SILKNOW

D5.6. Production of 3D printed textiles for Instituto Cervantes and the creative industries

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Authors:	Piotr Twardo, Paweł Twardo
Reviewers:	Dunia Mladenic, Mar Gaitán
Approved by:	Cristina Portalés (UVEG)
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List of acronyms	
CNC	Computer Numerical Control
EASD	Escola d'Art i Superior de Disseny de València (Design School, Valencia)
FFF	Fused Filament Fabrication
IC	Instituto Cervantes
MF	Monkeyfab S.C.
PET	Polyethylene terephthalate
PHA	Polyhydroxyalkanoate
PLA	Polylactic acid
TPE	Thermoplastic elastomer
UVEG	Universitat de València Estudi General

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This deliverable concerns 3D printing on fabrics, printing samples from the Virtual Loom and the exploitation of the results of the technological research carried out in previous work packages. The influence of researched technology on the Monkeyfab 3D printing process and the sustainability of industrial 3D printing is also discussed.

1. INTRODUCTION

This deliverable, D5.6 “Production of 3D printed textiles for IC and the Creative industries”, is of the type “DEM” (demonstrator). MF has produced a set of 3D printouts for different purposes (mainly for the educational and fashion sectors), which are described and depicted in the following sections. It is relevant to highlight that the work described here has been possible thanks to the collaboration of MF with other partners (mainly UVEG) and external collaborations (e.g. fashion designer Patrick Wojciechowski). Hence, MF has been able to produce 3D printouts that meet the requirements of different targeted audiences.
As part of this document, we also address sustainability issues involving 3D printing production and the positive impact that the project results have had on MF.

2. RELATIONSHIP WITH OTHER DELIVERABLES

As part of D5.3 “Design and adaptation of 3D printers for textiles”, MF’s 3D printers were adapted in order to print the resulting 3D models of the Virtual Loom. To that end, UVEG maintained continuous communication with MF and provided them with some initial 3D models derived from the Virtual Loom. MF produced a number of 3D prints, of different sizes and resolutions, and carried out some trials to combine two colors in a single 3D printed piece.

In D5.4 “Design and implementation of the Virtual Loom”, we produced some 3D virtual samples using different weaving techniques, and in D5.5 “Visualization and deployable components” we worked on their production as STL files, to make them available for 3D printing technology. The outcomes of D5.4 and D5.5 are the inputs of D5.6.

The 3D printouts produced in D5.6, are going to be used in educational contexts and by the creative industries, as part of WP7 and WP8. In particular, MF has, so far, worked on printouts for the following audiences:

- Printouts on fabrics: MF has collaborated with the fashion designer Patrick Wojciechowski, who has designed a collection of dresses based on GARIN’s historical silk fabric designs for printing on fabrics. The results will be exhibited at a fashion event as part of WP8.
- Printouts of 3D representations of fabrics, with different weaving techniques (outcomes of D5.4 and D5.5): these will be used in the exhibitions that will be organized by the Instituto Cervantes. This is related to D7.4 “Usability evaluation in learning environments”.

- Printouts of 3D jewelry designs: we have established an external collaboration with the EASD (Escuela de Arte Superior y Diseño, Valencia). They have produced eight virtual models, based on SILKNOW's Virtual Loom. The printouts will be combined with silk fabrics and exhibited. This is related to the exploitation of the project's results.

These printouts are described in the following sections.

3. INTRODUCTION TO THE FFF 3D PRINTING PROCESS

Fused Filament Fabrication (FFF) is a 3D printing technology based on building objects from molten plastic lines deposited, layer by layer, on top of each other. The details of this technology, and Monkeyfab research, have been covered in the previous deliverable. This report focuses on the process from a 3D model perspective.

3.1. 3D model in triangular mesh format (.stl)

3D modeling is the basis of successful 3D printing. Only correct models provide predictable results.

The main requirement for a 3D model is that it should be error free (no intersecting triangles, duplicated edges, small holes, etc.) and watertight, which means a closed triangular mesh in stl format. It should be the correct size to fit on a 3D printer printing area, and not be too small. The model can then be loaded into slicer software to create a text file with instructions for the printer (gcode file).

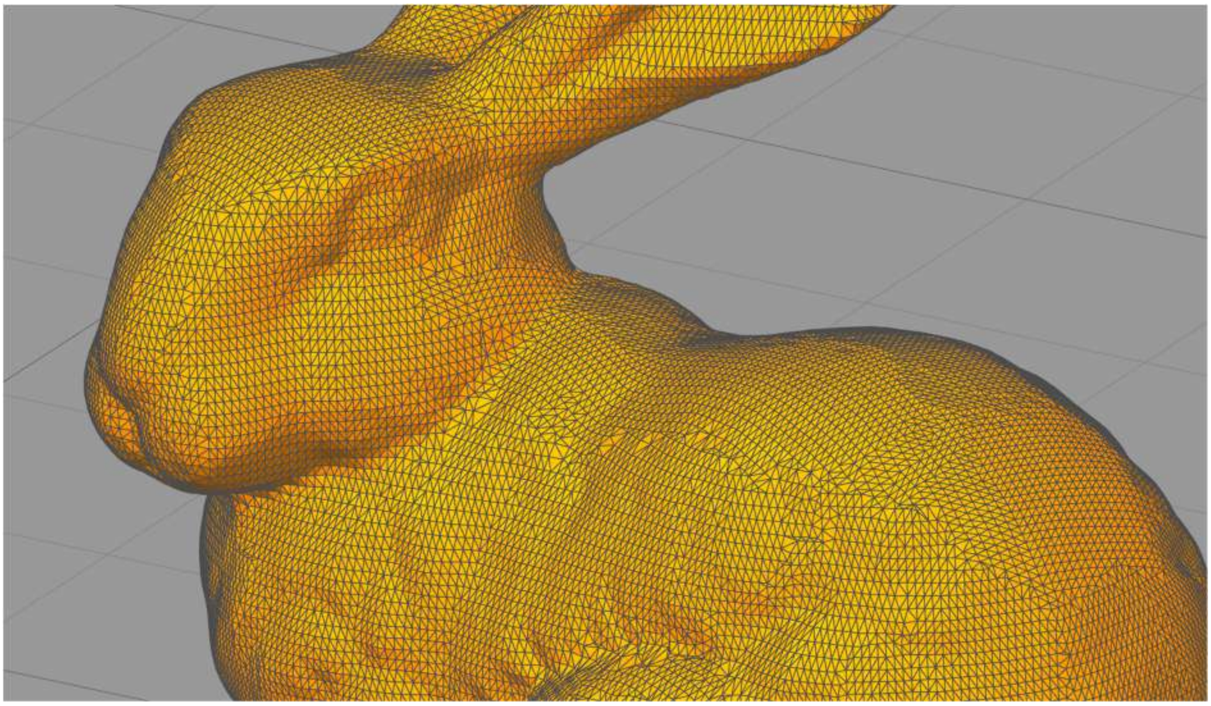


Figure 1. Stanford Bunny model in .stl format. Stanford 3D scanning repository.

3.2. Slicer software

Slicer software analyzes the model and slices it layer by layer with user-set parameters. The parameters control every aspect of the process, and have a great influence on the final 3D print.

The result of the slicing process is a set of commands, which determine the operation of the printer.

These commands are gcode standard commands, and are shared between most 3D printers and CNC machines. Most of them are movement commands, which are represented as curves in 3D space of the slicer software window. At this point it is crucial to investigate the slicing result to avoid any printing errors. Every operation of the printer (move, extrude, set temperature, enable cooling fan, etc.) is a result of gcode command execution.

The result is then saved to disk in .gcode format. This is a common ASCII text file which can easily be further investigated, or post processed e.g. to issue a pause command after a certain layer has finished.

