

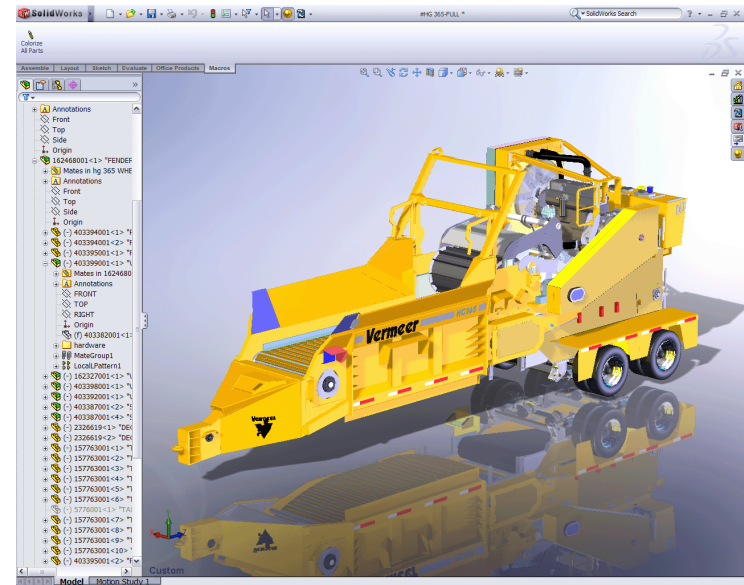
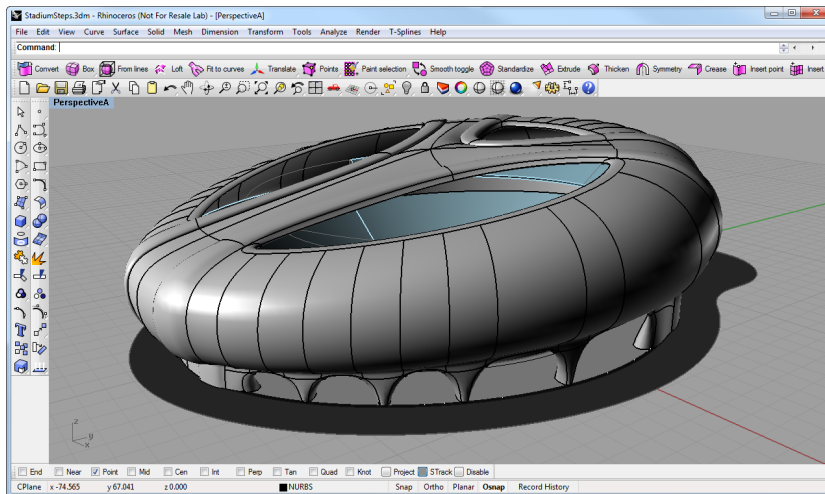
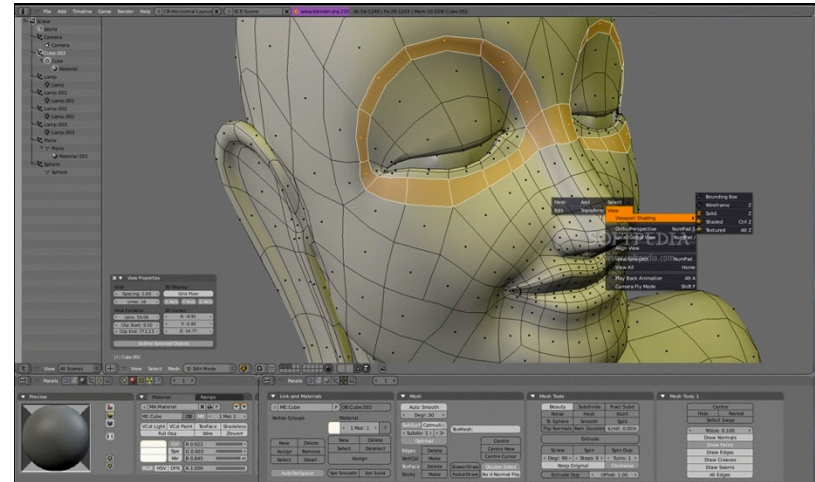
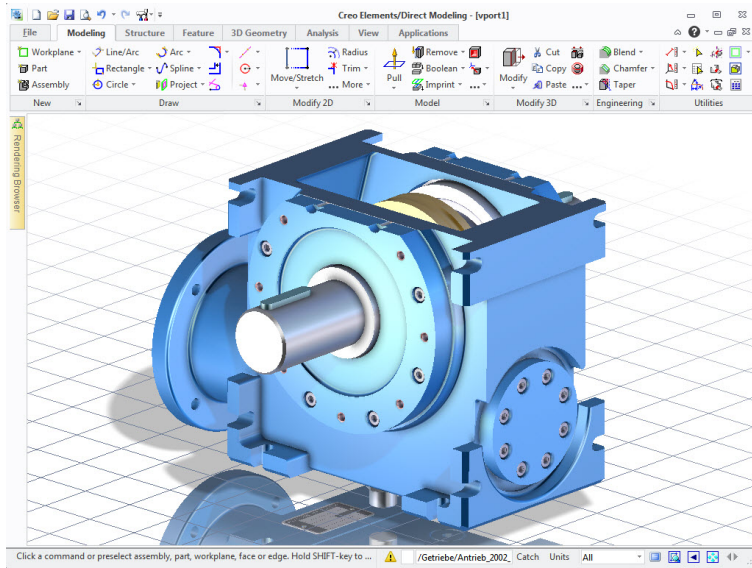
# Design Representations and Interfaces

