



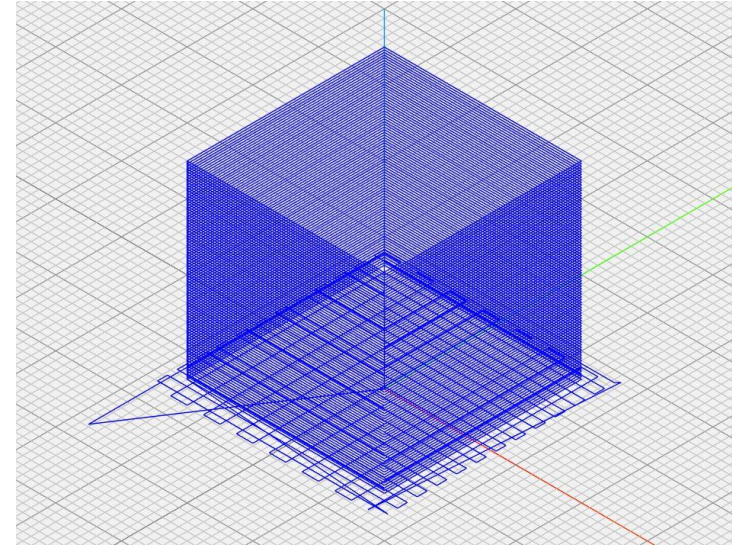
Digital Fabrication Midterm

- *Arman R & Raghav HK -*
R2-3D

Flexible Cubes

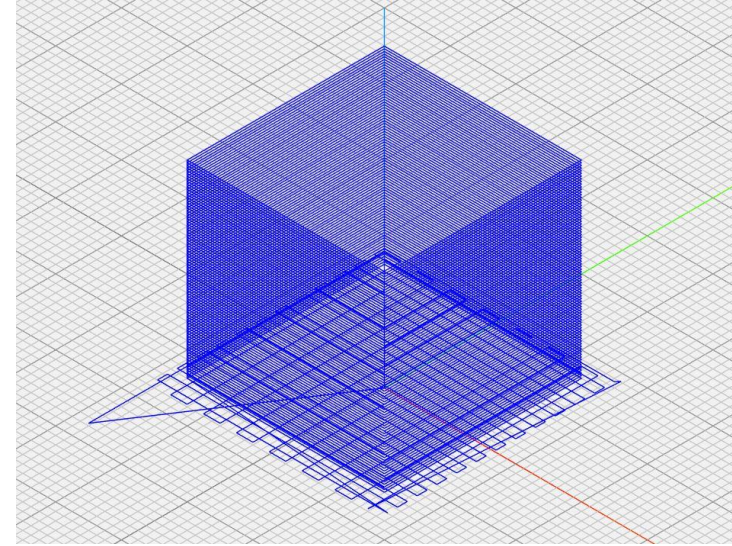
By [diatom on thingiverse](#)

Goal of this project is to create a tool for novice users to generate different shapes from a simple cube without a need for any support to print.



General parameters

- Number of layers
- Width and length of base layer
- Printing speed (F)
- The intended shape type.