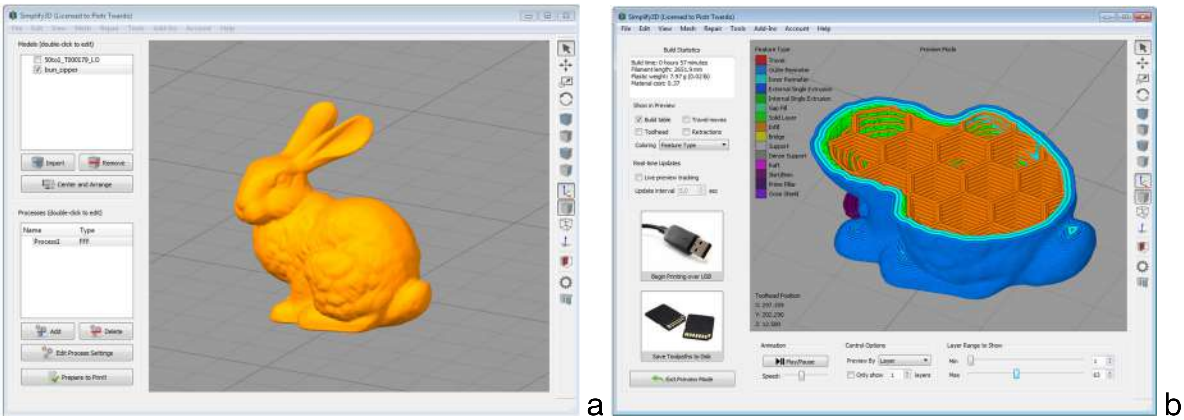


Figure 2. Simplified 3D, where: a) One of the slicer softwares used by MF; b) View of a gcode file generated by the slicer.

3.3. Printing gcode file

The file is uploaded into the printer and printed. Each 3D printer has its own electronic controller, and the controller reads the gcode file line by line and drives the machine.

4. PRINTING ON FABRICS - ARTISTIC SAMPLES

4.1. Characteristics of artistic items

Creativity is the most unique human capability; it determines who we are, differentiating people among cultures and from each other. People have been trying to realise their visions from the very beginning. Now with modern technologies the possibilities are greater than ever.

The term “artistic” defines an infinite range of objects which can, potentially, have any form and be made of any material. We believe that the best thing technology can do for artists is to support their creative freedom.

The ability to manufacture artistic ideas is a great challenge that no single technology can handle. Each technology has its strengths and can be exploited to produce a certain type of object.

3D printing is a vast subject in itself, as it consists of several different technologies with different capabilities. The key to success is to choose a technology able to provide the desired results, or design an object which leverages a certain technology.

4.2. Advantages and drawbacks of FFF technology

FFF 3D printing is a technology used by Monkeyfab printers. The artistic samples have been designed to use it to push its limits. The strength of the technology lies in the variety of materials which can be used.

Users can choose different types of plastic of almost any color. There is a high market demand for PLA; several companies in Poland have trouble fulfilling the demand because of a PLA pellet (the substratum for PLA filament) shortage.

Many manufacturers constantly develop new filaments, most notably Kai Parthy Lay filaments: https://www.matterhackers.com/store/c/Kai%20Parthy%20Lay%20Series and ColorFabb which include any color from the RAL palette. The possibilities for experimentation are vast and will only grow in the future.

It is also possible to use plastic from recycled PET bottles. Bioplastics such as PLA, which are biodegradable, are very popular.

Another strength of FFF is the fact that a printed object is ready to use after removing its support structure and it does not require any chemical treatment.

FFF is not the fastest nor the most precise technology. Printed details can be only as small as the nozzle diameter allows, which usually means 0.2 – 0.4mm. Many objects often require delicate support structures which have to be carefully removed.

4.3. Printing on fabrics – possibilities and requirements

Printing on fabrics imposes a different set of constraints. Fabrics are deformable and flexible, attaching printed plastic objects to fabrics makes them rigid.

One way to avoid this is to use flexible rubber filaments, which deform with the fabric. They come in different colors and, moreover, they can have different hardnesses. Harder materials are easier to print but may be not flexible enough, while softer materials can follow the curvature of the fabric more easily, but can be challenging to print.

The other way requires specific design.Small objects printed on a fabric let it deform freely and leave space for controlling the deformation. This can lead to interesting artistic results.

4.4. Printing detailed artistic patterns

The above issues have been discussed with the artist Patrick Wojciechowski, to support the design process. Based on the discussion, we have decided how to proceed.

Figure 3. Fashion designer Patrick Wojciechowski (left) at MonkeyFab's facilities.

As a base fabric, lycra sheet has been chosen due to its flexibility and because it is able to create a good bond between the fabric and the molten filament. The filament chosen for printing is a kind of soft TPE (thermoplastic elastomer), soft enough not to damage the deforming tissue. The designed patterns are low profile organic shapes, some of which are shown in Figure 5. The artist took his inspiration from ancient weaving techniques and silk patterns, most notably the patterns supplied by Garin.

4.5. The printing process

3D models have been created from the patterns provided by Patryk Wojciechowski, a Polish fashion designer who is collaborating with us. His designs are inspired by silk heritage, especially from Garin's collection. In Figure 4, on the left-hand side there is a *Rica* design, which has a symmetrical, static central bouquet knotted with a loop holding stems. On the right-hand side, the design is inspired by the *Hortensia* that is influenced by early 20th century modernism, including for the first time closed buds, lilies and hydrangeas. This design is inspired by a moiré, which refers to those fabrics in which a ripple or watered finishing process has been produced by pressing or applying heat to flatten parts of the ribs and leaving the rest in relief in order to make them reflect the light differently.

Because the patterns consist of many thin curves, caution should be taken to ensure that the details are not too small for the slicer algorithm, otherwise no gcode is going to be created. This problem should be taken care of at the 3D modeling stage, where it is relatively easy to avoid and the level of control is higher. When the model is ready, changing it can be a time consuming task.

In a model with many thin walls it is vital that the wall thickness corresponds to the diameter of the nozzle. The optimal printed path width is 110 %– 120 % of the nozzle diameter. Wall width should be a multiple of this value. If the nozzle is 0.4 in diameter, the thinnest walls should be 220 % * 0.4 = 0.88 mm. Thicker walls should follow the following formula: 1.2 * nozzle diameter * number of outlines.

Otherwise, when too many outlines (printed paths) are compressed into a small area the surface of the print is degraded. If the wall is filled with too few outlines, the print can be weak and brittle (see Figure 5).

These rules apply only to thin walled models, thicker walls do not share the same problem because they are filled with an “infill” pattern and not with an outline itself (see Figure 6).

Figure 4. Drawings of artistic patterns. Author: Patryk Wojciechowski.

