WORKBOOK GARDENA

ROBOTIC VACUUM CLEANER

AUTUMN 2014 D7011A

GARDENA®

GARDENA MOWING IN.

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YOUR DUST, OUR LUST.

INTRODUCTION

This workbook is the product of a student groupwork in the course Advanced Prototyping at Luleå University of Technology, in the fall of 2014. The following chapters will guide you through the complete process of our model making, from the first ideas to a final full scale model of the design.

The project aim is to design and build a model of a robotic vacuum cleaner based on the design language of a given brand. Our group was assigned the Gardena brand, European leader of high quality gardening equipment. The course aim is to learn how to build advanced models with modern techniques and equipment.

We are proud to present our concept design of the Gardena RoboClean 4400 Li!

CONTENT

1 ANALYSIS

1.1 THE MARKET

Swedish company Electrolux introduced the first robot vacuum cleaner in the year of 1997. Today the market offers a wide range of models and brands. The average pricepoint of robot vacuum cleaners is between 500 - 7000 SEK. Most vacuums have a round shape and a dust capacity around 0,5 litres. The technique for navigation differs from brand to brand. Below is a brief comparison of some robotic vacuum cleaners on the market.

Model	Height (cm)	Dustbag (l)	Shape	Navigation
LG hom-bot Square	9	0,6	Square with rounded corners	Camera and optic sensor creates a “cleaning map” for the vacuum to follow.
Hoover Robocom rcb003	8,5	0,5	Round	IR-sensors are used to navigate but can not create a map.
I Robot roomba 650	9,2	0,47	Round	Responsive cleaning and dirt detection.
I Robot roomba 780	8,5	0,3	Round	Responsive cleaning and dirt detection.
Navibot S	8	0,5	Round	Camera on top creates a “cleaning map” for the vacuum to follow.
Neato XV-25	10,2	0,66	D-shaped	360 degree laser-scanner, vacuums in regular patterns.

1.2 THE GARDENA BRAND

GARDENA IMAGE

The Gardena brand was analyzed to define the style and image of the brand.

The Gardena image expresses design with focus on quality and ergonomics. The brand is probably most famous for its functional hose connections and watering systems, but the product portfolio contains equipment for all kinds of gardening.

Comfortable grips are recurring in all hand held equipment and the products express easy-to-use functions with a family friendly design. Contrast colors express the functions of the products creating an intuitive user interface. The colorful design in all products creates a joyful feeling and makes the products easily recognized. Gardena wants gardening to be fun and easy, not considered as work.









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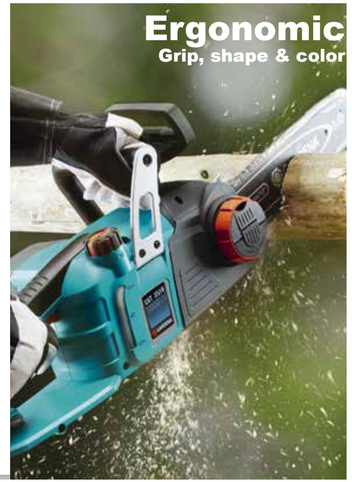


GARDENA STYLE

Round shapes and distinct surface transitions are typical Gardena design elements. Different surfaces separated with split lines and varying materials express different functions of the products.

The color palette is gray, turquoise and orange and the surfaces are mostly matte plastic and rubber. The orange color indicates a call to action for functions such as buttons and controls. Grooves in the gray surfaces are other recurring design elements.

The products have a playful expression with bright signature colors, soft lines and plastic materials. Ergonomic design is also expressed in most products through comfortable and functional grips.

2 DESIGN

2.1 SKETCHES

Starting the design process the group immediately felt the need to sketch ideas both on paper and with clay. Drawing on paper is a very quick way of testing shapes and colors but to examine the 3D-shape of the ideas, clay was easier and more understandable. Many ideas were developed and four initial concepts were brought to the first presentation.

Later on, the group did a sketching exercise when drawing individual versions of each existing concept during 10 min. The initial sketches then circulated so that everyone had time to continue building on each concept. This creative method made it possible for everyone to bring their ideas and tweaks to the table. The sketching continued and we switched between sketching on paper and sketching with clay.

CLAY MODELING 2.2

During the clay modeling-phase we had great help from Johan Gustafsson who shared his expertise about clay modeling. High quality industrial clay was used to shape the form but the model had a core of styrofoam not to waste the valuable clay. To apply the clay without adding any air holes a technique was used only applying thin layers and squeezing them onto the model with force.