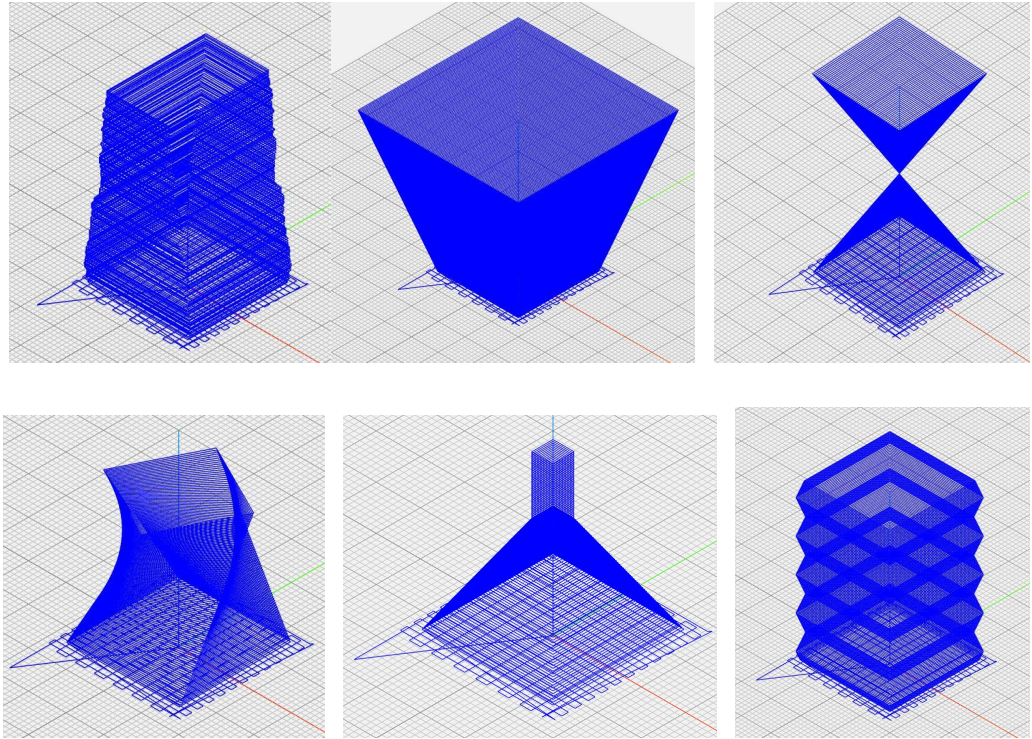
Standard Cube

- The first part of the g-code defines the default parameters(nozzle size, temperature, metric, etc.)
- Printing the first layer, based on length and width defined by user
- Each layer has 4 corners therefore 5 Positions in the same layer
- Maximum (x-y) movement should be less than 3mm for standard nozzle size (4mm) to eliminate a need for support structure

```
100 G1 X15.0 Y-15.0 Z1.62 F1556.0
101 G1 X15.0 Y15.0 Z1.62 F1556.0
102 G1 X-15.0 Y15.0 Z1.62 F1556.0
103 G1 X-15.0 Y-15.0 Z1.62 F1556.0
104 M103
105 G1 X-15.0 Y-15.0 Z1.97 F1556.0
106 M101
107 G1 X15.0 Y-15.0 Z1.97 F1556.0
108 G1 X15.0 Y15.0 Z1.97 F1556.0
109 G1 X-15.0 Y15.0 Z1.97 F1556.0
110 G1 X-15.0 Y-15.0 Z1.97 F1556.0
111 M103
112 G1 X-15.0 Y-15.0 Z2.32 F1556.0
```