Matt Keeter

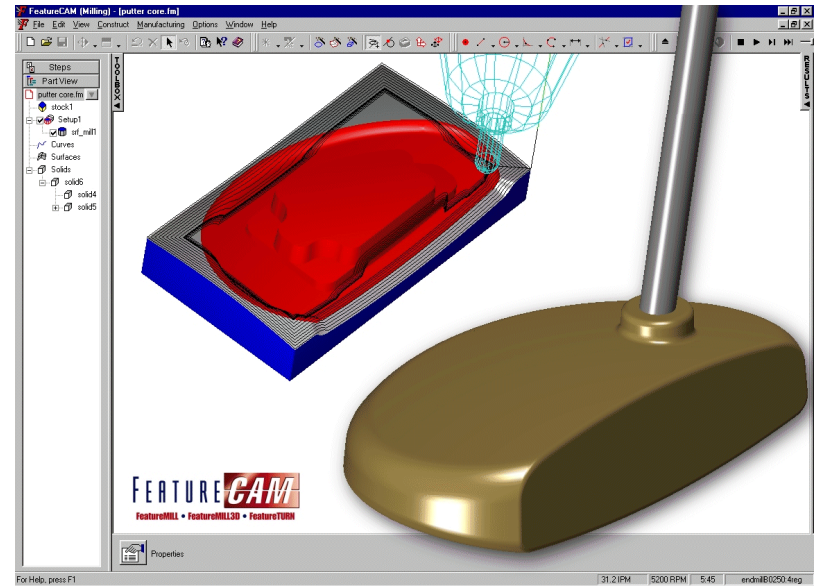
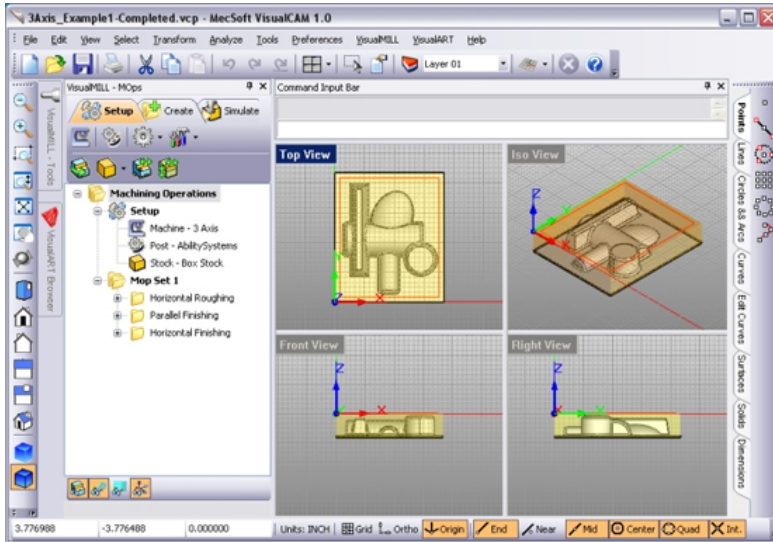
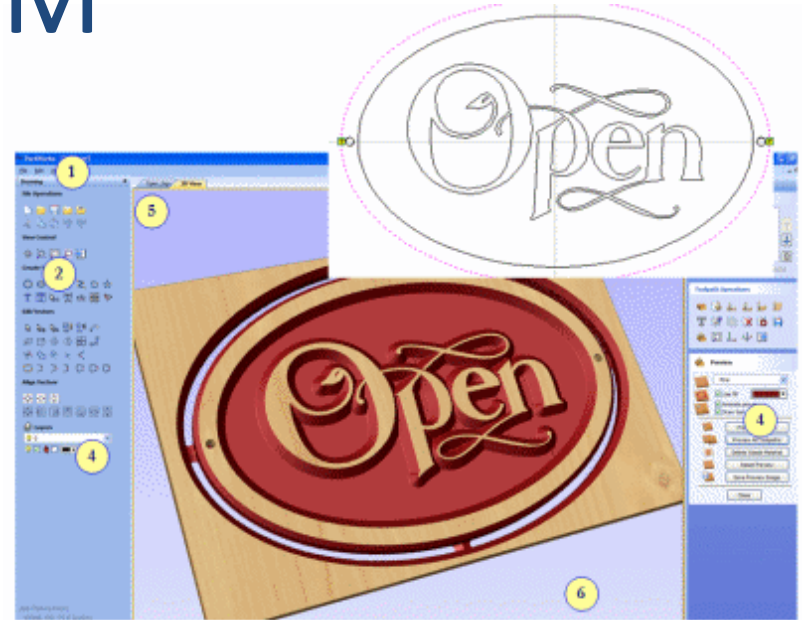
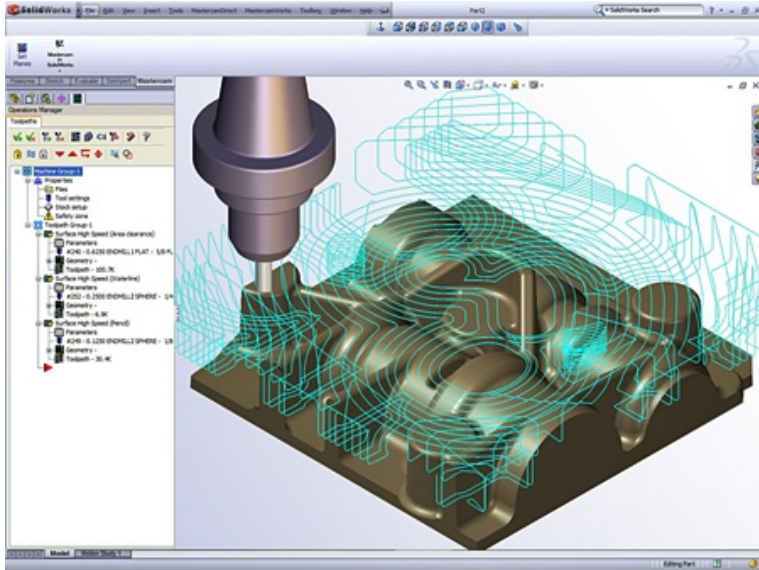
[matt.keeter@cba.mit.edu](mailto:matt.keeter@cba.mit.edu)

