SUTD Computational Fabrication Project Proposal

3D Printed Hair

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Problem and Motivation

In fused deposition modeling (FDM) 3D printing, we generally print objects that have a smooth surface. However, certain features such as lion fur or human hair are difficult to model or fabricate with current 3D printing technology.

Recently, a few 3D modellers have started to experiment with the properties of the plastic filament and parameters of FDM 3D printers to design hairy 3D prints. In the *Background* section, we will show examples of what we call the “hairy prints”, such as lion fur and horse tail. We learnt that the 3D modelling process of creating the hair is tedious and realised that it can probably be automated by using algorithms.

Our aim is to quicken the hair generation process for 3D printing by automating processes that can be automated such as the generation of the hair fibres in the 3D model. First, the user uploads a 3D object file into a Graphic User Interface (GUI). Next, the user selects regions where he/she wants hair to be generated. After the computation is complete, the user is shown a preview of the new “hairfied” 3D model. Finally, users will then download the hairified model which can be printed by a FDM 3D printer. Our solution will take into account the difficulties associated with modelling regions with uneven surfaces, curvature and orientation. We will fabricate several hairy prints for testing.

Background

1. StereoLithoGraphy (SLA) 3D Hair Printing Program: Cilllia[1]

Figure 1. Flowers with hairy texture printed using Cilllia

The MIT Media Lab researchers designed a program called Cilllia to generate hairy models that can be printed by the SLA 3D Printers. The program provides a user interface that allows the

[1] https://competition.adesignaward.com/design.php?ID=50708

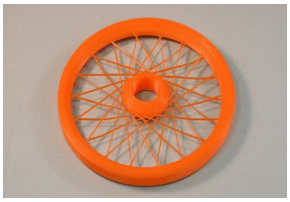
user to choose some parameters relating to the hair's properties such as hair density and hair length. The program does the slicing and model generation on its own without relying on other software such as CAD software or the 3D printer's slicer software. This is done on purpose so that it is able to generate very high density hairy models without crashing the CAD or slicer software. The MIT Media Lab team used a voxel-based model generation method to instruct the printer to print various hair geometry and structure.

However, compared to the SLA printers, the FDM printers are more common and affordable. It may be interesting to print hairy structures with the FDM printers.

2. FDM Hairy 3D Prints

Thin hair fibres are able to be printed due to a FDM printing technique called bridging. Bridging refers to the way FDM printers are able to print a plastic fibre using only two supports at the ends of the fibre. This means that there is no need for any supports throughout the length of the plastic fibre. This technique allows us to print interesting objects as shown in the table below.

Mark Leonard, Fibre Bridging Techniques[2]

			
3D Printed Paintbrush	3D Printed Spoked Wheel	3D Printed Broom	3D Printed Dream Catcher

[2] https://www.spyder3dworld.com/fiber-bridging-techniques-mark-leonard/
https://3dprint.com/32480/3d-print-paintbrush-bridging/

Even without utilising the bridging technique, FDM printers are still able to print strands of plastic fibres. The resulting fibres will curl during the printing process due to the lack of support at the end of the fibre. 3D modellers have played with this effect and came up with a few interesting designs shown below, in Figure 2 to 5.

