SUMMER 2021

PROJECT
GIRLSINSTEM

Highway to creativity in STEM

TOOLKIT

REVERSE ENGINEERING TOOLKIT

STEM-ACTIVITIES FOR YOUTH

Version 1.4, October 2023

This instructable was developed by De Creatieve STEM for Girls in STEM within the European ERASMUS+ Programme no. 2019-3-BE05-KA205-002788.

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REVERSE ENGINEERING

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GIRLSINSTEM

The EU project

The aim of this project, funded by the European Commission through the Erasmus+ programme, is to empower girls to pursue their interests in Science, Technology, Engineering and Maths (STEM) subjects.

The project will provide young girls and women with support and opportunities to experience the potential of studying STEM subjects and embarking on a fulfilling career in these disciplines.

The project has 4 main actions.

The project team will develop three toolkits for educators, focusing on three subjects; reverse engineering, e-textiles and digital art. These toolkits will provide all the information and resources for educators to be able to facilitate activites with young people on these subjects, in their own environments.

These toolkits will form the basis of three bootcamps which will take place during 2021. These are international bootcamps bringing together young girls and women from across Europe. Each bootcamp will focus on one subject and provide the opportunity for participants to engage with the activities being developed.

The project will also lead a mentoring programme for young females to deepen their knowledge for one specific STEM area. The programme will be implemented in partnership with local NGOs, enterprises and institutional environments, where volunteers from such organisations can accompany the youth to discover more about the areas they work in.

Find out more about the project through the website at:

www.girlsinstem.eu

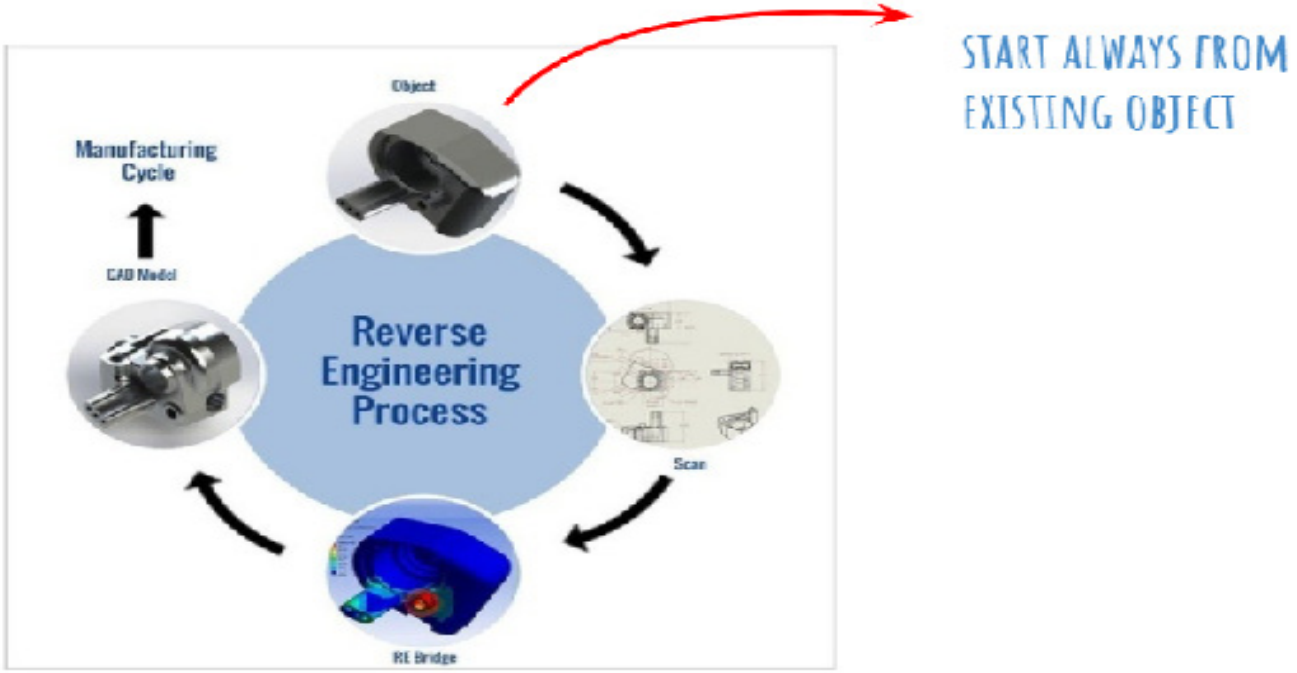
REVERSE ENGINEERING

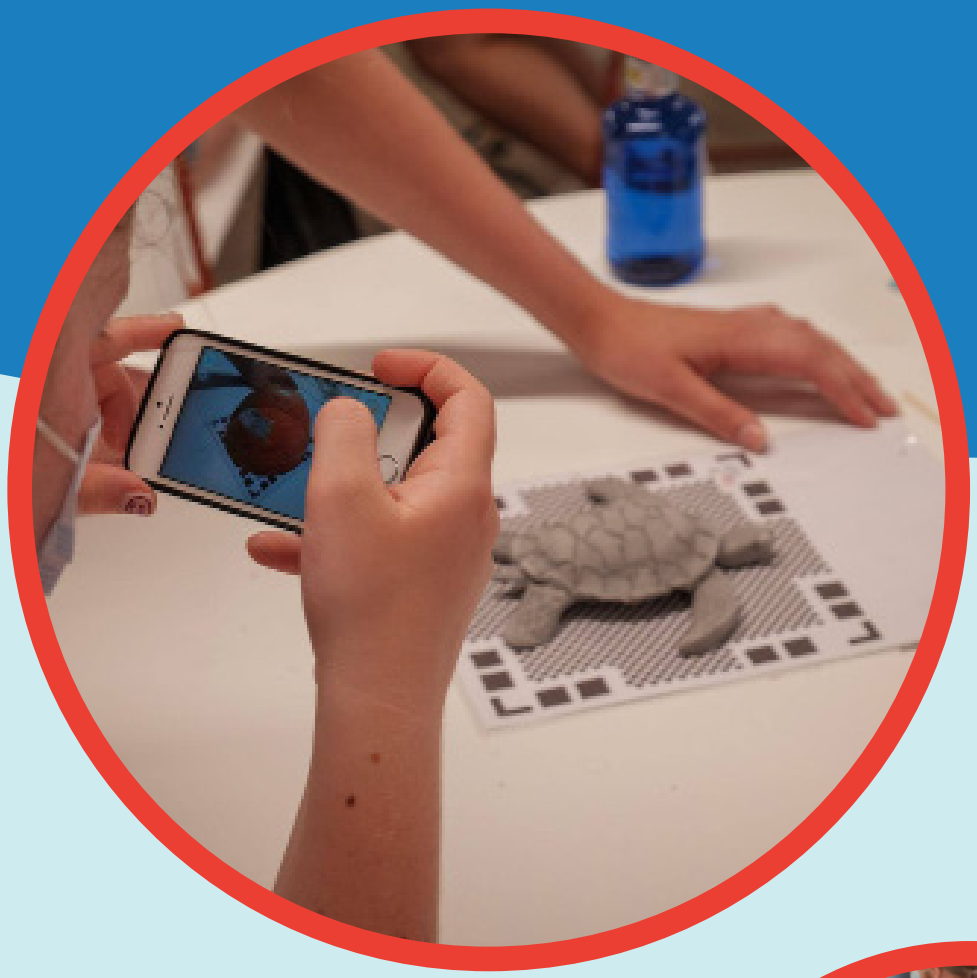
Introduction in RE

Reverse engineering is also known as back engineering, the goal is to obtain information to be able to reproduce a product

A reverse engineer works "backwards" from the original design process:

- Start with the end result
- Deconstruct the product
- Carry out assessments and measurements
- Obtain (physical) design information





3D SCANNING

A STARTER GUIDE

GIRLS in stem

4

WHAT IS 3D SCANNING?

The basics

3D scanning is the process of collecting 3D data of an object's shape and appearance. These data are then used to create a digital 3D model of the object. Essentially, 3D scanners create a digital copy of a real-world object. This digital copy or the 3D file can then be used for different purposes.

Photo: best 3D Scan

3D scanning is a great way to easily obtain files for 3D printing or for use in a digital environment like AR (augmented reality).

Generally, nowadays engineers are using this technology for reverse engineering processes. 3D scanner files are generally compatible with CAD software and 3D printing slicer software. In a scan, a network of points is measured and converted to an STL file, which is the common file format for 3D printers. The STL files can then be further edited and 3D printed as per the user's requirements.

Reverse engineering is paramount to multiple industries such as manufacturing, automotive, aerospace, and in a wider sense, even areas such as healthcare. It has a broad range of applications, including product improvement and reconstruction, design augmentation and many others.

Effortless export of 3D models from scanning and post-processing 3D software to a variety of widely used CAD and CAM programs allows users to easily analyse the data and perform further operations for reverse engineering a product or part.

3d-scanning fits within the framework of reverse engineering!

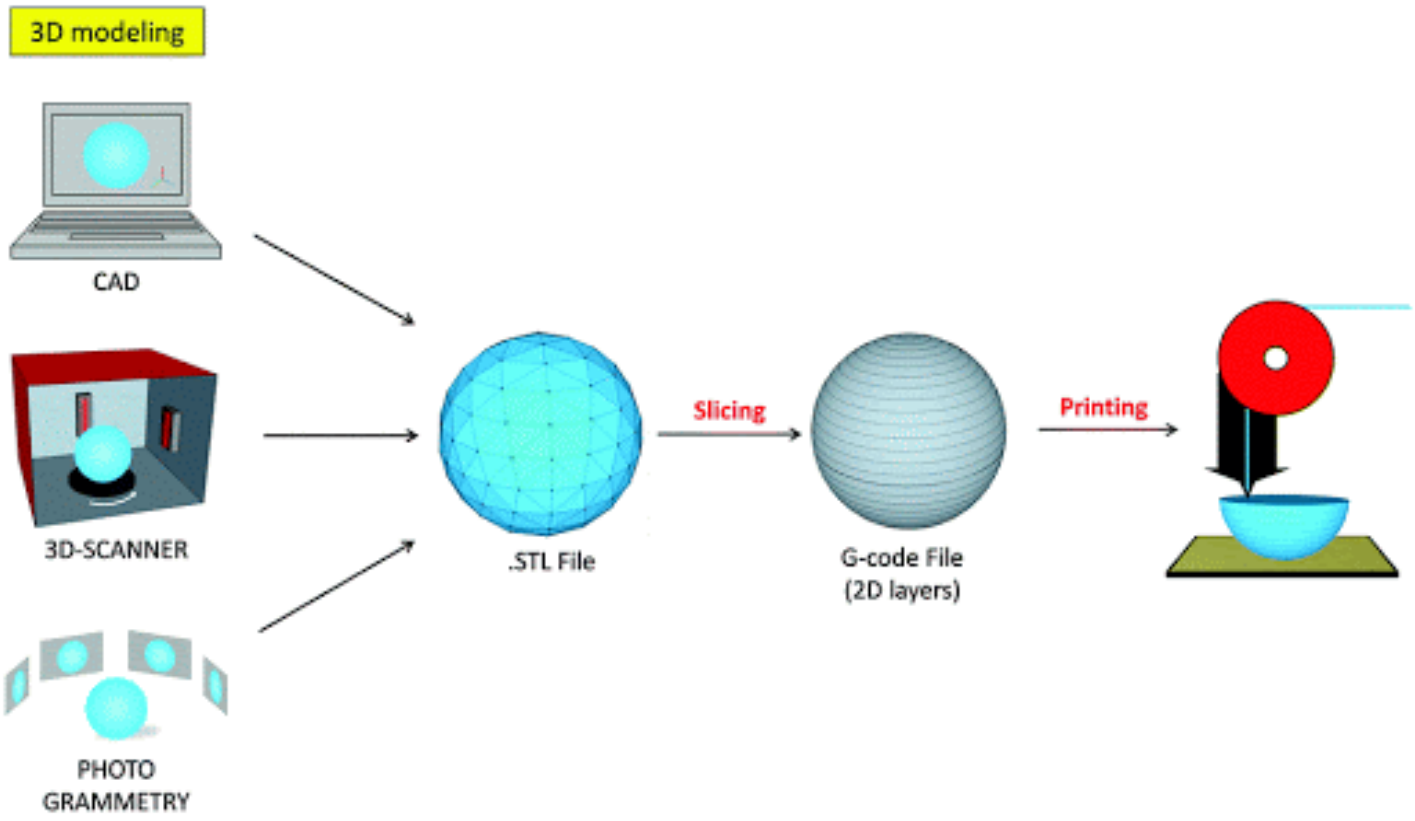
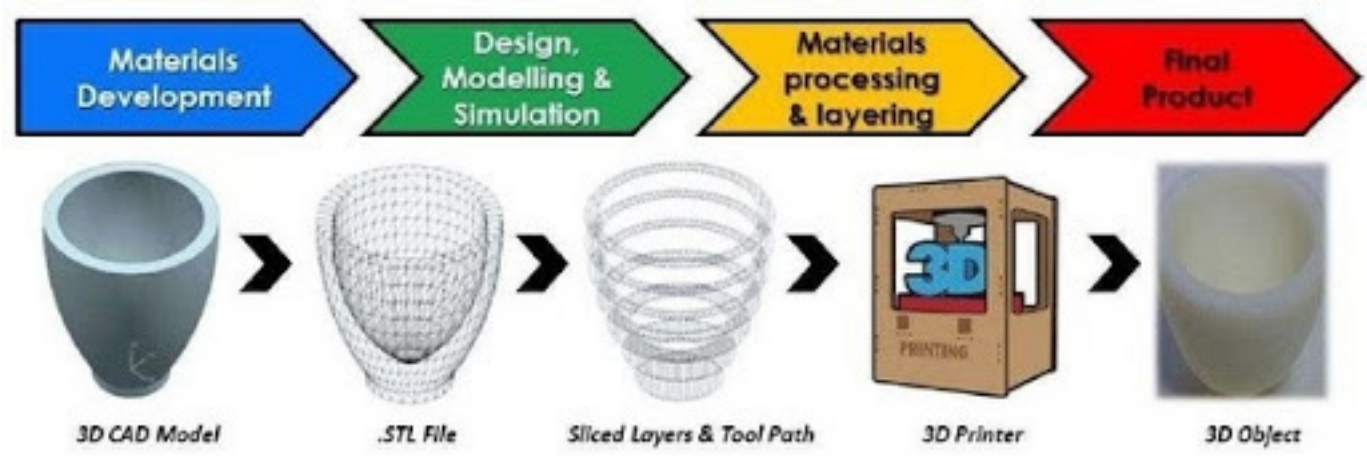


Photo: 3D print starting from a CAD design or from 3D scanning

3D SCANNING

Techniques

In a classical method of production, a model is first digitally built and then fabricated



Thanks to the rapid technological progress, it is now also possible to make a 3D scan with a smartphone. This digital file can be used to update and reproduce the parent object.

There are different types of 3d scanning methods and principles they are based on. We list here two of them.

1. LASER TRIANGULATION 3D SCANNING TECHNOLOGY.

Laser-based 3D scanners use a process called trigonometric triangulation to accurately capture a 3D shape as millions of points. Laser scanners work by projecting a laser line or multiple lines onto an object and then capturing its reflection with a single sensor or multiple sensors.

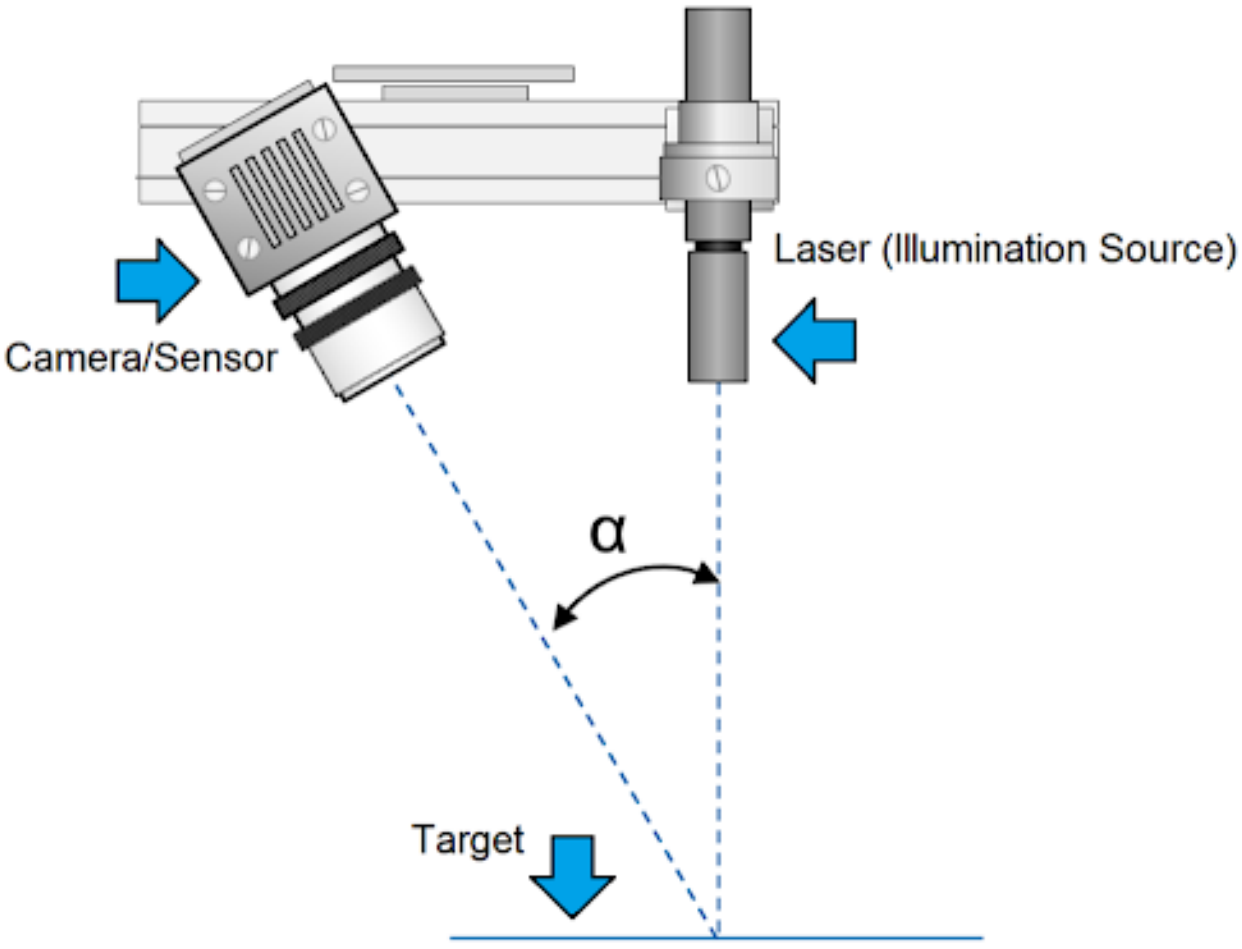


Photo: Movimed, 3/2021

The sensors are located at a known distance from the laser's source. Accurate point measurements can then be made by calculating the reflection angle of the laser light. Laser scanners are very popular and come in many designs.

2. PHOTOGRAMMETRY.

This technology is quite simple. It involves stitching together photographs of an object taken from different angles. The photos are taken using a camera or even your smartphone with specific camera settings, while the stitching of those photos is done by special software. The software identifies pixels that correspond to the same physical point and brings pictures together accordingly.

