system concept was oriented towards skate parks. This concept would enable automatic video capture of a skate run based on cameras embedded in the skate park obstacles. A system would detect where the skater is and create an edited video for instant download after the run. The different cameras would cover different areas such as a close-up of a rail and a general view of a bowl (see figure 24).

The skater would start a run while the software system in the background determines which cameras to fetch video from, and at which point of the run (see figure 25).

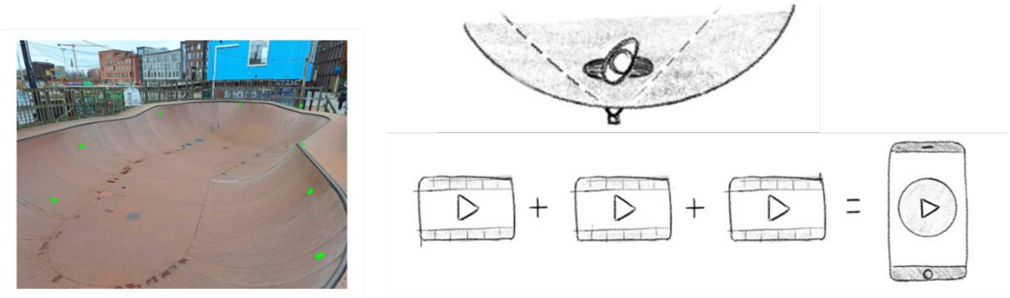

Figure 24: *Green dots represents cameras. Clips get combined into one video*

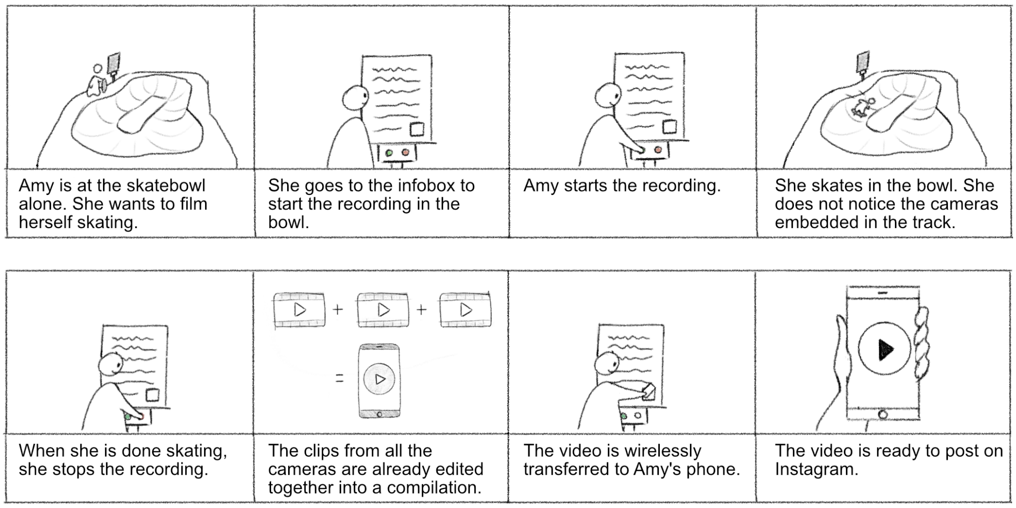

Figure 25: *Using the integrated system at a skate bowl*

4.3.3 Concept 3 - The automatic tracker

This concept consisted of a tripod with retractable legs, a sensor/camera array, a phone mount, and motors to turn the phone mount so the skater could stay in frame while skating (see figure 26 and 27). We also considered a non-motor design that would zoom and pan digitally, like how the Veo camera works [60]. The whole system would need to be compact enough to fit in a small backpack along with a skater's regular gear.

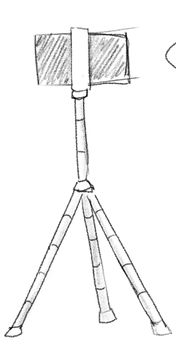

Figure 26: *Tripod concept*

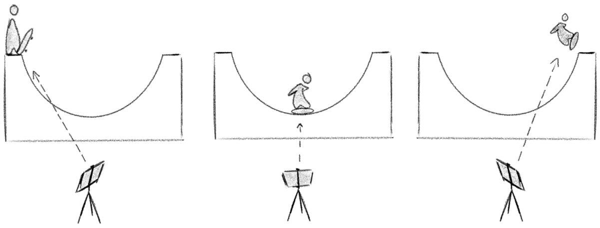

Figure 27: *Tripod tracking a skater*

We tested different camera heights to determine the length of the tripod. Jakob stood on top of a stone approximately the same height as a skateboard, and we took pictures with a phone (see figures 28-30). We used 0.5 zoom, since we found that skaters use the same setting. They also film ground level shots or knee level shots. Therefore, we held the phone upside down, to get the camera as close to the ground as possible. From our test, we determined that the camera does not need to go above 35 cm from ground (see figure 31).

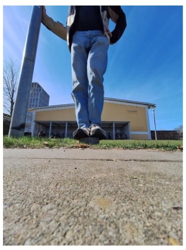

Figure 28: *Approx. 4 cm off ground, no tilt*

Figure 29: *Approx. 35 cm off ground, tilted slightly upwards*

Figure 30: *Approx. 4 cm off ground, tilted upwards*

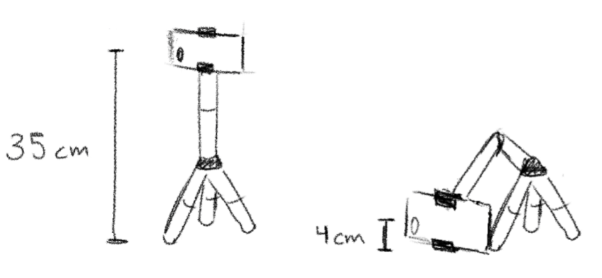

Figure 31: *Tripod with adjustable height*

During the feedback session, we received multiple key insights. The tripod part of the concept was questioned. Could we place the tracker on rails or somehow introduce movement? We considered small rail pieces the skater could put together to make a larger track for the camera (see figure 32). This could be quite bothersome for the skater; both to bring all the pieces, build the track, and the fact that other skaters would have to avoid the whole track during filming.

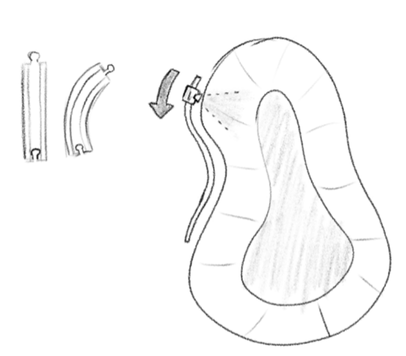

Figure 32: *Top-down view of skate bowl with a track for camera*

We also considered a rail-free solution where the user would preprogram a path, by physically moving the camera (on wheels) on the desired path (see figure 33 and 34).

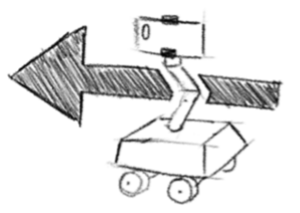

Figure 33: *Tracker on wheel, like a RC car*

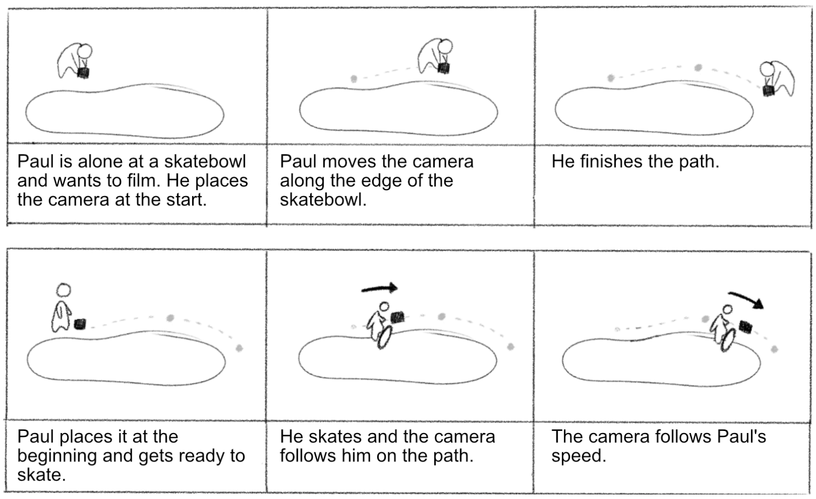

Figure 34: *Storyboard of tracker on wheels*

4.3.4 Concept selection and rating

Based on the feedback session and our own reflections we decided to move forward with the VX2025 concept in three variations:

- A completely new VX1000 build from the ground up with modern technology
- A VX1000 case for mobile phones with a screen for previewing the camera feed
- A VX1000 case for mobile phones without a screen

Alongside the automatic tracker concept in three variations:

- A stationary tripod with motors for keeping the skater in frame
- A stationary tripod with an ultrawide camera that would be panned with software
- A dynamically movable tripod on wheels with motors for tracking

These were again rated in a matrix based on selected parameters to make sure they weren't selected or eliminated based only on our internal excitement. In addition to the parameters mentioned in the last matrix, we also set up business parameters. Here we estimated the components needed for each concept along with their prices and set up an estimated retail price. The prices were based on European commercial resellers. Based on this we calculated the possible profit margin as well as estimated the market potential (see figure 35).

Økonomi	Komponenter	Tlf	Tfl. u skærm	Selvstændigt kamera	Tripod	Tripod hjul
	Kamera	100		100		
	RBP	230		230		
	Mikrofon	50	50	50		
	Skærm	130		130		
	Case	60	60	60		
	Assembly	250	150	300		
	NFC modul			30		
	Case				60	100
	Motor				190	380
	Sensor				40	80
	Assembly				150	300
Pris m. moms		820	260	900	290	560
Pris u. moms		**615**	**195**	**675**	**217,5**	**420**
Estm. salgspris		1000	750	1500	1000	2000
Profit		385	555	825	782,5	1580
Profitmargin i %		**38,50%**	**74,00%**	**55,00%**	**78,25%**	**79,00%**

Figure 35: *Budget sheet*

We also split up our internal excitement from group to individual ratings. This made sure no compromises were made, and everyone got their say. The dynamic tripod on wheels got on most points with 60: 4 ahead of the second best.

Our plan for prototyping this concept was to create two prototypes. One would be a technical prototype for object tracking and movement of the camera and car. The other would be the GUI and interactions of the app design. The development of these will be discussed in the following chapters.

4.4 Development of software and hardware

Once set on the concept we wanted to create, we started prototyping the technical aspects to test the best possible approach. The first problem was establishing what sort of computing device/board to use. We needed to run a computer vision algorithm which required processing power along with easy camera integration. Therefore, we chose the Raspberry Pi 4B (RPi4).

4.4.1 Connection to the Raspberry Pi

Typical ways of establishing remote access to a RPi4 include SSH, VNC and Raspberry Pi Connect [56]. However, since we wanted to control the Raspberry Pi remotely from a website with a custom GUI (for controlling the prototype), these options weren't applicable. Our first thought was to use Bluetooth. Specifically for the technical prototype a Bluetooth Low Energy (BLE) connection, as this uses little power and is ideal for transmitting small amounts of data [36].