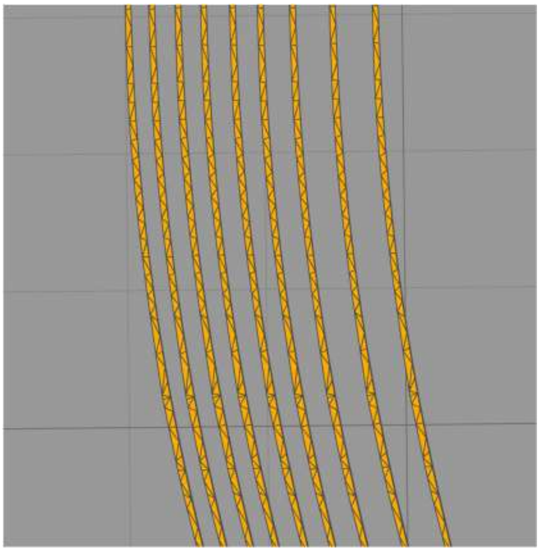
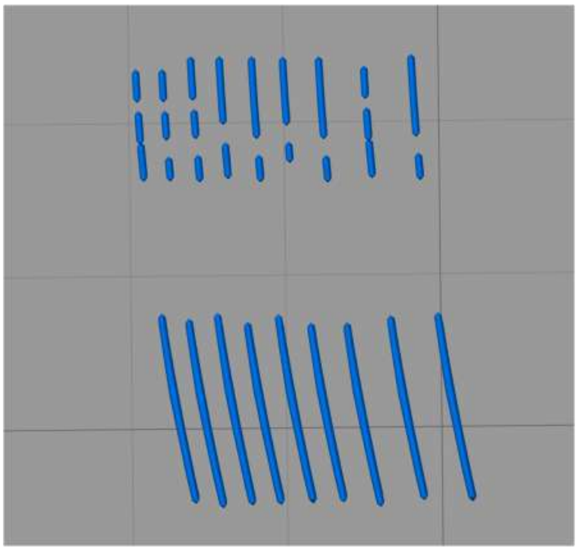
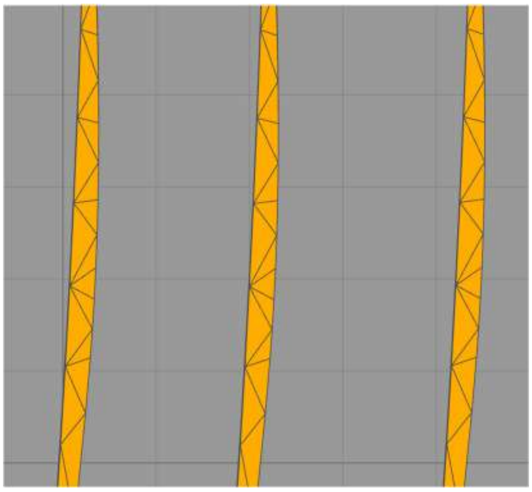

a

b

Figure 5. a) Thin walled model and; b) erroneous g-code, the paths do not fit between the walls.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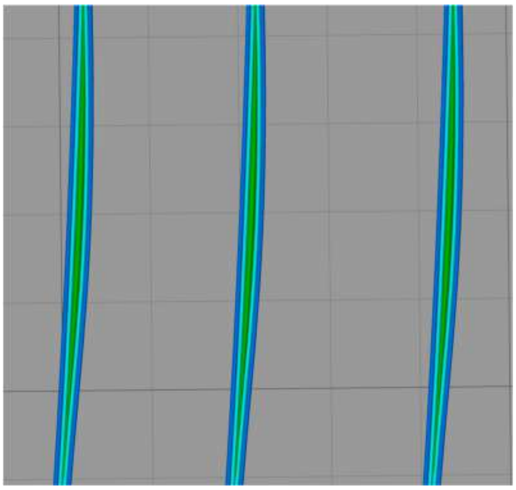

b

Figure 6. a) Thickened model walls and; b) correct g-code paths.

With the gcode prepared, the next step is to probe the print bed, leveraging the newly designed printhead. The importance of this process has been discussed in the deliverable D5.3. The printer controller measures the unevenness of the printing platform and offsets the printhead accordingly during the printing process.

After measuring the bed, a piece of fabric can be placed on the printing platform and fixed in place.

The printing process is then started and, having prepared everything thoroughly and taken the appropriate precautions, the process should run smoothly.

The results are good quality prints, firmly attached to the fabric (see Figure 7).

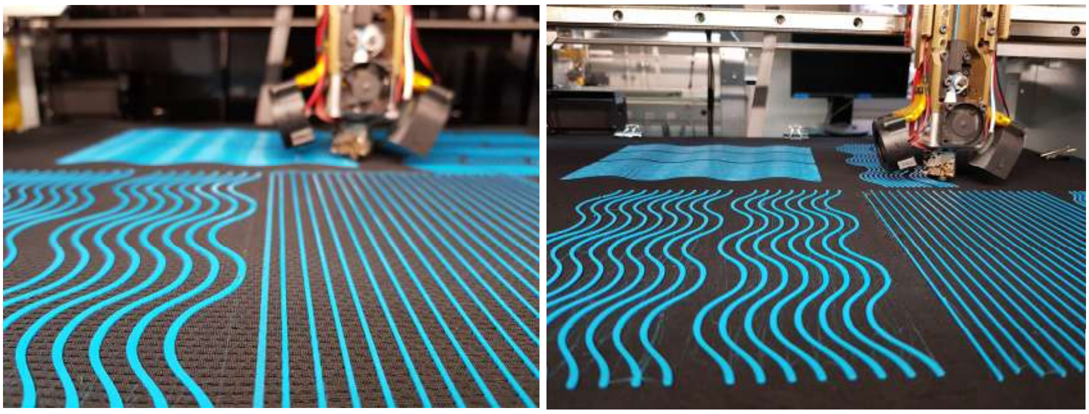


Figure 7. Pictures of printed results of a thermoplastic elastomer on lycra sheet.

4.6. Future research

Printing on fabrics with today's technology leaves a lot of room for further experimentation. One interesting direction is 4D printing. Fabrics and filaments have different elasticities. A fabric can be pre-strained on the printing platform before printing. After removing it from the printing platform, the fabric compresses back, changing the shape and deforming the printed pattern or object. Such deformation can be harnessed to obtain new forms. Combined with a variety of different filaments, this could provide many new possibilities for artists.

5. PRINTING SAMPLES FROM THE VIRTUAL LOOM

5.1. Sample scale and orientation

Successful 3D printing requires adequately scaled 3D models. If the model is too small, the slicer software produces erroneous results, such as distorting the details or not producing any results at all.

The scale of the model depends on the diameter of the printer nozzle. The most common nozzle diameter is 0.4 mm. A single wall of a printed object consists of two outlines, and if the thickness of the wall is less than 1mm, then it will not be taken into account by the slicing algorithm and no printing commands will be generated.

The other problem with small details occurs when printing paths are too short, e.g. when a printer has to print a series of very small circles. The generated paths are too short for the extrusion mechanism to print correctly, printing errors accumulate and after a few layers the print does not resemble the model.

The orientation of the model on the printing platform has a great influence on the quality of the print and the features of the fabric that require highlighting. Models printed in different orientations produce different results. Because the fabric is a thin sheet, it is desirable to print it hanging vertically on the printing platform rather than lying flat, which would seem to be more natural. Choosing a vertical orientation means that the model needs to feature an additional stand to keep it from falling over.

5.2. Sample geometry

The samples from the Virtual Loom are usually very small and detailed, which is to be expected when dealing with fabrics. Their real size does not allow them to be printed directly.

The samples display the interwoven threads with great precision, and are extremely valuable for the exploration of different weaving techniques. These same properties make them harder to print on common FFF 3D printers. To allow them to be printed successfully, and to achieve high quality, software 3D processing would be desirable.

The aim of printing a fabric sample can be twofold: to show the pattern on the fabric or to investigate the weave. These two goals require models with different sizes and characteristics that need to be processed in different ways.

5.2.1. Models used to show the pattern

Models used to show the pattern cover a larger area of the sample and details of interwoven threads are unnecessary. Also, such details often cause the aforementioned problems in the slicing process.

A large area of a fabric is also very thin and, as such, impossible to print.

The sample needs to have several modifications carried out:

1. Remove the excessive internal details
2. Thicken
3. Orient vertically and add a stand for support

5.2.2. Model for the investigation of weaving technique

The model for the investigation of weaving technique shows only a fragment of the fabric but should be enlarged several times. The fragment has to be chosen and cut out of the original model.

Such an enlarged model consists of a number of separated thread meshes arranged horizontally and vertically. The horizontal threads would force the slicing algorithms to create additional support structures which would contaminate the final result. To avoid this, the model has to be rotated 45 degrees before cutting out a fragment. Then, all of the threads will be oriented diagonally to the printing platform and thus safe to print. After cutting, the resulting hole in the mesh has to be closed.