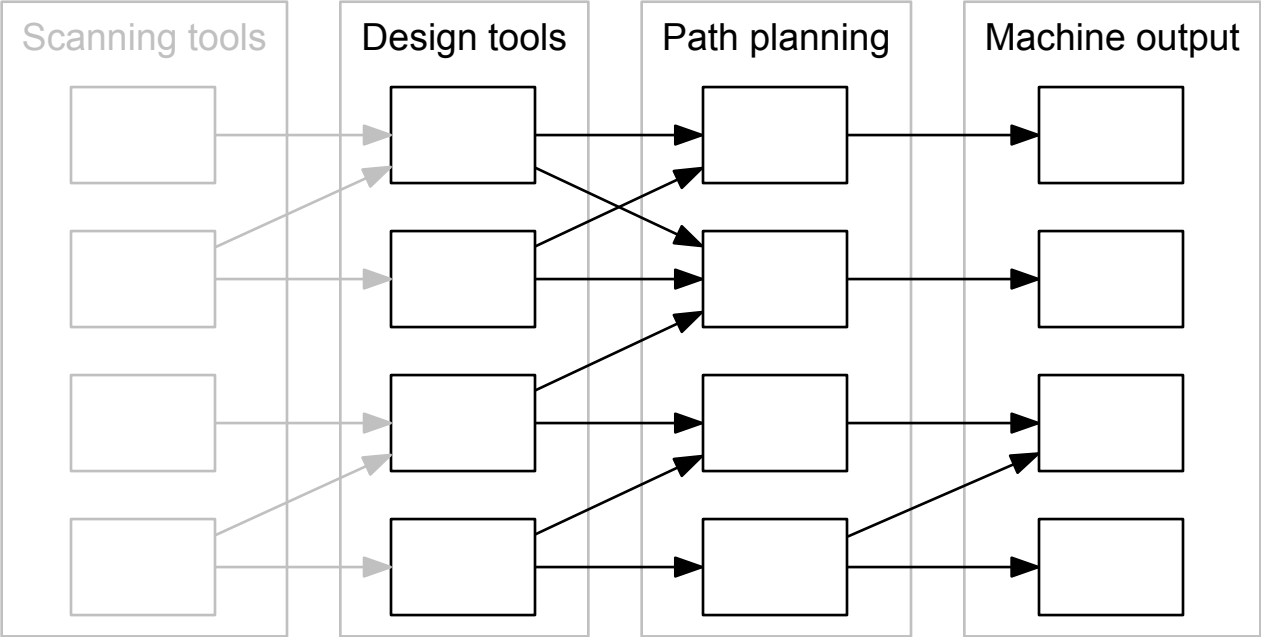


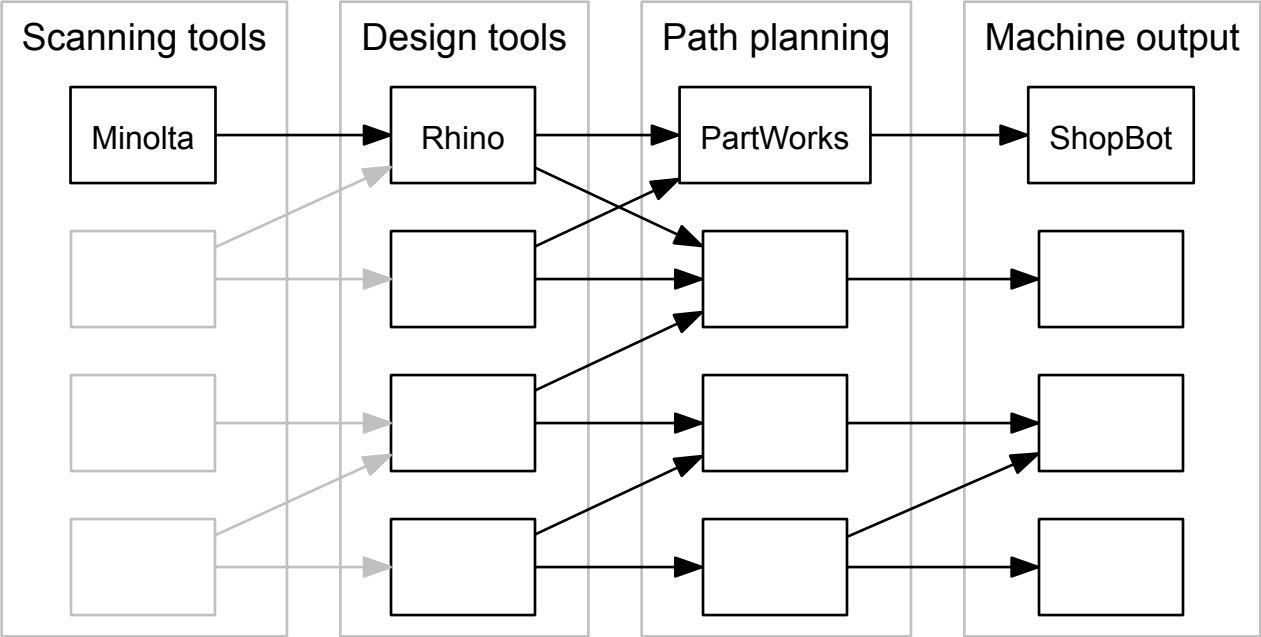
# CAD



# CAM



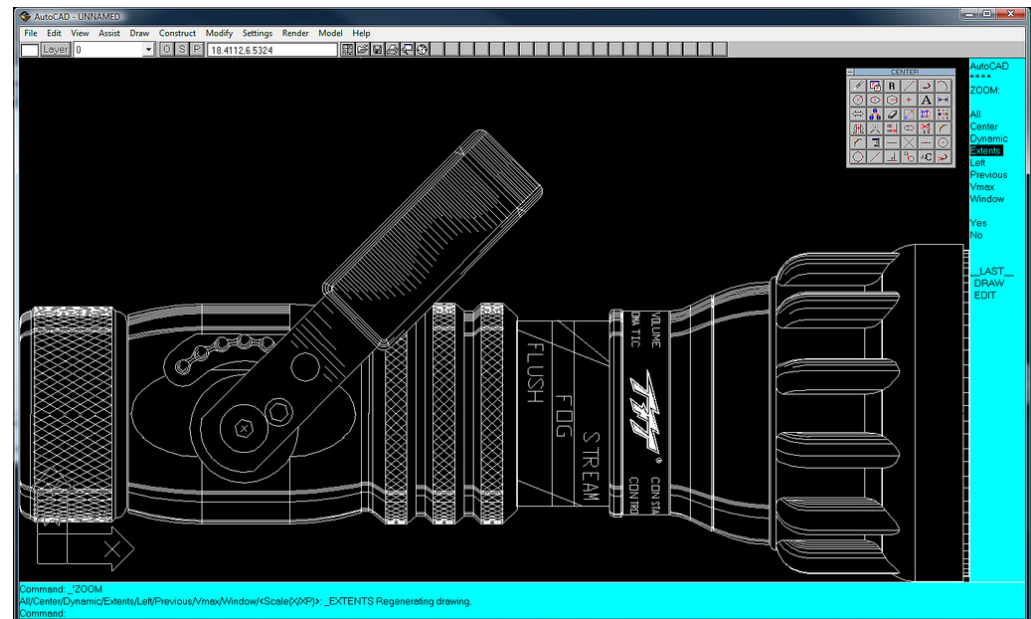




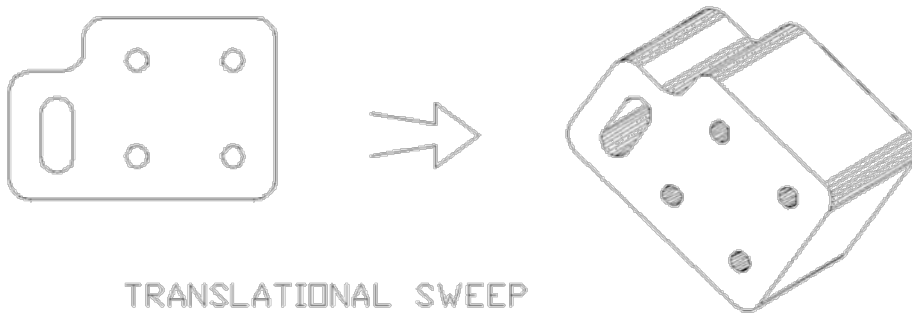


Early design tools reflected the heritage of drawing boards

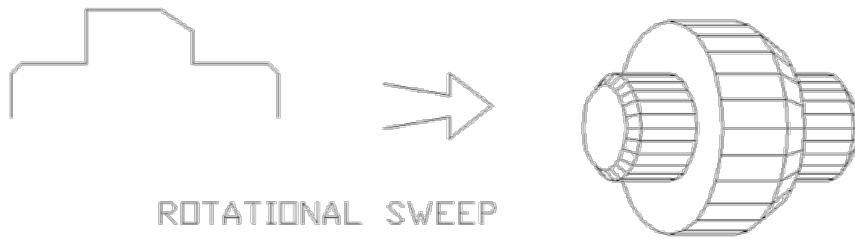
2D representations are based on edges and lines



2D drawings can be extruded, revolved, lofted into 3D shapes

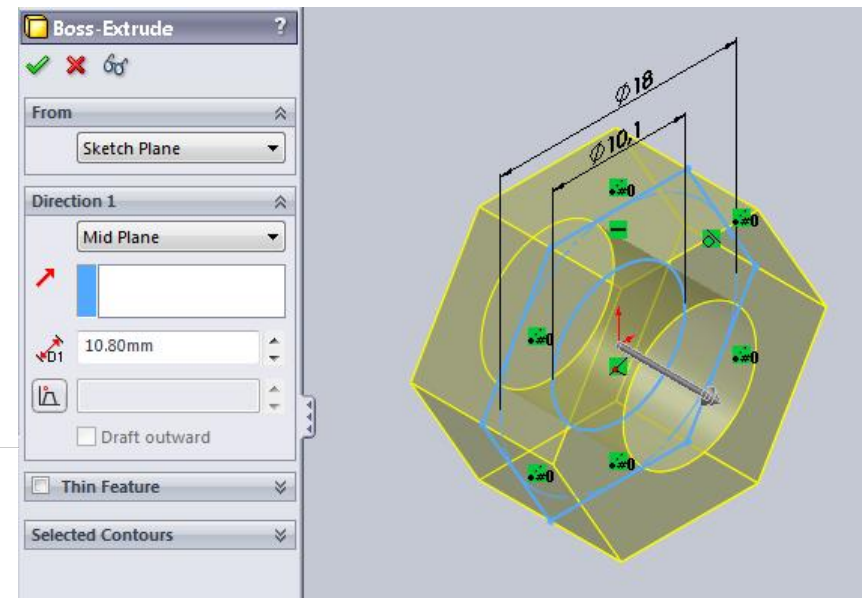
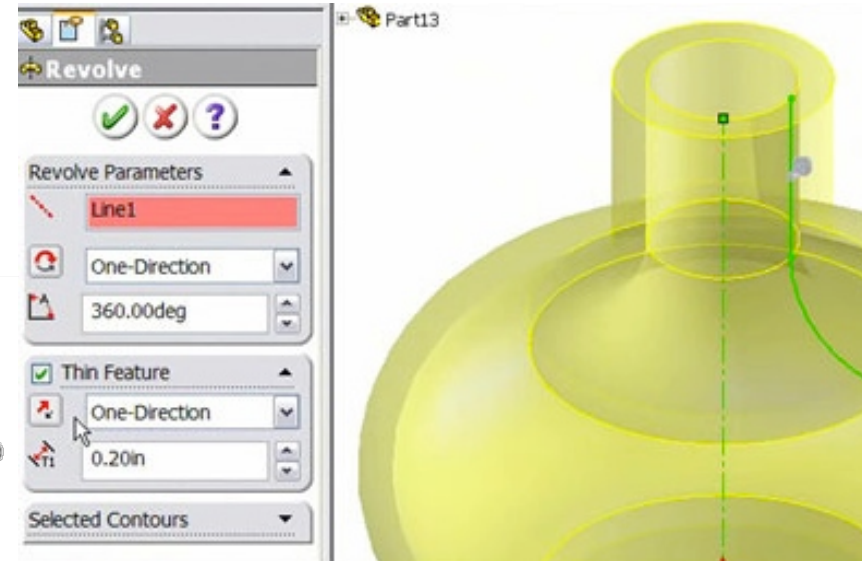