To use BLE we needed to set up a GATT server on the RPi4 [31]. This was tried through multiple guides [12, 8] but we never succeeded in establishing a connection. A regular Bluetooth connection was established with the Blue Dot python library [37] but the UI capabilities of that library were too limited for our use case. Furthermore, Bluetooth doesn't work when we need to transmit commands to two devices simultaneously. This would be the case when we chose the LEGO Mindstorm EV3 as the platform for the mobile base, as described in the next section.

Instead, we chose the MQTT protocol [41] as this allows us to broadcast messages to multiple devices simultaneously without having direct connections between them. Furthermore, the MQTT protocol is very lightweight and can run on the limited processing power of the EV3-brick [41].

In the final product, the ideal solution would be to use Bluetooth as this would allow for a direct connection to a specific device i.e. if multiple people brought a FlowFrame to the same area, it should be possible to connect to your specific device.

4.4.2 LEGO Mindstorm

In order to save time, we decided to use the LEGO Mindstorm EV3 platform /citeev3LEGO2025, based on the recommendation of LabTools. Furthermore, the EV3 platform allowed us to quickly prototype a moveable platform while being customizable enough to fit our use case. Speed was the primary concern in choosing the EV3, but we determined a little movement was sufficient to showcase the concept.

4.4.3 Height adjustment

Based on our field work, we considered integrating height adjustment into our prototype. The EV3 platform allowed us to quickly prototype a system for vertical adjustment of the camera module. By using an EV3 large motor [32], along with a series of gears, we could power the studs up and down as seen on figure 36. On top of these the pan-tilt module would be placed.

Figure 36: *Construction for vertical adjustment*

4.4.4 Computer Vision tests

The object tracking element of the prototype was made to test the technical feasibility of such a system, which is also mentioned by Floyd as one of the main reasons to prototype [21]. To enable us to detect and track objects, we used the OpenCV open-source library for computer vision. We used multiple of the pre-trained and tested models for our detection and tracking, as this enabled us to quickly prototype, without training our own model. The OpenCV library is used as part of a Python program running on our RPi4. Most of the testing was done on a laptop to enable us to view a graphical representation of the captured video stream from OpenCV (see figure 47).

Figure 37: *Graphical representation of Different OpenCV modes. Left to right: Background seperation, Contour detection, Edge detection and threshold*

These graphical representations were a good starting point but didn't provide any tracking capabilities and we therefore turned to more advanced models for the finals prototype. These will be presented in the prototype section.

4.4.5 Pan-tilt module

For prototyping the pan-tilt module we acquired two SG-5010 servo motors [1] along with a PCA9685 servo motor driver [2]. The servo motors have a maximum of 180 degrees of movement [1]. We determined that it would be enough rotation capacity for accomplishing the goals of the prototype. Continuous rotation would be preferable in the final product and could be obtained by using stepless DC motors instead [62].

The PCA9685 was used for two reasons. Firstly, it lets us connect multiple motors to the Raspberry Pi through the SDA and SCL pin, which there are only one of each on the board. Secondly, the motors are controlled by PWM signals, and while they would work fine by themselves, the Raspberry Pi camera introduces noise to these signals, which makes the motors jitter violently. The use of PCA9685 prevents the signal noise, so the motors can move in a controlled manner. [69]

Once the motors were connected to the RPi4, we wrote a Python program to control them using keyboard inputs. This allowed us to verify that the motors were functioning properly and move on the integrating them with the object tracking program.

4.5 GUI

The most important interaction in the app was how users would create the path FlowFrame would follow. We worked with the basis that the path must be set before the skater steps on the board. We reasoned that this would be more technically achievable than for the FlowFrame to follow and react to its surroundings live.

We began, with a hybrid brainstorm session, exploring various control methods [23]. From this, three feasible concepts emerged: ground-based line-following, GPS waypoints on a digital map, and a virtual joystick for logging of movement to repeat during filming. To externalize our early interface ideas, we started by sketching a few on paper, turning lose concepts into tangible layouts that we could review and refine (see figure 38) [13].

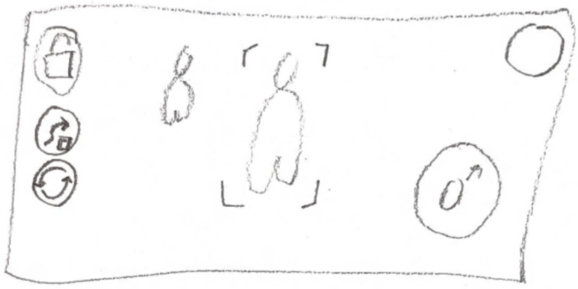

Figure 38: *Sketch of screen for selecting tracking target*

We then arranged a paper cut-out of the joystick control method to get a hands-on feel for how the elements would relate on screen [13]. Using a lightweight comparison, against criteria like feasibility, setup effort, and environmental constraints, we discarded the line-following option [51]. We found that the skateparks' surfaces often are graffitied, which would obscure the line. The drawing of lines would also require extra materials, like chalk, for the skaters to draw lines.

4.5.1 Digital Prototyping in Figma

In Figma we crafted mid-fidelity prototypes for the GPS-waypoint, joystick controls and other parts of the app flow. These interactive designs let us simulate aspects of the controls and provide a full flow of the interactions. By providing clickable and shareable models, our Figma prototypes became the centerpiece for productive and collaborative conversations [68].

We used the Figma prototype during testing of the interface with our classmates. Their feedback on spatial structure and sizing of elements, alongside reactions to the general concept, helped us refine the design. After each session, we incorporated their insights into Figma, creating new iterations (see figure 39-43). We approached it as an action-and-reflection cycle, which is at the center of experience-centered design [68].

Figure 39: *Iterations of the record button*

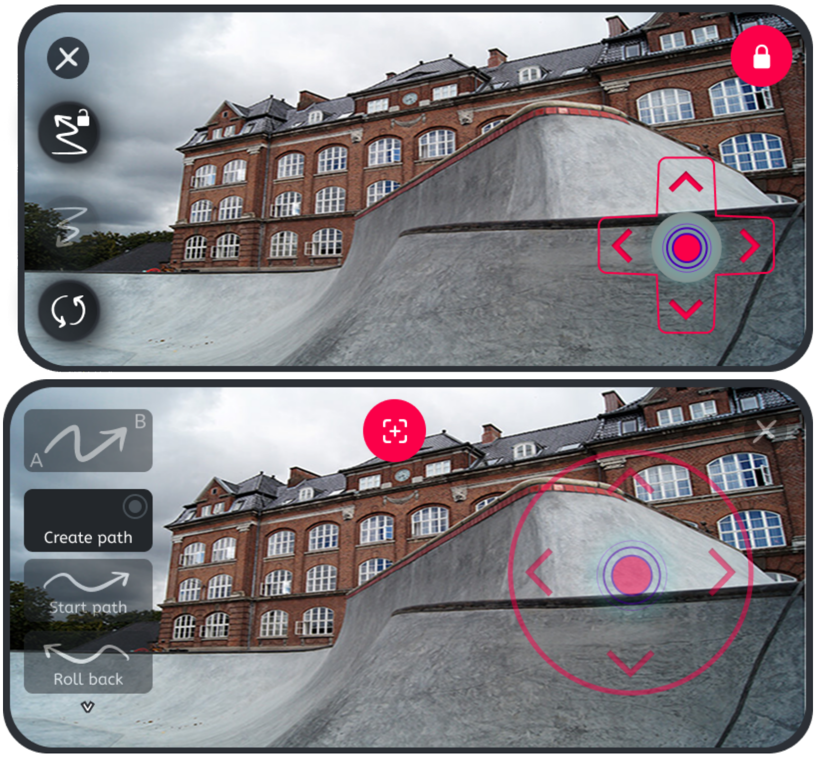

Figure 40: *Iterations of the joystick control method with a live feed from camera*

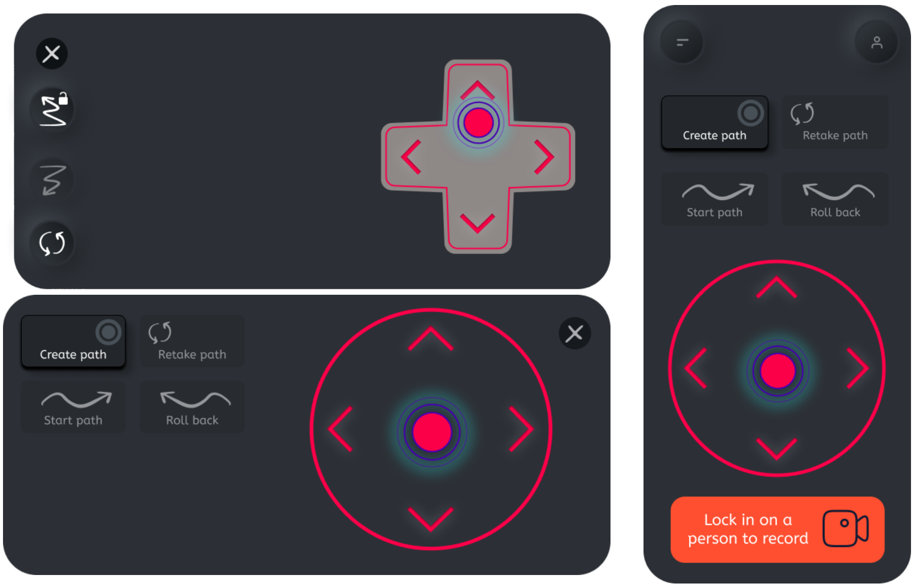

Figure 41: *Iterations of the joystick control method without live feed from camera*