To be able to make the model's shape as close to the sketches as possible templates were made. There were template for the front view, sideview, the pattern of the bumper, the silhouette of the rear etc. By scraping clay off the model with customized tools according to the templates, desired surfaces were developed. To make the surface perfect, a wet hot cloth were used to make the oil in the clay rise to the surface.

1

2

3

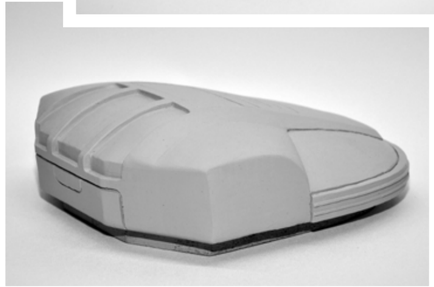
1 Adding clay to a foam core.

2 Making smooth surfaces with nice curvature.

3 Final work with details.

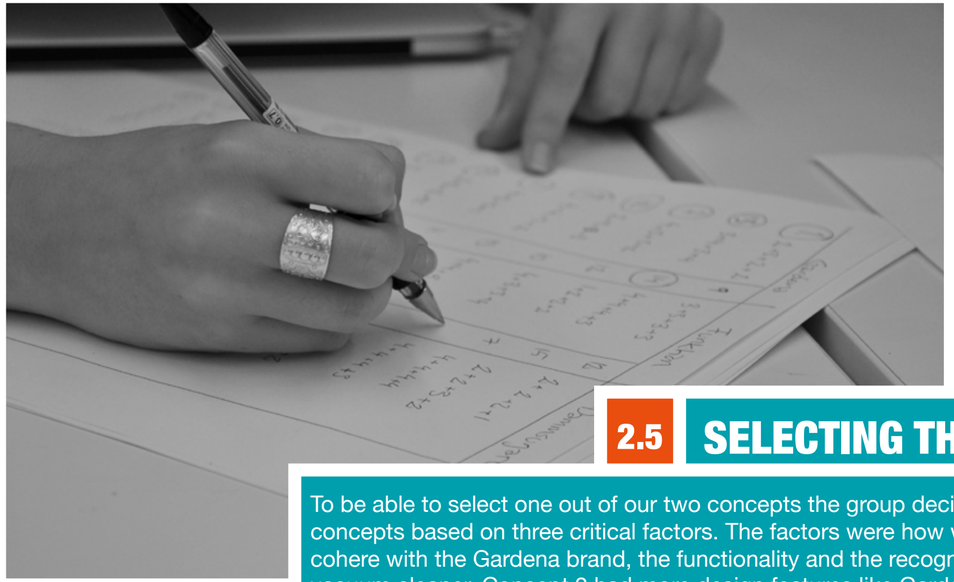
2.3 CONCEPT 1

- Big bumper to create a sturdy and functional look to the overall design. A classic Gardena pattern with thin rounded lines covers the bumper.
- Dashboard with two most important control buttons and a display.
- A large orange button to open the shell and access the dust bin. The button is meant to resemble the Gardena's well known hose coupling which also separates different parts.
- Wheelhouse creating radial shapes according to the Gardena design profile.
- Curvated surfaces with distinct surface transitions to create friendly looking but controlled surfaces according to the Gardena brand.
- Ergonomic handle for carrying. The handle has a ergonomic pattern to indicate that it is a handle and to create a good grip.
- Turquoise will be the dominant colour of this concept because of the large turquoise shell. Dark gray will be used to differ parts with different functions such as the bumper, handle and dashboard.



2.4 CONCEPT 2

- A big bumper to create a sturdy and functional look to the overall design. A classic Gardena pattern with thin rounded lines are covering the bumper.
- Dashboard with two most important control buttons and a display.
- Wheelhouse creating radial shapes according to the Gardena design profile.
- Curvated surfaces with distinct transitions creates friendly looking but controlled surfaces according to the Gardena brand.
- Easy access to the dust bin on the rear. Pressing a orange button the bin will easily pop out.
- Inlets at the back to lead the user's attention to the dust bin on the rear. Inlets are well used design features on Gardena products.
- Turquoise will not be as dominant in concept two as in concept 1. The main upper body will be in turquoise but the lower body, bumper and dust container will be in grey creating a grayer overall impression.