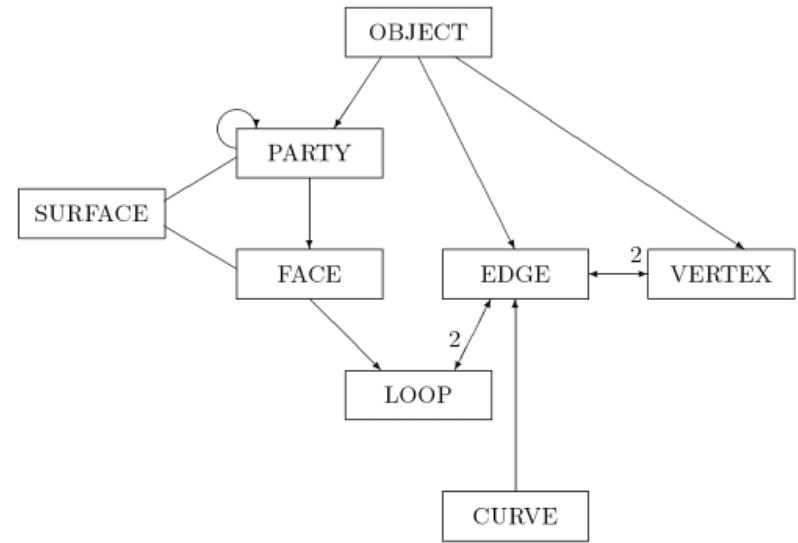
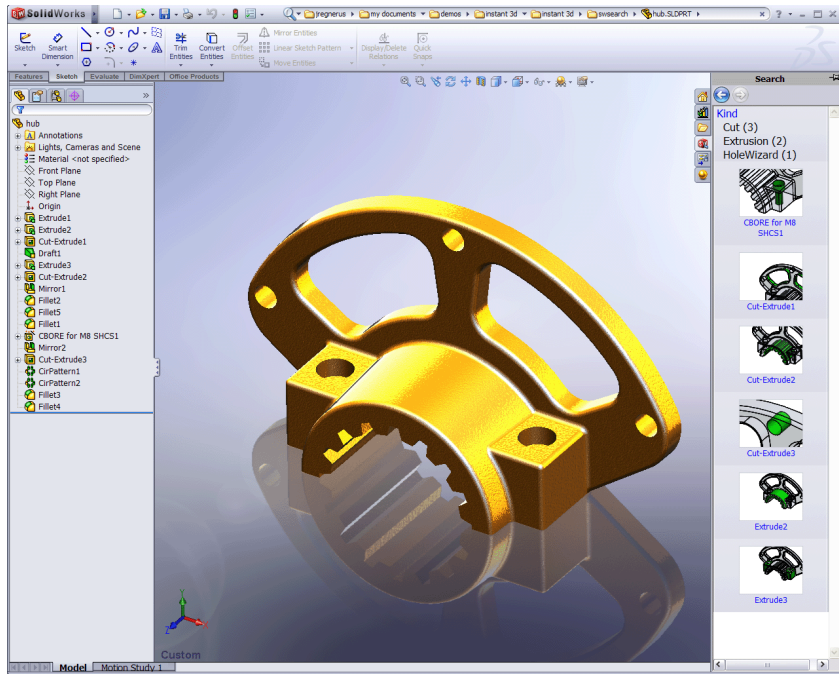
TRANSLATIONAL SWEEP