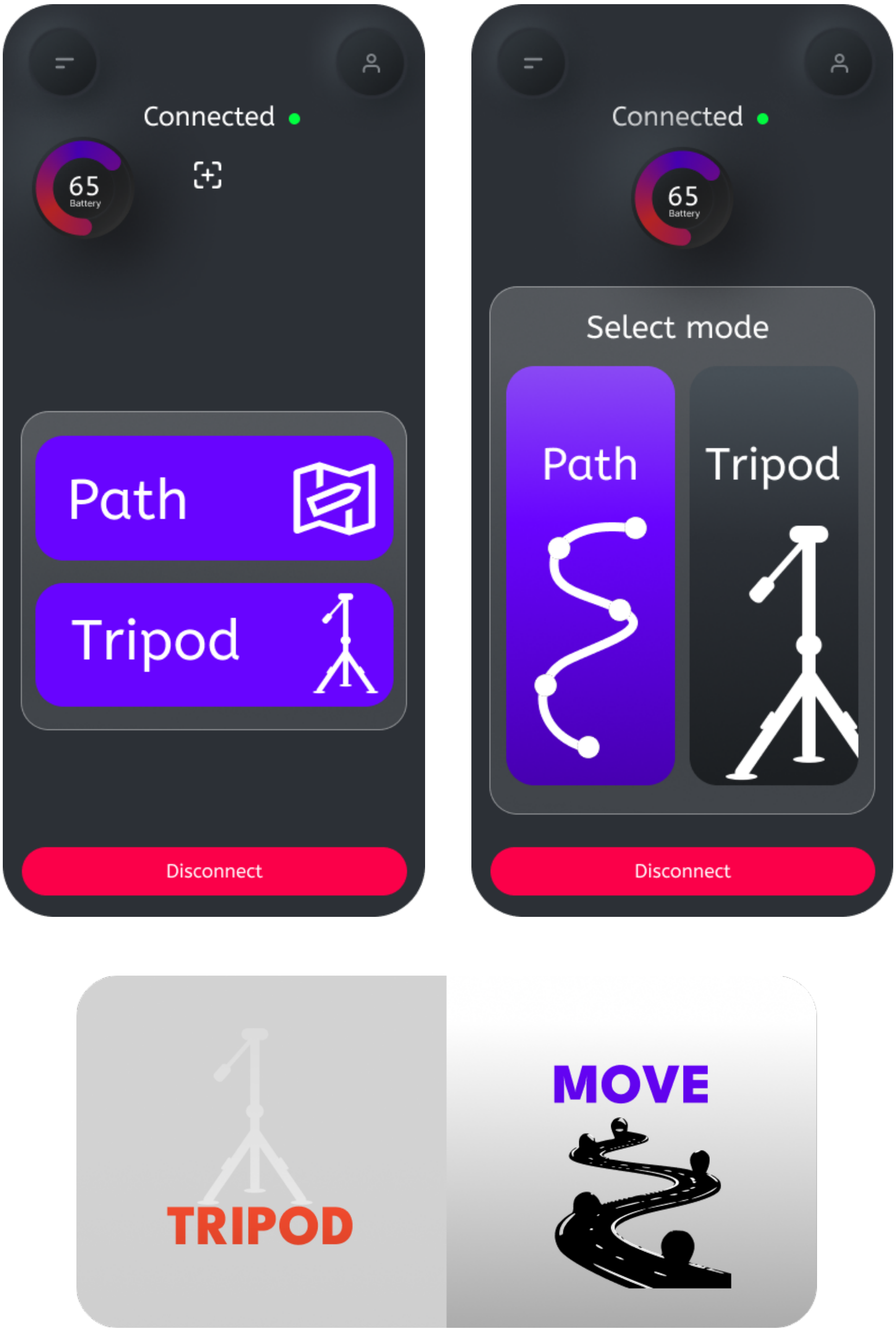

Figure 42: *Iterations of the start screen*

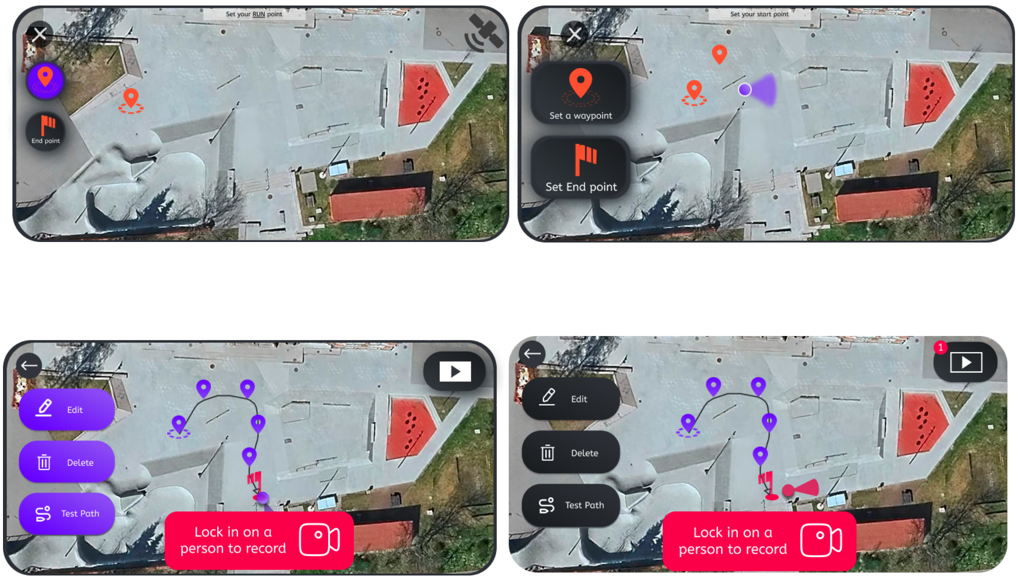

Figure 43: *Iterations of the waypoint control method*

After evaluating the prototypes with users, we reflected on the design. During the prototyping phase we focused on integrating the visual elements of important functions but neglected design details. The design would therefore benefit from an overhaul in both detail and the broader picture. This would make the design clearer and more consistent. We went back to the design and made changes to fix some of these inconsistencies and apply more design principles.

We made the color scheme, button sizes, text sizes and general visual style more consistent throughout the whole app. We also implemented other design principles:

- The *go back* symbols (see figure 44) provide safe exploration, since the user always can go back to earlier pages or the start page [63].

Figure 44: *Go back button*

- The *lock button* has two different visualizations, which indicate its state to the user [25]. If there is no person to lock onto the button is disabled, which is shown by its transparency (see figure 45). If instead there is a person in frame, the button becomes the same color as the other buttons and can be pressed.

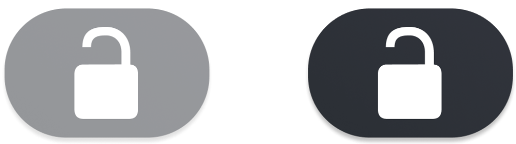

Figure 45: *Deactive and active lock button*

- The buttons for creating and interacting with the path are similar in color and form, and they are placed closely together. By the Gestalt rules of similarity and proximity, they are sensed to be related and have the same function [64]. We use this to make it clearer that these buttons are used for interacting with the path.
- On the start screen, the two mode buttons are encaged by a light gray box which creates a common region [64] (see figure 46). Together with the buttons' big size and bright colors they fulfill the visibility principle – the first step to the goal should be clear [61].
- If the user selects a video in the library, that video becomes the focal point, which makes the possible interactions more visible (see figure 47) [64].

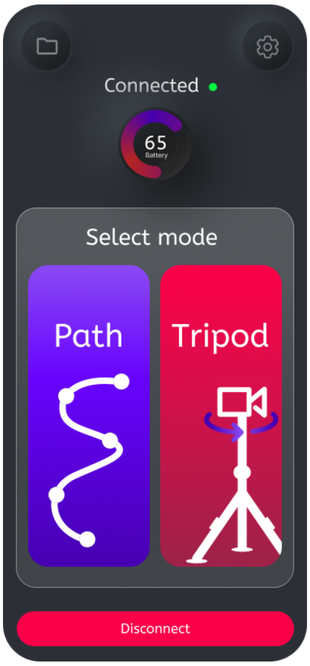

Figure 46: *Final Screen of mode selection*

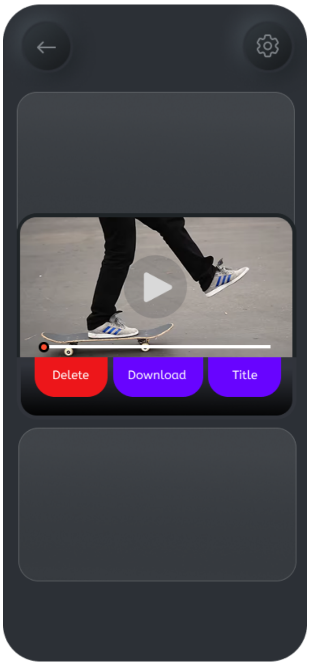

Figure 47: *Final Screen of Library*

4.6 Form

During the prototyping phase we mostly focused on the technical aspects and the GUI. We did, however, do a hybrid brainstorm sketching session to explore different forms for FlowFrame. The sketches from this brainstorm focusing on exploration and wild ideas, can be seen below on figure 48.

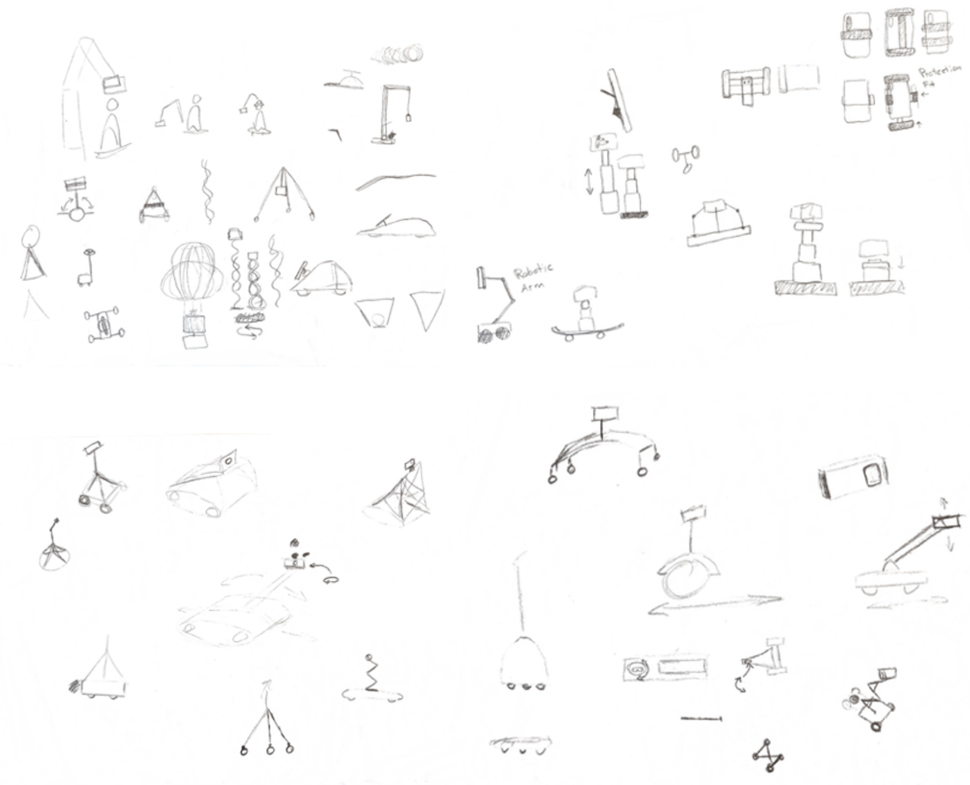

Figure 48: *Sketches of form*

We made a quick foam model to externalize the approximate size of the final product (see figure 49). This was based on a vision of an expandable platform that we were considering along the way, conceptualized in the first sketching session. The final product would have to be small enough to fit in a backpack and we thought the expandable platform would be necessary for stability reasons. This was dropped when we realized how small and lightweight products like the DJI Pocket 2 can make the camera and gimbal module. We used this model during evaluations, so the participants got a physical object in their hands, and we could move it around to simulate the path run.