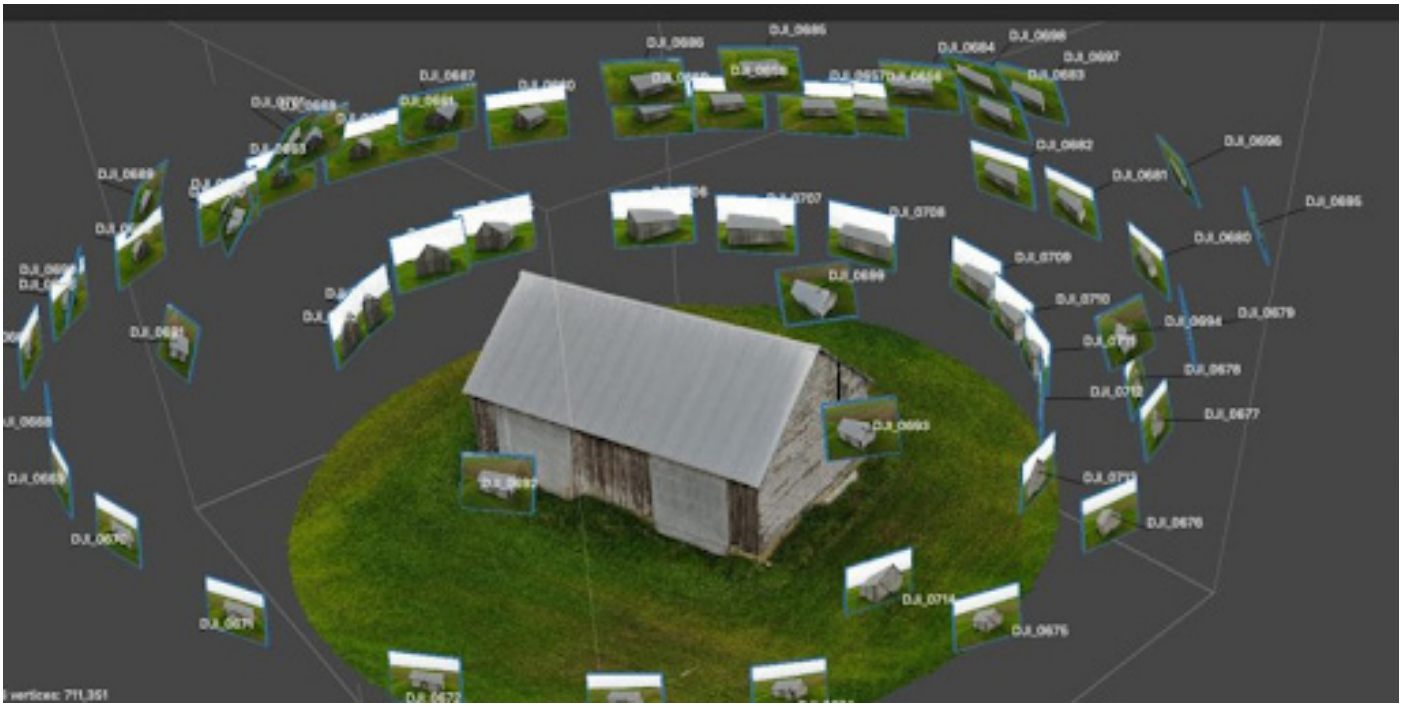


Photo: Bitfib, 3/2021

Parameters like the focal length of the lens and its distortion need to be fed into the software by the user to create an accurate model. Photogrammetry is so simple that you can pick up your phone right now and start taking pictures.

The big advantage of using photogrammetry is its accuracy level and the speed with which the data of an object is acquired. The downside with this technique is the time it takes to run the image data through the software and the sensitivity of the end result to the resolution of the photographs. You need to have a good camera with high resolution and DPI (dots per inch) to get a good end result.

3D SCANNING

Applications

3D scanning is not only used in the manufacturing and design sector, but also in the film industry. Just think of CGI images where actors wear a special suit to convert their real movements into a digital file that can then be edited.

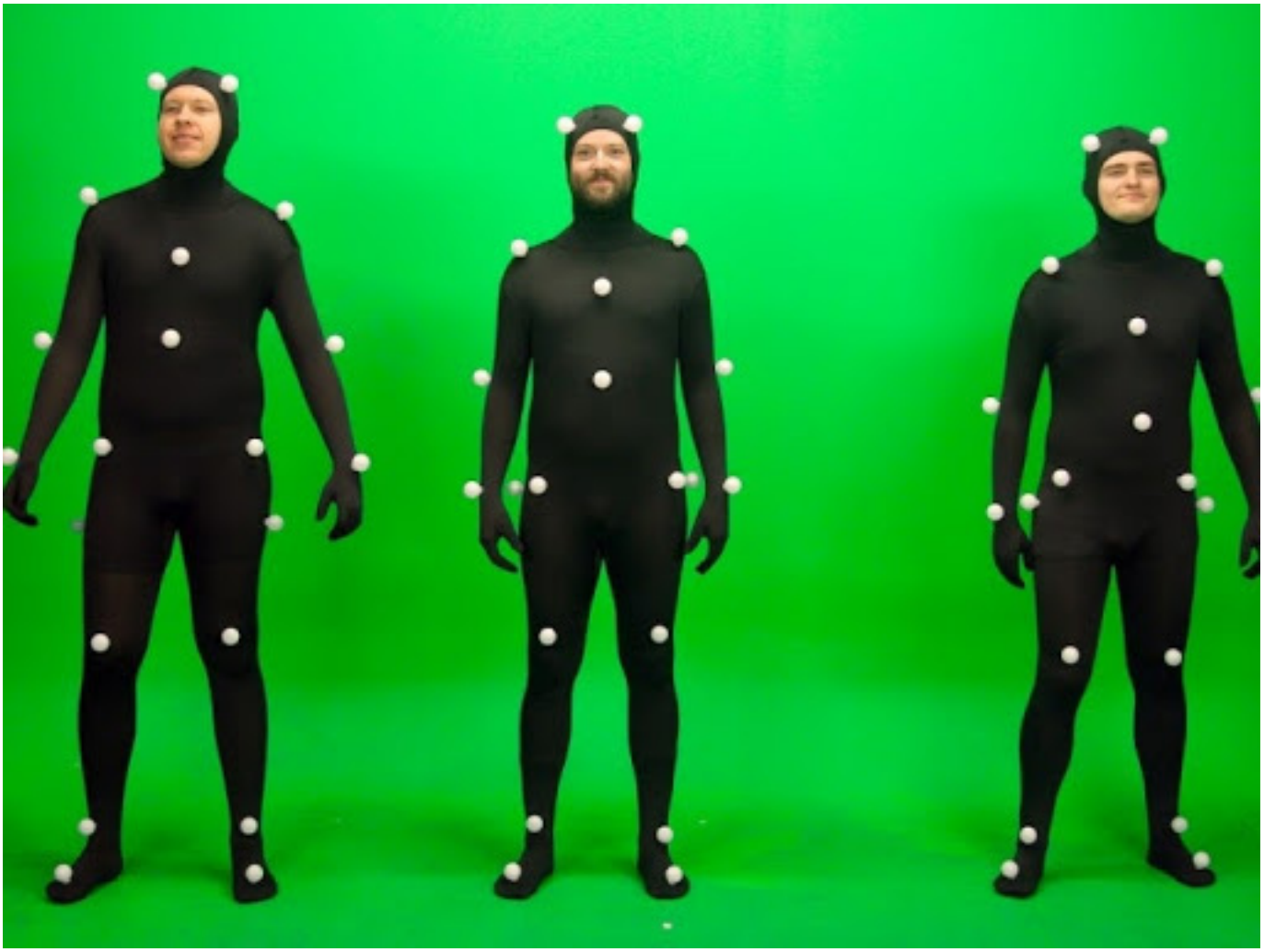


Photo: Bitfib, 3/2021

MUSEUMS

3D scanning is widely being used in museums. Perfectly identical, true-to-scale or scaled copies of ancient artefacts to preserve and to teach without risking damage to a priceless item.

MEDICINE/HEALTH

3D scanning enables the design and production of prosthetics. Coupled with 3D printing, this process results in a fraction of the time and cost of traditionally used methods.

Photo: all3D, 3/2021

ENGINEERING

The ability to scan any object and then use CAD for modification makes both reverse engineering and rapid prototyping an extremely streamlined process. Detailed measurements can be performed and investigation in to mechanical properties is simplified.

SCIENCE/RESEARCH

3D scanning permits the detailed study of any object. At any one time, research fellows around the world are studying an infinite array of materials. From advanced topography to optical measurements and archiving, the introduction of 3D scanning opens up a lot of possibilities.

AUGMENTED REALITY (AR)

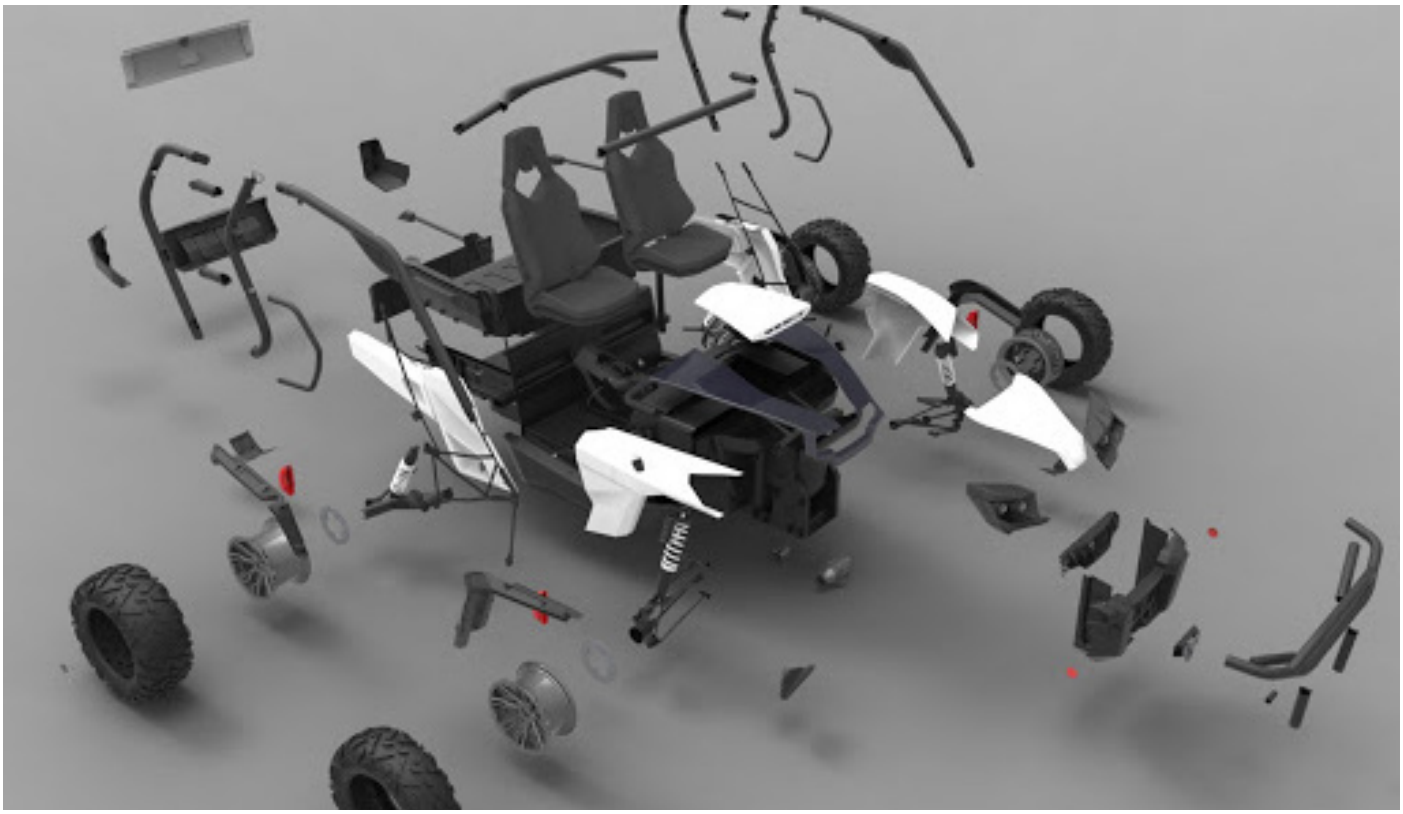
The use of a 3D scanner creates an unparalleled sense of accessibility and customization when it comes to creating assets for AR. Developers can import an exact representation of the item they want to import into the app bypassing the painstakingly 3D design work completely.

Creating assets for augmented reality from scratch can be indeed an arduous process. Typically, it starts with a 2D sketch, then an artist spends many hours using design software to convert that 2D image into a 3D asset, which is then imported for use in the AR app.

Whatever the application, remember that 3d scanning is not a goal in itself but a technique used when 3d modeling via CAD techniques gets too complicated or cumbersome.

3D SCANNING X RE

Speeding up reverse engineering



Contrary to manual methods and other 3D measurement technologies, portable 3D scanners significantly speed up the reverse engineering process.

- Firstly, they are quick to set up and can often be used right on the production floor.
- Secondly, 3D scanners can capture millions of data points per second. Depending upon the part, a user can achieve a scan to mesh in seconds. The speed of 3D scanners can greatly accelerate a manufacturer's reverse engineering workflows.
- Thirdly, 3D scanners are highly accurate - regardless of the complexity of a part's geometry or surface finish. This eliminates not only human error often associated with manual measurements but also inefficient back-and-forth data acquisition and lengthy interpretation of results.

SMARTPHONE

A pocket-sized 3D scanner

SCAN-TASTIC!

A 3D scanner app can turn almost any smartphone into a pocket-sized 3D scanner. 3D scanning apps are based on photogrammetry, a 3D scanning technology that creates 3D models out of 2D photos.

You take pictures of an object from different angles and then a software "stitches" the images together. This technology allows you to turn your smartphone into a 3D scanner.

With a 3D scanning app, you can 3D scan objects, rooms, and can even be used for 3D body scanning. You can use a 3D scanner app to create 3D objects for augmented reality. It's also possible to create 3D models for 3D printing.

There are different possibilities to choose from, here a list (in alphabetical order) of possible apps for Android & Iphone.

Application	Country	Price	Operating System	Extra hardware needed
3DSizeME	Canada	Free	iOS	Yes ($379)
3D Creator	Sweden	Free	Android	No
Canvas	United States	Free	iOS (iPads only)	Yes ($379)
Capture: 3D Scan Anything	United States	Free	iOS (iPhone X)	No
ItSeez3D	Russia	Free	iOS (iPads only)	Yes ($379)
Qlone	Israel	Free	iOS/Android	No
Scandy Pro	United States	Free	iOS (iPhone X)	No
Scann3D	Hungary	Free	Android	No

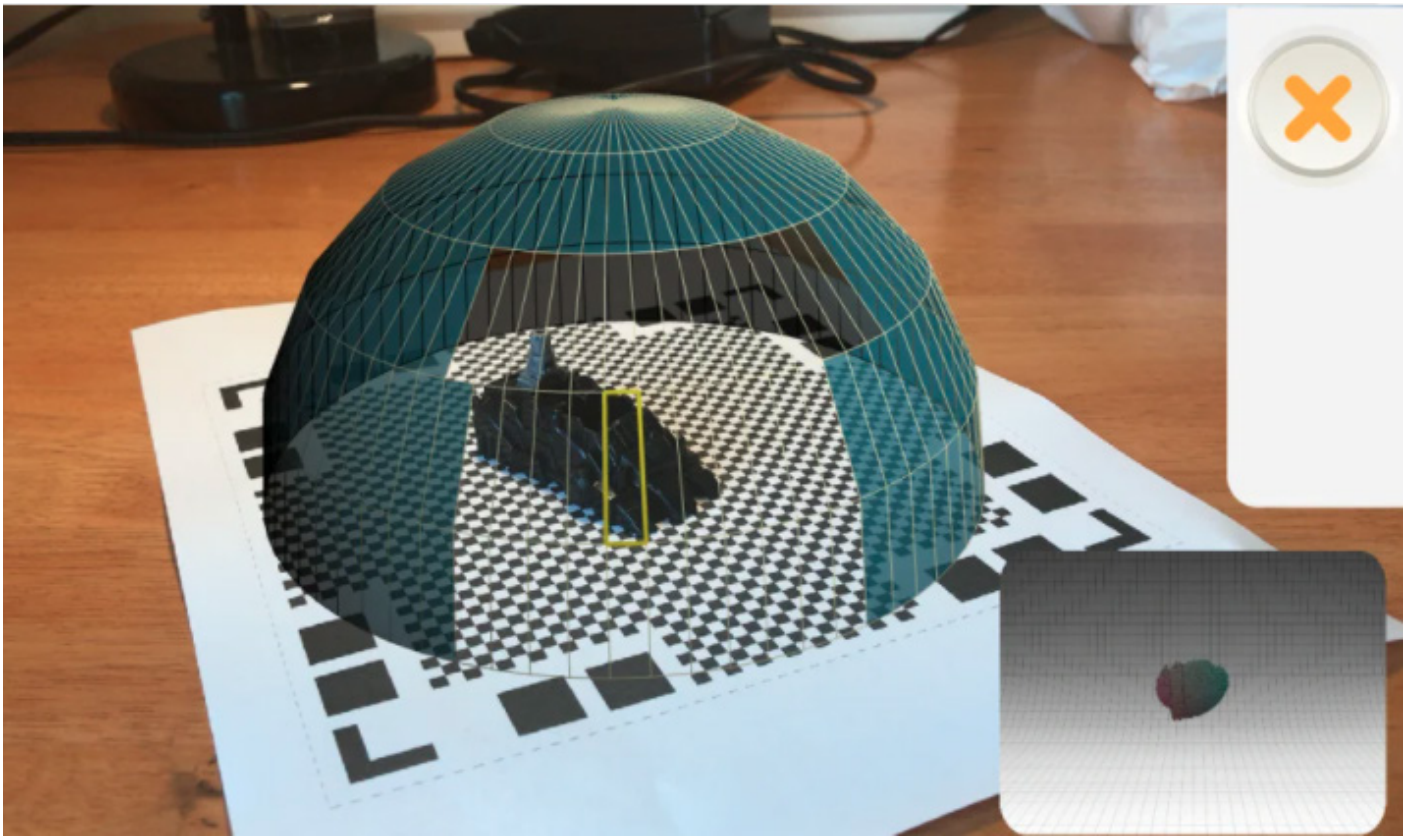
QLONE

3D scanning with Qlone

3D SCANNER APP FOR ANDROID & IPHONE

In this tutorial you will learn how to 3D scan objects using Qlone (pun on clone), an application for android and iphone.

Beware that Qlone requires you to pay for each export. Alternatively you can purchase a subscription that grants you unlimited exports over a limited period of time.



NEEDED

- Qlone: https://www.qlone.pro/, download it from googleplay on your mobile phone.
- Smartphone
- Qlone mat
- Qlone vertical back mat (optional)
- Object to scan and/or play dough

GOOD TO KNOW BEFORE YOU START

- Cost: Freemium, that is free for basic use (no export of files possible) and 10 euro for the pro version that allows you to export an unlimited amount of files.
- Exporting GIFs, videos, images, and to Sketchfab and social media is free but exporting an OBJ or STL file isn't free. You can either pay per file or buy the pro version for unlimited exports as mentioned above.
- Platforms: iOS (9.0 or later), Android (7.0 and up)
- Quality: the files are not very precise but it is a good option for beginners and hobbyists
- Target users: 3D printing enthusiasts, STEM educators, AR/VR content creators, eCommerce showcasers

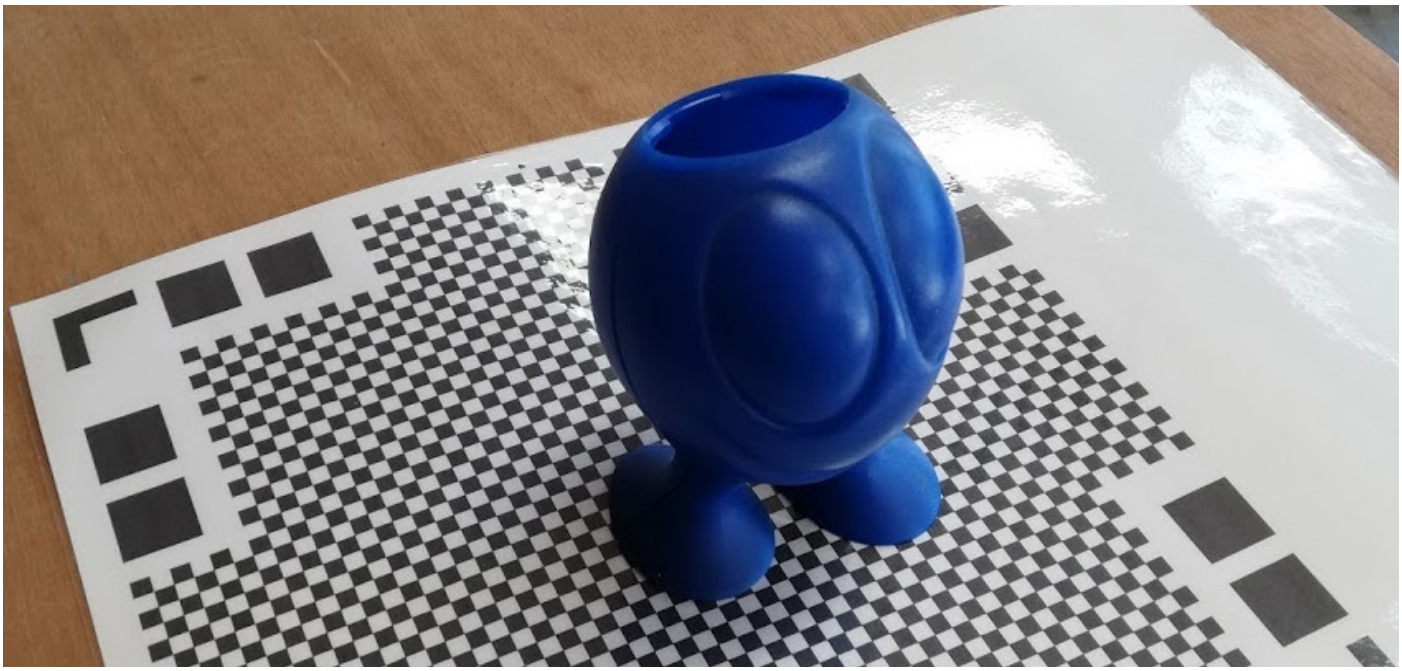
STEPS

1. Print out the Qlone mat

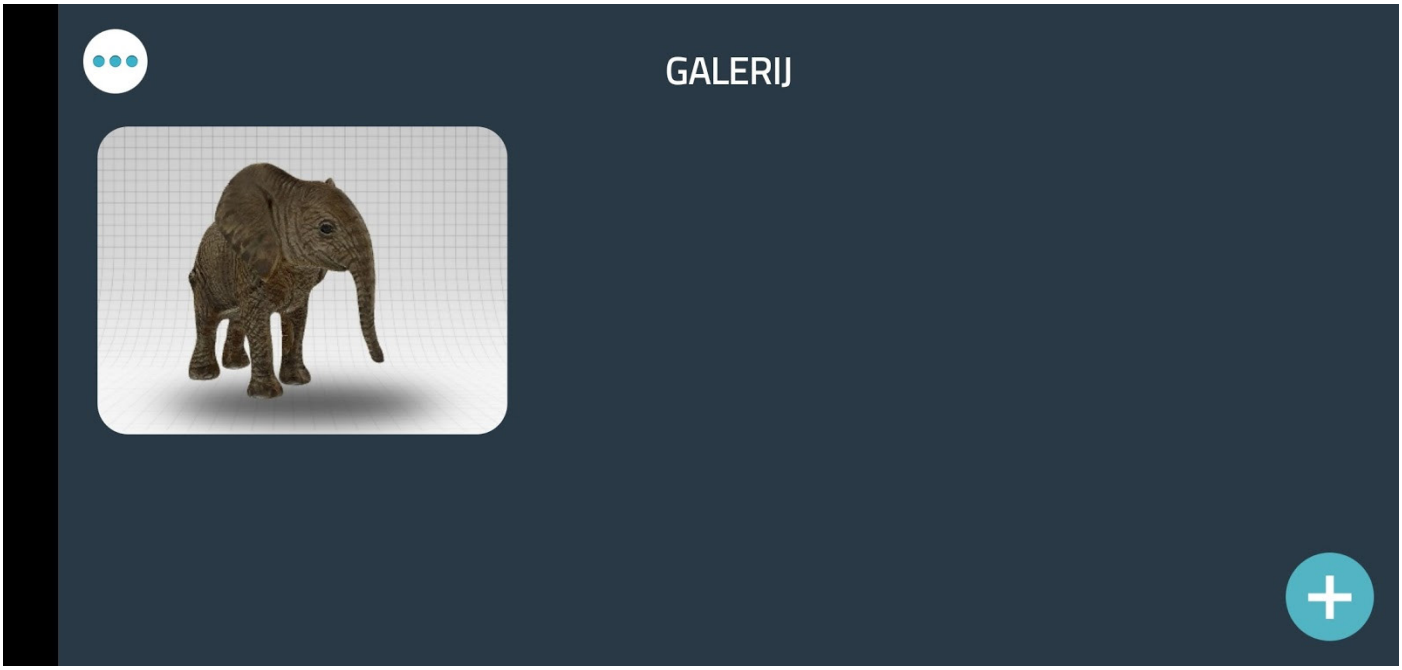
(Either download and print via de link, or print the image in the last page of this document).

