BSc Thesis Creative Technology

Making Assistive Technology Accessible

A Case Study of the Coat Assistant

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Abstract

Assistive devices often lack accessibility and customisation, making it difficult for individuals with specific needs to find suitable solutions. This thesis explores how assistive technology can be made on a small scale. For this thesis, the coat assistant was used as an example. The coat assistant is a device made to help users put on their coats independently. It was made by Jan and Sebastiaan at home so Sebastiaan, who had ALS, was able to go outside independently. The coat assistant can not be put on the market due to regulations, money and missing documentation. These challenges are faced by multiple assistive devices that are made in a non-professional environment. The devices show great potential and can help a lot of people but are not able to be found on the market. This thesis identifies these challenges and finds an alternative for making these devices accessible.

Fab Labs were used as a small-scale manufacturing method. A Fab Lab is a small-scale workshop that provides everyone with access to tools for digital fabrication and prototyping. Projects are shared open-source which means that everyone is able to modify or use existing projects. The research involved a state-of-the-art review to identify which projects exist, an analysis of regulatory requirements, including the Medical Device Regulation (MDR) and interviews with Fab Labs and companies to understand the feasibility of small-scale manufacturing. A co-design session was done to generate new ideas after which the ideas were evaluated and made Fab Lab compatible.

From this research, guiding principles were made for both the coat assistant development and similar assistive technology projects. The coat assistant should focus on improved safety features, user-friendly components and beginner-friendly documentation. Strategies for assistive technology projects included designing Fab Lab-compatible components, creating a detailed parts list, aligning project goals with new components and sharing designs open-source.

The findings show that making assistive devices open-source in a Fab Lab is a good option to make projects accessible for as many people while tackling the challenges of regulatory compliance, investing money and developing documentation. When documentation is in place and the product has been user-tested on safety and usability conversations with assistive technology companies can resume to see the market potential.

This thesis highlights how Fab Labs can empower individuals to create customized assistive devices, making solutions more adaptable and accessible. By sharing designs openly, this research encourages further innovation, enabling users to develop assistive technology tailored to their needs.

Keywords: FabLab, 3D printing, healthcare, products, disability, assistive technology

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Most importantly I am very grateful that the coat assistant confirmed that my future lays in making products for people not only facing a disability but having a problem in general. I want to keep learning and pursue a career in this field.

Contents

Chapter 1

Introduction

Assistive technologies are essential for improving the lives of people with disabilities. With these devices, people with a disability can live a more independent life. These devices range from a customised knife holder to an eye-controlled wheelchair. All of these devices have one thing in common: they need to be customized to fit a person. The existing products which can be bought at assistive technology companies are often very general and can not be customized. They thus do not fit a person which means that they are often unusable for very specific problems.

Frustration among people with a disability arises since there are no practical assistive devices that help them maintain their independence or make their lives easier. Many assistive devices are made at home by people having the knowledge and skills to create their own solutions. They develop something which is able to solve their specific problem but it can also solve the problems of other people. These assistive devices are often not known since it is very difficult to get them on the market. Challenges include complying with regulations, investing a lot of money and lacking documentation. People without knowledge and skills are not able to make their own customized solution which can be very frustrating. The solution to their problem can be very simple and easily made.

Tackling these challenges helps people to share their solutions to inspire others to make their own. One of these assistive devices that faces similar challenges is the coat assistant. The coat assistant was made by Jan and Sebastiaan at home. Sebastiaan had ALS (Amyotrophic Lateral Sclerosis) which means that his muscles slowly stopped working. He was unable to move his arms but still wanted to go outside independently, which is why together with his father Jan they developed the coat assistant. A coat can be put on this assistant with magnets and the machine can lift the coat on his body. Jan and Sebastiaan's aim is to make the coat assistant accessible to as many people facing not only ALS but in general a disability to the arms. Sebastiaan unfortunately passed away during this project. The goal is to share his legacy and create an accessible coat assistant which can help others with similar challenges.

Jan and Sebastiaan tried getting the coat assistant on the market but were unable due to the regulations, investments and no existing documentation. Jan and Sebastiaan reached out to Ability Tech to make the coat assistant more accessible. This research was done at Ability Tech which produces assistive devices for people with a disability and thus faces similar challenges regularly. These challenges must be tackled to help people live better lives which is why this research explored how assistive, such as the coat assistant, can be made on a small scale. Since the coat assistant was tailored to Sebastiaan it was also explored how the coat assistant's design needs to be adapted to accommodate different body types and conditions.

Chapter 2

Background Research

A background research was done to explore how assistive devices like the coat assistant can be made on a small scale. This is done by first looking at small-scale manufacturing options and understanding which is best to use for this project. Second, an interview is done with Jan and Sebastiaan. This interview is an introduction to their life and the project. The second part is an explanation of the coat assistant works and looks. The third part is a literature review about what a Fab Lab is and which challenges Fab Labs face. The fourth part is about the State of the Art in which is looked at which assistive devices exist. The fifth part are the expert interviews. After that the steps to take a product from prototype to the market are discussed and a conclusion is drawn about which way to go for making the coat assistant widely available for everyone in need.

2.1 Interview with Jan and Sebastiaan

At the start of the project, an interview with Jan and Sebastiaan was done. In this interview, they were asked multiple questions about their coping with ALS, the functioning of the coat assistant and the future of the coat assistant. This interview gave a lot of insights which are valuable for the rest of the project and was done before the passing of Sebastiaan.

2.1.1 Challenges in Sebastiaan's Daily Life and Project Vision

The first insight is about the life of Sebastiaan. Since ALS is a progressive condition it is not clear how his life will progress. He is not able to use the coat assistant anymore and has help 24/7. The caretakers are faster in putting on his coat which makes the coat assistant redundant. The wish of Jan and Sebastiaan for this project is to help out as many people as possible. For the project, this means that the design is not a secret and can be used by others to create new versions. If the project generates some form of income they would like a percentage to go to a foundation for example the ALS Foundation to invest in the purpose of why they started this project.

2.1.2 Target Audience and Improved Functionality

The second insight is that the coat assistant is the most valuable for people having a disability to their arms and who live independently. They want to be independent and go out the door without assistance. As mentioned a caretaker is faster to help with putting on a coat so for those people this project is not of much value. A great add-on can be to have the coat assistant working with other clothing pieces which close in the front. In addition, magnets can be sewn into the collar and zipper part to automatically close the coat.

2.1.3 Design Adaptability and Improvements

The third insight is that the coat assistant is tailored to Sebastiaan. Others might not be able to use this design so some changes need to happen. The coat assistant needs to be made for different body types such as people having different lengths and widths. For the design, this means that it needs to have a feature which can adjust the coat assistant to different people. Next to the changes to include different body types, there are some parts of the design which need some improvement. One of these parts is the clamps that hold the sleeves of the coat. They are too weak and can be made in a better way. The second part is the neck clamp to which the coat is attached through magnets. The arms of this clamp are not dynamic enough to fully move around the neck and close the coat while standing comfortably. Another thing that can be looked into is the area in which the coat assistant can be placed. Currently, it is a self-standing thing which takes up quite some space. A change could be to fit it onto the inside of a door so it takes up less space. This could be an addition for someone living in a small apartment. Next to that, the coat assistant was not used much by people with longer hair so it can be valuable to look into safety features.

2.1.4 Lack of Design Documentation

The fourth insight is that the coat assistant was made in a family setting so a manual or detailed drawings of the design have not been made. Jan has put some effort into making drawings but these are not perfect yet.

2.1.5 Market Challenges and Alternative Development Models

The fifth insight is that the family tried to get it on the market but soon noticed that it takes a lot of money and effort to meet all the rules and regulations. To go around these problems Fab Labs and collaborating with companies can be valuable options. A Fab Lab can be easily accessed to make the project yourself and the project can be shared with everyone without needing strict rules and regulations. However, a downside is that a Fab Lab does not have the specific knowledge needed for such a project and thus can not fully give the support needed. For collaborating with companies you need to find a big enough company that is willing to put in their time and money. Next to that, it can take a long time before the project meets all the rules and regulations on the market. All of these insights are used throughout the rest of the project.

2.2 The Coat Assistant Made by Jan and Sebastiaan

The coat assistant was made by Jan and Sebastiaan at home. After Sebastiaan was unable to put on his coat they quickly started thinking, "Can't we make something that hangs a coat somewhere and lifts it behind me?". It started with a wooden board with ropes, simply holding a coat with Velcro at first, and it would lift upward. But very quickly, they realized that just lifting it wasn't enough, that's when Jan continued developing it. He created several models until they arrived at the coat assistant where it is at now.

In Figure 2.1 A an earlier version of the coat assistant can be seen. It already looks close to the current design but has some different design features.

(A) Earlier Version of the Coat Assistant

(B) Coat Assistant During the Building Process

(C) Current Coat Design

FIGURE 2.1: Versions of the coat assistant

In Figure 2.1 B the frame of the current design can be seen. This serves as the base for the coat assistant and is made out of aluminium. In Figure 2.2 the current design of the coat assistant can be seen. The coat assistant has five main parts which can be found below:

1. Neck clamp: pulls the coat over the shoulders and closes it at the front.
2. Sleeves clamp: holds the sleeves while putting on the coat and taking it off.
3. Frame: a place where all components come together.
4. Lift: move the coat up and down.
5. Footrest: operate the coat assistant and give stability to the frame.

FIGURE 2.2: Footrest Buttons

The coat assistant is controlled with the buttons on the floor. Each button indicates a different function. The function of the buttons when you look from the front from bottom to top are:

1. Switch for the linear actuator to move the lift up or down
2. Pressing the button to move the lift up and down
3. Open and closing of the neck clamp
4. Turning the electromagnet on and off
5. Open and close of the sleeve clamp

The coat assistant can put on the coat in different steps, these steps can be found below. The coat is already present on the coat assistant and hangs on there through the use of a combination of magnets on the collar and electromagnets which are always on. Next to that the sleeves clamps which are closed keep the sleeves in place. The first step for a person is to step on the footrest and place themselves against the back wall while standing and facing away from the frame. The second step is to put your hands above the sleeve openings after which the button is pressed to lift the coat assistant, it goes up while the button is pressed. After the coat assistant is at the correct height, above the shoulders, a person can push the button of the neck clamp, the neck clamp closes and lifts the coat around the shoulders and takes care of connecting the magnetic zipper. After that, the person is able to push the button to turn off the electromagnet. Now the electromagnet is not magnetic any more and the magnets in the collar are let go. After this the neck clamp and sleeves clamp can be opened and a person is able to walk away from the coat assistant. When taking of the coat all the steps are reversed.

FIGURE 2.3: Coat assistant Steps

2.3 Small-scale manufacturing

Small-scale manufacturing refers to the production of goods in limited quantities, typically in contrast to large-scale mass production. This approach is often used by startups, makers, or businesses seeking to test a product idea, create customized items, or meet niche market demands. Small-scale manufacturing allows for flexibility, lower upfront costs and the ability to iterate quickly based on customer feedback. There are several options for small-scale production, including 3D printing, which is ideal for creating prototypes or small batches with complex designs; CNC machining, which offers high precision for small series of metal or plastic parts; and injection molding, which, while typically associated with mass production, can be adapted for low-volume runs with reduced tooling costs.

Additionally, makers production methods, such as handcrafting or assembly, are suitable for unique, customized products. Most of the options for small-scale production include machines such as 3D printers, laser cutter or CNC cutters. A Fab Lab is a small scale workshop that provides everyone access to tools for digital fabrication and prototyping. These tools include 3D printers and lasercutters. The advantages of producing a product on a small-scale in a Fab Lab using these tools can be a great way of developing projects such as the coat assistant.

2.4 Ethical Analysis

Developing assistive technologies raises ethical questions, these were identified in an ethical review done during the Reflection Report Assignment [15]. The two key dilemmas were accessibility and affordability and balancing rules and regulations with human needs. These dilemmas highlight the importance of designing solutions for everyone that comply with ethical principles. These insights help in balancing the societal impact with technical and regulatory constraints. In this section, both of these dilemmas are discussed and a conclusion is drawn.

2.4.1 Dilemma 1: Accessibility and Affordability

The first dilemma is how can the coat assistant be made accessible and affordable for as many people, regardless of their situation. There are two main ways to create the coat assistant: making it yourself in a Fab Lab or collaborating with a medical device company. These options present a dilemma: should the coat assistant be designed to be inexpensive but potentially less accessible, or should it be priced higher while being more accessible? The project aims to make the coat assistant accessible to as many people as possible so thinking about both ways contributes to the bigger picture.

When a person wants to make the coat assistant at a Fab Lab they enter a Fab Lab with the open-source project and start talking with the people working there. Both probably do not have any experience with a project like this before and thus need to invest a lot of time and effort into getting started with this project. The barrier to going to a Fab Lab and accessing the project is low, next to that you can produce it more cheaply since the costs at a Fab Lab are low. Although Fab Labs are low-cost and open-access, creating the coat assistant in this way demands a lot of knowledge and hands-on skills, which limits accessibility for those without technical experience. Hands-on skills in this case are even more difficult since the person needing the coat assistant is unable to use their hands.

In contrast, getting a coat assistant at a medical device company is more straightforward, as users receive a ready-made product that can be used almost immediately. Receiving support is also easier since a specialist at the company can assist. However, scheduling a meeting may be more complicated due to the location of the company and the amount of specialists. Furthermore, specialists may have to meet about multiple projects, leading to longer wait times for assistance. For maintenance and repairs, spare parts are available but may take time to restock, potentially leaving users without a working device for extended periods. Since the coat assistant is bought at a company the price is higher than making it yourself in a Fab Lab.

2.4.2 Dilemma 2: Rules and Regulations vs Being Human

The second dilemma is balancing the moral duty to help others by providing access to assistive technology with the responsibility to follow laws and regulations that ensure safety. On one hand, strict rules and regulations are crucial for ensuring the safety and quality of medical devices. However, these standards often lead to approval processes which take up a lot of time and high costs. This can slow down the innovation of new products and make devices less accessible for individuals who need them. Assistive technologies often require a lot of customization to meet specific needs, but the rules made for these devices look more at mass-produced solutions. This limits the ability to quickly create personalized devices for specific needs. The people wanting these personalized devices often get told by general medical device companies that they need to wait and that there is no product which is made for them. Standard-made assistive devices need to fit people with a specific need, these devices are distributed by big companies who do not look into personal details. People with a disability already feel more left out since they are not able to live the same life as someone without a disability. These assistive devices can let them feel like a normal person again. Rules are there to ensure safety but do they go above quality of life?

2.4.3 Summary Ethical Review

The ethical review highlights the importance of making assistive devices like the coat assistant affordable and accessible while following necessary rules. Fab Labs are a cheaper way to make the device, but they require technical skills that not everyone has. On the other hand, collaborating with medical companies offers ready-to-use solutions but introduces higher costs and reduced flexibility. This project tries to combine the best of both options by creating designs that are easy to produce and accessible to more people.

The review also points out that current rules, like the MDR law, focus more on safety than on personalizing devices for people with specific needs. This creates challenges for innovative projects like the coat assistant. To handle these issues, it's important to add disclaimers like "Use at Your Own Risk" and to work with legal experts and Fab Lab communities. This approach can help balance safety and innovation.

The coat assistant is especially important for people with disabilities, who often struggle to find affordable and personalized assistive devices. This project shows how assistive technology can be made cheaper and more customizable, giving people more independence. By showing a new way to create assistive devices, this project could inspire changes in how healthcare and regulations support innovation.

2.5 Literature Review

During the course Academic Writing (AW) a literature review was done [16]. The aim of this literature review is to explore the potential of making assistive technology in Fab Labs. This is done through exploring the concept of Fab Labs and analysing insights gained from existing research conducted within these spaces. First, the characteristics of a Fab Lab will be explored. Second, insights gained from research done in Fab Labs will be discussed.

2.5.1 Characteristics of Fab Labs

A Fab Lab is short for Fabrication Laboratory which are labs/workshops where everyone is able to make things. It is an open workshop where specific machines and tools can be found. First, the origin of Fab Labs is discussed. Second, the characteristics of Fab Labs will be discussed. A lot of characteristics about Fab Labs can be found, these can be categorized into four types of characteristics and are discussed below.

Origin

According to Garcia-Luiz [11], Fab Labs originates at the Massachusetts Institute of Technology (MIT) from Professor Gershenfeld's subject, called "How to Make (Almost) Anything". The idea was to democratize access to high-tech fabrication tools, allowing ordinary people to invent, create, and fabricate physical products. The benefits of a Fab Lab according to Gershenfeld [13] include the ability to build, disassemble and reassemble products, to explore sustainable solutions and to produce objects in small volumes, locally and only according to need.

Accessibility

The first characteristic of Fab Labs revolves around accessibility. Fab Labs are designed to be inclusive spaces where everyone can access advanced digital fabrication tools and resources. According to De Boer [6], Fab Labs serve as structured yet open communities, bringing together fabricators, artists, scientists, engineers, educators, and amateurs of all ages and professions. This accessibility allows people to design, create, and prototype items using digital technologies, as noted by Johns et al. [26]. The ability to take a personal idea from concept to functional prototype, while iterating through various stages, is a core feature of Fab Labs, as emphasized by Walter-Hermann et al. [50]. In addition, Savastano et al. [44] further highlight that Fab Labs aim to provide everyone with equal access to these instruments, unleashing human creativity through diverse approaches.

Community and Collaboration

The second characteristic is about community and collaboration. Fab Labs not only offers access to tools but also fosters a strong sense of community where collaboration and knowledge sharing are highly encouraged. They serve as hubs of innovation and problem-solving within local communities, as observed by Naboni et al. [32], where individuals exchange ideas and skills. Next to that, Garcia-Ruiz et al. [12] add that knowledge-sharing among users is a key aspect of the Fab Lab environment. Since the first Fab Lab was established around 2000, their numbers have skyrocketed, now present in over 100 countries with 1,750 labs worldwide. This growth can be due to the popularization of digital fabrication technologies such as the 3D printer [11].

Rules and Structure

Third, the characteristic of rules and structure used in Fab Labs is discussed. Fab Labs operate under a structured set of guidelines known as the Fab Charter, which distinguishes them from makers and hackerspaces [6]. This charter outlines key principles that all Fab Labs must adhere to, ensuring a level of consistency across the global network. As described by García-Ruiz et al. [12], these principles include the commitment of Fab Labs to function as community resources, dedicating specific times for public access. Additionally, all Fab Labs are required to maintain a standard set of tools and technologies, which enables them to collaborate on projects and share processes across the wider Fab Lab network. This sense of networked collaboration is essential to the Fab Lab ethos. Furthermore, the Fab Charter promotes the open-source philosophy, encouraging the free exchange of knowledge and ideas. Although users are permitted to pursue commercial initiatives, these projects are expected to be developed within the Fab Lab initially but later made outside of the Fab Lab environment. This balance between community engagement, open-source collaboration, and entrepreneurial development is what defines the structured yet flexible nature of Fab Labs.