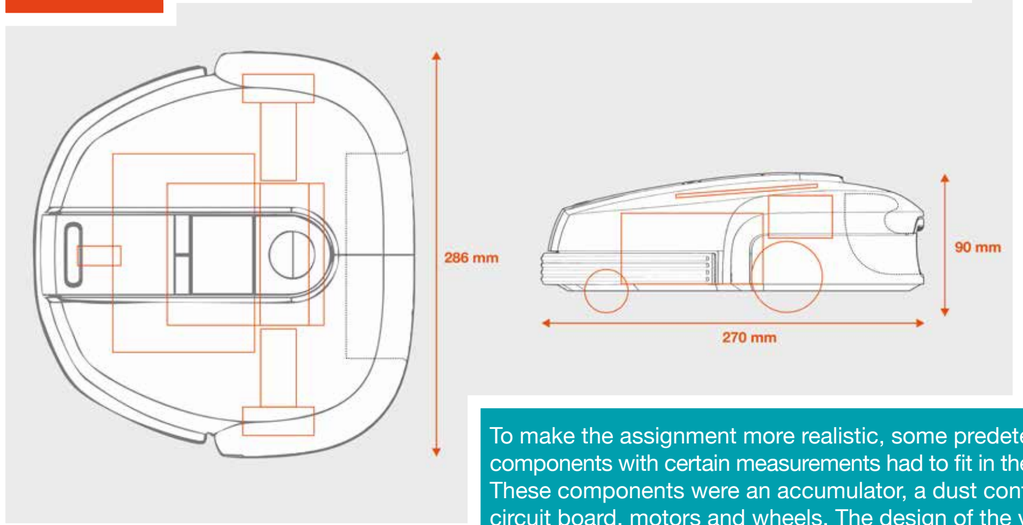


2.5 SELECTING THE DESIGN

To be able to select one out of our two concepts the group decided to rate the concepts based on three critical factors. The factors were how well the design cohere with the Gardena brand, the functionality and the recognition of a robot vacuum cleaner. Concept 2 had more design features like Gardena but had an overall edgy and sporty feel. Concept 1 had a more playful and kind overall look which both fit well with the Gardena design and suits an indoor environment.

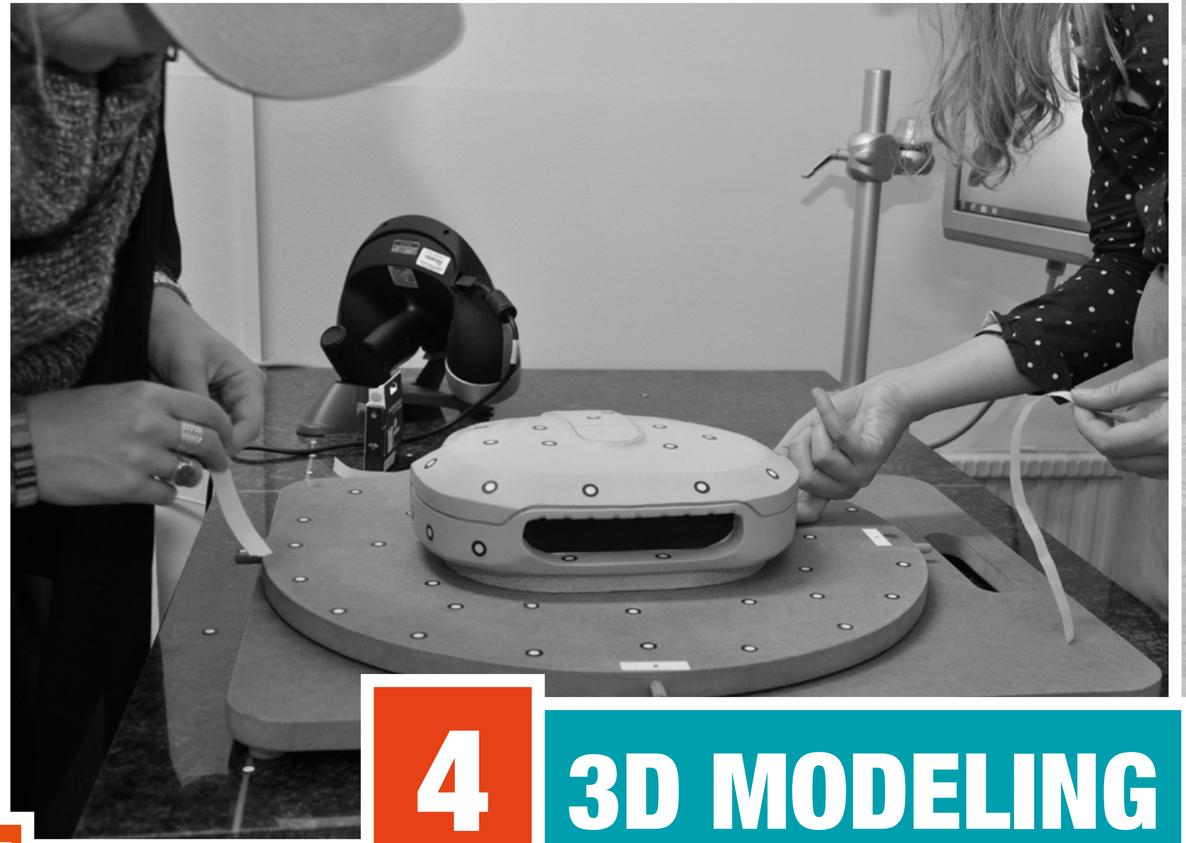
We rated the concepts within the group as well as used a test group and concept 1 got the highest score. Both concepts got equal rating on functionality but concept 1 got higher scores on both coherence with the Gardena brand and recognition of a robot vacuum cleaner. Therefore, concept 1 was chosen for further development and prototyping.

