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# Pendant Designer

## **Tim Treurniet**

Eindhoven University of Technology

La Place, Den Dolech 2

5612AZ Eindhoven, The Netherlands

t.s.treurniet@student.tue.nl

## **Abstract**

This report describes the final design for the course “Golden Ratio and Generative Arts”. The final design is a software tool which allows user to customize a pendant for a necklace. The tool uses mathematics to generate a three-dimensional model which can be saved and exported. This file can then be 3D printed or machined using various rapid prototyping methods. In this report, Fused Deposition Modeling (FDM) and resin Digital Light Processing (DLP) are applied for the materialization of the pendants.

## **Introduction**

Digital manufacturing techniques have been inherently connected to most product manufacturing processes for decades, due to their reliability and efficiency, at least for high quantity production [1]. More recently, rapid prototyping techniques are seeing an increase in popularity [2]. As the name suggests, it is mainly applied in prototyping phases, but applications in manufacturing occur as well. Although laser cutting, additive manufacturing and CNC machining are slower at higher quantities, they are applied in certain production processes as well, mainly when customization or personalization is required.

In my previous design projects, I have twice come across a situation where part of my final design was a tool to allow for such customization and personalization. However, due



Example of a pendant

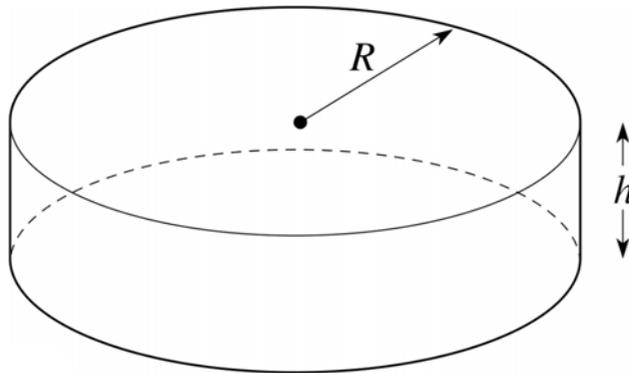
to time constraints and lack of programming knowledge, this part was never realized. These encounters were my main motivation to explore the possibilities in using programming and mathematics for the generation of three-dimensional geometry.

### Mathematics

The pendant consists of several segments which are generated in similar ways with slight alteration in the equations. Each of the segments is created by a series of discs, consisting of two circular layers on top each other. In order to create a smooth transition, the coordinates of the bottom half are copied from the coordinates of the top half from the previous disc.

$$x = a + r * \cos t$$

$$y = a + r * \sin t$$

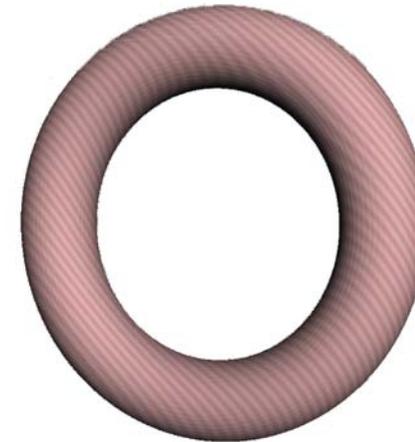


A single disc

### Ring

The first part of the pendant consists of the ring, which is used to mount the pendant to a chain. After each layer, the orientation of the model is rotated. The ring is constructed using 400 layers, each one rotated by the value of  $\pi/200$ , resulting in a full circle of  $2 * \pi$ . Since the inner diameter of a ring is smaller than the outer diameter, simply placing discs on top of each other would not result in a smooth model. To compensate, the height (h) of each disc varies within each disc, its value being the result of the following parabola function for values above zero.

$$y = -x^2 + 1$$



Ring segment

### Start and end

These segments close off the main shape of the pendant. Similar to the ring, the discs are rotated and the height

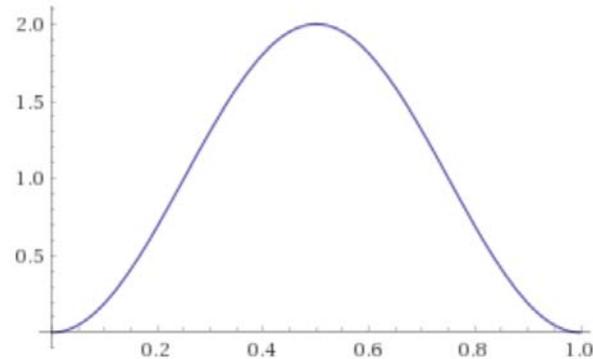
## Instructions:

Press 'C' to create a new segment.  
Press 'X' to switch segment type.  
Press 'Z' to undo a segment.  
Press '1' and '2' to edit the width of the tubes.  
Press '3' and '4' to edit the height of the tubes.  
Press 'S' to save and export the model.