Tools

The last characteristic discussed is the tools used in a Fab Lab. A Fab Lab is equipped with a standard set of tools that includes a laser cutter, CNC milling machine, 3D printer, and an electronics workstation. As said by Pedersen et al. [35] "the Fab Lab provides users not only with basic construction equipment but enables them to meet high design standards with their fabrications." In terms of hardware Fleischmann et al. [10] say Fab Labs provide various electronic components like microcontrollers, wires, sensors, buttons, actuators, motors, and breadboards. The software available in Fab Labs supports all stages of the design, building, and control processes for both the machines and the parts being created. As said by Konopek et al. [28] and Fleischmann et al. [10] Fab Labs often use open-source software. The advanced tools combined with digital fabrication technologies allow users to transform their digital designs into physical objects.

All of these characteristics make them uniquely suited to the development of assistive devices, which often require personalization to meet specific needs. By offering an inclusive environment, Fab Labs align with the goals of this project, which focuses on creating an accessible coat assistant.

2.5.2 Insights on Fab Labs

The insights on Fab Labs span a wide range of areas. According to this literature review, there are three main insights.

Commercialization

The first insight is the commercialization of products. Since many of the products created in Fab Labs are designed for specific individuals with particular requirements, they may not appeal to a large enough audience to make commercialization viable. As a result, many projects fall into the "Valley of Death"—a phase where products struggle to move from invention to commercialization. This gap, as described by Markham et al. [30], is the space between the technical invention or market recognition of an idea and the efforts to commercialize it. This is unfortunate, as many of these products could be beneficial to individuals with a variety of disabilities. As said by Thorsen et al. [46] standard off-the-shelf products often do not meet the unique needs of people with specific disabilities which thus makes the personalized creations of Fab Labs especially valuable.

When it comes to facing these challenges, particularly the Valley of Death, Fab Labs may not be suitable for mass production. As Carqueijó et al. [5] note, Fab Labs are not intended to replace traditional large-scale manufacturing. However, they have great potential in developing custom products by giving people the ability to design and produce items specific to personal or local needs. These spaces provide access to affordable tools and allow for rapid prototyping of nearly any object, all while maintaining low costs, much like mass production. Diez et al. [7] further emphasizes that Fab Labs are part of a broader shift in consumer power, where consumers are no longer just customizing products or easily switching suppliers. Instead, they are becoming their producers, participating in an economy of sharing and mass collaboration (MC), which contrasts with traditional Mass Production (MP) by focusing on the ability to frequently modify and adapt products to evolving needs, all while keeping costs low. Bravi et al. [2] agree with this and add that in this new model, customers become "co-designers," who are actively engaging in the design process. This collaborative approach aligns with the core activities of a Fab Lab, where individuals create their goods while also contributing to a community of makers.

Knowledge Transfer and Realizing Ideals

In addition to commercialization challenges the second insight is about the difficulty Fab Labs face with knowledge transfer and realizing ideals. Although Fab Labs are designed for non-experts to use, understanding how to operate the machines isn't always straightforward. Most users need to invest significant time and energy into studying manuals before mastering basic functions. As noted by Dreessen [8]. Furthermore, despite the Fab Lab principles of openness, collaboration, and customisation, these ideals are not always fully realized. Johns et al. [26] point out that, in reality, individualism and competition often overshadow collective innovation. Makers may work in isolation, and Fab Labs can become disconnected from the local communities they aim to serve. Additionally, participants may resist the entrepreneurial mindset encouraged in Fab Labs, preferring not to commercialize their creations.

Patient driven design

The third insight is about how patient-driven design is used in a Fab Lab. According to Pedersen et al. [35] an issue faced by Fab Labs in using patient-driven design is their limited capacity for conducting controlled user tests with specific target groups which is an important part of refining products in areas like healthcare. Without proper testing, it is difficult to ensure that these products meet the needs of potential users which further complicates the path to commercialization. However, as Thorsen et al. [46] suggest, the Maker approach to producing objects for personal use could present an opportunity for a paradigm shift in rehabilitation thinking. This shift would involve changing the role of the patient from a passive receiver of care to an active participant in creating specialized solutions. It has been reported that one in ten chronic patients already develops innovative solutions for personal use, highlighting the potential for Fab Labs to empower individuals in making personalized assistive devices.

2.5.3 Summary Literature Review

The literature review emphasizes that Fab Labs excel as community-driven spaces where rapid iteration and refinement are possible. These strengths can be leveraged to create a coat assistant that is both affordable and adaptable. Additionally, addressing challenges like regulatory compliance and user testing will ensure the device is practical and effective. Next to that, the knowledge transfer required to operate Fab Lab machinery often limits accessibility for non-expert users. A look should be taken at how this transfer can be done at a low level as possible to include as many people as possible.

Drawing on the insights gained from the literature review, this project highlights the relevance of Fab Labs in developing assistive technology. By providing access to tools and fostering a culture of collaboration and innovation, Fab Labs offer a unique platform for creating personalized solutions. By enabling users to customize the coat assistant to their specific needs, the project empowers individuals to take control of their assistive devices, transforming them into co-designers rather than mere end-users. The coat assistant aims to embody these principles, demonstrating how assistive devices can be developed in a way that is affordable, adaptable, and user-driven.

Since no research papers could be found on assistive technology a limitation of this review is that assistive technology is a new and emerging area of research for Fab Labs. Insights were gained but they were not related to assistive technology research. More research is needed into the relationship between Fab Labs and assistive technology. Projects without academic research have not been considered and searched for but could be interesting to look at. The ability to customize products while reducing both costs and production time makes Fab Labs appealing for developing devices like a coat assistant. However, more research is needed to see the feasibility of designing and manufacturing assistive devices in Fab Labs. Additionally, important things such as support and repair, as well as regulatory compliance, need further investigation to ensure that assistive devices can be designed and made in Fab Labs.

2.6 State Of The Art

The current State Of The Art of coat assistants and medical devices made in Fab Labs is quite limited. A distinction can be made in three categories: open-source platforms, Fab Labs and assistive device companies. These categories operate in different ways and have different types of products.

2.6.1 Open-source Platforms

Open-source refers to a type of project, software, or product where the original design, code, or documentation is made freely available to the public. This allows anyone to use, modify, and distribute it under certain conditions, often specified by an open-source license. There are multiple platforms where projects can be shared open-source. These platforms are: Thingiverse [45], Instructables [24], Remap [42] and Careables/Welder [3]. A search was done on all four websites with the search words: assistive devices, coat assistant, disability and handicap.

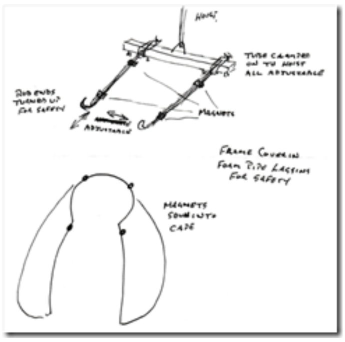
The only coat assistant related projects were found on Remap. Remap is a company at which devices are made and adapted for people with a disability. On the website a page about their solutions can be found. On this page six projects can be found closely related to the coat assistant.

(A) Device to put coat on [40]

(B) Coat maid [39]

(C) Coat dressing aid [38]

(D) Coat donning aid [37]



(E) Aid to put on outdoor clothing [36]

(F) Dressing aid for Jack [41]

FIGURE 2.4: Remap coat assistants

Looking at these projects it can be seen that there is not one design for a coat assistant. Each coat assistant has a frame to which a jacket can be attached. Five of these projects (Figure 2.1 a, b, c, e and f) have a lifting system built-in to lift the jacket to the correct height of the person. Thus they also use electronics to make the coat assistant work.

In these coat assistants different ways of attaching the coat to the frame are used namely, using clamps, using magnets, using a hanger and using a modified brake system that mimics fingers holding a jacket. The coat assistants are operated through the push of a button or releasing a brake. To make the coat assistant stable, a platform is added onto which the person stands during the process or it is attached to chair or hoisting lift. The coat assistants are movable either through lifting or rolling them to another place but in general are difficult to more.

None of these coat assistants have ways of fully closing the jacket around the shoulders and neck and making sure that the zipper shuts in some way. In the projects is not named how the zipper is closed and in some cases the person needs to wiggle themselves in the jacket for the last part around the shoulders. After the coat is on the body it is only stated in 2.2 b that the coat assistant needs to be reset manually. The others are unclear if they need a reset. Next to that it is not stated if the coat assistant is able to help by taking of the coat again. These projects were not only made for coats but also for shirts having a front button opening. Especially in the case of the clamp, modified brake and hanger of every type of clothing can be used.

The people who are able to use these coat assistants differ per design. For figure 2.1 a person is able to walk in with their walking frame but needs to be able to stand up themselves. The arms are laid on the wooden frame and thus need to be up in the air. Not all persons with a disability to the arms are able to lay their arms on this system. In figure 2.1 b a person is able to sit down and put the arms in the sleeves of the coat. It is unclear how low the entry of the sleeves are at the start point. Some people are not able to put their arms to the back and lift them to fit into the sleeves. In figure 2.1 c this is the case and the coat can be lowered as much as needed to not lift the arms into the sleeves.

Figure 2.2 a is not usable for most people having a disability to their arms. The coat is attached to two clamps on a rope and the person is able to wiggle their way into their jacket. The rope is just about long enough so the person can fit their arms into their sleeves. For this project a person must be able to use the rest of their upper and lower body to wiggle it into place.

Figure 2.2 b and c both have a system to which the coat is attached and is able to lower as far as needed to put in the arms in the sleeves after which the coat is lifted in the air onto the shoulders.

Next to the coat assistant projects there can also be a number of projects found on assistive devices. Ranging from extended zippers to a mouse controlled by the mouth. These were found on Instructables and Welder/Careables.

(A) K-zip [25] (B) Cup [4] (C) Mouse by mouth [51]

FIGURE 2.5: Assistive technology open-source projects

2.6.2 Fab Labs

In Fab Labs no project like the coat assistant could be found but there were a lot of interesting assistive device projects which were made in a Fab Lab. Examples of these project can be find below with explanation of the types of project. Next to that multiple Fab Labs focussing on disabilities were found and even a sub branch from Fab Labs called REHAB-LAB, which ties in closely to the subject of assistive devices. First the project are discussed and after that different types of Fab Labs.

(A) 50 dollar prosthetic [51] (B) DIY finger split [49]

FIGURE 2.6: Fab Lab Assistive Devices part 1

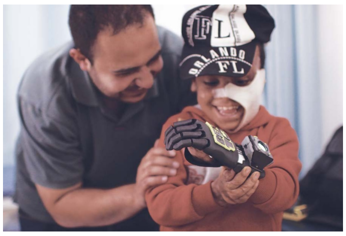
50 dollar prosthetic

One of them is the 50 dollar prosthetic, it is a lower limb prosthetic developed by Fab Lab Waag to be locally made under 50 dollar. It can be seen in figure 2.5 a.

DIY finger splint

Another assistive device made in Fab Lab Waag is the DIY finger splint. It is made for people who injured their finger and is often able to help with the healing process. Since every finger is different this splint is developed to fit every finger. People are able to measure their finger and input this data into the computer which makes a 3D model out of it and sends it to the printer. The result is a personal well-fitting finger splint which can be seen in figure 2.5 b.

(A) EASYRIDER II [52]



(B) Refugee Open Ware [53]

FIGURE 2.7: Fab Lab Assistive Devices part 2

EASYRIDER II

Next to that the EASYRIDER II was made by Fab Lab Budapest which can be seen in figure 2.6 a. It looks like a toy even though the main purpose is to help children transport themselves without any additional help. The aim of the tool is to work the muscles while providing an experience of play and joy for the kids.

Refugee Open Ware

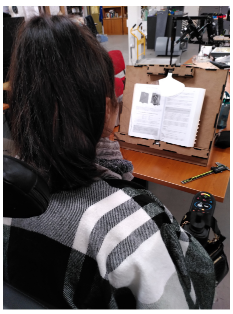
A prosthetic also worth mentioning is the Regufee Open Ware which can be seen in figure 2.6 b. It is a famous 3D printing project in the medical area and is related to prosthetics specifically about being able to make your own prosthetic. This project is developed for refugees with keeping the user's preferences closely in mind. The prosthetic is designed in such a way that it helps the refugees to reduce the loss of function thus use the limb again and be part of their personal identity.

My Human Kit

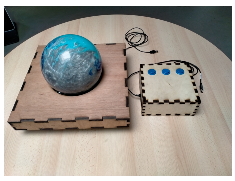
Next to the interesting projects names above there is also a Fab Lab specialized in helping people with a disability to design projects that help their daily life. The Fab Lab is located in Rennes, Britany and is called My Human Kit. The website shows some interesting projects. They provide help to people with different disabilities which range from a COVID proof attachment for a wheelchair to a printer made for printing braille which can be seen in figure 2.7 a and b.

(A) COVID protection [54]

(B) Braille printer [51]



(C) Page turner [9]



(D) Pedastrian trackball [9]

FIGURE 2.8: My Human Kit projects and EirLab project

EirLab

Another Fab Lab worth mentioning is the EirLab [9] in Talence, France. They started a participatory design process by and for people with disabilities in a Fab Lab. In the article first participatory design is explained after which the theory is put into practice. The projects which used these concepts are afterwards explained. The projects range from a pedestrian trackball to a page turner which can be seen in figure 2.7 c and d. This is a great example of how to involve people with disabilities in designing their own solutions.

REHAB-LAB

FIGURE 2.9: REHAB-LAB

Next to the Fab Labs doing projects related to healthcare and disability there is also a sub-network of Fab Labs called REHAB-LAB [29]. They are integrated or supervised by health and care organizations. As said in their REHAB-LAB charter, people with special needs are given the opportunity to participate in the design of their own assistive devices with the support of healthcare professionals. According to their website there are currently 61 of these REHAB-LABs around the world of which most are located in France and now slowly spreading through Europe with no labs in the Netherlands. On their website a lot of assistive device made in REHAB-LABs can be found. Next to that a lot of information about the legal challenges and 3D printing techniques can be found.

2.6.3 Assistive Technology Companies

Medical devices, also known as medical aids, are products used to treat a disease or chronic condition or to support you in living as independently and comfortably as possible. This includes equipment and consumables. A research was done on Dutch assistive device company websites to see which products are available to directly buy and use. A variety of assistive devices has been found with the focus on the dressing and undressing of people. Below an overview of these products can be found with pictures. These products are made to assist people in the dressing and undressing of their clothing. They do not resemble anything like the coat assistant in terms of functionality and design. Next to that these products need some form of hand and arm movement which is not the case for the coat assistant.

(A) Slip lift [23]

(B) Zip grip [31]

(C) Button and zipper hook [22]

(D) Doff N' Donner [21]

(E) Robot glove [19]

(F) Clothing stick [20]

(G) Bra dressing aid [47]

(H) Pant dressing aid [18]

FIGURE 2.10: Assistive devices

2.6.4 Summary State of the Art

In conclusion, while six projects resembling the coat assistant are documented on REMAP, these primarily focus on DIY home solutions and lack the functionality of undressing. The coat assistant aims to provide a broader range of features that enhance user independence. Although there are numerous of interesting projects emerging from Fab Labs that demonstrate the potential for innovation no coat assistants have been developed within these environments or on other platforms. Existing assistive technology companies typically offer standard products that do not fit to individual needs highlighting a significant gap in the market. Since there are no comparable projects this highlights the potential for creating a coat assistant in a Fab Lab. Prioritizing customization and user-centered design to meet the needs of individuals with disabilities.

2.7 Expert Interviews

To complement the theoretical insights from the literature, expert interviews were conducted to gain practical perspectives on the topic. The selected experts, with extensive experience in relevant fields, provided valuable real-world insights into current challenges and trends. This section will describe the interview methodology, introduce the experts, and summarize the key findings. Two types of interviews were carried out namely with Fab Labs and assistive technology companies. The interviews with Fab Labs were focused on the ability of producing a product like the coat assistant in a Fab Lab. The interviews with assistive technology companies focused more on the business and occupational therapist side.

2.7.1 Interview Fab Lab 1

Fab Lab 1 shares his experiences with various assistive devices he used to support his wife who suffered from ALS just like Sebastiaan. While he used a wide range of aids, including wheelchairs, scooters, and lifts, he ultimately found a simple sliding sheet to be the most effective. He reveals a gap in rehabilitation services that struggled to keep up with the pace of the ALS's rapid progression. Bart is skeptical about a coat-assist device for ALS patients, noting the short usability window before people are not able to use it all and pointing out that personal caregivers are often faster. Next to that the problem is not solved with putting on a coat, the person needs to be able to go out the door without using their hands. Despite this, he sees potential in Fab Labs for creating practical, small-scale devices. He says Fab Labs can be seen as "repair cafés" that can produce customizable and affordable aids, especially for unique medical needs. Additionally, Bart sees potential in integrating warmth elements into the coat, drawing inspiration from projects like the sleeping bag coat for the homeless, which provides both warmth and convenience. He stresses that ALS patients and people not able to use their hands, need solutions beyond just a coat-assist as they face many daily challenges. Bart himself developed a simple and portable medication organizer to fit the need of people using medication.

2.7.2 Interview Fab Lab 2

Fab Lab 2 provides resources like 3D printers, laser cutters and CNC machines. Making it an ideal space for creating custom devices including a coat assistant. Such a project can largely be made in-house using the Fab Lab's tools with standard parts purchased and customized components fabricated on-site. By using standard parts and producing custom components the device can be assembled in a DIY kit similar to IKEA products. Since Fab Labs are open-source and make personal projects the Fab Labs are less bound by commercial regulations allowing for more accessible solutions. The global Fab Lab network is able to share open-source designs and resources across locations. In designing the coat assistant the emphasis would be on accessible materials and machine capabilities and specifically avoiding complex metalwork. A Bill of Materials, design drawings for components and personalized scripts can be used to support customization. The Fab Lab staff provide essential support for users with disabilities to adapt projects to their needs.

2.7.3 Interview Fab Lab 3

Fab Lab 3 hosts open evenings where visitors can work on their projects with help from volunteers. While the Fab Lab offers support, complex projects like the coat-assist device are challenging for users without technical expertise to complete independently. Volunteers may not always have the capacity to provide one-on-one help. Therefore, detailed documentation, such as thorough manuals and visual instructions is essential. Open-source resources and wikis facilitate sharing knowledge on machine settings and can inspire innovation, though specialized projects may require a dedicated support person. Open-source designs at Fab Lab also include disclaimers to ensure safe use. A focus on detailed manuals and visual instructions could help users independently make and personalize projects like the coat assistant. Next to that an important thing noted by the Fab Lab was the limited space to store big projects in a Fab Lab, this needs to be kept in mind during next stages.

2.7.4 Interview Fab Lab 4

Fab Lab 4 suggests a simplified design for the coat-assist device, potentially using wood instead of metal for added stability and easier handling. They offer creative alternatives, such as attaching the coat-assist device to a door or using pulleys, bicycle chains and other simple mechanical systems. They emphasize returning to the basic functionality of each component, enhancing both safety and practicality, such as avoiding strong magnets that could accidentally attach to surfaces outdoors. Fab Lab 4 also highlights the financial challenges in developing a prototype and stresses the importance of feedback to continuously improve the design.