3 PACKING STUDY

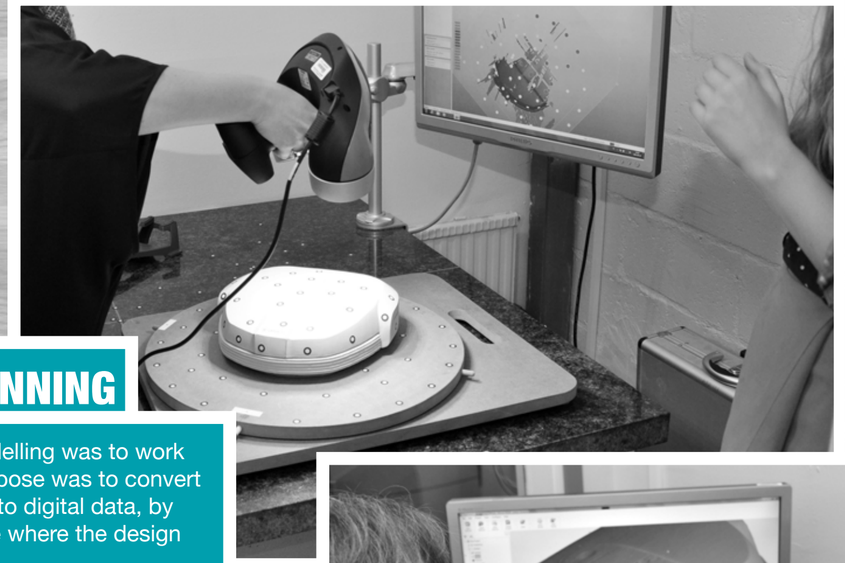


To make the assignment more realistic, some predetermined components with certain measurements had to fit in the vacuum. These components were an accumulator, a dust container, a circuit board, motors and wheels. The design of the vacuum needed to provide the necessary space for these components.

The packing-study was made using CAD software, modelling the components according to the given measurements to make sure they would fit inside the vacuum.



