

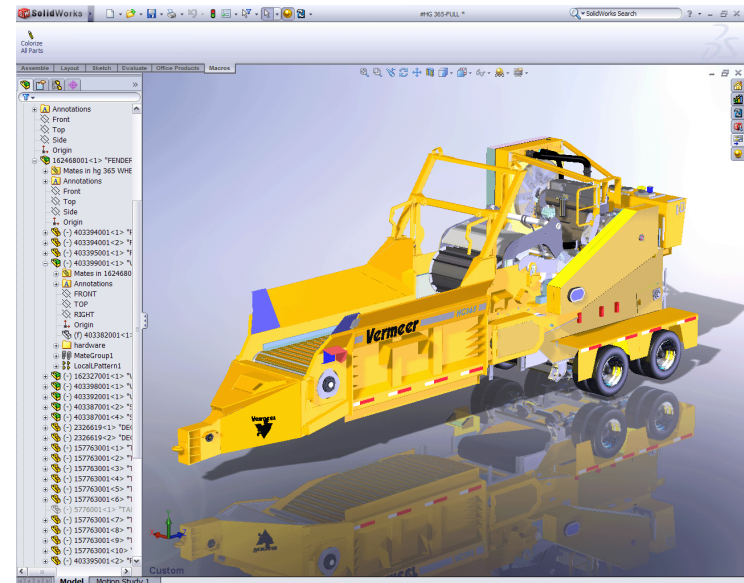
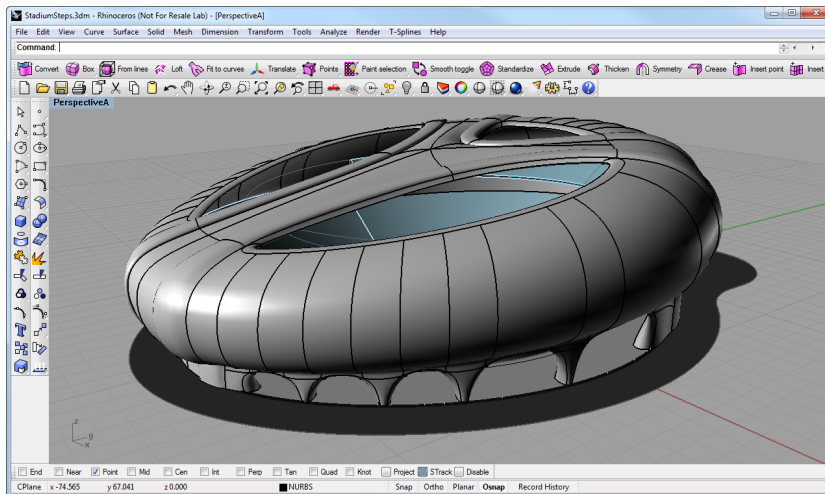
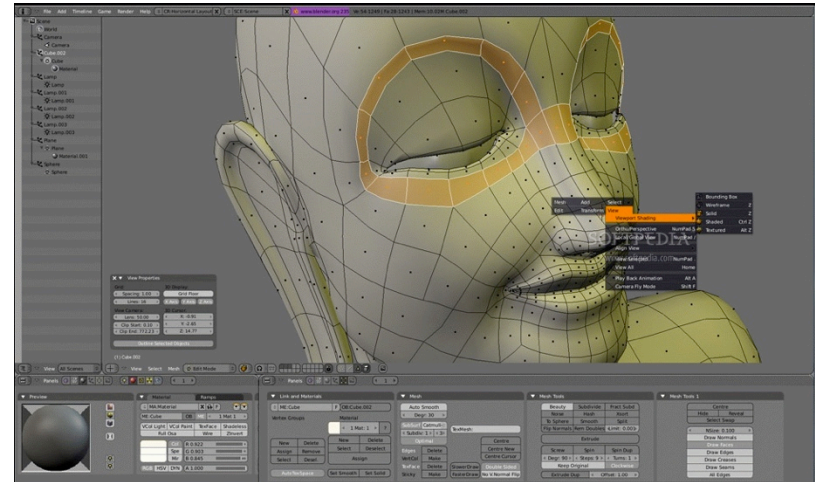
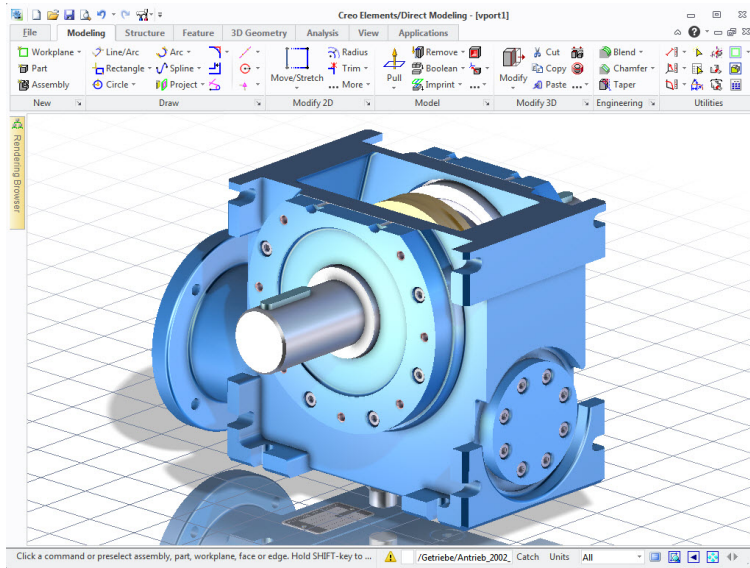
Design Representations and Interfaces