You can print it in A4 format or bigger if you wish to scan bigger objects. As a rule of thumb: the mat should be 1.5x the size of the object .

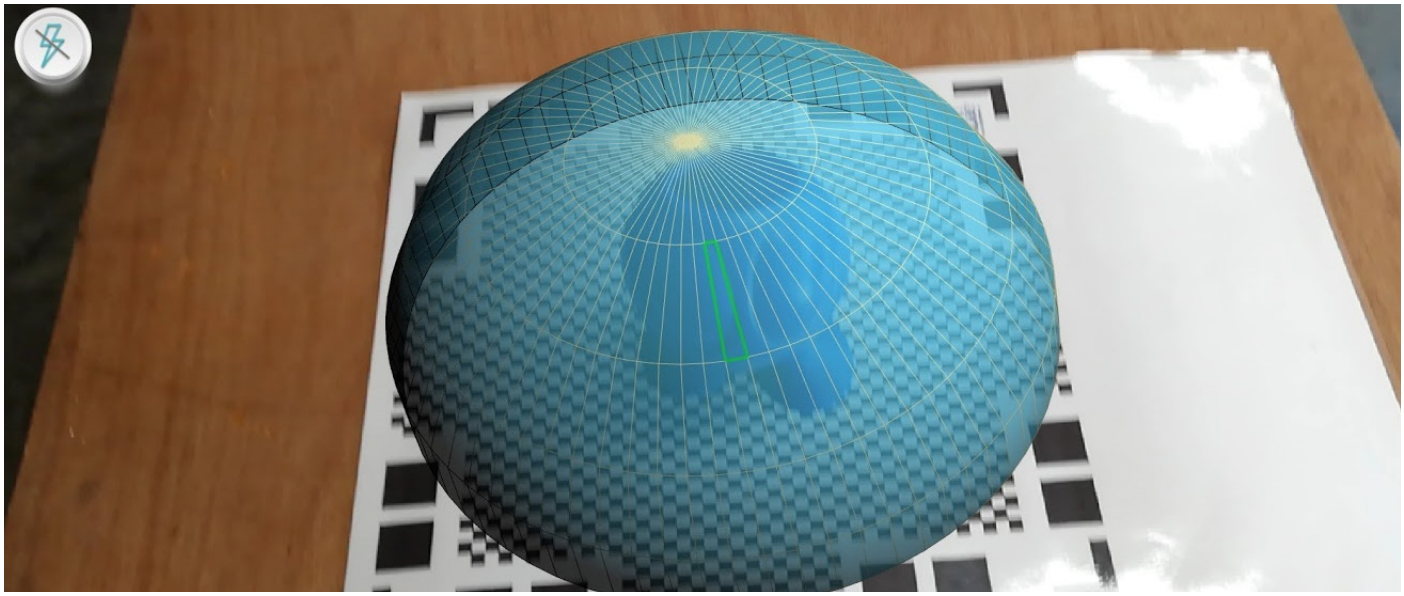
2. Place the object you want to scan on in the middle Qlone mat.



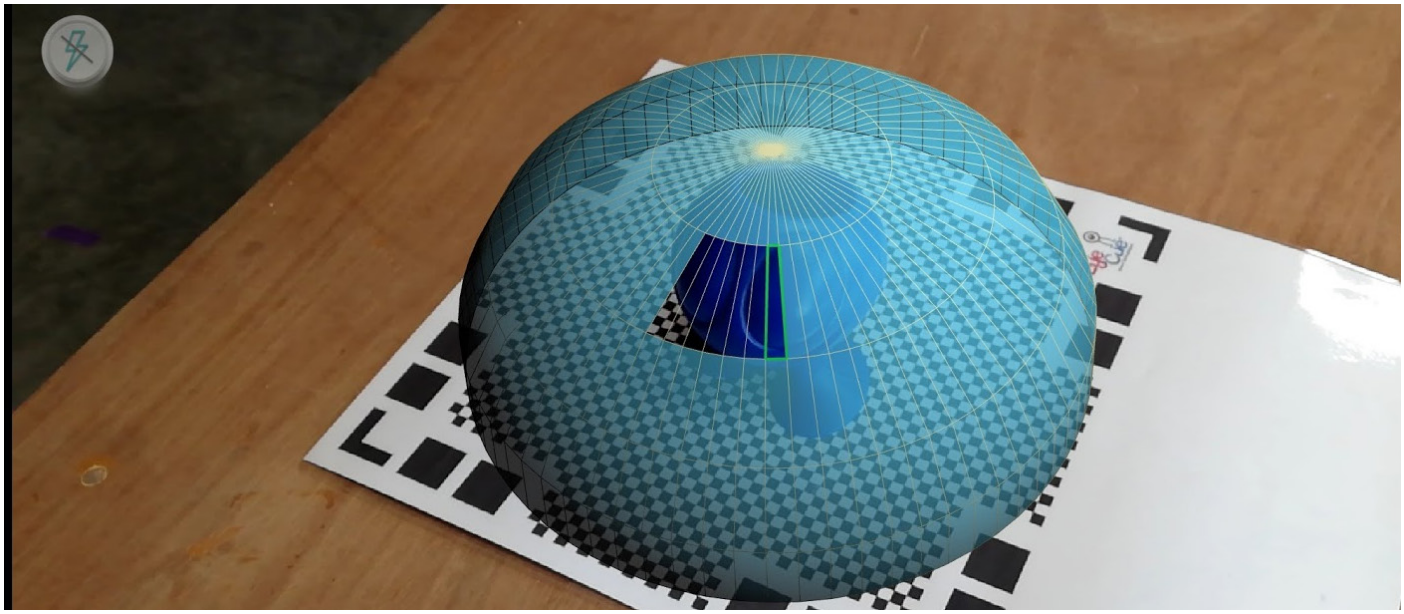
3. Launch the application on your smartphone. Click on + to start a new file.



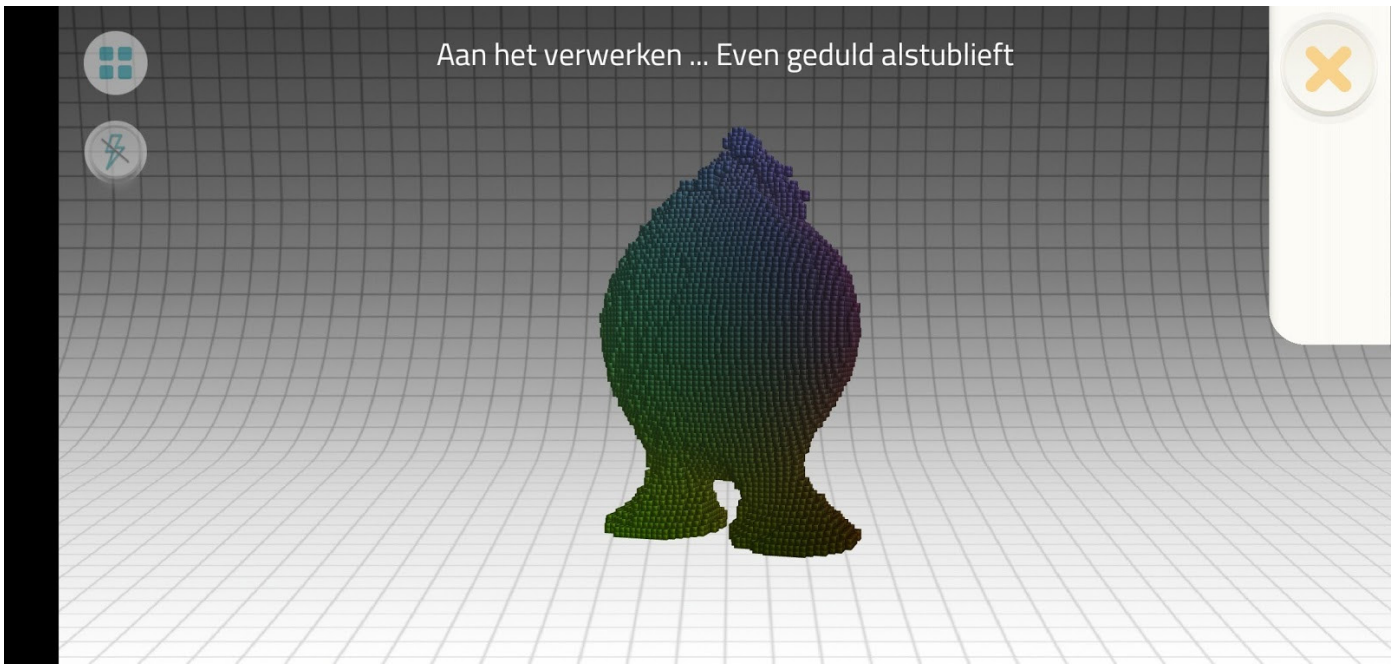
4. Move your phone so that the app will detect the mat: the blue AR dome will appear around the object.



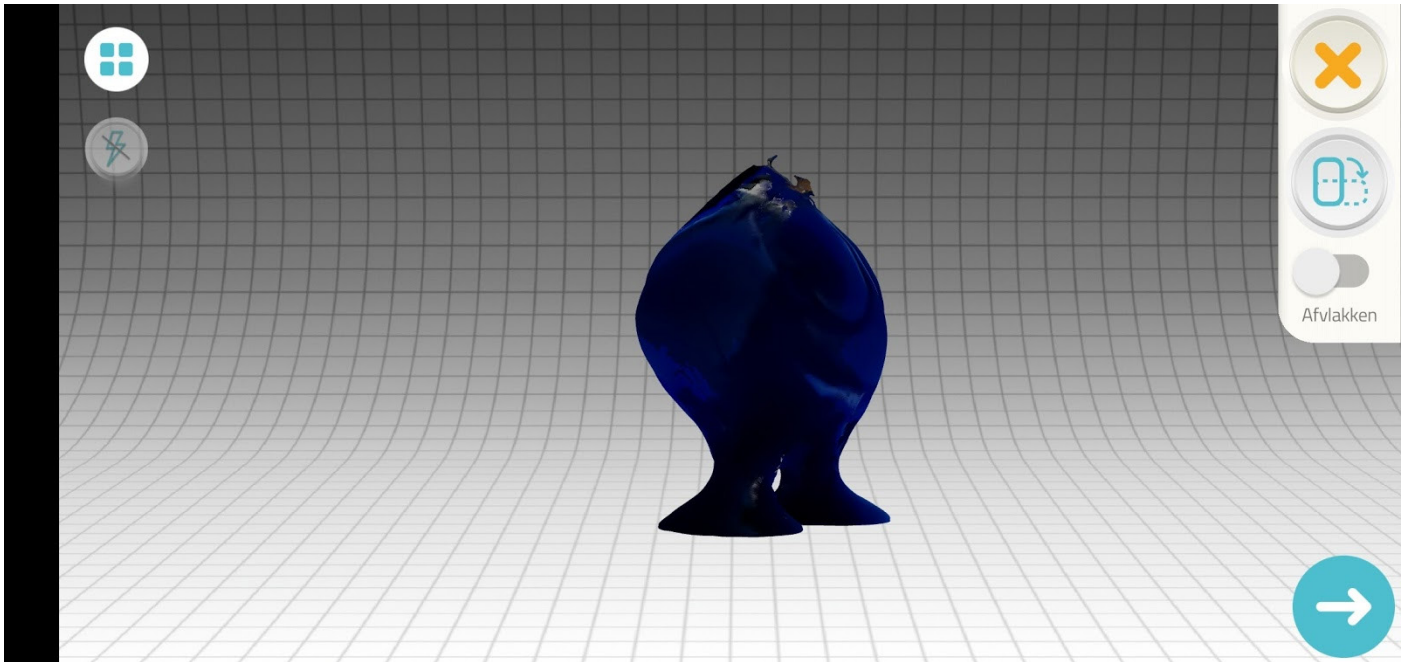
5. Once you see the blue dome, scanning is simple: you simply press the plus button and then move your phone or the object around until the AR dome is clear (the blue disappears).



6. The software will render the model.



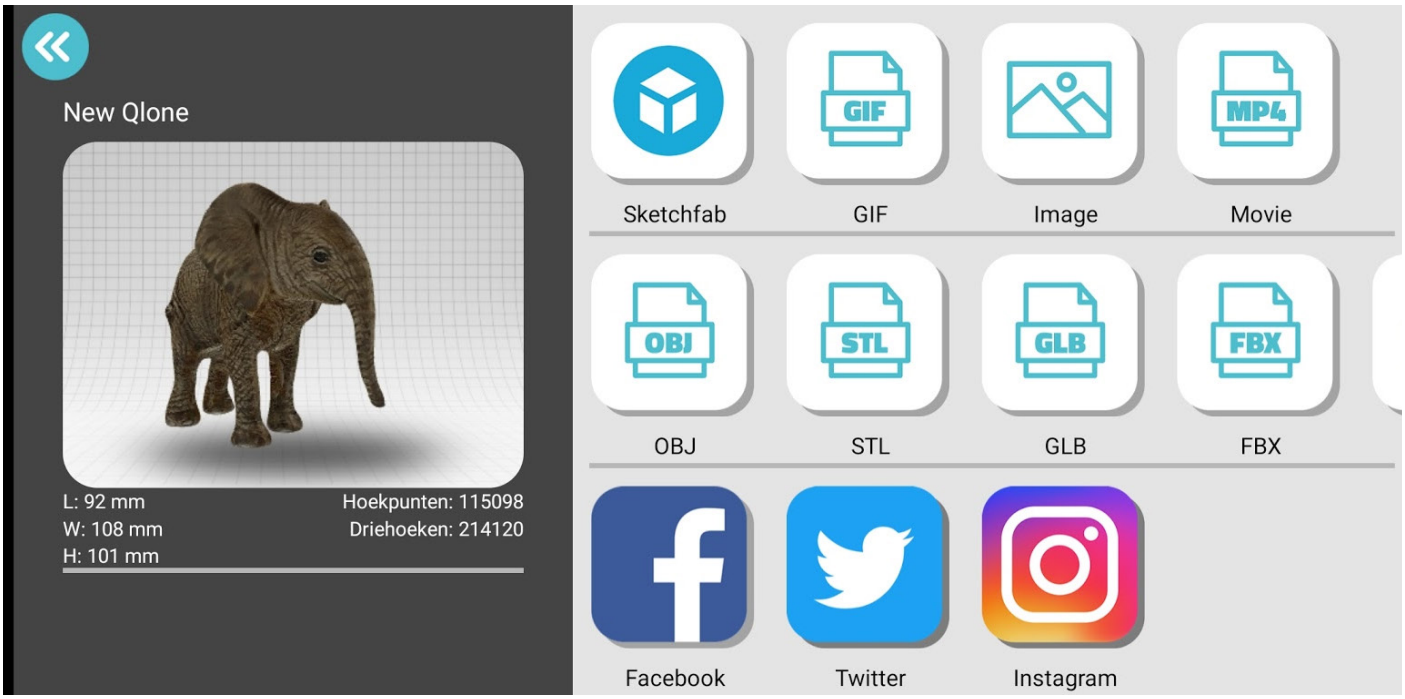
7. Wait until the rendering is ready and click on the blue arrow to see the result in 360 .



8. Now, you can export the scan in the right format and share it with others or you can export the scan to use for 3d printing or AR applications.

Export for 3d printing or AR. We use 2 different formats:

- .STL for 3D printing
- .GLB for augmented reality.

