

# Digital Workflows for Digital Fabrication

Matt Keeter

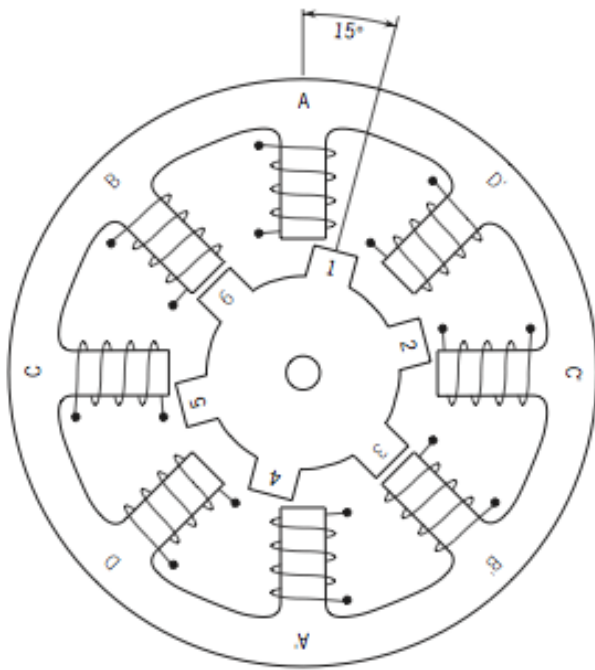
[matt.keeter@cba.mit.edu](mailto:matt.keeter@cba.mit.edu)



# Digital vs. Analog



# Digital vs. Analog



## Now

Discrete representations

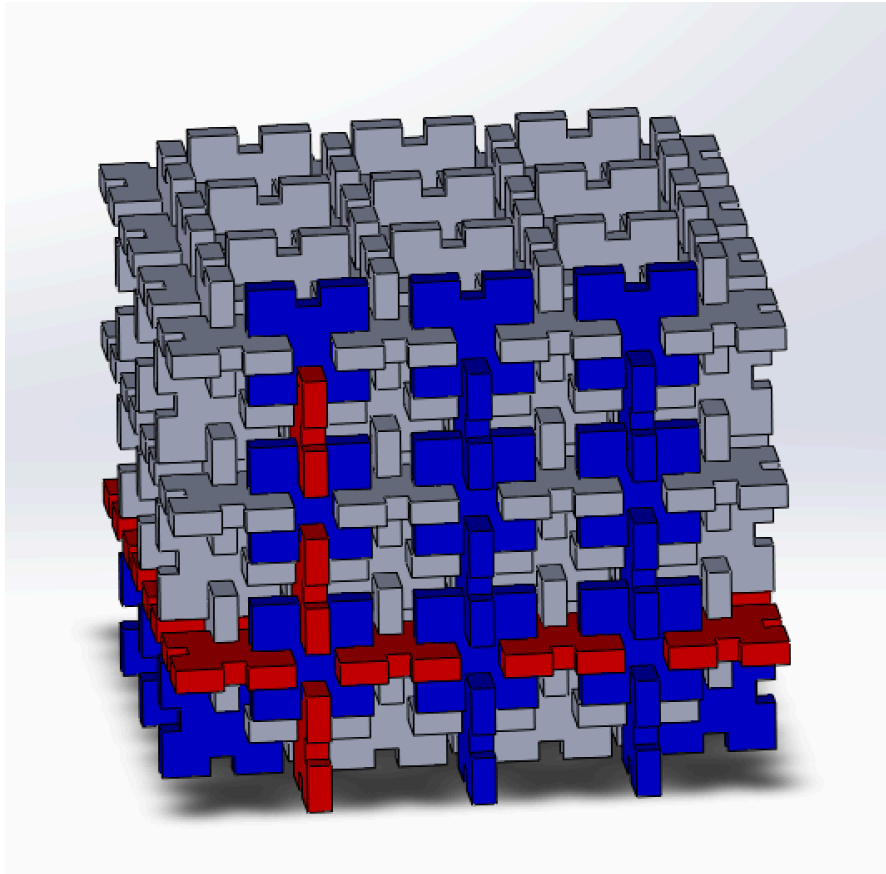
Machines with discrete behavior

## Future

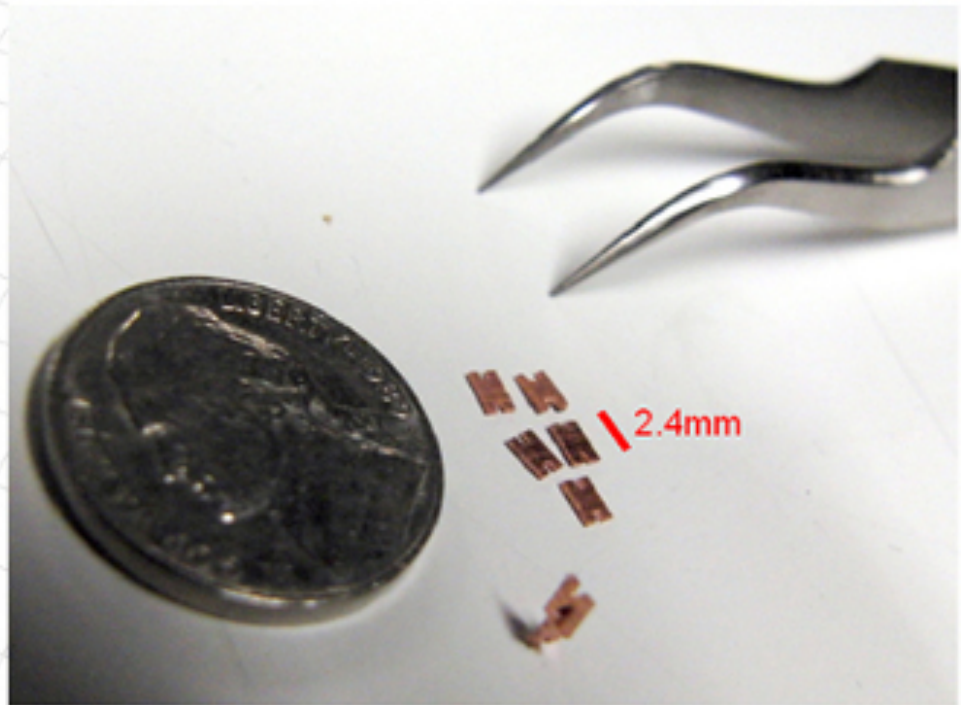
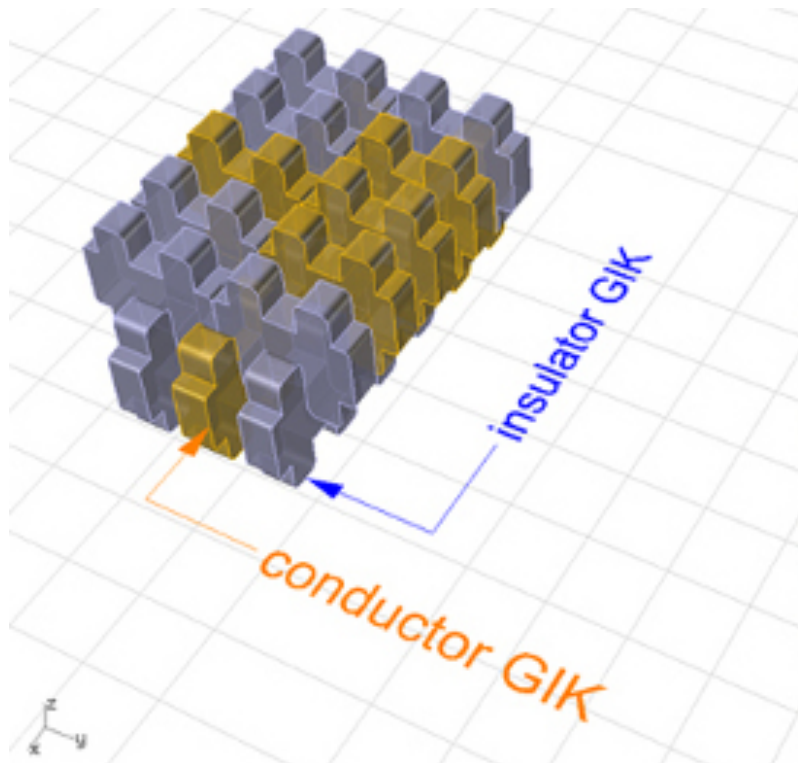
Discrete materials