Matt Keeter

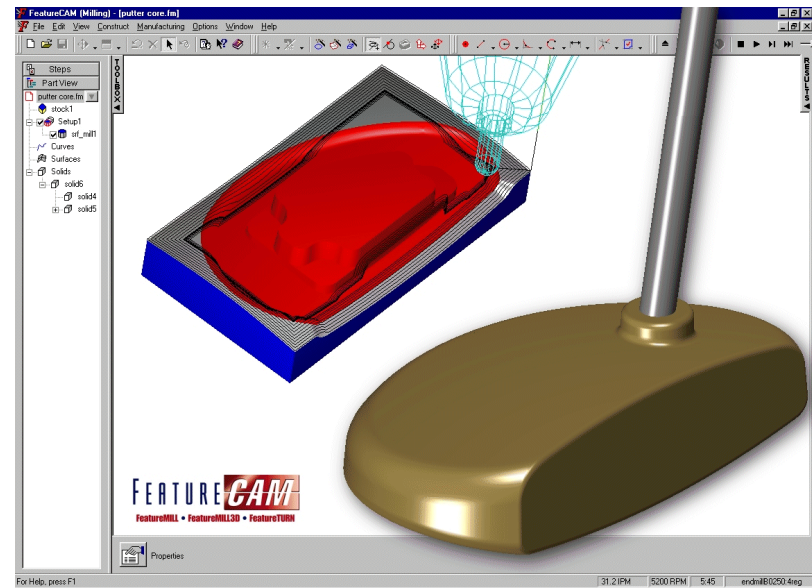
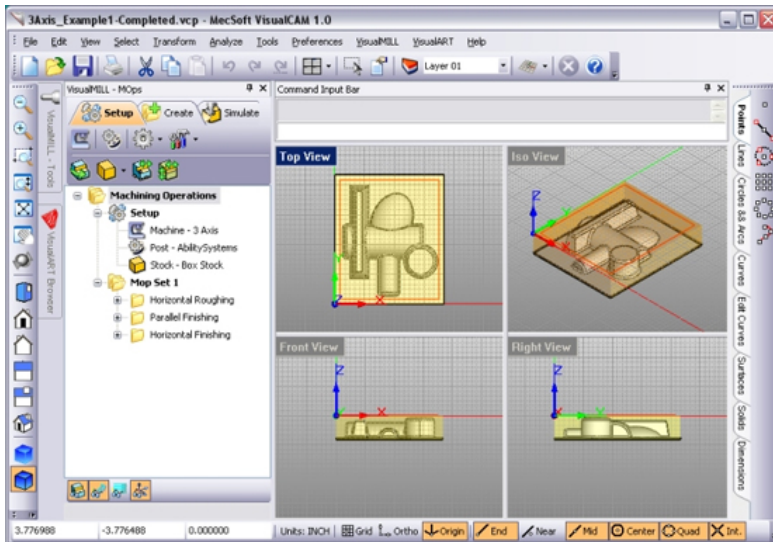
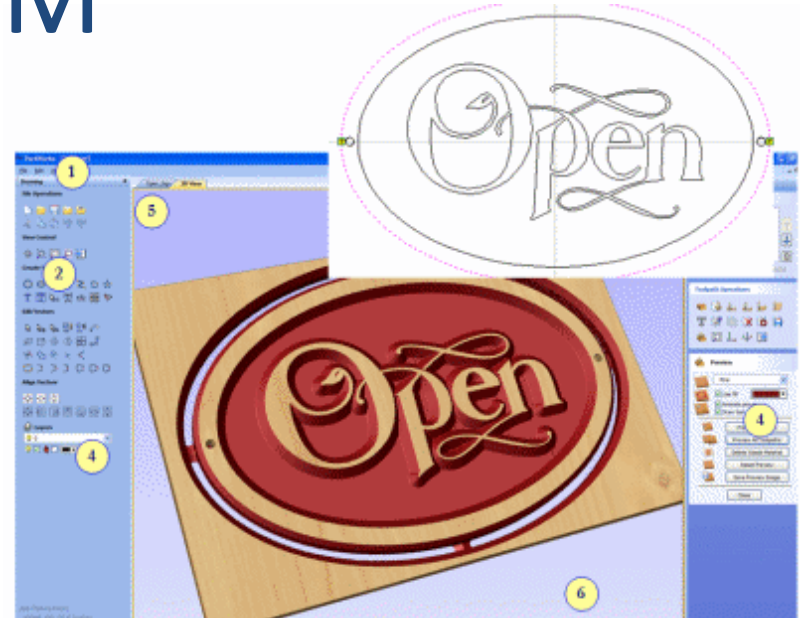
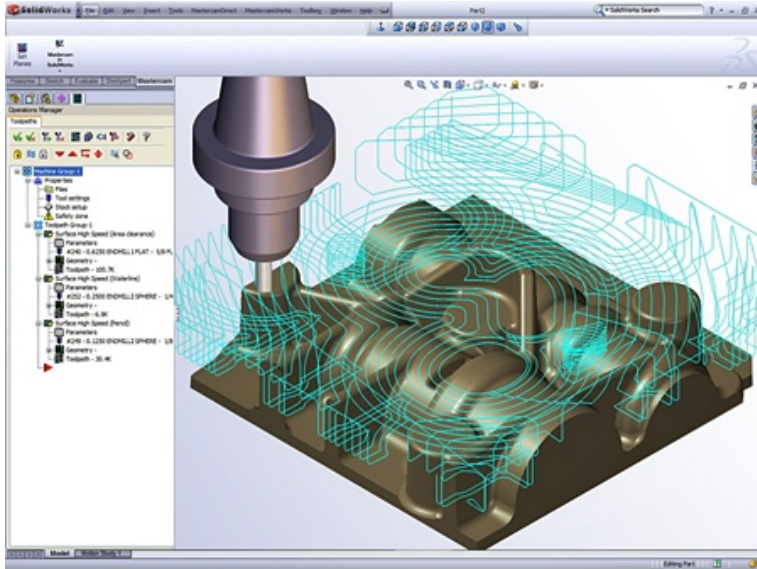
matt.keeter@cba.mit.edu

