RoboVac - Ascender

go or come up a (slope or staircase); ascend

Bachelor thesis 2022

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2022
ISRN: LUT-DVIDE/EX--22/50577-SE

Abstract

For my bachelor thesis, I wanted to explore and develop a new kind of robot vacuum cleaner. A robot vacuum cleaner that can climb stairs. Not that there is a big need for it for us to function as human beings. But to make the already established robot vacuums go even further. Simply to make time for more important moments of the user's life.

During my project, I researched and evaluated different methods for a robot vacuum to climb up a stair. Experimenting with sketches and mockups to find a functioning, climbing mechanism, without overcomplicated electronics.

As the project went along I learned that a technical innovation might not be as easy to finalize in such a short amount of time, as I had previously thought.

But.

Everything came together in a visualized model with a tech pack to describe all components within. A full-scale and semi-working prototype was also made to back up my findings and confirm the functionality of the mechanism.

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Brief & motivation

A stairclimbing robot vacuum cleaner (that's also cleans the baseboard)

Robot vacuum cleaners have found its ways into our homes nowadays and it is here to stay.
It lets you take care of other things such as other kinds of cleaning or just leaving more time for people to enjoy other things in their lives. What is yet an obstacle and limitation, is its ability to reach the upper floor of many homes. They are also not equipped to clean baseboards in an efficient way to save people from or with back problems.

Intended outcome
A full-scale conceptual prototype of a stairclimbing robot vacuum.

Market analysis

I based my market research on regular robot vacuums for inspiration but also to get a sense of the size, shape, and all the components, needed inside.

They were categorized and grouped based on their look and design features, rather than their function.

Besides grouping the robot vacuums by their look, I noticed that the most popular shape for a robot vacuum was clearly a round shape.
Why is the robot vacuum mostly round?
May it be due to the tech pack?
I wanted to investigate the triangular shape in my project since I do see that it could be beneficial for cleaning around sharp edges.

Heavy on the styling

Clean lines

Deviating shape

Office vibe

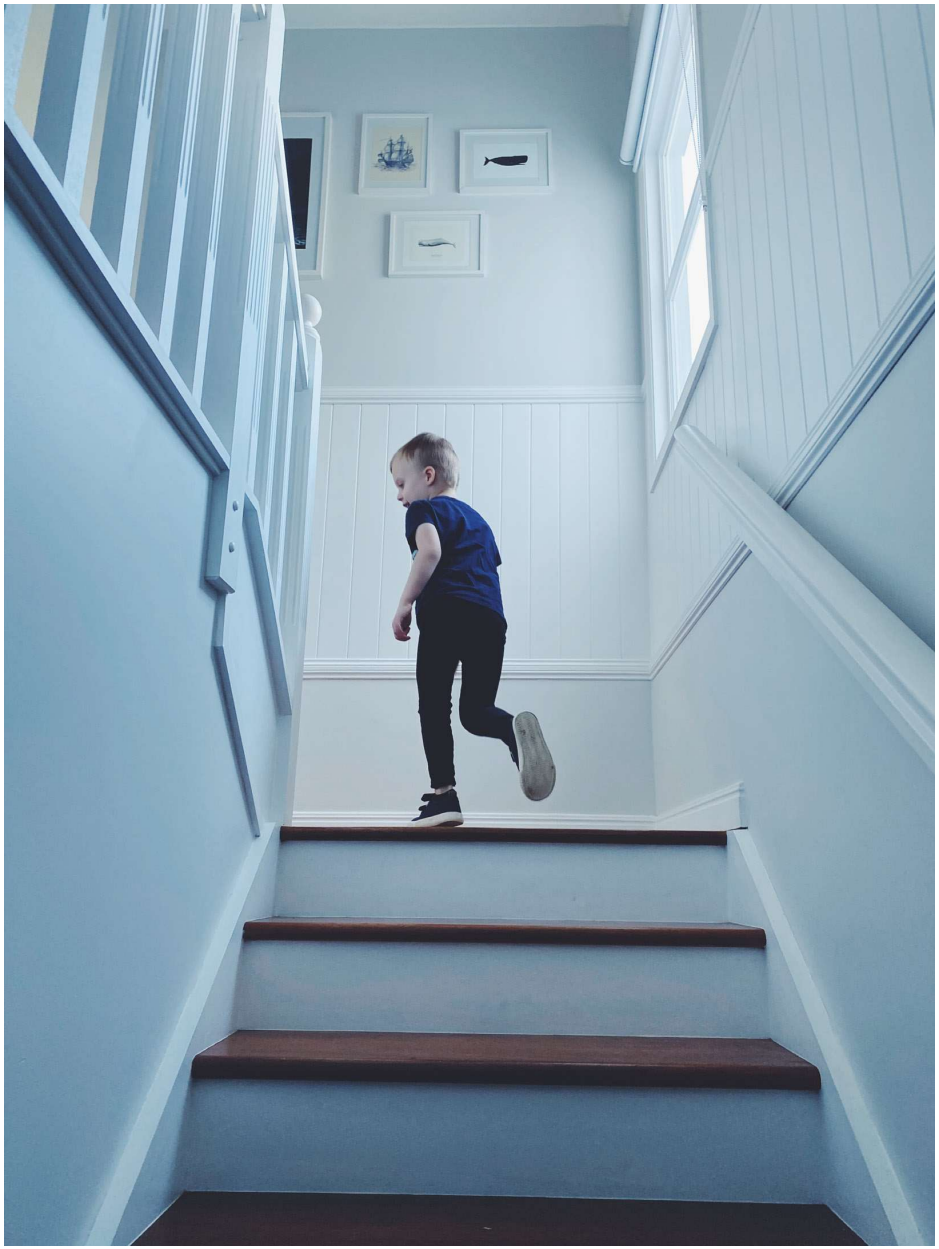
Target group

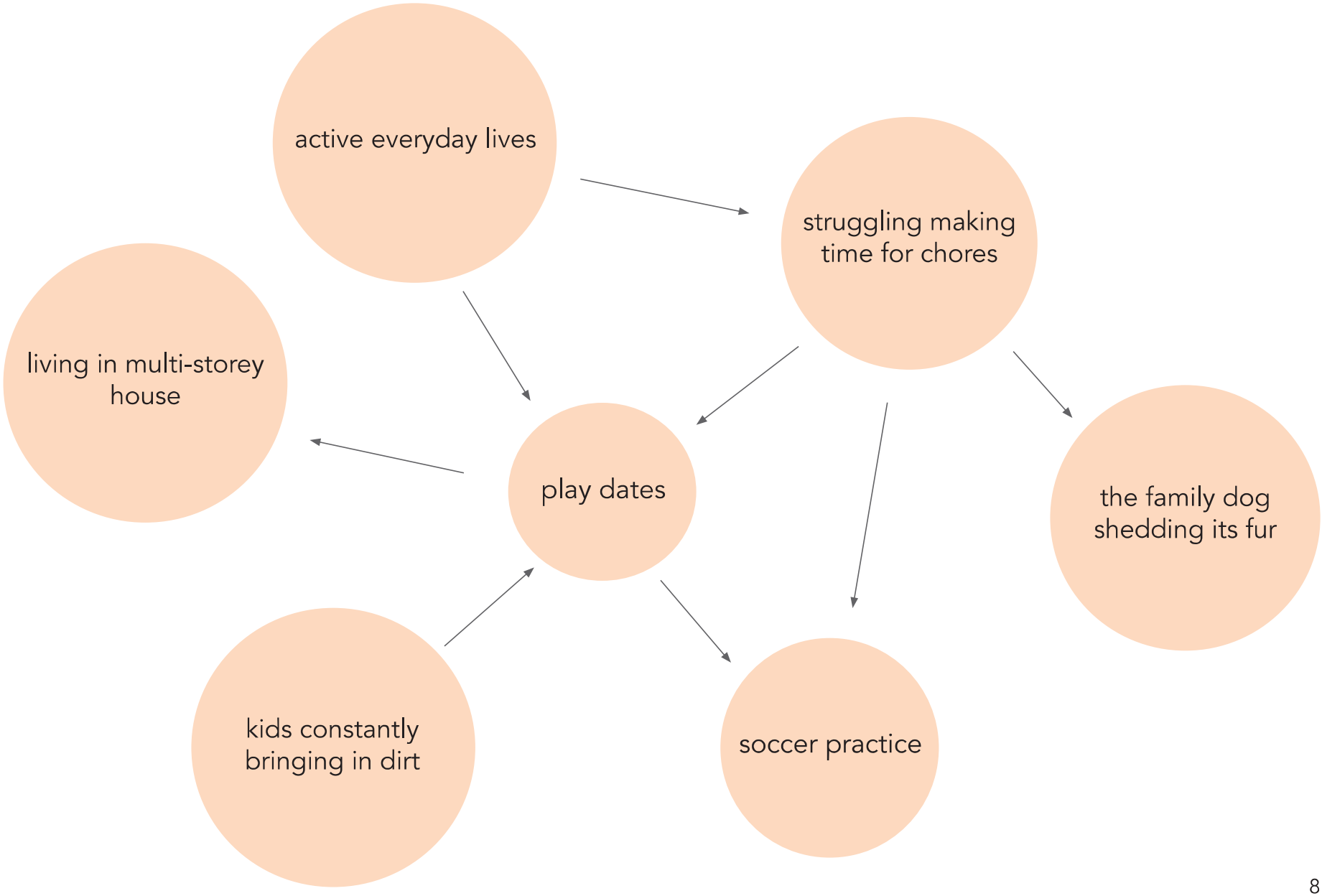
Multiple children families

A stairclimbing robot vacuum could be for anyone since there is really no specific end-user for this type of product, other than living in a house with a staircase.

The chosen target group was more about having someone to design for, instead of just diving right into the design process with no specified user or intent.
So I decided to make this my target group because I feel like this kind of living situation can be very challenging with management when it comes to doing chores.

And that the homes of this kind of group are usually in the biggest need of a good clean.




active everyday lives
struggling making time for chores
living in multi-storey house
play dates
the family dog shedding its fur
kids constantly bringing in dirt
soccer practice

Moodboard & themes

With my target group and this type of not-yet-discovered-product in mind, I put together 2 different themes with different directions to choose from, regarding the design language.

These directions/design languages ended up changing as the project went along.