Automatic assembly

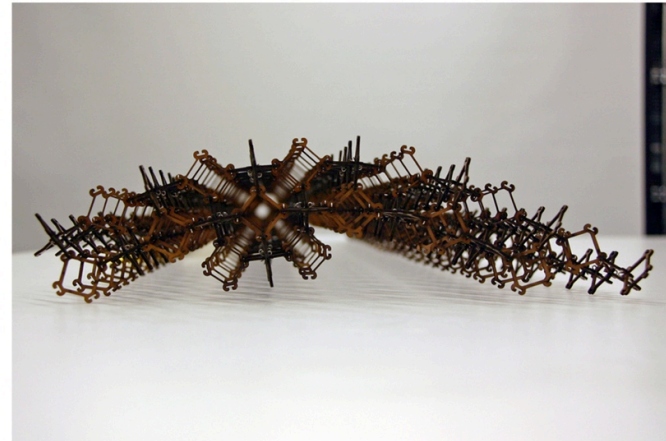
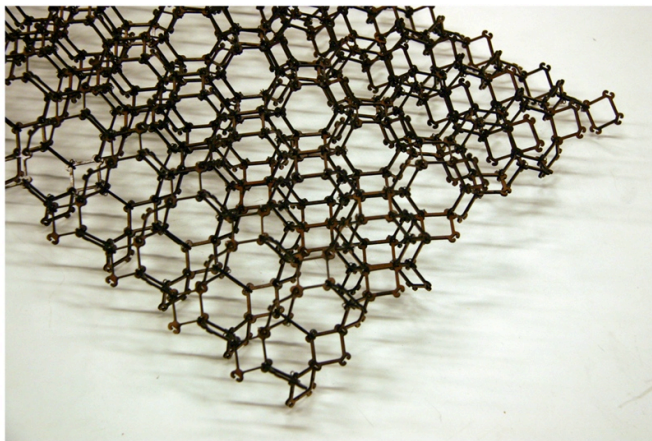
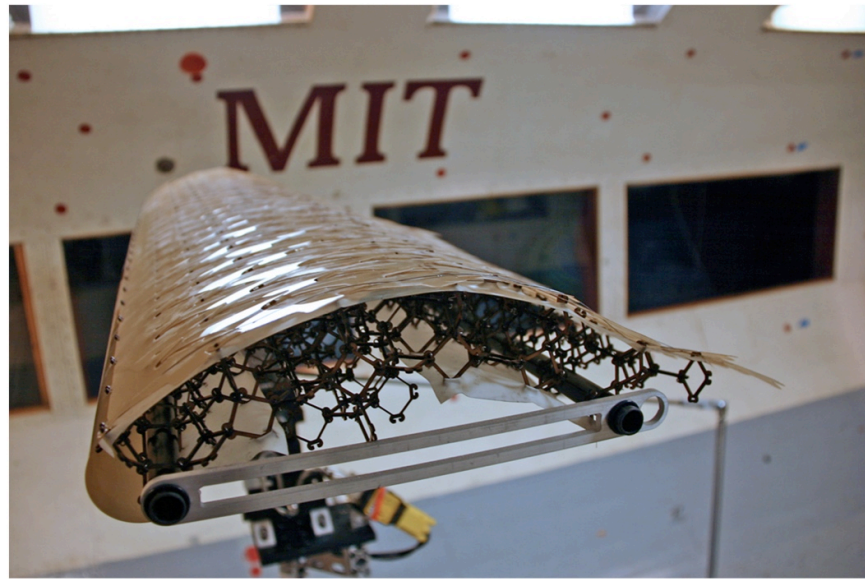
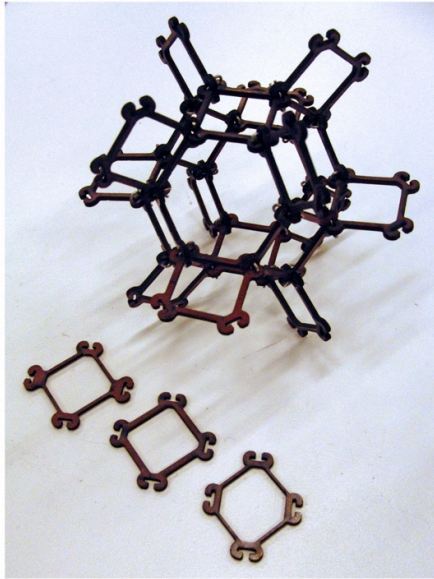
# Dense Digital Materials