ROTATIONAL SWEEP

These operations mimic machining techniques

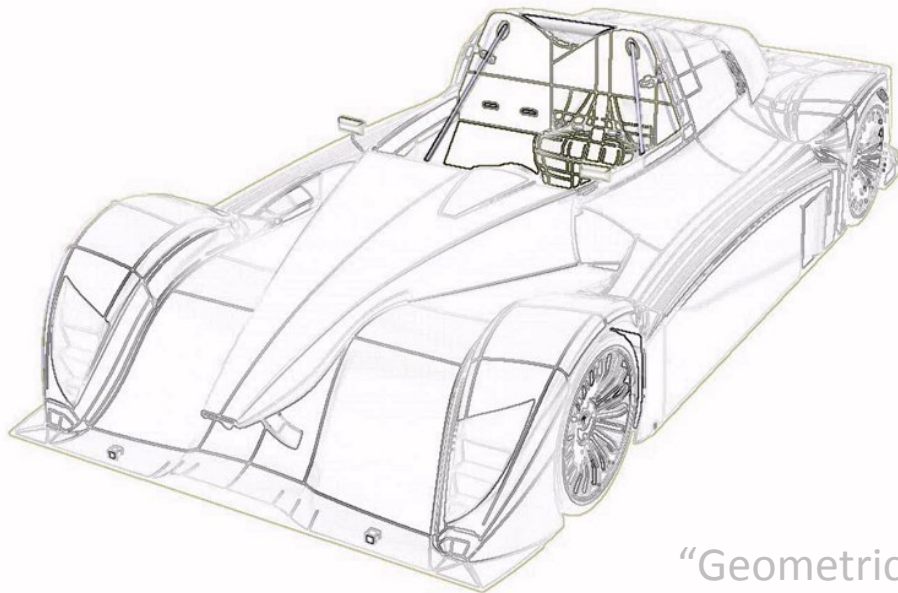




Gradual evolution  
from drafting

+ Limited rendering  
hardware

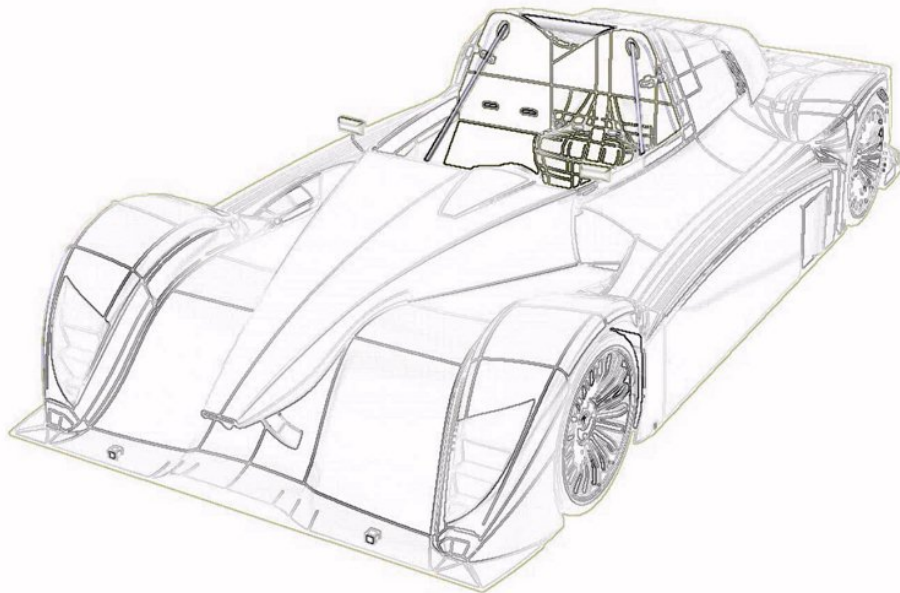
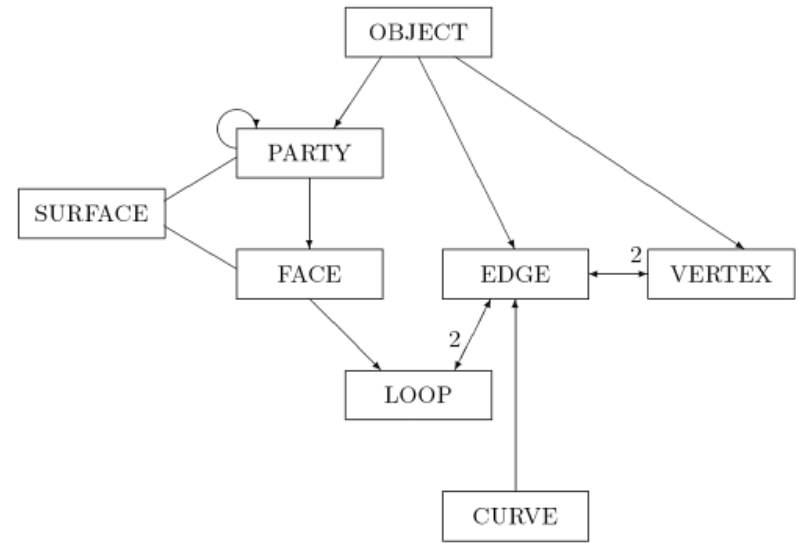
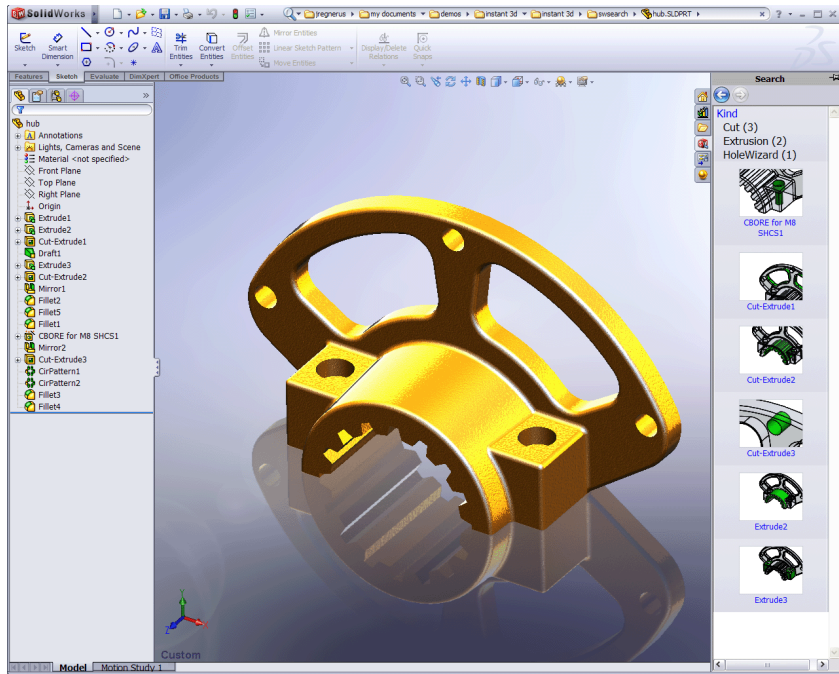
= Widespread use of  
boundary representations



“Designing with Volumes” (Braid, 1974)

“Geometric modeling for computer vision” (Baumgart, 1974)





- Very easy to render
- Fragile representation
- Computational solid geometry is hard
- Writing custom CAD software is tricky

# Problems

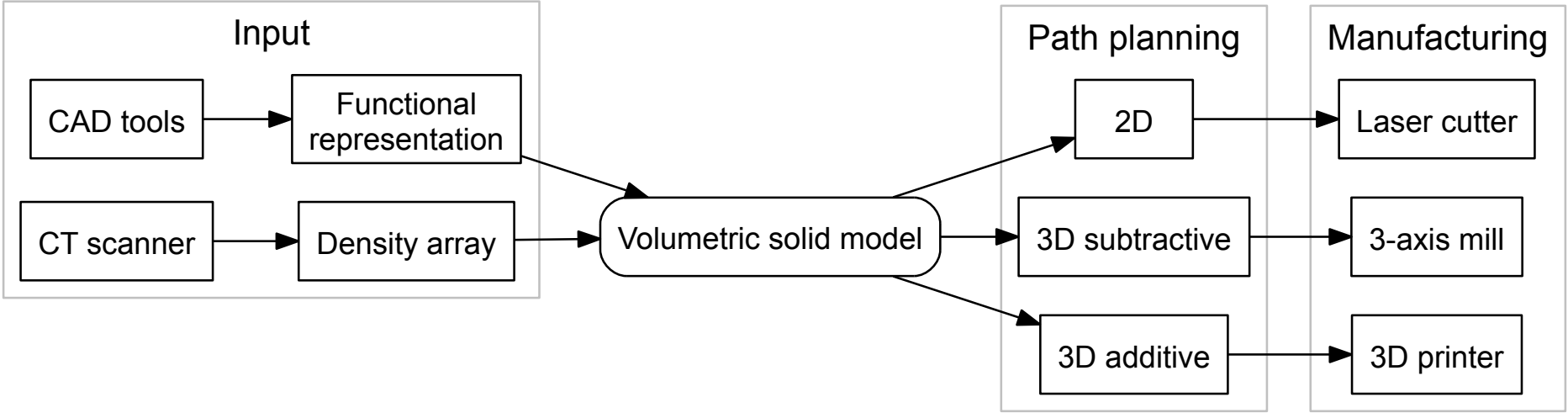
- Watertight volumes and clean meshes
- File size / resolution
- Toolpath planning
- Combinatorial explosion