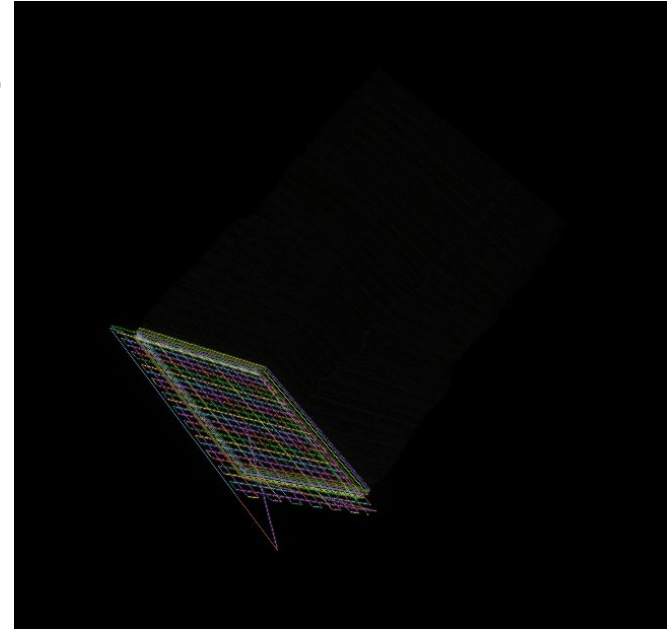

Modified Cube designs

- Random
- Truncated Pyramid
- Hourglass
- Twist
- Flask
- Waved Pattern



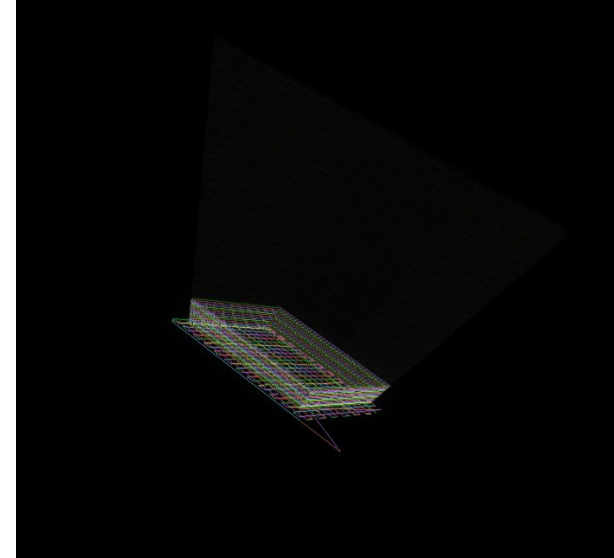
Random

- Random difference in coordinates of corners should be less than 3 millimeter to be able to hold its weight without support.
- It can be combined with other modifications such as wave or twist to create more complex shapes.



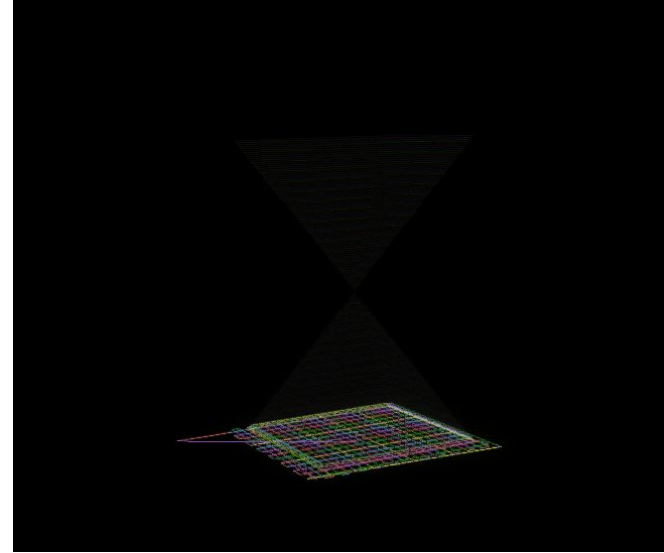
Truncated Pyramid

- Starts as the same width of the base cube
- Each layer adds 0.2 millimeter to x and y
- Height depends on user defined number of layers