# Dense Digital Materials



# Digital Composite Wing

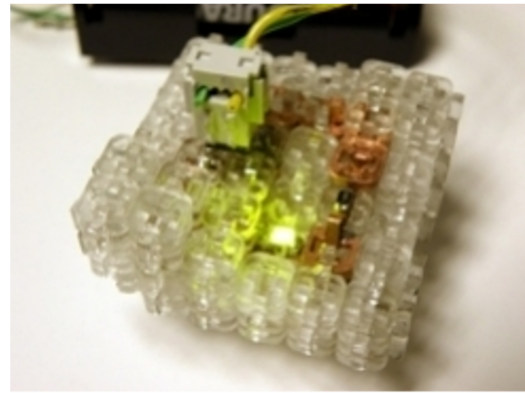
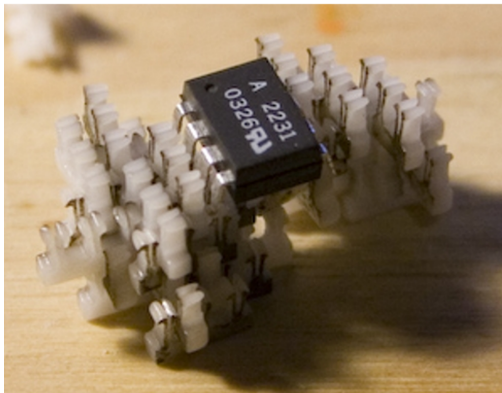
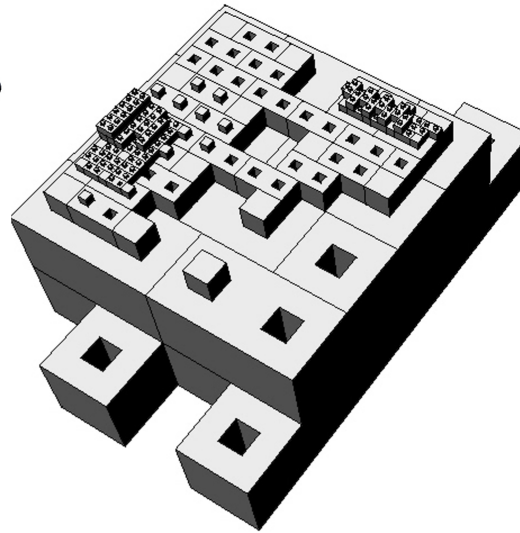
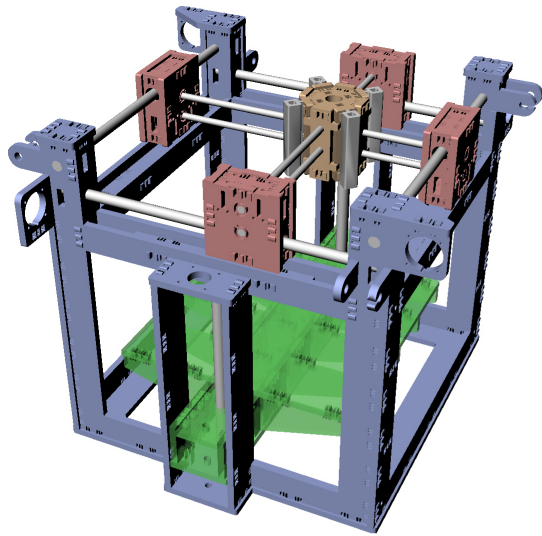