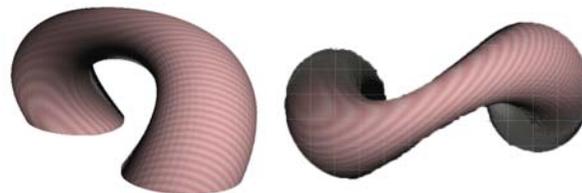
Instructions for user input

follows the parabola, although only half a circle is created. The radius of the discs ( $r$ ) is defined by a sine function. A sine was chosen over a parabola to allow for smoothing at the beginning and ending of the shape.

$$r = \sin(2 * \pi * (x - 0.25)) + 1$$



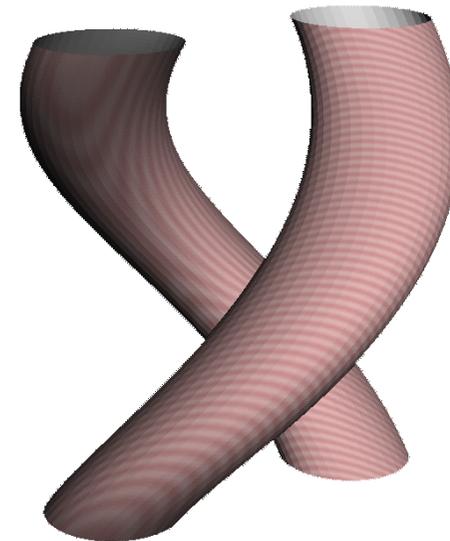
Furthermore, in order to smoothly transition from the curved segments of the main body, the Y coordinates of the shape follow a sine curve.



Begin and end of the main body

## Helix segment

The default option for segments in the main body of the pendant is a helix structure. On each layer, two discs are created. The coordinates of the center of these discs follow the shape of a circle, each on opposite side of each other. The math for this circle is identical for the creation of the discs themselves, although it features a larger radius. With each layer, the discs move along this circle until half of a rotation has been completed. Similar to the start/end segment, the radius of the discs follows a sine curve with smoothing at the start and end. The value of this radius is defined by user input. The amount of discs per segment, i.e. the height, is defined by user input as well. Furthermore, the same concept of using coordinates from the previous disc is applied as well.

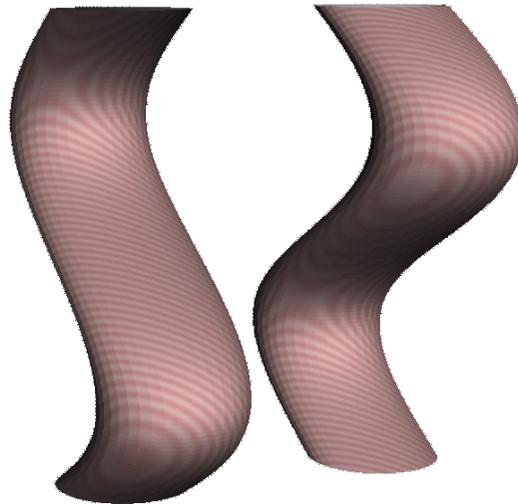


A helix segment

### *Straight segment*

For each segment, the user can switch between the aforementioned helix segment or a straight segment. The shape is called straight since the X coordinate remains the same. The Y coordinate however, is defined by a sine curve. For the second “pillar”, the new Y coordinate for each new layer is subtracted instead of added to the existing value. The shape allows for the same customization of the helix segment.

$$y = r * \sin 2x$$



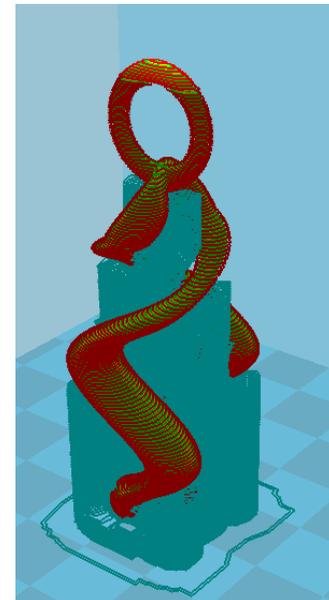
A straight segment

### **Materialization**

When the user is satisfied with the result, the tool exports the models to an object (OBJ) file. Using software called “Netfabb”, slight imperfections are automatically fixed, and the model is converted to a more common SurfaceTesselationLanguage (STL) file. This software and all others mentioned in this report are free to download.