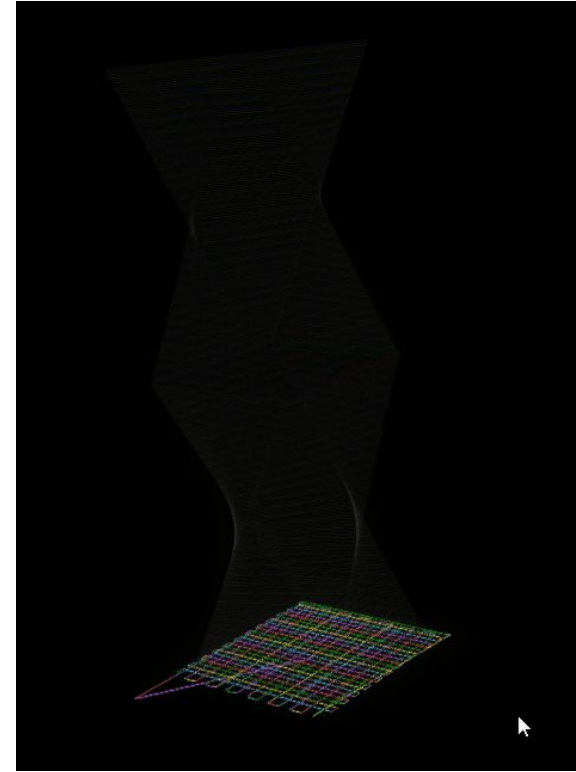
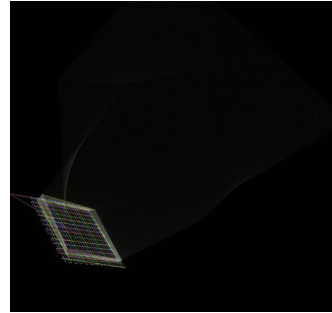
Hourglass

- This function can generate both pyramid and hourglass.
- User can define number of layers.
- By decreasing the x-y difference of the layers, steeper slopes can be generated
- Converges to a point, and expands again in simulation.
- Would need supports while printing.



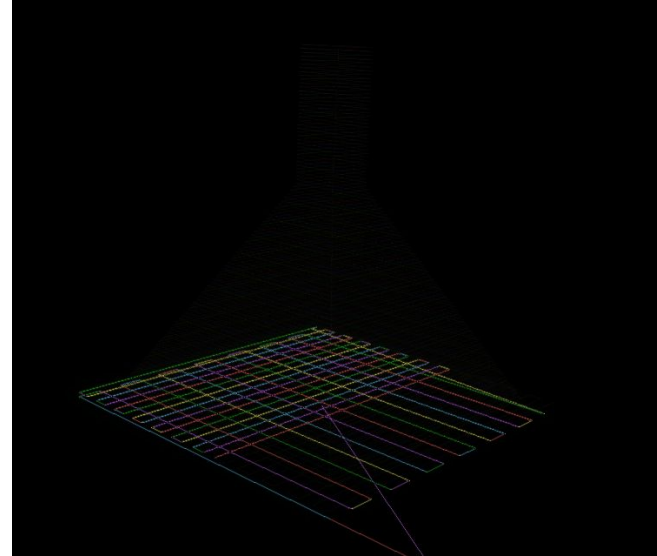
Twist

- User can define it to be clockwise or counterclockwise.
- At each layer, corners move 0.2 millimeter in x and y direction, along the edges, which creates a twisting effect.
- Random combos created with invalid inputs



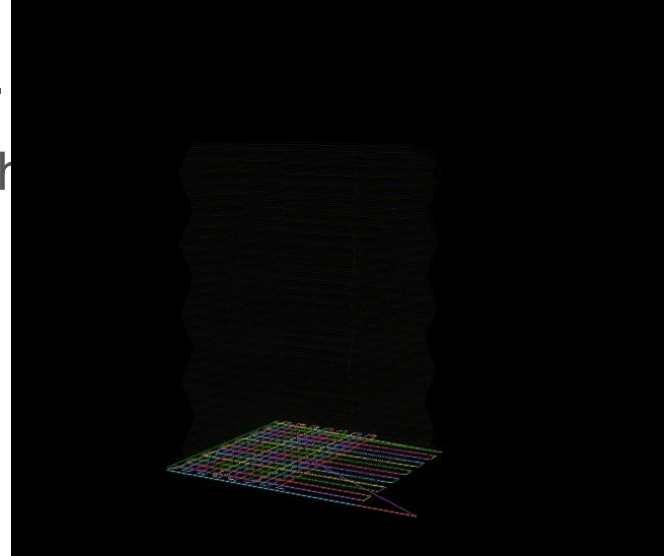
Flask

- This form is same as the hourglass except when edges reach 1.5 millimeters, it stops shrinking which creates a flask (beaker shape).
- Or an upside down funnel.