# Solution

Hierarchical, volumetric solids

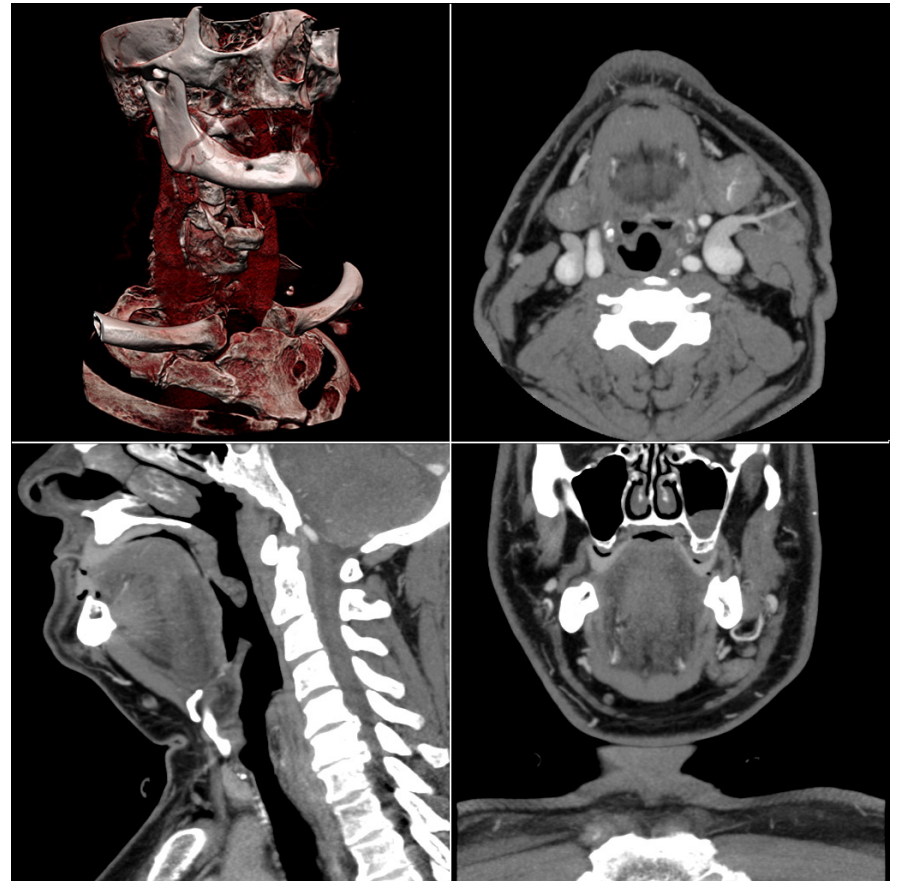
End-to-end CAD/CAM workflow





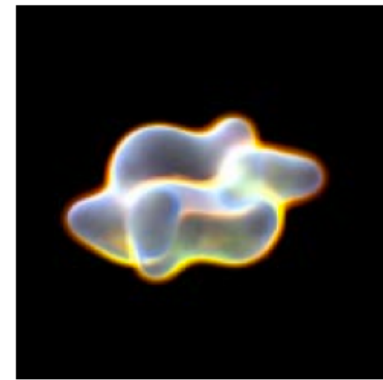
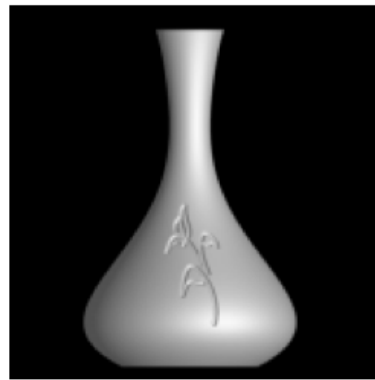
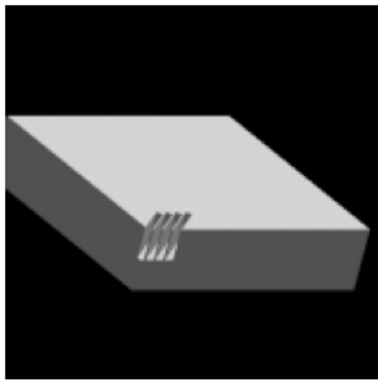
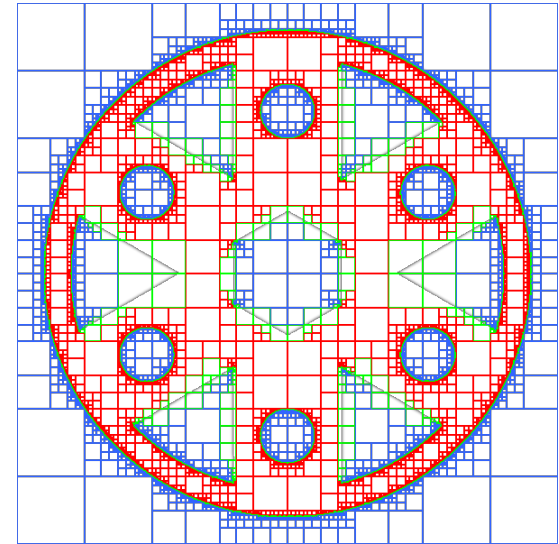
# Lattice Representations

- Discrete volumetric representation  
e.g. CT scan data
- Samples on regular 3D lattice
- Scales poorly  
–  $n^3$



# Hierarchical Representation

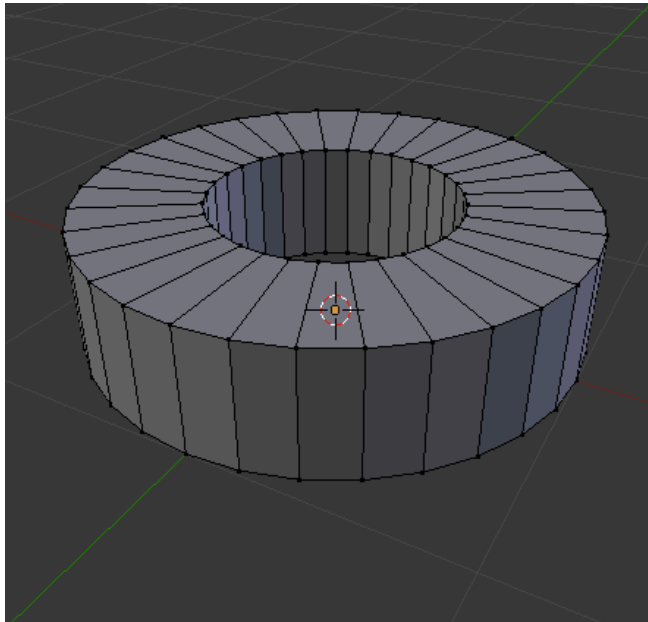
- Adaptively sampled distance fields (ASDFs)
- Hierarchical, space-efficient volumetric representation



“Adaptively Sampled Distance Fields:  
A General Representation of Shape for Computer Graphics” (Frisken, 2000)

