Re-FREAM
Re-Thinking of Fashion in Research and Artist collaborating development for Urban Manufacturing

Hub "Additive Manufacturing"

Deliverable 4.6
Final printed prototypes fabricated by using optimized software

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S+T+ARTS LIGHTHOUSE Re-FREAM

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Working Package WP4

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Contributions by: Haratech GmbH

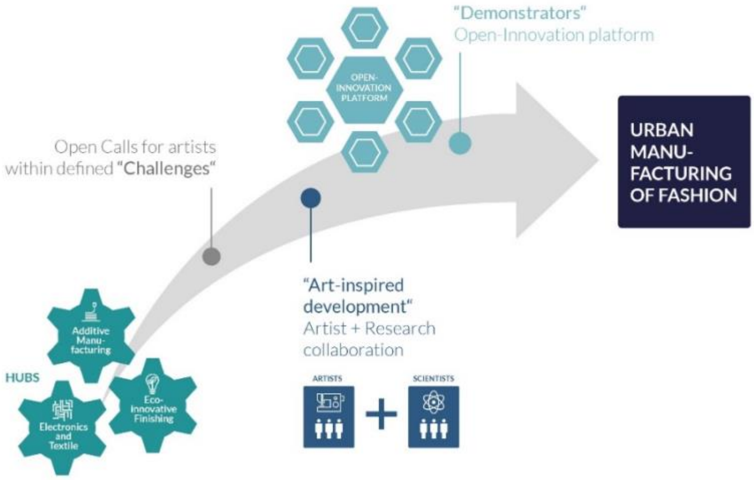
Project co-funded by the European Commission within H2020 Framework Programme		
Dissemination Level		
PU	Public	x
CO	Confidential, only for members of the consortium (including the Commission Services)	
Type		
R	Document, report (excluding the periodic and final reports)	
DEM	Demonstrator, pilot, prototype, plan designs	x
DEC	Websites, patents filing, press & media actions, videos, etc.	

Contents

0 Context Information

0.1 The Re-FREAM Project

Re-FREAM will support **art-driven innovation** in European R&I projects by inclusion of artists in research consortia via linked third parties. The artistic community receives a strong support from art-related partners like the Art University of Linz (UFG) and the European Institute of Design (IED), creative hubs and facilitators like Wear-IT Berlin (FashionTech), AITEX, ARCA and CREATIVE REGION combined with remarkable technology from IZM Fraunhofer (E-textiles), STRATASYS, HARATECH (3D-printing), EMPA (3D body simulation), CARE APPLICATIONS (Garment nebulization) and PROFACTOR (Additive manufacturing).



Re-FREAM boosts **art-inspired urban manufacturing**, where the city becomes a new production space. Especially for **creative fashion**, urban manufacturing offers a great opportunity to create an alternative to the much criticized production in low-wage countries.

Three technologies (additive manufacturing, electronics on textiles and eco-innovative finishing of fashion) will be explored together. **In co-creation** 20 awarded Artist/ Researcher teams, digitalized manufacturing of fashion will be developed up to TRL 5 to enable small-scale production of fashion in urban environment. An **Open-Innovation Platform** will finally link the know-how and the communities of the hubs, will offer access to relevant facilities and make the Re-FREAM art-inspired urban manufacturing working model sustainable.

0.2 Document history

Version	Date	Change/Reason for change
V1.0	07.10.2021	Draft template prepared for partner input
V1.1	28.10.2021	Partner (UFG) edited version for partner (HAR) input
V1.2	28.10.2021	Input from HAR added
V1.3	28.10.2021	UFG review HAR input and changes.
V1.4	11.11.2021	UFG review PRO input and changes
V1.5	12.11.2021	Finalization by PRO and CRE

0.3 Purpose and Scope of Deliverable Report D4.6

Demonstrator or prototype of a fashion art object from the 2nd round created with the help of the further optimized software for digital shaping and fabrication of 3D objects with a Fused Filament Fabrication (FFF) printer using bio-based materials.