# Assemblers

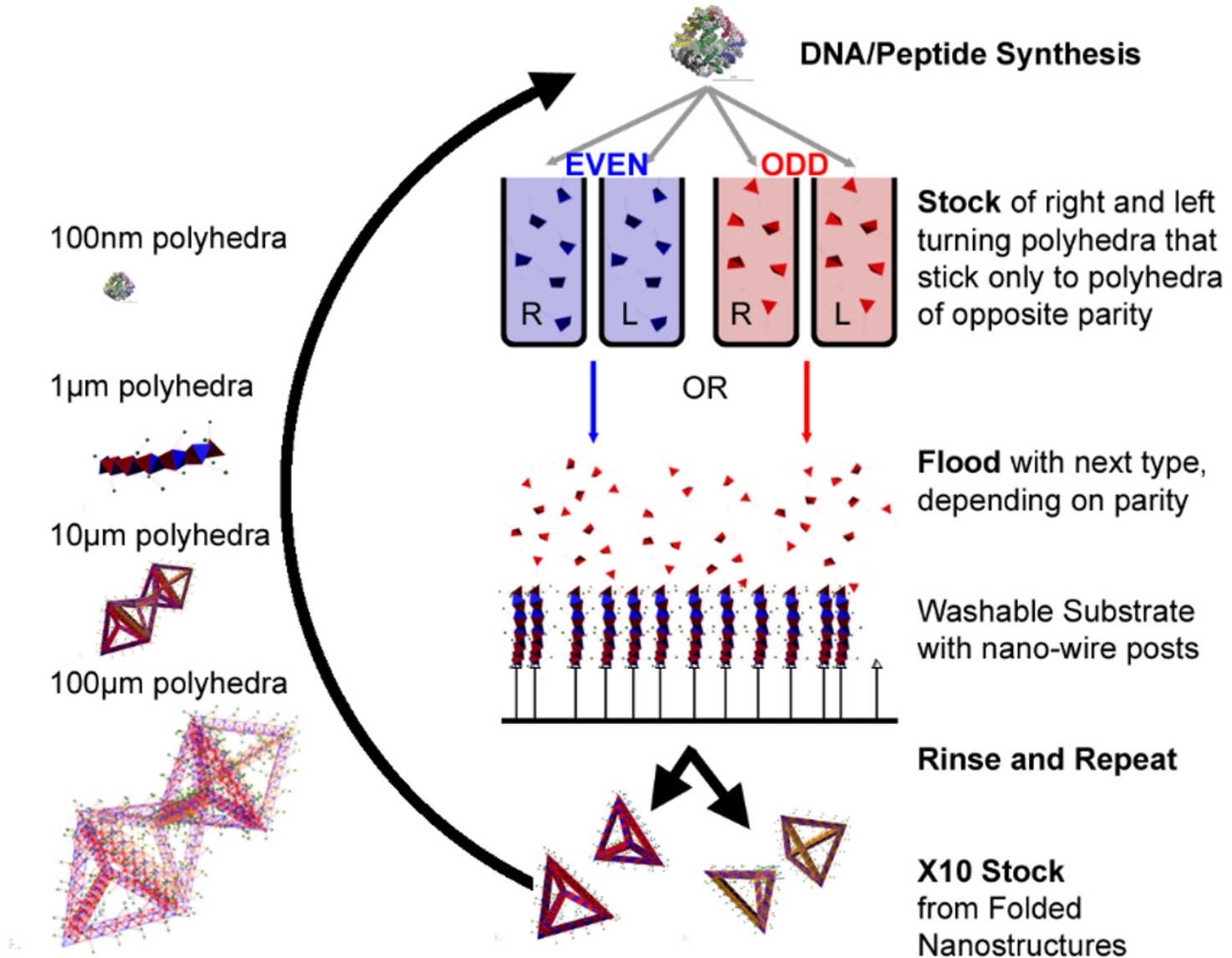




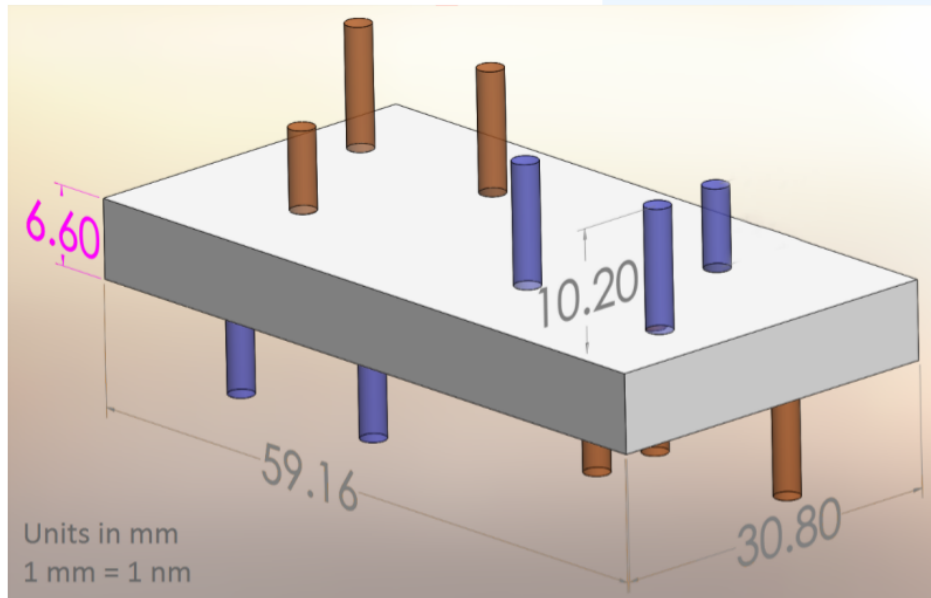
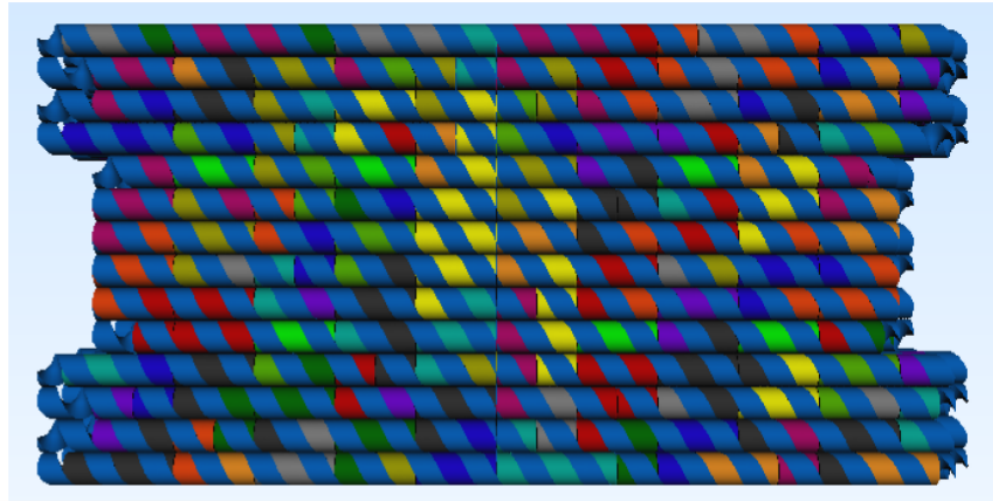
# Future Assemblers



# Hierarchical Fabrication by Coded Folding

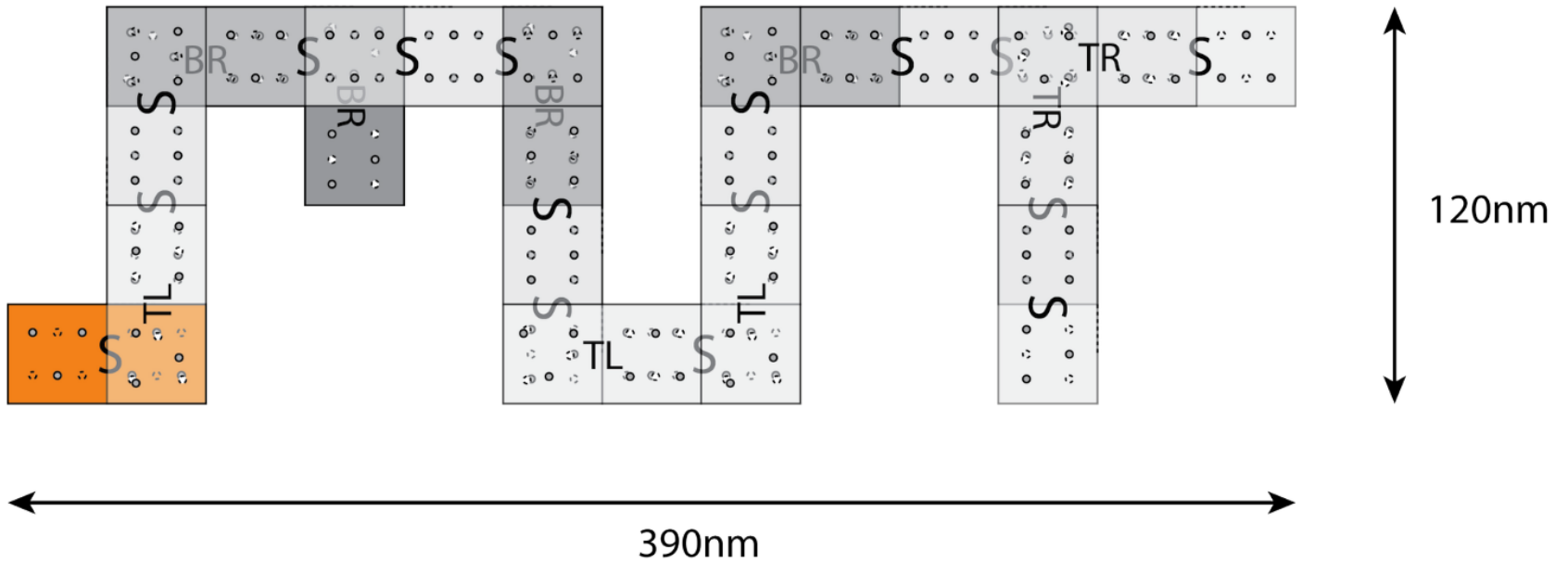


# Bricks



# Shape example

Seed+L+S+S+R+S+(R)+S+S+R+S+S+L+S+L+S+S+R+S+S+(R+S+S)+R+S



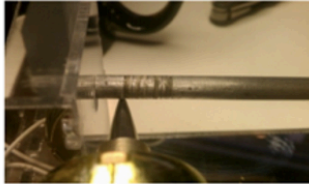
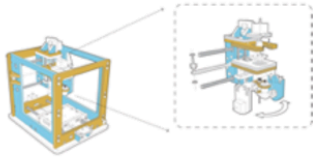

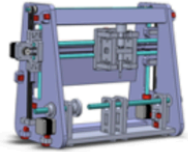
# Machines Today

Browser address bar: <http://mtm.cba.mit.edu/> | Search: Google




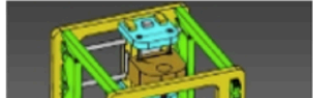
The Machines that Make Project a...