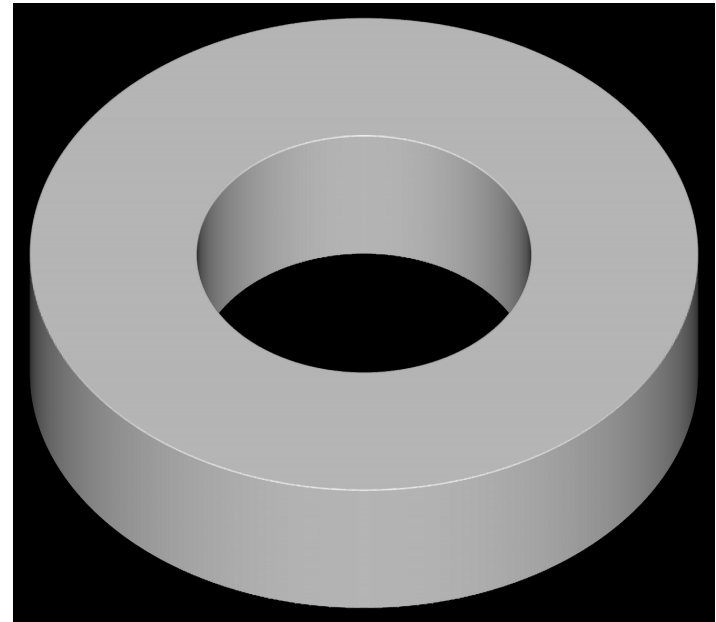
# CAD without B-Reps

Boundary Representation



128 vertices, 256 edges, 128 faces

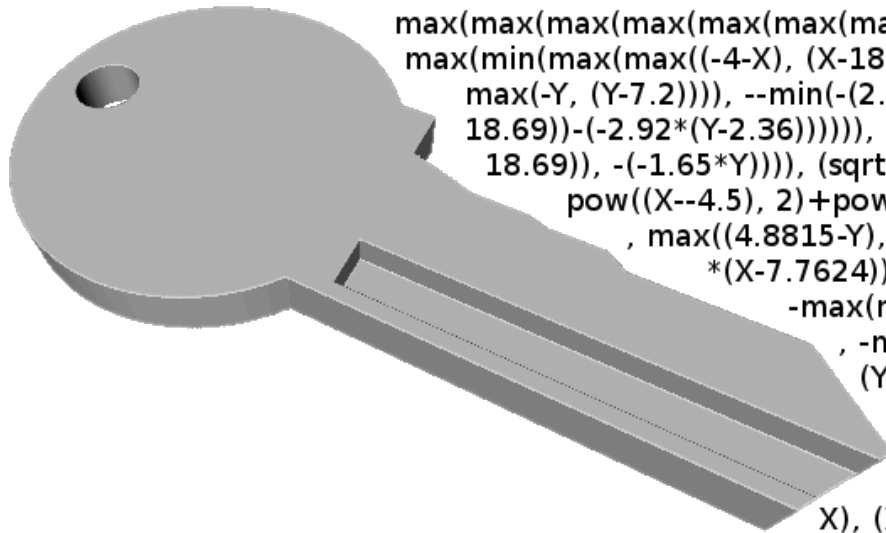
Functional Representation



$(0.25 < X^2 + Y^2 < 1) \ \&\& \ (0 < Z < 0.5)$

“A Constructive Geometry for Computer Graphics” (Ricci, 1973)  
“Interactive techniques for implicit modeling” (Bloomenthal, 1990)

# CAD without B-Reps

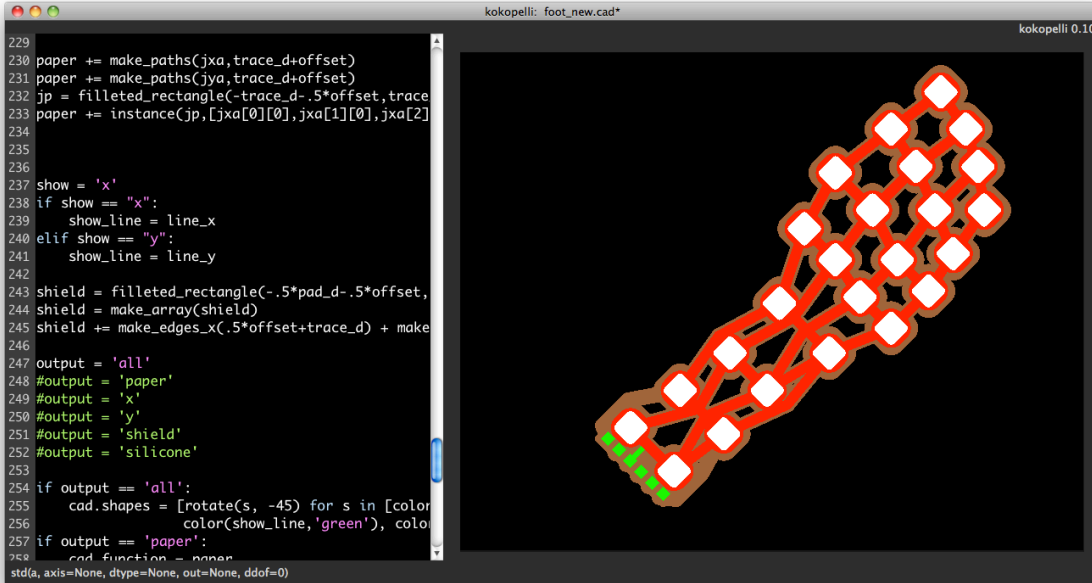


```
max(max(max(max(max(max(max(max(max(max(max(max(max(min (max(
max(min(max(max((-4-X), (X-18.69)), max(-Y, (Y-5.52))), max(max((-4-X),(X-5.59)),
max(-Y, (Y-7.2))), --min(-2.92*(Y-5.52)), min((-3.16*(X-18.69)), ((3.16*(X-
18.69))-(-2.92*(Y-2.36))))), --min(((2.13*(X-17.04))-(1.65*Y)), min((-2.13*(X-
18.69)), -(-1.65*Y))), (sqrt((pow((X--0.41), 2)+pow((Y-3.6), 2)))--6)), -(sqrt((
pow((X--4.5), 2)+pow((Y-3.6), 2)))--1)), -max(max((7.7624-X), (X-9.4539))
, max((4.8815-Y), (Y-5.52))), --min(-2.1724*(Y-5.52)), min((-0.6385
*(X-7.7624)), ((0.6385*(X-7.7624))-(-2.1724*(Y-4.8815))))),
-max(max((5.59-X), (X-7.7624)), max((5.52-Y), (Y-18.69))))
, -max(max((10.0256-X), (X-11.7171)), max((4.6824-Y),
(Y-5.52))), --min(-0.5717*(Y-4.8815)), min((-0.1991*
(X-10.0256)), ((0.1991*(X-10.0256))-(-0.5717*(Y-
4.6824))))), -max(max((9.4539-X), (X-10.0256)),
max((4.8815-Y), (Y-18.69))), -max(max((12.3552-
X), (X-14.0467)), max((4.2598-Y), [432 more characters]
```

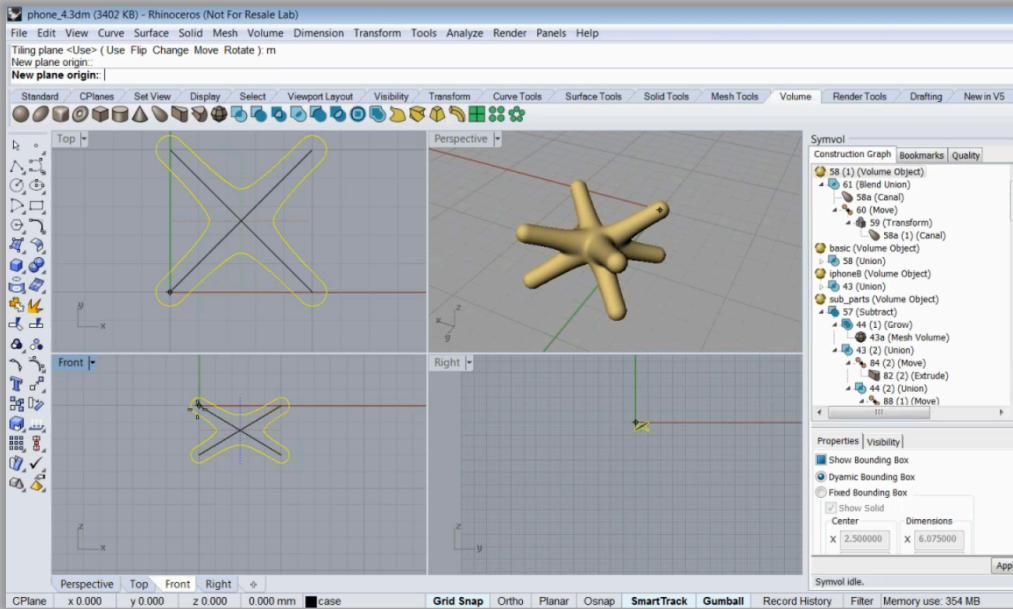
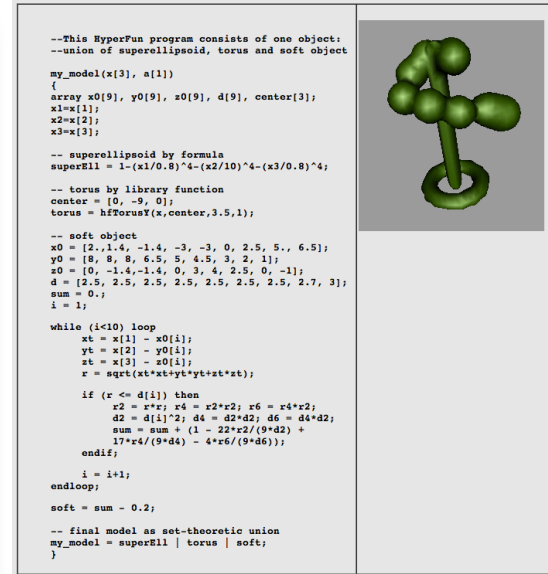
TSA master key