2.7.5 Interview Marketing

The company is familiar with Ability Tech but has limited knowledge of assistive devices like the coat assistant. They recommend reaching out to Focal, an organization experienced in eating and arm support devices, which closely aligns with this product. The company primarily focuses on communication and control adaptations. For reimbursement by an insurance provider the device must fit within the framework and meet strict requirements including MDR regulations which are more extensive than CE standards. Finding a supplier with an insurance contract who believes in the product and can demonstrate that there is a demand for the product is essential. However, there is a risk that the product might be too niche or that similar solutions already exist. They emphasize the need to decide whether to remain a producer or to work with a reseller. If self-producing, the device must comply with all regulations and ensure continuity. If developed through a Fab Lab, it falls outside insurance coverage, simplifying regulatory demands. Finally, they evaluate each device for functionality, market potential, pricing, reimbursement and the stability of the manufacturer.

2.7.6 Interview Occupational Therapist

The company primarily focuses on people with intellectual, visual or motoric disabilities, rather than the specific target group requiring a coat-assist device. In a conversation with the occupational therapist their approach to developing a new aid would involve studying how ten people struggle with a particular task, identifying what makes it difficult, such as range of motion, strength, finesse, or visual challenges. After that they determine the most common difficulty and focus on solving that problem. The goal is to create a universal product that works well for as many people as possible. Once developed, they test the product with a wide group of users to assess its effectiveness. They have seen examples like a clothing hanger with pulleys and emphasize the risks of the neck clamp in the current design. This could be dangerous if users are unable to release themselves, such as individuals with epilepsy experiencing a seizure and getting stuck. They recommend using Velcro, specifically a type with two soft sides, instead of magnets. Magnets could also interfere with pacemakers or emergency alarms worn around the neck. They suggest ideas such as an arm that pulls the coat forward or a chair with armrests and without a back to give people more balance whilst putting on the coat. Next to that they mostly look at how a coat is being put on normally compared to with the machine. Testing prototypes with a diverse group of users is essential to ensure the design is both suitable and safe. The target group is very specific, as few people experience only arm-related issues. Above all, the coat assistant must be safe, as it is aimed at individuals living independently at home.

2.7.7 Summary Expert Interviews

The interviews with representatives from various Fab Labs reveal a lot of the challenges and opportunities associated with developing the coat assistant in a Fab Lab. Overall they agree that such a project is possible to execute but still have some points which need to be kept in mind. First it became clear that the design needs some simplifying to use the materials often used in Fab Labs, namely wood and plastic. A list can be made stating all the components of the coat assistant and categorizing them based on their ability to be made in a Fab Lab. From this list a division between standard and Fab Lab components can be made. The Fab Lab components can be redesigned to fit the machines used in a Fab Lab and simplify the design while standard components can be bought in a store. Second, the coat assistant is able to put on a coat but does not improve the rest of the mobility issues for someone without arm movement wanting to go outside. Third, a way to deal with the storing of the big project during the making process needs to be thought of. Since some Fab Labs are not able to store such a project. Fourth, a financial plan should be made about the coat assistant stating how much it costs to make it and if people developing the coat assistant receive anything for their help.

In short, the Fab Labs recommend a simpler design with well-documented interactive steps and support to make the project more suitable to be made within a Fab Lab.

2.8 From Prototype to Product on the Market

Jan and Sebastiaan already took multiple steps to get the coat assistant on the market. Money and rules and regulations and an absence of documentation were the main pain points when getting it on the market. In this section is explained which steps people need to take to bring such a product on the market and how these steps influence a project like the coat assistant.

According to the KVK [27] the steps to get a product on the market are:

1. Research
2. Comply with product safety rules
3. Look for funding
4. Protect your intellectual property
5. Draw up a marketing plan
6. Find customers

7. Explore the foreign market
8. Keep improving and protecting your product

All of these steps still need a lot of detailing before the product can be put on the market. The most important step regarding assistive devices is the complying with product safety rules. When designing an assistive device for people who have a disability the Medical Device Regulation (MDR) comes into play. This law is intended to improve the safety, quality and traceability of medical devices within the European Union. Medical devices are used in the treatment of a condition or disability. Since the coat assistant mostly focuses on people who have a disability to the arms the product falls under this law.

When the coat assistant falls under the MDR law a lot of things need to be done. All of the steps can be found at the Rijksoverheid website [43]. These steps are unachievable for the coat assistant since there is not enough resources, expertise and time.

However after doing a lot of research and having conversation, mail contact with multiple people and companies to see if the coat assistant would fall under MDR law, the definition of this law became unclear. Everything about this grey area can be found in appendix 7. It thus all comes down to how the coat assistant is being described as a product [48]. When it is a coat assistant which is for everyone who wants assistance in putting on their coat it does not fall under the MDR. On the other hand when it is a device that helps people with a disability to the arms put on their coat independently it does fall under the MDR.

Next to that when the coat assistant is promoted as medical device it still can fall under the MDR or when using a use at your own risk statement it can still fall under the MDR when the purpose aligns with the definition of a medical device. There is however a difference when sharing a project open-source for personal, non-commercial use, then the regulation does not apply. But when the device is distributed, sold or promoted for broader user, compliance becomes necessary.

This grey area is difficult to navigate without professional assistance of people who have a lot of experience in this area. Jan and Sebastiaan reached out to many companies who all said we are interested but not at this point. When looking at the pain points of getting it on the market again it can be seen that an assistive or healthcare device company is able to get the project more money and has the expertise to meet the rules and regulations after the documentation is worked out in detail. Since this stage involves a lot of prototyping and takes time a Fab Lab can be used to assist during these stages. A lot needs to be done to get it to the next step but the goal of the project was to make it as accessible as possible. This can be done through making the project open-source to collaborate with as many people as possible to get it to the next stage while having the option for people to already make the coat assistant as a personal project themselves. Next to that the purpose of the coat assistant must be changed from people having a disability to the arms to people in general, this also increases the target group of the coat assistant. Additionally, a legal professional must be asked to ensure the project complies with basic safety and the regulations. Lastly, disclaimers must be added about the intended use and risk and emphasized that it is for personal experimentation rather than commercial use.

After the coat assistant has a more detailed documentation, conversations with companies can be done to see if they want to take the product to the market. If not the project can stay open-source and be made by people themselves.

2.9 Conclusion Background Research

This chapter examined how assistive devices, like the coat assistant, can be made on a small scale, focusing on Fab Labs as a community-driven solution. These labs offer digital fabrication tools that can help make assistive devices customizable and accessible. It also considered collaborating with medical device companies to overcome regulatory challenges and ensure the devices meet diverse needs.

The interview with Jan and Sebastiaan revealed that the coat assistant is most useful for people with arm disabilities who wish to live independently. The design, initially made for Sebastiaan, needs adjustments for various body types, and certain components require improvement. The coat assistant is also bulky and changes are needed to make it more adaptable for different living spaces.

Fab Labs provide an affordable way to prototype but they lack the resources to fully address medical device regulations. Partnering with medical companies can help navigate these challenges. The State of the Art section showed that there is a market gap for customizable assistive devices like the coat assistant, highlighting the potential for development within Fab Labs.

Expert interviews indicated that simplifying the design for use with Fab Lab materials, such as wood and plastic, is crucial. They also suggested creating clear documentation and developing a financial plan. The best way forward is to focus on making the coat assistant open-source and producing it in a Fab Lab. This will allow the design to be shared and improved by a wide community, bypassing the regulatory hurdles that traditional manufacturing and medical device companies face. By creating an open-source project, the coat assistant can be made more accessible and affordable.

Once the design is fully developed, with clear documentation and a functional prototype, the next step would be to reach out to companies again. Conversations with potential partners can be revisited to see if they are interested in bringing the product to the market. If companies are not willing to invest, the open-source model will remain, allowing individuals to create and modify the coat assistant themselves. This approach offers the flexibility to continue the development of the project and ensures that it remains accessible to those who need it.

Chapter 3

Methods and Techniques

This chapter explains how the coat assistant was developed and improved to meet users' needs. It describes the tools, methods and steps used in the project, from the first ideas to making prototypes and reviewing the documentation.

There are multiple activities that took place during the project, these include:

- Component List: Creating a list of components and divide the components between standard and Fab Lab components
- Co-design Session: Generating ideas for new designs and components
- Redesigning Components: Generating ideas for components which can be made in a Fab Lab
- Setting Up Documentation: Looking into what needs to be documented and how it is going to be documented
- Testing Documentation and Components: Interviewing Fab Labs to check if the documentation and components are feasible to use in a Fab Lab

3.1 Component List

A component list was created through the use of Google Sheets. The current design was used to create this list. The list was created through looking at the coat assistant and seeing which parts were used. For the part that no specific part could be found more general materials were picked which might not be accurate. Multiple rows were added for different features, the explanation can be found in appendix 2. Multiple component categories were used to easily see to which part (neck clamp, sleeves clamp, lift, frame or footrest) the component belongs. Next to that a division was made between electronics and material components to later on see which parts can be swapped with part made in a Fab Lab. Components made from electronics are more difficult to swap than the material components. Next to the categorization component amounts and prices were included to give an idea about how much money is spend on such a project. Every component was searched for on the internet through aliexpress, electronic stores or hardware stores. Next to the prices the delivery times are included to give an overview how long it will take certain components to be delivered and which component can become a problem. For the electronics components the details found on the components on the current design were put into a column to find the correct component and requirements.

In short a Bill of Materials (BoM) was used to create a list of standard components, including links to suppliers and technical specifications.

After that a division was made between Fab Lab and standard component. Fab Lab components were able to be made in a Fab Lab with a redesign or modification, standard components are bought in stores. This division was made based on evaluating the essential need of it being bought in a store. For example electronic parts are more likely to be bought in a store instead of Fab Lab made.

3.2 Design Requirements

From an interview with Jan and Sebastiaan the components which needed to change to accommodate a broader user group and to improve the design were identified and put into a list. These requirements were used to see which components need the most attention and need to be changed through the expert use of Jan and Sebastiaan.

Next to that a list with general requirements was made based on the background research to determine the most important requirements for this project. After that, part requirements were made to see what function each part has and what it minimally should be able to execute. These requirements are all put into a list in the thesis or inserted as an image made in Canva.

3.3 Co-design Session

Rethinking the design was done in multiple steps. The first step was the co-design session. The initial goal of this session was to take a look at which components can be made in a Fab Lab and how these components can be redesigned to fit Fab Lab machines and materials. However during the co-design it became clear that this goal was unrealistic since people were able to generate a lot of idead and not link it to a Fab Lab since they did not have experience with such a lab. The goal was changed to generating ideas about changing parts and components.

The session was done in the Designlab Empathize room. The participants were able to join the co-design session if they were someone working at a Fab Lab or anyone having experience with designing parts to fit 3D printers, laser cutters or CNC cutters. Recruiting was done through sharing the co-design invitation on Whatsapp with student in different groupchats. Next to that e-mails were send to all companies and Fab Labs who were talked to during the background phase. 5 participants participated in the co-design session which took around 2 hours. The participants were all students from different studies and backgrounds.

The co-design session had different steps, namely:

1. Welcome and introduction
2. Signing consent forms
3. Showing the coat assistant and explaining what it does
4. Showing and explaining the component list and the part categories
5. Brainstorming about the ideas and coming up with more ideas
6. Showing the design requirements and evaluating which ideas fit the requirements

7. Filling in evaluation form

During the co-design session the participants were able to draw on post-its and paper but mostly used the whiteboard on the wall to illustrate their ideas. Pictures of the whiteboard were taken to keep the ideas. After the brainstorm a conclusion was drawn about the most important ideas through a conversation in which everyone shared their opinions about the ideas.

3.4 Rethinking the Design

Rethinking the Design was done after the co-design session in which a lot of ideas were generated. Since not all components were included more ideas were generated through a simplified look at the design. Keeping in mind the minimal function and determining which products or materials were able to execute that function in some way. Next to that a look was taken at existing project and products in the surroundings to see how products for a specific use can also be applied to a different project having a different function. These ideas were put into a big list after which a sorting was done on ideas that improve or add something to the current design.

These ideas were worked out in detail with sketches and text. After that the advantages and disadvantages of every idea were stated and evaluated. These ideas were evaluated through the use of the idea evaluation table in which the most important criteria for developing these ideas for the purpose of the project were used. These were safety, easy to make, easy to develop, adaptability and affordability. Each of these criteria received a score from 1 to 5 after which the totals were calculated and a decision was made based on the score, criteria and purpose of the project.

This evaluation was done to make a decision about which three ideas were going to be used to be redesigned to fit a Fab Lab more specifically the materials and machines used in Fab Labs. After that the components were redesigned at home through the use of a FDM 3D printer and knowledge gathered during different project and subject during Creative Technology. The materails and machines used in a Fab Lab were often used during the study or personal project. During the redesign phase Solidworks was used to model the components and export them as .stl after which Ultimaker Cura was used to slice the models for the 3D printer. The 3D printer which was used is the Ender 3 V2 with an upgraded metal extruder, flexible print bed, improved bed springs and a automatic bed leveler BlTouch.

3.5 Setting Up Documentation

The documentation setup was made through scanning articles online about different ways to document projects. After that a decision was made to make a website and existing knowledge about GitHub was used to make a decision about choosing an open-source and free website hosting and building. GitHub Pages was a hosting platforms already known since GitHub was already previously used during projects. Hugo was chosen through seeing which static site generator existed and seeing it was very customizable and scalable for big projects compared to others.

The list of what to include in the documentation and the structure was made through looking at existing projects and Fab Lab websites using documentation. Next to that the information gathered during other steps of this research was included to make the list.

3.6 Testing Documentation and Components

After the documentation setup and component ideas were worked out two interviews took place to test these things. The interviews were done with two people working at Fab Labs in the Netherlands. One interview was done in a Fab Lab and the other took place online. Both interview took around 40 minutes and were recorded. This recording was afterwards put into TurboScribe to transcribe the audio. After that the text was highlighted in different colours resembling different subjects and a summary was made for every part.

The interview setup was as follows:

1. Filling in consent form
2. Start recording
3. Explain the purpose of the conversation
4. Explain the parts list, show tools and ask questions
5. Explain the new components, how they were made and ask questions
6. Explain the documentation setup and ask questions
7. Explain that these were all the components and fill out the general evaluation form
8. Thank the participants and ask if there are any remaining questions
9. Stop recording

Four subjects were used during the interview, namely: current design, new components, documentation and support. For each of the subjects there was one main question for which an answer was searched. These questions are:

- Is the current design feasible to make in a Fab Lab?
- Are the new components feasible to make in a Fab Lab?
- Can someone get started in a Fab Lab with this documentation?
- Is it feasible to make this project in a Fab Lab with the support of a Fab Lab?

These questions can be found on the evaluation form, this form was used to rate each of these questions and include the most important comments. The feasibility was rated from one to five and in the table the explanation of this rating can be found.

Value	Meaning
1	Not feasible at all
2	Not feasible
3	Neutral / can be better
4	Feasible
5	Very feasible

Table 3.1: Rating explanation

3.7 Interview setup

Two interviews were conducted with Fab Labs in the Netherlands. Each interview focused on distinct topics and questions were asked to explore those specific areas in detail. During the interview, the research findings from the thesis were shared. The topics discussed and the related questions were as follows:

- **Current design**
  - Is the current design feasible to make in a Fab Lab?
- **New components**
  - Are the new components feasible to make in a Fab Lab?
- **Documentation**
  - Can someone get started in a Fab Lab with this documentation?
- **Support**
  - Is it feasible to make this project in a Fab Lab with the support of a Fab Lab?

After the interview an evaluation form was filled in to give a quick summary about the feasibility and the most important comments. In appendix 6 the evaluation form can be found. In the evaluation form a feasibility rating was used which ranged from one to five.

Chapter 4

Ideation

During the ideation phase, the focus was on exploring ideas to improve and modify the coat assistant. This process began with making a detailed the component list, outlining each part of the coat assistant. Next, the design requirements are discussed. Ideas from the co-design session are then presented, including suggestions for new designs and modifications to existing components. The evaluation of these co-design ideas follows, assessing their feasibility and potential impact. Finally, additional ideas for modifying components not addressed during the co-design session were explored and discussed.

4.1 Parts List

The coat assistant was originally built at home without keeping a detailed list of the parts used. To address this, a parts list was made based on the design of the coat assistant. This list provides a clear overview of all the parts used in the coat assistant. With this list the coat assistant becomes more reproducible since people are now able to identify and purchase the parts needed to build their own. To improve the accessibility, the list includes links to manufacturers, costs and technical details. The complete list is found in Appendix 1 with an explanation of the list in Appendix 2.

The coat assistant has a lot of different parts ranging from the aluminium frame to a small bolt. To create a better understanding of which part executes which function, five main components have been identified. The coat assistant is split into the neck clamp, sleeve clamp, frame, lift and footrest.

In the parts list the cost of the individual parts can be found. The total price of the parts for the coat assistant is estimated around 1100 euros, this excludes the man hours of building the coat assistant. Making the list took around two days and is an essential part in making the coat assistant accessible. It not only improves understanding of each part's role but also simplifies troubleshooting and maintenance.

When making the parts list a list of components was made based on the amount of trouble a person would have during the assembly of the component. The list is ordered from one to five, with one being the most amount of trouble, next to that an explanation can be found.

1. Neck clamp
    - Is made out of a lot of parts (electronic and non-electronic) which precisely fit together and uses gears. It is also a very DIY component and not store bought.
2. Lift

- Made out of electronic components that need to work together.

3. Sleeves clamp
    - Made out of a ready-made clamp but it needs to be placed correctly and the servo need to be correctly programmed.
4. Footrest
    - Wood must be cut to shape and buttons need to be placed correctly.
5. Frame
    - No electronic components and is made out of aluminium frames which are bolted together.

4.2 Design Requirements

Design requirements were established to identify the key functions and details essential to the coat assistant. To create these requirements, feedback from Jan and Sebastiaan regarding necessary design changes was compiled into a list. This was followed by developing general requirements based on background research and knowledge.

From the general requirements, specific part requirements were derived, clarifying the function of each component. These requirements served as a foundation for evaluating new design ideas and ensuring they met the intended goals.

4.2.1 Design Changes According to Jan and Sebastiaan

Firstly the necessary design changes according to Jan and Sebastiaan were put into a list. The changes that needed to happen were:

- Making the coat assistant easily adaptable to fit people
- Accommodating different body types, able to fit people with different lengths and widths
- Improving the clamps of sleeves, they are too weak
- Making the neck clamp more dynamic to fit around the neck better and close the coat
- Taking a look at the area which is used for the coat assistant, looking at other frames, bases and a way of operating.
- Improving safety, long hair can become stuck at the neck clamp

4.2.2 General Requirements

Secondly a list with general requirements was made, these requirements were:

- Being able to put on a coat independently
- Affordable
- Easy to use

- Compact
- Adjustable in height
- Adjustable in width
- Operating without using the arms
- As close to a normal coat as possible

4.2.3 Component Requirements

Thirdly, a list of requirements was created for every component of the coat assistant, including the specific function of each component. This list can be found in Appendix 3 and plays a crucial role in understanding the current design and how each part contributes to the overall functionality of the coat assistant.

By outlining the purpose and role of every component, this list provides valuable insight into the coat assistant works. It also serves as a reference for identifying potential areas for improvement and ensures that any modifications align with the original design's intent. Furthermore, the requirements list is essential for effective troubleshooting, as it helps pinpoint issues within specific components. Next to that the list helps others with replicating the coat assistant since it helps them understand the coat assistant.