5.3. Remodeling the samples

5.3.1. Models used to show the pattern

The re-meshing procedure consists of the following steps:

1. Project a dense mesh grid onto the model from both sides (Figure 8, Images a-d).

To create a watertight uniform mesh out of the sample, the grids are projected onto the sample from both sides. The density (number of rows and columns) in the grid and the resolution of the sample determines the resolution of the output mesh. This projection results in two separate grids, deformed accordingly to the base sample.

2. Move the two projected grids apart from each other to add width:

To add width to the final mesh, the two grids should be separated from each other by a few mm. This ensures that the model will be thick enough for the slicing algorithm.

3. Close the gaps between the grids

To create a watertight model, the grids must be connected together. This is achieved by bridging the opposite grid edges.

4. Model the stand

Even after adding thickness by moving the grids, these few mm can be too little to print reliably. Thin models are prone to falling. To ensure the printing process will be successful, an additional stand is added.

5. Imprint the name of the fabric onto the stand (optional)

There are many samples, and having a sample name imprinted on the stand is desirable for learning purposes and to keep the printed samples in order.

6. Join the grids to the stand into a watertight mesh using a boolean union operation.

The final step is to create one unified mesh out of the pattern mesh and the stand. This is achieved with a boolean union operation. Boolean operations on triangular meshes are especially tricky for all 3D software, and it is not uncommon to create an erroneous boolean mesh. It is advisable to check the final mesh for errors before printing. The final mesh is shown in image Figure 8-e.

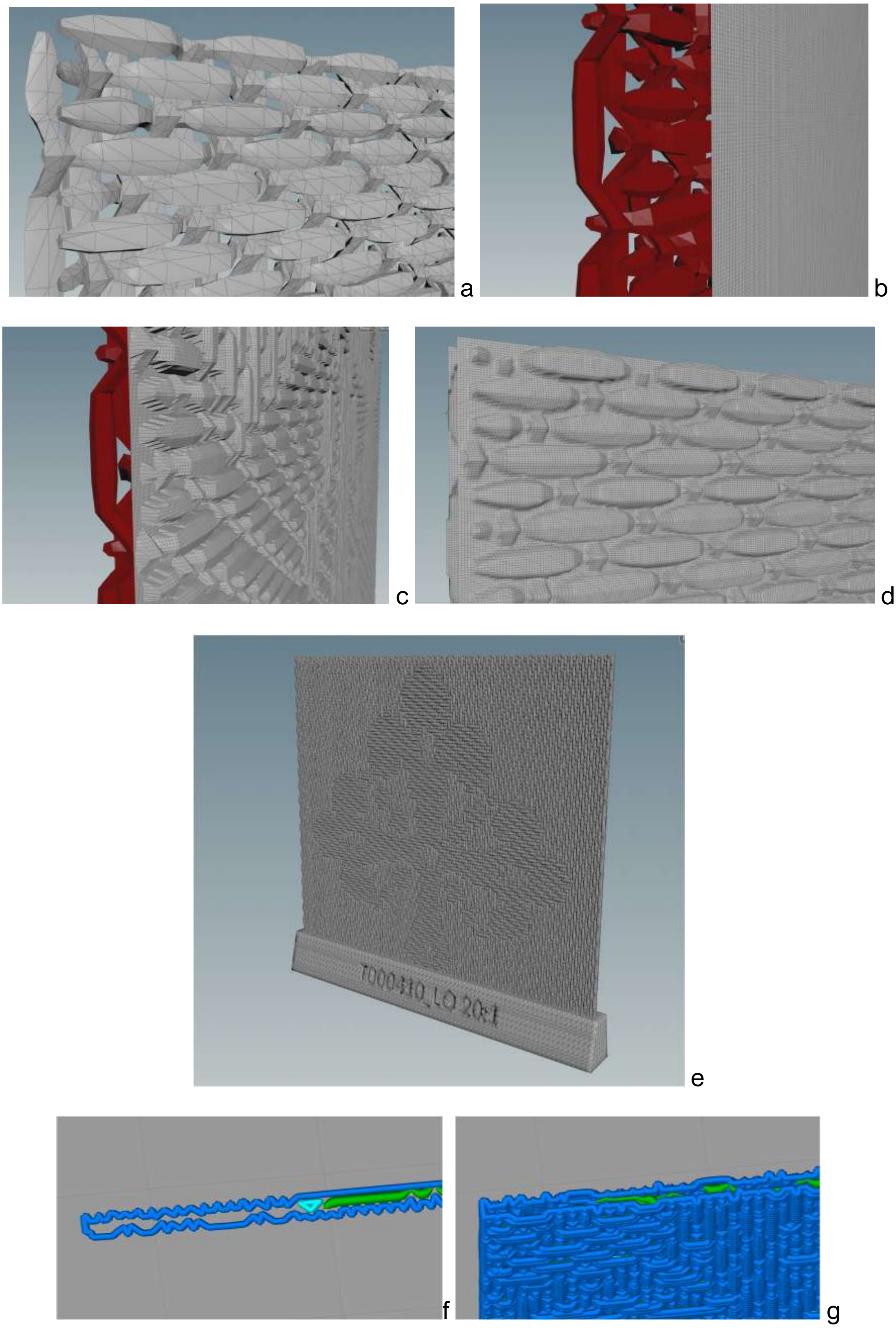
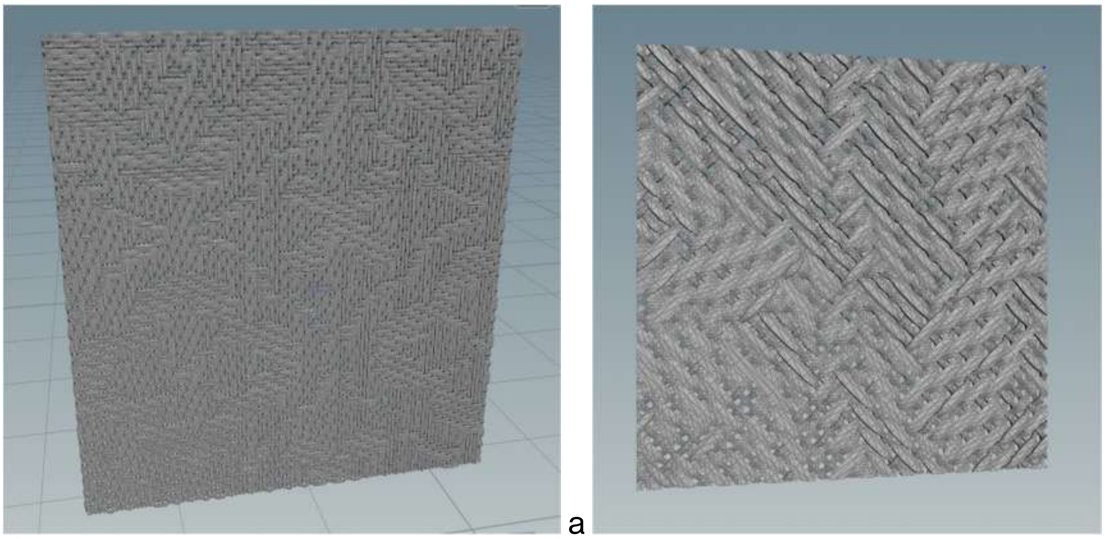


Figure 8. Models used to show the pattern, where: a) Disconnected mesh with gaps; b) High resolution grid against the model; c) The grid projected onto the model; d) Watertight front surface of the model; e) Fully remodeled sample; f) and g) Correct g-codes.

5.3.2. Model for the investigation of weaving techniques

The re-meshing procedure consists of the following steps:

1. Enlarge the model
2. Rotate 45 degrees
3. Cut out the desired fragment
4. Close the holes
5. Add a stand (optional).



a b

Figure 9. Different weaving techniques, where: a) Original sample; b) Enlarged, rotated and cropped for printing.