## Machines that Make

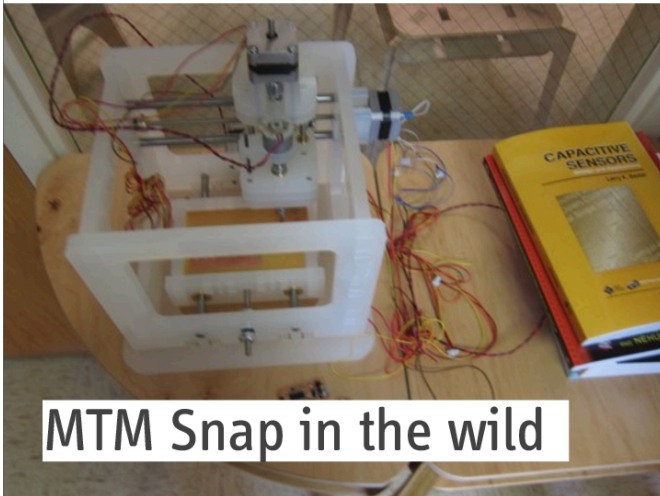
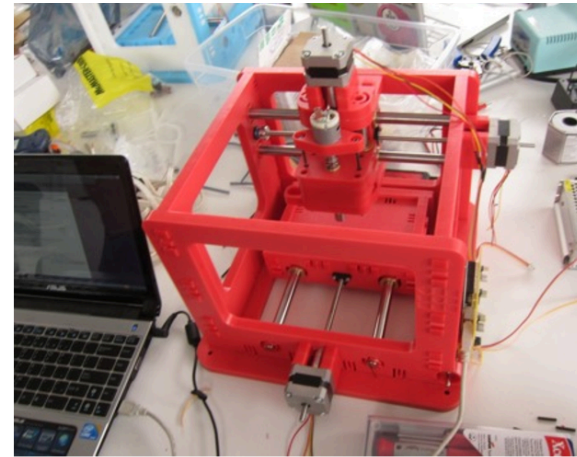
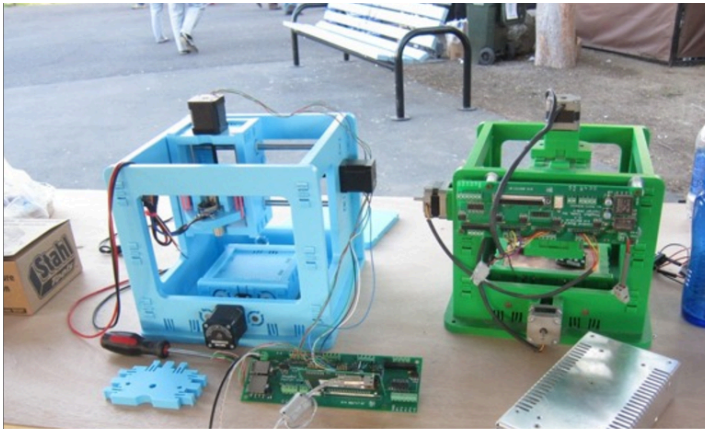
The Machine that make project at the [MIT Center for Bits and Atoms](#) seeks to develop low-cost machines that can be made using CNC equipment, like available in fab

DIY EDM	5 Axis Timing Belt MTM	POP Fab	Multi-processes lathe
			
An entry level (under \$500) EDM machine for making carbide/HSS tooling and/or lead screws	Low cost 5 axis machining.	A suitcase milling machine, 3d printer, and vinyl cutter.	The additive lathe is a 3D printer that prints on rotation objects.

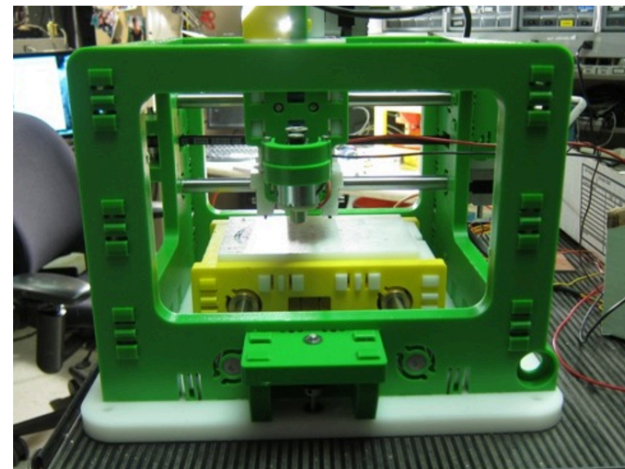
## Machines that Make Machines Spring 2012