4.3 Generating and Evaluating Co-design Ideas

The original design of the coat assistant was tailored specifically for Sebastiaan, which means that some changes to the design needed to happen to accommodate others. Additionally, some parts of the coat assistant were made by Jan himself, making them challenging to replicate. To ensure the device can be reproduced in a Fab Lab, the components need to be either store-bought or fabricated using common Fab Lab equipment such as a 3D printer, laser cutter, or CNC cutter.

To address these challenges, a co-design session was conducted to generate ideas for modifying parts and components. The session resulted in a comprehensive list of ideas, from which three were selected for further exploration. The complete list of ideas can be found in Appendix 5, while sketches and brainstorming notes captured on a whiteboard during the session are included in Appendix 4. The section below elaborates and evaluates the three main new design concepts and four new component ideas that emerged from the co-design session. These ideas provide an insight into making the coat assistant more adaptable and reproducible.

4.3.1 Co-design New Design Ideas

The three new design ideas which were generated during the co-design session can be seen in Figure 4.1 with a small sketch. Below the figure an explanation of the idea can be found.

FIGURE 4.1: New design ideas

Idea 1: Bat Jacket

The first concept is the "Bat Jacket," designed to simplify the process of putting on a jacket. In this idea, the jacket is completely open along the sleeves and sides, giving it the appearance of a cape or poncho. The jacket is placed over the head and all the seams are lined with magnets. When the jacket is lifted and lowered onto the body, the magnets connect, automatically closing the jacket.

Idea 2: Teddybear

The second concept involves a "Teddybear" mechanism, which simulates giving the user a hug before helping them put on their jacket. The jacket is secured by closing it at the back, making it easy for the user to wear without requiring significant arm movement.

Idea 3: Turning Tables

The third concept, "Turning Tables," uses a rotating platform to assist in putting on a jacket. The user remains stationary while the jacket rotates around them. This design avoids the need for a part that fully encircles the body, providing a simple and effective solution.

4.3.2 Evaluating New Design Ideas

The evaluation of the three new designs involved comparing them to the current coat assistant design, with a focus on functionality and usability. Each idea was assessed through a structured list of pros and cons, highlighting their unique strengths and limitations. Since the concepts differ significantly, this process provided valuable insights that can guide future design improvements.

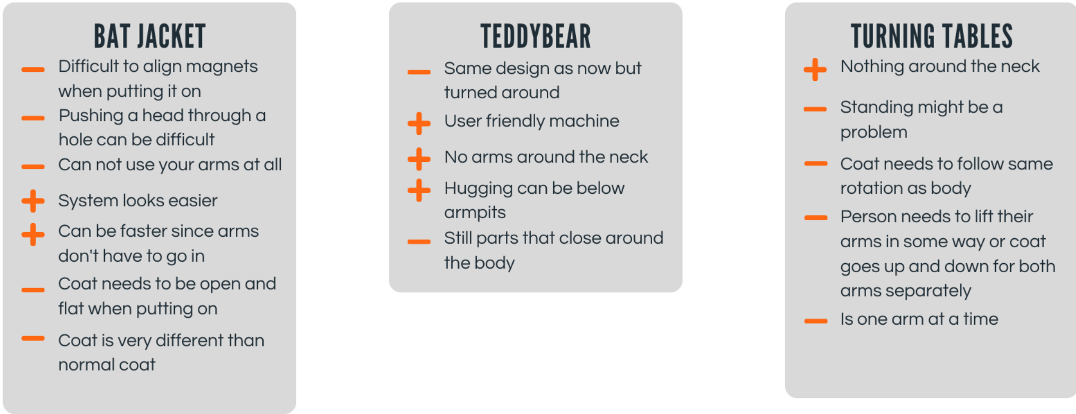


FIGURE 4.2: Evaluating New Design Ideas

Insights from the Bat Jacket

The Bat Jacket presents considerable potential for wheelchair users due to its adaptable design. It could be explored in the following variations:

- Sleeveless Design: This version eliminates sleeves, allowing the jacket to drape around the body. This removes the challenge of threading arms through sleeves.
- Magnetic Sleeves: Magnets could be incorporated to allow sleeves to close securely around the arms while maintaining functionality.

This idea emphasizes practicality and inclusivity, offering solutions tailored to specific user needs. However, to avoid stigmatization, the Bat Jacket should closely resemble a standard coat, creating a sense of normality for users. While it may not suit everyone, it offers a promising alternative for certain individuals.

Insights from the Teddybear

The Teddybear design is creative and potentially engaging, especially as it could make the neck clamp less intimidating by presenting it as a "hug" rather than a mechanical device. However, a review of its pros and cons revealed that it does not fully address the current design's challenges. Although it may not be directly applicable, the Teddybear concept can inspire future ideas or serve as a playful adaptation.

Insights from the Turning Tables

The Turning Tables concept also shows promise by mimicking the natural motion used when someone independently puts on a coat or receives assistance. Users typically begin with their more challenging arm, then rotate their body to position the other arm. This rotational approach could inspire a new design that aligns with intuitive movements.

While all three designs present promising ideas, they differ significantly from the current coat assistant design and fall outside the project's immediate scope of making the device more accessible and reproducible. However, these concepts can serve as inspiration for others, sparking new directions in assistive technology design.

4.3.3 New Component Ideas

The four new component ideas which were generated during the co-design session can be seen in Figure 4.3 with a small sketch. Below the figure an explanation of the idea can be found.

FIGURE 4.3: New component ideas

Idea 1: Stool

This concept involves a stool without a backrest but equipped with armrests. The design allows a person to sit while using the coat assistant, providing increased stability and safety during the process of putting on a jacket.

Idea 2: Sleeves Opening

A mechanism is proposed to hold sleeves open using a spring and small "fingers" that clamp inside the sleeve. These flexible fingers attach to the inner fabric, keeping the sleeve open. When the spring is released, the fingers retract, allowing the sleeve to be removed smoothly.

Idea 3: Rubber Neck Clamp

The neck clamp could be made from flexible materials, such as rubber, to enhance user safety and comfort. Using a bendable 3D-printed mold ensures the clamp is flexible enough to allow for quick release. Additionally, incorporating endstops in the design prevents the clamp from closing too tightly, reducing the risk of choking or discomfort.

Idea 4: Over the Head

This idea reimagines the jacket-closing process by using arms that move over the user's head rather than around the neck. This design minimizes the risk of entrapment and ensures the user can exit the machine easily and safely.

4.3.4 Evaluating New Component Ideas

Four new components were evaluated through comparing them with each other and looking at how they execute their function.

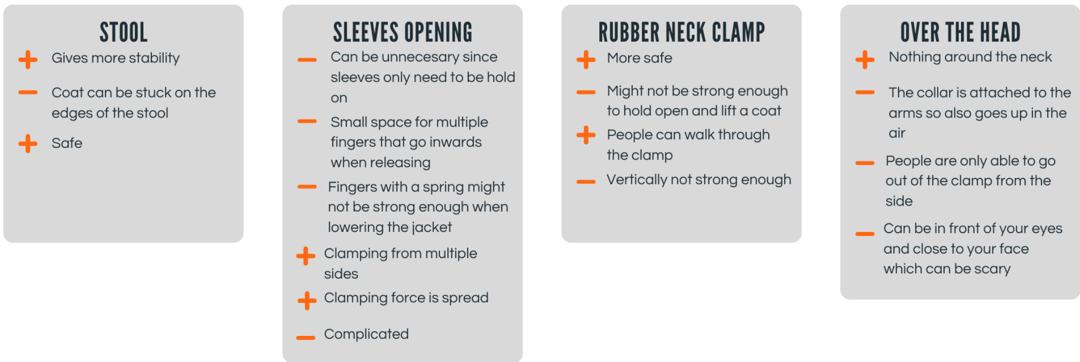


Figure 4.4: Evaluating New Component Ideas

The components generated during the co-design session offer varying levels of utility, with some showing potential for application and others being less relevant.

- Stool: This component is highly valuable for improving user stability and expanding the accessibility of the coat assistant to a broader audience.
- Sleeves Opening: This idea is unnecessary, as the sleeves only need to be clamped, not held open. The coat sleeves should be designed large enough to allow the arm to slide in and out easily.
- Rubber Neck Clamp: The current neck clamp poses safety risks, so redesigning it with rubber and a more user-friendly mechanism is a strong improvement.
- Over-the-Head Clamp: This concept could be useful if it functions like a joystick, allowing movement not only up and down but also side to side. Without this flexibility, the coat would either require adaptation or be lifted too high, making it impractical.

From the co-design session it can be concluded that the ideas generated are very broad and are not directly able to be made in a Fab Lab. It can also be concluded that the new designs are ideas that need a lot of ideation to have a working prototype. With the positives and negatives in mind it does not seem that one of these ideas is better than the current design. These three design ideas can be used to do a small research to see if they are able to execute the same function as the current design or work for different users. For now these three ideas will not be used in the rest of the project. The component ideas need some further detailing to see if they can improve the current design and be made in a Fab Lab.

In conclusion, the co-design session generated a range of broad and innovative ideas, but most are not immediately feasible for fabrication in a Fab Lab. Developing prototypes for the new design ideas would require significant further ideation and refinement. When considering the pros and cons, none of the new design concepts appear to offer a clear advantage over the current design. However, they could serve as a basis for exploratory research to determine whether they could fulfill the same functions or meet the needs of different user groups. At this stage, these three design concepts will not be incorporated into the rest of the project.

The component ideas show potential and require further refinement to evaluate their ability to enhance the current design and their feasibility for fabrication in a Fab Lab. However, these ideas primarily include an existing stool that can be purchased, modifications to the neck clamp, and an impractical concept for the sleeves. As a result, additional brainstorming and ideation are necessary to identify components that can be easily updated and prioritize those most in need of improvement.

4.4 Rethinking the Current Design

Building on the outcomes of the co-design session, which primarily focused on generating ideas for the neck clamp, this section explores new concepts for the remaining components. These additional ideas aim to address gaps in the design and identify potential improvements across other aspects of the coat assistant.

4.4.1 Sleeve Clamp Enhancements

The current sleeve clamp, depicted on the left in Figure 4.5, is constructed from metal and is readily available for purchase on platforms like AliExpress. In addition to this metal version, there are several alternative designs on Thingiverse that can be fabricated using a laser cutter or 3D printer.

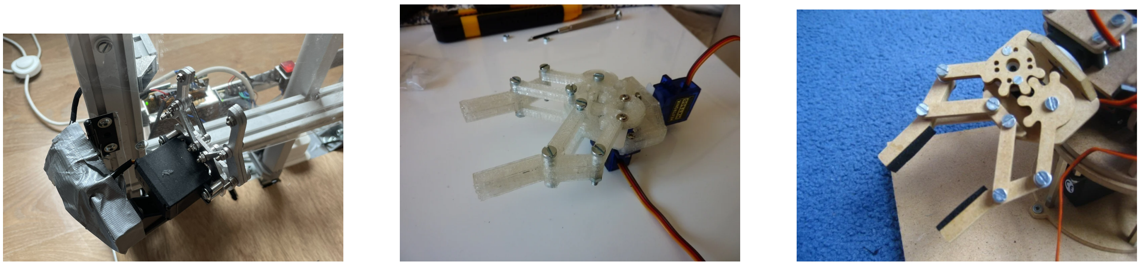


FIGURE 4.5: Grippers

Material Improvements for Grip

In addition to exploring wooden or plastic alternatives, the grip of the clamp can be significantly improved by modifying the material used on the tips. Several options for enhancing grip include:

- Velcro: Velcro offers a strong yet removable grip, allowing the clamps to release easily when disengaged. Velcro can be applied both on the gripper and the inner surface of the sleeves.

- Sandpaper: While effective for grip, sandpaper could potentially damage delicate coat materials, making it less ideal for certain users.
- Rubber or Silicone Tips: Rubber or silicone feet can improve grip strength without risking damage to the coat fabric. These materials provide a balance of security and usability.

Figure 4.6: Materials to Improve Grip

Strength Enhancements

The strength of the sleeve clamp can be enhanced by upgrading the servo motor used in its operation.

To improve the strength of the gripper a different servo motor can be used which has more torque. In the wood and plastic gripper the HXT 900 (1.6 kg/cm) servo is used, there are other grippers which use the MG 995 (10 kg/cm). The metal gripper already uses a stronger servo namely the MG 996 (13 kg/cm). To fit different types of servo to the gripper the dimensions of the servo attachments in the gripper need to be changed. More research is needed into specific types usable for this sleeve clamp.

To further enhance the strength and grip of the sleeve clamp, a ring can be incorporated inside the coat sleeve. The gripper arms would securely hold onto this ring, providing a more reliable grip. Alternatively, a thicker seam at the end of the sleeve could be added to prevent the sleeve from staying open, allowing the grippers to grasp the fabric more effectively.

The gripper tips could also be redesigned to improve functionality. Instead of straight arms, hooks could be added to the ends of the gripper arms, making it easier to grip the ring or thicker seam. Additionally, the surface of the gripper arms could be modified with features like triangles or half-circles to further enhance their ability to hold onto the material securely. Even silicon circles which can be bought in a store can be used to increase the grip.

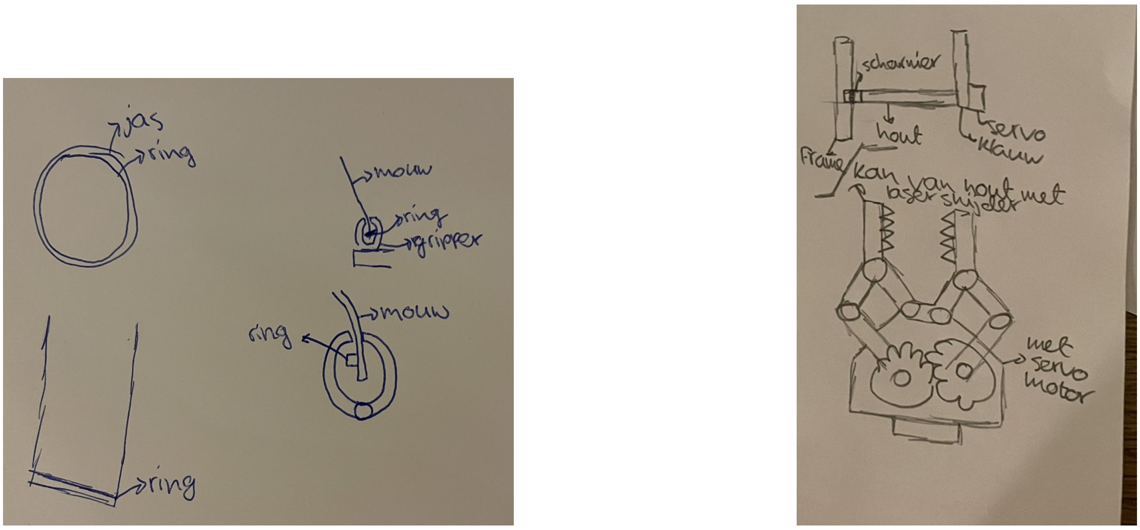


FIGURE 4.7: Gripper tips

By addressing both the materials and the mechanical design, these modifications aim to improve the overall performance and usability of the sleeve clamps, enhancing their reliability and adaptability for a wider range of users and coat designs.

4.4.2 Frame and Lift Enhancements

The frame serves as the central structure that connects all components of the coat assistant. In the current design, the frame and lift are constructed from aluminium profiles purchased from a store. The coat assistant is a free-standing device, occupying a considerable amount of space. One alternative is to mount the system on a door, which would eliminate most of the aluminium profiles and reduce the overall footprint. Another possibility is to build the frame and lift from wood. Since wood is heavier than aluminium, a test must be conducted to verify whether the actuator can support the additional weight.

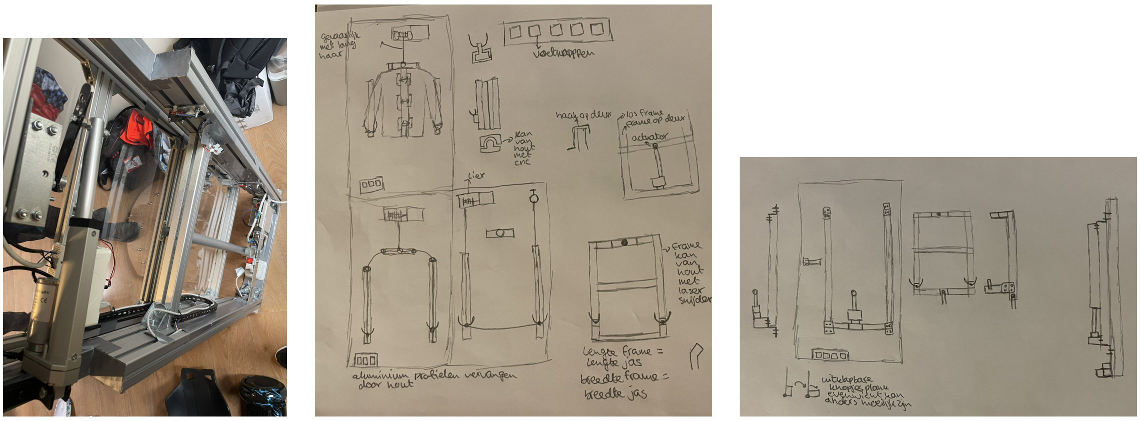


FIGURE 4.8: Frame and Lift Ideas

Saving Space

To save space and reduce the coat assistant's footprint, it can be designed to hang on a door. There are several bracket options for mounting the coat assistant to a door. One option is an S-bracket, which hangs on the door, while another is an L-bracket that is screwed directly into the door. Additionally the guiding rails for the frame are typically made of aluminium but could also be constructed from wood. However, aluminium rails are smoother, so research is necessary to determine if wooden rails can provide the same functionality. Alternatively, the round section of the rail could be purchased from a store, and the remaining parts could be laser or CNC cut. The store bought aluminium rails also feature a round slider component to which blocks are attached. Since a laser cutter can produce straight cuts but not round ones, creating the slider part with this method may be challenging. The aluminium blocks contain a plastic insert that houses ball bearings to facilitate smooth movement. One solution could be to 3D print the blocks with spaces to house the ball bearings, offering a similar effect.