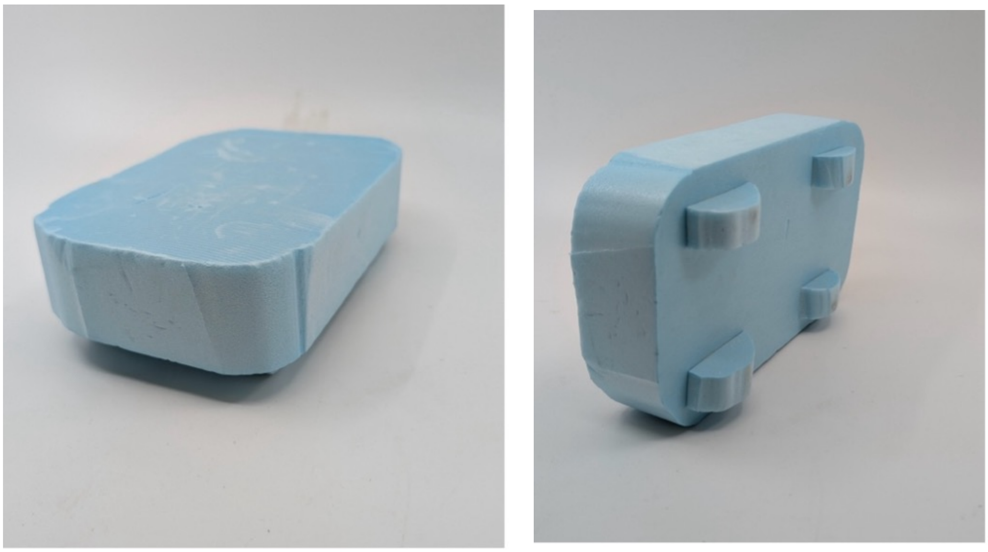

Figure 49: *Foam model for size expectations*

We sketched different technical possibilities for aspects like the gyro, wheels, and camera stand (see figure 50). Afterwards we sketched designs that incorporated multiple of these technical details and different forms (see figure 51).

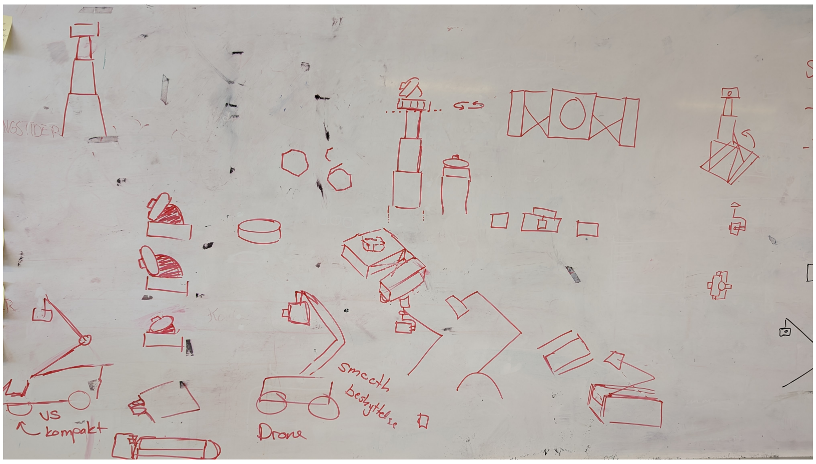

Figure 50: *Sketches of technical possibilities*

Figure 51: *Sketches of form*

We chose a form and made a more refined sketch (see figure 52-53). This sketch was also used during evaluations to help the participants visualize the final product. Afterwards we also built a cardboard model to combine the design and the size as a way of thinking using material, highlighted by Dix and Gongora [13] (see figure 54).

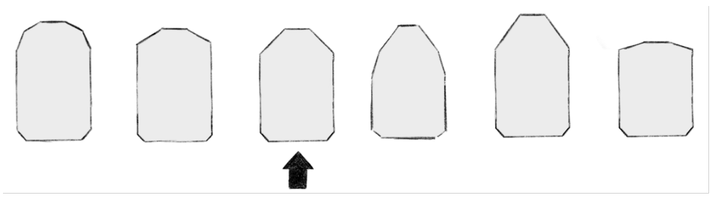

Figure 52: *Exploration and selection of form*

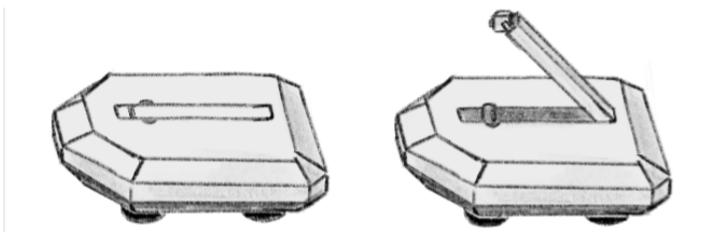

Figure 53: *Final sketch*

Figure 54: *Cardboard model*

To help convey the concept and technical details more clearly, a 3D model with movable parts and renderings of the model was made (see figure 55). A video demonstration of the movable parts can be seen here -> YouTube video. The side panels of the car would be made of absorbent rubber to help protect the car from loose skateboards and other obstacles. If damaged enough, they can be replaced.

Figure 55: *Final rendering*

5 Prototype

The purposes of the two prototypes (technical and GUI) are very different and therefore their focus on prototype filters and prototype manifestations are different as well [35].

The tangible prototype focuses on the functionality and data filters. It should functionally work, with the correct data [35]. We see the prototype as an experimental prototype, as we were testing the viability of such a system [21]. It is built with the easiest available materials and rough GUI for the controls to make more time for development of the functional goals. Therefore, the appearance, interactivity and spatial structure filters were not prioritised in this prototype. The resolution of this prototype is medium [35]. It includes multiple moveable aspects, an object tracking system and 3D printed components, but it is not made to be presented to users as it is lacking in both visual and functional quality. The scope was to get our system to work technically, but not optimally as required for the final product. As a result, the movement is rigid, people easily get lost from the tracking and the resulting video is jittery. It did however successfully track people and move the camera module accordingly.

The GUI prototype was created to illustrate the interactions, flow and aesthetics of the application, that is required by FlowFrame. This is an exploratory approach to prototyping as stated by Floyd [21]. It is made in Figma, so there are no functionality or data handling in this prototype. Appearance, interactivity and spatial structure filters were in focus in this prototype, while focus on the functionality and data filters were small. We would argue this prototypes resolution is medium. The overall design language is in place, but details are missing throughout the UI.

5.1 Physical design

Our tangible prototype can be seen on figure 56. It consists of three main components (see figure 57). A python-driven flask web app allows us to control the prototype's movement by driving forward, back, left and right as well as toggling recording and tracking. A Raspberry Pi 4B (RPi4) handles the object tracking, recording and movement of pan and tilt motors while a LEGO Mindstorm EV3-brick handles the movement of the vehicle in general. A detailed view of the interconnectedness of these different components can be seen on the system diagram in figure 58.

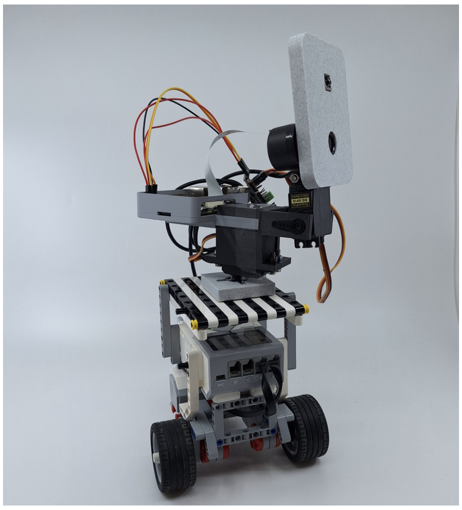

Figure 56: *Tangible prototype*

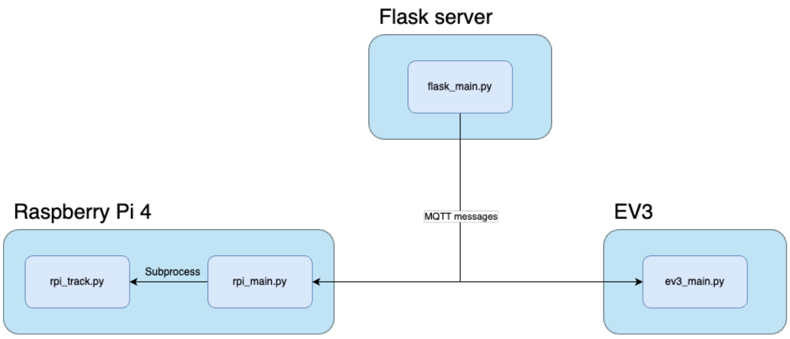

Figure 57: *System diagram overview*

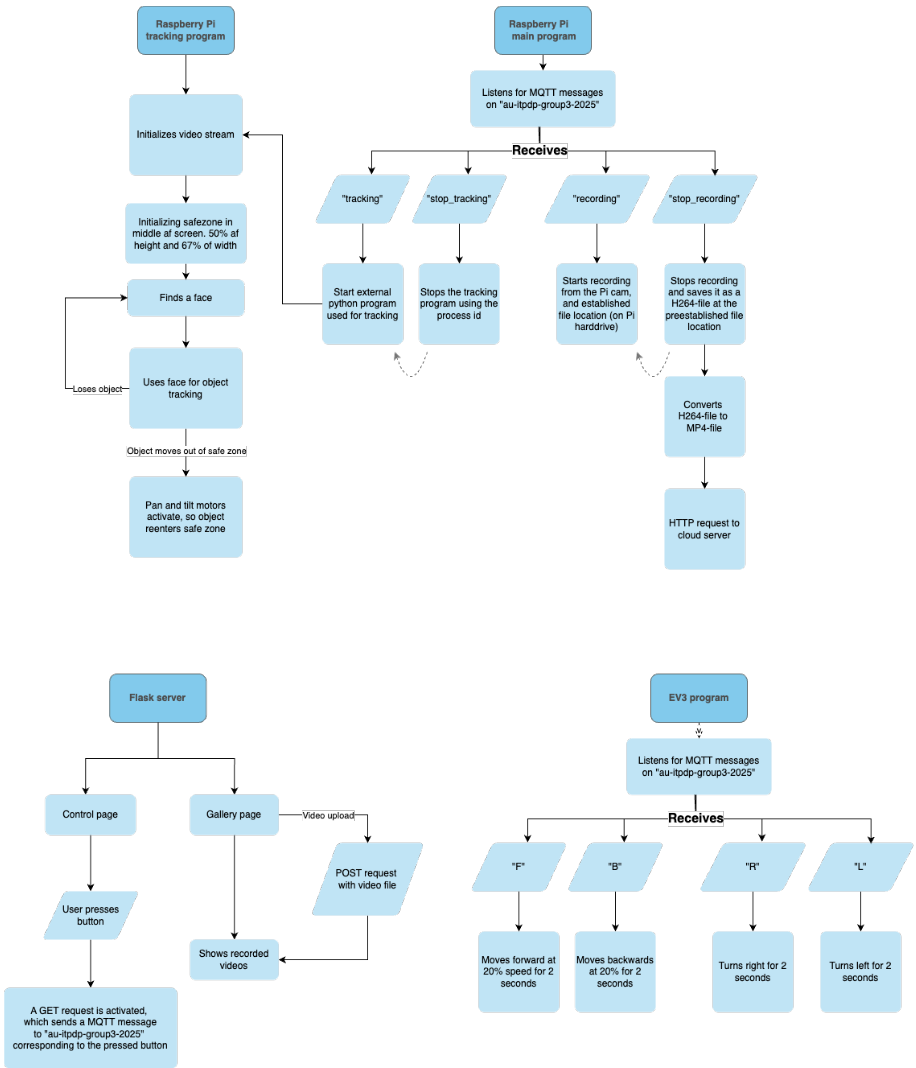

Figure 58: *System diagram detailed*

5.2 Hardware

The hardware setup for our tangible prototype is simple (see figure 59). At the core is the RPi4, connected to a PCA9685 servo driver which controls two SG90 servo motors for the pan tilt camera head, enabling object tracking. A 1080p webcam is the video input for the tracking program, while a Raspberry Pi Camera Module v3 [54] records video. For mobility, a EV3-brick powers two large EV3 motors. Detailed descriptions of each part of the tangible prototype will follow below.