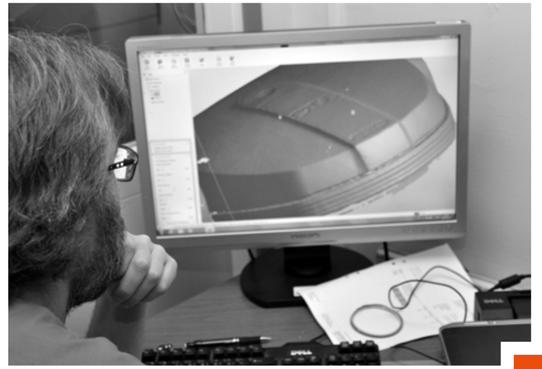
4 3D MODELING



4.1 LASER SCANNING

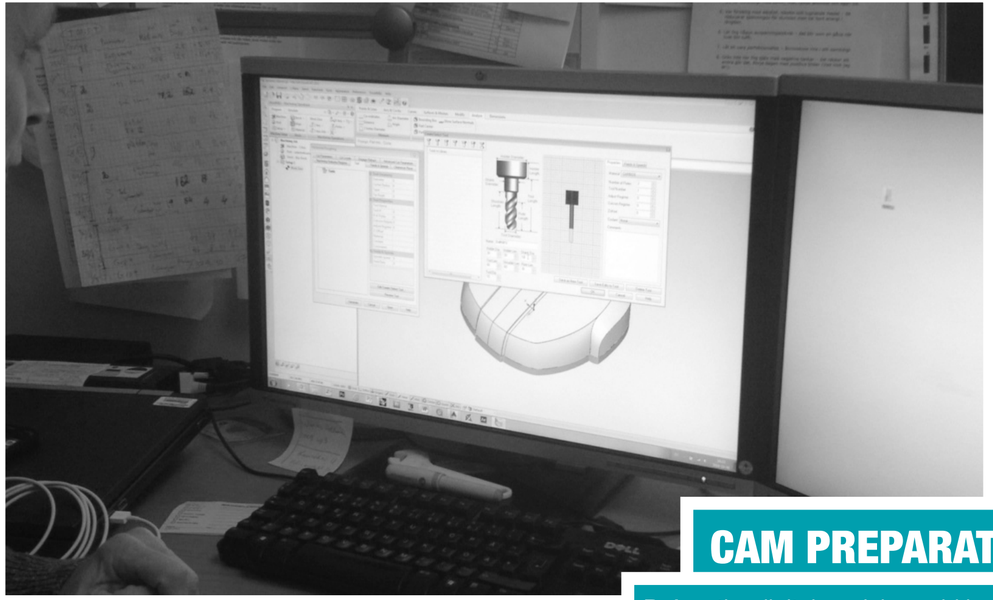
The next step after clay-modelling was to work with CAID software. The purpose was to convert the shape of the clay model to digital data, by importing it in CAID software where the design was developed further.

The clay model was imported to a computer using a laser scanner. The laser scanner is an advanced optical instrument that can measure the surfaces and curvatures of a model. With the help of a reference system consisting of stickered dots put on the model and a plane that the model reseted on, it produced an accurate digital mesh model of the actual clay model shape.



CAD MODELING 4.2

There are several reasons to use the computer in the design process. It is a required step for the computer aided manufacturing, but it is also a great tool to develop the design, creating details and evaluating concepts. The group used the softwares Autodesk Alias and Siemens NX for modeling and Luxion Keyshot for rendering. The digital models were exported for manufacturing by CNC milling and rapid prototyping.



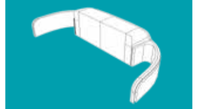
CAM PREPARATION 4.3

Before the digital models could be realized in a physical model, both the CNC and rapid prototype machines had to be prepared. The machines are running a system adapted to their purpose so the digital models needed to be imported in a specific format. When the digital models were imported and the machines set up the physical manufacturing process begun.

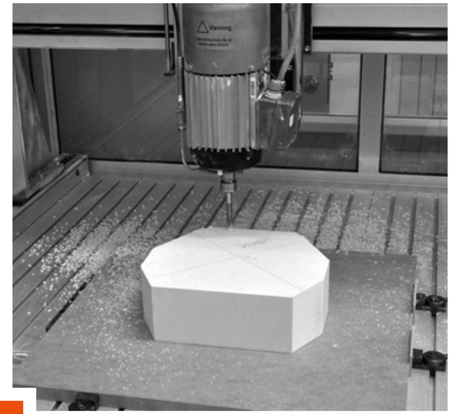
5 MANUFACTURING

5.1 MANUFACTURING PLAN

A manufacturing plan was set up at the beginning of the project to plan every step of the process. Deadlines were assigned to each manufacturing step to assure that the prototype was ready in time. The manufacturing plan also helped the group to know what to do next and to divide the work between the members.

PART	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5
 BOTTOM	Rapid proto-typing with high performance composite. Colour : black	Manual processing. Grinding and polishing.	Paintwork if necessary.		
 BUMPER	Rapid proto-typing with high performance composite. Colour : gray	Manual processing. Grinding and polishing.	Paintwork if necessary.	Assemble with bottom part.	
 HANDLE	Rapid prototyping with high perfor-mance composite. Colour : gray	Manual processing. Grinding and polishing.	Paintwork if necessary.	Assemble with bottom part.	
 MAIN BODY	CNC milling to create a plug for vacuum forming.	Vacuum forming.	Clear from ex-cess material.	Paintwork, colour and texture for matte finnish.	Assemble with bottom part.
 DASHBOARD	Rapid proto-typing with high performance composite. Colour : gray	Manual processing. Grinding and polishing.	Paintwork if necessary.	Assemble with main body.	