Virtual Machine Network	Timing Belt MTM	Fab-In-A-Box	MtM Snap-Lock
			

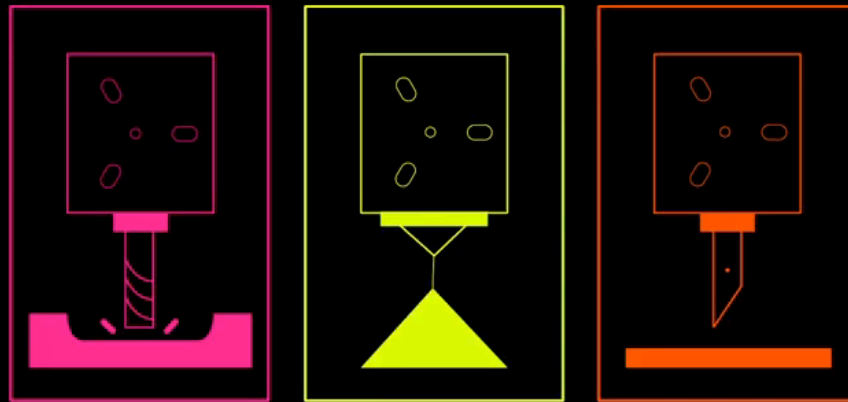
# MTM Snap



MTM Snap in the wild

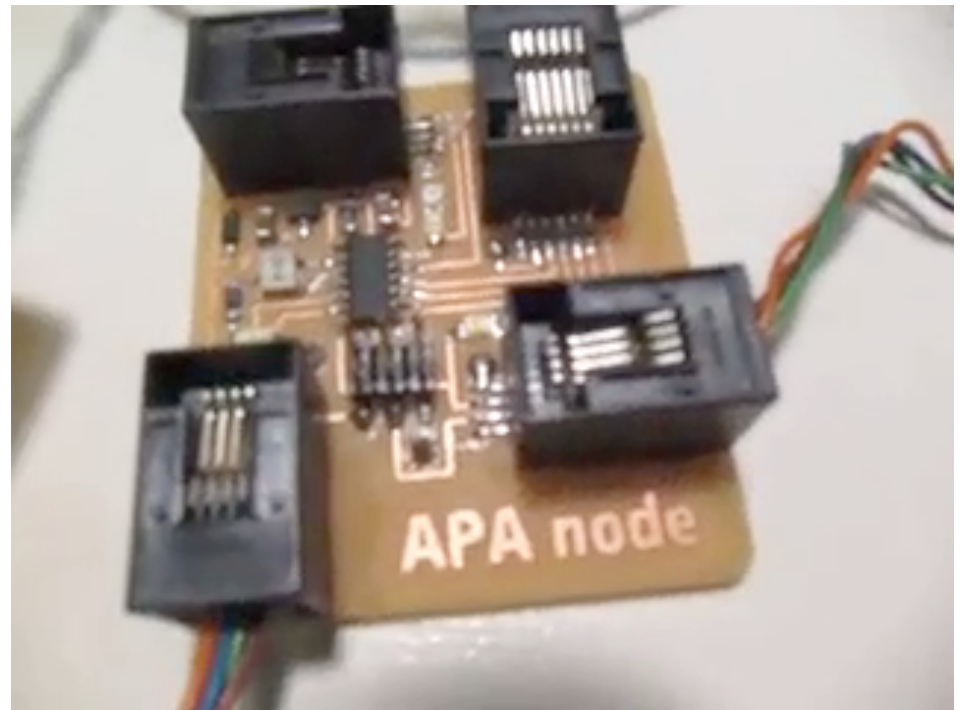


# POPFAB

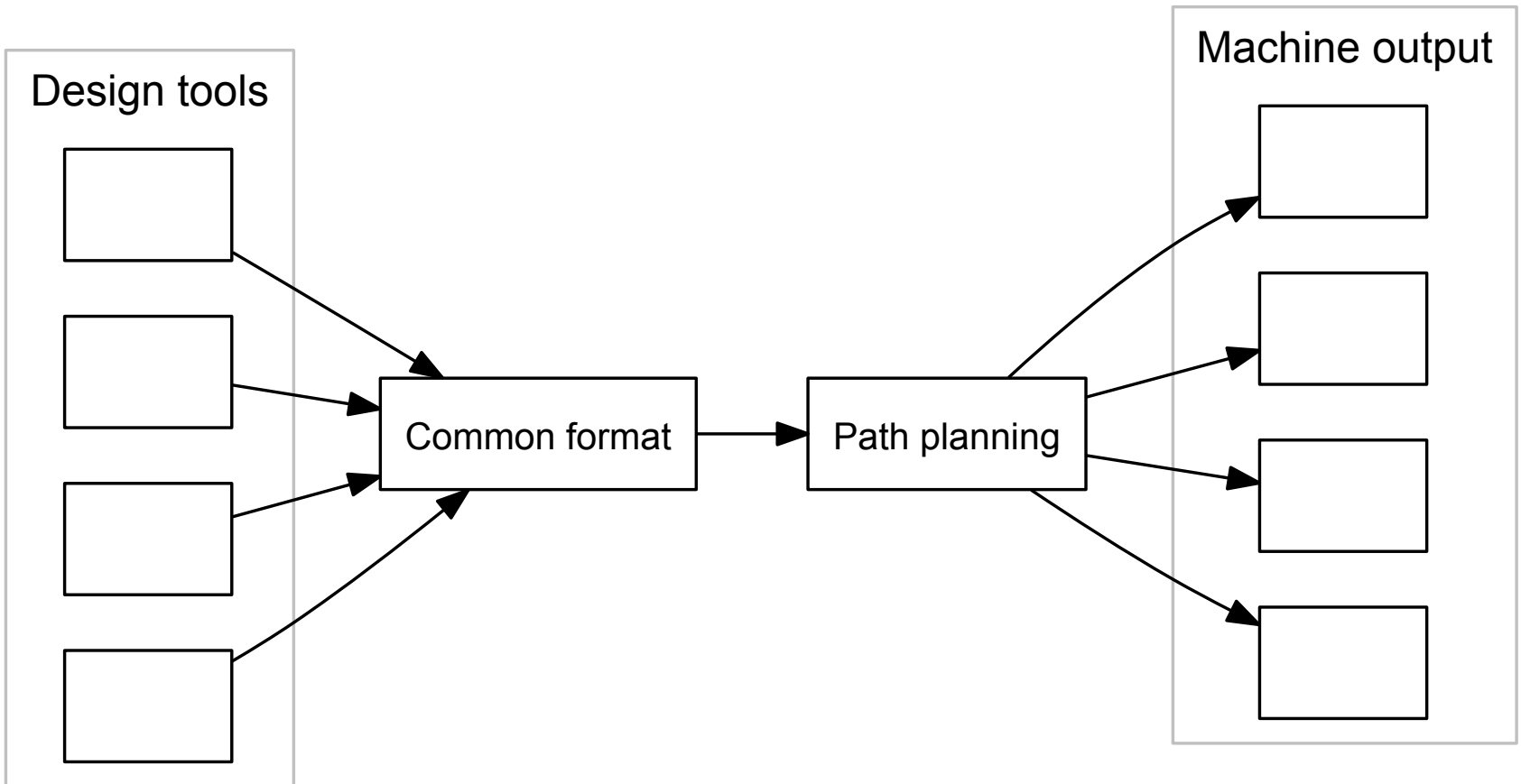


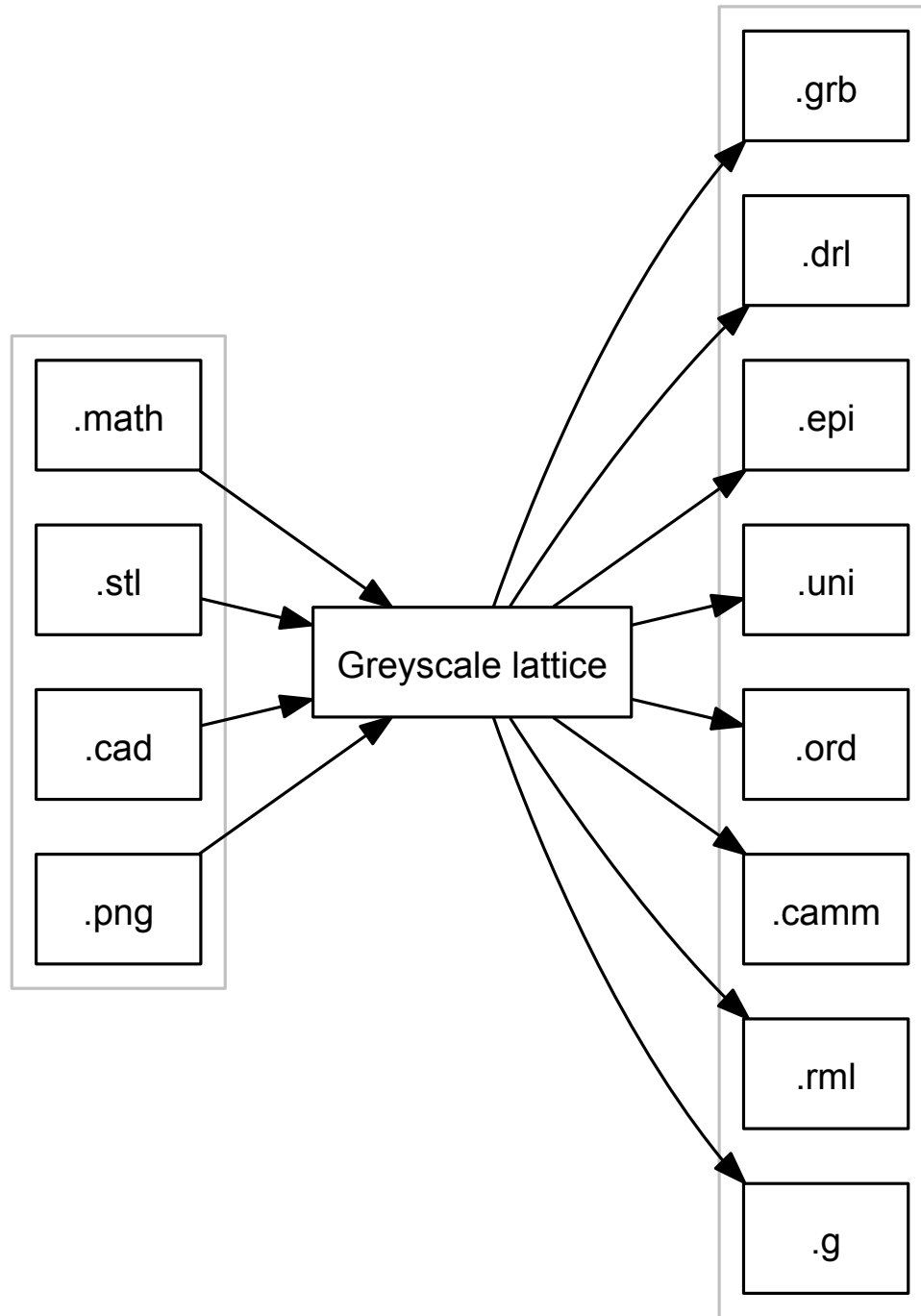
# VM Control

- Stateless machines
- Axes are nodes in a network
- Plug-and-play
- More control