1 Executive summary

Within Re-FREAM, artists are co-creating together with scientists to develop concepts for the future of fashion and urban manufacturing. The project Syntropia from Eugenia Morpurgo (designer and researcher) and Sophia Guggenberger (shoe designer and maker) aims to develop a shoe based on biomaterials which can grow on and be harvested from a single regenerative polycultural field. These shoes are manufactured with a combination of traditional and modern technologies.

Figure 1: Polycultural field illustration (left) and Final shoe prototypes.(right)

Figure 1 shows the theoretical polycultural field which provides the regenerative materials needed for the shoe production. Figure 2 shows the prototype output which is the result of the co-creation process.

During a 9 month period of co-creation with Eugenia and Sophia, their co-creation partners Haratech and the department of fashion of technology at the art university Linz (F&T) worked together to establish a 3D workflow where the whole shoe design process, from sketch to fabrication, becomes parametric and open-ended.

2 Optimized 3D software workflow for creation and fabrication

Together with F&T and Haratech, Eugenia and Sophia created a 3D workflow for the parametric shoe design process based on traditional methods. The 3D workflow covers the whole process from initial rough prototypes to digital fabrication and is fully open.

The 3D software Rhinoceros® and its parametric design plugin Grasshopper® were used throughout this project; the goal was to create one set of digital files where the design process is laid out. It works as a communication tool between all the co-creation partners. The files are self-explanatory and are open by design, so that changes can be made at any time. This ensures one can make various versions for review and testing purposes in the design stage as well as in the prototype fabrication stage.

Rhinoceros and Grasshopper are registered trademarks of Robert McNeel & Associates.

2.1 Shoe last

A last is a mechanical form shaped like a human foot, it forms the base of the shoe design and can be used to make the upper as well as the sole shapes.

As a starting point, a traditional shoe maker transferred the master last shape as developed with the artists and created a digital master last. This last is then graded to various EU based sizes, which means the shape is scaled by specific values in all three dimensions in order to create different sizes. F&T then re-engineered the grading by analyzing the grading system within Rhinoceros and Grasshopper. Figure 3 shows a screenshot of the Grasshopper definition where the basic system behind the grading is distilled.

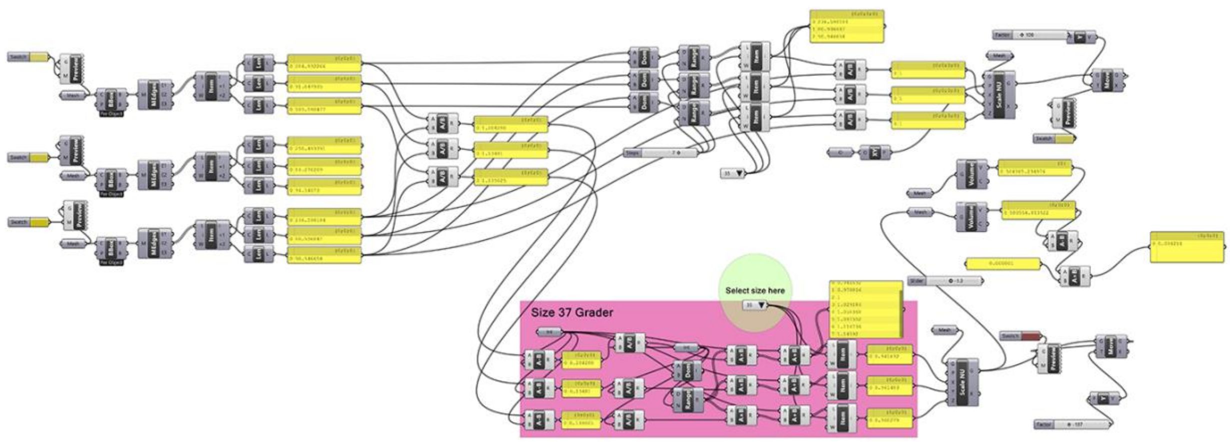


Figure 3: Screenshot of Grasshopper definition which can grade the last shape.