The remodeling has been done in SideEffects Houdini Apprentice 3D software.

5.4. Slicing process

The slicing process is the process of creating gcode commands from the 3D model, more specifically described in 3.2.

With correct models, slicing produces predictable results. The toolpaths are clean and the desired features are depicted with enough precision. The illustrative example in Figure 10 shows gcodes generated out from correctly prepared models. The image on the left depicts one printed layer viewed from the top. The image on the right shows several layers in an orthogonal view. Each blue or purple line is a path the printhead will follow.

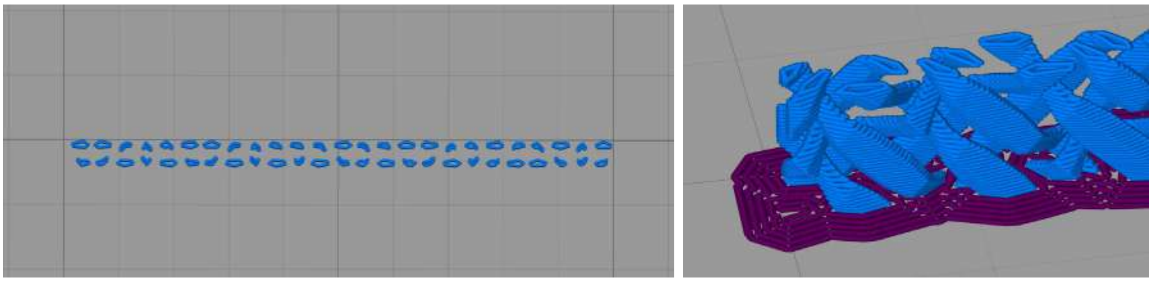


Figure 10. Correct g-codes of the second option.

5.5. Printing the samples

The printing samples show that the gcodes were correct. The objects does not have typical errors such as blobs of plastic sticking out, an uneven surface, holes in paths, etc. They have printed correctly, and have not fallen off the printing platform or deformed in an undesired way, nor have they overheated or failed in any other way.

The preparations carried out provide failsafe, high quality print outs of the Virtual Loom samples. Figure 11 shows an example of a pattern on the left, and an example of a weaving technique on the right.

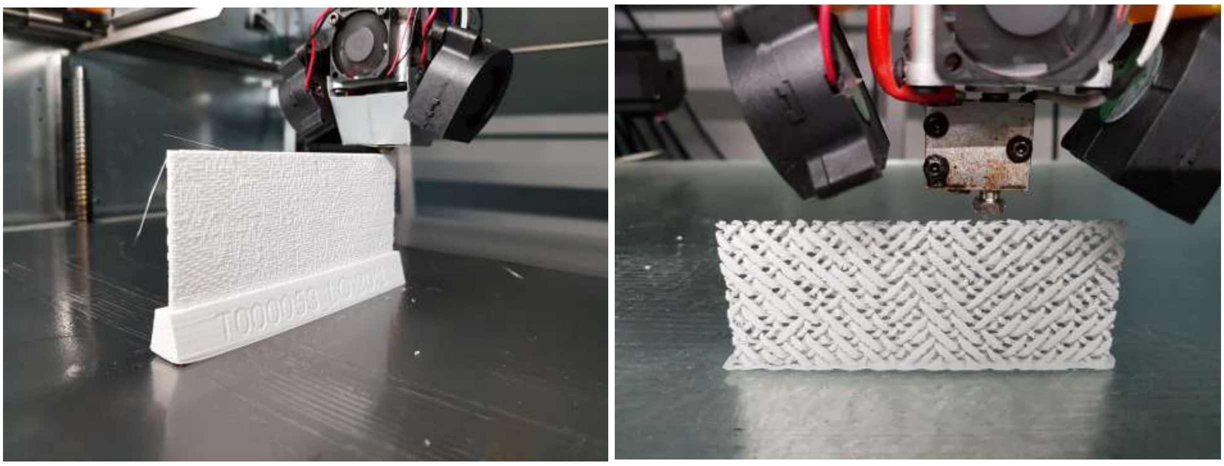


Figure 11. A detail showing a pattern and a weaving technique.

6. PRINTING SAMPLES FOR EASD

In the scope of the SILKNOW project communication activities, we have established a collaboration with the Design School in Valencia (EASD). This project began with a lesson in the School on the subject of Jewelry, where the UVEG ICT and SSH teams explained what SILKNOW is, the importance of silk in Europe and how the students could work creatively in order to disseminate this heritage. This first activity was also attended by the director of the subject, Jose Marín, who proposed using some outcomes of the image processing module of the Virtual Loom in order to design, in 3D, a set of brooches in combination with silk fabrics.

UVEG processed a set of images with the Virtual Loom, extracting the design in two plain colors (black/white) along with the contours, and made them available to EASD. Then, a total of eight students (in this case all females) produced the 3D brooches using CAD software. These models were exported to STL files and given to MF, who printed them. In Figure 12.1-8, the images, the 3D designs and the 3D printouts are shown for the eight brooches.

Figure 12.1 Design and 3D printout of a brooch. The fabric belongs to Garin’s collection.

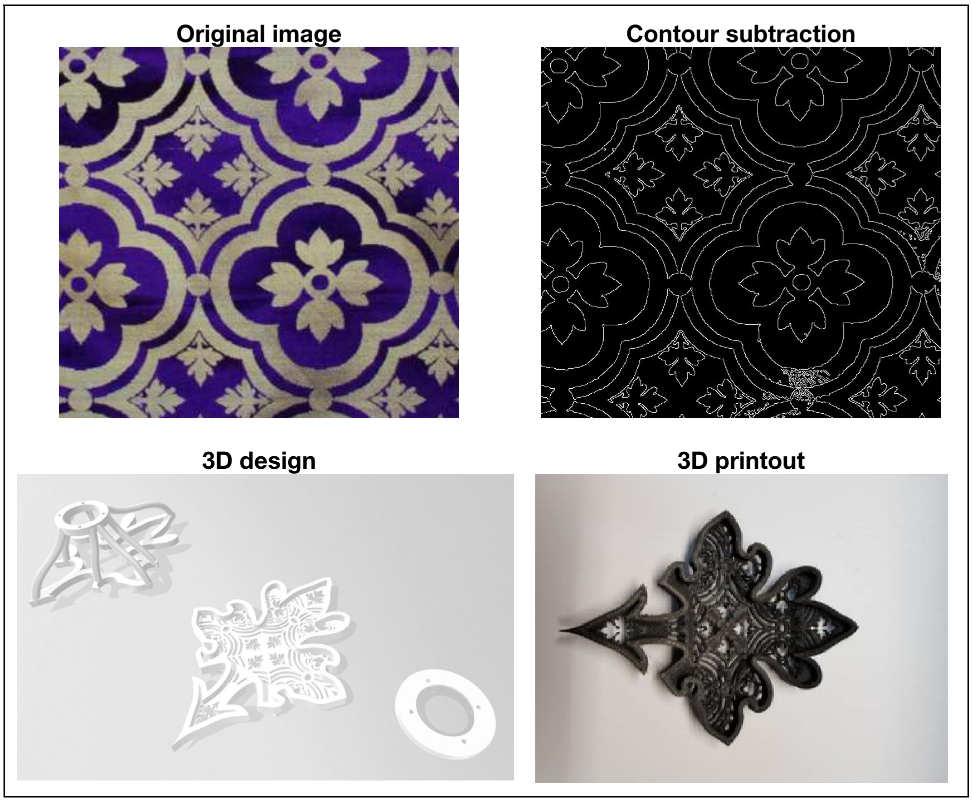


Figure 12.2. Design and 3D printout of a brooch. The fabric belongs to Garin's collection.