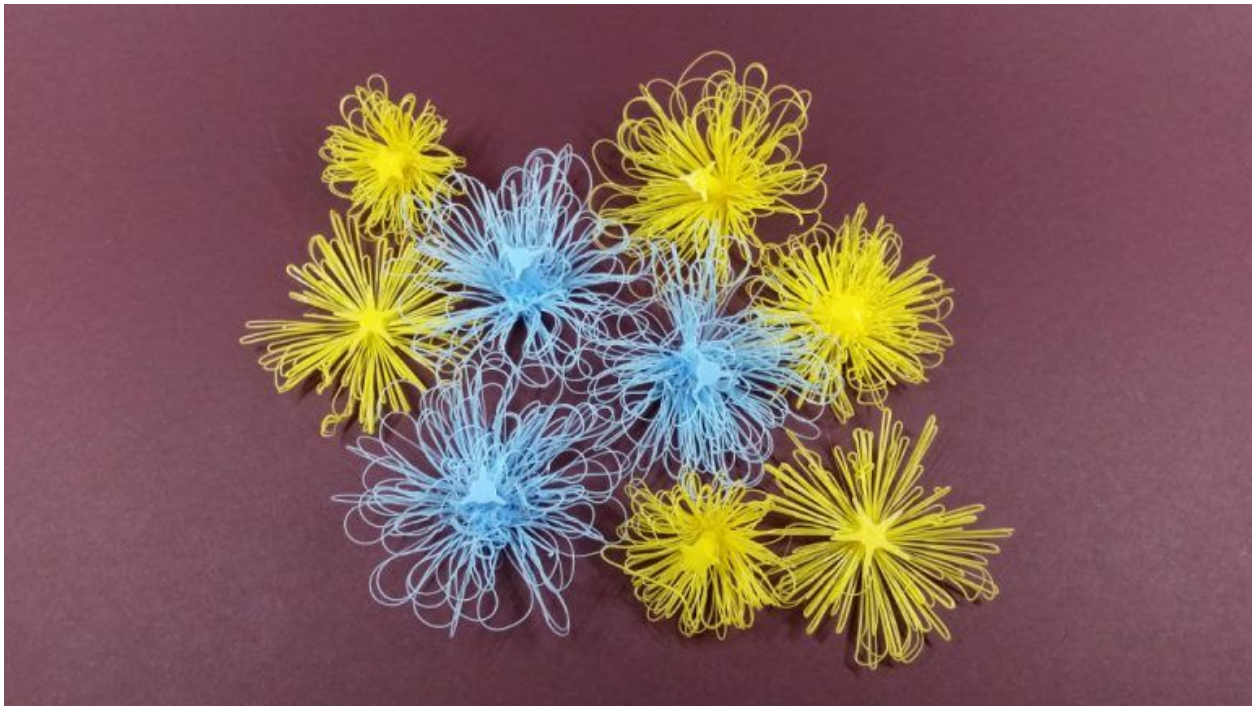


Figure 2. Mark Peeters, the creator of Drooloop Flowers, 2014[3]