Now it is possible to alter the size within the different sizing systems, be it EU or US, or go anywhere in between. With a couple of alterations, independent grading within the toe box or heel region is also possible.

This grading system is key for a parametric workflow, one only needs to alter the master design and the grading system can compute all the graded versions for the intended sizes.

2.2 Parametric design

The digitized last was supplied as a dense polygon mesh, consisting of thousands of triangular surfaces. F&T worked together with the artists to create a parametric model of the master last shape which outputs a smooth NURBS surface. NURBS is short for Non-uniform Rational B-Spline, a NURBS surface is mathematically defined by a relatively small set of control points. Figure 4 shows the difference between the measured polygon mesh model (top) and the re-engineered NURBS surface (bottom).

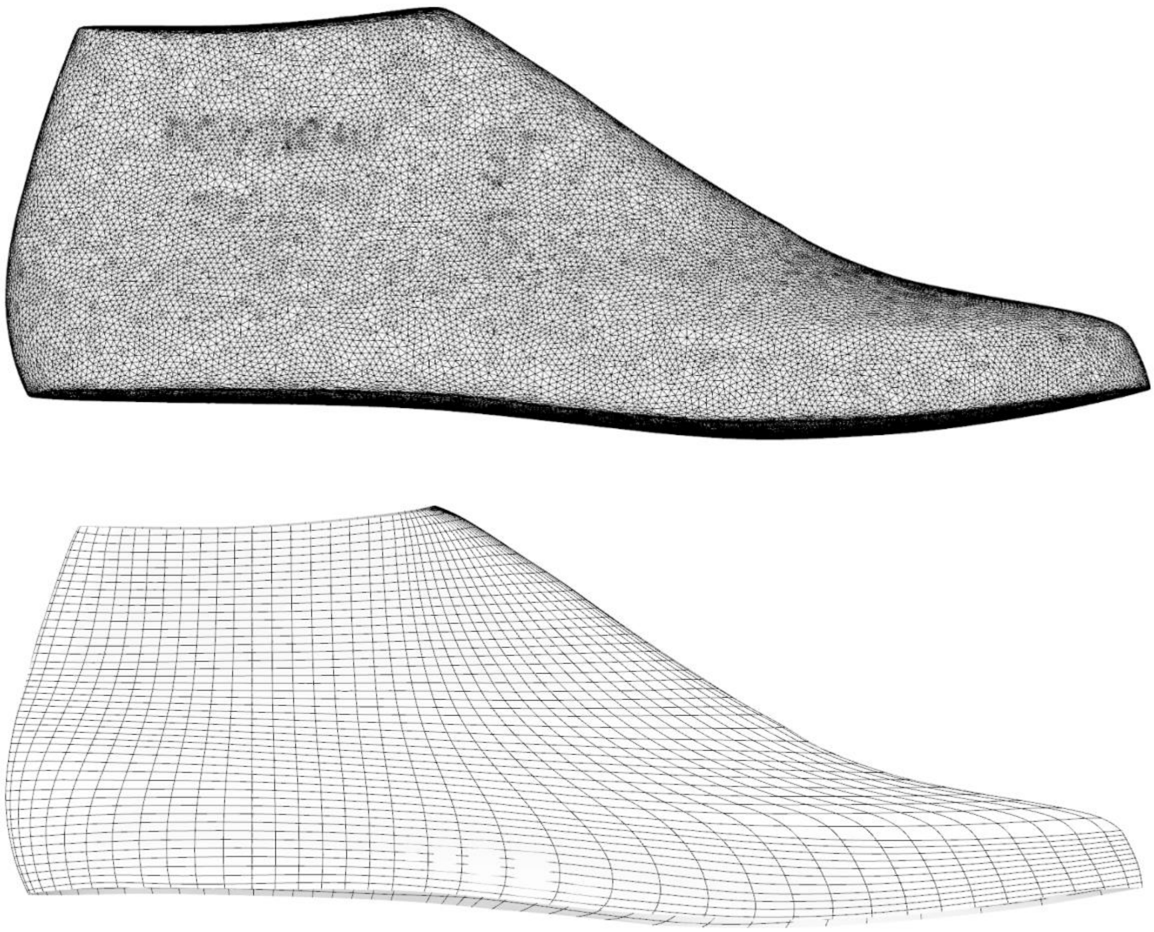


Figure 4: Polygon mesh of the master last on top, re-engineered NURBS model below.