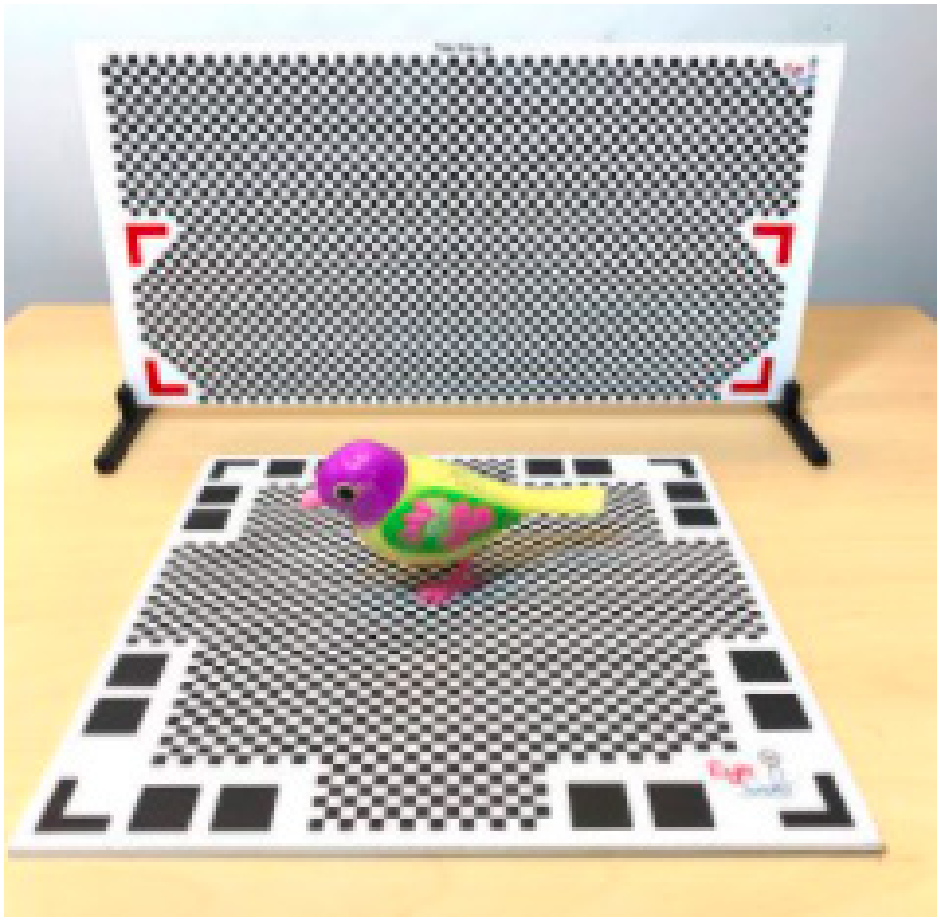


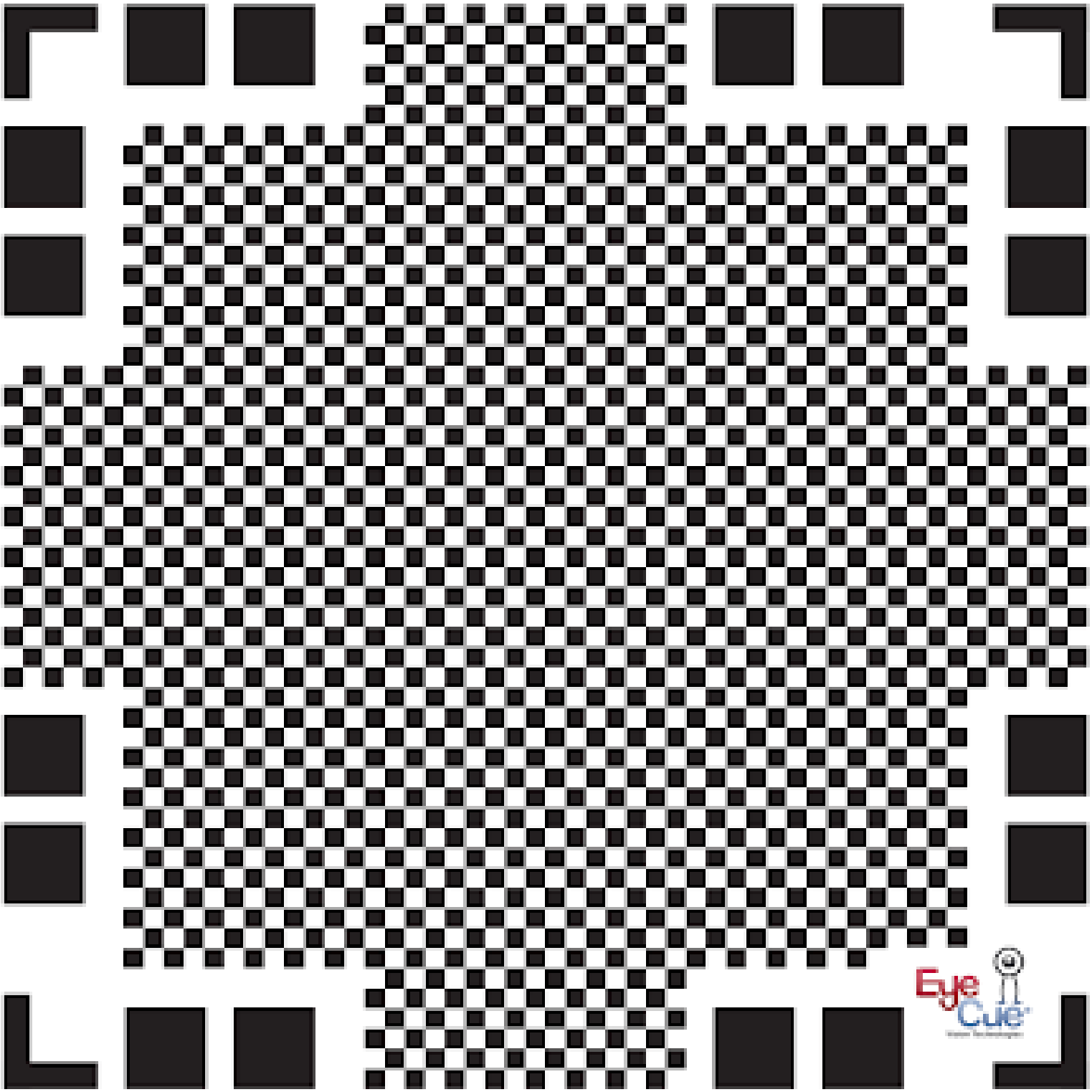
FOR GOOD TIPS AND GOOD BEST PRACTICES WATCH

- Tips: https://www.youtube.com/watch?v=WAvWqTzmylM
- Best practices: https://www.youtube.com/watch?v=NdHue7EmHXM

AND KEEP IN MIND

- Mat should be 1.5x the size of the object
- Good lighting is key
- Rotate the mat instead of moving the phone around
- Select the best settings for the object material
- Consider the use of a vertical back mat





SCANECT

3D scanning with Scanect

With Skanect (https://skanect.occipital.com/), capturing a full color 3D model of an object, a person or a room is easy and affordable.

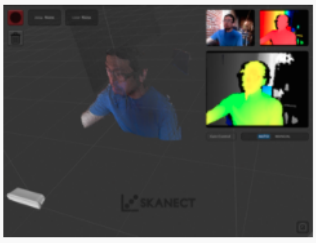
Skanect is a free program for 3D scanning but it also comes in a premium version and it gives great results for scanning people or large objects.

Before you start, good to know.

Features

End-To-End 3D Scanning

3D Capture



- Recording presets for body, object and room scanning
- Live feedback in low-, medium- or high-quality
- CPU- or GPU-accelerated reconstruction
- Record timer & countdown
- Full-scan or keyframe-only recording

3D Processing

- Model simplification
- Hole filling & watertight mesh generation
- Scaling & rotation
- Plane cropping for optimal 3D prints
- Colorization (with optional inpainting of unseen areas)
- Small parts removal

3D Sharing

- PRO Save full-resolution models (Free version limited to 5000 faces)
- Export to most popular 3D software and 3D printers that use .STL, .OBJ, .PLY, .VRML
- Per-vertex coloring (.OBJ, .PLY & .VRML file formats)
- Direct upload to Sketchfab and Shapeways

NEEDED

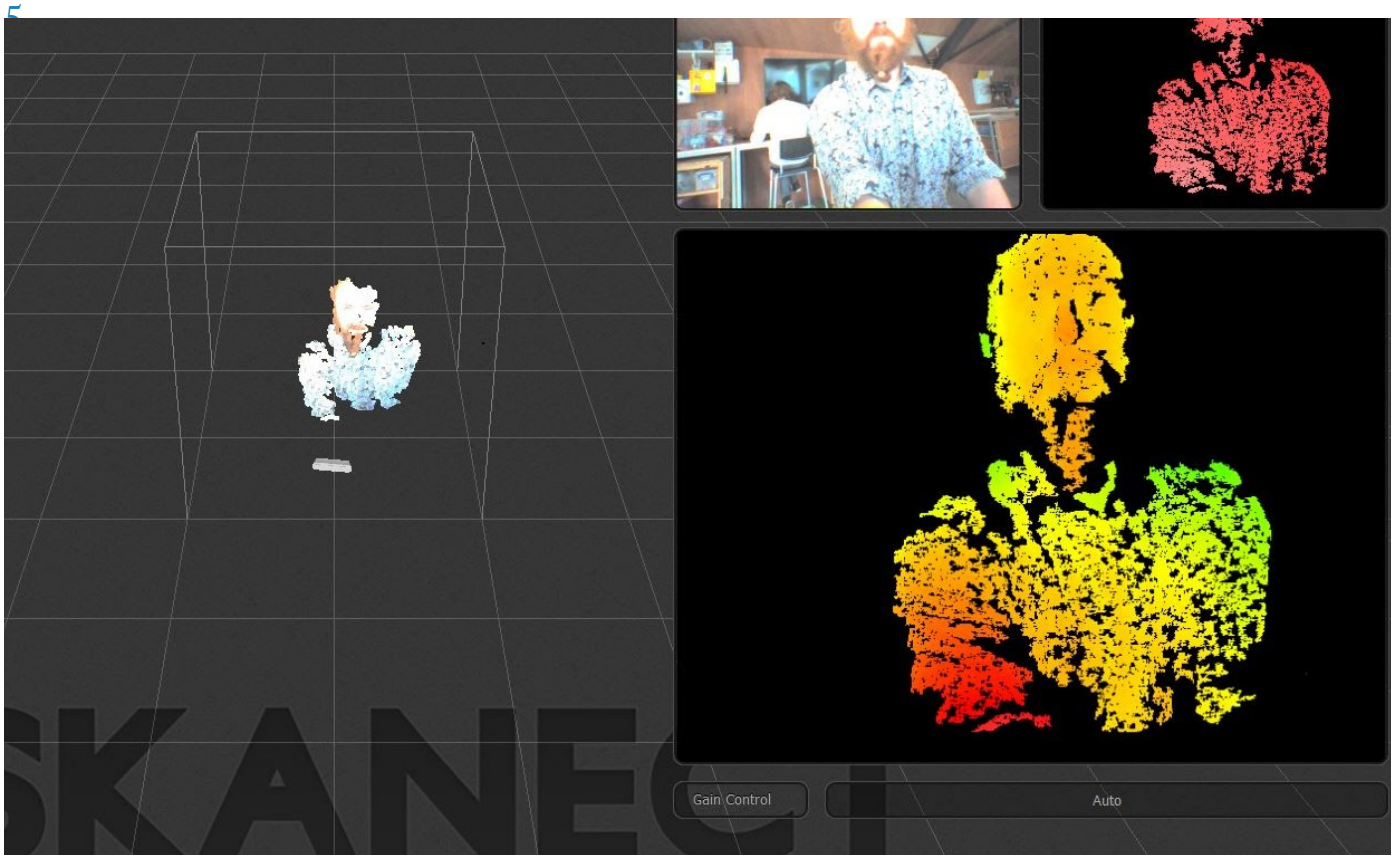
- Skanect software
- Structure core
- Computer

INSTRUCTIONS

1. Open skanect.
2. Select New and start inserting the right settings. Make sure the scanner is connected to the computer. Set the size of your scan area by using the Scene and the Bounding box. If you would like your scan area to be longer instead of a cube, you can select the Aspect ratio of Height x 2.
3. Click Start.

4. You are now in the Record tab. Adjust the position of the scanner and/or your object (person): place the object roughly in the center of the scan area. For example: go sit in front of the scanner and position yourself so that the most of the body in the top right corner is red.

5

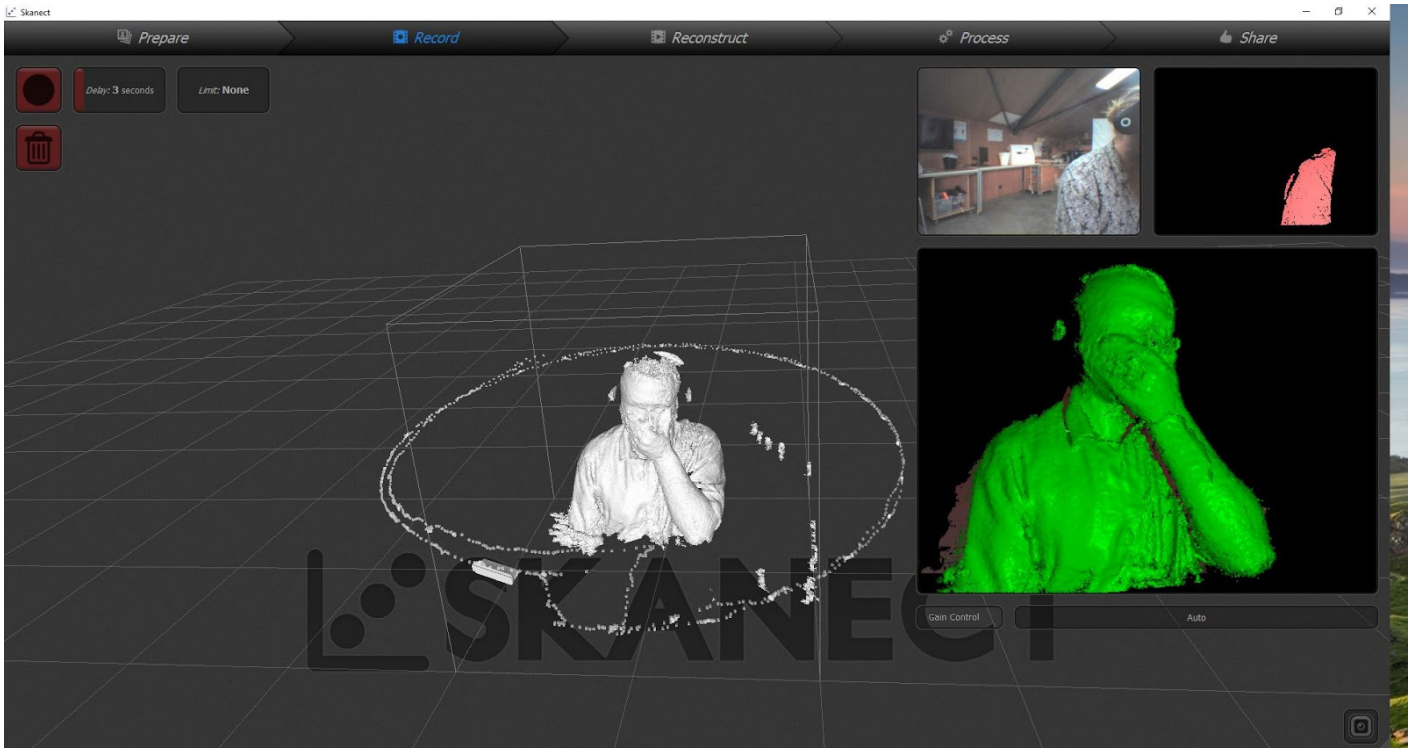


TIPS

- If you have a lot of hair you will need to put it in a knot or ponytail.
- Sit on a chair that can turn around.

CLICK THE RECORD BUTTON

5. Complete the scan of your object. You may do this either by leaving the scanner stationary and slowly rotating your object (by slowly spinning in your chair, etc.) or by leaving the object stationary and moving very slowly and steadily around it with the scanner. During this process, be sure not to move too fast, or you may receive a "Not Enough Geometry" or "Camera Moved too Fast" error and need to restart your scan. Green surfaces on your scan mean that the information is in focus and being properly gathered.



When you have obtained full coverage of your object, click the red Stop button.

6. In the Reconstruct tab, you can select some actions to get the best quality possible. Select Fusion. Select GPU for the Processor and High for Fidelity for the best quality. Click Run. Skanect will reconstruct your scan at full quality now (the live scan renders at less than full quality for speed reasons).

Note: To navigate around your model: left click and drag to rotate, right click and drag to zoom, and center click and drag to reposition.

7. Now proceed to the Process tab to edit/refine your model. Skanect provides some basic editing tools. Enough to get your model to a watertight, printable STL file.

Note: If you are familiar with other 3D modeling software or need more advanced editing capabilities, you might prefer to export your model as an STL file and continue editing in a program of your choice.

The most important actions you might want to use are:

- Fill holes: Will attempt to close any gaps in your model. Adjusting Smoothing settings will make the modifications more or less detailed. Adjusting Limit settings will tell the software to ignore holes over a certain size and only fill smaller holes.
- Watertight: The best option if you want to 3d print your model. It fills holes but on the mesh level. It is accurate but needs more time and the file gets bigger.
- Simplify: a scan is a very large file. With the simplify action the file gets smaller BUT the scan is less accurate.

8. The final step is to move to the Share tab to save and/or export your model.

- The Save function allows you to reopen your project in Skanect later for further editing.
- The Export Model function allows you to save your model out for 3D printing or editing in another software.
- Save as an STL file.

EINSCAN-SE

3D scanning with Einscan-SE

The einscan-SE is a compact powerful desktop 3D scanner. It is considered one of the easiest to use 3D scanning semi-professional tool for non-technical users and has a great price-to-performance ratio.

- This device can scan to 0.1mm accuracy.
- It is meant to scan objects with dimensions not larger than 10cmx10cmx10cm.
- Shiny objects are best first sprayed in a mat color or sticky reference dots are best put in place before scanning

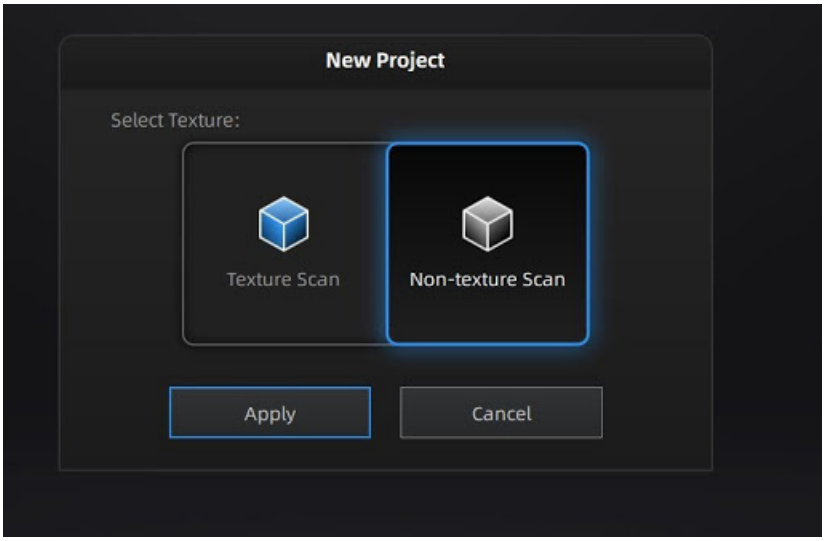
NEEDED

- Einscan-SE
- Computer (with einscan licensed software installed)
- Quick guidebook: https://www.einscan.com/wp-content/uploads/2020/05/Ein-Scan-SE-Guidebook.pdf
- Object to scan

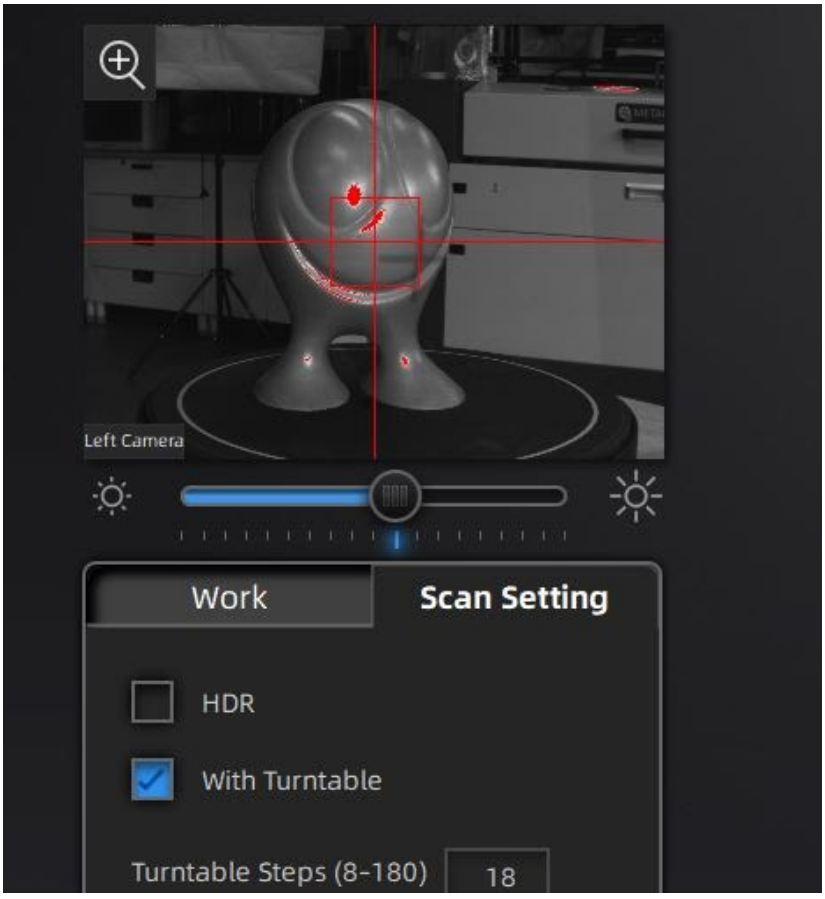
INSTRUCTIONS

1. Connect the machine to the computer and check that the computer detects the device. Start the software and click New Project.

2. You will have to choose between texture scan or a non-texture scan. Choose for a non-texture scan for 3D printing and a texture scan for digital use.



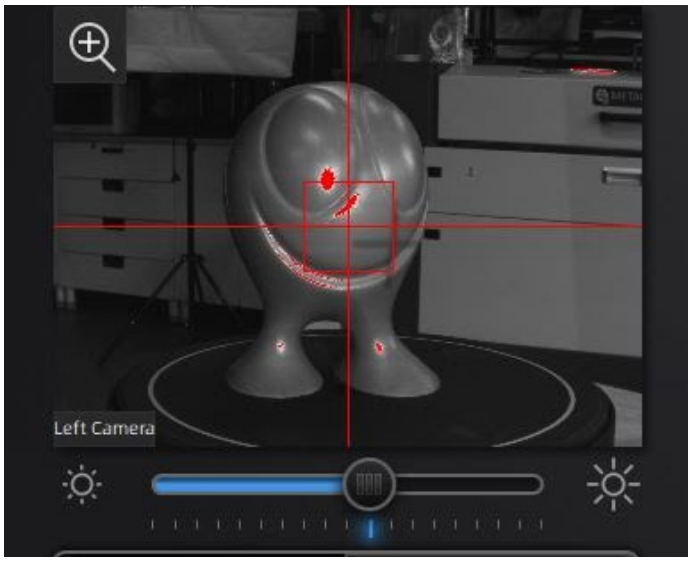
3. Place the object in the middle of the round turntable.