PART	STEP 1	STEP 2	STEP 3	STEP 4
 DISPLAY	Opt 1: Vacuum forming. Opt 2: Cut plexi-glass.	Manual polishing on edges.	Display layout in Adobe Illustrator.	Assemble with dashboard.
 BUTTONS	Rapid prototyping with high performance composite. Colour : big button-orange, small buttons- black/gray.	Manual processing. Grinding and polishing.	Paintwork if necessary.	Assemble with dashboard.
GARDENA LOGOTYPE	Opt 1: Badge from Gardena. Opt 2: Cut plexig-lass.	Opt 1: Assemble with dashboard. Opt 2: Manual polishing and flexion of plastic.	Opt 2: Print logotype in colour.	Opt 2: Assemble printed logotype with plexiglass on dashboard.
WHEELS	If necessary: split prefabricated wheels for the right fit.	Assemble with bottom part.		

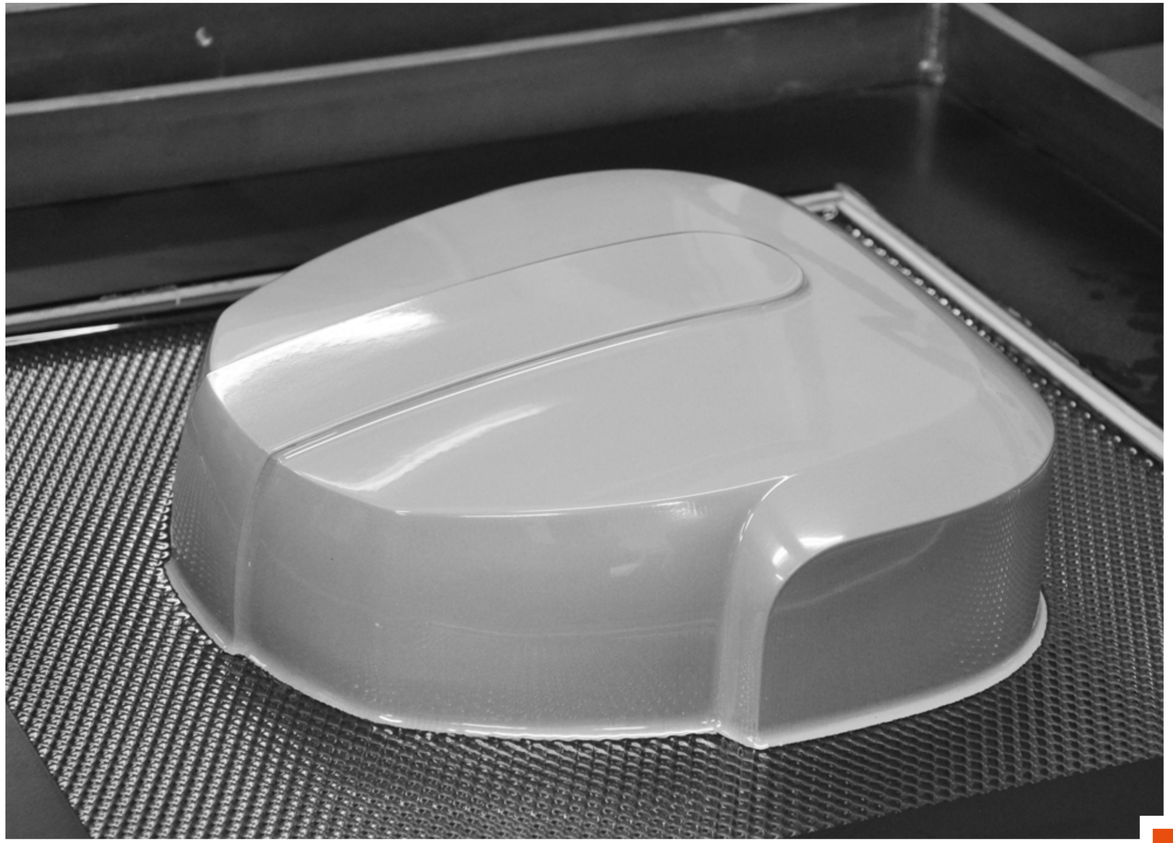


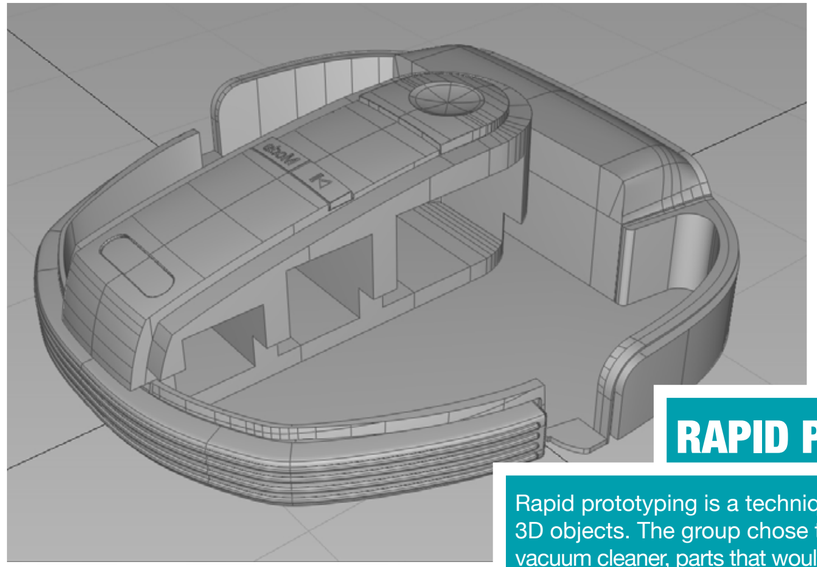
CNC MILLING 5.2

A block of polyurethane foam with the measurements slightly bigger than the CAD model was cut out manually and then mounted into a CNC milling machine. The CAM file was uploaded to the machine and the machine mills down the block to the shape of the CAD model. The polyurethane foam in the shape of the CAD model (the plug) was later used to vacuum form a shell.

VACUUM FORMING 5.3