Will Langford & Matt Keeter, 2012

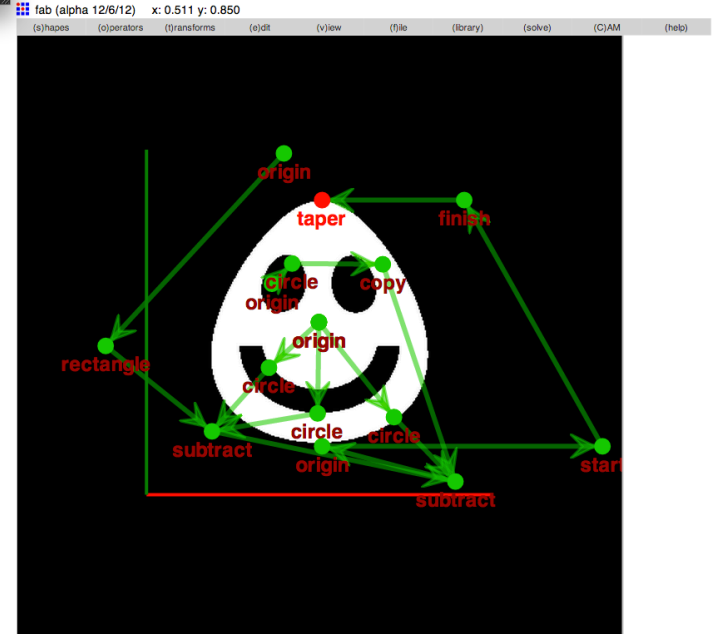
# kokopelli (Matt Keeter)



# Hyperfun (DMG)



Symvol™ for Rhino (Uformia)

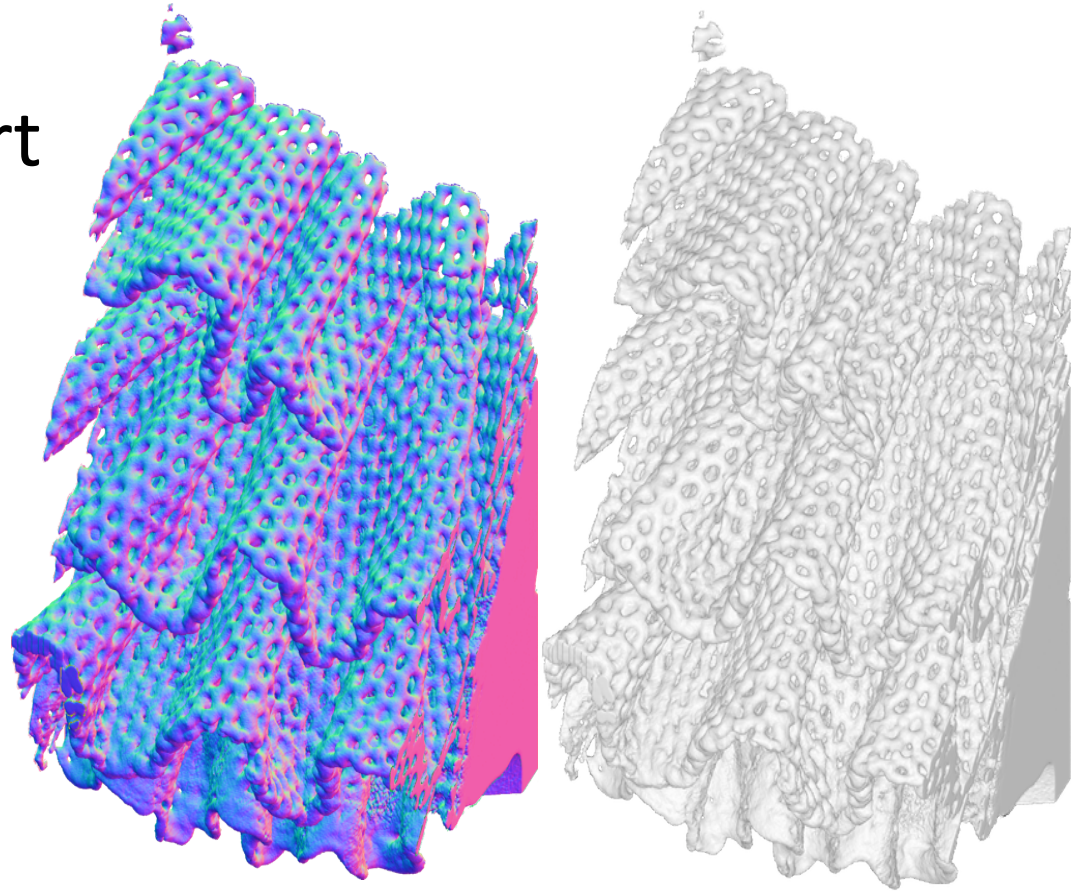


fabserver (Neil Gershenfeld)

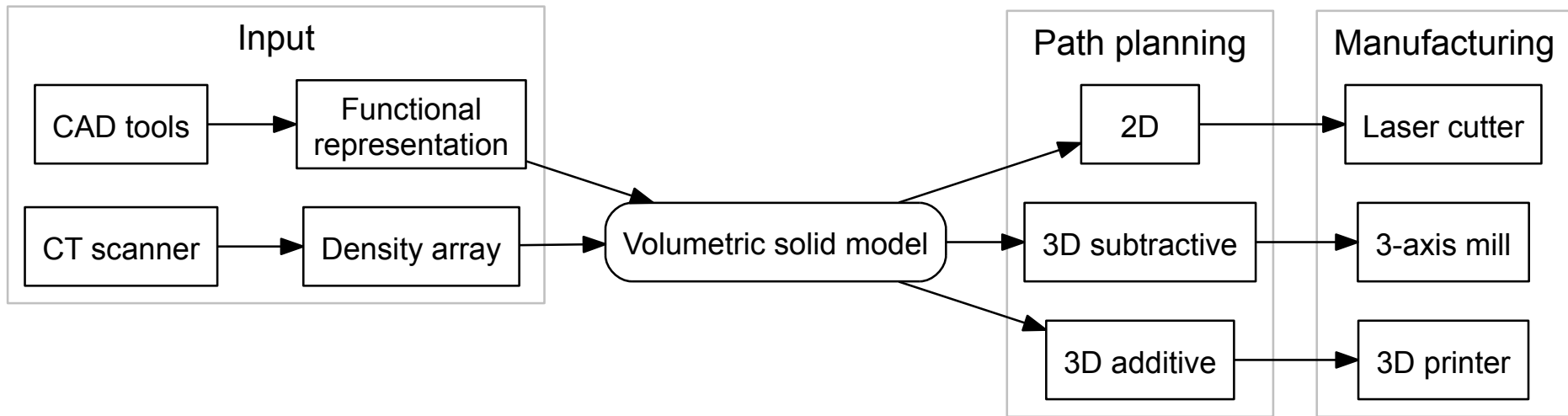


# Volumetric Data Import

- Easy CT data import
- Manufacturing from physical data
- File size reduction
  - 120 MB → 16 MB
- Scan → print for reproduction



Matt Keeter & Kenny Chung  
Collaboration with Jeff Koons



Matt Keeter

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