The NURBS model is a continuous surface which can be modified: with simple commands in the 3D software such as offsetting surfaces and trimming them, one can generate all the parts which can then be digitally fabricated. This also means one could also easily update this definition with other custom last shapes for future designs.

Since the last shape is fully parametric, all parts derived from it will also update automatically, ensuring to always have the latest version. One can also quickly make some slight alterations to achieve variations for aesthetic or manufacturing reasons.

The Rhinoceros and Grasshopper files were used together with Sophia Guggenberger for her shoe design, she had prior experience with Rhinoceros but not so much with Grasshopper. In order to communicate clearly by exchanging these files back and forth, a grouping and color-coding system was used to make it easier to focus on the specific parts one would like to change.

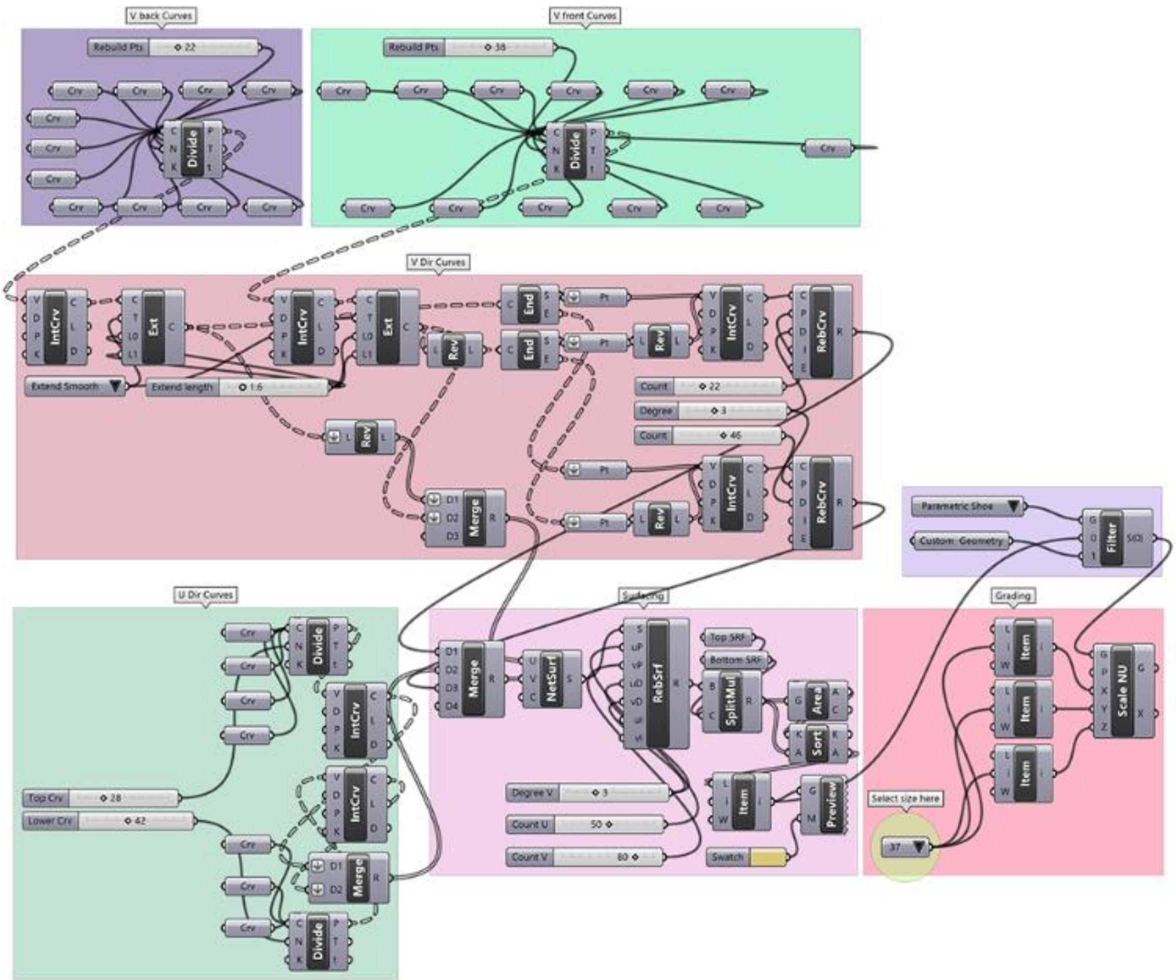


Figure 5: Screenshot of Grasshopper definition where the last is re-engineered based on the polygon mesh.