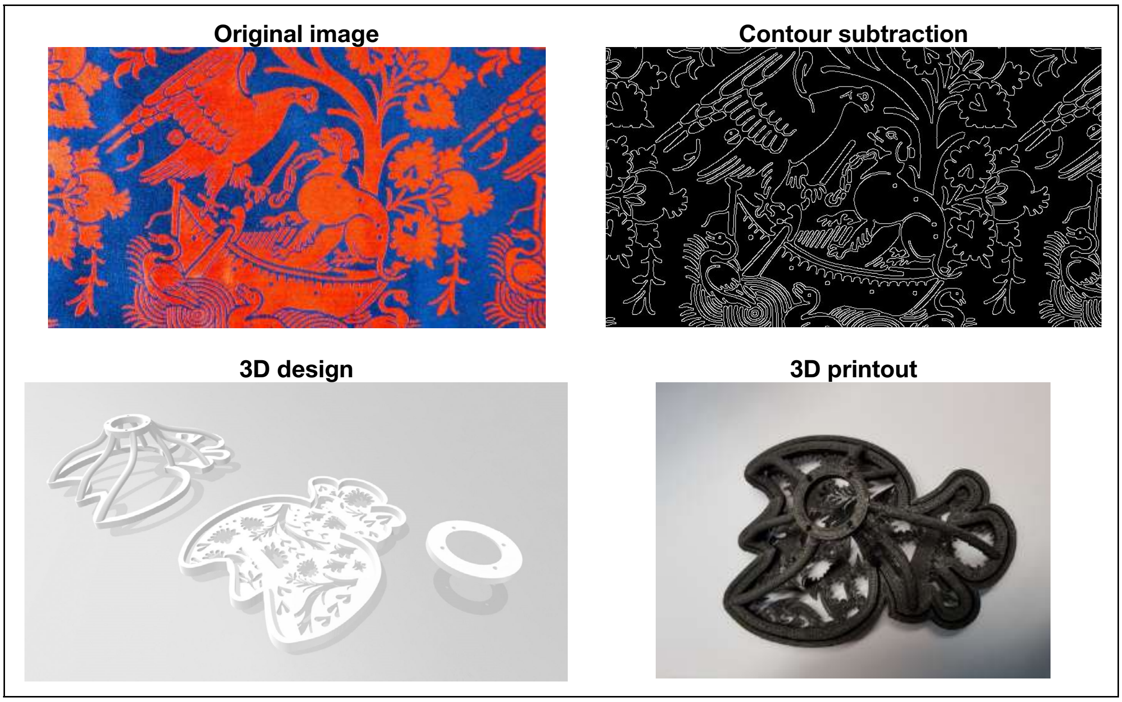


Figure 12.3. Design and 3D printout of a brooch. The fabric belongs to Haus der Seidenkultur Krefeld collection (https://seidenkultur.de/).

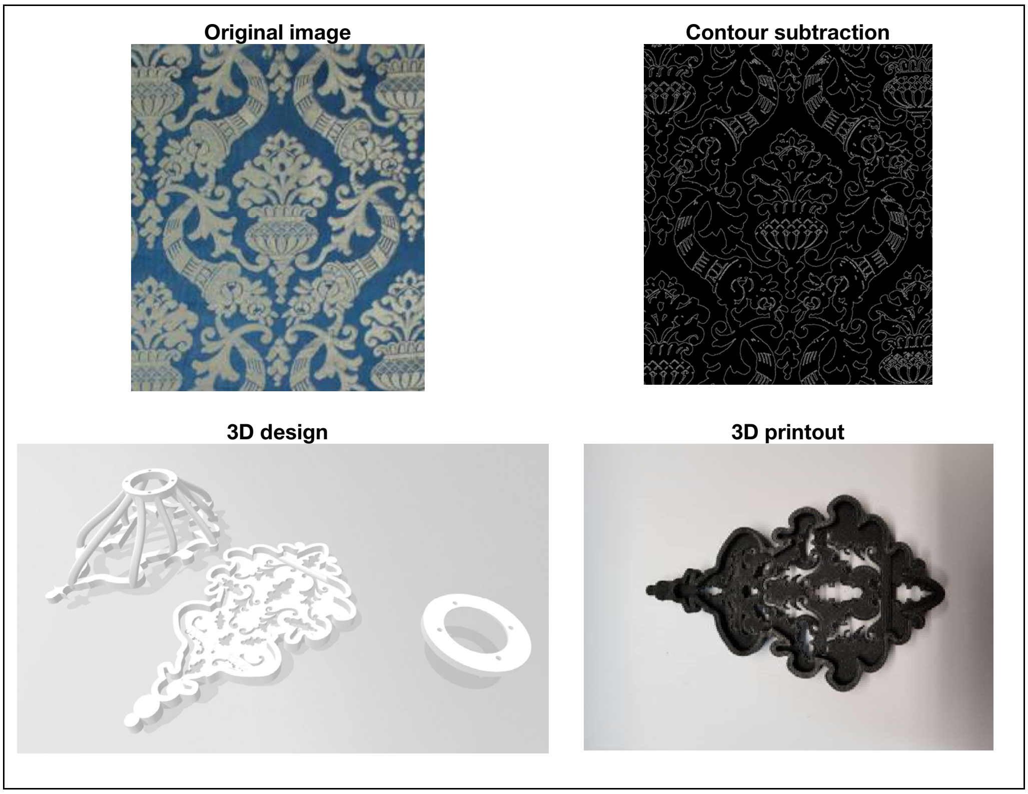


Figure 12.4. Design and 3D printout of a brooch. The fabric belongs to Garin's collection.

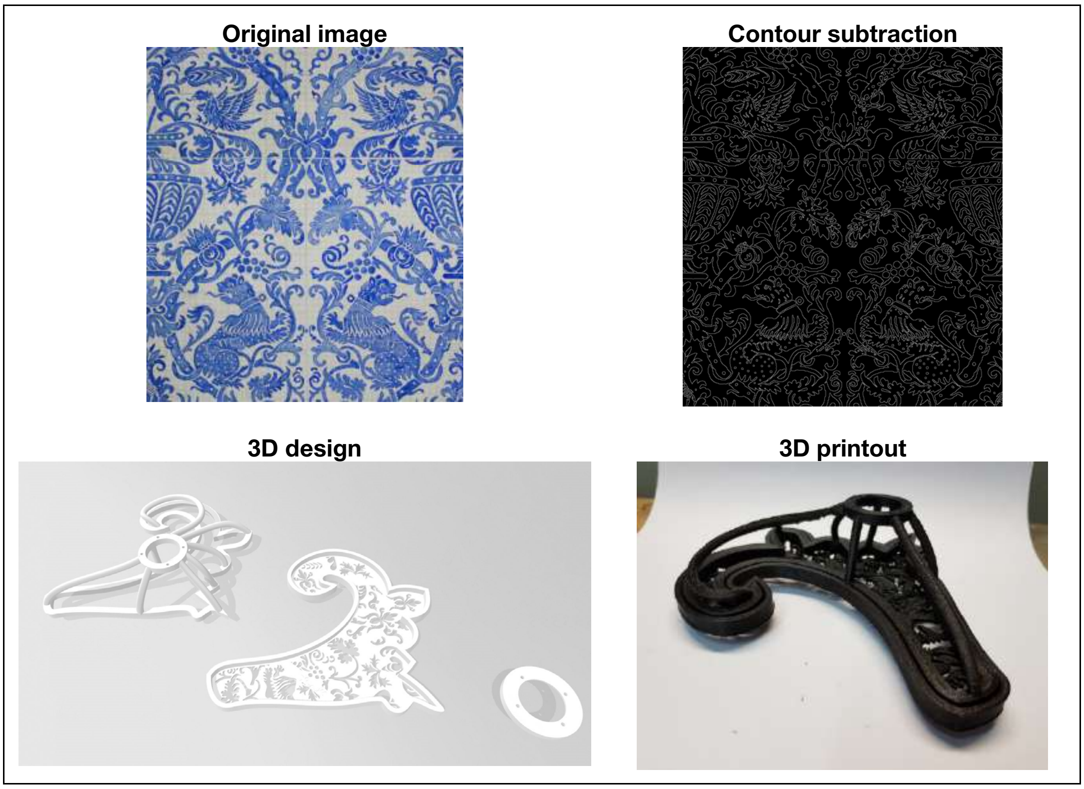


Figure 12.5. Design and 3D printout of a brooch. The technical drawing belongs to Garin's collection.