To form the shell of the vacuum cleaner we used a technique called vacuum forming. The plug that was formed in the CNC milling machine was placed in a vacuum-forming machine. In the vacuum-forming machine acrylic was clamped and heated. When reaching a specific temperature the acrylic was pulled over the plug and all the air between the surfaces was forced out creating vacuum. After cooling, the plug was ejected from the vacuum form.



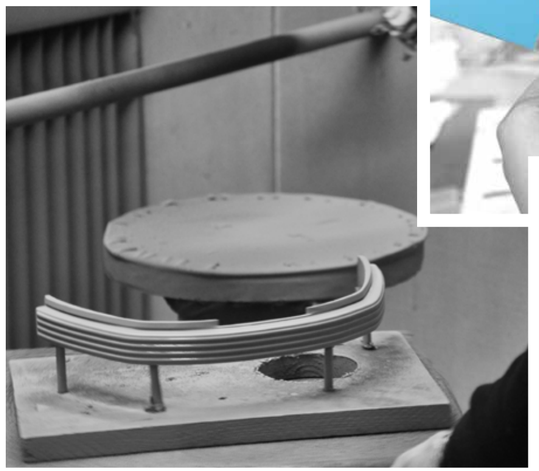


RAPID PROTOTYPING 5.4

Rapid prototyping is a technique that uses a CAD file to print 3D objects. The group chose to print several parts for the vacuum cleaner, parts that would have been difficult to manufacture with the other techniques available. The technique that we used was a plaster printer, which gives solid pieces with a slightly rough surface. The model is formed using a mixture of glue and plaster printed in thin layers. After the objects were printed we treated them with cyanoacrylate to make them harden. The picture above shows the CAD-file and to the right the different printed parts are seen mounted temporary. The parts were printed separately to simplyfy the coloring and the assembly of the model.

COLORING 5.5

The coloring process was comprehensive including a lot of testing and discussions about how to combine the Gardena colors. The aim was to keep the typical Gardena colours and combine them into a similar Gardena look while at the same time express an “indoor-product-feeling”. Several colour tests were made to find not only the right colors but also the right finish and texture for the details.