For example, the top two groups in figure 5 correspond with lines at the back (purple) and front (green) of the shoe, as seen from above. These files served as design tool as well as a way of communicating between the co-creation partners.

2.3 Digital fabrication

Haratech worked with Fused Filament Fabrication (FFF) printers for this project, using semi-rigid, bio-based, bio-degradable filaments. Figure 6 shows the first flat material tests to determine the best material combinations. After preliminary tests to define the optimal printing parameters, 2 materials have been selected for the second part of the experiments, namely producing and using custom-made filaments, made of a combination of said materials and a central thread reinforcement (hemp and cotton). The thread brings interesting mechanical properties, though at the cost of more delicate manufacturing methods, since the 3D printer shall either cut the thread at every tool "jump" (i.e. a tool movement with no material extrusion, between two locations), or print the whole part in one continuous line. To limit the complexity of the Syntropia project and to use the properties of the thread to its full potential, the latter has been chosen.

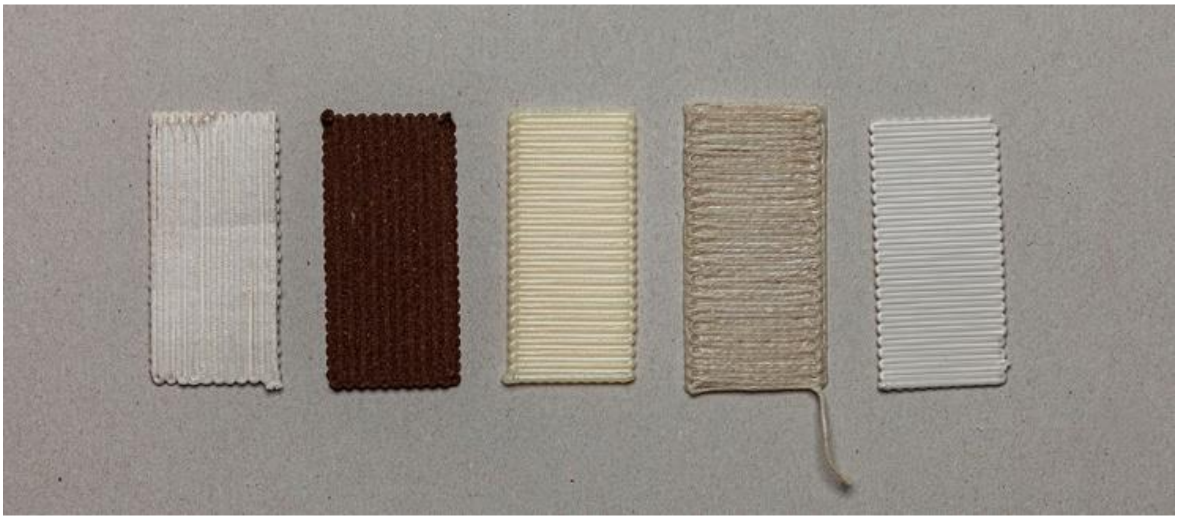


Figure 6: Flat 3D print tests with various material combinations.