Theme 1

friendly
soft
soothing
simple

Theme 2

energetic
stand out/singular
exciting
ready to do the job

Ideating - First round sketches & mockups

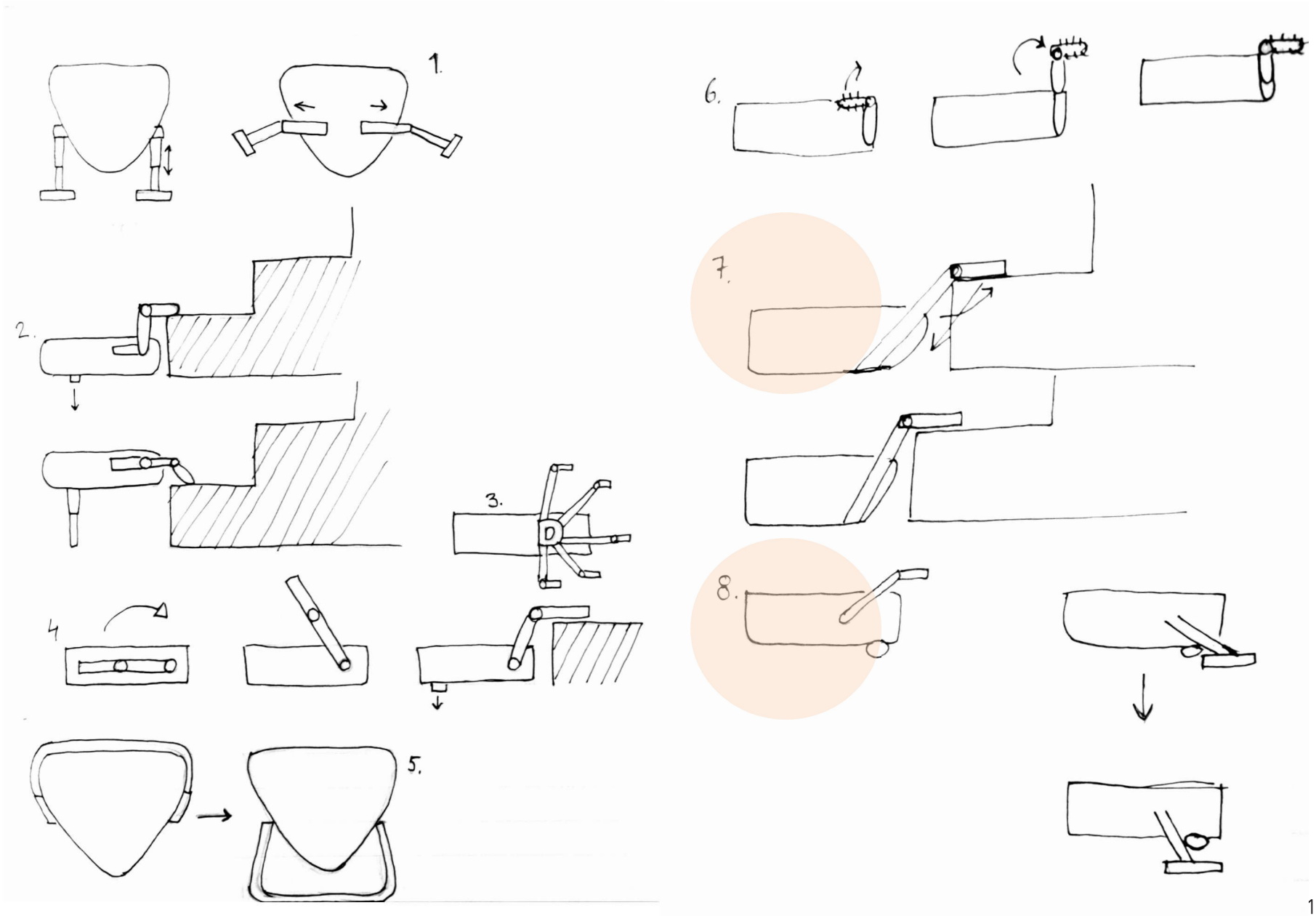
The first round of ideating was done by sketching several possible motions and joints. The concepts were then numbered an evaluated by how controlled and stable the stairclimbing motion would be, and the number of different components it would have to contain.

The electrical components were mapped out and a function analysis was established.

Most of the concepts were discarded rather quickly due to complicated mechanics.

All concepts were based on the robot vacuum being a triangular shape. Concepts 7 & 8 were the only concepts that inhabited qualities that seemed promising.

These 2 concepts were then further elaborated to investigate their potential.


1.
2.
3.
4
5.
6.
7.
8.

Function analysis	**F**
vacuum - the floor	N
vacuum - the baseboards	D
vacuum - the stair	D
allows - remote controlling via an app	D
operates - without man handle	N
be - able to climb stairs	N
be - able to park itself	N
be - able to climb thresholds	N
alert - when vacuuming bigger parts	D
alert - when full	N

Mapping out the TechPack

Side brush with rotating motor x 2 or 1

Dust filter

Main wheels x 2

Extra driving wheel in the back x 1

Front wheel that rotates x 1

Fan for air intake x 1

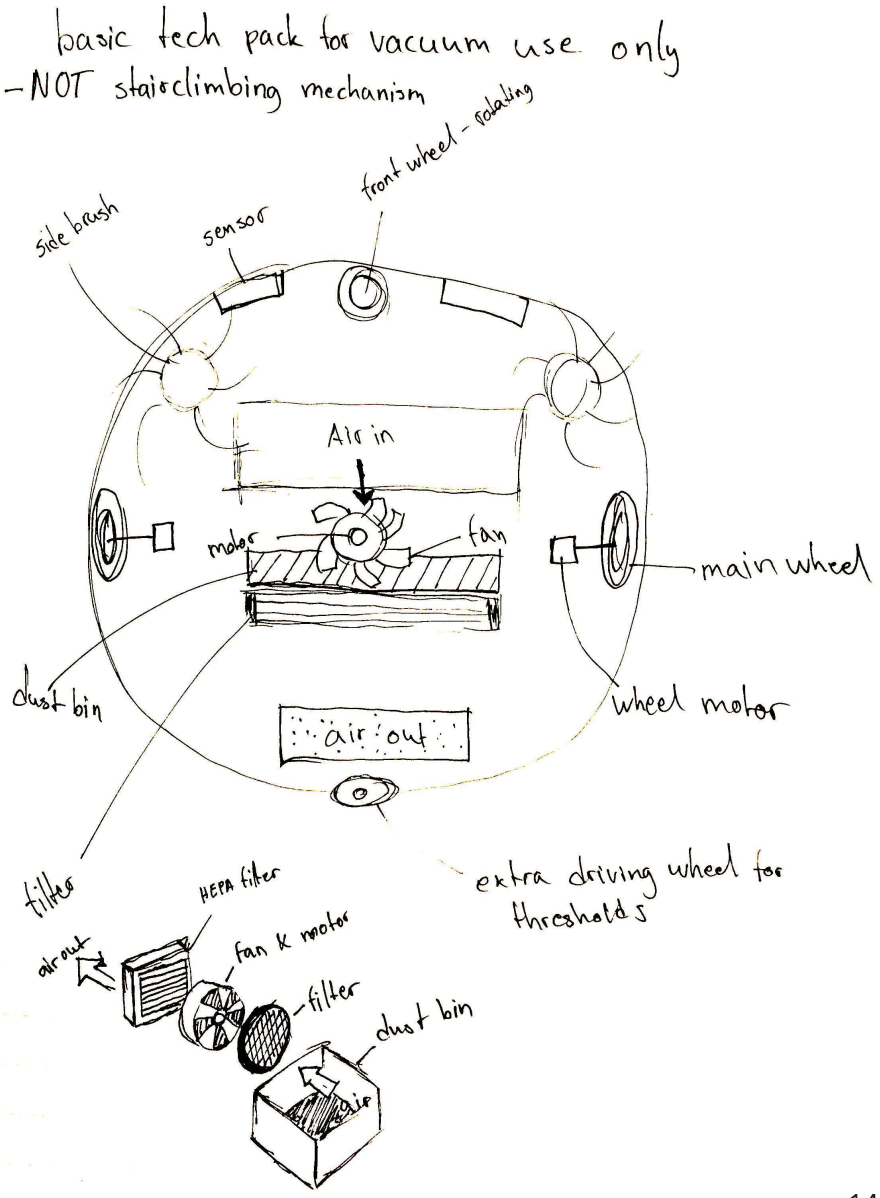
Fan motor x 1

Dust bag/box x 1

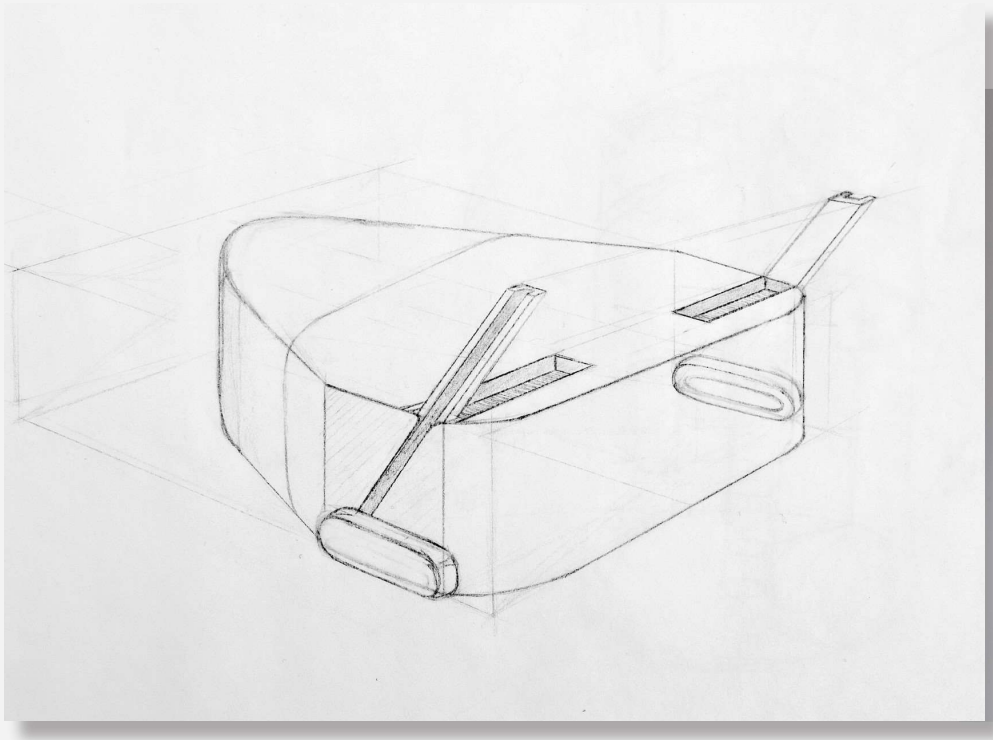
Motor for main wheels x (2?)

On/off switch x 1

Sensors for EVERYTHING?



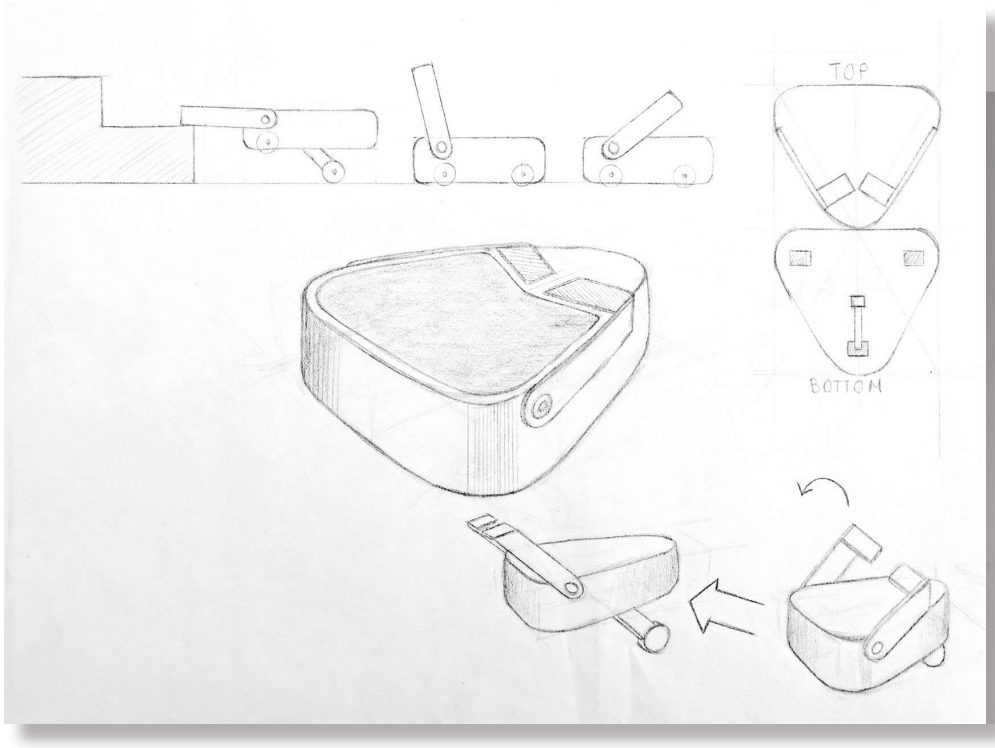
Concept 7

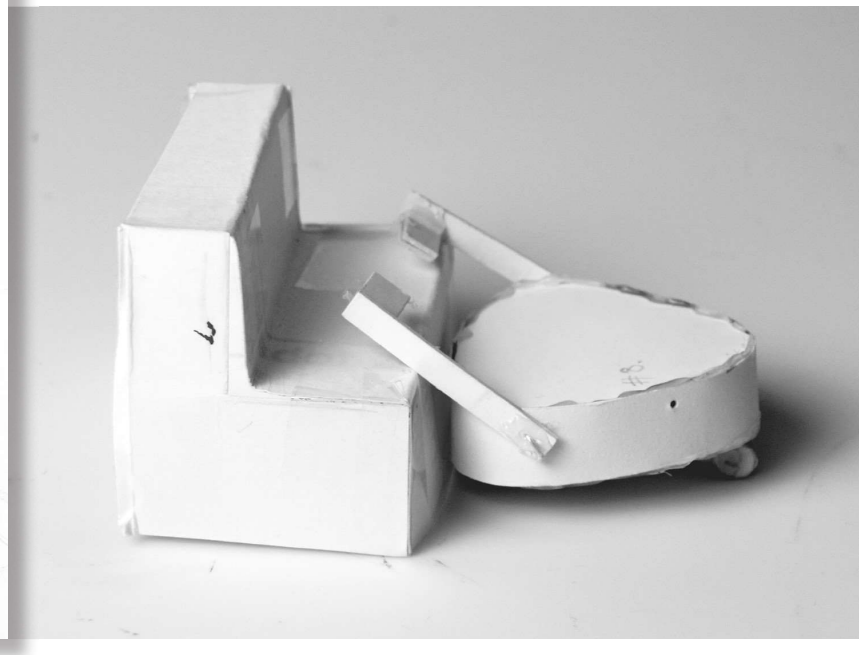


Concept 7 was based on caterpillar tracks that are used in a lot of rock/stair climbing robots in the military. The caterpillar tracks would be attached to a slot, where the wheels would be able to run up and down. Just like a lift, to grab the step above and hoist itself up. The slots would be able to fold in half to lay flat on top of the vacuum when not in use.