[3] https://www.thingiverse.com/thing:240158
http://3dwithus.com/hairy-3d-prints

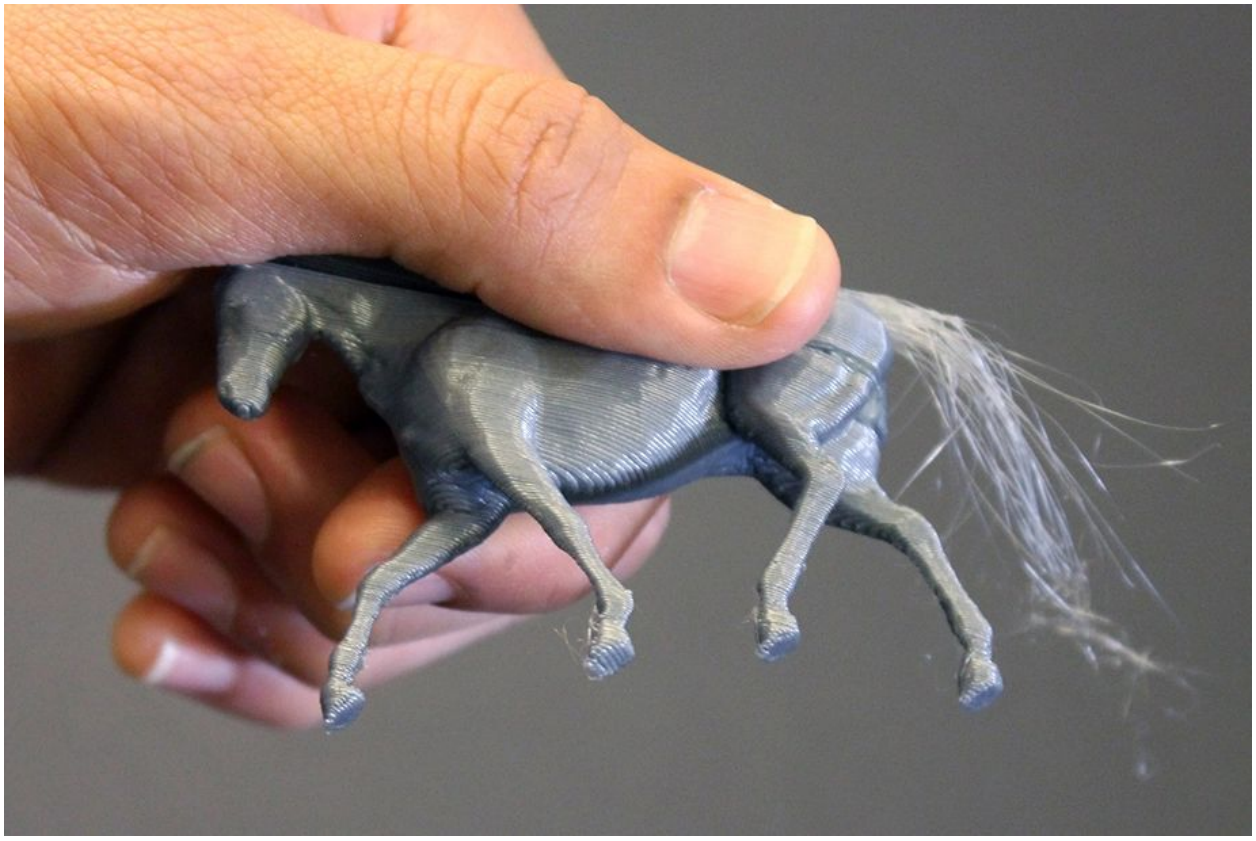


Figure 3. Plastic Horse Tail Hair, 2015[4]

[4] https://techcrunch.com/2015/11/04/researchers-can-now-created-3d-printed-plastic-hair/

Figure 4. Daniel Norée, Furry Vase, 2016[5]

Figure 5. Hairy Einstein, 2017[6]

[5] http://danielnoree.com/?p=786
[6] http://3dwithus.com/hairy-3d-prints

Hairy Lion, by Primoz Cepin, is one of the hairy 3D prints that became a huge hit. This print uses a cylindrical sacrificial wall to allow the hair fibres to bridge from the lion's face to the wall. This is the print that inspired us to embark on this project. The creator of this print stated that he will not be producing any more hairy 3D objects because it takes too much time to create the hair fibres using Solidworks. Our project hopes to address this problem by automating the generation of the hair fibres on the 3D model.

Figure 6. Hairy Lion, by Primoz Cepin[7]

[7] https://all3dp.com/hairy-lion-3d-printing/

Proposed technical method

Basic requirements

We will create a CAD program/plugin that:

- takes in a .stl or .obj file and load the 3D mesh
- allows user to select regions to be modified
- generates new model with added hairy features and relevant supports on specified regions
- export processed mesh in .stl or .obj that may be printed by a FDM printer

Advanced requirements

Hair customization

- Curly hair or straight hair
- Hair thickness
- Hair density

For the latter two hair properties, we need to decide the upper and lower boundary for each, and enforce the user hair specification input to fall within this valid range.

Geometries with complex surface structure

For geometries with regions that are hard to generate hair, we may consider the following approaches:

- Adjust the mesh orientation
- Generate hair near the specified region, and shape the printout to cover the empty region
- Identify the region property, and apply region-specific hair generation algorithm
- Advise the user to select a different region if hair cannot be generated optimally at the specified region

Development Platform

We will be using existing CAD software to allow us to interact with the 3D mesh. We will create a 3rd party plugin that allows the user to mark out areas of the 3D mesh to generate the hairy mesh. By using existing CAD software as a base, we can focus on generating the hairy meshes without having to create a mesh editor from scratch. The output file will be a format that is accepted by 3D printer softwares.