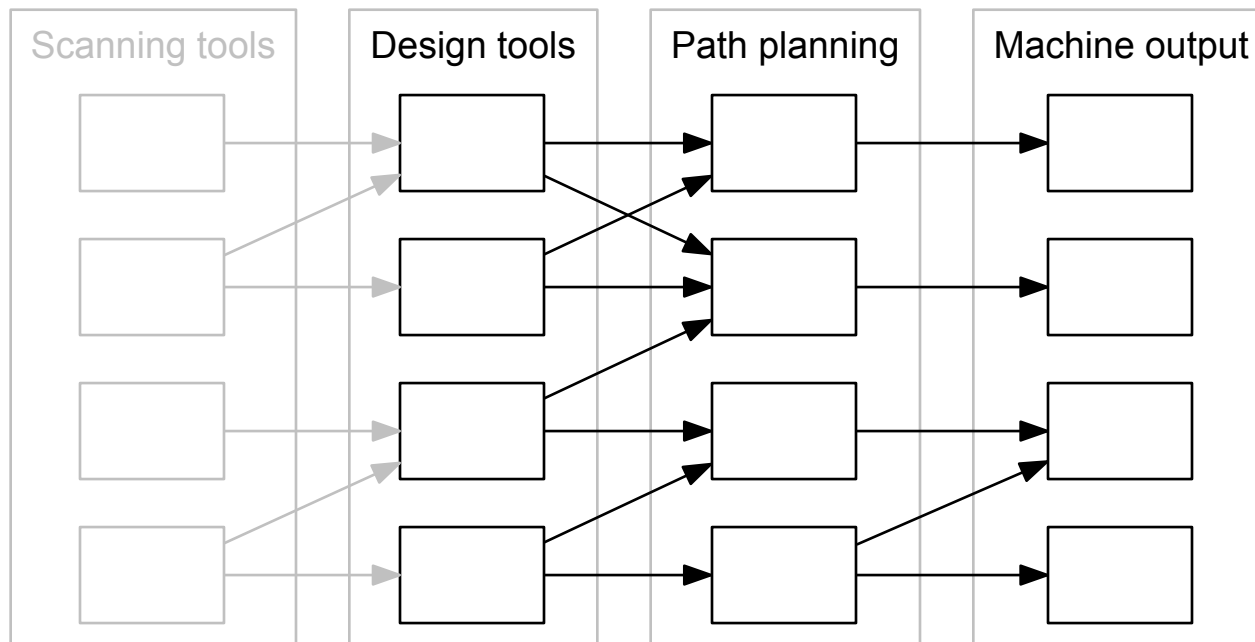


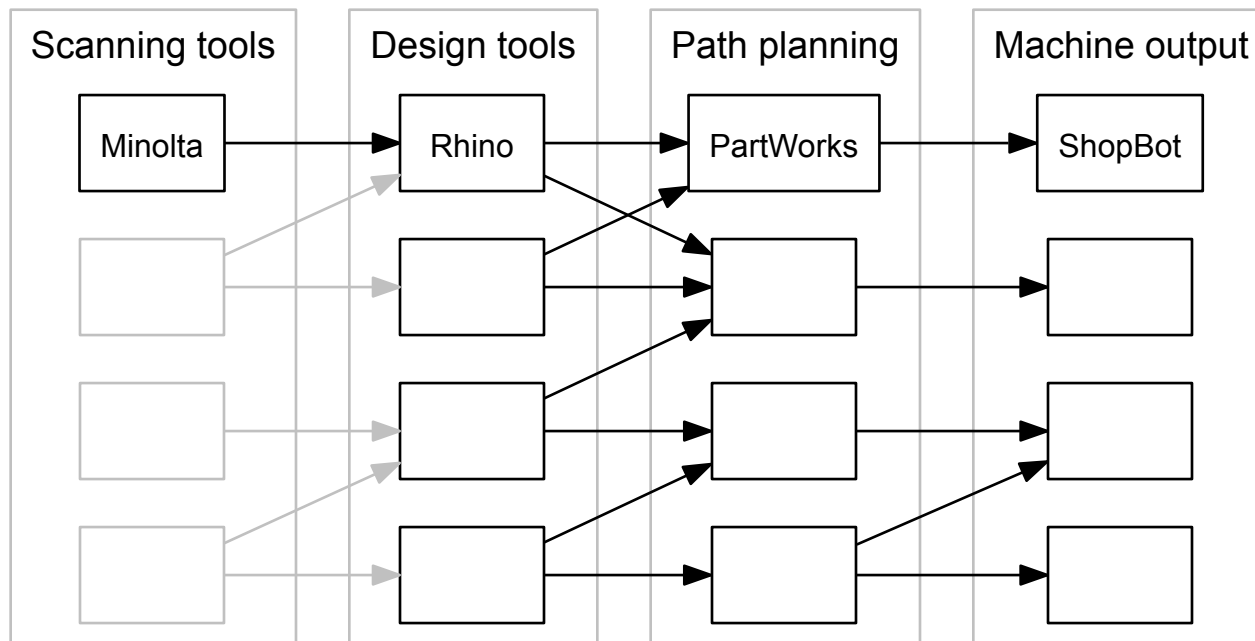