### *FDM*

For initial tests, FDM 3D printing was applied. This method is faster and cheaper than most other methods, but the quality is generally lower. Using software called “Cura”, support structures and G-code, the filetype most 3D printers use, were created.



Support structures and final model for FDM printing

### *DLP*

The final models were printed using a DLP resin printer. This method is capable of increased resolution on every axis. Jewelry making is one of the main application fields of this type of printer.

The support structures were created in "XYZWare\_Nobel". The resulting model is then imported into "Creation Workshop", which translates the file to G-code.



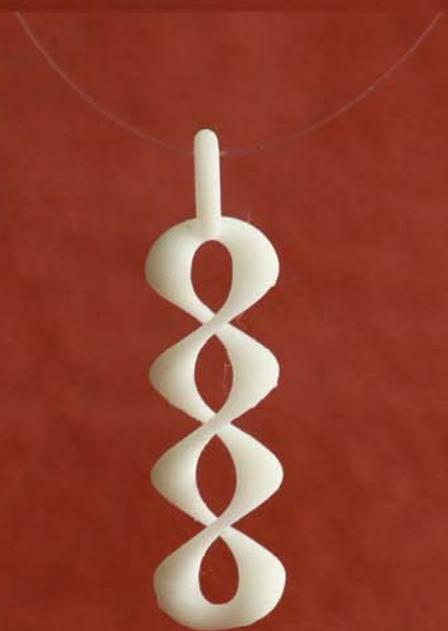
Support structures for DLP

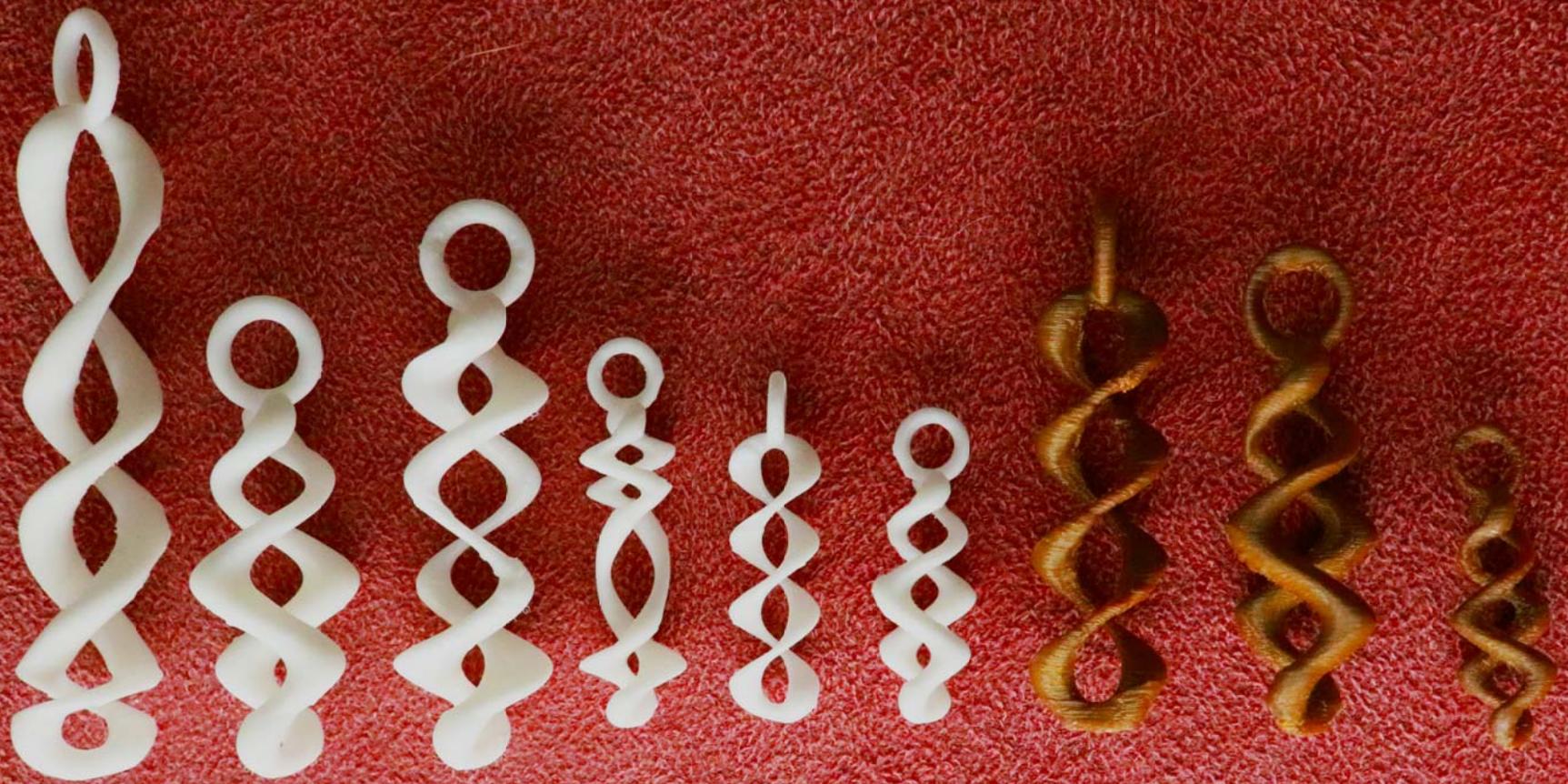


DLP model after printing

### **Future work**

Currently, the customization options are still somewhat limited. A future step for this project would be to extend these possibilities, and find more geometrical shapes with aesthetic qualities which are suitable for 3D printing. As for the materialization process, a step is actually missing. Jewelers who use DLP printing for their work generally use the model to create a mold, which is used for casting materials such as aluminum or gold. Naturally, this step greatly improves the end result, and for a final version it should not be excluded from this project.





## References

- [1] R. Brown, "Digital manufacturing: driving digital manufacturing to reality.," *In Proceedings of the 32nd conference on Winter simulation*, pp. 224-228, 2000.
- [2] B. P. Conner, G. Manogharan and A. Martof, "Making sense of 3-D printing: Creating a map of additive manufacturing products and services.," *Additive Manufacturing*, vol. 1, pp. 64-76, 2014.

## Appendix

The source code for the tool:

[https://drive.google.com/file/d/1xu4\\_hCWguBQCU16DNrokIjztbwku7HAa/view](https://drive.google.com/file/d/1xu4_hCWguBQCU16DNrokIjztbwku7HAa/view)

Executable version of the tool:

<https://drive.google.com/drive/folders/1iMcve2BplxRG733DtedwzHr5t1e1v0XI?usp=sharing>