4. Adjust brightness by sliding the bar until the object is slightly red.

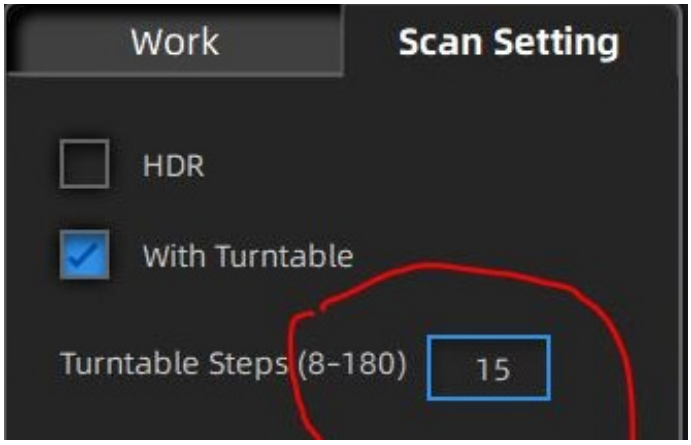
Settings will depend on your object surface condition. If too much red appears on the object shown in the window then it is over bright, too little red means the picture is too dark.

Too dark



Too bright

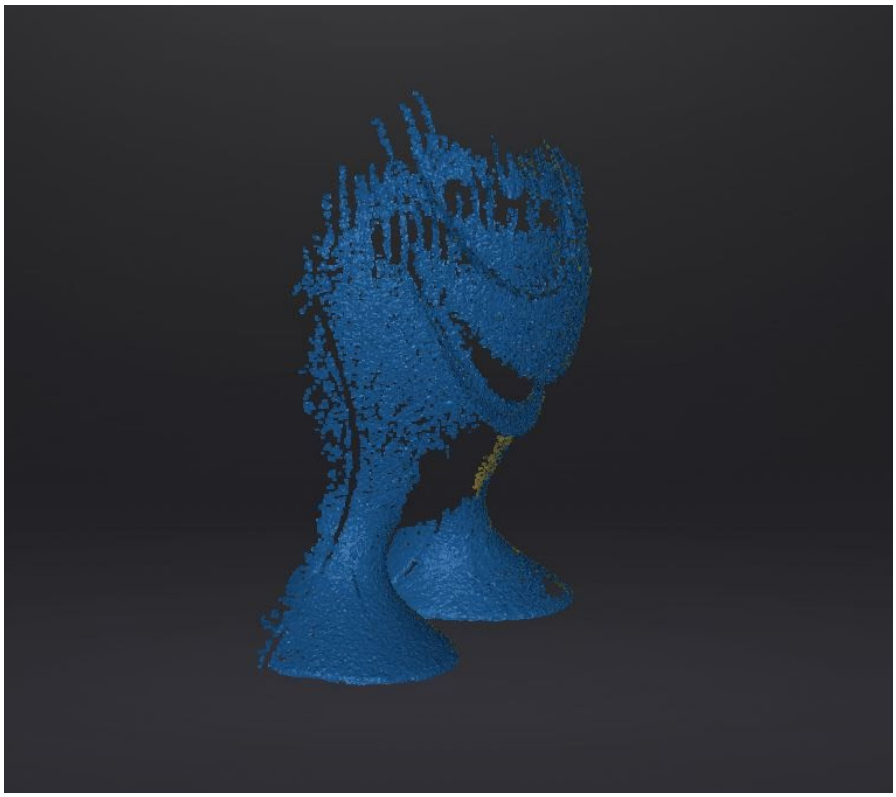
5. Choose how many steps for the scanning process.
    - The more steps you choose the more accurate the scan will be but the longer it takes.
    - The minimum is 8 steps.
    - Make sure the turntable is turned on.



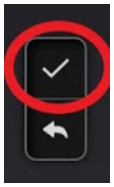
6. Click on the start button on the right of the screen.

7. The machine will start scanning the object.

- Wait patiently for the scan to finish
- Do not move the object during the scanning process
- You can keep track of the steps done on the device

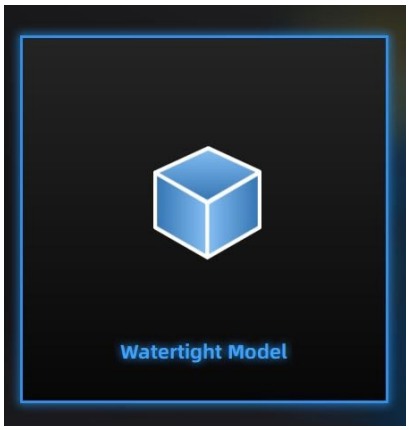


8. Control the scan and if good, click on the check mark.



9. Make a mesh from the scan. A mesh is a 3D model made up of points and surfaces. The program does this automatically.

10. Choose for a watertight model. The programme will detect if some parts are not completely filled and will then calculate a surface to fill them. Next, choose the quality for the mesh. The higher the quality the larger the file will be and more calculations are necessary from the computer.



11. Save the model. Asc, stl, obj and ply are available.

12. Press the touch switch for 1 second twice to turn the scanner off.

AR VIEWER APP

Displaying with AR viewer App

TUTORIAL: HOW TO DISPLAY YOUR 3D MODELS IN A REALISTIC ENVIRONMENT WITH AR VIEWER APP

AR (augmented reality) puts a layer on reality: an extra layer of information is placed on something else.

Just think of football results or the score in a quiz that appears on top of the camera image on TV or maybe you know Pokemon GO?

The latter is probably the game that made AR or Augmented Reality known to the general public.

NEEDED

- Smartphone
- Asset: 3d scanned object (file format .GTLF)
- AR Viewer EN

INSTRUCTIONS

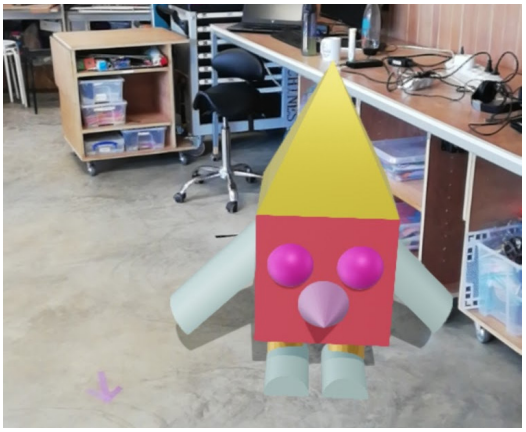
1. Install AR Viewer EN.This is a free app for mobile devices. It can be used with .GLTF file format

2. Make sure you have a scan as .GLTF file on your smartphone.

3. Open the app and choose environment recognition.

4. click on the + sign to import the file.

5. Place your asset in the chosen location. It is possible to modify the model (make it bigger or smaller) and walk around the model to look at it from all angles. Once you are satisfied with the position, take a photo.



ACTIVITIES

Scan-tastic and then what?

You have a 3D model obtained via 3D scanning. What can you easily do with it?

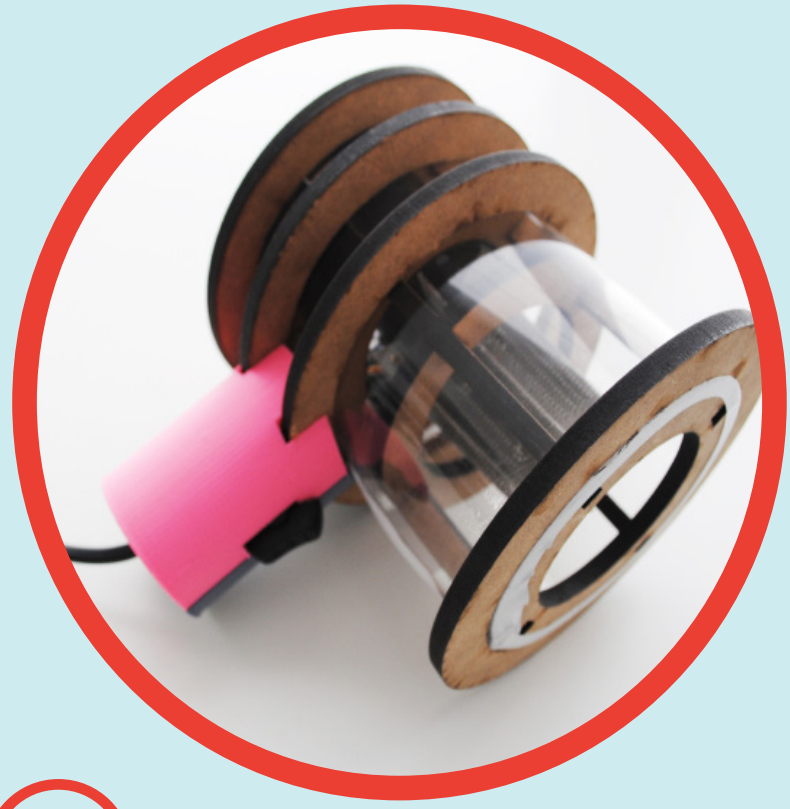
CHALLENGE 1: MAKE A PHYSICAL OBJECT VIA DIGITAL FABRICATION

3D scan a person or part of a person. Make a scaled 3D printed replica of that (part of a) person. You may use CAD software (eg. Tinkercad, Fusion 360 …) to modify the .stl file before printing.

CHALLENGE 2: ANIMATE YOUR STORYTELLING TIME WITH AR

(AUGMENTED REALITY)

- Choose 4 different places
- Think of a little story taking place in these 4 locations. The main character should be a funny creature you can make with clay.
- Make a quick storyboard in 4 scenes (one scene per location)
- Create a funny creature or character with playdough (modeling clay)
- 3D Scan it
- Upload your creature in AR Viewer EN
- Take pictures of your creature in the different locations
- Use 4 pictures to tell about the adventurous life of your creature



Highway to creativity in STEAM

TOOLKIT

DIY SMOKE MACHINE

TUTORIAL

GIRLS in stem

SMOKE MACHINE

From hairdryer to...

A fog/smoke machine is a device that emits a dense vapor that appears similar to fog or smoke. This artificial smoke is most commonly used in professional entertainment applications.

It is amazing how simple it is to build a very effective smoke machine using a few materials and a bit of science!

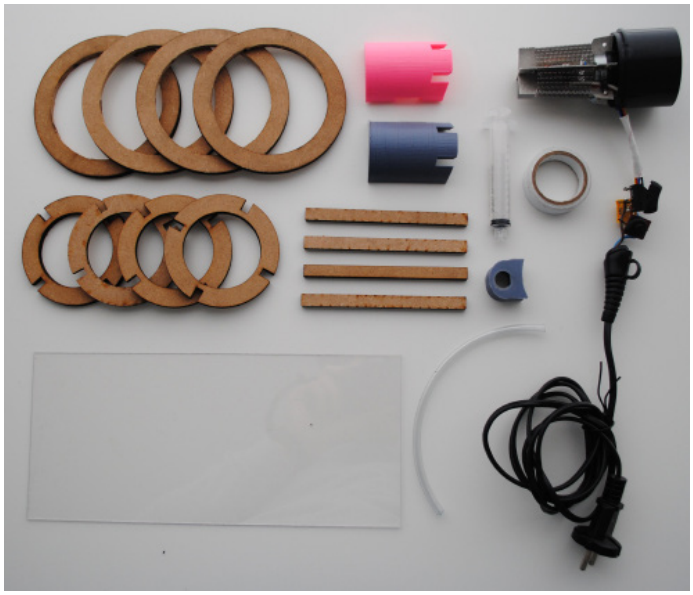
By reverse engineering we will build a heated "Smoke Machine" that heats a glycol-based solution to spray out a plume of white smoke/fog.

In this activity we will make a smoke machine in 3 steps.

- We start disassembling and analyzing an existing smoke machine.
- We disassemble and study the working of a hair dryer.
- We hack the hairdryer and build our own smoke machine!

PER PAIR

- Hairdryer (can be found at thrift shops)
- Tools (screwdrivers, scissors, and pliers)
- Plastic bins
- Safety glasses
- Syringe
- Silicone rubber tube
- MDF 6 mm thick
- PLA for 3d printing
- Glycerine
- Cotton balls (from a personal care shop)



FOR THE LARGER GROUP (8 TO 10)

- smoke machine
- camera to take pictures
- flip chart or white board

PREPARATION

1. Check the different screws in each hairdryer to figure out which ones are holding the hairdryers together and to make sure you have the right size and types of screwdrivers needed for disassembly.
2. Check the compatibility of the electrical plug of each hair dryer with the system in your country.
3. Check the different screws in the smoke machine to be sure you have the right tools for disassembling it.

TUTORIAL

... to smokemachine

1. Set up one island to test and then analyze the existing smoke machine - Execute this part as a group, use the directions in section ***Dissection of a smoke machine*** below.

Keep the 3 main goals of this part in mind:

- Take apart the smoke machine, try not to break pieces. You will need to put the machine back together!
- Investigate: Once the machine is open, examine and discuss each component. What material is the component made out of? How is that component connected to other components? What purpose does it serve?
- Draw: Sketch the inside of the machine and write down what you think a part's function is.

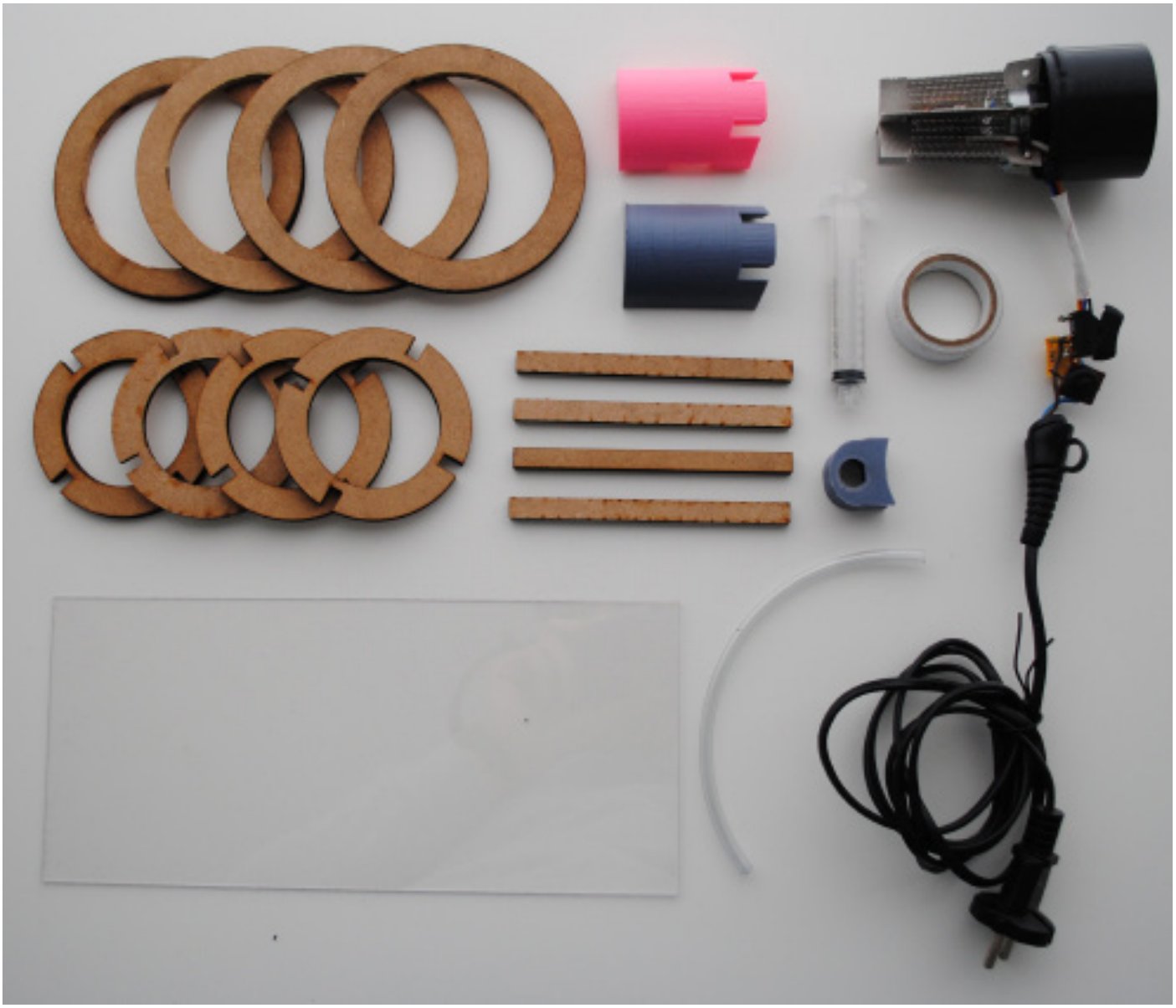
If time is limited you might want to do this part classically with a presentation. You can use the presentation in the toolkit. But let the group test the smoke machine.

2. Break the group into pairs.
3. Hand out the hairdryers and tools.
4. Be clear about the three 3 preliminary goals of this part of the activity:

- Take apart the hairdryer while trying not to break (too many) pieces. You will need the pieces!
- Investigate: Once the hairdryer is open, examine and discuss each component. What material is the component made out of? How is that component connected to other components? What purpose does it serve?
- Draw: Sketch the inside of the hairdryer and write downs what you think a part's function is.

5 Review with the entire group how you can hack the hairdryers and transform them into smoke/fog machines. Use the tutorial ***Hacking the hairdryer***.

6 Make sure you have access to a laser cutter to cut MDF and a 3D printer to make the handle and the syringe holder. If not, you can make these parts in advance in a maker space/ fablab and distribute them to the groups. The design files are included in the toolkit. The files are parametric and can be adapted to fit the right size of the hair dryer components.



DISSECTION

... of a smokemachine

How does a smoke machine work?

In the toolkit you find a working smoke machine. Screw it open and list the parts and their function. Use the table below to keep track of all the parts.

Every part is essential. Or is it not?

N°	PART	DESCRIPTION	FUNCTION
0	*push button*		*turning the machine on and off.*
1			
2			

3			
4			
5			
6			
7			

CONCLUSION

... for the smokemachine

Write down in your own words how the machine works.

- What are the 4 essential parts needed to make it work?
- Look on the internet if you can find extra information.
- It is important to make a good analysis, you will need it later.
- Also, make a schematic presentation of the workflow of the machine.

CONCLUSION

SCHEMATIC PRESENTATION

DISSECTION

... of a hairdryer

Let the participants disassemble their hairdryers. Get them thinking about the parts they will need to make a smoke machine. Do not lose or break anything! You will need the parts, so make a list.

Here are some questions to help you get them started:

- Count how many parts make up the hairdryer.
- What materials are they made out of?
- Why did the engineer choose those materials?
- Follow the electrical path of your hairdryer. Electricity comes from an electrical outlet through the hairdryer's electrical cord and onto the on/off switch and then where?

N°	PART	DESCRIPTION	FUNCTION
0	*switch*		*turning the machine on and off.*
1			
2			

3			
4			
5			

CONLUSION TIME! WHAT PARTS DO THE HAIRDRYER AND THE SMOKEMACHINE HAVE IN COMMON?

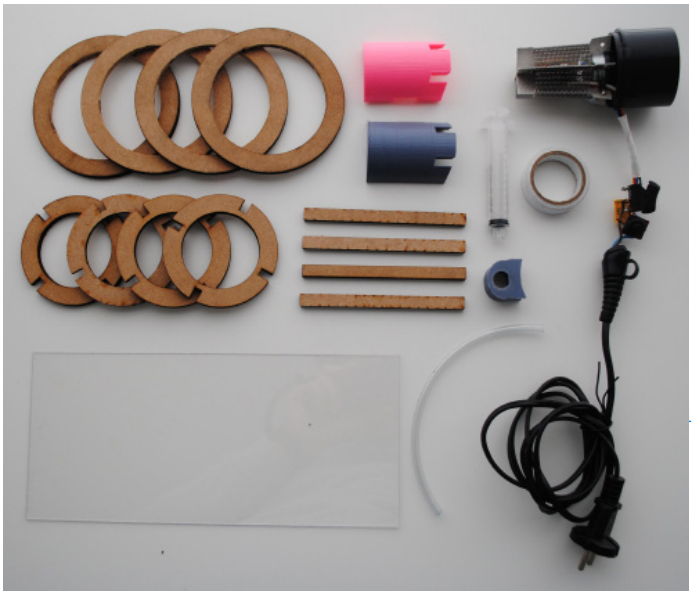
MAKE

The smokemachine

Collect the different parts that will be needed to make a fog machine.

You need 4 basic parts

- Heating element (heat wire)
- Blower (motor with screw)
- Dispenser of the liquid
- Housing



Two of those parts a hairdryer:

- Heating element
- Blower

You wil make the housing with a combination of lasercutting and 3D-printing. The liquid dispenser will be a syringe. You will need a syringe holder, you can make this for example by 3D-printing.

RECOVER

Start by recovering the heating element and the blower from the hairdryer. Be as careful as possible to ensure that the parts aren't damaged.