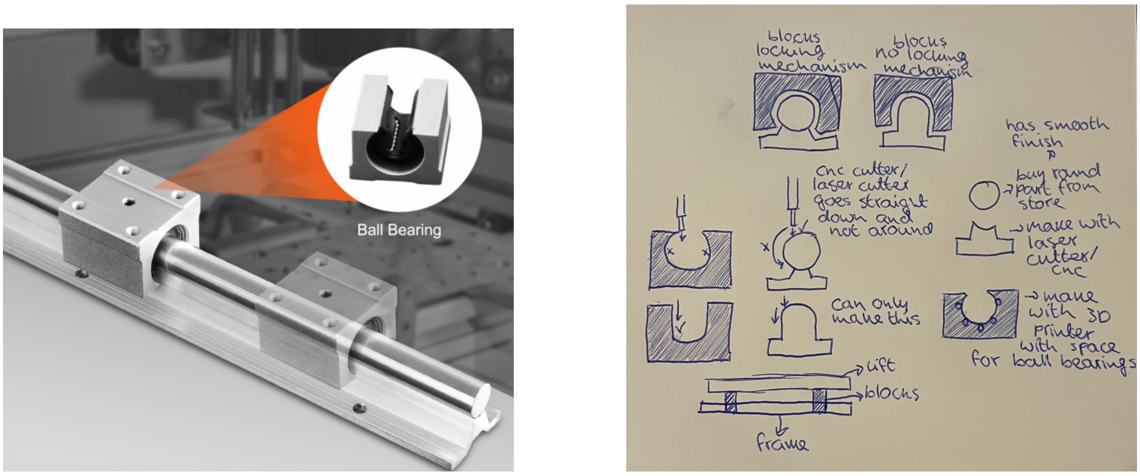


FIGURE 4.9: Guiding Rails

Utilizing Existing Components

The design of the lift and frame could also be adapted to utilize components commonly used in 3D printers. For instance, a stepper motor with a leadscrew, along with a rail system similar to those found in a Prusa MK4 3D printer, could be used to create a more compact and efficient lifting mechanism.

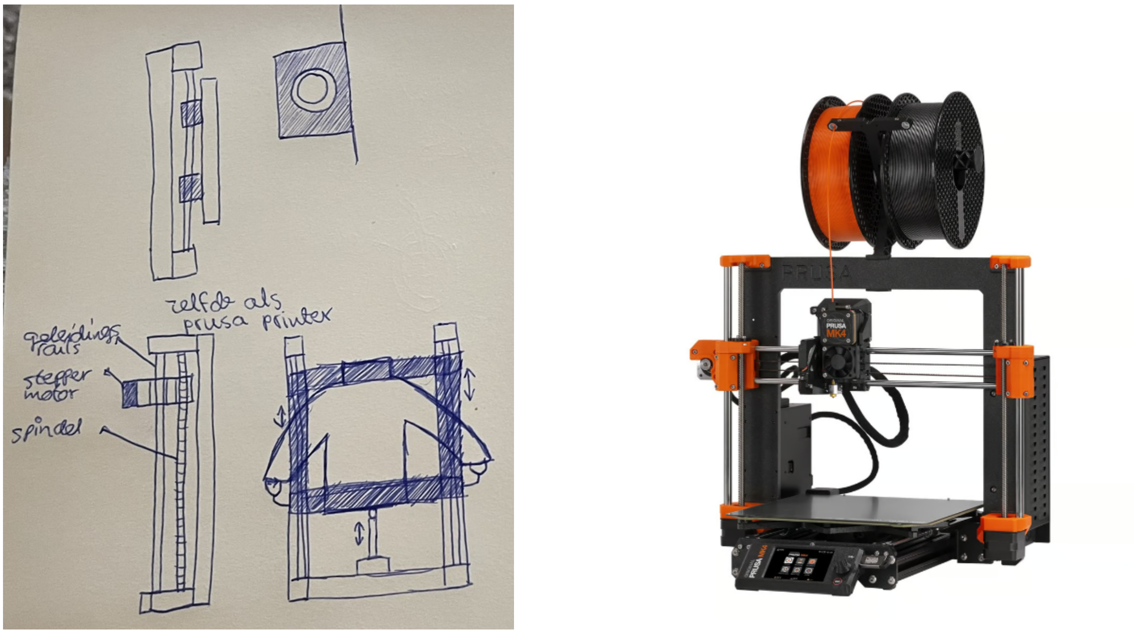


FIGURE 4.10: Lift ideas

All of these ideas contribute to enhancing the lift, but they will require testing and prototyping to ensure functionality.

4.4.3 Footrest Enhancements

During the co-design session, several small ideas were proposed to enhance the footrest and improve the operation of the coat assistant. These initial concepts were further developed, along with new ideas. One suggestion is to incorporate voice control, allowing the coat assistant to perform specific functions upon hearing commands, such as saying a colour to trigger a particular action. To ensure versatility and accessibility, voice control can be combined with physical buttons, guaranteeing that the coat assistant remains operable in various situations.

Another concept involves creating a foot pedal that functions like a joystick, enabling users to control the coat assistant's operations by, for example, moving their foot to the left. This system could either adapt an existing pedal or be designed with potentiometers, allowing for customization to suit the user's needs.

To enhance safety, one idea is to implement two pressure-sensitive buttons that the person must sit or stand against. Only when both buttons are pressed would the coat assistant be activated, ensuring that it doesn't function unless the user is properly positioned.

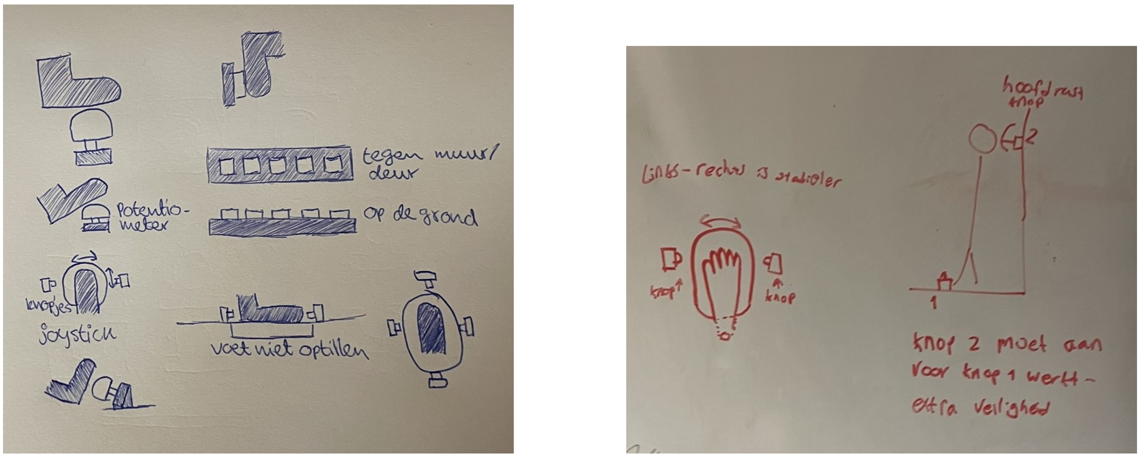


Figure 4.11: Footrest ideas

4.5 Conclusion Ideation

Generating ideas is an essential step in the design process, but it is important to recognize that while brainstorming is relatively easy, the development, prototyping and testing of these ideas require significant time and effort. Furthermore, many of the ideas developed during this phase may not immediately translate into workable solutions, especially if they cannot be fabricated using Fab Lab equipment. As such, there remains a need to bridge the gap between conceptual designs and practical execution.

The ideation process is continuous, with existing products and the current design providing valuable inspiration for further development. However, not all generated ideas may significantly improve upon the current design. Therefore, it may be more efficient to focus on refining and enhancing smaller components of the existing design rather than pursuing large-scale changes.

A well-organized component list is critical for assessing the feasibility and cost of each part, serving as a valuable reference for purchasing and budgeting. This list also acts as a baseline, which can be updated as design changes occur. While a detailed component list may benefit those with technical expertise, additional documentation, such as a manual or user guide, is essential for individuals with less technical knowledge or interest.

Finally, design requirements are crucial for evaluating the feasibility of proposed ideas. By applying these criteria, it is possible to assess which ideas align with the project's goals and can be realistically produced within a Fab Lab environment. Prioritizing components that can be easily fabricated and integrating them into the overall design ensures a practical and functional outcome.

Chapter 5

Specification

In this chapter, the focus shifts to analysing the designs and fabrication methods introduced in Chapter 4. In the first part each component will be assessed for its ability to be made in a Fab Lab and its potential to improve the existing design. In the second part attention will be given to the neck clamp, sleeves clamp and joystick with an emphasis on creating Fab Lab-compatible designs. During the research, several key considerations emerged that should be factored into the design of the new components. These considerations are summarized in the figure below.

This chapter focuses on analysing the designs presented in Chapter 4. The first section evaluates each idea based on its feasibility for fabrication in a Fab Lab and its potential to enhance the existing design. The second section focuses on refining the neck clamp, sleeves clamp and joystick, emphasizing the development of Fab Lab-compatible designs.

5.1 Analysing and Refining Designs for Fabrication

In this section various aspects of the redesigned components for the coat assistant were assessed through focusing on their practicality, safety and compatibility with Fab Lab capabilities. The evaluation explores the potential use of alternative materials, fabrication methods and innovative mechanisms to improve the functionality of all components. By comparing the proposed designs against current implementations this analysis aims to identify improvements that align with the project objectives and resource constraints.

5.1.1 Improving the Neck Clamp for Emergency Use

The current neck clamp poses safety concerns due to limited emergency release options. A proposed redesign incorporates 3D-printed thermoplastic elastomers (TPE), enabling users to push through the clamp if necessary. Challenges with TPE, including printability and material handling, require testing different types to identify the most suitable option. Another potential improvement is a pivoting mechanism using a joystick-style design to enhance functionality.

5.1.2 Optimizing the Sleeves Clamp for Strength and Usability

The sleeves clamp is best constructed from metal, given its superior strength compared to wood or plastic. While the current design relies on a pre-fabricated metal gripper with long delivery times, Fab Lab machining could enable localized production making it from wood or plastic. The design can be adapted for different servos and enhanced with grip features, such as silicone tips or 3D-printed additions. Additionally, a flexible ring at the sleeve's end, made from TPE or silicone, would improve usability and comfort by avoiding rigid, awkward shapes.

5.1.3 Exploring Material Options for the Frame and Lift

Switching from aluminum to wood for the frame and lift reduces cost but increases weight. Wood, easily processed in Fab Labs, offers adaptability for personalized designs, while aluminum remains lightweight and pre-cut for convenience. A comparison of motors suggests testing both linear actuators, which are reliable and robust, and stepper motors, which offer precision and cost efficiency, to determine the best fit for the lift mechanism.

5.1.4 Footrest Improvements and Control Integration

Improvements in the footrest and control systems include adding a joystick for centralized operation and exploring voice control as a supplementary feature. Physical controls remain essential for reliability. Adding a stool enhances stability and safety, though considerations are needed to prevent interference with the coat assistant's operation. Safety features, like dual-pressure buttons or distance sensors, ensure secure use without compromising functionality.

5.1.5 Idea Evaluation

The various component ideas are presented in the Figure 5.2, evaluated against criteria such as safety improvement, ease of fabrication, ease of development, adaptability, and affordability. Each criterion is rated on a scale from 1 to 5, with the total score calculated by summing the individual ratings. The total score is indicated next to each idea's name.

IDEAS	SAFETY	EASY TO MAKE	EASY TO DEVELOP	ADAPTABILITY	AFFORDABILITY
Rubber neck clamp (14)	+++	+++	+	++++	+++
Over the head clamp (14)	+++	+++	+	++++	+++
Sleeves clamp (16)	+	++++	+++	++++	++++
Clamp Grip (21)	+	+++++	+++++	+++++	+++++
Sleeves Ring (16)	+	++++	+++	++++	++++
Wooden frame (10)	+	++	++	+++	++
Stepper motor (9)	+	++	+	+++	++
Joystick (18)	++++	+++	+++	++++	++++
Stool (23)	++++	+++++	+++++	+++++	++++
Safety buttons (20)	+++++	++++	+++	++++	++++

FIGURE 5.1: Idea Evaluation

The evaluation revealed that the ideas related to the sleeves (sleeves clamp, clamp grip, and sleeves ring) received the highest scores. These ideas were combined into a single concept for execution in a Fab Lab due to their simplicity in development and fabrication. While the stool also scored highly, its practicality is limited as stools can be readily purchased, making it in a Fab Lab less valuable. Other high-scoring concepts included the safety buttons and joystick, both falling under the control system for the coat assistant. However, since the safety buttons primarily involve adding and coding a button, they are not directly linked to Fab Lab fabrication, which led to the selection of the joystick for further development. Lastly, the rubber neck clamp also scored highly, highlighting its importance for improvement. Efforts will focus on exploring how it can be produced within a Fab Lab. This analysis informs the next steps in refining and prototyping key components, aligning with the project's goals and Fab Lab capabilities.

5.2 From Design to Fab Lab

In the next phase, the gripper, joystick and neck clamp concepts will be developed to determine their feasibility for fabrication in a Fab Lab environment. Fab Lab-compatible designs rely on accessible materials like wood and plastic and fabrication techniques such as 3D printing, laser cutting and prototyping. Leveraging personal experience with tools like the Ender 3 V2 3D printer and SolidWorks, I opted to prototype these components myself for quicker iterations and practical testing.

5.2.1 Prototyping the Gripper

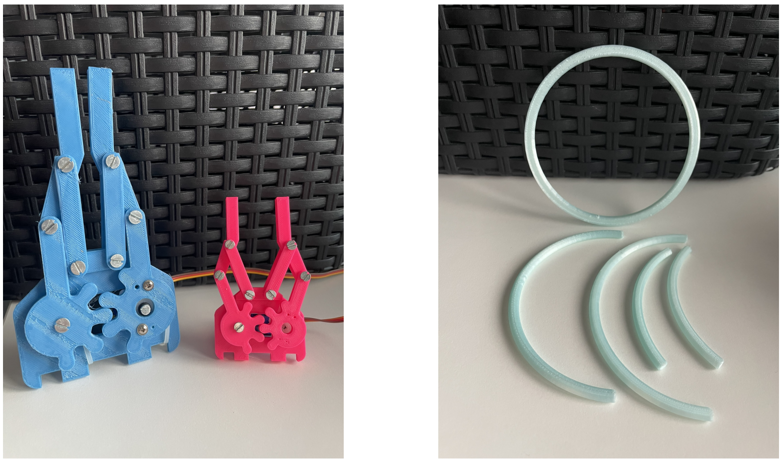


FIGURE 5.2: Plastic Gripper and Sleeves Insert

The gripper was evaluated for strength and compatibility with Fab Lab tools. An initial test involved scaling an existing 3D-printed gripper model from Thingiverse [1] to fit a stronger servo motor. While functional, the 3D-printed gripper was weaker than the current metal version. To enhance performance, TPU inserts for the sleeves were designed to improve grip and flexibility, though challenges with TPU printing on the Ender 3 V2 arose. Additional improvements included shark-tooth PLA tips and silicon attachments for enhanced grip. These were modelled in SolidWorks and adhered to the gripper with superglue or tape. All the prototypes can be found in Figure 5.2.

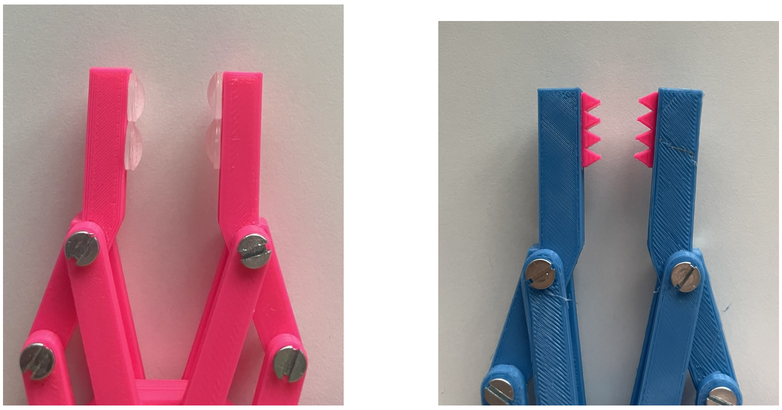


FIGURE 5.3: Gripper Tips

5.2.2 Prototyping the Joystick

A joystick design was created with four main components: a laser-cut wooden base, an adapter for the Arduino joystick, a custom box, and 3D-printed incline blocks. The adapter and box were designed to ensure stability under foot pressure and easy integration with the joystick. Incline blocks provided ergonomic positioning.

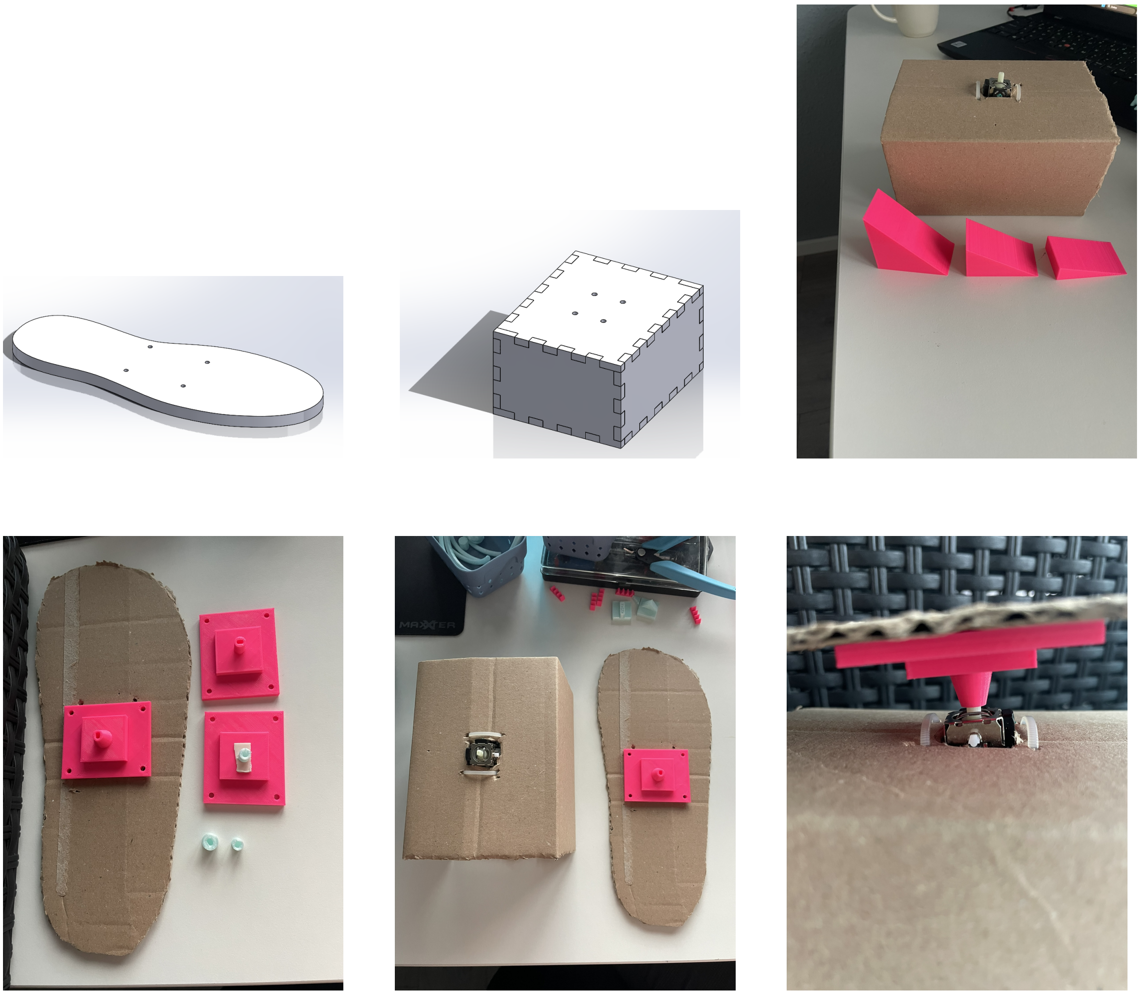


FIGURE 5.4: Joystick Design and Prototype

5.2.3 Prototyping the Neck clamp

A safer neck clamp concept was developed using TPU and metal for flexibility and emergency release. While TPU printing was limited, the concept included metal pipes joined with 3D-printed PLA adapters designed to break under specific stress for safety. Although not fully tested and worked out, this approach shows promise for a Fab Lab-compatible and safer design.