This concept, although having a secure mechanism, was rejected due to the many different electrical components. Making it unnecessarily complicated and expansive.

Concept 8





Concept 8 was based on having 2 arms that shared the same axis and rotated around the sides of the vacuum. While a supporting wheel was extended underneath in a simultaneous movement to help lift the vacuum up each step.

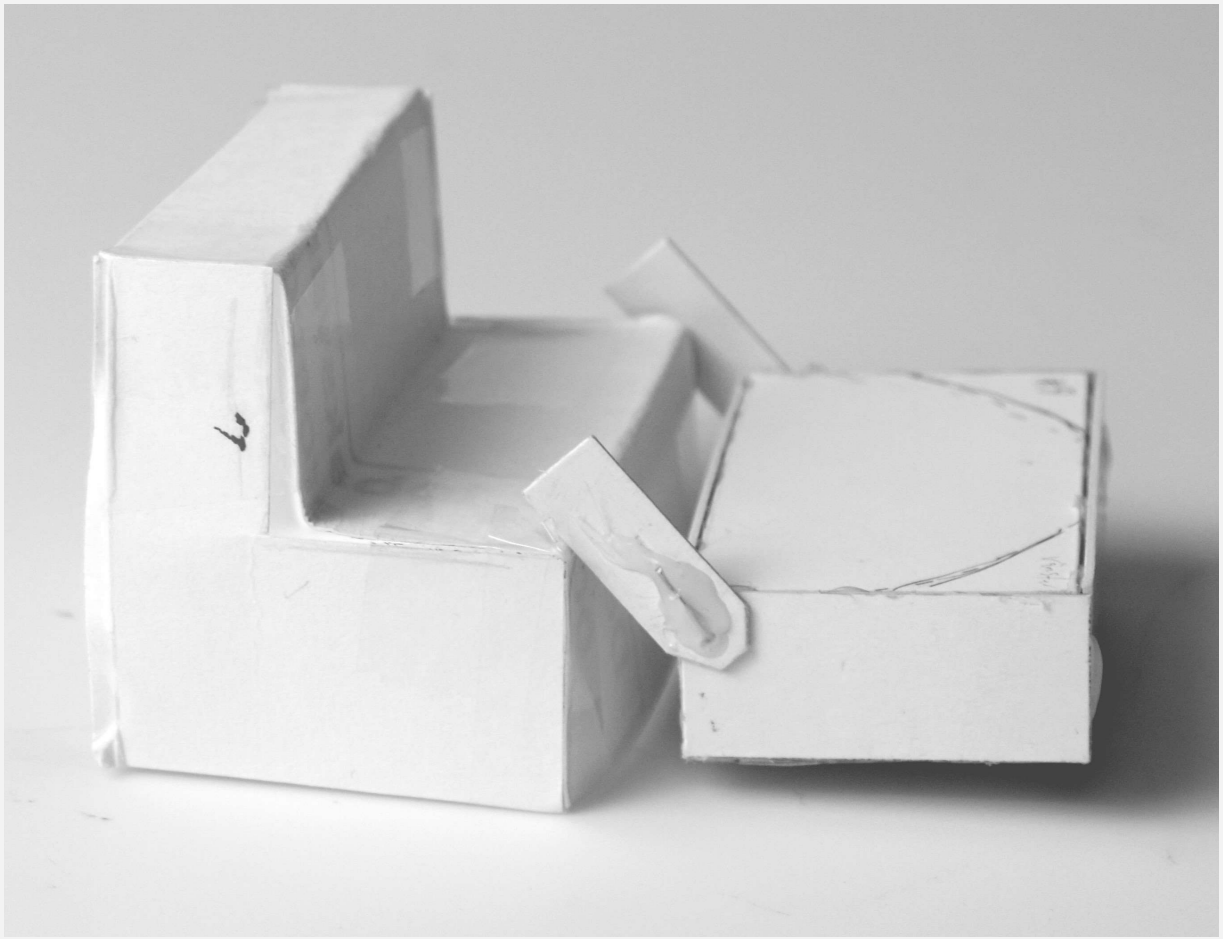
The problem that arose with this concept was the eventual double joint in the rotating arms if they were supposed to be able to fold in & out while also rotating 360 degrees. Also not result in a very stable motion.

Second round ideating - Mockups

After many failed concepts, a change of the robot vacuum's triangular shape was necessary.

Since there was no stairclimbing robot vacuum present on the market, the conventional shape had to change to fit the purpose better.

The triangular shape turned into a square shape.



A new concept was born based on the principle of the old "ruler & hammer" trick. The hammer holds itself up with the help of the ruler so that it looks like it defies all laws of gravity.
This seemed to be a cost-effective way of climbing the stairs since the mechanism utilized gravity rather than a bunch of electronics.

The principle was meant to have 2 arms rotating on the same axis, gripping each step while lifting its own weight.

Despite this concept seeming promising, its main purpose was compromised when the question - "how will it climb down the stairs then?" arose. Hence this concept was also discarded.

The breakthrough

With no successful stairclimbing mechanism insight, after many trials and errors, there seemed to be no solution just yet.

After a full day of researching military bomb robot's climbing properties, the shape of a karambit knife, and at 2 am, a sudden idea emerged. The idea was tested and refined the following week and defined the final concept. A concept that finally proved to be successful.

Military bomb robot

Karambit knife

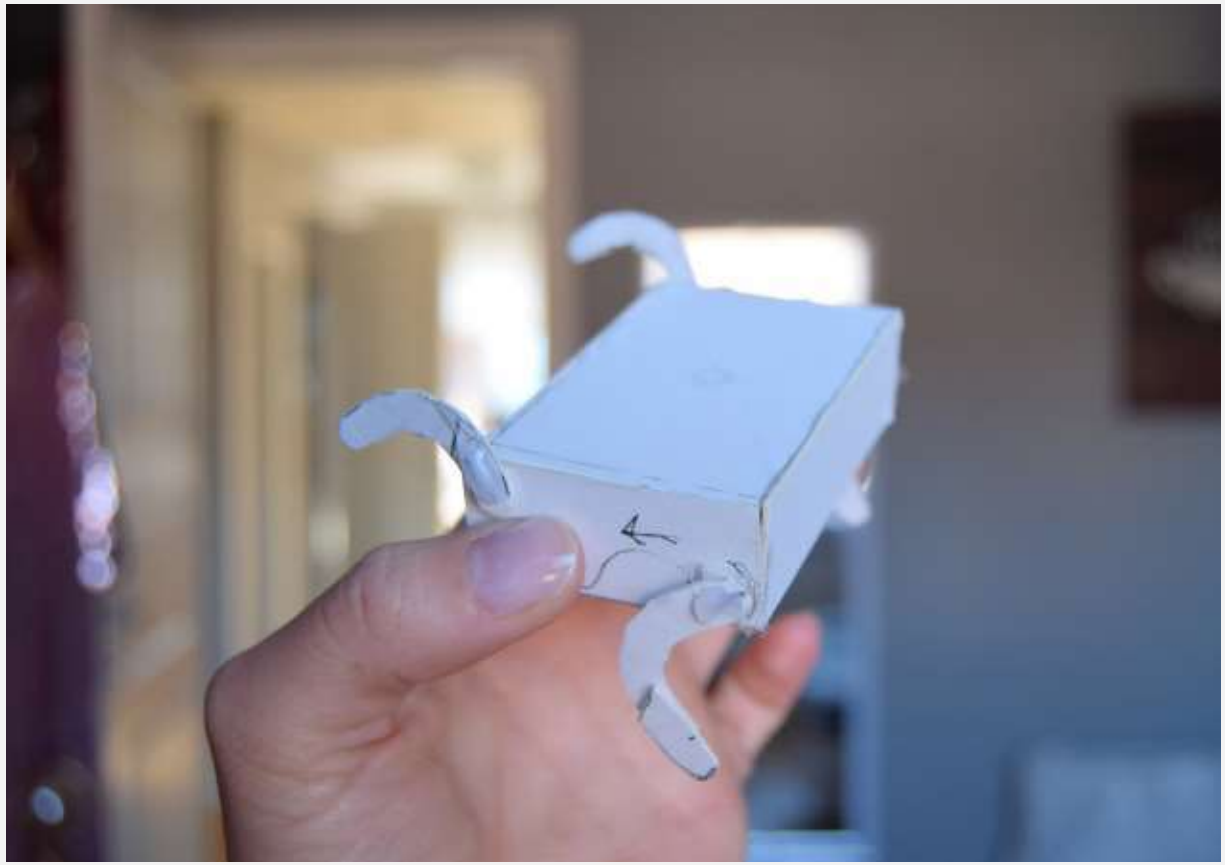
2 AM

The final concept

With much experimenting and a sudden insight in the middle of the night, a final and successful concept was born.

The concept consists of 4 arms/ blades, mounted in pairs and rotating along 2 different axes with different velocities to effectively climb each step with ease.

The rounded shape of the rotating blades is such that a smooth and steady descent is possible. The claw or boomerang shape also aids to grasp each step with certainty.

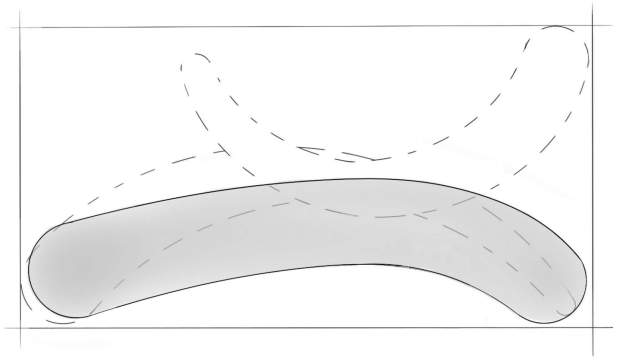


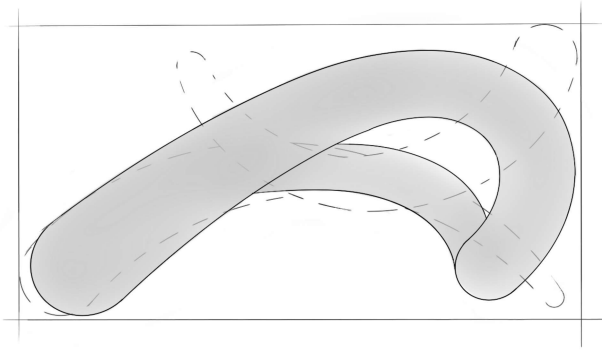
Final concept in 1:1 scale.

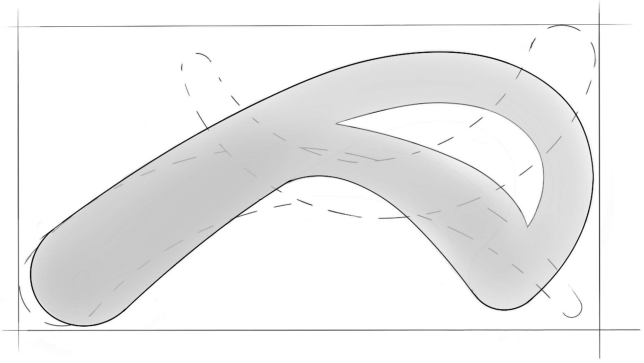
Variation sketches - Final concept

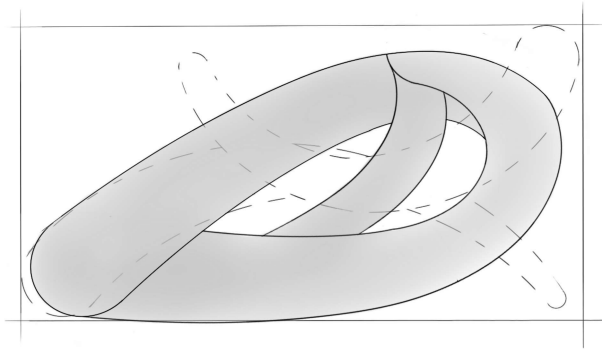
Variation sketches of the final concept were made.