Use the right tools!

MAKE

Use the given design files to make the casing.

To make the heating element holder you will need

MDF 3mm thickness

Laser cutter

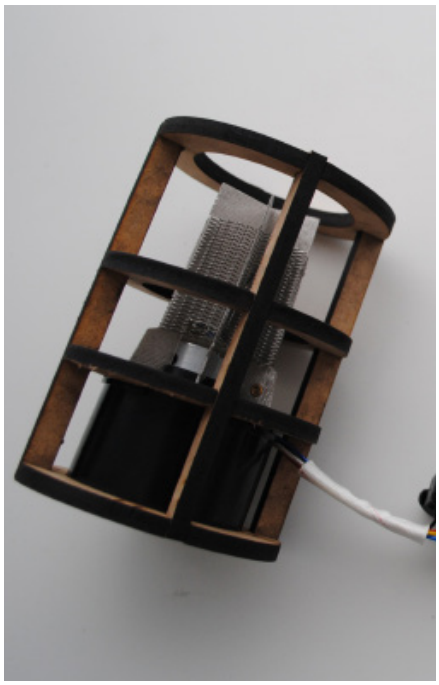
Glue

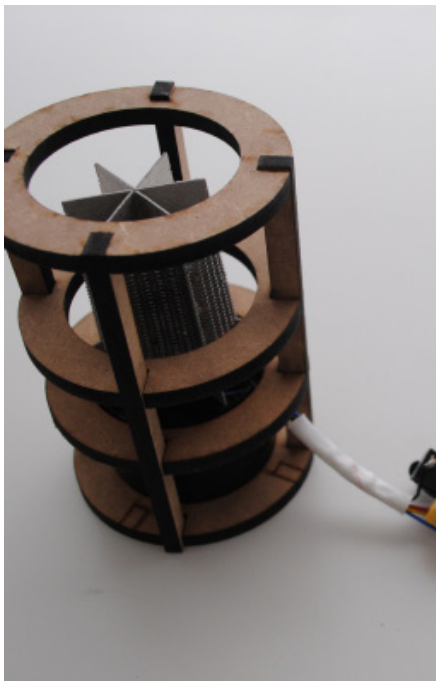
The design file of the holder: .svg

Use a laser cutter to cut the wood pieces. Use 6mm wood. Once cutted, assemble the holder as indicated in the photo below.

1 THE INNER CASING

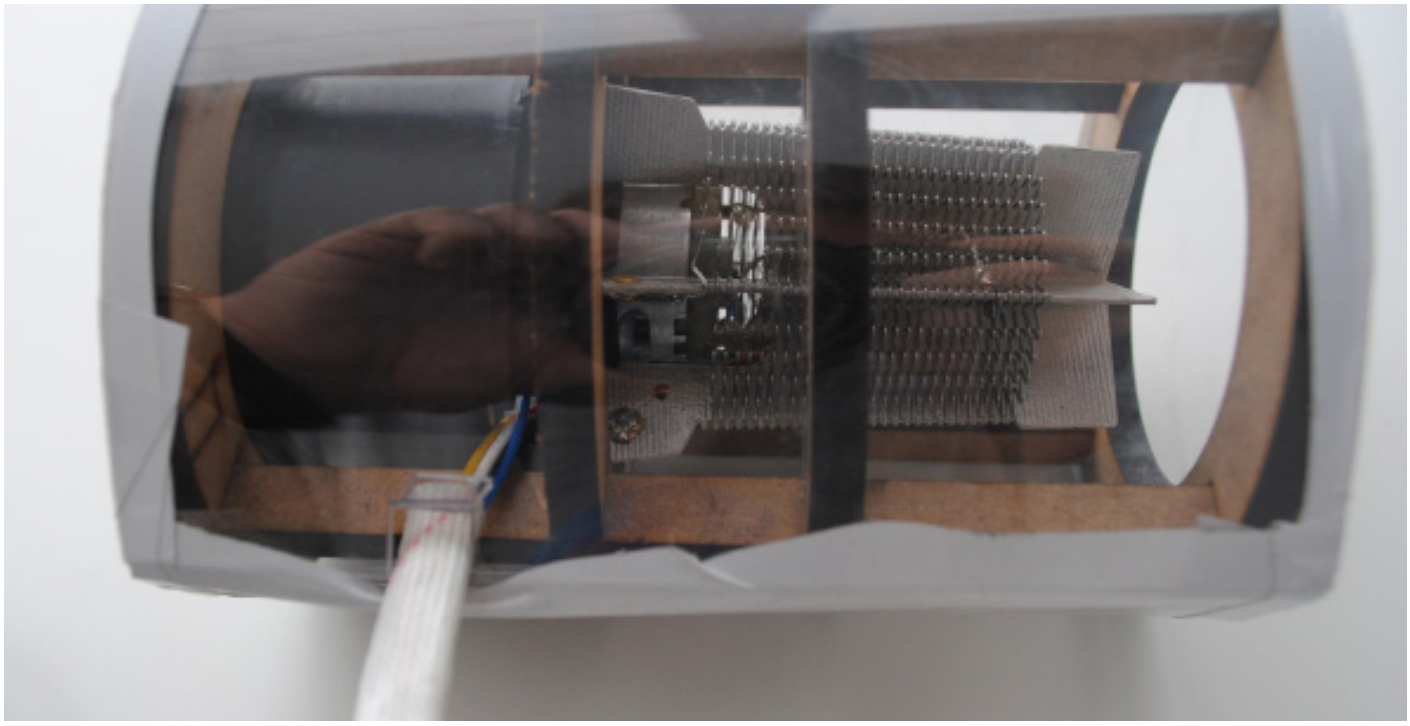
Take the 4 small circles. Build this structure around the heat element. Normally everything should fit perfectly. If the parts are too loose you can glue them with a little bit of wood glue.

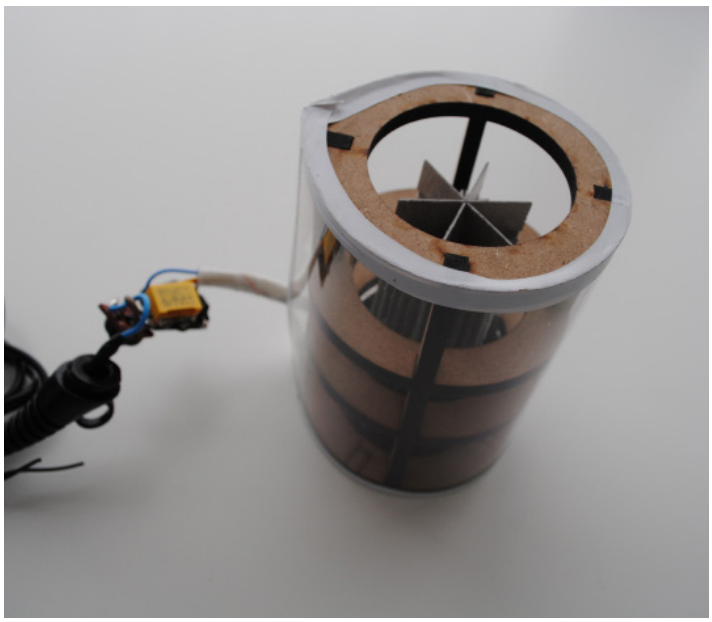


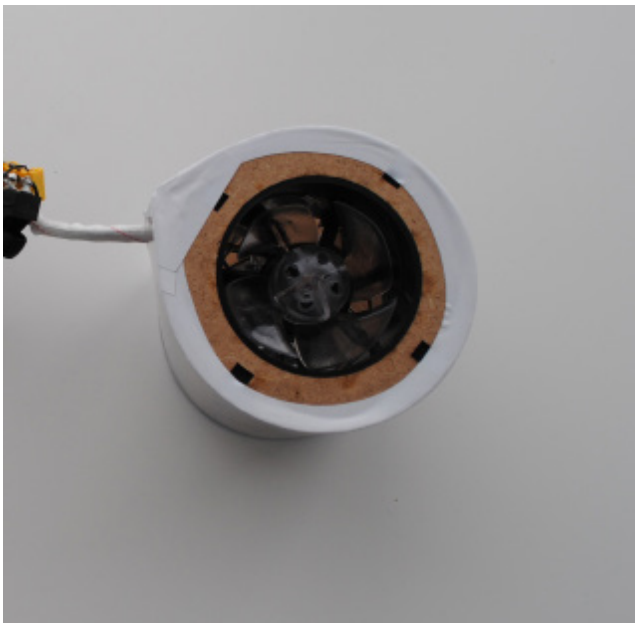


2 THE PLASTIC CASE

Wrap the plastic case around the part. Use electrical tape to fix it. Try to stretch the tape a bit. This way it will be airtight.

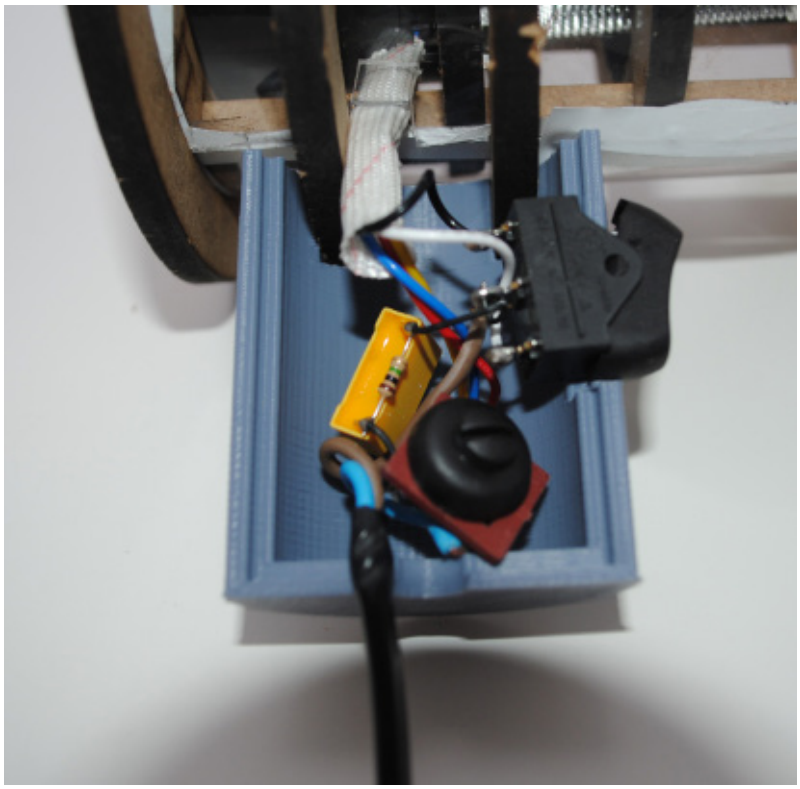


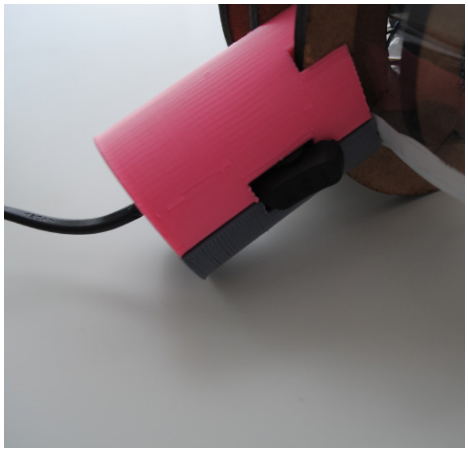




3 THE OUTER CASE AND HANDLE

Place the 4 big wooden circles around the whole part. The cable should be in the middle of the four parts. Now take the handle (2 3D printed parts). Place the electronics parts and the cables in the housing. Place the switch in the provided hole. For safety reasons u should fix everything with hot glue.

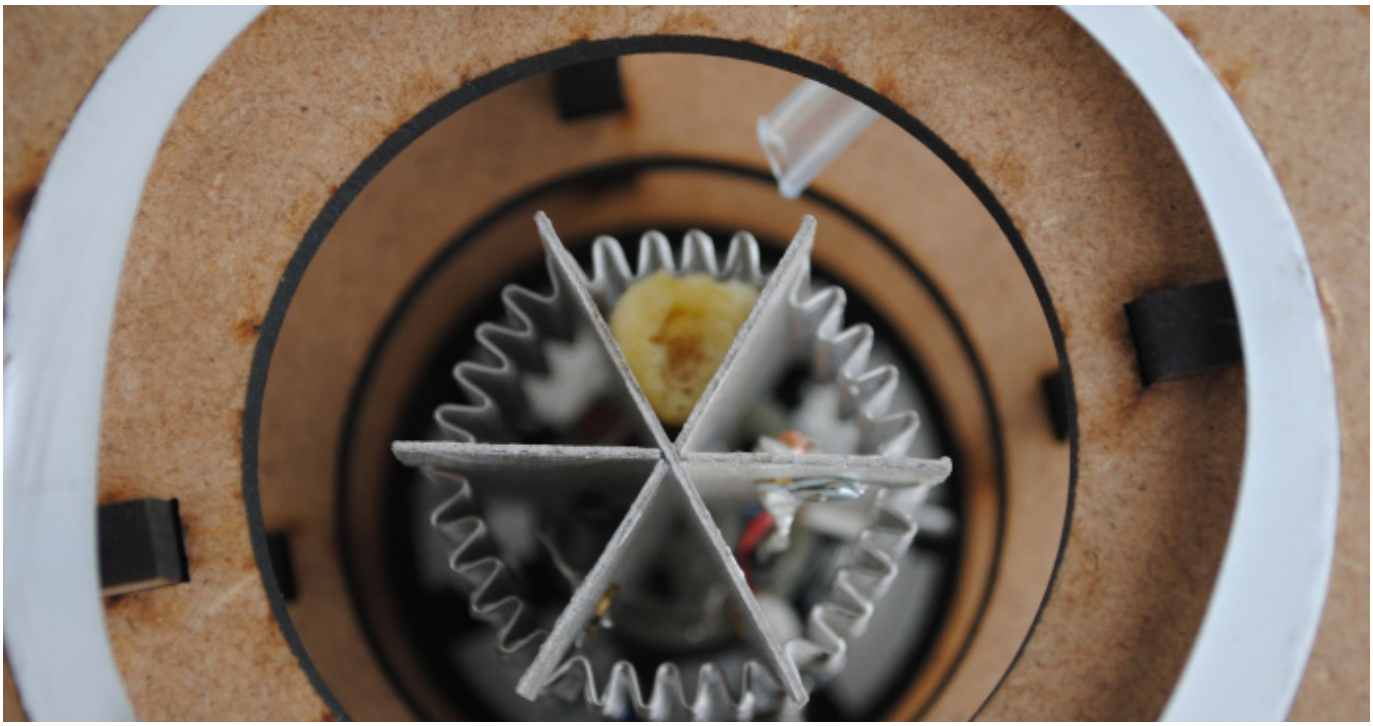


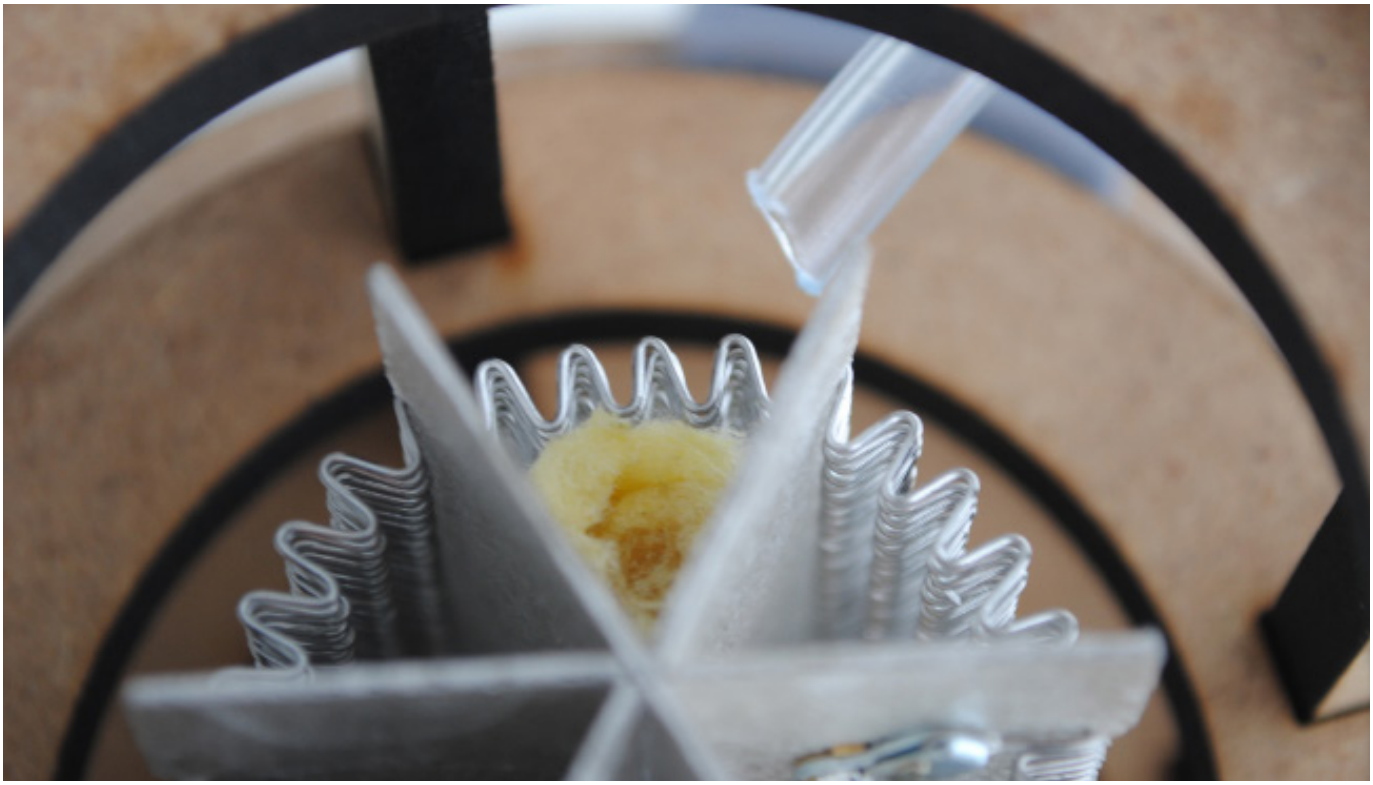


Place the second half on the part.

4 THE COTTON

Place the cotton between the heat wire underneath the tube.





Once everything is assembled, it is time to test and have some fun!

For a first test, where you also learn to correctly and safely use your machine, follow the following steps:

- fill the syringe with glycerine
- make sure the cotton is soaking with glycerine.
- put it in an outlet with an emergency stop, this way it is possible to put everything off.
- turn on the electricity
- turn on the on button.

WARNING!

Be careful and be safe!

- We work with heating elements that become very hot.
- Always make sure that the cotton ball stays moist with glycerine otherwise it will catch fire.
- Only use this appliance outdoors so that there is sufficient ventilation.
- The vapor coming out of the fog machine is not harmful.
- Never leave the appliance unattended.

DIY VACUUMCLEANER

TUTORIAL

GIRLS in stem

VACUUM CLEANER

From plastic bottle to...

Vacuum cleaner technology is simple: create a low-pressure system that forces air into a tube where dust and small debris can be picked up and stored. In essence, a fan connected to a tube. Think of sucking with a straw but then electronically.

So, it is not impossible to make your own vacuum cleaner.

By reverse engineering we will build a "Mini vacuum cleaner" that is handheld and runs on batteries.

In this activity we will build this machine in a few steps. We focus on.

- Analyzing an existing handheld vacuum cleaner.
- Studying the working of a fan.
- Rapid prototyping techniques: parametric design for 3D printing.

Materials needed

1. SOFTWARE

Fusion 360.

This is a CAD software in which you can make technical drawings. It can be downloaded from: www.autodesk.com/products/fusion-360/personal

2. DIGITAL TOOLS

- PC/laptop
- 3D printer
- Soldering station
- Lasercutter

3. DOWNLOADS

- FILE 1:Final_motor.f3d
- FILE 2: Final_case.f3d
- FILE 3: FINAL_filter.SVG

Note that you can also open and adjust our designs using other CAD software. For example www.onshape.com/en/

4. FOR 1 OR 2 PERSONS

- 2 plastic bottles (empty)
- DC motor (can be found in old electronic)
- A propeller (or a thin tin can or thin metal sheet or a thin PET sheet)
- On/off switch
- Electrical wires (+/-60cm)
- Battery holder
- Batteries
- MDF 3 mm (20cm *30cm)
- PET (thickness 2 mm)

FOR A LARGER GROUP (4-10 PERSONS)

- Glue (quick dry)
- Sharp cutting tools
- Ruler
- Drill
- Strip pliers
- Soldering iron
- PLA for 3D printing
- Computer/laptop
- Camera to take pictures
- Flip chart or white board

Preparation

1. Check the size of the bottles. It will be easier if everybody has the same type and size of bottle.
2. If you do not want to buy a propellor, you can make one out of a PET-sheet.
3. To make a powerful vacuum cleaner you could use a powerful high rpm 12v DC motor. If so use a DC adapter instead of batteries.