Possible CAD Software

FreeCAD: https://freecadweb.org/wiki/Help_FreeCAD

Grabert: https://www.graebert.com/en/plugindevelopment/plgingetstarted

Blender: https://www.blender.org/

Create Blender Plugin for Hairification

With Blender as one possible CAD software platform, we may process the input meshes as follows:

Use Blender's existing region selection tool, such as the one show in Figure 7:

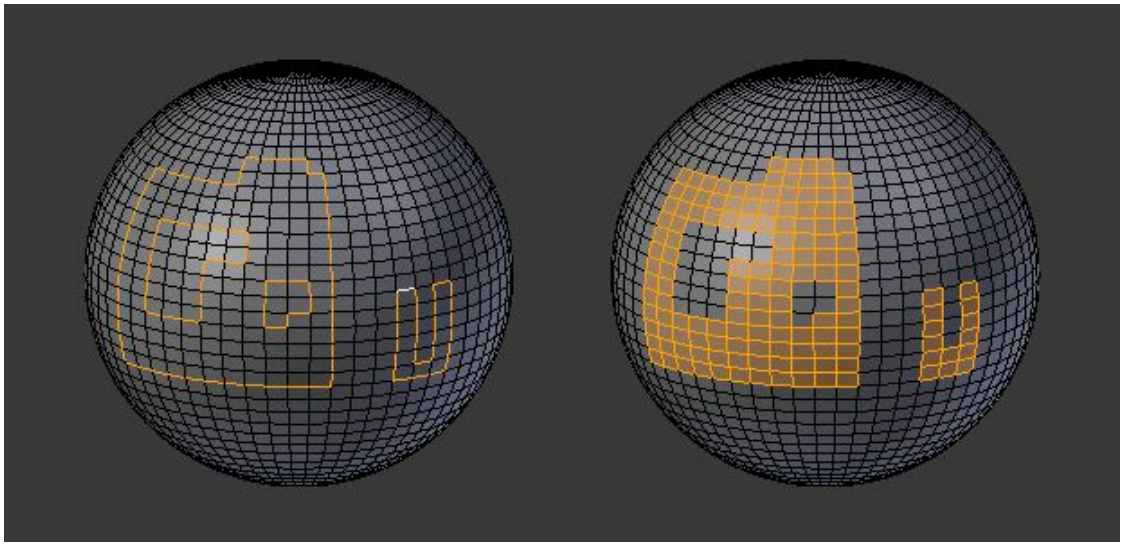


Figure 7. Loop inner region selection in Blender[8]

We may use the selected region as input, and process the input with customized addon.

This is the link to Blender API for creating addon:

https://docs.blender.org/api/blender_python_api_2_65_5/info_tutorial_addon.html

Instead of creating the addon from scratch, we may consider the following approach:

1. Manually add structure over 3D mesh for hairification;

[8] Source: https://docs.blender.org/manual/ja/dev/modeling/meshes/selecting/advanced.html#loop-inner-region

2. Isolate the code for this support structure (https://blender.stackexchange.com/questions/65129/how-do-i-create-a-script-for-geometry-i-create/65130)
3. Extend the code to suit different input meshes
4. Create Blender addon based on the extended code
5. Export the resulted .stl file and 3D print it for testing

Post-printing processing

The 3D printed hairy structure is likely to have a surrounding support which need to be removed. It can be done by cutting the hair with slim and sharp scissors or penknife, as close to the wall as possible (Figure 8).