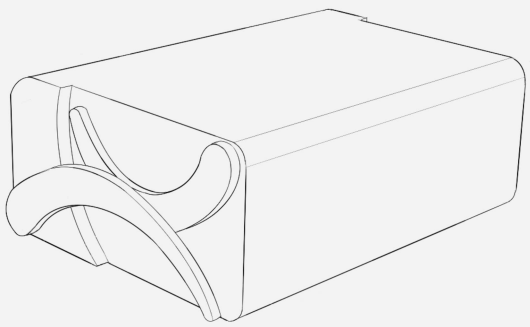
This included further shape studies of the rotor blades to look more aerodynamic.

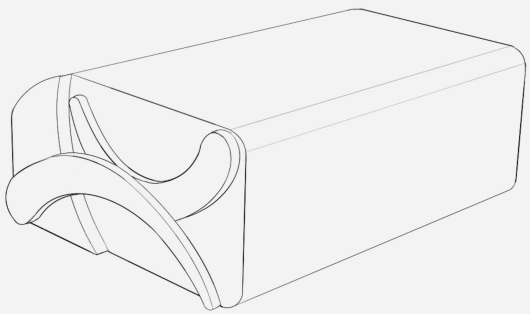


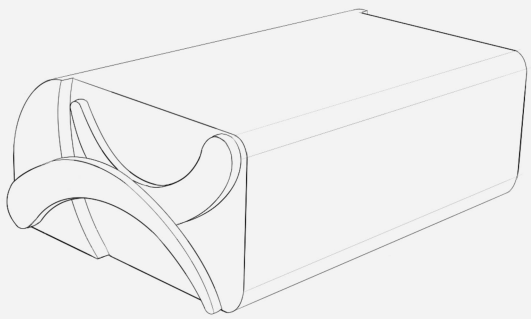


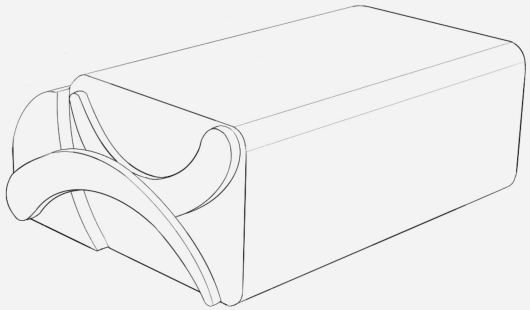


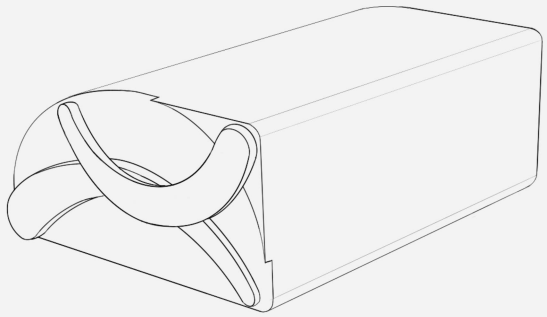


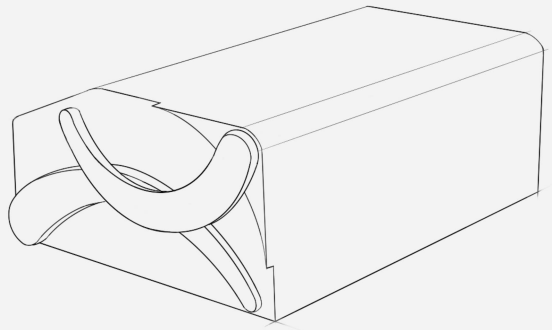




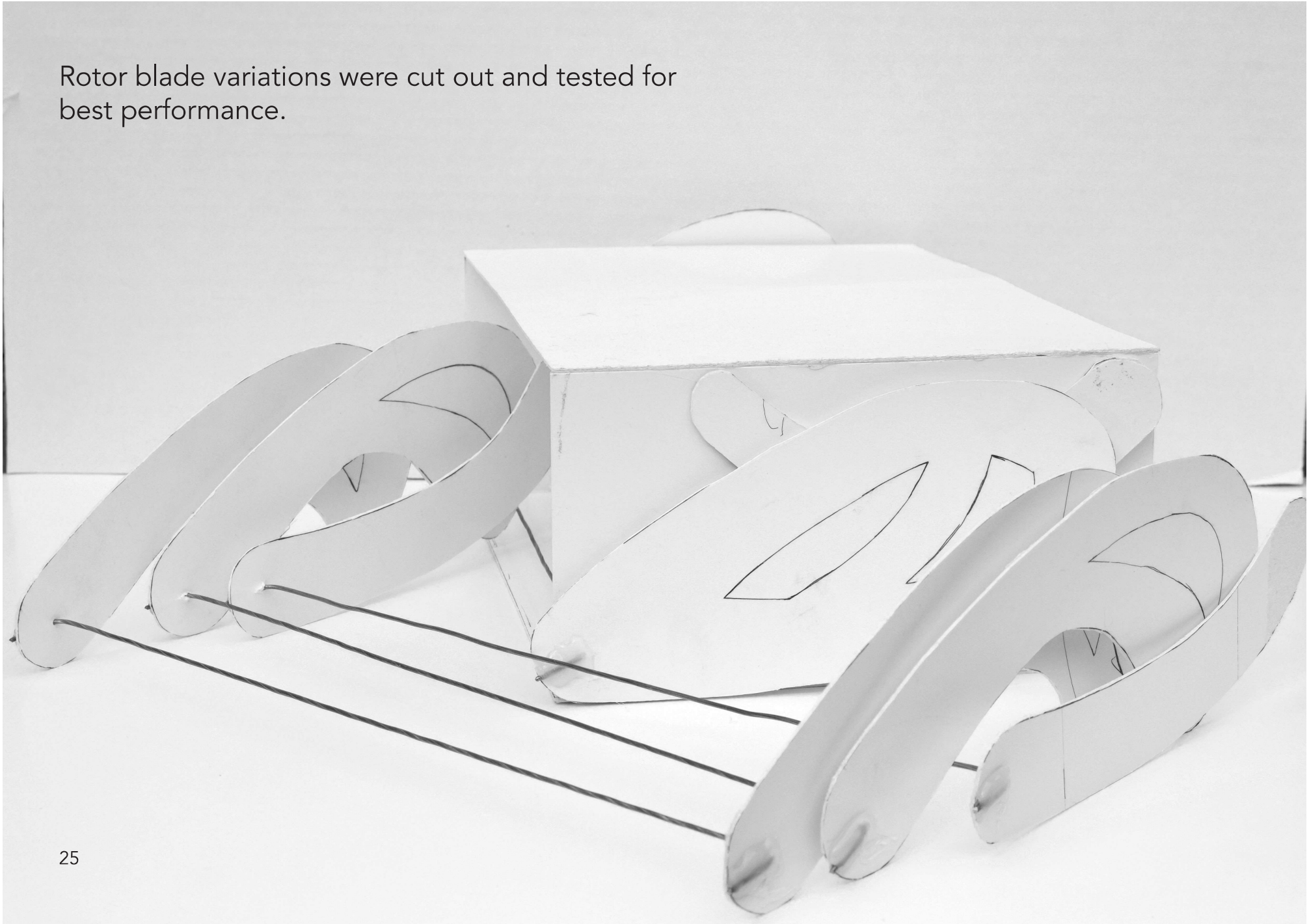








Rotor blade variations were cut out and tested for best performance.