Waved Pattern

- The main parameter for the waved pattern is the wave amplitude which user can define it.
- In this example wave amplitude is 0.75 which means that the widest and narrowest part of the shape has a displacement of 1.5mm.
(0.75 crest + 0.75 trough)



User Interface

- CMD interface, with simple menu and input.
- New g-code automatically saved as .txt for ease.
- Easy to add higher or lower level control in code.
- Simple to automate new designs with Python.

Name	Date modified
 make_wave_150layers	10/4/2020 8:30 PM
 new_gcode	10/4/2020 5:40 PM
 og_code	10/2/2020 1:10 PM
 test	10/4/2020 1:15 PM
 twist_300layers	10/4/2020 8:30 PM

Microsoft Windows [Version 10.0.18363.1082]

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```
D:\Documents\TAMU\Course Work\Fall 2020\CSCE 689 - Digital Fabrication Studio -JKim\midterm>C:\Users\vsrag\AppData\Local\Programs\Python\Python38\python.exe "d:/Documents/TAMU/Course Work/Fall 2020/CSCE 689 - Digital Fabrication Studio -JKim/midterm/new_gcode.py"
Enter choice of g_code:
```

1. Random
2. Wave
3. Hopper
4. Flask
5. Twist
6. Hourglass

Enter choice number: 2

Enter number of layers you would like: 150

G-code created. Check Folder for make_wave_150layers.txt

```
D:\Documents\TAMU\Course Work\Fall 2020\CSCE 689 - Digital Fabrication Studio -JKim\midterm>C:\Users\vsrag\AppData\Local\Programs\Python\Python38\python.exe "d:/Documents/TAMU/Course Work/Fall 2020/CSCE 689 - Digital Fabrication Studio -JKim/midterm/new_gcode.py"
Enter choice of g_code:
```

1. Random
2. Wave
3. Hopper
4. Flask
5. Twist
6. Hourglass

Enter choice number: 5

Enter direction of twist (l/r): 1

Enter number of layers you would like: 300

G-code created. Check Folder for twist_300layers.txt



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diffchecker.com

```
07 M103
90 (begin cube)
91 G1 X-15.0 Y-15.0 Z1.27 F1556.0
92 M101
93 G1 X15.0 Y-15.0 Z1.27 F1556.0
94 G1 X15.0 Y15.0 Z1.27 F1556.0
95 G1 X-15.0 Y15.0 Z1.27 F1556.0
96 G1 X-15.0 Y-15.0 Z1.27 F1556.0
97 M103
98 G1 X-15.0 Y-15.0 Z1.62 F1556.0
99 M101
100 G1 X15.0 Y-15.0 Z1.62 F1556.0
101 G1 X15.0 Y15.0 Z1.62 F1556.0
102 G1 X-15.0 Y15.0 Z1.62 F1556.0
103 G1 X-15.0 Y-15.0 Z1.62 F1556.0
104 M103
105 G1 X-15.0 Y-15.0 Z1.97 F1556.0
106 M101
107 G1 X15.0 Y-15.0 Z1.97 F1556.0
108 G1 X15.0 Y15.0 Z1.97 F1556.0
109 G1 X-15.0 Y15.0 Z1.97 F1556.0
110 G1 X-15.0 Y-15.0 Z1.97 F1556.0
111 M103
112 G1 X-15.0 Y-15.0 Z2.32 F1556.0
113 M101
114 G1 X15.0 Y-15.0 Z2.32 F1556.0
115 G1 X15.0 Y15.0 Z2.32 F1556.0
116 G1 X-15.0 Y15.0 Z2.32 F1556.0
117 G1 X-15.0 Y-15.0 Z2.32 F1556.0
118 M103
119 G1 X-15.0 Y-15.0 Z2.6699998 F1556.0
120 M101
121 G1 X15.0 Y-15.0 Z2.6699998 F1556.0
```