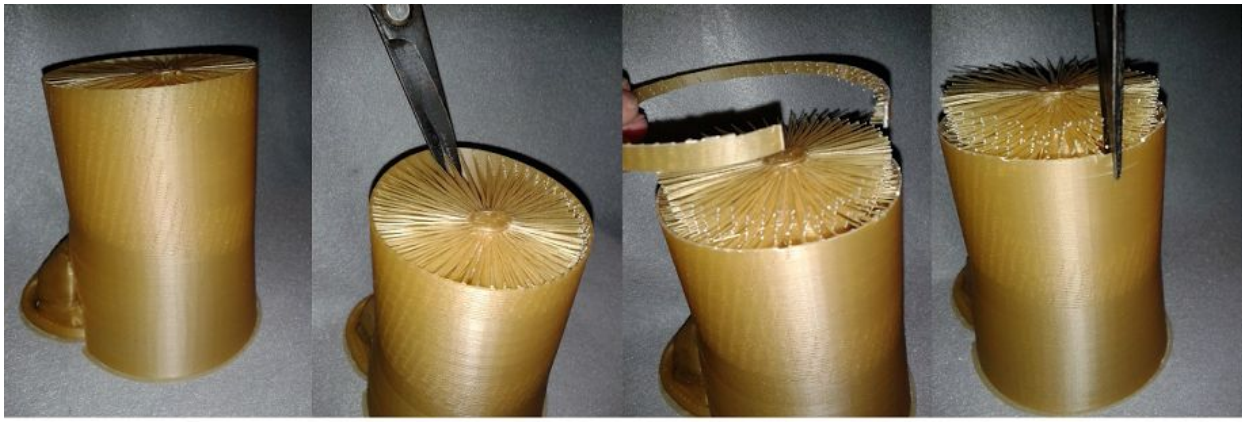


Figure 8. Cutting support structure[9]

As seen in Figure 9, The hair cut from the support structure are unidirectional and unrealistic. To shape the hair, a heat gun may be used to melt the hair, and we may shape the hair by hand. Extra caution need to be taken when handling the heat gun.

[9] Image source: https://www.thingiverse.com/thing:2007221

Figure 9. Hair shaping before and after[10]

Expected results

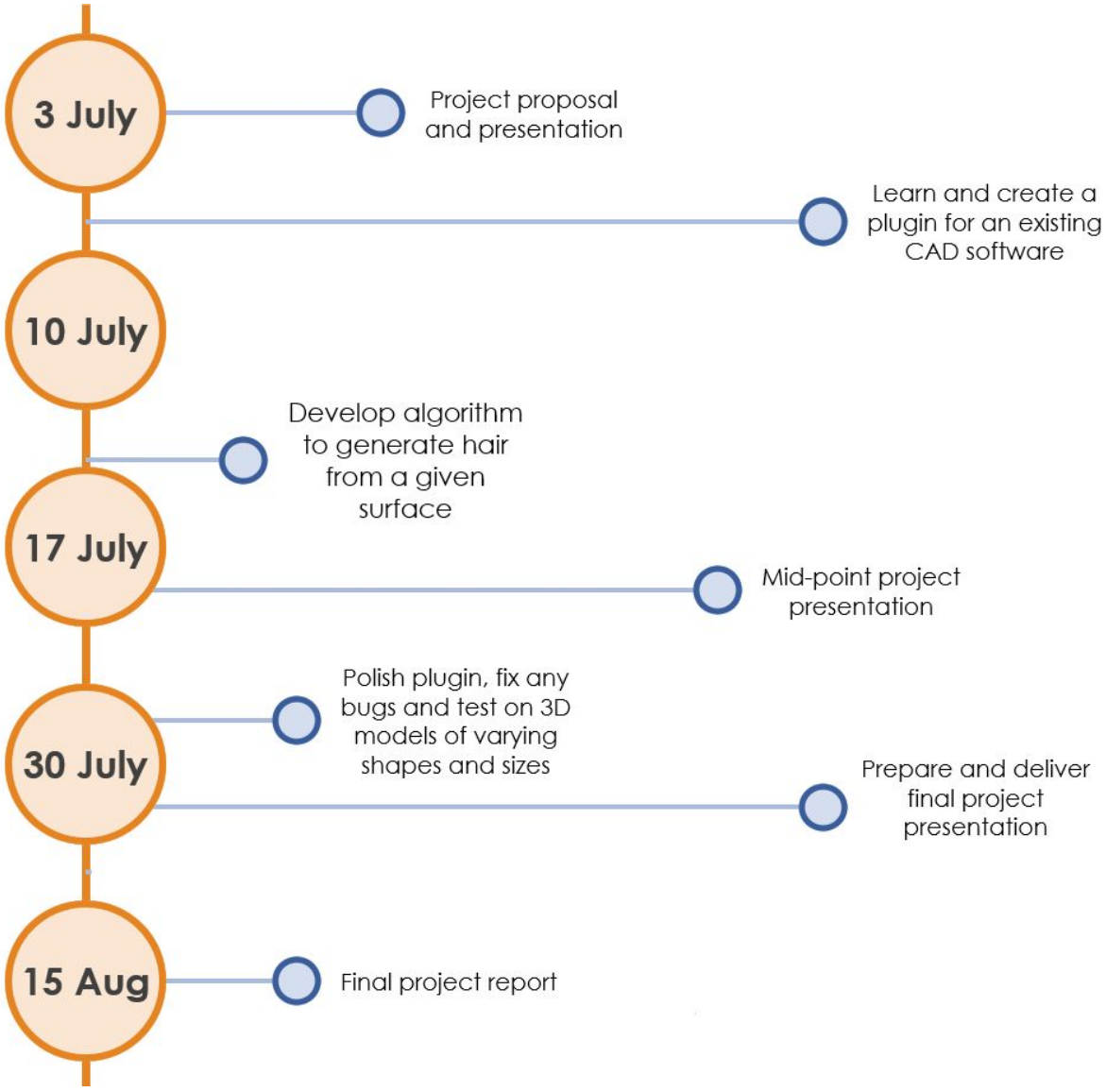
1. We would have developed a plug-in or add-in for a free CAD software that can take in a .stl or .obj file and load the 3D model.
2. The user can then select the meshes that he/she wants to convert to a hairy surface.
3. The program that we create should algorithmically generate the new 3D model with the added hairy features and relevant supports.
4. The user can proceed to print the newly generated model.
5. The program algorithm should work for objects of varying surfaces and sizes.