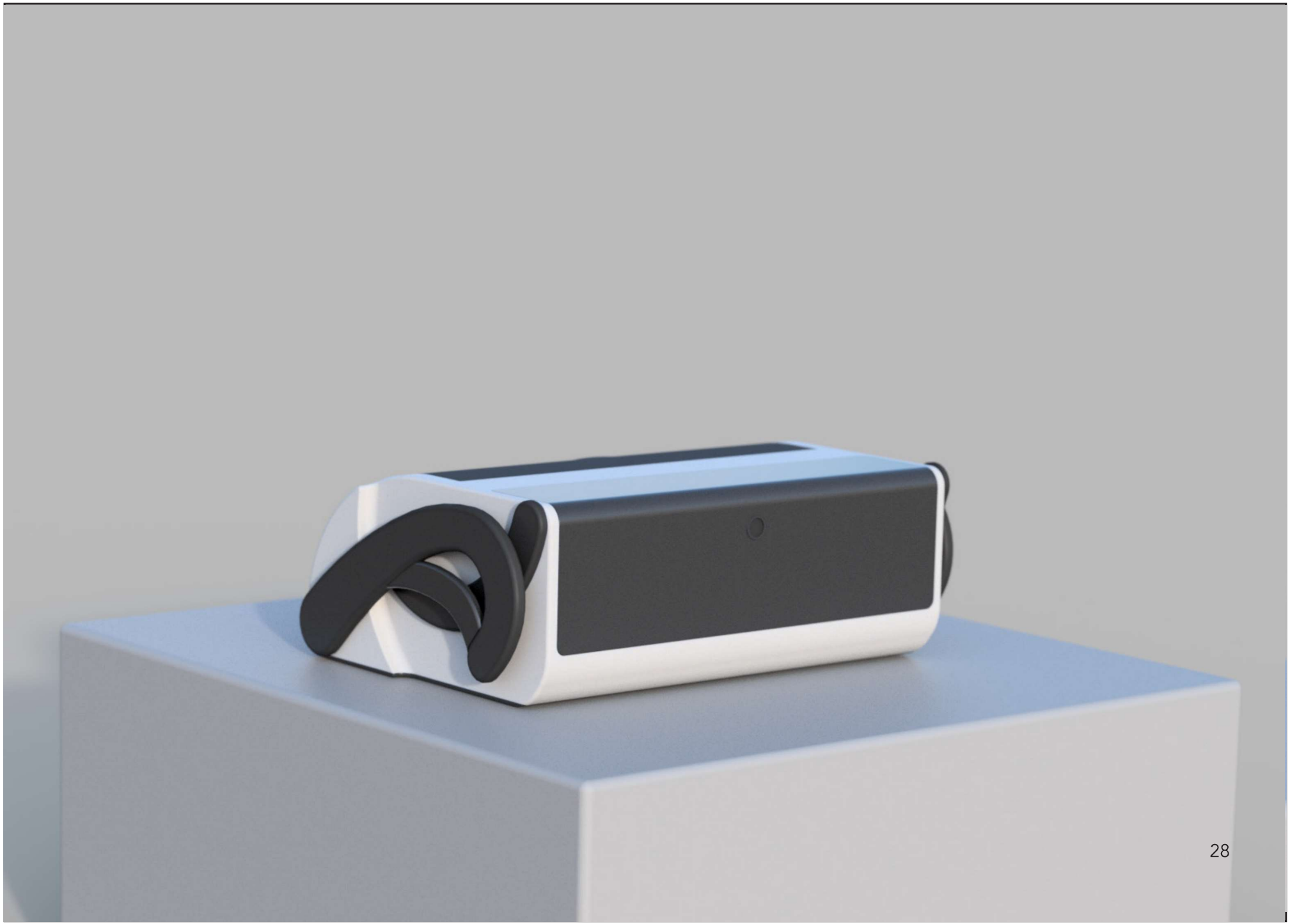


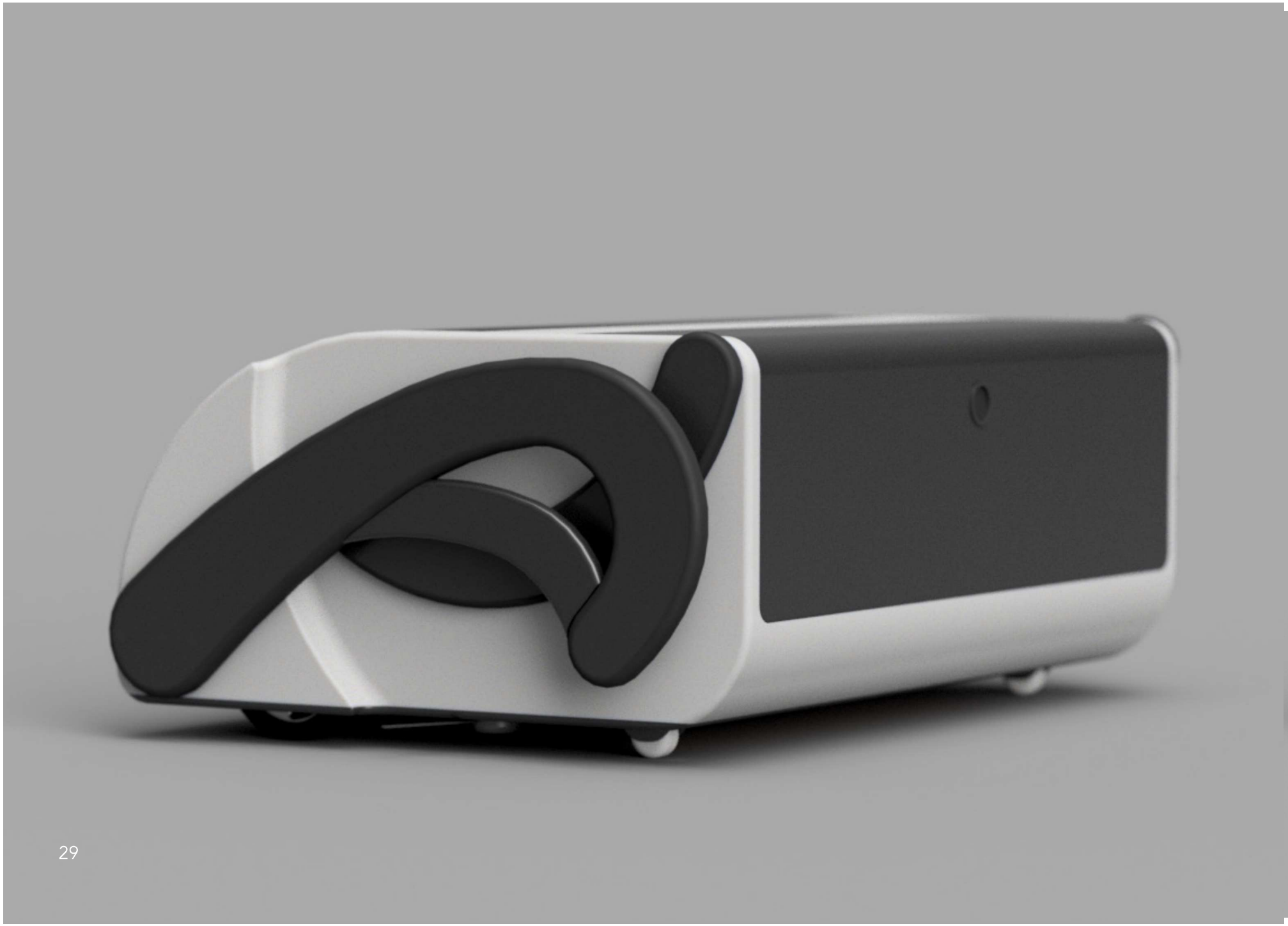
New theme

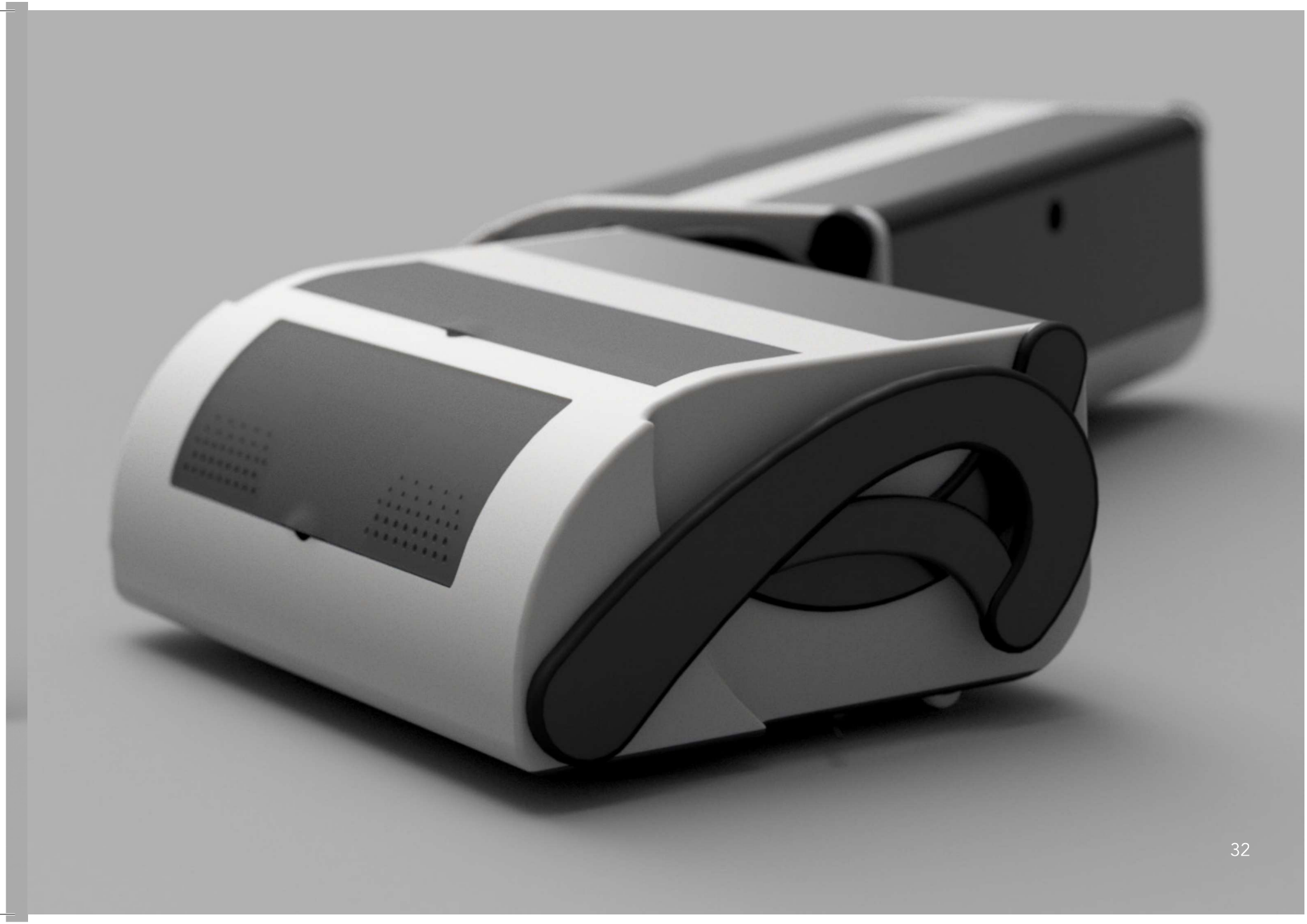
Design theme 1.2

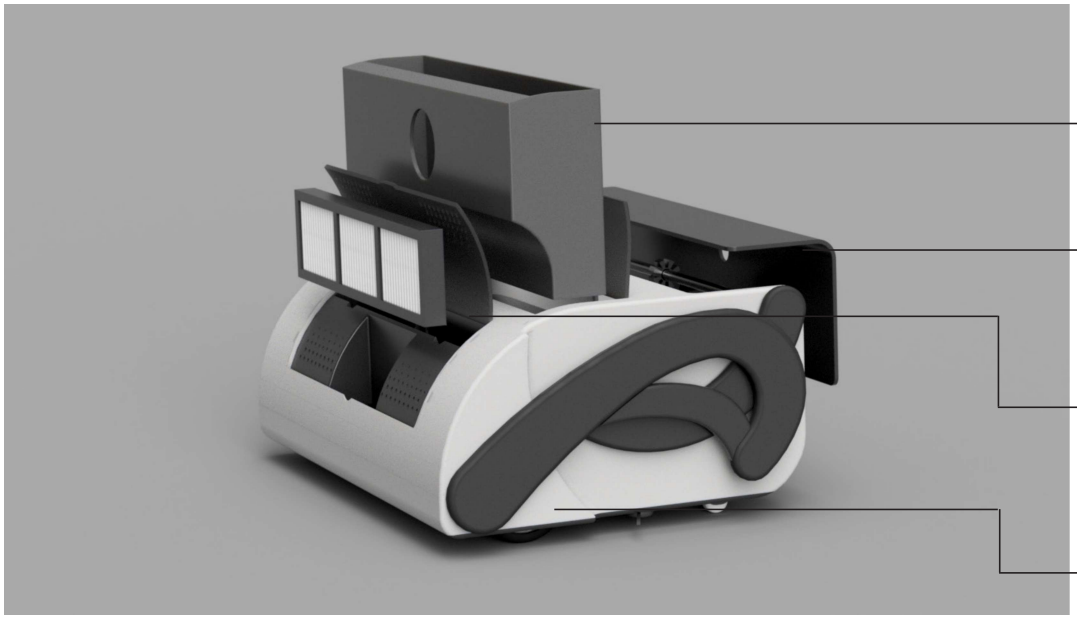
– Still minimal. But the softness of the shape is challenged with flat surfaces, blunt edges, and a distinct dark grey and white contrast.

The final product...







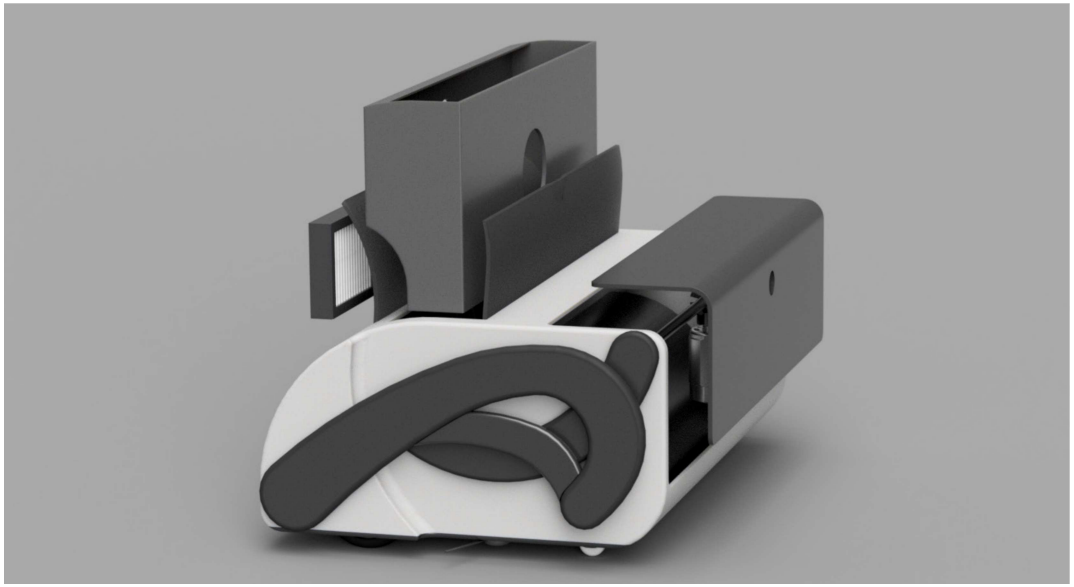


The dust bin is easy to empty after a good run of vacuuming. The overhanging edge allows the user to grip and pull out the dust bin in one motion.