```
07 M103
90 G1 X-15.0 Y-14.8 Z1.27 F1556.0
91 M101
92 G1 X14.8 Y-15.0 Z1.27 F1556.0
93 G1 X15.0 Y14.8 Z1.27 F1556.0
94 G1 X-14.8 Y15.0 Z1.27 F1556.0
95 G1 X-15.0 Y-14.8 Z1.27 F1556.0
96 M103
97 G1 X-15.0 Y-14.6 Z1.62 F1556.0
98 M101
99 G1 X14.6 Y-15.0 Z1.62 F1556.0
100 G1 X15.0 Y14.6 Z1.62 F1556.0
101 G1 X-14.6 Y15.0 Z1.62 F1556.0
102 G1 X-15.0 Y-14.6 Z1.62 F1556.0
103 M103
104 G1 X-15.0 Y-14.4 Z1.97 F1556.0
105 M101
106 G1 X14.4 Y-15.0 Z1.97 F1556.0
107 G1 X15.0 Y14.4 Z1.97 F1556.0
108 G1 X-14.4 Y15.0 Z1.97 F1556.0
109 G1 X-15.0 Y-14.4 Z1.97 F1556.0
110 M103
111 G1 X-15.0 Y-14.2 Z2.32 F1556.0
112 M101
113 G1 X14.2 Y-15.0 Z2.32 F1556.0
114 G1 X15.0 Y14.2 Z2.32 F1556.0
115 G1 X-14.2 Y15.0 Z2.32 F1556.0
116 G1 X-15.0 Y-14.2 Z2.32 F1556.0
117 M103
118 G1 X-15.0 Y-14.0 Z2.67 F1556.0
119 M101
120 G1 X14.0 Y-15.0 Z2.67 F1556.0
```



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Printing statistics of Simple cube.

G-Code Statistics			
Time		Speed	
Print Time	8:17	Average Speed	23.1 mm/s
Time Spent Accelerating/Decelerating	0:20 (4.2%)	Average Print Speed	NaN mm/s
Time Spent at Target Speed	7:56 (95.8%)	Average Travel Speed	23.1 mm/s
Total Z Hop Time	0:00	Raw Filament Usage Rate	0.00 mm/s, 0.00 cm/min
Total Retract/Prime Time	0:00	Min / Max XY Feedrate	560 (9.33mm/s) / 1556 (25.93mm/s)
Distance		Count	
Total Distance Moved	11.50 m	Number of Lines	672
Print / Travel Move Distance	0.00 m (0.0%) / 11.50 m (100.0%)	Total Move Commands (G0 & G1)	493
Distance Accelerating/Decelerating	0.25 m (2.1%)	Move Commands Reached Target Speed	410 (83.2%)
Distance at Target Speed	11.25 m (97.9%)	Print Move / Travel Move	0 (0.0%) / 493 (100.0%)
Raw Filament Usage	0.00 m, 0.00 cm ³	Z Hop Count	0
Printed Line Length per mm of Raw Filament	NaN mm	Retraction Count	0

Statistics from <https://www.gcodeanalyser.com/>

Conclusion

- Modifying g-code is a powerful way to teach how 3D printers work.
- The importance of nozzle size and layer continuity is key to print strong and flexible shapes.
- Simulation is a powerful tool to catch the mistakes before printing and wasting materials.
- Helps getting used to TPU printing and the problems it has (vs PLA).
- Code: <https://github.com/vsraghavhk/digital-fabrication-studio/tree/main/midterm>
- The G-code viewer and simulators used:
 - <https://jherm.com/gcode-viewer>
 - <https://ncviewer.com>





Thank you



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