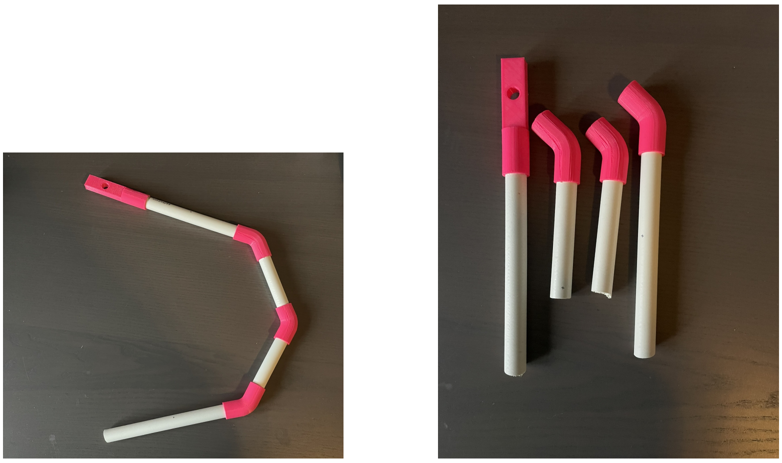


FIGURE 5.5: Neck clamp prototype

5.3 Conclusion Specification

In conclusion, the gripper, joystick, and neck clamp designs are functional and adaptable, yet there is still room for improvement and further research. For instance, developing a dimension-driven model where users only need to input their specific measurements, rather than modifying the entire design, could enhance usability. The iterative design process ensures that there will always be opportunities to refine and optimize these components.

Prototyping at home with personal equipment offers a major advantage in terms of speed and flexibility, enabling faster iterations and testing. With basic knowledge, such as 3D printing, it's easier to create custom models or adapt existing ones, making the design process more accessible and versatile. However, there is a learning curve to mastering these skills. For beginners, a Fab Lab provides the perfect environment to learn and receive expert guidance. Fab Labs offer valuable resources, enabling individuals without personal equipment to create and innovate while fostering an environment of learning and development. Fab Labs provide important resources, allowing people without personal equipment to create and innovate, while encouraging learning and growth.

Chapter 6

Realization

This chapter focuses on the requirements for creating the coat assistant in a Fab Lab. It reviews the current state of the project, highlighting which components and processes are well-developed and which ones still need improvement to allow users to replicate the design. The chapter seeks to answer the following questions:

- What tools and materials are needed for fabrication?
- Which steps or components need more detail before the project can be shared as open-source?
- How should the project be documented?
- And how can individuals build the coat assistant in a Fab Lab?

By addressing these questions, this chapter provides an overview of the project's readiness for open-source release, identifies areas needing further attention and offers clear instructions for building the design. The goal is to enable both beginner and experienced makers to recreate the coat assistant in their local Fab Lab or workshop.

6.1 Building the Current Design

First, the current design will be discussed. This design is made out of a lot of components which can be bought in a store. With a detailed guide on assembly, it can be constructed either in a Fab Lab or at home. The design has some flaws but is able to put on the coat of a person.

FIGURE 6.1: Tools needed to make the current design

Assembling the current design requires a variety of tools many of which are commonly available in Fab Labs. Individuals should check with a Fab Lab to see which tools are available. Additionally, these tools are relatively straightforward and can often be found in a home workshop. With the assistance of a handy neighbor, friend or Fab Lab the coat assistant can be successfully built.

6.2 Creating Project Documentation

The coat assistant design in itself does not sufficiently outline the steps required to make it in a Fab Lab or at home, for this documentation is needed. There are multiple steps in documenting a project for open-source usage. Below is an overview of these steps with guidance on how they can be applied to this project.

6.2.1 Choosing a Documentation Type

Documentation refers to the material which users and developers help to understand, use and develop the project. This project involves both software and hardware components which need to be documented. Most Fab Labs use wikis, open-source, free website hosting and website building using Markdown and static site generators for their documentation of projects. Documentation can be hosted on existing open-source websites or through creating a dedicated site for a specific project or Fab Lab. Open-source websites often have their own guidelines for sharing projects, which must be followed. The simplest option is to create a project-specific website that can be structured to provide easy access for users.

When creating a website, two important aspects to consider are hosting and website creation. Many tools are available for both, such as GitBook, Docusaurus, GitHub Pages, Wiki, Read The Docs, and Wiki.js [33].

GitHub [14] is a popular web-based platform for version control and collaboration which is mostly used by software developers to manage and share code. GitHub allows developers to work together on projects, track changes, and manage code versions efficiently. It also provides a free open-source service called GitHub Pages [34] which hosts static websites using content from a GitHub repository. This makes it easy to share the project's documentation in an open-source manner, allowing anyone to access it. A free static site generator, such as Hugo [17], can be used to customize and build the website. Hugo is fast, flexible, and open-source. Setting up the website can take time, especially for those unfamiliar with these systems. However, once the basics are understood, the setup becomes much easier and can be adapted to meet specific needs.

6.2.2 Setting Up the Documentation

Documentation is made out of a lot of different parts. The documentation has some requirements and/or best practices that should be kept in mind when designing the website which can be found in Figure 6.2.

FIGURE 6.2: Documentation requirements

In Appendix 8 an overview of the key elements that should be included in the documentation can be found. This overview is organized in a way that can be directly applied to the website. It incorporates topics identified during research, as well as best practices for setting up documentation from online sources.

6.3 Using the Documentation in a Fab Lab

This section provides a comprehensive guide for individuals looking to create the coat assistant in a Fab Lab. It covers the essential steps, considerations and preparations needed to begin the project successfully. To build the coat assistant in a Fab Lab, several steps must be followed. These steps, outlined in Appendix 9, serve as a guideline for beginners to navigate the process effectively.

When embarking on this project, several key questions may arise:

- How should you approach a Fab Lab with the documentation?
- What can you expect at a Fab Lab?
- What kind of support and assistance is available?

- How can you get in touch with a Fab Lab?

Preparing for the Fab Lab

Before visiting a Fab Lab, thorough preparation is crucial. Bring all relevant documentation, including detailed plans, designs, measurements, material lists and any other necessary information. Being well-prepared ensures a smoother experience and maximizes the use of Fab Lab resources.

What to Expect

Fab Labs provide a creative and practical workspace equipped with advanced tools such as 3D printers, CNC machines and laser cutters. Visitors can expect technical guidance on operating these machines, advice on material selection and recommendations for improving their designs.

Connecting with a Fab Lab

To find and contact a Fab Lab, visit their website for contact details, schedules and workshop information. Many Fab Labs offer tours, introductory sessions and consultations to familiarize users with their facilities and services.

Support and Assistance

Support at Fab Labs often includes:

- Help with equipment usage and troubleshooting.
- Suggestions for optimizing designs and workflows.
- Access to workshops, tutorials, or hands-on assistance from staff and volunteers.

For beginners, planning ahead is essential. Allocate sufficient time to learn about the machines and processes, especially if you are unfamiliar with them. This preparation ensures a productive and enjoyable experience while bringing your project to life.

6.4 Conclusion Realization

This chapter has provided a comprehensive overview of what is necessary to create the coat assistant in a Fab Lab. It has outlined the current design, highlighted the tools and materials required and identified gaps that need to be addressed for open-source documentation. Additionally, it has emphasized the importance of effective project documentation to ensure accessibility for users of all skill levels. By addressing questions about Fab Lab processes, expectations and support, this chapter equips makers with the knowledge and resources to successfully bring the coat assistant to life, fostering creativity and innovation.

Chapter 7

Evaluation

This chapter delves into the practical evaluation of the coat assistant design's feasibility within a Fab Lab. By conducting two interviews, the aim is to assess whether the current design and documentation are sufficient for successful replication and assembly. The process involves testing the assumptions from the realization phase against the real-world capabilities and limitations of a Fab Lab, identifying areas for improvement and understanding user experiences.

The evaluation seeks to answer key questions about the design's practicality, the usability of new components and the effectiveness of the provided documentation. Interviews are structured around several objectives: to explore whether the design can be fabricated using Fab Lab tools, determine if the new components can be made in a Fab Lab and assess how well the documentation supports people who want to make the product. By incorporating insights from Fab Lab professionals this chapter aims to refine the project's approach and ensure its accessibility to a diverse audience.

7.1 Interview Fab Lab 1

The first interview was done online with a Fab Lab professional.

7.1.1 Current design

Is the current design feasible to make in a Fab Lab?

The current design of the coat assistant is feasible to create in a Fab Lab, but with limitations. It doesn't require extensive digital fabrication, making it accessible for Fab Lab users who might not have advanced skills in such tools. However, the practicality of building it at a Fab Lab depends heavily on the specific policies and resources available at that location. For instance, some Fab Labs do not offer storage facilities, meaning users must transport components back and forth after each session. This logistical challenge is particularly difficult for a large project such as the coat assistant with many parts. Building the project at home seems more convenient with the option to go to a Fab Lab for things like programming the Arduino or soldering.

Is a guide enough to help people make the current design?

Whether a guide alone is sufficient to assemble the project depends on the user's prior experience. For people comfortable with tools and technical instructions a manual may be enough. However, users with less experience or difficulty understanding detailed instructions may find the process daunting. Projects like this often require hands-on adjustments, making them better suited for those with a DIY mindset. Next to that the guide could serve as inspiration, much like how open-source projects are shared on hackathon platforms. Users might adapt it to suit their own needs, which can be easily done in a Fab Lab. However, for people wanting a functional coat assistant a simplified and modular design with minimal assembly requirements would fit.

What is the cost of creating a coat assistant in a Fab Lab?

The cost of creating the coat assistant includes purchasing materials and paying for Fab Lab machine usage. While Fab Lab volunteers can offer free guidance, machine operations often incur fees, such as startup costs and material usage charges. These expenses are usually affordable but must be considered when budgeting for the project.

7.1.2 New components

Can the new components be made in a Fab Lab?

New components of the coat assistant are particularly well-suited for fabrication at Fab Labs, as these spaces are designed for experimentation and creative problem-solving. People who go to a Fab Lab love to thinker and make their own parts. Next to that the new components are made of materials which are used in a Fab Lab making it easy to make them in a Fab Lab. However, if the goal is purely functional, users might prefer the current design that can be quickly made. Since they only care about a functioning prototype instead of changing and making the new component. This approach reduces the need for a Fab Lab since a person is able to make it at home.

The new components however can take more people to a Fab Lab to for example create the joystick or a different version of a component. In this case the Fab Lab is able to help them out but they do need to have interest in making the components themselves. A Fab Lab is never going to take over the project and build it for someone, the person themselves always has the responsiblity when making a project. At a Fab Lab multiple workshops are organized to familiarize people with the equipment and materials. Especially to make the lab accessible for people without a technical background. Ultimately, new components foster the kind of creative mindset that defines Fab Labs.

7.1.3 Documentation

Can someone use this documentation to get started in a Fab Lab?

The documentation needs to reach the right person that is able to use github and understand how they can make the project with the things available. Next to that they should understand how to contribute something themselves and know where to put it. It depends on the person and their background and interest if they are able to use it.

Are there pieces missing from this list?

From the first look at the list it looks like there is more than enough information instead of missing. A chat is always nice and really helps people but there need to be people who respond on the messages which is sometimes difficult. Code that is easy to find and detailed manuals with images and videos are most important for the building process. Including a use at your own risk statement is very smart to counter the questions about who is responsible. In conclusion, it looks like it is a lot of work to set up but will help the project.

7.1.4 Support

Do you think the step-by-step guide is close to the reality?

To effectively use a Fab Lab for your project it's crucial to align your plan with the Fab Lab's structure and resources. The general approach seems logical but it's essential to tailor it per project, assessing how much a Fab Lab is needed. Before purchasing materials it is best to contact the Fab Lab to check available tools and capabilities to ensure the compatibility with both standard and new components. It is best to explore the website of Fab Labs for schedules, tours and equipment reservations. Procedures vary by Fab Lab so research their requirements early on in the project. A lot of time is needed to understand the machines and materials so start the process well in advance as fabrication takes time.

7.1.5 Evaluation form

During the interview an evaluation form was filled in about the feasibility of different aspects. It is an overview of the most important parts of the interview.

QUESTIONS	RATING	COMMENTS
Is the current design feasible to make in a FabLab?	1 **2** 3 4 5	FabLab is not needed during every step to make the current design. Current design is feasible to make at home and do the electronics and soldering in FabLab.
Are the new components feasible to make in a FabLab?	1 2 3 4 **5**	Very feasible since components are made with techniques used in FabLab
Can someone get started in a FabLab with this documentation?	1 2 **3** 4 5	Depends on the technical knowledge and interest of a person in making their own projects.
Is it feasible to make this project in a FabLab with the support of a FabLab?	1 2 3 **4** 5	Responsiblity for making the project is at the person themselves. FabLab can help support in making the project.

FIGURE 7.1: Evaluation form 1

7.2 Interview Fab Lab 2

The second interview was done in a Fab Lab with a Fab Lab professional.

7.2.1 Current design

Is the current deisgn feasible to make in a Fab Lab?

The coat assistant's current design is simple enough for individuals with basic DIY skills to assemble at home. However, certain elements need improvement for durability and usability. For example, the inclusion of a breadboard, while functional, is considered a no-go in professional settings. Instead, a custom PCB (printed circuit board), easily created in a Fab Lab would provide a cleaner and more reliable solution. Similarly, crown connectors which are currently used to join cables are not ideal and should be replaced with safer alternatives. The exposed electrical connections present significant safety concerns. A 3D-printed cover, fabricated in a Fab Lab, could shield these areas and adhere to design guidelines that prevent accidental contact. Additional features like a strain relief mechanism should also be incorporated to ensure cables remain secure even if accidentally pulled. Next to that the Fab Lab facilities provide specialized tools and guidance and accommodates users who may not have access to soldering stations or similar equipment at home. This accessibility ensures that even those with limited technical experience can replicate the coat assistant.

7.2.2 New components

Can the new components be made in a Fab Lab?

Since most components were fabricated using a standard FDM 3D printer they are definitely able to be made in a Fab Lab. If they can be created at home using standard equipment, they can be created anywhere. For the new components the same thing applies as the current design a combination can be made to make it at home and fabricate some components in a Fab Lab. A combination between making it at home and making some components in the Fab Lab looks like a very convenient way of making the project.

7.2.3 Documentation

Can someone use this documentation to get started in a Fab Lab?

To make the coat assistant truly accessible comprehensive documentation is essential. A Git repository could serve as a centralized hub for all files and instructions. Including an "IKEA-style" guide with step-by-step visuals ensures even beginners can follow along with ease. Such documentation could adopt an "Instructables-like" approach, guiding users from purchasing components on platforms like AliExpress to assembling the device. Next to that attention must be paid to making sure the beginner is able to find the information that they need in one look. Addressing common fears around electronics and microcontrollers is crucial. For example, links to beginner-friendly Arduino tutorials could help simplify these aspects. Highlighting safety measures, such as avoiding open electrical connections, reassures users who might feel intimidated by technical elements.

7.2.4 Support

Do you think the step-by-step guide is close to the reality?

The step-by-step guide looks to be how it works in real life. Platforms like Fab Labs.io can help users locate nearby Fab Labs to get in contact and wee which materials and machines are used. Moreover, it's essential to clarify that people build their own projects in Fab Labs. Visitors should understand that while guidance is available, they are expected to actively participate in creating the project themselves.

7.2.5 Making a One-pager

A tip that was shared to actually make a one page website during the assignment on which the project already could be found with everything that has been researched until now. This could be done to increase publicity through Fab Labs sharing this website and to make it available for anyone that has interest. Doing it now makes sure that it gets done and not lost in the list of things to do.

7.2.6 Evaluation form

The most important parts of the interview concerning feasibility can be found in the image below.

QUESTIONS	RATING	COMMENTS
Is the current design feasible to make in a FabLab?	1 2 3 4 **5**	Definitely feasible but you can ask yourself the question if a FabLab is really needed since it can be made with tools at home.
Are the new components feasible to make in a FabLab?	1 2 3 4 **5**	Designs are made with materials and machines that is also used in a FabLab
Can someone get started in a FabLab with this documentation?	1 2 **3** 4 5	Depends on the details if someone understands it and currently it is a setup so can not determine
Is it feasible to make this project in a FabLab with the support of a FabLab?	1 2 3 4 **5**	FabLab can provide materials, machines, tools and guidance during every step.

FIGURE 7.2: Evaluation form 2

7.3 Conclusion Evaluation

In conclusion, the evaluation of the coat assistant design within Fab Labs focused on four key aspects. First, while the current design is feasible to create in a Fab Lab, improvements are needed to enhance safety and usability, such as replacing the breadboard with a custom PCB. Additionally, the design can be constructed at home with the right tools and resources.

Second, new components can be fabricated in a Fab Lab, but this requires users to actively engage in the making process. Third, the documentation must be detailed, accessible and beginner-friendly, ensuring it guides users effectively. The software should also be explained in a way that reduces intimidation, as understanding the documentation heavily depends on a user's background and interests.

Finally, while Fab Labs offer valuable support, individuals must recognize that the project is their responsibility, not the Fab Lab's. Significant time and effort are required to learn about the machines and materials, as Fab Lab procedures and equipment vary. Each project needs to be tailored to the specific user and Fab Lab context.

An additional recommendation is to create a concise, one-page website with an overview of the documentation. This can be done during the final stages of the project to make it more accessible for a wider audience.

Chapter 8

Conclusion

This thesis explored how the coat assistant can be reproduced on a small scale and adapted to accommodate various body types and needs. The project aimed to address the challenge of creating assistive devices that are customizable, accessible and replicable. The findings provide practical insights into the design and replication of the coat assistant while emphasizing the role of Fab Labs and open-source documentation.

Assistive devices often lack accessibility and customization for individuals with specific needs. This project wanted to address these limitations by designing a coat assistant that can be built in a Fab Lab, making assistive technology more accessible and adaptable for users.

8.0.1 Guiding Principles for the Development of the Coat Assistant

The research identified several guiding principles for the development of the Coat Assistant. The development of the coat assistant requires a focus on safety, customization and usability. This section outlines key principles specific to the design and production of the coat assistant, ensuring it is adaptable, functional and user-friendly. By using Fab Labs and open-source collaboration, the goal is to create a prototype that can be easily replicated and improved over time. The principles are:

1. Focus on Safety and Usability
    - Improve safety features such as replacing breadboards with custom PCBs and adding protective covers to prevent accidents.
    - Make sure components are user-friendly, particularly for individuals with limited technical knowledge.
2. Prioritize Customization and Adaptability
    - Develop dimension-driven models allowing users to input specific measurements for tailored designs.
    - Adjust the design to accommodate diverse body types, living spaces and user conditions.
3. Prototyping
    - Simplify the design to use materials and tools readily available in Fab Labs, such as wood and plastic, for greater accessibility.