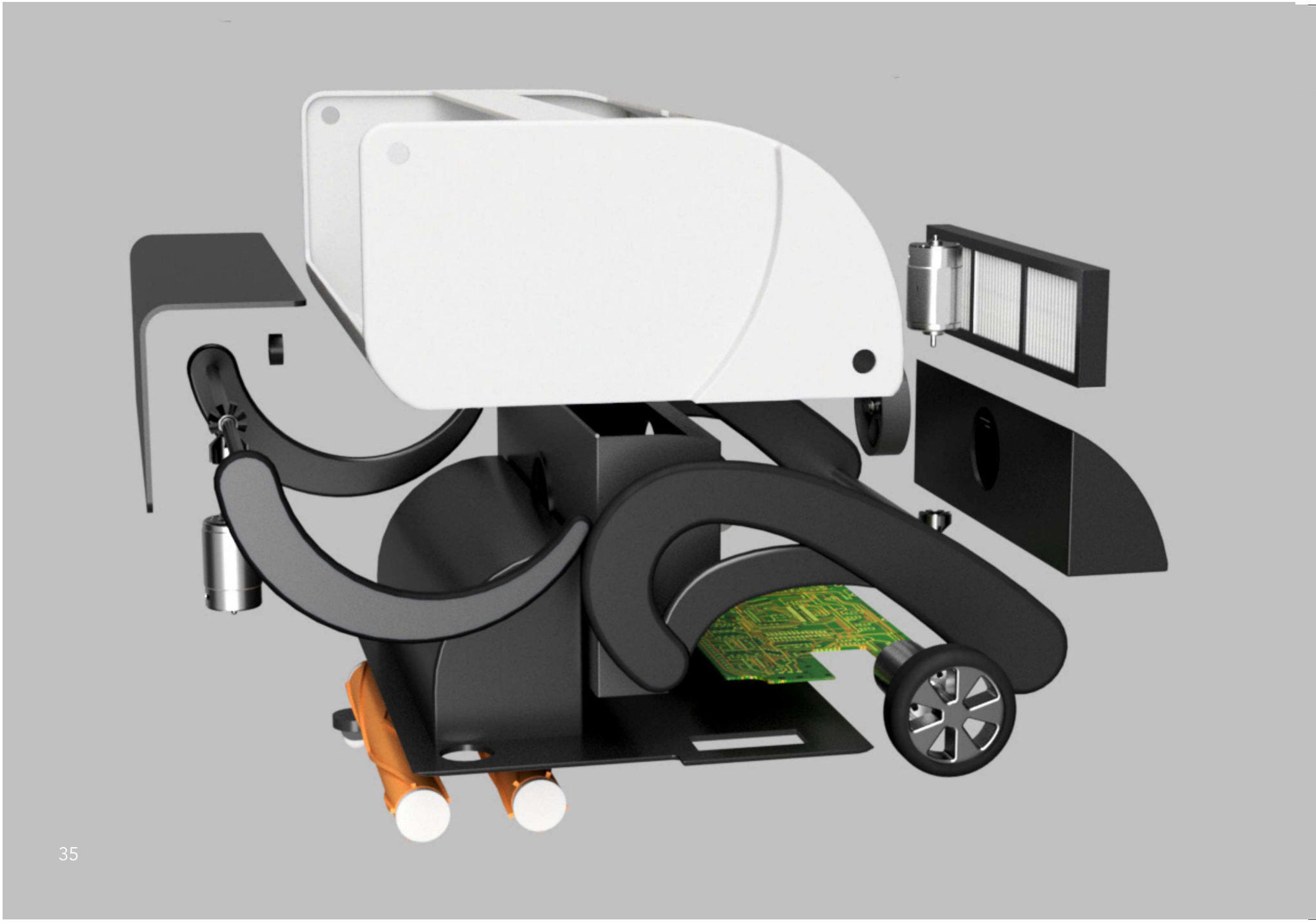
The repair hatch is to get easy access to the front motor, distance sensor and front gears if something needs to be replaced. The back components can be accessed underneath the bottom plate.

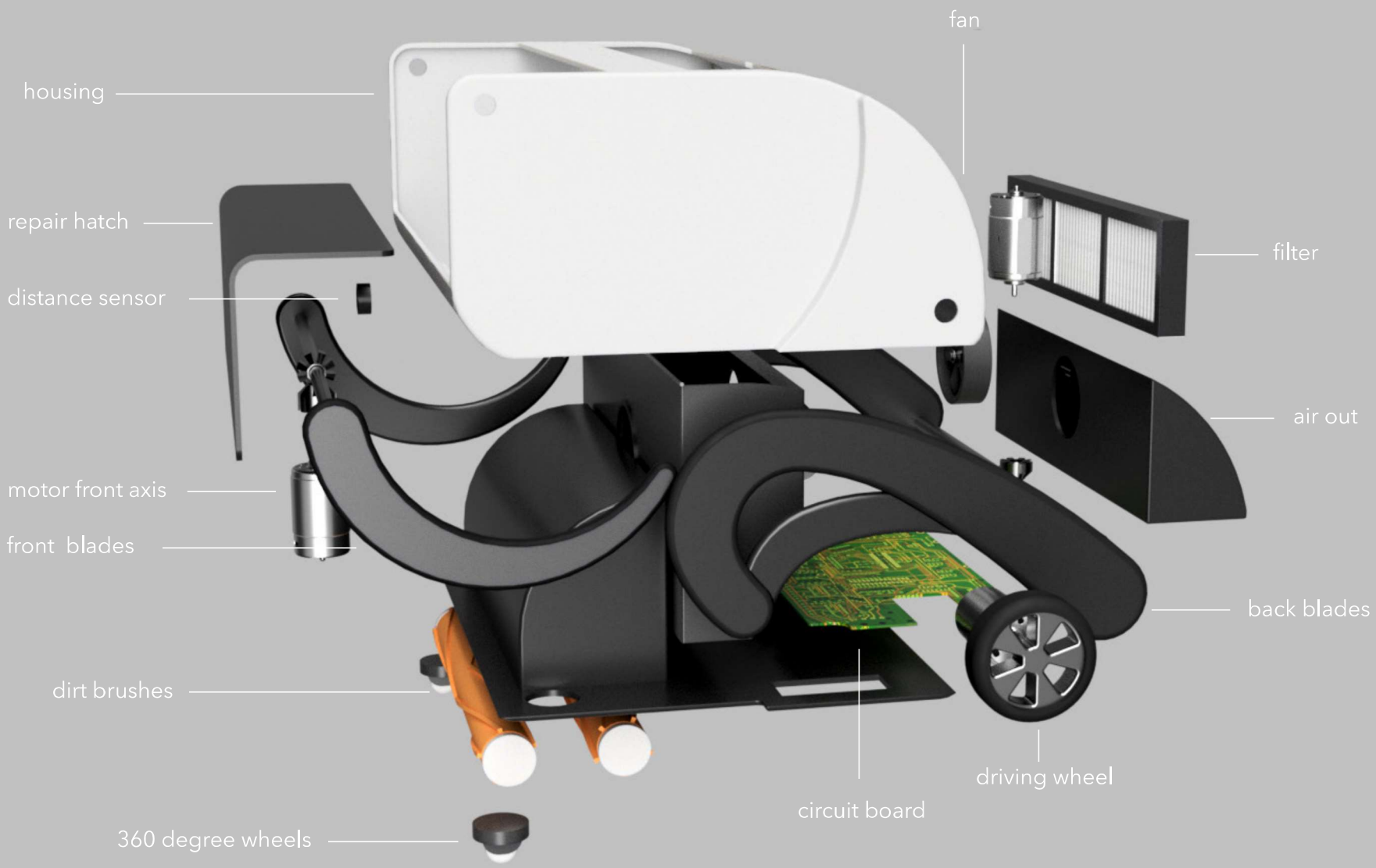
Filters can easily be changed by just lifting up the back hatch. Notches in the filter container may help the user to better grip the filter.

Rotor blades has a radius that effectively grips each step of the stair and allows for a soft movement while climbing. The blades has a silicone strip along the center, to prevent slip.



All features that the user can interact with, are in a different colour. This is to provide the user with an intuitive experience while operating the vacuum.




fan
housing
repair hatch
filter
distance sensor
air out
motor front axis
front blades
back blades
dirt brushes
driving wheel
circuit board
360 degree wheels

Colour, Material & Finish

All materials for the housing and rotor blades are made in ABS plastic.
ABS plastic is used for most of the robot vacuums on the market due to it being a very lightweight material yet strong enough and stain-resistant. It is also a cheap material to mold all the parts in.

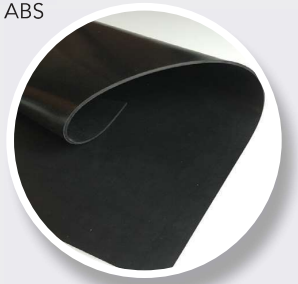
For the hatches where the user can change the filter and empty the dust bin, the material is a semitransparent ABS plastic to show the outline of the components hiding inside, to give clues of what sits where.

For the rotor blades, a silicone strip is placed along the sides to prevent any slip while the vacuum is in stairclimbing mode.

The finish of the housing and rotor blades has a frosted texture to further prevent or hide any staining or notches that might develop over time.

The colours used for the robot vacuum are white contrasting with a charcoal nuance. All components in charcoal are supposed to indicate either movement or that the user can interact with these areas. To make it intuitive for the user where it is possible to open the housing or exchange any parts.

Frosted semitransparant ABS

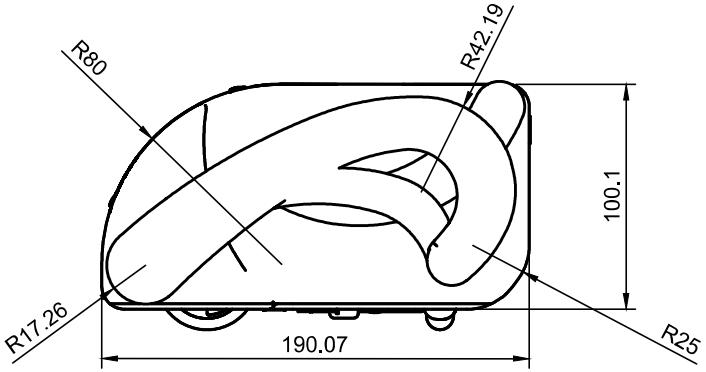


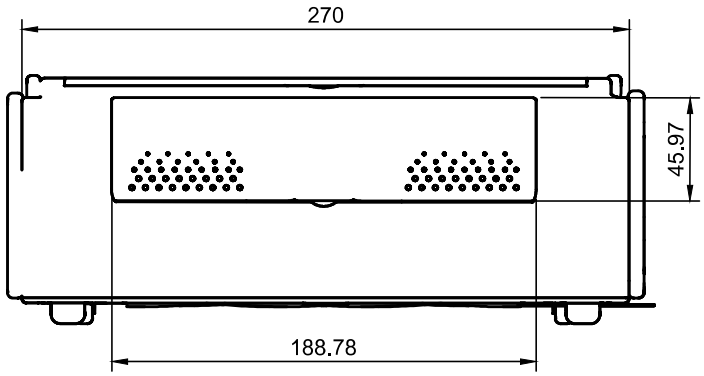
Dark grey silicone

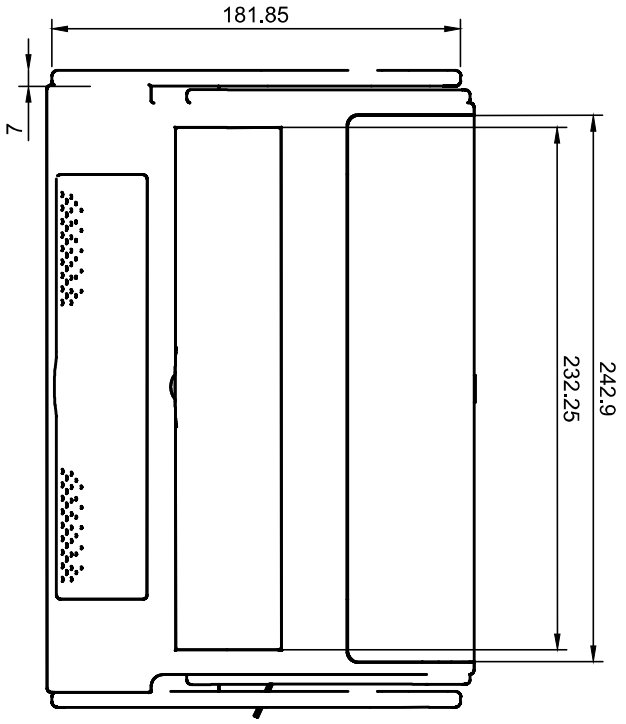
Frosted charcoal ABS

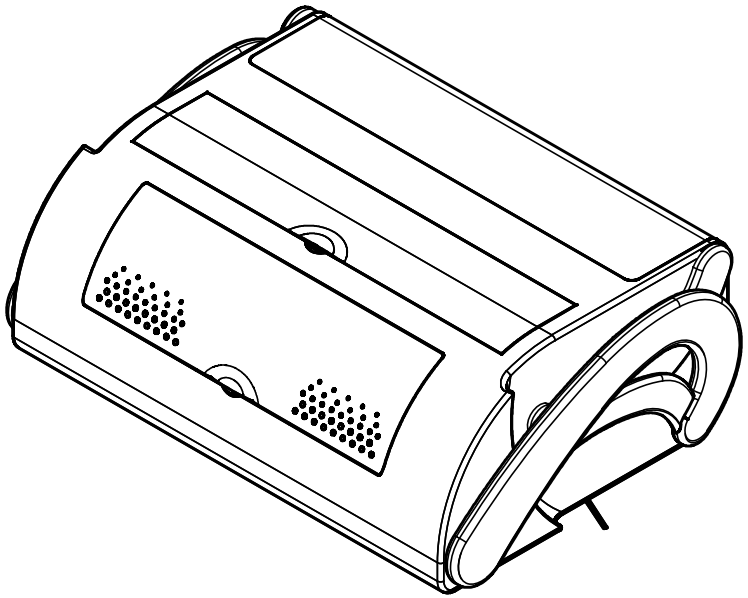
Fosted white ABS

Technical drawing









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		Melinda Andersson	
		Document type: Technical drawing	Document status
		Title: Robot vacuum	DWG No.: 1
			Rev. / Date of issue: 05/05 2022 / Sheet: 1/1

Final Concept in full scale

The full-scale model was made by cutting and forging a metal plate, that was placed on the bottom as the base for the construction.