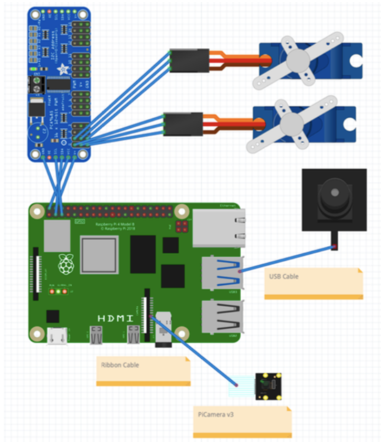

Figure 59: *Hardware diagram*

5.3 Pan and Tilt module

The container and mount were modelled in Fusion 360 and then 3D printed. The mount has holes at the button so it can be attached to the car using LEGO pieces. The top of the mount has space for the horns that come with the servo motors to be embedded into, which makes it more compact. We used the same technique on the tilt motor with a modified horn. The container for the pan motor is secured to the motor using bolts for stability. See figures 60-63.

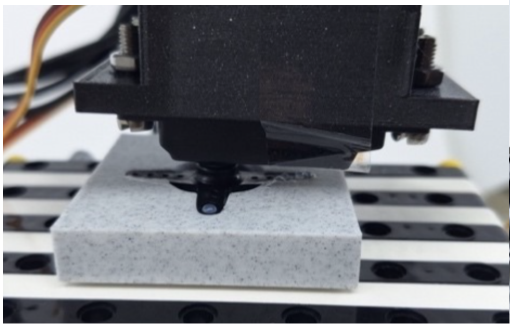

Figure 60: *Horns embedded in 3D printed block*

Figure 61: *3D printed block attached to LEGO base*

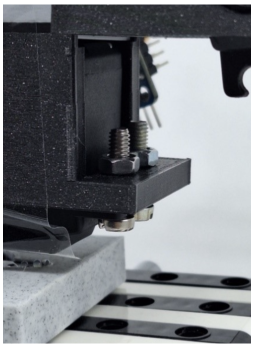

Figure 62: *Motor case attached with bolts*

Figure 63: *Horn embedded in 3D printed case for pan motor*

The Raspberry Pi container is placed behind the pan motor, to balance the weight of the cameras on the pan motor. Even so, the setup is still quite front heavy, which makes it shake a lot when the car stops at the end of a forward movement. This can be combatted by the car driving slower, but it still is not ideal.

The tilt axis of movement is hindered by the placement of the Raspberry Pi container and the short ribbon cable from the Pi. This would be resolved in the final product, but as a prototype the tilt-function is not critical.

5.4 Flask web app

The main task of the web app is to act as a controller for the prototype. The web app consists of two pages - a gallery page and a control page (see figure 64). We use the MQTT protocol to forward our input to the RPi4 and EV3 devices. When we press the forward button, it publishes a message on the topic *au-itpdp-group3-2025* through the free and public broker *emqx.broker.io*[18].

This broker is great for development and prototyping purposes but is not recommended for production as the messages sent through this broker are visible to all connected devices [18]. In a real product, you would set up a custom and secured MQTT service. We therefore set up a very specific topic to limit the chances of messages from external senders interfering with our own messages.

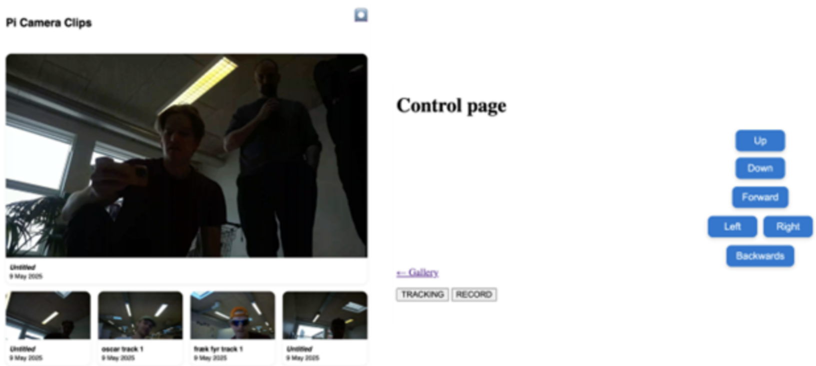

Figure 64: *Interface for web app*

5.5 Raspberry Pi 4

The Raspberry Pi 4 is the main processing device of our prototype. It handles the object detection and tracking through a webcam along with recording video and moving the pan and tilt module. The basis of the system is a python program that listens for MQTT commands on the topic mentioned above . Commands for the EV3-brick is sent on the same topic, so the first job of the program is to determine whether the message is relevant for the RPi.
The relevant messages are:

- *Recording* – starts a recording
- *Stop_recording* – stops the recording
- *Tracking* – starts the tracking program
- *Stop_tracking* – stops the active tracking program

5.6 Recording

The recording is done through the libcamera open-source camera stack [34]. We start and stop a 1080p video recording in the H264 codec based on the MQTT commands received. The produced H264 file is converted to a MP4 file with FFmpeg [20]. This MP4 file is then sent to our flask webserver through a HTTP POST request [38].

5.7 Tracking

We are using the MedianFlow tracker class in OpenCV for object tracking [47]. This model is excellent at tracking objects with smooth and predictable movements, which is a good fit for our use case [47]. To test the MedianFlow tracker we set up a program where you could visually initialize the tracker by drawing a box around your desires tracking target (see figure 65).

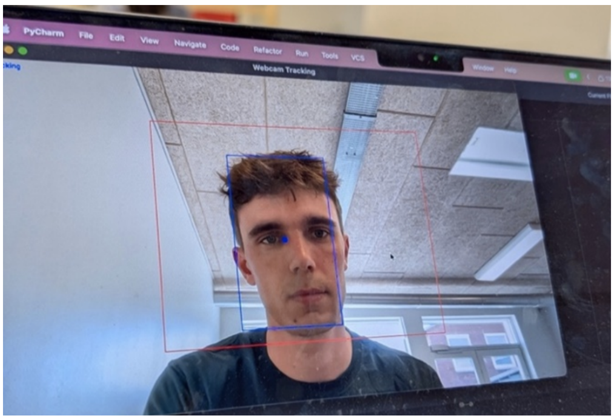

Figure 65: *Safe zone visualization*

The drawn box would try to stay locked on to an object as it moves around the frame (the blue box on figure 65). To make the testing more suitable for our specific use case, we set up a safe zone in the middle of the screen of 960 x 720 pixels on a 1920 x 1080 video stream (the red box on figure 65), along with logic to check if the tracked object was outside this area. This allowed us to simulate when the motors on the actual product would move, as it would not be suitable for them to always be active.

Drawing the box was all well and good for visualizing the program on a laptop, but with no screen attached to the RPi4, we could not use this method for the actual prototype. Instead, we added a Haar cascades face detection model [48] included in OpenCV to identify faces and select the first face as the region of interest.

This way we are initializing the MedianFlow object tracking based on face detection on the video stream. The face tracking is only used to initialize the tracker and to reacquire a tracking target if the original target is lost. Afterwards, the MedianFlow object tracking algorithm takes over.

5.8 LEGO Mindstorm

Our tangible prototype uses a simple, integrated hardware setup. The base is a LEGO Mindstorm EV3 platform running EV3dev [19] with two front wheels and a rear ball caster for stable movement using just two motors.

Running EV3dev and specifically the python version - python-ev3dev [52] - allows us to create and run python programs that control the EV3's motors. It receives MQTT over the shared topic with the RPi4.
The relevant commands for the EV3 are:

- *F* – Uses the MoveTank class [53] to move forward at 20 percentage speed for 2 seconds
- *B* – Uses MoveTank to move backwards at 20 percentage speed for 2 seconds
- *R* – Uses MoveTank to turn right for 1 seconds
- *L* – Uses MoveTank to turn left for 1 seconds

5.9 Graphical User Interface

The GUI prototype is made as a click-through prototype in Figma to give users a feel of how the app for FlowFrame could work. This can also be described as the anticipated user experience (AUX), since the method of click-through simulates the vision of the prototype's GUI without having a final product. This is mentioned by Roto to be the point of a prototype [58].

The GUI prototype is purely a visual demonstration with no underlying code, designed to illustrate how waypoints define the path that FlowFrame follows. For the entire flow see the link in chapter 2. The user starts by being offered to pick either path mode or tripod mode (see figure 66).

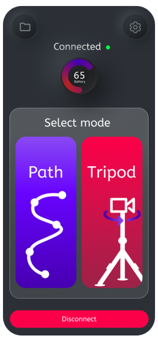

Figure 66: *Select mode on the start screen*

Entering the path mode, the user are presented with a map of their current location (see figure 67). In this case we chose Læssøesgades Skole as this is a popular skate spot in Aarhus. On this screen a marker represents the user's location and orientation. Buttons for placing a start-point, entering the library and returning to the start screen are also visible. Users can place waypoints on a map to create a path. In the actual app this would be done by walking around the skatepark and clicking on the *Set waypoint* button. The waypoints will be placed using the phone's location. Generation of the path will be based on the waypoints. In our Figma prototype, we have pre-made a path with 6 waypoints to illustrate this concept (see figure 68).

Figure 67: *Map based on user location*

Figure 68: *Waypoints have been placed by the user*

When the endpoint has been set, the user is presented with the screen on figure 69. This screen allows for editing or deletion of the path as well as running a test drive of the path.

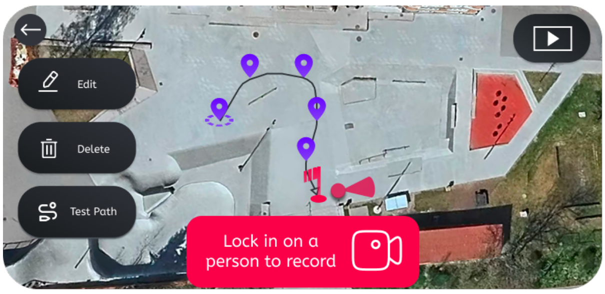

Figure 69: *Finished path*

To be able to start the recording, the user needs to lock the camera onto a person, which the FlowFrame would track. This can be seen on figure 70. If you entered tripod mode on the home screen, you would go directly into this view.

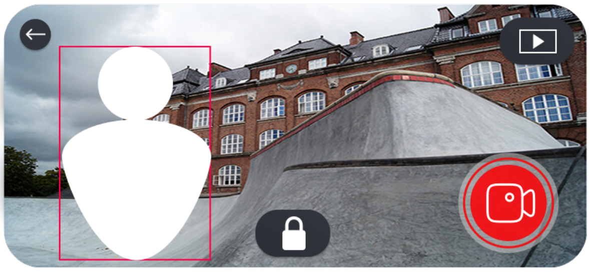

Figure 70: *Selected person to track*

The prototype includes a library view where users can browse previously recorded footage, with each entry tagged with GPS location and start time (see figure 71). From this screen, users can edit, delete or preview any clip. They can also download clips to get the footage locally on their phone and ready to be uploaded to social media (see figure 72).