- Enable rapid prototyping both at home and in Fab Labs to accelerate iteration and user testing.

4. Use Open-Source Documentation

   - Create detailed, beginner-friendly documentation, including step-by-step instructions, visuals and a comprehensive Bill of Materials.
   - Develop a concise, one-page website to provide an accessible project overview for users.

5. Plan for Long-Term Development

   - Once the design is fully functional and has documentation, revisit companies to explore commercialization options.
   - If commercialization is not feasible, keep the project open-source to make sure that the coat assistant is accessible.

6. Use Fab Labs for Learning and Support

   - Encourage users to use Fab Lab resources and expertise, while recognizing that responsibility for a project is with the individual.

8.0.2 Guiding Principles for Assistive Technology Projects

The principles in this section apply to projects with similar goals or challenges to the coat assistant. These guidelines emphasize the use of community resources, digital fabrication and open-source collaboration. By following these best practices, other projects can benefit from a process that fosters innovation and accessibility, making it easier for makers to create effective, adaptable solutions for diverse needs. These principles are:

1. Use the Community

   - Use Fab Labs as development places which provide access to digital fabrication tools.
   - Partner with relevant organizations, such as medical companies, to navigate regulatory challenges and improve publicity.

2. Ideation and Refinement

   - Focus on improving smaller components rather than changing the overall design.
   - Use parts lists to manage costs and adapt designs when components change.

3. Prototyping and Learning

   - Make sure that designs are compatible with Fab Lab tools and materials to simplify the making process.
   - Create an environment where beginners can learn and make things with help from experts.

4. Open-Source Sharing

   - Share all documentation, designs and findings open-source to encourage people to make their own version.

- Use an open-source approach to go around regulatory challenges, make it affordable and improve the accessibility.

5. Addressing Common Challenges
   - Ensure projects are adaptable to various user needs and conditions.
   - Focus on safety, usability and scalability, ensuring designs are practical and effective.

6. Connect Ideas with the Real-world.
   - Prioritize ideas that align with project goals and can be produced within a Fab Lab.
   - Apply clear design requirements to assess feasibility and ensure functionality in the final product.

This project shows how Fab Labs make it possible for anyone to create and improve assistive devices that fit their specific needs. Sharing this project as open-source gives others a step-by-step guide to make similar devices and helps to increase the accessibility in creating assistive technology.

Chapter 9

Discussion and Future Work

9.1 Discussion

The coat assistant shows the potential of creating assistive devices on a small scale. Designing and building solutions in Fab Labs or even at home using simple tools like a 3D printer. However, the project also presents several challenges and areas requiring further attention.

One limitation is the study's narrow scope. Interviews were done with only a small number of Fab Labs, which may not fully represent the different Fab Labs worldwide. They can vary in their procedures and cultures which lead to differences with the interviewed Fab Lab.

Additionally, while Jan's ability to design and make the coat assistant is impressive, it is important to acknowledge that not everyone has the same knowledge. Many people may lack the skills or knowledge to replicate the project. This also has an impact on similar projects since the scalability is uncertain. A project may require specific circumstances or knowledge to be done in the same way as the coat assistant.

Moreover, the guiding principles developed in this project may not be complete. Without legal input of an expert regarding relevant rules and regulations, it remains uncertain whether the coat assistant complies with rules and regulations. A more thorough examination of the rules and regulations surrounding the creation and use of assistive devices should be done.

There is also a practical limitation, individuals can create a functioning coat assistant independently. While DIY approaches can be empowering, they can also introduce risks. Assembling a working prototype relies heavily on a person's skill level and access to appropriate materials. Eventually, there may be a point where professional intervention, collaborating with a medical device company, becomes necessary to develop these projects more effectively.

The documentation of the project poses further challenges. Instruction quality heavily relies on the author, making it difficult to ensure it can be used by all users. People from different backgrounds may struggle to use the documentation which show the need for documentation that can be used by different skill levels and learning styles. Furthermore, it is essential to acknowledge that creating documentation that can be used by all is an impossible task. Therefore, the base of the documentation should focus on supporting individuals with some experience in project-making who are eager to learn about the digital fabrication techniques.

Additionally, the coat assistant still needs to be tested on different people. Currently it is not clear if the coat assistant also works well for other people with different conditions.

The true usability and the target group of the coat assistant remain unknown until testing is done. Understanding how the coat assistant works for various people will help to adapt the design.

Finally, there is limited information about similar projects. Clear examples of assistive devices created in Fab Labs that others can replicate are lacking. If more thorough and effective searches were conducted, it might uncover existing projects that could provide valuable insights. Since they were not found during the research they should also have a need for better documentation and sharing. Addressing these challenges could enable the coat assistant to serve as a model for others and inspire other projects.

In summary, while the coat assistant offers valuable insights and potential for creating the coat assistant and other assistive devices, several challenges must be addressed. Understanding these challenges will be crucial for future developments and for making the coat assistant accessible.

9.2 Future Work

The coat assistant is an example for creating small-scale, customizable assistive devices. However, further improvements are needed which can be found below.

9.2.1 Testing the Design

One of the next steps should be to make the coat assistant, to test whether the design and documentation are feasible to use. Feedback from this process can identify areas for improvement, such as unclear instructions or problematic parts. Next to that the coat assistant should be tested with people having different body types and conditions. This will help adapt the design to make it more accessible.

9.2.2 Refining the Design

Based on testing results, the design should be updated to address any issues found during assembly or use. Safety improvements and simpler parts could make the coat assistant easier and safer for a wider range of people to build. Next to the improvements appearing from testing a start can already be made with increasing the safety through making hoods and changing dangerous part such as the neck clamp.

9.2.3 Improving Documentation

Efforts should focus on creating high-quality documentation that is easy to follow even for beginners. This includes detailed written steps, photos and possibly video tutorials. Providing translations for different languages could also make the project accessible to a global audience. Next to that the website setup as said in the evaluation chapter should be put into practice, working out al the subsections and details. After that a test can be done to see if people are able to work with the documentation and which details still need improving.

9.2.4 Exploring New Components and Collaboration

New ideas for parts and designs should be explored to keep the project evolving. This could include modular parts that make the device even more flexible for different users and situations. These components can be developed and made by everyone interested in the project. Next to that collaboration with other makers and projects could help improve the design and documentation. Sharing experiences and learning from others' successes and challenges would strengthen the coat assistant as an open-source initiative.

9.2.5 Thinking About Legal and Ethical Issues

More work needs to be done to address legal and ethical concerns. For example, finding ways to balance sharing the project openly while ensuring it's safe and fair for everyone to use. Next to that the disclaimer and ethical view should be worked out on the website.

9.2.6 Publicity

Creating publicity is essential to make people aware of the coat assistant. This can be done by sharing the project on social media, presenting it at maker fairs and collaborating with disability organizations. Publishing detailed guides, videos and tutorials on platforms like YouTube or GitHub can also help reach a wider audience and encourage others to build, improve or adapt the coat assistant for their needs. By spreading the word and making it easy to access the project can inspire and help more people.

9.2.7 Exploring Alternatives to Fab Labs

Since the project doesn't rely on Fab Labs, further development should explore how to make the coat assistant even more accessible for at-home makers. This might include sourcing commonly available materials or simplifying assembly steps for people without advanced tools. An important part can also be to include a machine guide for which 3D printer or lasercutter to buy for your home workspace. Alongside that a look can be taken at open-source 3D printers and lasercutters to help people in building their own instead of buying them.

9.2.8 Conclusion

Future work should thus focus on improving the design, improving documentation and making it easier for others to build. It's also important to let more people know about the coat assistant so they can make it or get inspired by it. By working on these things the project can become more accessible and help and inspire people in creating their own personalized assistive devices.

Appendix

.1 Parts list

Onderdeel	Categorie	Type onderdeel	Aantal	Kosten	Totaal kost	Opmerkingen	Link
Totaal				€ xx	€ 1.081,69	*Opmerkingen*	
Elektromagneten KK P50/29D	Nekklem	Elektronica	3	€ 59,95	€ 179,85	12V 50 KG Dia 50 mm	https://shorturl.at/VR2uY
Lineaire actuator 600 N	Nekklem	Elektronica	1	€ 56,29	€ 56,29	500N variant in link DC 12V, 1(	https://dennisdeal.com/produ
Lineaire actuator 800 N	Lift	Elektronica	1	€ 99,99	€ 99,99	DC 12V, 500mm, 20mm/s, 80(	https://dennisdeal.com/produ
Mini breadboard (2x)	Frame	Elektronica	2	€ 0,79	€ 1,58	*Opmerkingen*	https://elektronicavoorjou.nl/p
Servo motoren (2x)	Mouwen klem	Elektronica	2	€ 10,95	€ 21,90	*Opmerkingen*	https://elektronicavoorjou.nl/p
Aluminium profiel sleuf 5 20x20N-O	Frame	Materiaal	1	€ 70,34	€ 70,34	2x 40cm, 2x 57, 1x 48, 2x 20, 1	https://shorturl.at/GQrBo
Aluminium profiel sleuf 5 20x40N-O	Frame	Materiaal	1	€ 62,28	€ 62,28	2x 40cm, 2x 90, 2x 17, 1x11	https://www.tech-specialist.co
Aluminium profiel sleuf 8 40x40-E	Frame	Materiaal	1	€ 10,24	€ 10,24	1x 40	https://www.tech-specialist.co
Aluminium profiel sleuf 8 20x80-E	Frame	Materiaal	1	€ 84,47	€ 84,47	2x 101, 1x 40	https://www.tech-specialist.co
Plexiglas 95x48 cm	Frame	Materiaal	1	€ 12,69	€ 12,69	*Opmerkingen*	https://www.plexiglas.nl/prod
Angle brackets 2x2 sleuf 5	Frame	Materiaal	14	€ 1,88	€ 26,32	*Opmerkingen*	https://shorturl.at/mjUSJ
Angle brackets 4x4 sleuf 8	Frame	Materiaal	6	€ 3,69	€ 22,14	*Opmerkingen*	https://www.tech-specialist.co
Inbouwvoeding	Frame	Elektronica	1	€ 13,92	€ 13,92	*Opmerkingen*	https://shorturl.at/T4snM
Voeding transformator omvormer JC-18(	Frame	Elektronica	1	€ 13,19	€ 13,19	*Opmerkingen*	https://nl.aliexpress.com/item
Endstop v-156-1c25 micro switch	Lift	Elektronica	2	€ 0,99	€ 1,98	*Opmerkingen*	https://shorturl.at/A0eb8
Lineaire geleidingsrails	Lift	Materiaal	1	€ 45,99	€ 45,99	Rails+blocks 2 keer 930 mm d	https://shorturl.at/lWQ5A
Metalen klauw	Mouwen klem	Materiaal	2	€ 5,82	€ 11,64	*Opmerkingen*	https://www.amazon.nl/RELA
Signaal lamp rood	Frame	Elektronica	1	€ 5,99	€ 5,99	*Opmerkingen*	https://www.conrad.nl/nl/p/ba
Arduino	Frame	Elektronica	2	€ 24,99	€ 49,98	Gebruikt maar eentje	https://www.conrad.nl/nl/p/ar
Kabelslang	Frame	Materiaal	1	€ 15,99	€ 15,99	5m	https://www.bol.com/nl/nl/p/
Kabelrups	Frame	Materiaal	1	€ 14,21	€ 14,21	1m	https://www.bol.com/nl/nl/p/
Kroonsteentjes	Frame	Materiaal	1	€ 2,45	€ 2,45	*Opmerkingen*	https://www.hornbach.nl/p/kr
Lasdoos	Frame	Materiaal	1	€ 2,29	€ 2,29	*Opmerkingen*	https://www.gamma.nl/assort
Wandcontactdoos	Frame	Materiaal	1	€ 7,87	€ 7,87	*Opmerkingen*	https://www.elektramat.nl/gira
Arduino kabel lang	Frame	Elektronica	1	€ 4,99	€ 4,99	USB A naar USB B	https://elektronicavoorjou.nl/p

FIGURE 1: Parts list part 1

Onderdeel	Categorie	Type onderdeel	Aantal	Kosten	Totaal kost	Opmerkingen	Link
Totaal				€ xx	€ 1.081,69	Opmerkingen	
Arduino voeding	Frame	Elektronica	1	€ 1,95	€ 1,95	Opmerkingen	https://elektronicavoorjou.nl/p
USB adapter	Frame	Elektronica	1	€ 7,49	€ 7,49	Opmerkingen	https://elektronicavoorjou.nl/p
Voetschakelaar	Frame	Elektronica	1	€ 6,40	€ 6,40	Opmerkingen	https://www.bol.com/nl/nl/p/l
Stroomkabel	Nekklem	Elektronica	1	€ 13,80	€ 13,80	Opmerkingen	https://www.bol.com/nl/nl/p/s
Tie wraps	Nekklem	Materiaal	1	€ 11,95	€ 11,95	300mm 100stuks	https://www.bol.com/nl/nl/p/v
Draadeind	Nekklem	Materiaal	1	€ 6,50	€ 6,50	M8x 100cm	https://www.123-3d.nl/123-3D
Stelvoeten	Voetenplank	Materiaal	1	€ 13,99	€ 13,99	Opmerkingen	https://www.bol.com/nl/nl/p/s
Voet knopjes	Voetenplank	Elektronica	1	€ 3,08	€ 3,08	Opmerkingen	https://nl.aliexpress.com/item
Elektronica kabel	Voetenplank	Elektronica	1	€ 11,83	€ 11,83	Verschillende kleuren	https://nl.aliexpress.com/item
Scharnier	Mouwen klem	Materiaal	2	€ 5,49	€ 10,98	Opmerkingen	https://www.gamma.nl/assort
Houtenplank	Voetenplank	Materiaal	1	€ 7,99	€ 7,99	Opmerkingen	https://www.karwei.nl/assorti
Verbindingsplaat klem connector	Mouwen klem	Materiaal	1	€ 4,79	€ 4,79	zijn er vier dus ook voor onder	https://www.karwei.nl/assorti
Verbindingsplaat Actuator houder	Nekklem	Materiaal		€ xx	€ 0,00	Zelfde als hierboven	
Verbindingsplaat actuator arm	Nekklem	Materiaal		€ xx	€ 0,00	Zelfde als hierboven	
Versterkingshoek	Nekklem	Materiaal	3	€ 3,19	€ 9,57	Opmerkingen	https://www.gamma.nl/assort
Hoekverbinding	Frame	Materiaal	1	€ 20,00	€ 20,00	Opmerkingen	https://www.amazon.nl/Hoekl
Actuator houder	Lift	Materiaal	2	€ 1,39	€ 2,78	Opmerkingen	https://www.gamma.nl/assort
Staal voor knopjes houder	Voetenplank	Materiaal	1	€ 12,99	€ 12,99	Opmerkingen	https://www.gamma.nl/assort
Staal voor korte en lange arm van nek	Nekklem	Materiaal		€ xx	€ 0,00	Zelfde als hierboven	
Nek armen buis	Nekklem	Materiaal	1	€ 2,55	€ 2,55	Opmerkingen	https://www.hornbach.nl/p/ka
Leadscrew draadeind adapter arm nek	Nekklem	Materiaal	2	€ 6,00	€ 12,00	2 nodig	https://www.123-3d.nl/123-3D
Lager as bevestiging	Nekklem	Materiaal	2	€ 8,25	€ 16,50	4 nodig	https://www.123-3d.nl/123-3D
Tandwielen (niet zeker)	Nekklem	Materiaal	2	€ 3,72	€ 7,44	24 tanden M8 draad dus 8mm	https://nl.aliexpress.com/item
Magneten voor in de jas	Nekklem	Elektronica	1	€ 18,53	€ 18,53	50 mm	https://nl.aliexpress.com/item
Bouten	Frame	Materiaal	1	€ 20,00	€ 20,00	Opmerkingen	

FIGURE 2: Parts list part 2

.2 Explanation parts list

- Column 1: Name
  - Shows the name of the component
- Column 2: Component category
  - To indicate to which main component the part belongs
- Column 3: Type of part
  - Indicating if a part is electronics or material
- Column 4-6: Price
  - Shows the price per part
- Column 7: Comments
  - Shows the comments or details for a part
- Column 8: Link
  - Includes a link to a shop where the part can be bought

.3 Component requirements

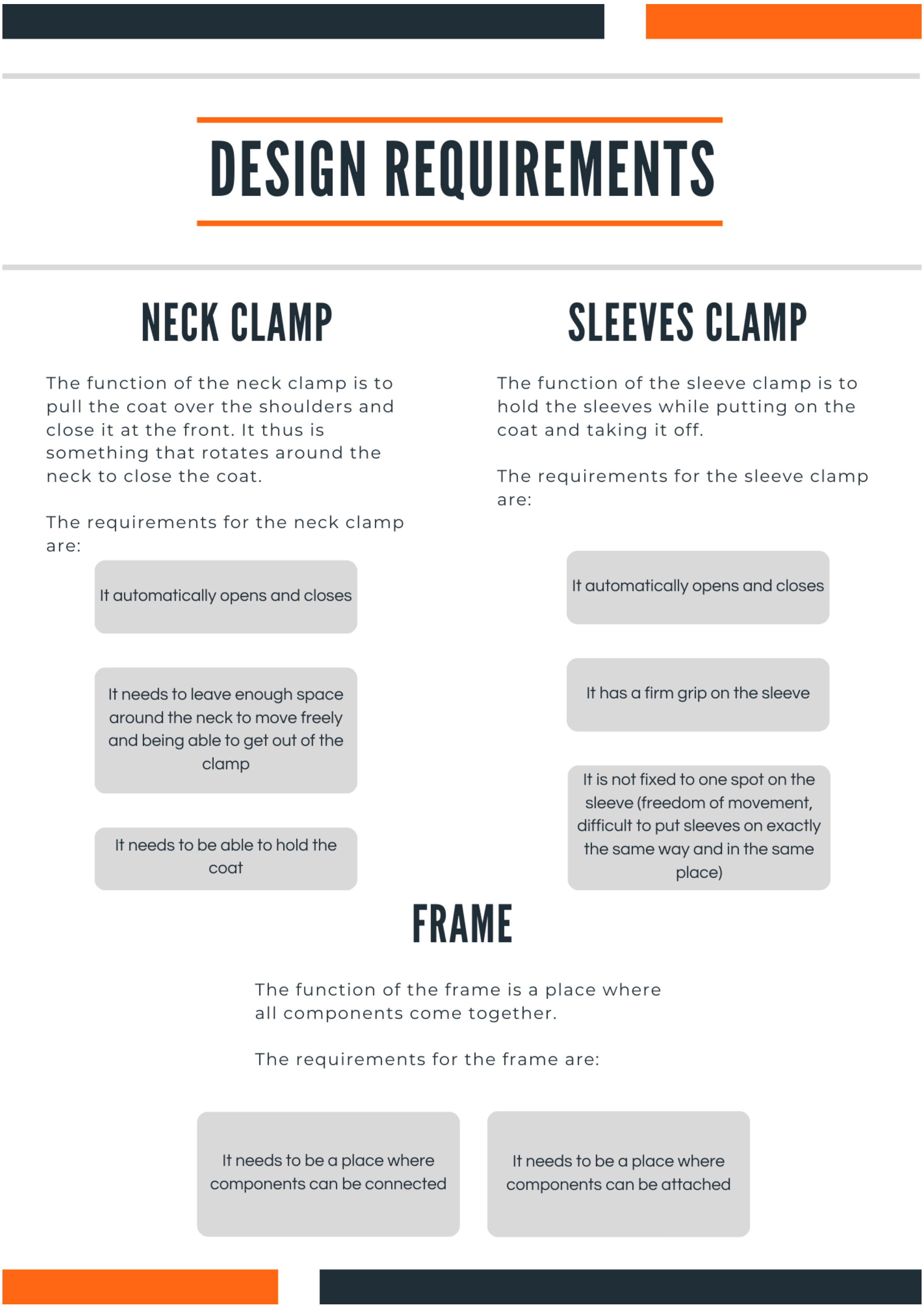


FIGURE 3: Component requirements part 1

DESIGN REQUIREMENTS

LIFT

The function of the lift is to move the coat up and down.