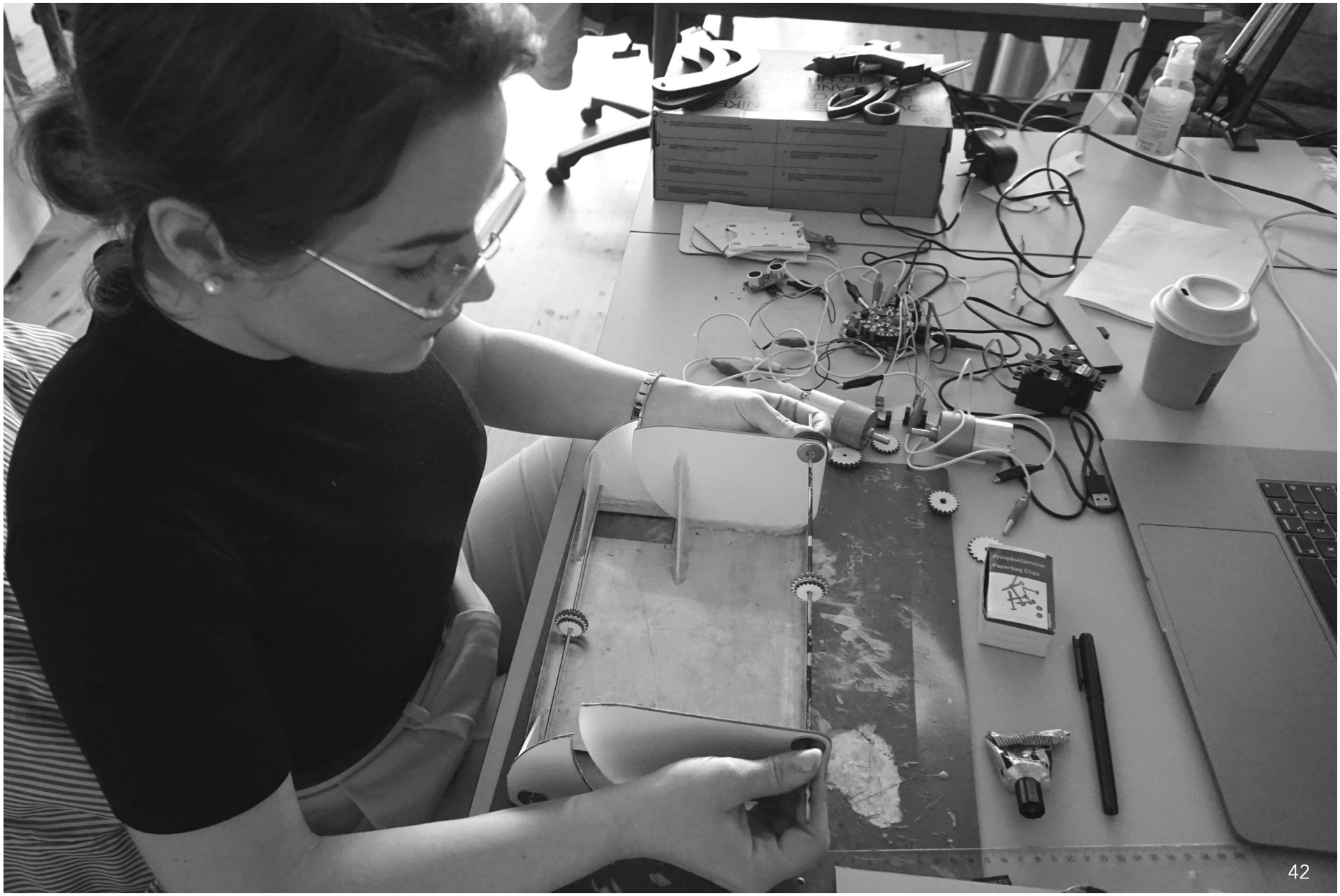
The walls and rotor blades were laser cut in 2mm cardboard and glued together with the metal sheet base.

Interaction parts were spraypainted in black.

Copper wire was used for the axis of the rotor blades. Sitting on the rotor blad axis respectively, the motor axis is several laser-cut gearwheels in 2mm cardboard, glued together.

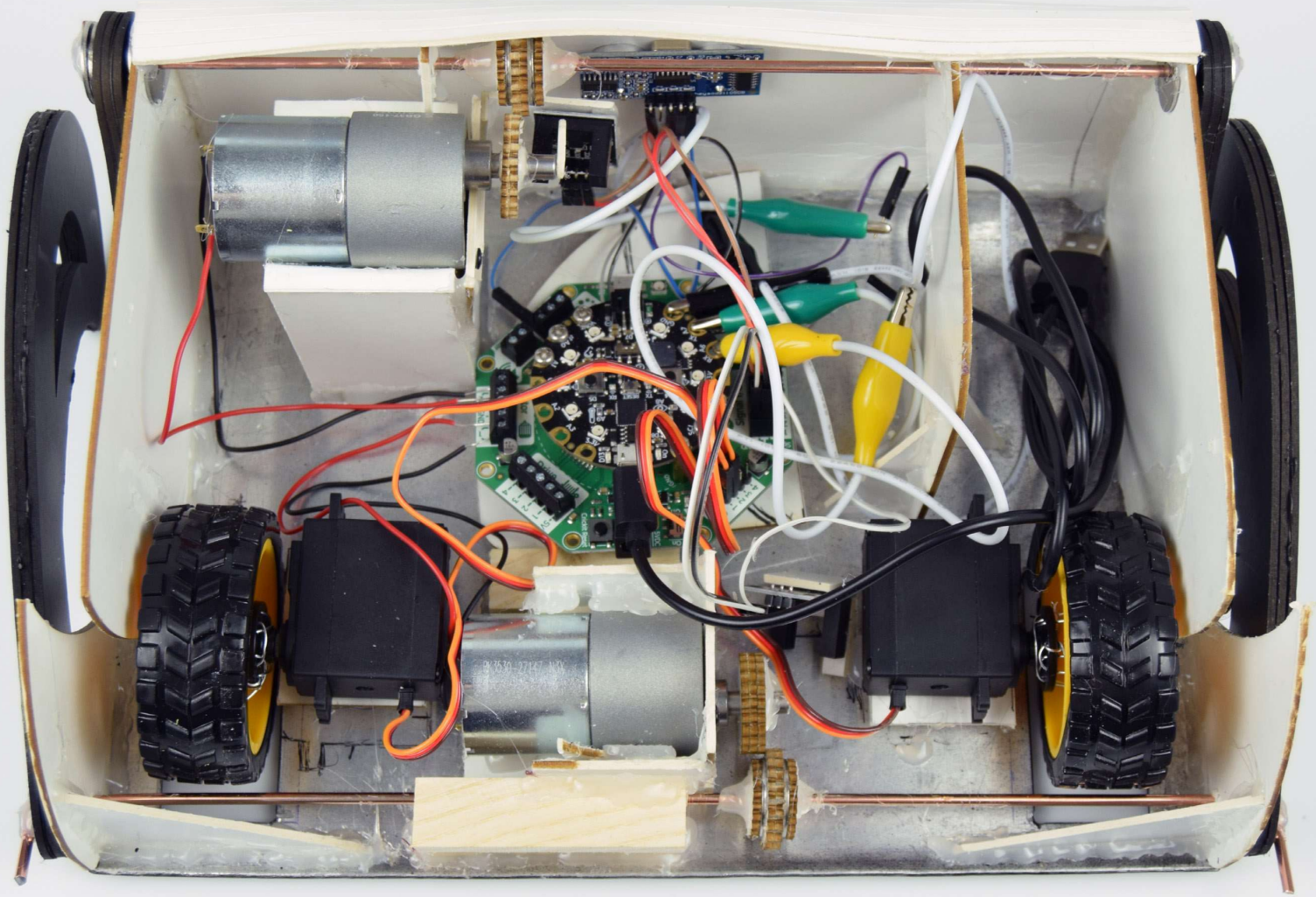
Electrical components

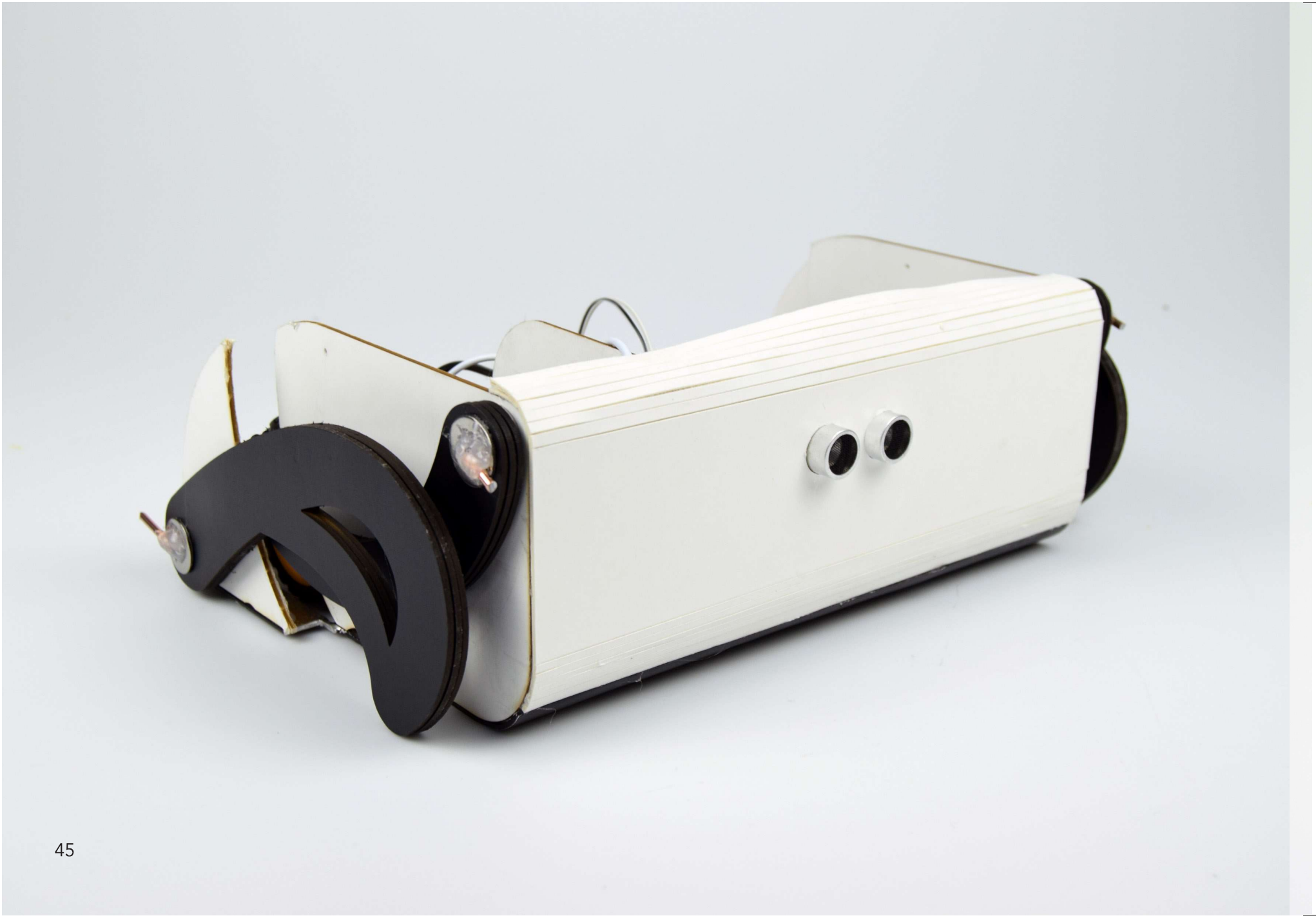
Adafruit Playground express
Adafruit Crickit board
2, DC motors, 67 RPM
2, 360 degree servo motors - with attached wheels
Ultrasound sensor - to measure distance from step
2, digital transducers - to measure DC motors laps