[10] Image source: https://www.thingiverse.com/thing:2007221

Figure 10. Test 3D print: hairy lion with hair shaped with a heat gun (1)

Figure 11. Test 3D print: hairy lion with hair shaped with a heat gun (2)

Timeline


3 July
Project proposal and presentation
Learn and create a plugin for an existing CAD software
10 July
Develop algorithm to generate hair from a given surface
17 July
Mid-point project presentation
30 July
Polish plugin, fix any bugs and test on 3D models of varying shapes and sizes
Prepare and deliver final project presentation
15 Aug
Final project report

Expected cost and resources needed

Using the small Hairy Lion 3D print as a gauge, we will require about 15g of filament per print. Assuming we will be printing about 50 of these, we will require approximately 750g of filament.

We also require more booking slots for 3D printing because we have all exceeded the quota for the month. We will be using the 3D printers extensively for testing purposes.

Reference

1) Hairy Lion, Thingiverse, https://www.thingiverse.com/thing:2007221
2) Blender region selection, https://docs.blender.org/manual/ja/dev/modeling/meshes/selecting/advanced.html#loop-inner-region
3) FDM Fibre Bridging Techniques, https://www.spyder3dworld.com/fiber-bridging-techniques-mark-leonard/
4) FDM Fibre Bridging 3D Model, https://3dprint.com/32480/3d-print-paintbrush-bridging/
5) Examples of hairy 3D Prints without sacrificial wall, http://3dwithus.com/hairy-3d-prints/
6) Carnegie Mellon hair printing techniques, https://techcrunch.com/2015/11/04/researchers-can-now-created-3d-printed-plastic-hair/
7) Furry Vase, http://danielnoree.com/?p=786
8) Hairy Lion, https://all3dp.com/hairy-lion-3d-printing/
9) Blender - Loop inner region, https://docs.blender.org/manual/ja/dev/modeling/meshes/selecting/advanced.html#loop-inner-region/
10) Blender - addon tutorial, https://docs.blender.org/api/blender_python_api_2_65_5/info_tutorial_addon.html
11) Blender - Scripting, https://blender.stackexchange.com/questions/65129/how-do-i-create-a-script-for-geometry-i-create/65130
12) SLA Cilllia, https://competition.adesignaward.com/design.php?ID=50708