The usual 3D print preparation workflow implies using a software called a "slicer" to generate the print paths and specific sets of instructions for a particular printer, a so-called GCODE file. Considering the unconventional shapes and paths to be printed, common slicers did not provide the necessary level of influence on the actual printing process and path creation, since they are mostly made for horizontal, layer-by-layer printing. Figure 7 shows some basic geometry tests with a regular slicer.

Figure 7: 3D geometry print tests with regular slicer

For the shoe frames it was important to work with the specific geometry, therefore more tests were needed, apart from the flat and primitive 3D geometry like a cylinder. Figure 8 shows print tests with specific parts of the back of the shoe design.

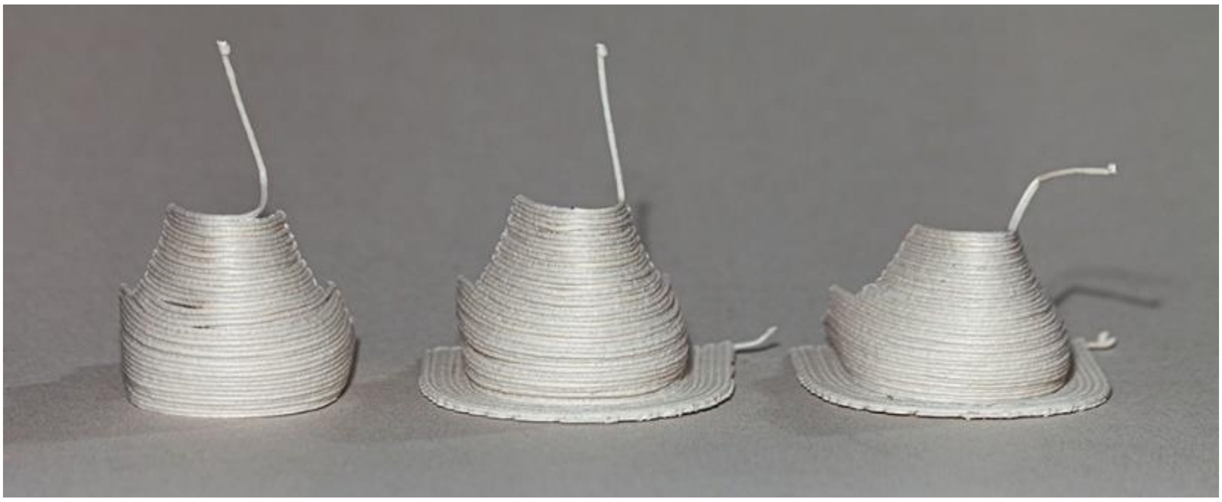


Figure 8: 3D geometry print tests with parts of shoe frames.

Meanwhile, Eugenia Morpurgo and Sophia GUggenberger first started working with a simple thread on a mock-up of the last in order to obtain the best way to distribute the continuous path, which informed the design strategy for the slicing on the 3D model.
This is a great example of how analog design strategy can influence the digital design, figure 9 shows analog thread placement on a shoe last and some digital tests using various line placement.