The requirements for the lift are:

- It needs to automatically move up and down
- It needs to be adjustable in height
- It needs to be able to travel the height of a person's back
- It needs to be able to lift the weight of the coat
- The distance between neck clamp and sleeve clamp must remain the same when moving it up and down

FOOTREST

The function of the footrest is to operate the coat assistant and give stability.

The requirements for the footrest are:

- It needs to be able to operate the coat assistant hands-free
- It needs to be in an accessible place
- It needs to operate the coat assistant while standing upright or sitting in a chair
- It needs to give the coat assistant stability

Figure 4: Component requirements part 2

.4 Co-design whiteboard sketches

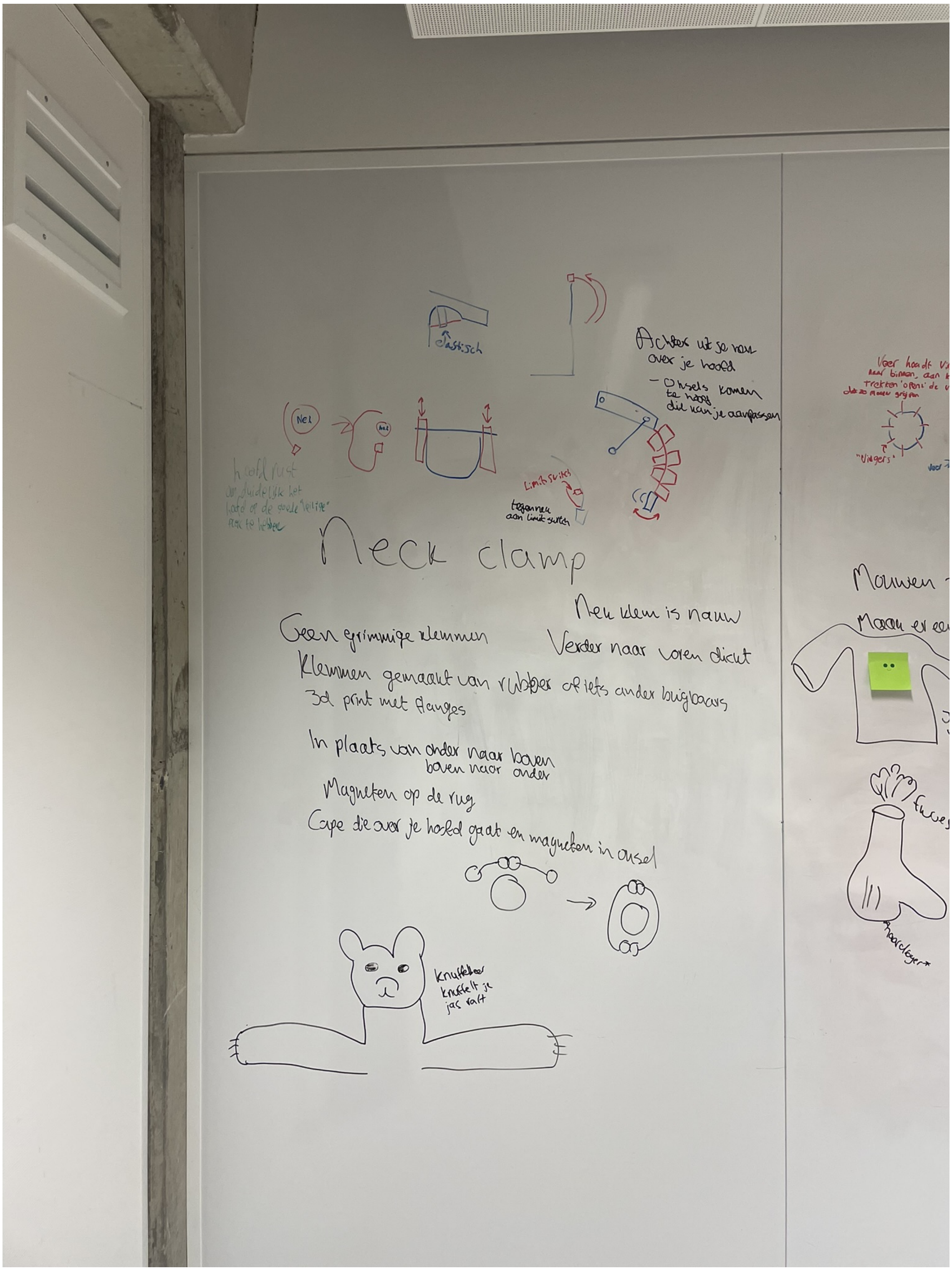


FIGURE 5: Neck clamp sketches

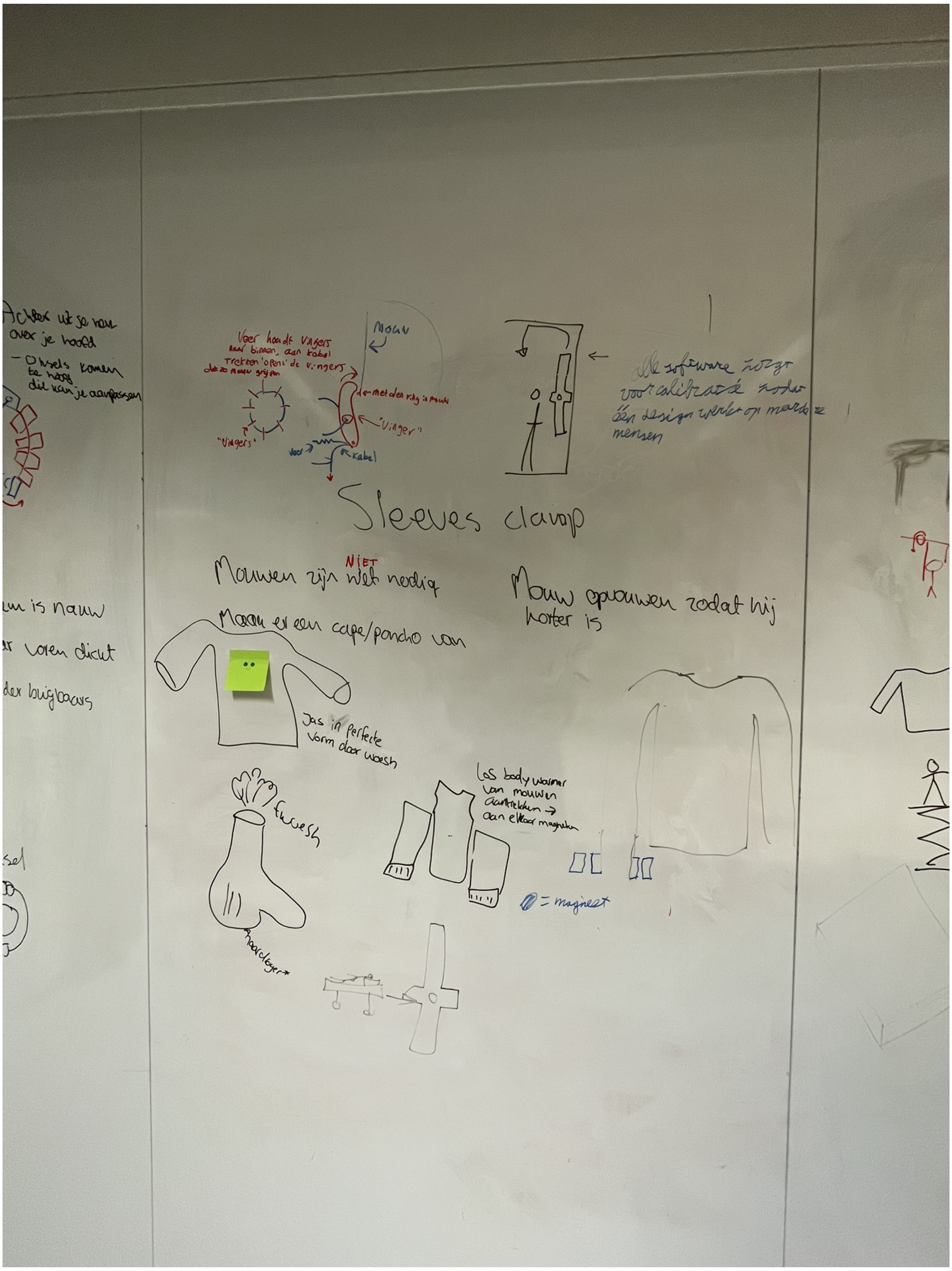


Figure 6: Sleeves clamp sketches

FIGURE 7: Lift sketches

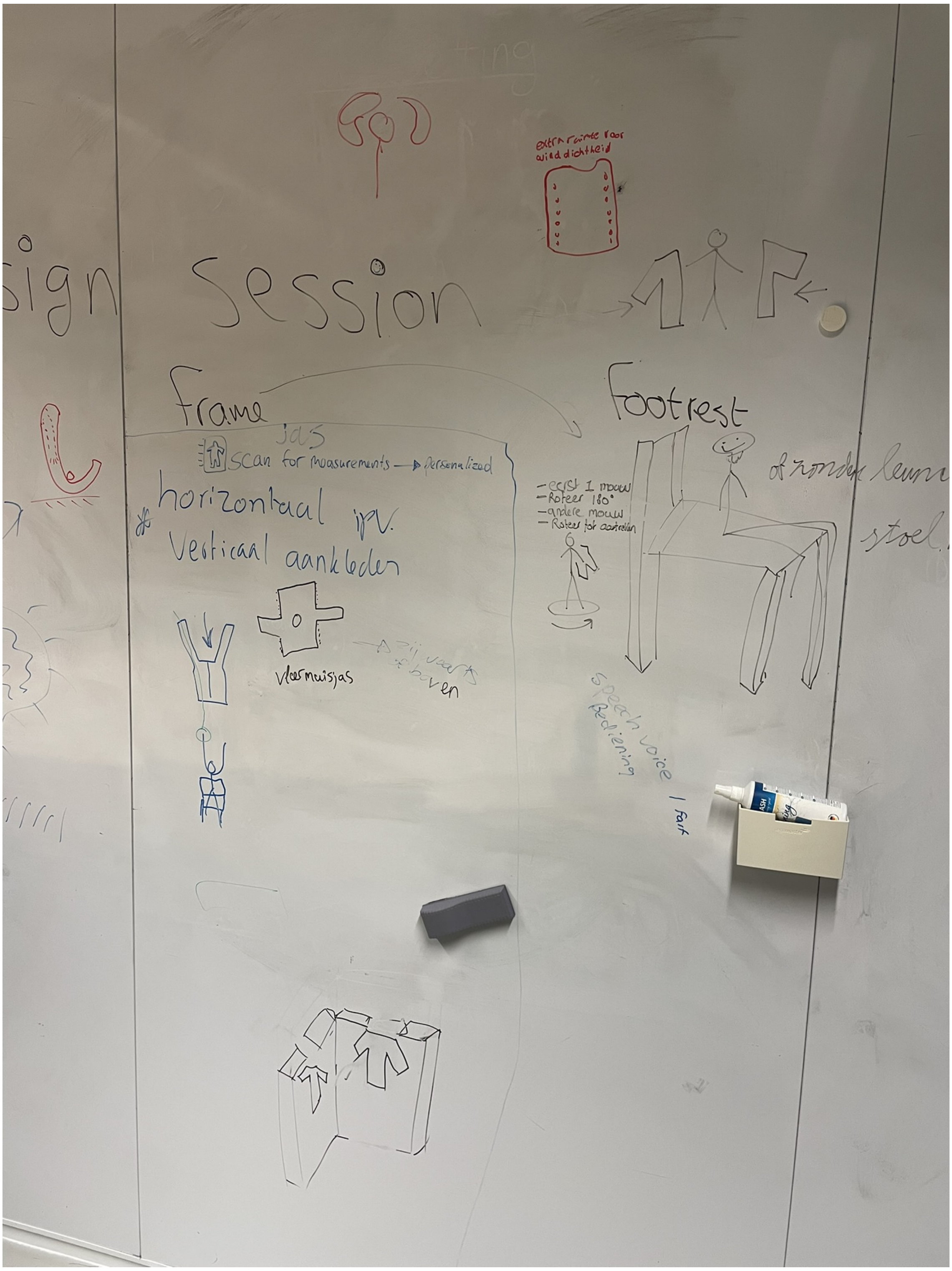


Figure 8: Frame and footrest sketches

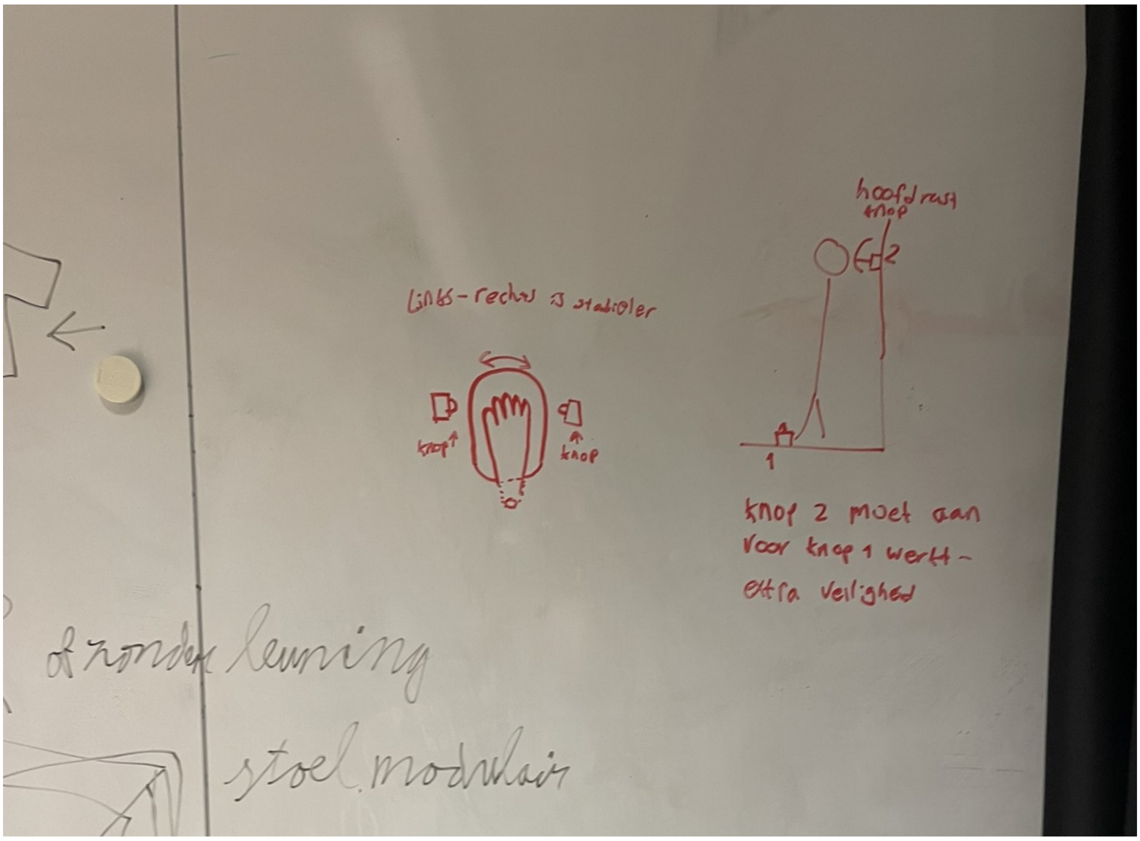


FIGURE 9: Footrest sketches

.5 Co-design ideas

Figure 10: Co-design ideas part 1

CO-DESIGN IDEAS

- Waarom kan hij niet liggen
- Liggen en dan opstaan is moeilijk als je armen niet goed kan gebruiken
- Ligend neemt nog veel meer ruimte in
- Sta-op stoel gebriken voor krukje zonder rug
- Vertical MRI scan
- Nano machines die je jas om je heen bouwt
- 3d printer die om je heen print
- stofzuiger die jas van je weg zuigt
- Bubbelvoetbal
- Hooibalen inpak machines

FIGURE 11: Co-design ideas part 2

.6 Evaluation form

EVALUATION FORM

QUESTIONS	RATING	COMMENTS
Is the current design feasible to make in a FabLab?	1 2 3 4 5	
Are the new components feasible to make in a FabLab?	1 2 3 4 5	
Can someone get started in a FabLab with this documentation?	1 2 3 4 5	
Is it feasible to make this project in a FabLab with the support of a FabLab?	1 2 3 4 5	

Figure 12: Evaluation form

.7 Coat Assistant MDR or not?

Figure 13: Coat Assistant MDR or not?

.8 How to Set Up the Website

Figure 14: Website structure

.9 How to Make Your Own Coat Assistant

STEP-BY-STEP GUIDE

1. Review documentation: Go through the online documentation thoroughly to understand the project.
2. Buy components: Look at the components list and buy the part from the stores.
3. Contact the FabLab:
   - Visit the FabLab website.
   - Check their contact details (email, phone, or online contact form).
   - Reach out to inquire about material availability, equipment access and scheduling.
4. Enter the FabLab
   - Upon arrival, register at the FabLab reception (if required).
   - Introduce yourself and explain the project.
   - Ask for a tour of the available equipment and any additional guidance on usage.
5. Identify Materials: Ensure that the materials needed are available at the FabLab (e.g., plastics, metals, and wood).
6. Understand Equipment: Familiarize yourself with the machines used at the FabLab (laser cutters, CNC machines, 3D printers).
7. Understand Customization: Look at the details for customising your coat assistant and determine what applies to you and which you want to use.
8. Prepare Files: Download or print CAD models, 3D files, and schematics.
9. Schedule Time: If the FabLab is busy, book time slots for specific machines (e.g., 3D printers, CNC routers).
10. Test and Prototype: Create small test pieces to check fit and functionality.
11. Request Assistance: If unsure, ask staff for help with machine settings or design adjustments.
12. Assembly: After fabricating all parts, follow the documentation to assemble and test the project.
13. Iterate and Adjust: If issues arise, refine designs and return for additional fabrication.

Figure 15: Step-by-step guide

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