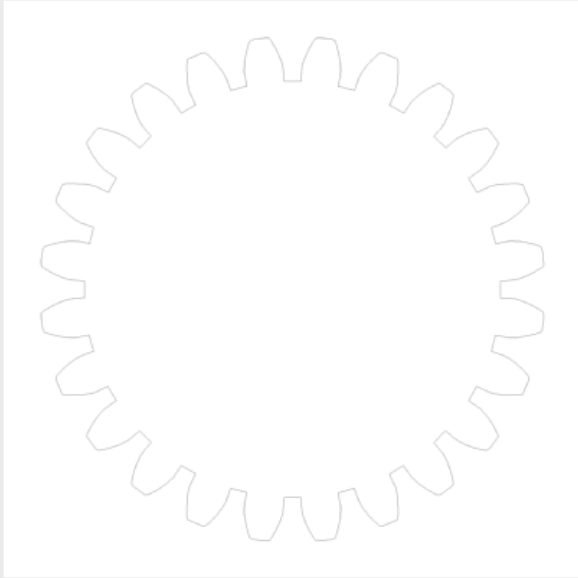
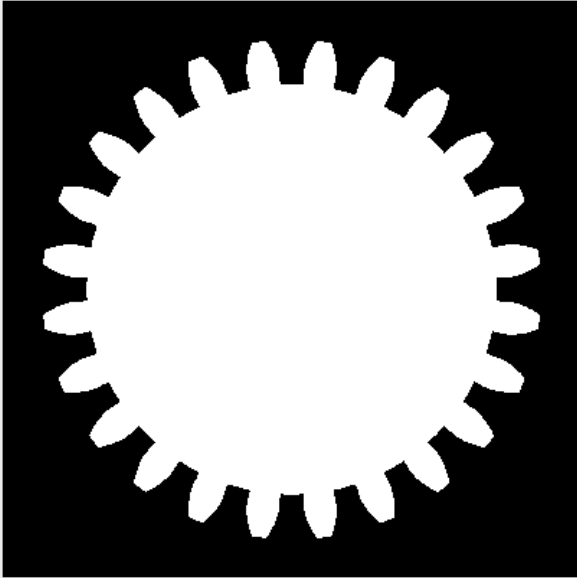


# Fab Modules

make\_png\_epi

defaults  quit

from: png to: path to: epi



send it!

load .png  
resize .png  
x: 15.764 mm y: 18.717 mm

read /Users/mkeeter/grad/cba/fab/fab8/parametric gear/gear.png  
bit depth: 16  
x pixels: 1904, y pixels: 1904  
x pixels/m: 99947, y pixels/m: 99947  
dx: 19.050097 mm, dy: 19.050097 mm

make .path view .path

diameter (mm) offsets (-1 to fill)  
0.25 1

overlap (0-1) 2D threshold (0-1)  
0.5 0.5

error (pixels) 2D z (mm)  
1.1 0

3D settings

make .epi

2D power (%) speed (%)  
25 75


xmin (mm) ymin (mm)  
0 0

3D power (%) rate  
100 500

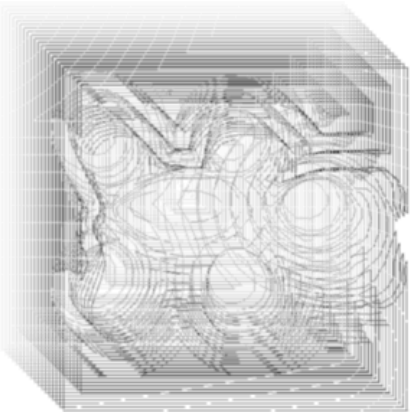
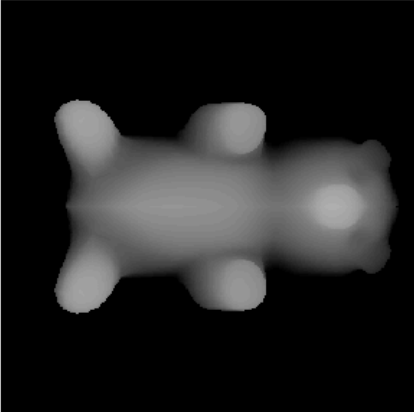
autofocus

# Fab Modules

make\_png\_rml

wax rough cut (1/8)  quit

from: png to: path to: rml



send it!

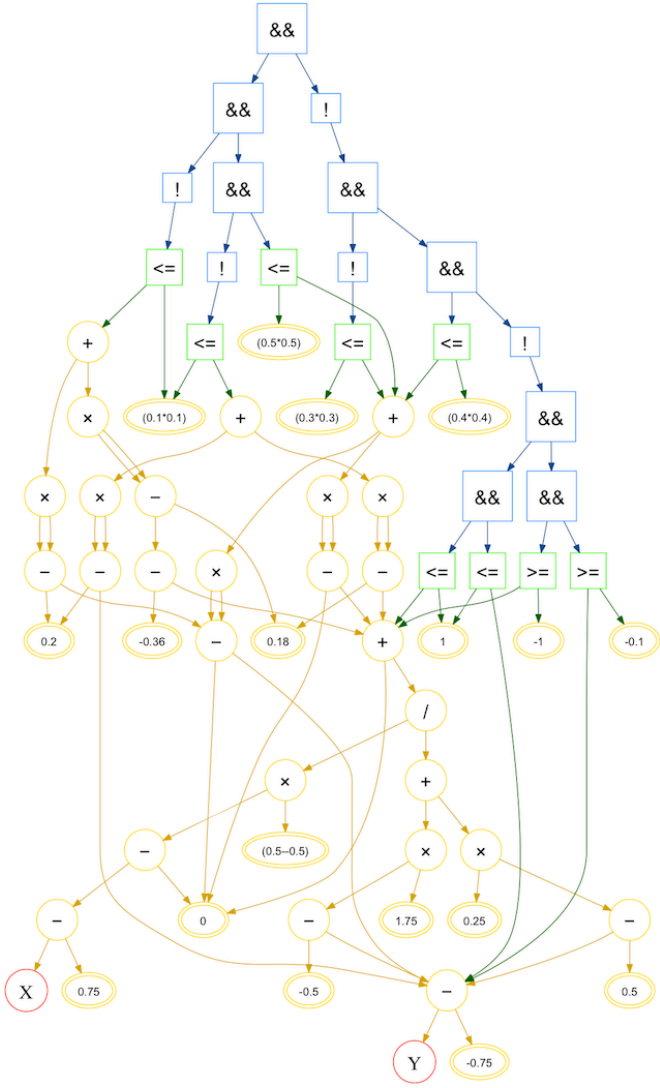
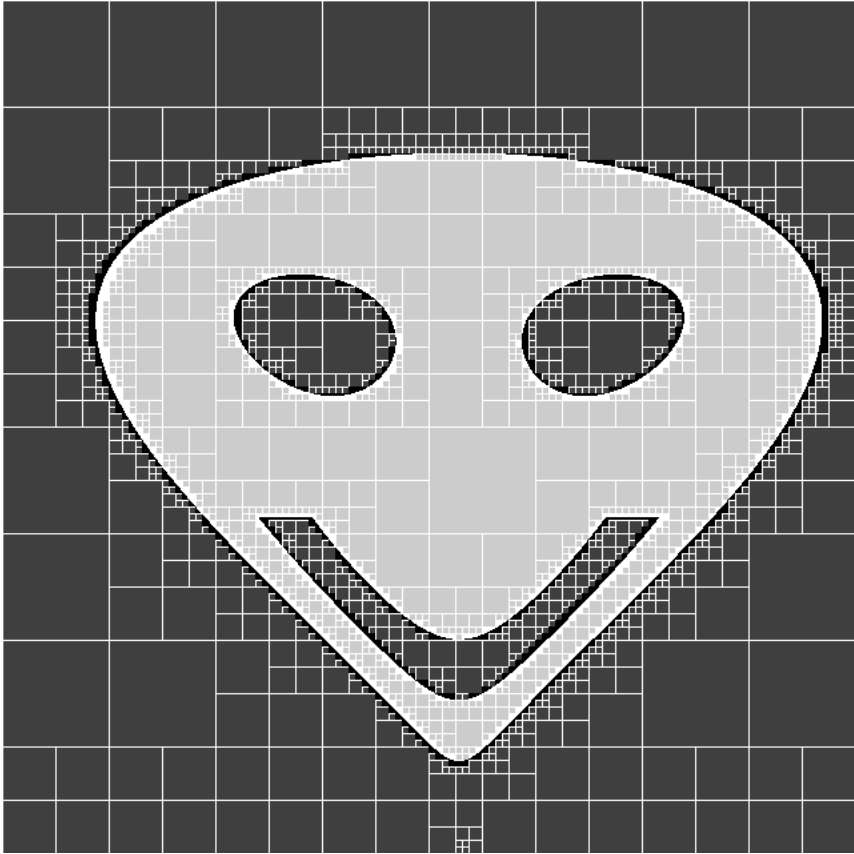
load .png  
resize .png  
x: 66.689 mm y: 35.368 mm  
read bear.png  
bit depth: 16  
x pixels: 703, y pixels: 703  
x pixels/m: 9988, y pixels/m: 9988  
dx: 70.384460 mm, dy: 70.384460 mm