**Reflection**

As mentioned in this report, my main motivation for choosing this course was to gain experience in creating tools for personalization and customization, specifically for three-dimensional objects. I have applied rapid prototyping in several projects already and believe that this personalization is one of its most valuable qualities, one which designers can apply in many different scenarios. Although this example in a jewelry context is in contradiction with the functionality I generally intend to apply in my design, I believe that the potential of such generative applications goes beyond aesthetics. One example I thought of is scanning maps and generating 3D models in order to print physical models for people with visual disabilities, with the potential of adding personalized icons or other tactile information.

The addition of this third dimension in a processing sketch introduced challenges in creating a valid model for 3D printing. Due to this challenge, the mathematical complexity is lower than I would have preferred. Many of the mathematical concepts that were introduced in the lectures make for a difficult translation to 3D, especially when intending to do more with 3D than simply extruding a two-dimensional image. The current tool is based on combinations and variations of basic equations. Although combining these into 3D shapes was challenging and the results could be considered aesthetically pleasing, the level of depth in mathematics is where I would have wanted to improve more.

I can clearly see many improvements in my programming and applied mathematics skills, but the physical element of this course has been insightful as well. I have used FDM 3D printing quite extensively for many different applications, but creating small detailed objects was never one of them. The expected yet disappointing results made me consider alternatives, each with their individual advantages and drawbacks. Although using DLP seems to fit the concept, I did not manage to experiment with all possible methods. Extending my knowledge and mainly experience with alternatives is a subject that has definitely attracted my interest and will be carefully considered in my future work.