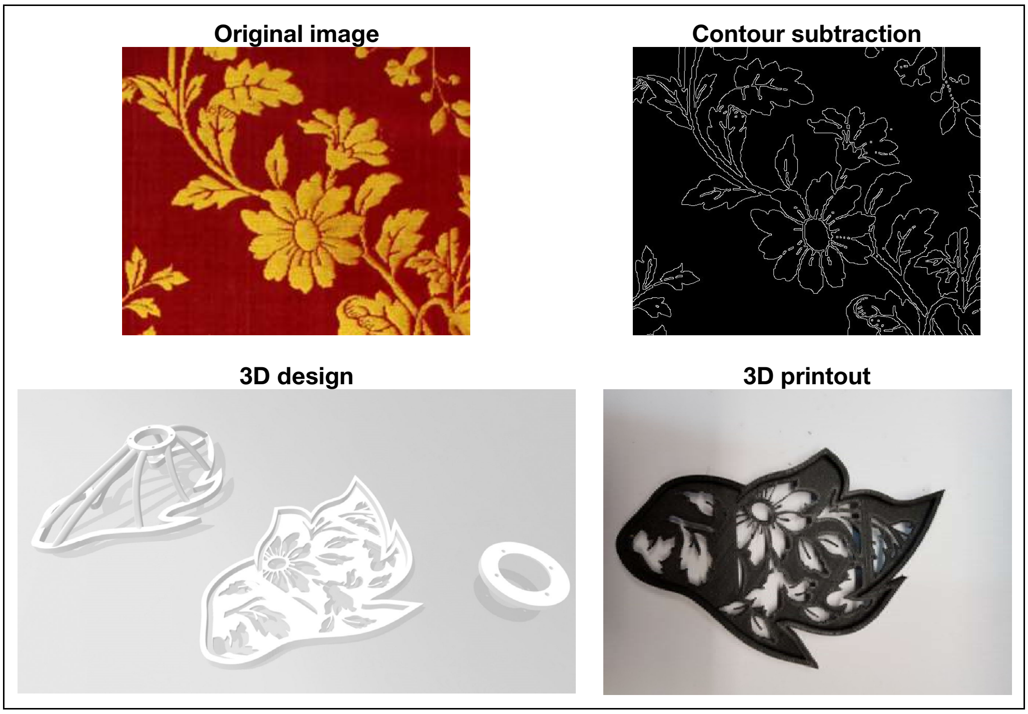


Figure 12.6. Design and 3D printout of a brooch. The fabric belongs to Garin's collection.

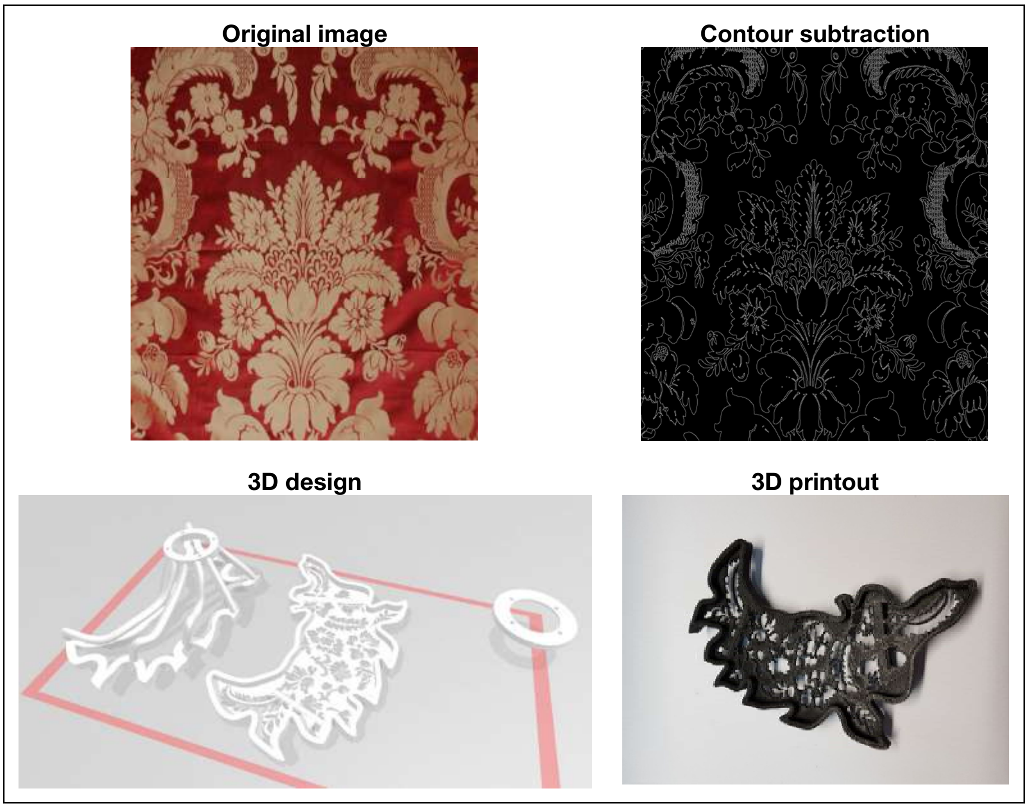


Figure 12.7. Design and 3D printout of a brooch. The fabric belongs to Garin's collection.

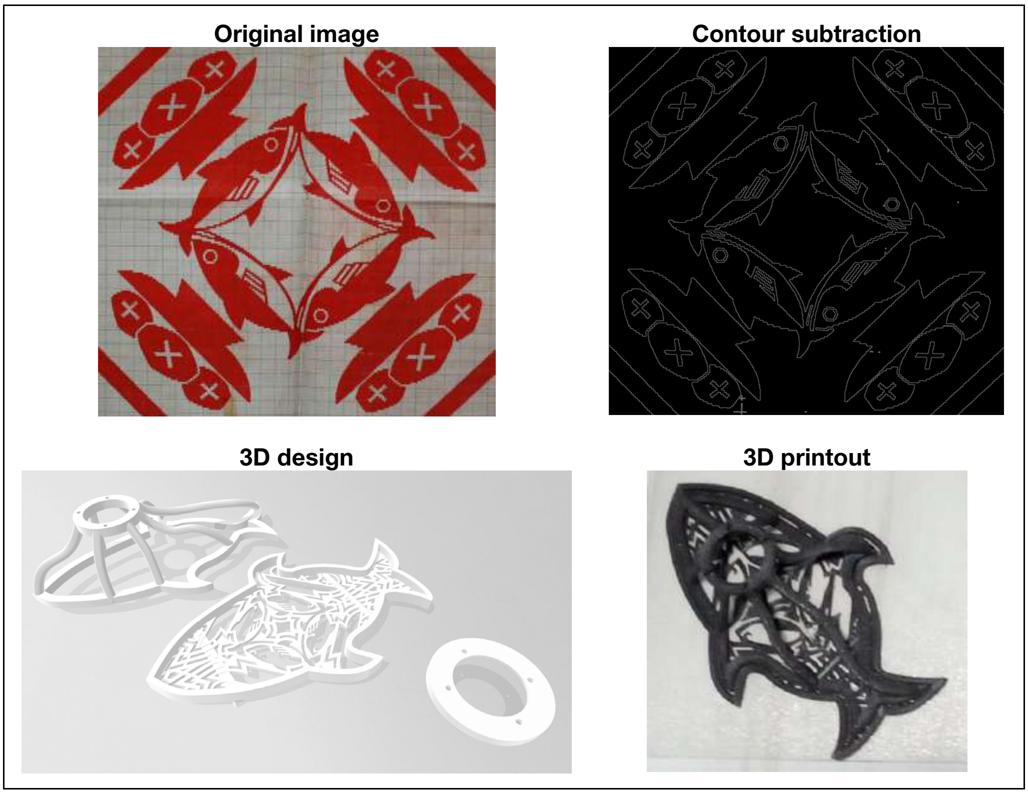


Figure 12.8. Design and 3D printout of a brooch. The technical drawing belongs to Garin's collection.