All the parts are included in the toolkit. You might choose using a recycled motor of your own, and a recycled PET bottle of your own.

We build the mini handheld vacuum cleaner in 8 main steps. You will need access to a 3D printer and laser cutter. In our construction we will use a small 3V DC motor, which does not give a very powerful machine. You can recycle this motors from various old electronic apparatuses such as cd players, electronic toothbrushes, …

If you can find a more powerful one (12 V), go for it and take care to adapt batteries to the appropriate voltage.

MAIN STEPS IN THE CONSTRUCTION

1. Make the dustcollector
2. Design and laser cut the motor holder
3. Make a propeller mechanism
4. Make and attach the fan to the motor
5. Place the motor with fan in the plastic bottle (bottom part)
6. Connect the motor to the batterypack & switch
7. Make the vacuum cleaner body
8. Test te device

A Design & 3D print connections & handle
B Make and fix the filter
C Fix and attach the bottle part

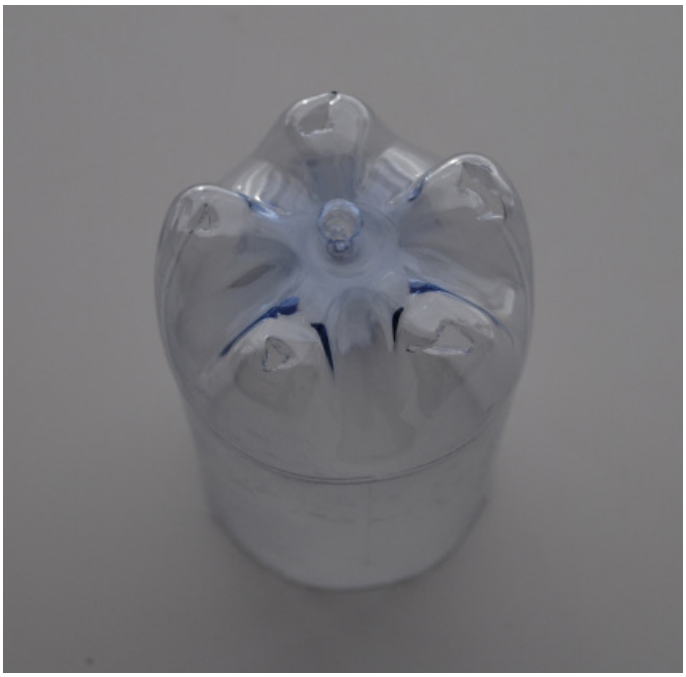
MAKE

... The dustcollector

CUT THE BOTTLE

Take the empty plastic bottle and cut it in 2 parts. The front part is two thirds and the back part is one third of the bottle.

The front part will function as a dust collector, in the bottom part we will place the engine: motor and fan.



MAKE HOLES IN THE BACK

Using a soldering rod or a heated needle or a drill, make holes on the entire bottom of the bottle. This is useful for letting suction air out.

DESIGN

... The motor holder

The design of the motor holder is made by parametric design (CAD) for laser cutting.

Download the file Final_motor.f3d and open it with fusion360

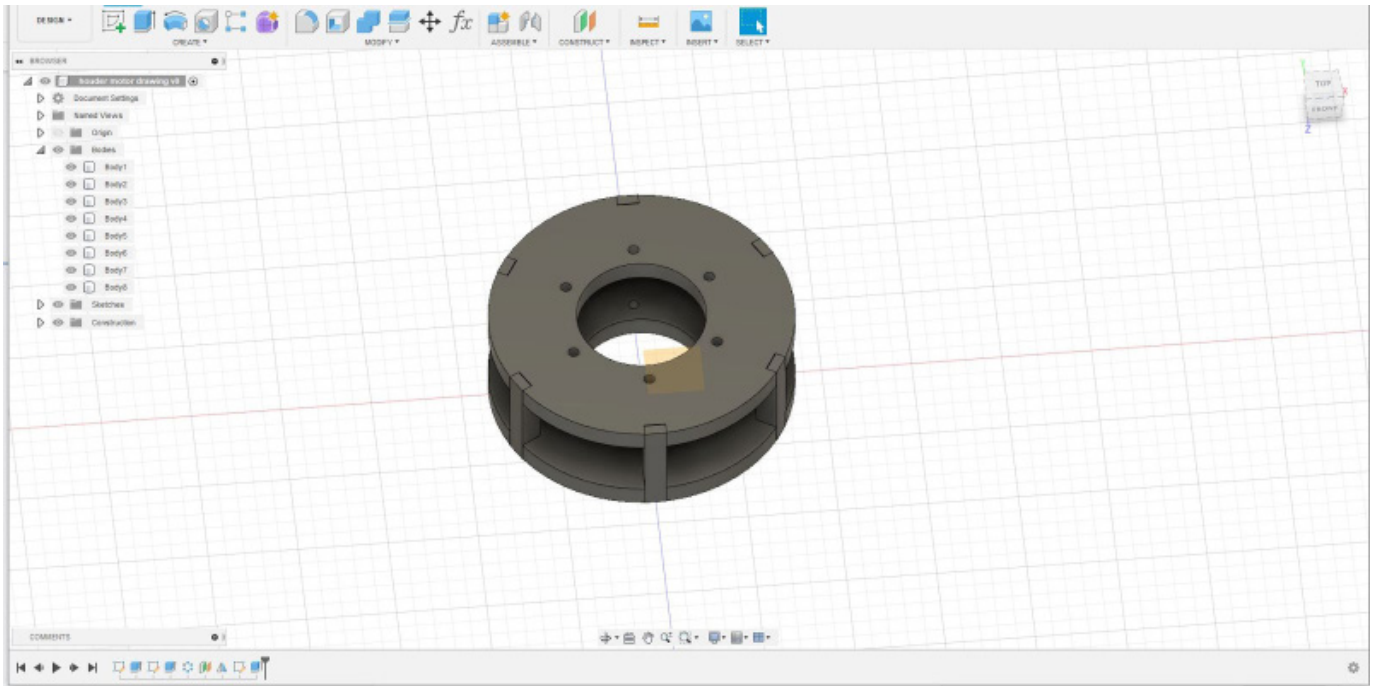
Measure the dimensions of the motor and write them down, you will need:

- height of the motor
- diameter of the motor

The design of the motor also depends on the bottle, more specifically:

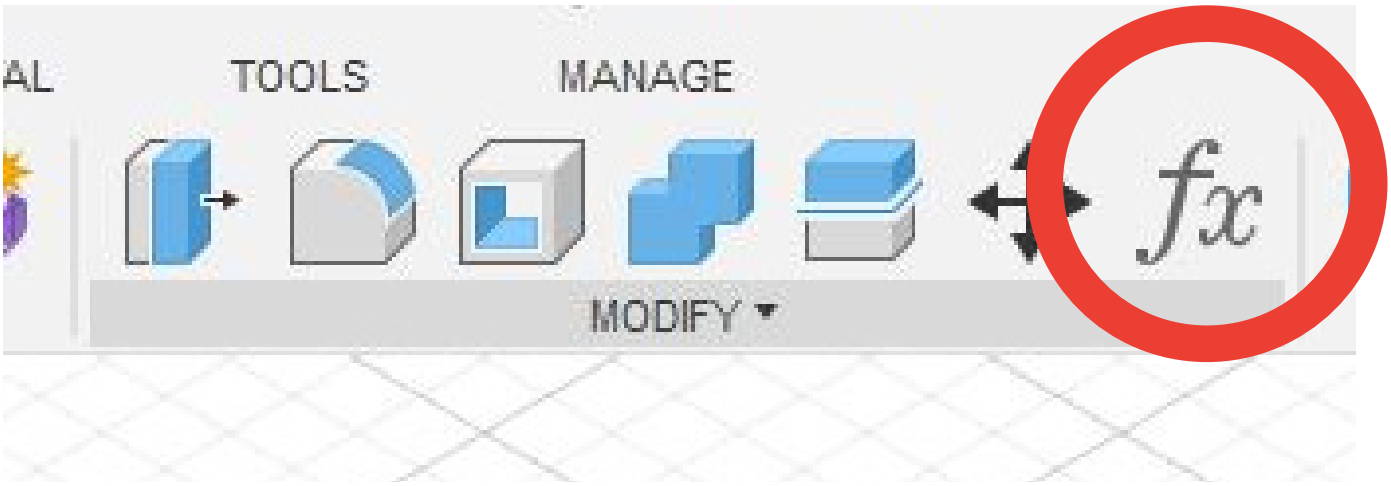
- diameter of the bottle

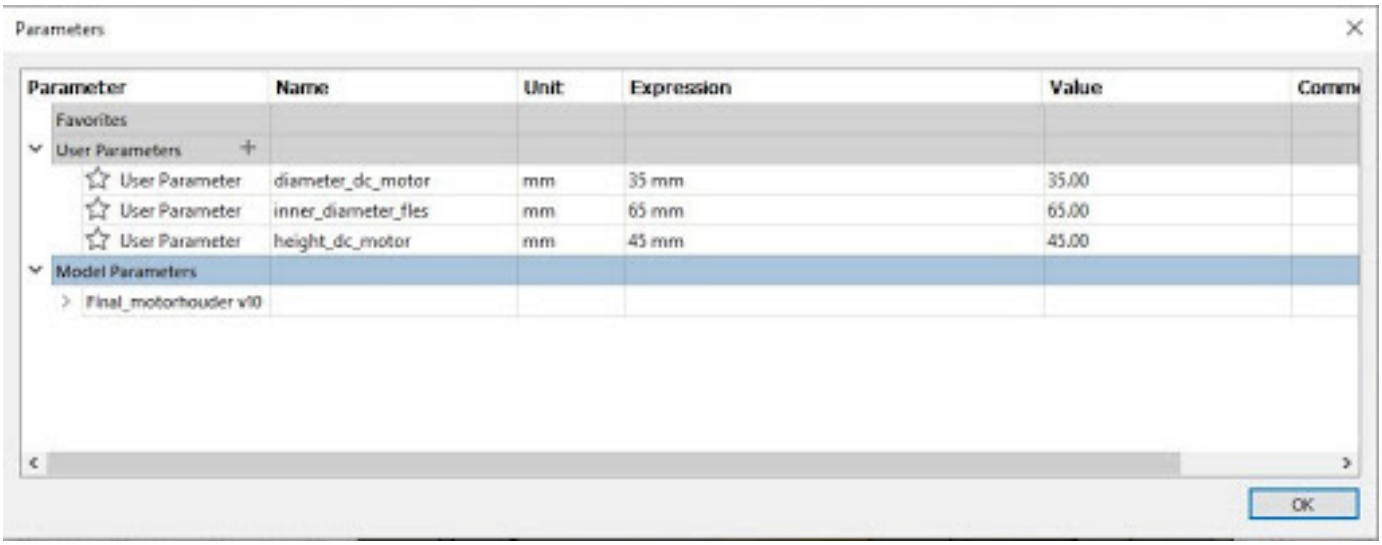
It is very important that you measure these dimensions precisely. Once you have them, open the file Final_motor.f3d in fusion 360, you should see both the 3D file and the drawing:



CHANGE DIMENSIONS

Change the parameters where needed. Click on f(x), a sub window will open where you can change the parameters.





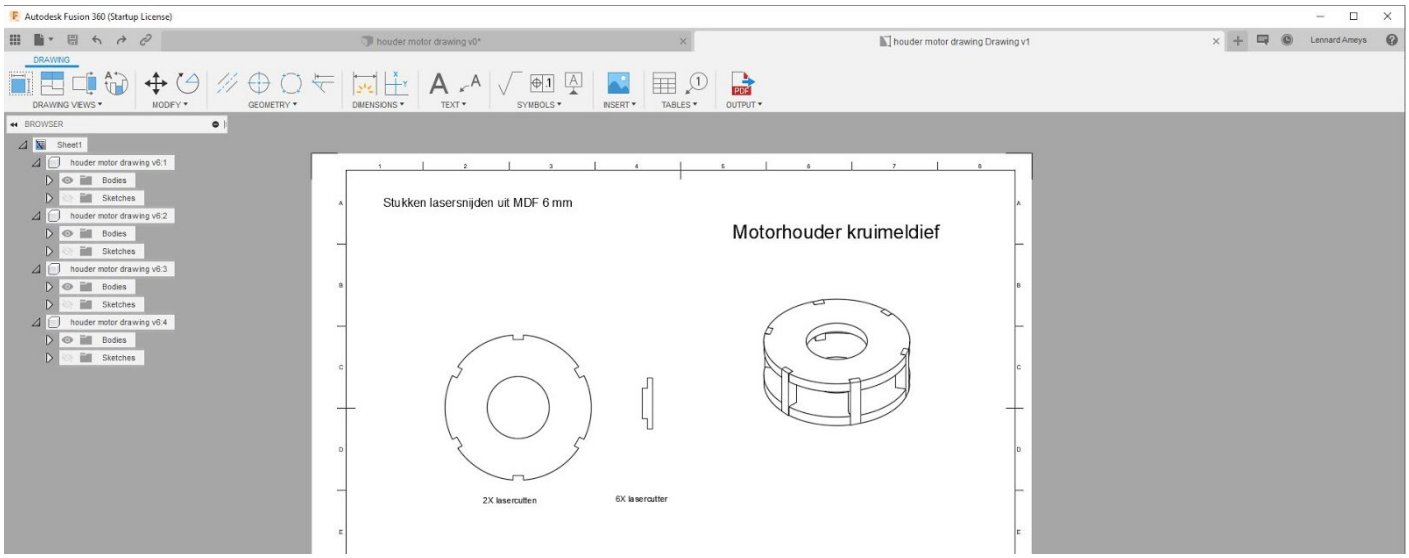
In this spreadsheet you can change 3 parameters. Change them accordingly. If you close the window you will see that the size of the object in preview has changed automatically.

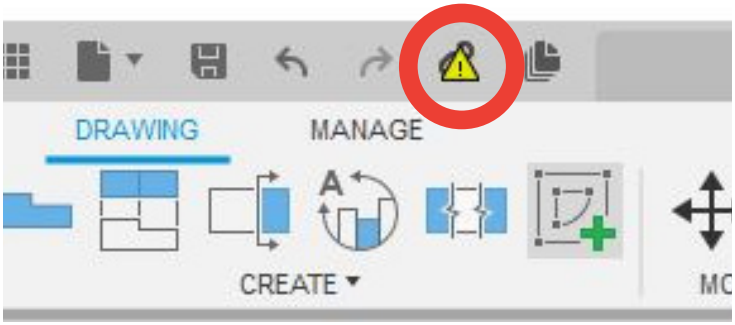
Save the new model by clicking “ctrl+s”.

ADJUST THE DRAWING

Within this context, the drawing is the technical file that we use to laser cut. It is linked to the first file but it should be updated after the changes in dimension were made.

Go to the drawing window.





In the top left corner appears a yellow exclamation mark, this is the program telling us that the drawing is not up to date.

Click on the exclamation mark to update the drawing according to the new parameters.

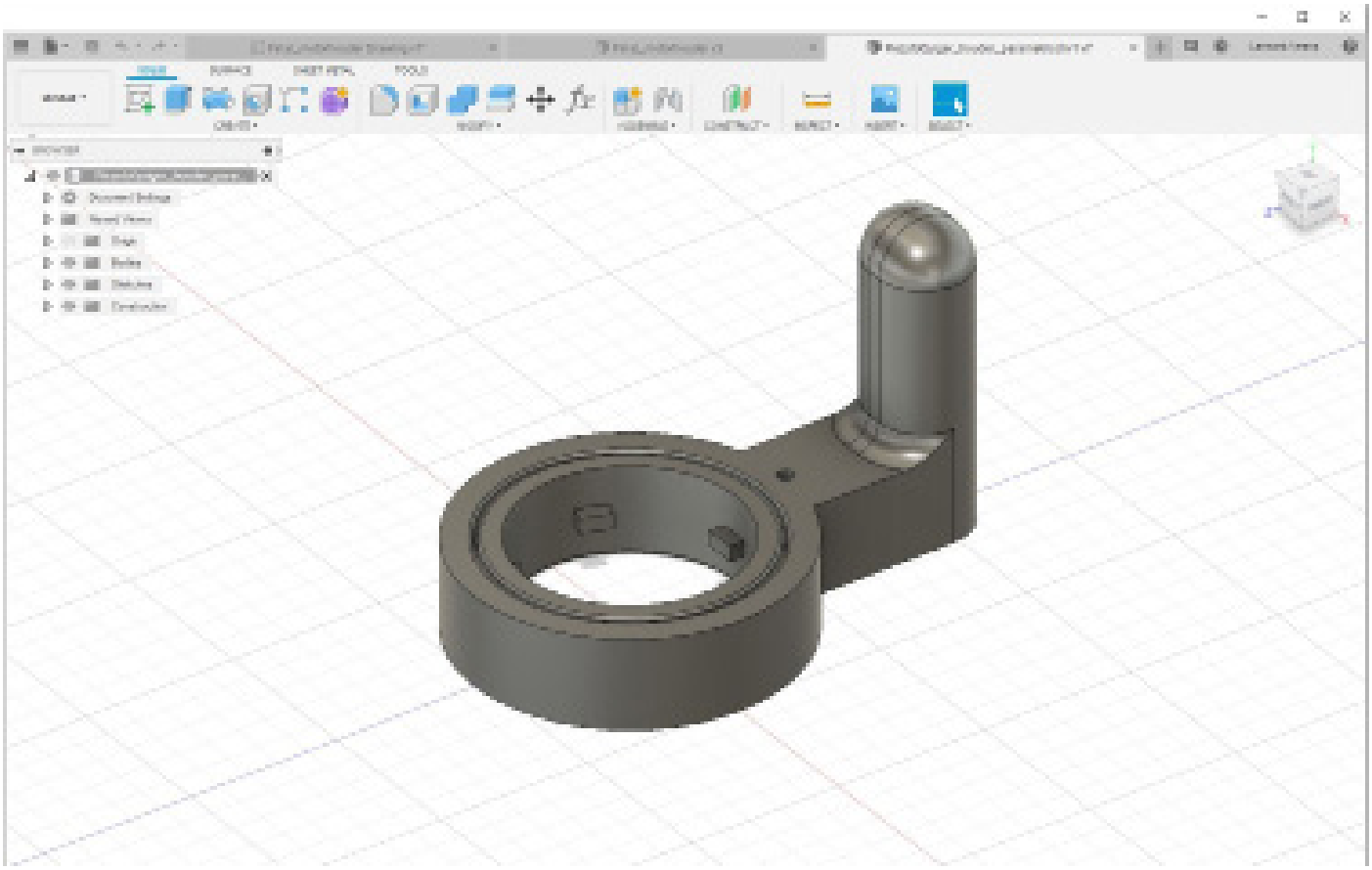
Download the SVG file or the PDF.

DESIGN

... The bottle holder and handle

Open de file Final_case.f3d in fusion 360. Proceed as for the motor holder to adjust the parameter, diameter of the bottle, as needed.

Write down for later use the diameter of …



3D print the file.

We used 1.75 mm PLA, 30% infill, but this depends on the specs of the 3D-printer.

DESIGN

... The filter

Open the file Finel_filter.svg. Adjust the diameter to the diameter of the filter holder. Save and then laser cut from the PET sheet. Adjust the diameter to the diameter of the bottle. Save and laser cut out MDF.

... a propeller mechanisme

If you want to make your own propeller mechanism, you can either use a thin metal sheet (for example recycling a thin metal sheet from a cola can) or a piece of PET sheet.

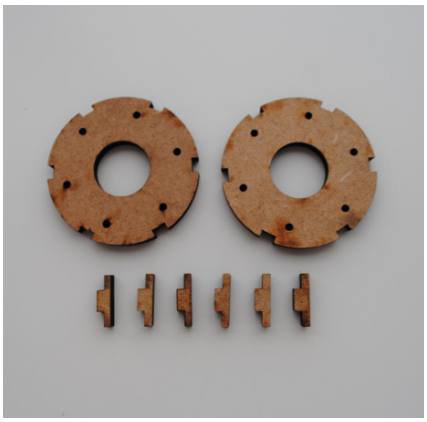
- Draw a circle equal to the diameter of the large bottle on a thin metal sheet. You can also make it with a laser cutter.
- Cut the circle using metal cutting scissors and then draw a small concentric circle near the centre.
- Draw 4 lines through the center to divide the circle in 8 wings portions. You will cut them later.
- Cut the sheet along the marked lines to make 8 sectors.
- Bend each sector equally to make a propeller as shown in the image and also drill a hole in the centre.