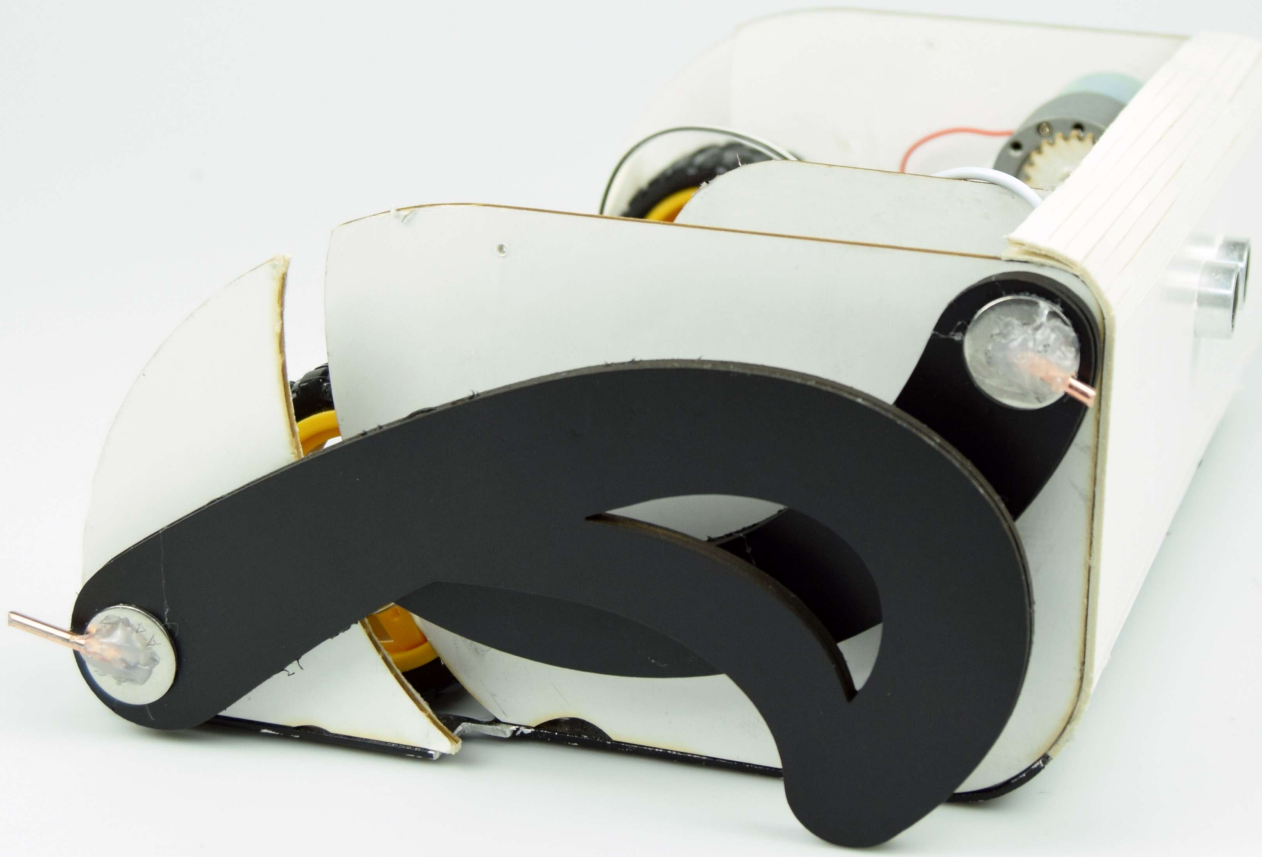

Provpåsklämmor
Paperbag Clips

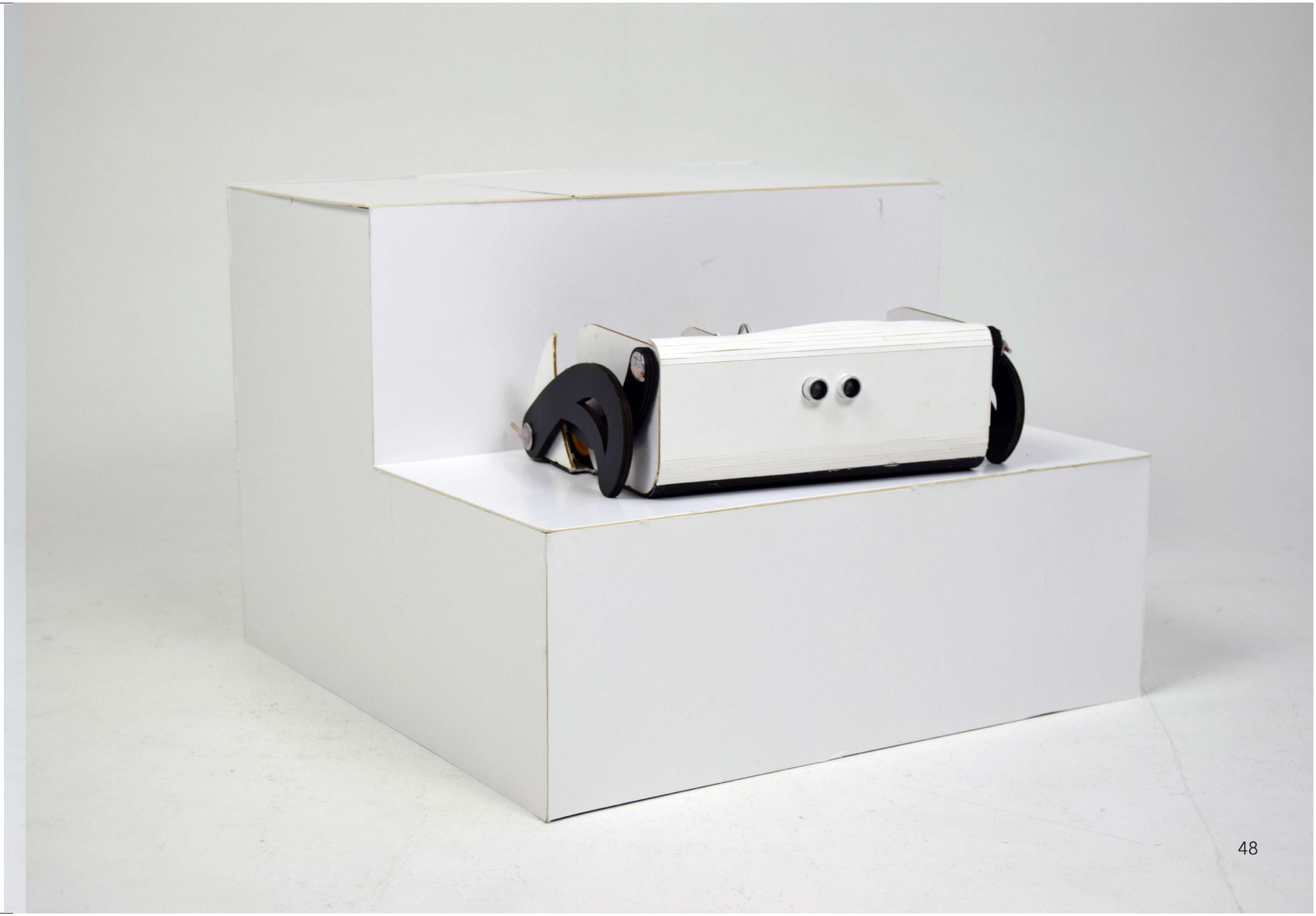
```
let distance = 0
forever(function () {
    pins.A7.digitalWrite(false)
    control.waitMicros(2)
    pins.A7.digitalWrite(true)
    control.waitMicros(10)
    pins.A7.digitalWrite(false)
    distance = pins.A6.pulseIn(PulseValue.High) / 58
    light.graph(distance, 30)
    console.logValue("distancem", distance)
    if (distance >= 0.25 && distance <= 20) {
        servos.A1.stop()
        servos.A2.stop()
        light.setAll(0xff0000)
        crickit.motor1.run(70)
        crickit.motor2.run(70)
    } else {
        crickit.servo1.run(20)
        crickit.servo2.run(20)
        light.setAll(0xffff00)
        pause(2000)
        crickit.motor1.stop()
        crickit.motor2.stop()
    }
    control.runInParallel(function () {
        if (crickit.signal1.digitalRead() && (distance >= 4 && distance <= 20)) {
            crickit.motor1.stop()
        }
        if (crickit.signal3.digitalRead() && (distance >= 4 && distance <= 20)) {
            crickit.motor2.stop()
        }
    })
})

```

The code used to program the full scale model.









Future Improvements

In my brief, I stated that I would like the robot vacuum to be able to clean baseboards since this is an area very close to the floor and is often neglected. So I would have liked to explore the baseboard cleaning abilities further. Maybe there could be certain attachments to the rotor blades with bristles of some kind.

Many of today's robot vacuums, comes with an app where you as a user, can track the activities of your vacuum and even layout your floorplan for the vacuum to follow. I feel like an app would be needed for this robot vacuum, where you can see the areas that has been vacuumed. There could be a function where you can also track the health of the battery and other parts, to stay up to date on the condition your vacuum is in or if there is a need of any repairs.
In addition to an app, there should also be some kind of notification system. For when bigger pieces are vacuumed so that if the user's wedding ring accidentally ends up in the dust bin, it won't be lost forever.

For further improvements, it would be great if the robot vacuum can empty itself in an additional station. There are a few robot vacuums on the market already that are able to empty themself into a bigger dustbin station, so the user does not have to empty it every day.

Reflection

This project was a crazy ride to be working on. I have learned a lot, and most above all, to have faith even if everything feels hopeless with no solution in sight.
I did manage to finalize my project and I am very happy about that.
Even if, of course looking back, I would change a few things along the way. I would like to have spent more time on the features left for future improvements. The reason for the additional features ending up on a future improvements page, was the extremely time-consuming task of actually producing a fully working prototype. Or at least trying to.

I do hope to elaborate on this project in the future, because I am very excited about its potential.

I would also like to thank everybody who supported me in any way during this project. May it be classmates, supervisors, external teachers, friends & family.
Thank you.

And thank you for reading this documentation of my degree project for bachelor of fine arts in design, 2022.

Over and out.

Sources

Pictures

https://robotnyheter.se/2016/10/23/makita-drc200-en-robotdammsugare-for-kommersiellt-bruk/

https://www.philips.se/c-p/FC8802_02/robotdammsugare

https://www.netonnet.se/art/hem-fritid/dammsugare-rengoring/robotdammsugare/neato-botvac-connected-d650/1008009.9263/?siteType=2

https://www.bäst-i-test.se/robotdammsugare

https://unsplash.com/s/photos/child-staircase

https://www.pinterest.se/pin/487092515943898744/

https://www.behance.net/gallery/80200057/MARUI-BABY-BOTTLE-STERILIZER/modules/465050707

https://www.pinterest.se/pin/571957221424291373/

https://www.yankodesign.com/2017/01/24/for-immaculate-undies/

https://icona-designgroup.com/project/spacepod/

https://shop5d.tk/ProductDetail.aspx?iid=38337636&pr=97.88

https://www.pinterest.se/pin/103090278961488389/

https://www.ibzstore.com/?category_id=6050293

https://www.trendhunter.com/trends/electric-motorcycle-concept

https://www.medisana.de/the-homecarerobot.html

https://www.pinterest.se/pin/418834834101679549/

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