DETAILS AND ASSEMBLY 5.6

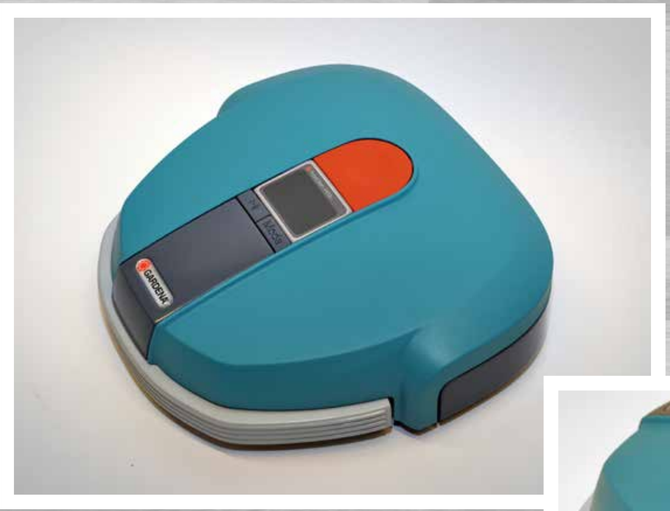
When producing the different parts for rapid prototyping we made sure that they would fit properly. In the early stage of CAID, an assembly structure were made to facilitate the fitting of the parts. A ”spine” in the baseplate and ”tracks” in the connecting details were made to ensure that the parts would always be centred on the bottom plate while still be able to slide back and forth to secure a ”perfect” fit. The shell had to be processed after vacuum forming to fit the connecting parts, this was made by sawing and sanding it with hand tools. Two different methods were tested when making the display. Vacuum forming made a softer looking display with bent corners, while a cut out plexiglass gave a sharper expression. The vacuum formed display was chosen for the final prototype.

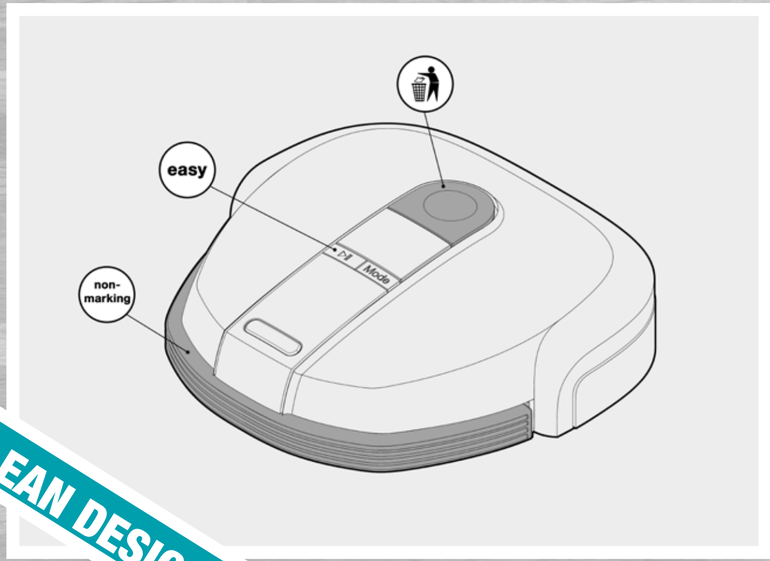
6 FINAL DESIGN

Cleaning does no longer mean effort, Gardena RoboClean 4400 Li will do the hard work for you! The robotic vacuum cleaner features an easy user-interface with only two buttons. One play/pause-button to start and stop the cleaning operation, and one mode-button to select different cleaning modes. The different modes could be path-patterns for the vacuum to follow, or time-based programs that the user has pre-selected. The vacuum is equipped with a 3-inch display to show current battery-and dust-level as well as the current cleaning mode.

A bumper in the front of the vacuum cleaner senses when an object is in its path and the vacuum will then automatically change direction. To empty the dust-container the user will simply press the orange button located on the top, which opens the shell The RoboClean 4400 Li also features a convenient grip for easy handling.

CARE WITH HANDLE.





CLEAN DESIGN

7 REFLECTIONS

The manufacturing plan has been a great tool and allowed the team to create a good structure for the work. Deadlines have been kept and even ahead of sometimes, letting us try different ideas and variations.

Both tutors and classmates have given a lot of feedback during the course; this has been an important input for the development of the design. Particularly when choosing the final design, the class and teachers opinions on the different designs helped to make a final decision.

We decided to start off with building a CAD model in both Siemens NX and Autocad Alias to try out which software was best suited for our model. Both programs have different strengths and weaknesses and in the end we exported the main shape of the model from NX to Alias. Problems with tolerances occurred because of this, which made it hard to make the models into solid objects in Alias.

During the design process, a lot of Gardena products were being analysed to find the correct material, textures and colors. At an early stage we felt the need to try some coloring and spraying techniques to imitate the Gardena products. We spent a lot of time testing, discussing and comparing textures and colors to the original products several times to get the right look on the final model.

WE WANT TO THANK

Dennis Pettersson, *Professor - Innovation and Design*
For tuition and feedback during the project.

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For guiding us through the techniques of clay modelling.

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For giving us the Gardena graphic guidelines and a logotype.

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