The result of this work will be shown at an exhibition in Valencia, where a whole day will be dedicated to the students. During this presentation, fashion designs created by students from the design school will be shown. Therefore, the students will be able to interact with the people living in the area and raise awareness of the importance of silk heritage through creativity.

In addition, the 3D designs will be visible on all the project's and the school's social networks, along with the possibility of showing them in one of the Instituto Cervantes events, in order to give them a more European projection.

7. SUSTAINABILITY IN 3D PRINTING PRODUCTION

7.1. The scale of the issue

FFF 3D printing has become widely popular with lots of companies using 3D printing to enhance their workflow. Makers and enthusiasts all over the world use 3D printers at home.

The demand for common PLA filaments is growing steadily, and has become a challenge for PLA source pellet producers. This means that more plastic is being produced.

A large part of the plastic is used for the support structures and after being detached it goes straight to the garbage. A high percentage of 3D printed objects are temporary or test objects and have a short life span.

In terms of plastic garbage production, today 3D printing is not comparable to the production of packaging, toys or other products, but the industry is growing and research on sustainability is needed.

7.2. Directions for improvement

7.2.1 Using bioplastics for 3D printing

Research into bioplastics is a high priority. Plastic waste can be found everywhere on earth, from the peak of Mount Everest down to the Challengers Deep. Disposed pieces disintegrate into tiny particles and will last for hundreds of thousands of years, poisoning every living organism. Bioplastics are materials created out of renewable sources. They can be consumed by protozoa, and thus decompose into simple, non-toxic chemical compounds. http://www.bioplastics.guide/ref/bioplastics/biodegradable-bioplastics

Polylactic acid (PLA) is one of them. It is a very popular polymer that is produced from cornstarch. While it is considered biodegradable, PLA waste has to be composted under special conditions in order to fully disintegrate. Successful composting of PLA is impossible today, as it goes into the same container as a lot of different polymers. At present, PLA is being burned along with many other plastic material waste in order to recover energy.

To effectively dispose of PLA, it has to be separated from other plastics, otherwise it is just another pollutant.

There are other polymers such as PHA (polyhydroxyalkanoate) which could develop promising properties that are worth waiting for. PHA is recovered from bacteria that store it as their energy source, and it biodegrades in the ambient environment. It could be used to produce food packaging, straws and other products that inevitably end up in the environment.

https://www.biobasedpress.eu/2016/08/pha-promising-versatile-biodegradable

3D printing is not a high volume technology. It is not used to manufacture disposable goods. The desirable properties of a 3D printed object are its durability, resistance to the environment (UV, temperature, water), long term dimensional stability and other features not commonly connected to desirable features of bioplastics.

3D printing is used to produce sculptures and statues for outdoor exhibitions. It is important that the sculpture will not decompose over the next few years, otherwise it could be a real threat.

Figure 13. Statue of St. Antoine that MF manufactured for the Łagiewniki church in Łódź.

PHA is not widely used in the 3D printing industry yet; the availability of PHA filaments is inferior to the overwhelming availability of PLA and PET. While PLA is known to withstand harsh conditions and remain stable through the years, the properties of PHA and PHA mixed filaments are neither well tested nor trusted by the 3D printing community. It could become the bioplastic of the future, when its popularity and availability grows. If not in industrial 3D printing, for sure at the consumer level, but most notably for the disposable goods (packaging, straws, disposable plastic cutlery, etc.) market.

As public awareness rises, the demand for bioplastics can only grow.

Experimental polymers are eagerly used by makers and small design companies, but industry requires durable, tested materials such as ABS or polyamide, and this is not going to change soon. Industrial 3D printing produces machine parts which have to be durable, chemically resistant, and behave in a predictable way throughout the years. Bioplastics are not a contender in this area and they will not replace technical materials.

In reality, bioplastics are not the solution for today; their development has a long way to go before any serious usage in the 3D printing world will be seen.

7.2.2 Making filament from recycled plastic.

Recycling is a much easier and tenable solution. A polymer has to sustain its properties during the recycling process. Most common plastics do not, but PET polymer, out of which most plastic bottles are produced, is an exception. Its properties do not change during the recycling process.

There is recycled PET filament on the market that contains 80% plastic from scrap bottles.

At the moment, the price of recycled PET is too high to consider it as competition for PLA in the mass market, but the direction is very promising. PET filaments are second in popularity. They are easy to print and produce high quality results.

Apart from ready-made recycled filament, there are a few machines for home and studio use that produce filaments from plastic scraps. They are by no means comparable to industrial filament extruders, but the movement is gaining traction. With these machines, it is easy to produce filament out of almost any plastic.

Recycling is the solution that can be readily used, it will only become more popular and available.

7.2.3. 3D printer power consumption.

The process of 3D printing is very time consuming and usually takes several hours.

Almost all 3D printers are equipped with heated nozzles, and a heated chamber or a heated bed. Power consumption of a common printer is around 120 – 200 W for a small sized one, and several kW for large industrial machines. Many consumer level printers are open, and the heat produced by the heated bed is dissipated. In cold countries, this is not necessarily a problem because the heat generated helps to heat up the house or office. It is desirable, and much more energy efficient, to use enclosed printers where the heat loss is much lower. Several printers working constantly for days consume a lot of power, and the carbon footprint of their work is not negligible. As energy prices go up, companies are starting to take this into account. There are many more enclosed printers today than a few years ago. They are more efficient, safer machines which also provide better results due to stable thermal conditions during the printing process.

8. IMPACT OF THE PROJECT’S RESULTS ON THE MF PRINTING PROCESS

The results of the project have been incorporated into MF production printers and they are in constant use. All projects and orders carried out by MF take advantage of these results. The research has been shown to enhance the printing process in many of the areas specified below.

New printheads are much more stable and predictable; they produce better quality results and are fast and easy to service. The time required for basic servicing, such as changing the nozzle, repairing or replacing the hotend or the whole printhead has been decreased by an order of magnitude. The policy “replace now, repair later” has been effectively introduced and has greatly improved MF’s workflow.

Time and power saving flexible magnetic printing sheet has increased work capacity and reduced inter-job delays, as less time is required to cool down and then heat up the printing platform again.

Now, queued jobs are printed rapidly one by one. The flexible sheet cools and heats up fast. Printed objects are easy and safe to remove.

MF is working on a new generation of large scale, industrial 3D printers to replace the current 3D printing farm. All machines will be equipped with the technology developed within the Project.

The possibility of effectively printing on fabrics is going to help MF to gain new markets in the areas of art and design, and introduce new possibilities for artists.

MF is currently working on a new line of large-scale 3D printers which will include the results of the Projects. They will populate the new MF printing farm planned for late 2020.

MF is also investigating the possibility of introducing new printers into the market in 2021.

9. CONCLUSION

For this deliverable, a collection of 3D printouts has been produced. These printouts have different characteristics, as they are intended to be used by different target audiences, or have different purposes. However, a common characteristic of all of them is that they are closely related to European silk heritage, as the starting point for all of them are original historical fabrics and/or designs.

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