Figure 71: *Library with the users recordings*

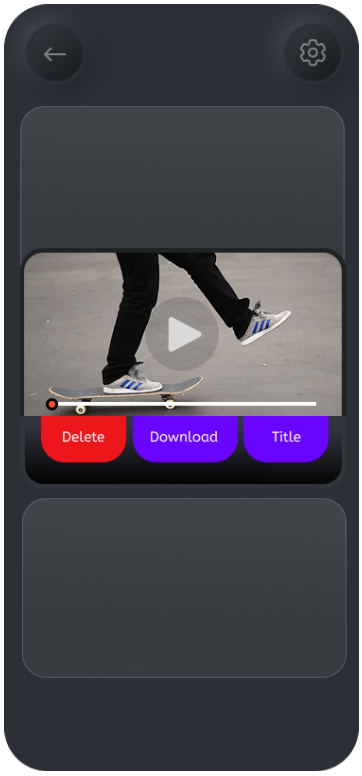

Figure 72: *Library with a video selected*

6 Evaluation

To understand our user's experience and feelings towards our prototype, we conducted AUX evaluations using multiple methods like think aloud tests, semi-structured interviews and observations [7]. Before our evaluation, we created three main goals and corresponding hypotheses for the evaluation. We used these as focus points for the tasks, interviews, and questionnaire.

The control method of the FlowFrame's movement and path creation is an aspect we had often returned to during concept and prototype development, but we had not been able to conclude which control method to implement. We wanted to specifically find out which method the participants preferred or if they had other ideas. We had the following hypothesis:

- *The preference between GPS waypoints or the joystick would not be clear between the participants.*

We also wanted to find out if the skaters could easily use our prototype in the intended way. Was the usage clear and straightforward, or did breakpoints appear? This would be done by testing the following hypothesis:

- *The participants would succeed in creating a video, but creating the path would be difficult for them.*

The last thing we wanted to investigate is whether the skaters could see themselves using the two modes of our product (tripod and path). Would they prefer one over the other? Our hypothesis was:

- *The participants would find value in both modes but would prefer tripod mode.*

6.1 Arrangement

We had two in-person evaluations and another participant who filled out an online questionnaire. Both in-person evaluations were documented by an audio recording as well as written notes. Per our background questionnaire (see appendix 7), we know that the participants were all male, aged 22 (P10), 36 (P11) and 46 (P1). All participants skated more than 2-4 times a week. Their comfort level with new apps and websites was average and above. All had a touch screen smartphone, which is necessary for our product.

Having just two evaluations, we attempted to conduct two additional evaluations in person, but they did not take place due to scheduling challenges on the participants' sides. We recognized that this left us with insufficient data and therefore created an online questionnaire. This questionnaire with P10 focused on the overall usage scenario and the GUI. Specifically, the questionnaire was a Word-document with text introducing our product and containing two main tasks: a walk-through of the storyboard along with a click-through of our Figma prototype. During these tasks, the participant was encouraged to write down any thoughts. Following these tasks, we presented a few questions in relation to the hypotheses of the main evaluation. We asked about how they would prefer to make a route along with our two proposed solutions, how they would prefer the camera to lock onto a person, preference about height on the camera as well as the perceived reaction to bringing FlowFrame to a skatepark. The full questionnaire can be seen in appendix 8. The questionnaire provided useful data but was, as we expected, not as effective as the in-person evaluations, as the answers were short and undescriptive.

We started both evaluations by introducing ourselves and the project. There were three tasks the participants had to do. During the first task they were given a storyboard of the use case (see appendix 9) and had to read it while thinking aloud. This allowed us to better follow their stream of thought and identify strengths and weaknesses in our interface [7]. The storyboard also gave the participants a general idea of product usage. In it we intentionally left out the part where the user creates the path, to not influence them on the second task.

In the second task, we asked the participants how they would create these paths in broad terms. We then introduced them to the waypoint and joystick idea through the GUI we had created for each while asking them to think aloud. We had the screens printed out and glued to cardboard in the shape of a phone to make it more tangible (see figure 73-74). The sequence of the methods shown to the participants was swapped for each evaluation to not create a bias. We asked which method they preferred and why as well as clarifying and follow-up questions.

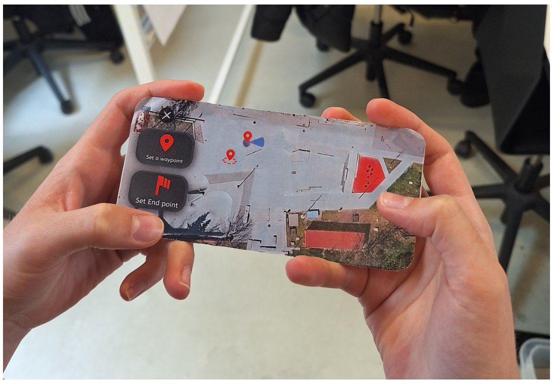

Figure 73: *Tangible GUI map*

Figure 74: *Tangible GUI start screen*

In the third task, we asked them to *use* our prototype to create a video. We used more phone screens and the blue foam model. We had planned to simulate the finished video by filming the skater ourselves using their created path. During the task the participants were in such a flow-state that we thought interruptions would have been distracting. It also became clear during the task that the participants had a strong understanding of our vision, so we decided it wasn't necessary to go through with the filming part.

After the three tasks, we conducted a semi-structured interview where among other things we asked about their general experience with the prototype and their opinions on the two modes (tripod and path).

The in-person evaluations were conducted at different locations based on the weather and the participants' preferences. The first was conducted at Godsbanen with P11. Robin was the main facilitator, Mikkel provided follow up questions, and Jakob took written notes and observed. The prototype handling was done by Mikkel and Robin, i.e. when Robin was presenting a task, Mikkel was preparing the related prototype part and vice versa. During the third task, we walked around the skate park.

The second evaluation took place on Dokk1's roofed balcony with P1, since it was raining. Jakob was the main facilitator, Robin provided follow up questions, and Mikkel took written notes and observed. We sat at a table bench and the participant skated around the tables during the third task.

6.2 Analysis

The audio recordings were transcribed with the GoodTape AI tool and manually corrected. To analyze this data, we used the 6-phase approach from the thematic analysis method [9]. During transcription and the readthrough of them we familiarized ourselves with the data. From here we read though it again and identified codes, in which there were both semantic and latent [9]. The codes including the participant ID were inserted into the online whiteboard app Miro [39], where we organized them into initial themes. We reworked and renamed the themes along the way, so each were focused on one specific topic. This approach gave us a great understanding of the data from, which we gained valuable insights used in concluding our evaluation goals.

6.3 Results

The AUX evaluations and questionnaire gave us valuable insight into the participants' experience with the prototype. From this data, we can offer answers to our hypotheses.

Hypothesis 1: The preference between GPS waypoints or the joystick would not be clear between the participants.

This was found to be wrong. Every participant preferred using waypoints and two of them even suggested using some form of waypoints on maps, before being introduced to our solutions. P11 commented that editing the path with waypoints was quite easy and if a mistake was made using the joystick method, it seemed he would have to start over, which he described as frustrating.

Hypothesis 2: The participants would succeed in creating a video, but creating the path would be difficult for them.

The participants all succeeded in *creating* a video with minimal help from us. The waypoint method was used for creating the paths, since every participant preferred it. The path creation was not difficult for the participants. They understood with high accuracy what functions the elements on the screen had. As explained in the previous section, the creation of a video was dropped during the evaluation.

Hypothesis 3: The participants would find value in both modes but would prefer tripod mode.

This was proven to be correct, both in terms of practicality and cultural acceptance. P1 and P11 raised concerns about an RC-car like object driving around in a skate park where being in the way of others/traffic and collisions were the main concerns. Besides that, it was mentioned by both P11 and P10 that they would never use path mode among other skaters, suggesting a cultural barrier, which was mentioned by P11. He did, however, find it hard to describe exactly why. This could also stem from the fact that some skaters already use tripods when filming, whereas RC-cars are seen as toys and do not belong in a skate park.

P11 did point out that even though he would not use the path mode, he knew someone that would. His friend lived in a city where the skateboard scene was almost dead and there was no one to help him record skate videos. P11 clearly indicated that his friend would find value in FlowFrame's path mode.

All participants showed direct interest in the product consisting of only the tripod mode. P1 and P11 did acknowledge the value added by dynamic movement, but P11 stated that skaters are notoriously cheap and would buy the option best suited for their needs. As the tripod-only product would be significantly cheaper, due to less advanced hardware and software, this would be the version they would buy.

7 Reflection

7.1 Literature

In our early prototyping process of the app's interaction design, we made the mistake of jumping straight into Figma almost without sketching on paper or experience prototyping [10]. This led us to invest time in a joystick-controlled route system. During evaluations we realized this was the wrong direction, because editing the path could not be done easily. Had we used experience prototyping, we would probably have realized this sooner and focused our energy elsewhere.

Had we used more sketching early on, we could also quickly have explored possibly better designs for our app and avoided overcommitting. Sketching, as Baskinger points out, helps test ideas flexibly before diving into details [6].

During development of the Figma prototype we tested the design on some of our classmates. The participants usually gave feedback on graphics and small details, but not the overall interaction design, which was needed in this phase of development. Greenberg and Buxton warn that treating early ideas as finished prototypes can waste time and suppress better solutions [26]. Going forward, we will start with sketches and low-fidelity paper flows to identify strong concepts before moving into digital tools.

Our design process of the GUI was disorganized. We did small tests and iterations, but it would have been more efficient, if we had worked in a more structured manner. This could be done by using the UI design process (see figure 75) [29].

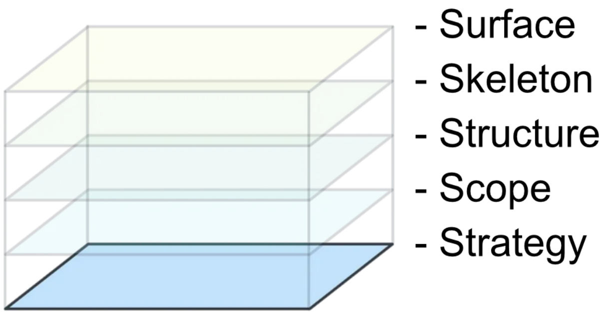

Figure 75: *The UI design process. Starts with a foundation and builds upon it*

We were introduced to this model after we had started on the GUI design, but it could still have helped if we had reviewed the design process then. We had essentially jumped straight into the skeleton and surface part, skipping strategy, scope and structure. If we had allocated more time and focus on these three aspects, we would probably have ended with a more consistent design and would not have needed to do the last iteration (explained in chapter 4.5.1).

Through this process we kept in mind that design problems are wicked, but we continued to be open-minded, even though there was not a clear answer and multiple different stakeholders [43]. This is best shown by us mostly solving the filming problem with our prototype, but creating other problems, as it clashed with skate culture.

7.2 Field studies

Our field studies consisted of two different cases of observations alongside 4 semi-structured interviews. Analysis of these gave us insights into skating and its strong culture.

It is very clear that filming skate tricks and runs are a huge part of skate culture. It is a theme running across generations and skill levels with professionals inspiring newcomers to the scene. We found that when filming, a low camera perspective angled a little upwards, was the minimum requirement. FlowFrame is made to function with a low but also adjustable height.