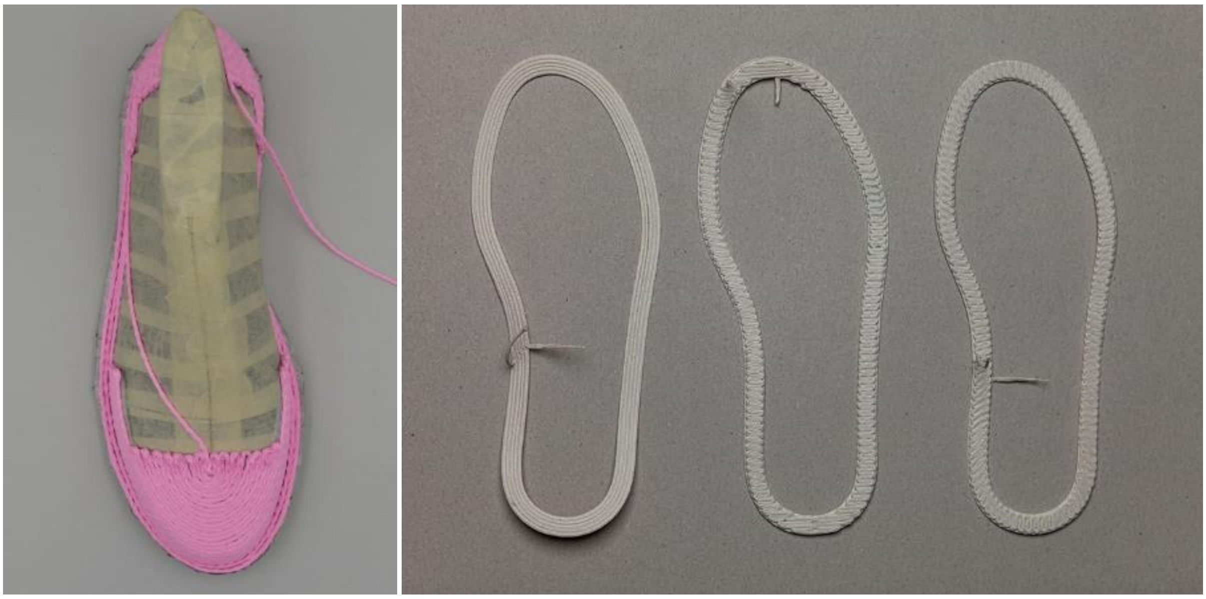


Figure 9: Analog thread placement test on the left vs digital placement tests on the right.

Haratech and F&T collaborated on a further Grasshopper definition which translates a curve from the 3D model into a custom GCODE. This allowed the artists to prepare the path in Rhinoceros and then feed the curves into the Grasshopper definition to generate a continuous path. In figure 10 you can see an overview of the GCODE generator definition which takes the lines and inserts the printer-specific instructions to make the custom GCODE.

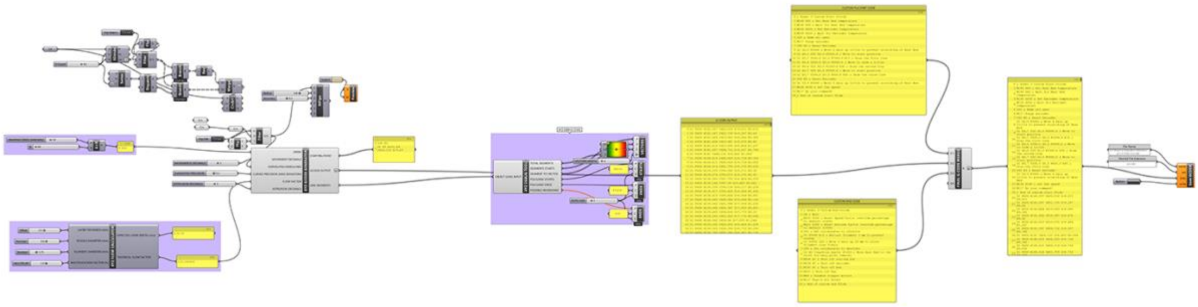


Figure 10: Grasshopper custom GCODE generator definition.

With a usual slicer, the user has little influence and visibility over the (mostly automatic) path generation. The current custom script allows the designer to preview and remodel the path before generating the GCODE and sending it to the printer. Figure 11 shows a preview for a toebox shape of a shoe.