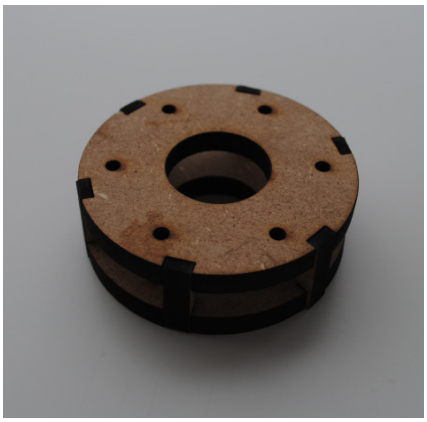
MAKE

... The motor

ASSEMBLING THE MOTOR HOLDER

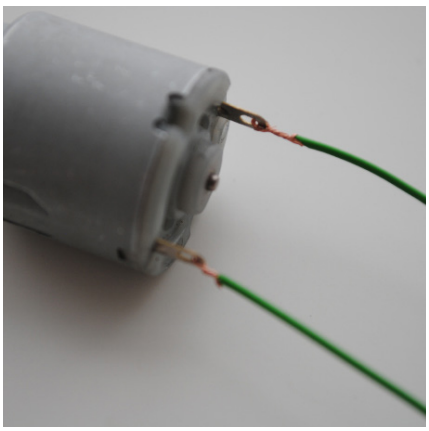
Collect the laser cut MDF pieces of the motor holder. Assemble them in three easy steps, everything should fit without needing glue.

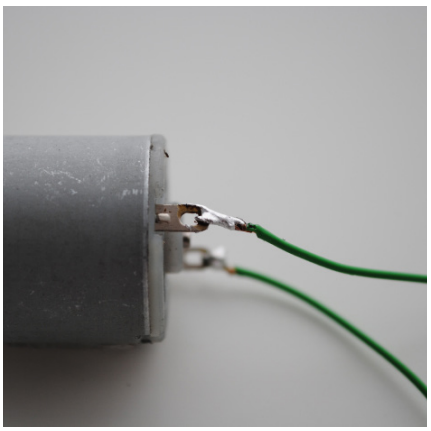


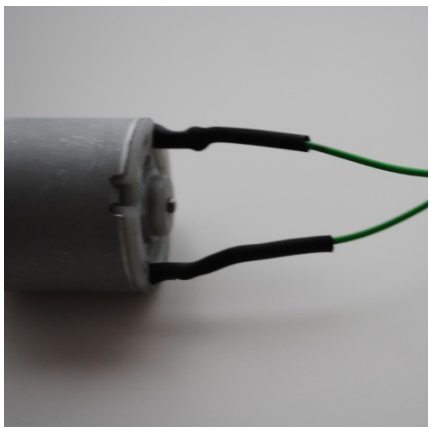


WIRING THE MOTOR

Using a soldering rod, connect electrical wire onto the motor. Then solder on each 'foot' of the motor an electrical wire about 30 cm long. Finish by securing them with a heat shrink tubing.

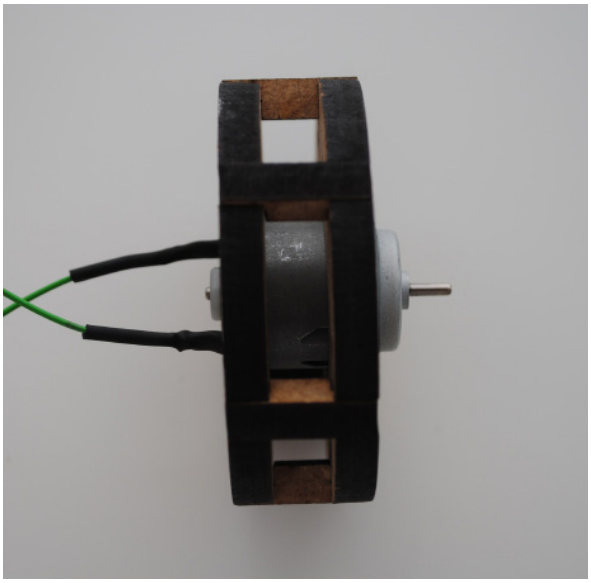






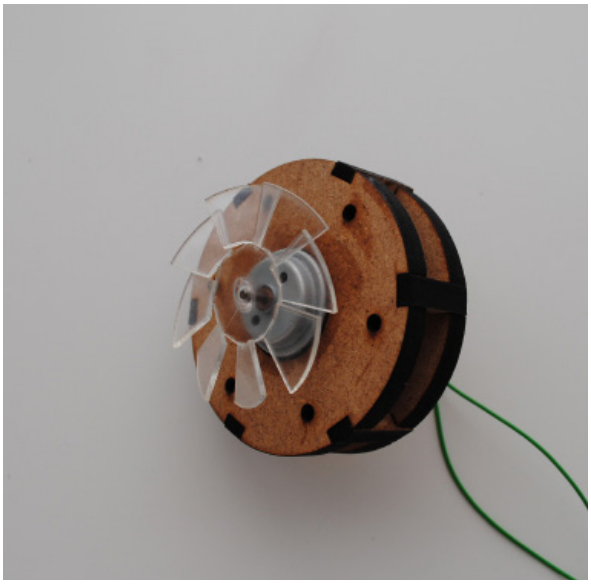
PLACING THE MOTOR IN THE HOLDER

Place the motor in the holder. If measured correctly it will fit perfectly, otherwise adjust and eventually secure with glue.



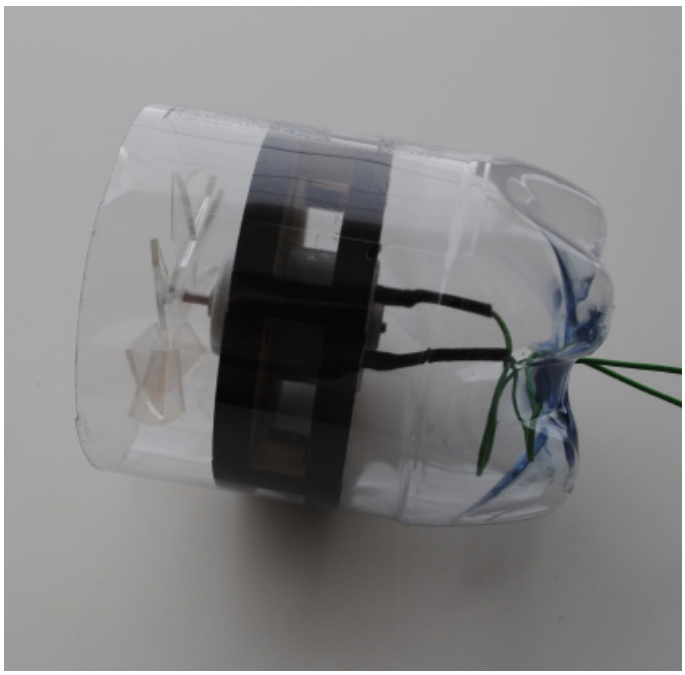
ATTACHING THE FAN TO THE MOTOR

Take the DC motor and attach the propeller to the motor shaft. Secure it safely with glue.



PLACING THE FAN IN THE PLASTIC BOTTLE BOTTOM PORTION

Make a hole at the bottom of the bottle. Place the assembled motor+fan in the back part of the bottle. Don't forget pushing the cables through the hole at the bottom of the bottle.



If the fit is too loose in the bottle, warm the bottle with a heat gun. The PET bottle will shrink when heated.

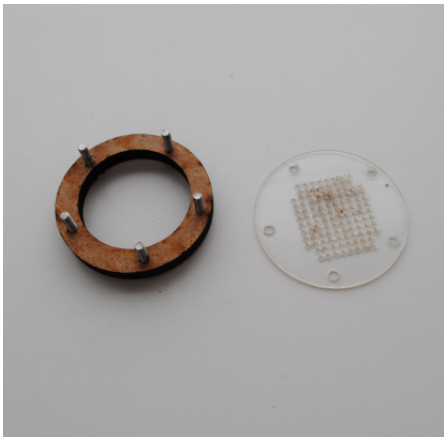
PET (the plastic from which bottles are made) is a thermoplastic plastic. This means that it can melt again if it is heated. all PET bottles are made from the same product. This mother mold is heated and drawn into a mold. The nice thing about this material is that when heated, it wants to return to its original shape and, in the case of PET bottles, starts to shrink.

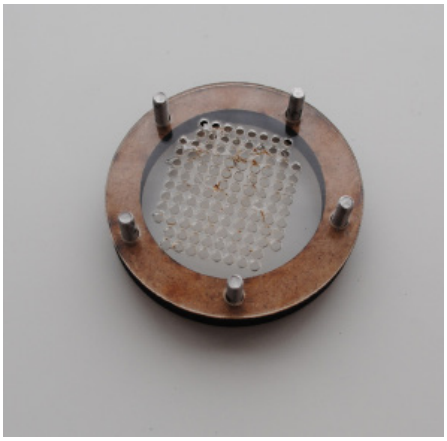
Collect the filter, filter holder, 4 nuts and bolts. Assemble in 3 steps as indicated in the pictures below.

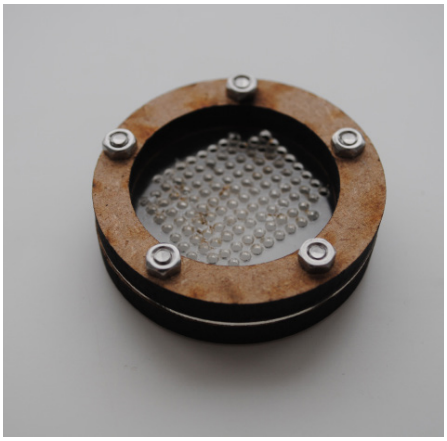
Push the filter in the 3D printed handle. Push it completely until it stops

ASSEMBLE

... The filter



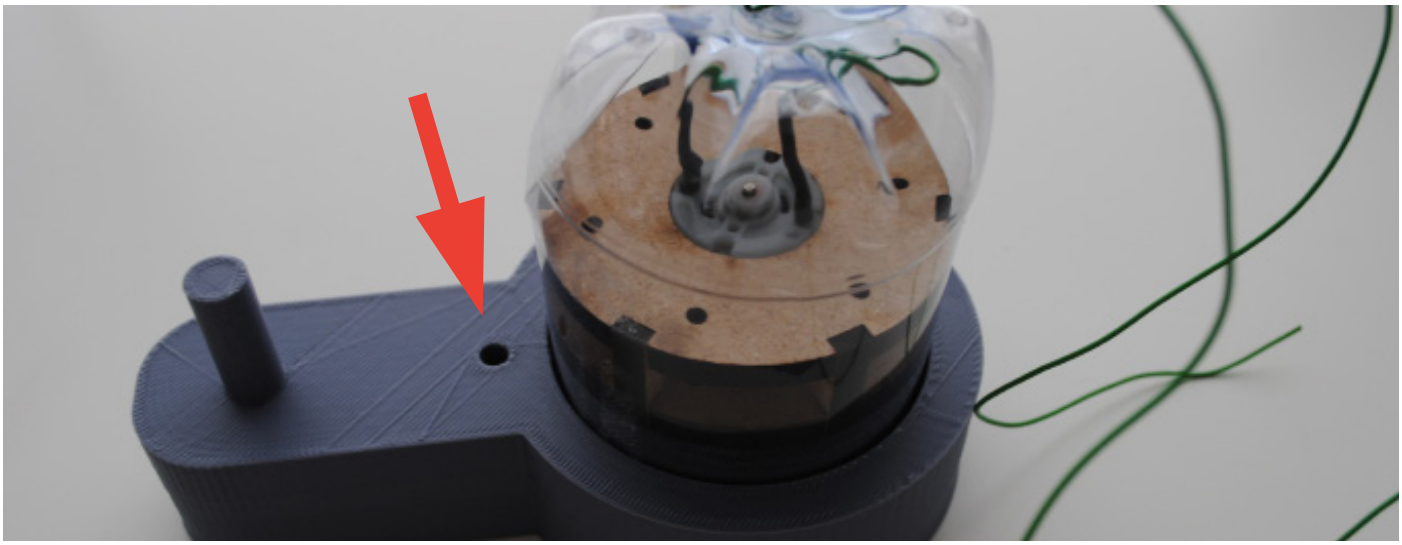




FIX THE HANDLE TO BOTTOM PART OF THE BOTTLE

Take the 3D printed handle and push the bottom part of the bottle, with the motor already in pace, into the slot.

Fix both the pieces tight together and secure with super glue.



ASSEMBLE

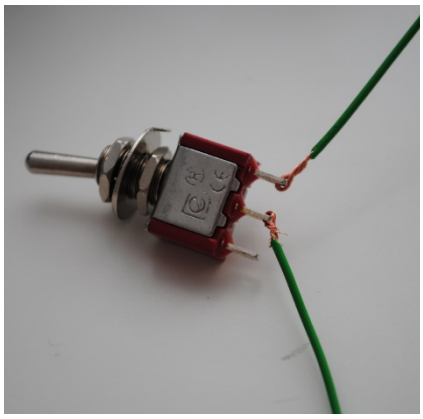
... The vacuum cleaner

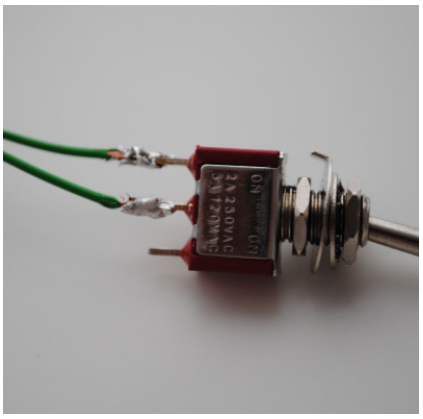
CONNECTING THE MOTOR TO THE BATTERY PACK & SWITCH

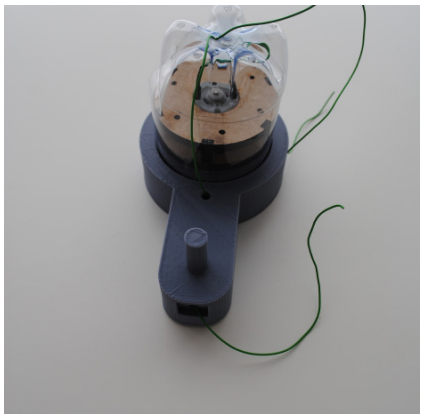
Solder & place the switch. Take 1 of the two wires that came from the motor and put it through the hole in the handle so that it comes out from the top.

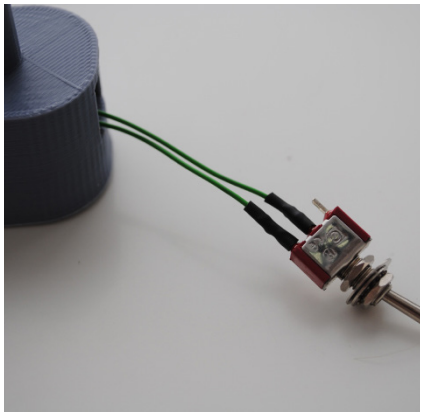
Cut the wire into 2 pieces and solder the two pieces to the switch. Put the loose end through the handle again.

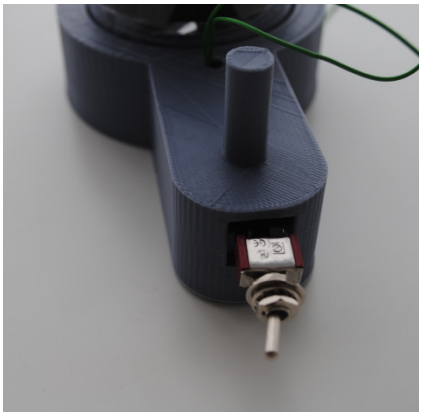
Glue the switch to the handle in the space provided.











PLACE THE BATTERY PACK

Take the 2 wires coming out of the handle, strip them and connect them (do not solder yet) with the two ends, red and black, of a battery clip.

Connect to a battery and turn on.

Check if the fan is sucking or blowing air.

If the fan is sucking, you are good and you may now solder the wires of the battery clip. (Remove battery before soldering).

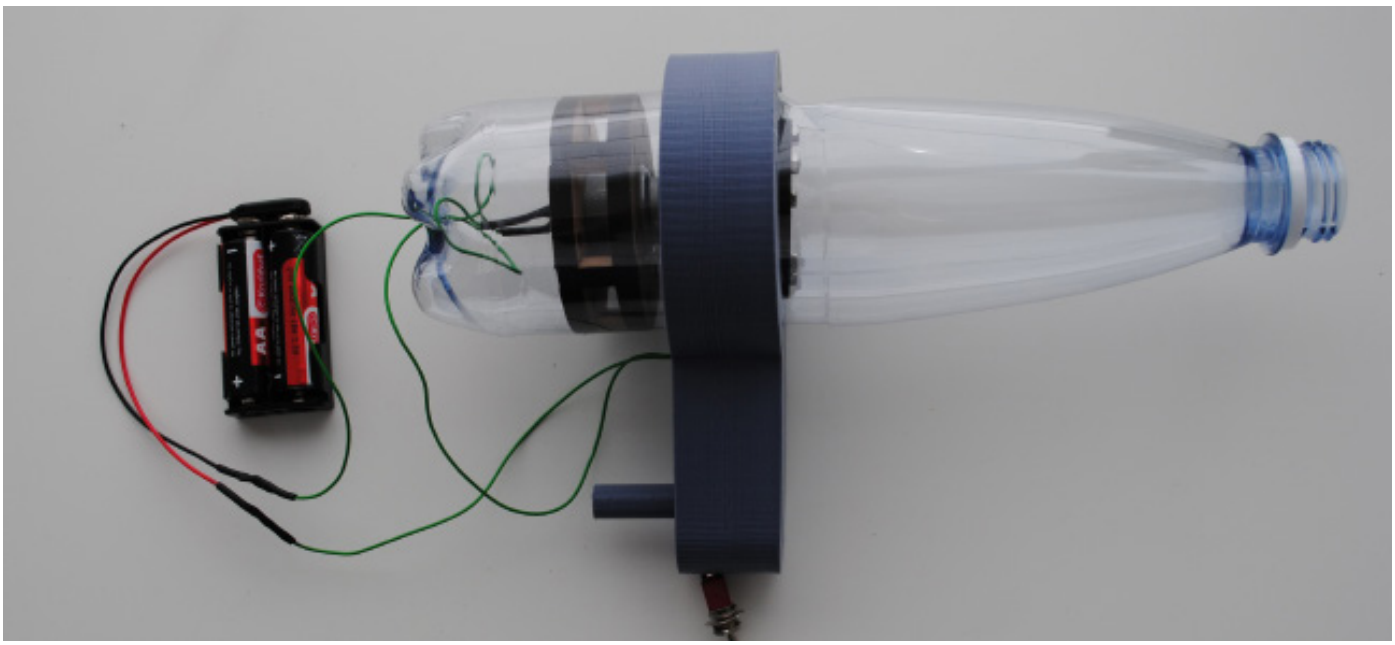
If the fan is blowing, switch the red and black wire of the battery holder. Test and then solder.

(If you are using a 12V DC motor and a 12 V adapter, you want to solder here a DC adapter jack to connect than to the 12 V adapter)

Glue the battery clip to the handle.

FIX THE DUST COLLECTOR

Fix the top part of the bottle in the top slot of the 3D printed handle. Please note, this should not be glued as it must be detachable to dispose of the garbage.



TEST

The Vacuumcleaner

TEST THE DEVICE

Our homemade powerful vacuum cleaner is now ready. Connect the battery and turn On the switch to test the device. The Vacuum cleaner works really well with small pieces.The power depends on the type of motor.

EXTENSION: FROM SUCKING TO BLOWING

What are blowers?

Blowers are used to circulate air. They are mechanical devices that usually run on DC motors that use centrifugal force to expel air.

A blower is the opposite of a vacuum cleaner but uses the same principle to manipulate air flow. Blowers have various functions from cooling (ventilator) to cleaning the leaves from your yard. A blower can also be used to inflate an air mattress.

Can you think of a way to Reverse Engineer a vacuum cleaner and make it blow? (for bigger project starting from a big vacuum cleaner see: https://www.housemeproud.com/how-to-reverse-a-vacuum-cleaner-to-inflate/)

THE PARTNERS

GIRLS IN STEM

De Creatieve STEM is a non-profit organization dedicated to providing inclusive STEM education and learning activities for future innovators. They offer after-school programs, experiences at FabLabs (digital fabrication workshops).

Dijijeunes is an NGO that promotes literacy, inclusion and the development of digital skills, thus helping to create benefits for society.

iDrops organizes and guides innovation processes related to six social challenges: Care, New Knowledge, Sustainability, Superdiversity, Global Innovation and Community Development.

Fundacja Ad Meritum is a non-profit organization that supports the understanding and development of skills of young people and adults in Europe.

INTRAS Foundation is a non-profit organization dedicated to research and intervention in mental health, with the aim of accompanying people in their recovery process.

Highway to creativity in reverse TOOLKIT

DISASSEMBLE, SKETCH, RECAP!

Learn what it takes to be an engineer and dive heads-on into reverse engineering. Our Highway to Creativity in Reverse toolkit provides instructions on how to get acquainted with this field, basic theoretical background, ideas for fun and easy exercises and step by step instructions for 3 projects about manufacturing, electronics and programming.

Find out more about the project through the website at:

www.girlsinstem.eu

Co-funded by the Erasmus+ Programme of the European Union