make .path view .path  
diameter (mm) offsets (-1 to fill)  
3.175 -1  
overlap (0-1) 2D threshold (0-1)  
0.25 0.5  
error (pixels) 2D z (mm)  
1.5 0

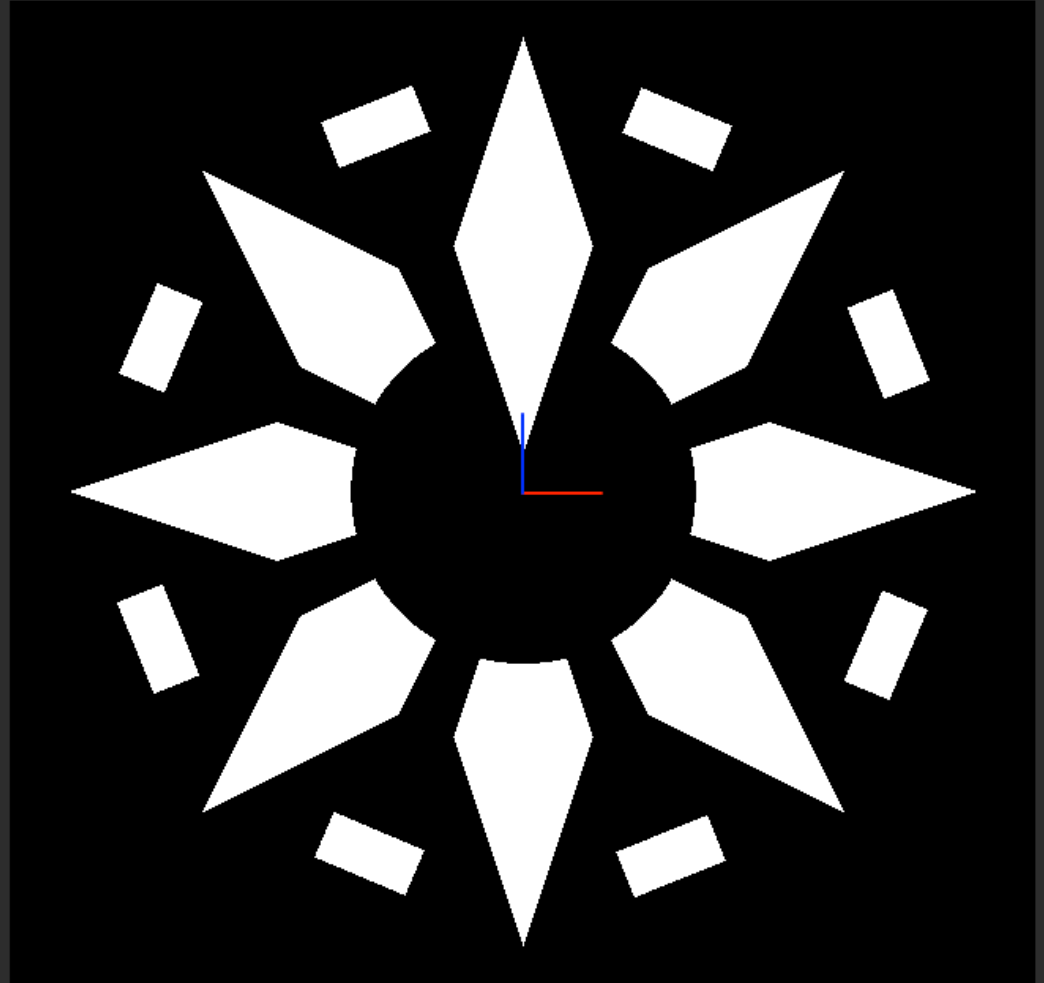
3D settings

make .rml  
speed (mm/s) jog (mm)  
20 1  
xmin (mm) ymin (mm)  
20 20  
move to xmin,ymin

# F-Reps



```
1 from cad_shapes import *
2 from cad_text import *
3
4 R = rectangle(-0.2, 0.2, -0.2, 0.2)
5 R = rotate(R, 45)
6 R = scale_y(R, 0, 3)
7 R = move(R, 0, 1)
8
9 B = circle(0, 1.6, 0.3)
10 B = rectangle(-0.2, 0.2, 1.5, 1.7)
11 B = rotate(B, 360/16)
12
13 pattern = ''
14 for i in range(8):
15     pattern += rotate(R + B, i*360/8)
16 pattern -= circle(0, 0, 0.7)
17
18 X = rectangle(-0.4, 0.4, -0.4, 0.4)
19 X += rotate(X, 45)
20 cad.function = pattern + R
21
22 # Render boundaries
23 cad.xmin = -2
24 cad.xmax = 2
25 cad.ymin = -2
26 cad.ymax = 2
27 cad.mm_per_unit = 25.4 # inch units
```



# Future Directions

- Hierarchical volumetric representation
  - Input from volumetric scan data
  - CAD/CAM without triangulation
- Simulation
- Physical modeling
- Constraint solving
  - Integrated into scripting?
  - Integrated into solver?