For skate videos, skaters would include movement of the camera as well. That is usually done by a cameraman following close behind on a skateboard or panning the camera when the skater pass. Path mode allows FlowFrame to follow a custom path set by the skater, mimicking another skater following behind. Tripod mode allows FlowFrame to be stationary but still pan and tilt to follow the skater, much like the panning usage scenario we found from our field work. Either way, getting close to the action is essential too. This makes everything look faster, higher and more nerve racking.

We found that most skaters arrive at the skate spots with just a small backpack. Because of this, FlowFrame was prioritized to be as compact as possible, resulting in an expandable camera arm design that allows for a balance of size, stability and structural integrity.

7.3 Evaluation method

The execution of our evaluations did not go entirely to plan. For both in-person evaluations we had set up around a table; the facilitator and secondary interviewer on one side and the observer/note-taker on the other, with room for the participant. This way the observer could easily follow along in the participants actions. However, when the participants arrived, they wanted to sit at another location, which resulted in a cluttered and non-optimal setup. P11 at Godsbanen wanted to sit closer to his mates skating, which directly affected the evaluation as he was distracted by watching their skate tricks and talking with them at multiple occasions. Because of the setup (see figure 76) it was difficult for the observer to see P11's interactions with the GUI prototype or things he showed to us on his phone.

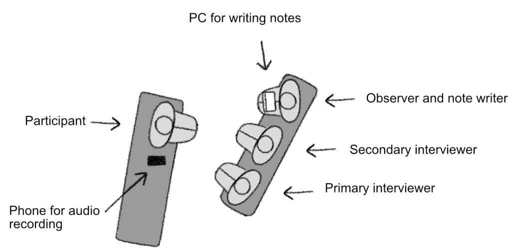

Figure 76: *Setup for evaluation at Godsbanen*

P1 at Dokk1 did not want to sit inside the building, where we had set up, as he wanted to be able to smoke during the evaluation. Here we prioritized the relationship with the participants even though this led to a less-than-optimal setup.

During the evaluation phase, we made a last-minute decision to gather additional data with an online questionnaire. While this gave some insights and provided us with more data, it is clear that this was done in a hurry. The format was lacking and some of the questions too leading. A more appropriate way to gather more data could have been an online video call. This would provide extra flexibility to fit into the participants schedule along with a more engaging and interactive evaluation compared to the questionnaire. Alternatively, recording a video of the prototypes with an explanation of the concept and adding this in an online questionnaire could also have been useful.

7.4 Analysis

The overall concept was received very positively by the participants and they quickly understood the use case and added to it. For example, P11 said he could use the tripod-mode for a second angle in the films he makes using his handheld cameras. The participants could see value in our product for both themselves and others they knew. In this way we succeeded in making a prototype for skaters.

The participants saw a lot of value in a significantly more advanced product. Without probing, all participants expressed a wish for the FlowFrame to more dynamically move with the skater and be more aware of its surroundings. For example, if the skater falls behind on the path the FlowFrame should also slow down, and if the skater falls the FlowFrame should not finish its path. The participants also expressed a need for more control of the camera, namely the height, angle, speed and framerates (slow motion) at different points along the created path. These are important aspects and should be considered for a potential second iteration of the prototype.

During the evaluation we observed that all participants walked in front of the camera to lock them in, rather than using the joystick on the screen. While prototyping we thought it would be a bother, but that didn't seem to be the case during evaluation. Therefore, we removed the joystick from the UI in our last iteration described in chapter 4.5.1.

Our original idea consisted only of the camera tracking tripod, which had been made by others before, like the DJI Osmo Mobile 7 described in related work. We added movement because the assignment required novelty in the concept. This did add value by making the resulting video more dynamic, but it also conflicted with skater culture. We found that the participants thought it weird to have an RC-car like object driving around others in a skatepark and most of the participants got embarrassed by the thought. In this way we have not succeeded in creating a product suitable for skaters.

7.5 Future work

An important challenge moving forward is speed. Our tangible prototype, built with LEGO Mindstorms EV3, was useful for testing technical possibilities but too slow to follow a skater effectively. A second iteration could focus on replacing the LEGO Mindstorm platform with a faster and more stable motorized base. The app's path creation interface and interaction design should also be improved based on more test and user feedback.

During the evaluation the participants expressed that most of the value in the product came from the tripod-mode. When given the choice everyone answered they would buy only the tripod instead of the more expensive system with both tripod and path functions. Therefore, for the final product, we envision a modular system composed of:

- A tracking tripod for stationary filming with automatic subject tracking. This corresponds to tripod mode.
- An optional motorized base the tripod could be mounted on, allowing for dynamic tracking along a full skate run. This corresponds to path mode.

This setup gives users flexibility based on their filming needs, while keeping the system scalable and more in line with skater culture. To further support this vision, additional field studies will be needed to determine whether FlowFrame truly needs to be wheeled or if a camera tracking tripod alone satisfies the users' needs. This would help us validate whether modular mobility is essential or optional.

7.6 Related work

FlowFrame positions itself in a gap between existing commercial products such as drones and handheld camera gimbals. Drones struggle with low, under-the-board angles which emphasize tricks. They are often also legally restricted in urban environments. Handheld gimbals still require skateboarding skills.

To address this gap in the marked, we looked at robotics and computer vision for inspiration. Prior work on vision-based robots demonstrates the potential of low-cost tracking systems using platforms like Raspberry Pi and OpenCV. These systems can autonomously follow a target using object recognition and show promising applications for mobile filming. [50, 5]

Our prototype is a mobile, low angle tracking camera on wheels designed specifically for skateboarding. This positions us uniquely between drones, camera gimbals and object tracking robots. This brings robotic object-following techniques into a new domain.

The modular system could hinder the novelty of our product and our unique position in the market. However, such a product could be supported by the claims of our evaluation participants, who found the tripod mode to offer the most value. This is a domain that could be dominated by gimbals like DJI Pocket 2 and DJI Osmo Mobile 7, but our participants didn't use any of these existing products or mention anyone who did. The participant saw value in the modular system even though the novelty is questionable. However, this could also be attributed to the participants not knowing about the DJI products.

7.7 Business potential

We updated our BMC to include the modular system The new business Model canva is simular to the earlier one, but we have added that we now have 2 product that can be sold individual. This will let customers be able to purchase one of the products and not commit to buying the entire product. This makes our market bigger since we can sell to more customers. Potentially we would be able to sell the to individual product for more since the use case has increased, without any major cost of production. The reason we split the product was to be able to sell to users that did not see them self use the vehicle. So, by splitting the product up, we can now sell to bigger market. (See figure 77) and in a better resolution in Appendix 10.

KP
Key-partners
Sponsorships with respected skate brands (e.g., Vans, Independent, Polar) and individual influencers to boost credibility and reach the target audience.

Manufacturing
(Hardware manufacturing companies to produce the tripod and mobile base at scale. Could include robotics or camera component suppliers.

Events
Partnerships with local and global skate events, shops, and parks to showcase and demo the product in real-world environments

KA
Key Activities
Building partnerships with skate influencers for early adoption and brand trust. (Not the best skater, but the most respected.)
Developing a community-driven feedback loop for app updates and feature requests.

KY
Key Resources
Hardware components (tripod, motor base, sensors), software infrastructure (tracking algorithms, app, UI), brand and early user community, skilled team (robotics, UX, marketing), and user feedback from field studies and testing.

VP
Value propositions
FlowFrame is a unique product that taps into an untouched market.

Our unique way of filming skateboards enables them to catch the perfect angle on the entire run, all by themselves.

Empowers skaters to create professional-looking solo footage with no crew or filming experience.

Modular design allows users to start small with a stationary tracking tripod and later expand to a mobile filming solution.

CR
Customer Relations
Community-building through user-generated content, featured edits on social channels, and continuous feedback loops.

C
Channels
Sponsorship.
TikTok & Instagram (huge platform for short skate edits)
Website & YouTube Channel (How to videos).
Discord/Reddit (for community & support)
Skate shops (as physical points of exposure)

CS
Customer Segments
Our users are skaters that need someone to film them do tricks on the skateboards.
This will also include people that have a group of friends that they regularly skate with but need to have a backup solution when no friends are available to film.

FlowFrame can also be used for crews that do not need movement, but an extra dynamic angle for the perfect footage.

Content creators / skate influencers who need consistent, high-quality solo footage

Beginner skaters who want to track their own progress through video without relying on others

Cost
Cost Structure
Production cost
Marketing cost (Sponsorships, Events)
Organic content (Youtube guides, Instagram, and evt.)
Customer support / app maintenance costs
R&D for hardware and tracking software

Revenue
Revenue sources
Sales of FlowFrame in retail
Sales of FlowFrame online
Subscription-based features for the app (e.g., premium tracking, route saving, cloud storage)
Accessory upsells (extra batteries, upgraded camera arms, etc.)

Figure 77: *Setup for Evaluation*

8 Conclusion

We set out to investigate the skateboarding community in Aarhus through ethnographic field work. This gave us insights into skateboarding culture and led us to the subject of filming skate videos. Here we identified multiple breakpoints. Phones can be damaged and create static videos. Cult-like cameras such as the Sony VX1000 are hard to get hold of and require someone skilled in both skateboarding and video recording to operate. These breakdowns inspired us to create a prototype that would assist skaters in filming their tricks. We created multiple prototypes with different filtering dimensions. The tangible prototype was an experimental prototype to test the feasibility of our OpenCV tracking system while the GUI was an exploratory prototype based on peer feedback and UI design principles.

We conducted an evaluation with real skaters to test our hypotheses on control methods and anticipated value. Users were happy with and saw potential in the tripod mode while the path mode was seen as embarrassing.

We have succeeded in creating a prototype for a product that would assist skaters with filming their tricks. Along the way we discovered new directions of value for the product like using FlowFrame as a secondary camera angle. We did, however, fail in making a product that was culturally acceptable to the skateboarding community. We assume a modular system, which we propose, would be more successful in this criterion, but further evaluations would be required to confirm this.

References

[1] Adafruit. Standard servo - towerpro sg-5010 - 5010, 2025. URL https://www.adafruit.com/product/155. Commercial product page.

[2] Adafruit. Adafruit 16-channel 12-bit pwm/servo driver - i2c interface - pca9685, 2025. URL https://www.adafruit.com/product/815. Commercial product page.

[3] Kristin Adler, Sanna Salanterä, and Maya Zumstein-Shaha. Focus group interviews in child, youth, and parent research: An integrative literature review. *International Journal of Qualitative Methods*, 18, 2019. doi: 10.1177/1609406919887274.

[4] A. Al-Juraidan, A. Jraggh, and B. Al-Mazeedi. Object following robot using computer vision. Capstone Project, American University of Kuwait, 2020.

[5] A. Ambikapathy, J. Sandilya, A. Tiwari, G. Singh, and L. Varshney. Analysis of object following robot module using android, arduino and open cv, raspberry pi with opencv and color based vision recognition. In N. Priyadarshi, S. Padmanaban, R.K. Ghadai, A.R. Panda, and R. Patel, editors, *Advances in Power Systems and Energy Management*, volume 690 of *Lecture Notes in Electrical Engineering*. Springer, Singapore, 2021. doi: 10.1007/978-981-15-7504-4_35. URL https://doi.org/10.1007/978-981-15-7504-4_35. Accessed June 3, 2025.

[6] M. Baskinger. Pencils before pixels: A primer in hand-generated sketching. *Interactions*, 15(2):28–36, 2008. doi: 10.1145/1340961.1340970.