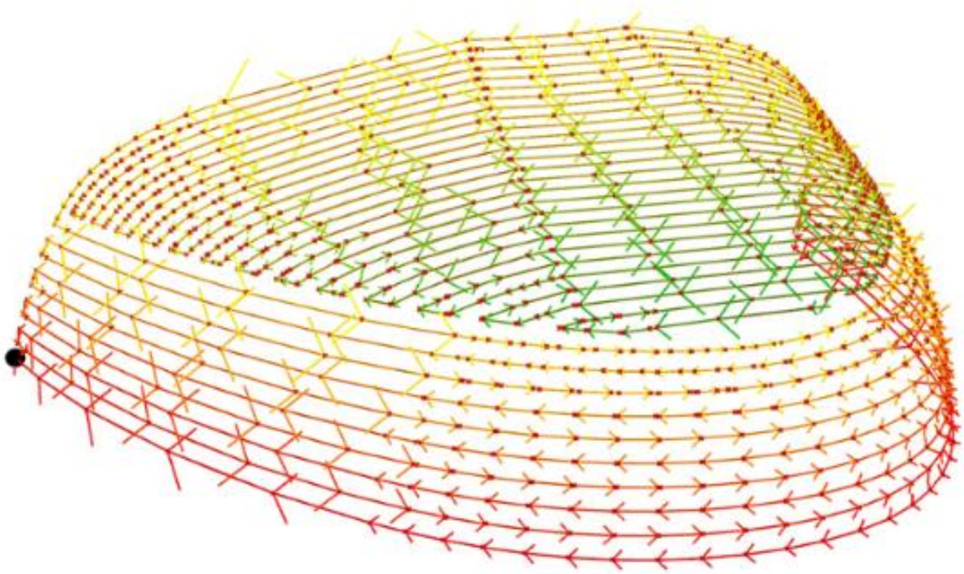


Figure 11: Preview of the continuous path generation within the grasshopper script, including end points and directions.

Parameters such as layer height, wall thickness, printing speed, temperature, ideal distance for adhesion, etc. all come into play when slicing the 3D model. These were all tested, so that the ideal values can then be incorporated into the fabrication definition.

3 Shoe prototypes

Haratech, Sophia Guggenberger and Eugenia Morpurgo made numerous tests with unfilled and filled filament to get the ideal settings for each application.

Figure 12: Printing tests with varying settings.

At this stage, a lot of different parameters come into play, and a thorough documentation of all tests involved is needed to keep track of the best settings, figure 12 shows prints where the same part is printed with various settings, some of which proved not to be feasible for production.

The printed parts were ultimately joined together with the other research outcomes from the project, resulting in four variations of the Syntropia shoe, which can be seen in figure 13.

Figure 13: 4 prototypes of full shoe where all the materials come together.

Eugenia Morpurgo and Sophia Guggenberger envision the shoe as a flexible framework, where each component can be produced with different levels of technological complexity according to the infrastructure locally available. Figure 14 shows how two very different technologies come together within one shoe, yet their aesthetic shares a common language.

Figure 14: Close-up view of unfilled 3D printed parts and woven upper.

4 Summary and outlook

Since the start of the project, all co-creation partners agreed to work towards an open-source outcome, which made the developed 3D workflow a creative tool in its own right, not just tied to the Syntropia shoe in particular. It offers creative freedom within the ideation stage to develop the design as well as within the prototyping stage to perfect the settings to digitally fabricate the shapes generated in the previous stages.

The open-ended nature of the approach makes it scalable as well, where one could offer a version to a local manufacturing partner which has their own local sources for bio-based materials. One could also prepare the design workflow and print various shoe parts on home-based FFF printers, as the artists did themselves during this project.

5 Image credits

Figure 1: Anastasija Mass
Figure 2: Elisabeth Handl
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Figure 6: Elisabeth Handl
Figure 7: Elisabeth Handl
Figure 8: Elisabeth Handl
Figure 9: Sophia Guggenberg & Elisabeth Handl
Figure 10: Sander Hofstee
Figure 11: Sander Hofstee
Figure 12: Elisabeth Handl
Figure 13: Elisabeth Handl
Figure 14: Elisabeth Handl