[7] Ann Blandford, Daisy Furniss, and Stephann Makri. *Qualitative HCI research: Going behind the scenes*, volume 9. Morgan & Claypool, 2016.

[8] Blueooth. How to deplot bluez on raspberry pi 3 and use it, August 2018. URL https://www.bluetooth.com/wp-content/uploads/2019/03/T1804_How-to-set-up-BlueZ_LFC_FINAL-2.pdf#page=4.77. Guide PDF.

[9] Virginia Braun and Victoria Clarke. Thematic analysis. In Harris Cooper, Paul M. Camic, Debra L. Long, A. T. Panter, David Rindskopf, and Kenneth J. Sher, editors, *APA Handbook of Research Methods in Psychology, Vol. 2: Research Designs: Quantitative, Qualitative, Neuropsychological, and Biological*, pages 57–71. American Psychological Association, 2012. doi: 10.1037/13620-004.

[10] M. Buchenau and J. F. Suri. Experience prototyping. In *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, pages 424–433, August 2000.

[11] John M. Carroll. Five reasons for scenario-based design. In *Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences*, pages 1–11. IEEE, 1999.

[12] Correlium. Connect to ble on raspberry pi 4. URL https://support.avh.corellium.com/devices/rpi4/rpi4-ble#use-ble-between-a-raspberry-pi-4-board-and-an-android-device. Support article.

[13] Alan Dix and Luis Gongora. Externalisation and design. In *Proceedings of the Second Conference on Creativity and Innovation in Design*, pages 31–42, 2011.

[14] DJI. Dji pocket 2: Magic at hand, 2020. URL https://www.dji.com/pocket-2. DJI Brand Website.

[15] DJI. Dji flip: Open new possibilities, 2025. URL https://www.dji.com/. DJI Brand Website.

[16] DJI. Dji osmo mobile 7, 2025. URL https://www.dji.com/dk/osmo-mobile-7-series. DJI Official Website.

[17] Easy Sociology. Non-participant observation. https://easysociology.com/research-methods/non-participant-observation/, 2024.

[18] EMQX. Free public mqtt broker, 2025. URL https://www.emqx.com/en/mqtt/public-mqtt5-broker. Article.

[19] ev3dev.org. ev3dev is your ev3 re-imagined, 2025. URL https://www.ev3dev.org/. Landing page.

[20] FFmpeg. A complete, cross-platform solution to record, convert and stream audio and video, 2024. URL https://www.ffmpeg.org/. Landing page.

[21] Christiane Floyd. A systematic look at prototyping. In *Approaches to Prototyping*, pages 1–18. Springer Berlin Heidelberg, 1984.

[22] Zane Foley. History of skateboarding: Notable events that took place, 2025. URL https://www.redbull.com/us-en/history-of-skateboarding.

[23] Karan Girotra, Christian Terwiesch, and Karl T. Ulrich. Idea Generation and the Quality of the Best Idea. *Management Science*, 56(4):591–605, 2010. doi: 10.1287/mnsc.1090.1144.

[24] GoodTape. Goodtape — ai-powered transcription tool, 2024. URL https://goodtape.io. Accessed: 2025-06-03.

[25] Google. Material design: Interaction states – usage, n.d. URL https://m2.material.io/design/interaction/states.html#usage. Accessed: 2025-05-25.

[26] S. Greenberg and B. Buxton. Usability evaluation considered harmful (some of the time). In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 111–120, 2008. doi: 10.1145/1357054.1357074.

[27] Kim Halskov and Peter Dalsgaard. Inspiration card workshops. In *Proceedings of the 6th Conference on Designing Interactive Systems*, pages 2–11, 2006.

[28] Karen Holtzblatt and Hugh R. Beyer. *Contextual design.* Interaction Design Foundation - IxDF, 2nd edition, n.d. Accessed May 10th 2023 from https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/contextual-design.

[29] Jeff Wang. Crash course: Ui design, January 2017. URL https://medium.com/hh-design/crash-course-ui-design-25d13ff60962. Medium article.

[30] Karlheinz Kautz. Improvisation in information systems development practice. *Journal of Information Technology Case and Application Research*, 11(4):32–36, October 2009. doi: 10.1080/15228053.2009.10856170. URL https://doi.org/10.1080/15228053.2009.10856170. Accessed June 4, 2025.

[31] Kevin Townsend. Introduction to bluetooth low energy, March 2014. URL https://learn.adafruit.com/introduction-to-bluetooth-low-energy/gatt. Learning article.

[32] LEGO Education. Ev3 motors, 2016. URL https://le-www-live-s.legocdn.com/sc/media/images/resource-site/files/ev3_chromebook_userguide_us_motors-f19da6c7d1d9b1af1d6b8c9e8359f11c.pdf. Documentation PDF.

[33] LEGO® Education. Lego® mindstorms® education ev3 core set, 2025. URL https://education.lego.com/da-dk/products/lego-mindstorms-education-ev3-core-set/5003400/. Commercial product page.

[34] Libcamera. Home page, 2023. URL https://libcamera.org/. Landing page.

[35] Youn-Kyung Lim, Erik Stolterman, and Josh Tenenberg. The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 15(2):1–27, 2008.

[36] Link Labs. Bluetooth vs. bluetooth low energy: What's the difference? [2023 update], May 2023. URL https://www.link-labs.com/blog/bluetooth-vs-bluetooth-low-energy. Blog post.

[37] Martin O'Hanlon. Blue dot docs - getting started, 2023. URL https://bluedot.readthedocs.io/en/latest/gettingstarted.html. Documentation page.

[38] MDN Web Docs. Post - http | mdn, 2024. URL https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Methods/POST.

[39] Miro. Miro — the visual collaboration platform for every team, 2024. URL https://miro.com. Accessed: 2025-06-03.

[40] David L. Morgan. Focus groups. *Annual Review of Sociology*, 22(1):129–136, 1996. doi: 10.1146/annurev.soc.22.1.129.

[41] MQTT. Mqtt: The standard for iot messaging, 2024. URL https://mqtt.org/. Landing page.

[42] NEEWER. Dl400 motorized camera slider dolly kit with app control, 2024. URL https://neewer.com/. Neewer Product Page.

[43] Harold G. Nelson and Erik Stolterman. *The Design Way: Intentional Change in an Unpredictable World.* MIT Press, 2014.

[44] Yen ning Chang, Youn kyung Lim, and Erik Stolterman. Personas: From theory to practices. In *Proceedings of the 5th Nordic Conference on Human-Computer Interaction: Building Bridges*, pages 439–442, Lund, Sweden, 2008. ACM. doi: 10.1145/1463160.1463214.

[45] Bob Olsen. Aarhus local summer mix, October 2024. URL https://www.youtube.com/watch?v=-WvZIeQEhOU. YouTube video.

[46] OpenCV. Open computer vision library, 2025. URL https://opencv.org/. Landing page.

[47] OpenCV. cv::trackermedianflow class reference, 2025. URL https://docs.opencv.org/3.4/d7/d86/classcv_1_1TrackerMedianFlow.html. Documentation page.

[48] OpenCV Documentation. Cascade classifier - opencv 3.4. documentation, 2024. URL https://docs.opencv.org/3.4/db/d28/tutorial_cascade_classifier.html.

[49] S. Otto, A. Schmitt, D. Dücker, and R. Seifried. Teaching vision-based control for autonomous driving with lego mindstorms ev3, raspberry pi, and simulink. In *Proceedings in Applied Mathematics and Mechanics*, 2018.

[50] Novie Dave Perez, Jocelyn Villaverde, Wellie Cereneo, Aila Custodio, Sandro Broax Conde, and Liezel Bulawan. Design and development of a raspberry pi-based shopping cart following robot through computer vision and object tracking method. In *2022 IEEE Region 10 Symposium (TENSYMP)*, pages 1–6, 2022. doi: 10.1109/TENSYMP54529.2022.9864520.

[51] Stuart Pugh. Concept selection – a method that works. In *Proceedings of the 9th International Conference on Engineering Design (ICED '81)*. MIT OpenCourseWare, 1981. URL https://ocw.mit.edu/courses/esd-33-systems-engineering-summer-2004/9946d04e866e096b918b4a151df59656_s7_pg_cnpt_slctn.pdf. Accessed: 2025-06-03.

[52] python-ev3dev. Python language bindings for ev3dev, 2015. URL https://ev3dev-lang.readthedocs.io/projects/python-ev3dev/en/stable/. Documentation page.

[53] python-ev3dev. Motor classes - movetank, 2015. URL https://ev3dev-lang.readthedocs.io/projects/python-ev3dev/en/stable/motors.html#move-tank. Documentation Page.

[54] Raspberry Pi. Raspberry pi camera module 3, 2025. URL https://www.raspberrypi.com/products/camera-module-3/. Commercial product page.

[55] Raspberry Pi. Raspberry pi 4 model b, 2025. URL https://www.raspberrypi.com/products/raspberry-pi-4-model-b/. Commercial product page.

[56] Raspberry Pi. Remote access, 2025. URL https://www.raspberrypi.com/documentation/computers/remote-access.html. Documentation page.

[57] Red Bull Skateboarding. Vx1000: The story of skateboarding's most iconic camera, June 2023. URL https://www.youtube.com/watch?v=qAhR1aWwLG0&t=939s. YouTube video.

[58] V. Roto, E. Law, A. Vermeeren, and J. Hoonhout. Ux white paper, 2011. URL https://allaboutux.org/uxwhitepaper.

[59] Elizabeth B.-N. Sanders and Udaya Dandavate. Design for experiencing: New tools. In *Proceedings of the 1st International Conference on Design and Emotion*, pages 87–88, 1999.

[60] Steve O'Hear. Veo uses ai to let amateur soccer clubs video matches without the need for a camera operator, August 2017. URL https://techcrunch.com/2017/08/30/veo/. Article.

[61] Debbie Stone, Caroline Jarrett, Mark Woodroffe, and Shailey Minocha. *User Interface Design and Evaluation*. Morgan Kaufmann, 2005.

[62] The Pi Hut. What's the difference between dc, servo stepper motors?, March 2019. URL https://thepihut.com/blogs/raspberry-pi-tutorials/whats-the-difference-between-dc-servo-amp-stepper-motors.

[63] Jenifer Tidwell. *Designing Interfaces: Patterns for Effective Interaction Design*. O'Reilly Media, 2010.

[64] UserTesting. Gestalt principles of design: The definitive guide, n.d. URL https://www.usertesting.com/blog/gestalt-principles. Accessed: 2025-05-25.

[65] VICE. Let the chaos begin | king of the road (s1 e1), June 2016. URL https://www.youtube.com/watch?v=-WvZIeQEhOU. YouTube video.

[66] Nick vonWerssowetz. Strangers. Video, YouTube, jan 2015. URL https://www.youtube.com/watch?v=-WvZIeQEhOU. 0:59.

[67] Larry E. Wood. Semi-structured interviewing for user-centered design. *interactions*, 4(2): 52–53, 1997. doi: 10.1145/245129.245134.

[68] Peter Wright and John McCarthy. *Experience-centered Design: Designers, Users, and Communities in Dialogue*, volume 3. Morgan & Claypool, 2010.

[69] YouTube. Servo pwm demonstration, 2025. URL https://www.youtube.com/watch?v=hsE0PabLuPE&t=348s. YouTube video.