CAD



CAM



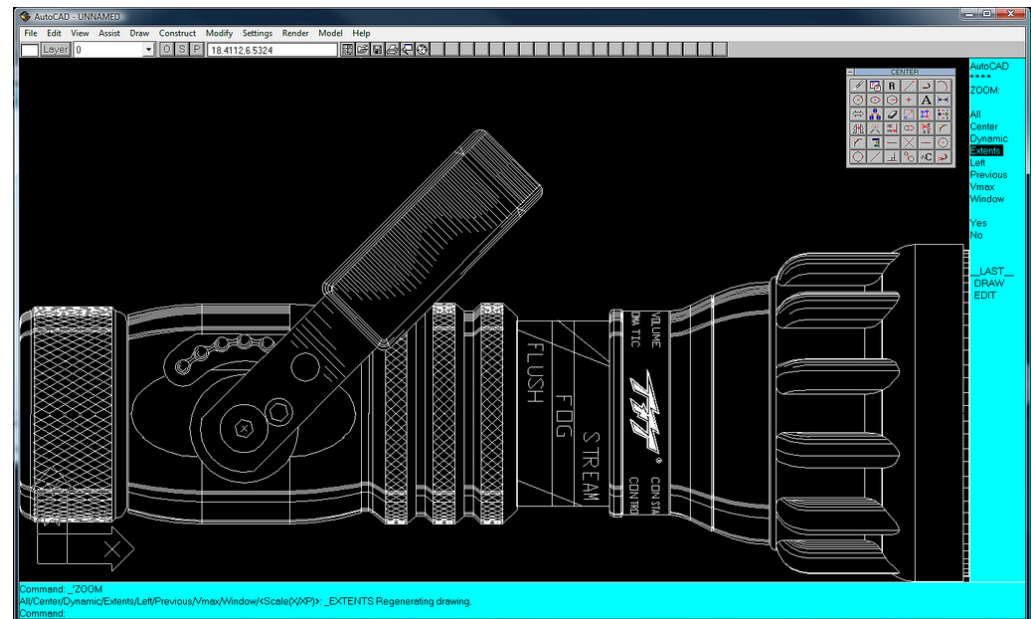




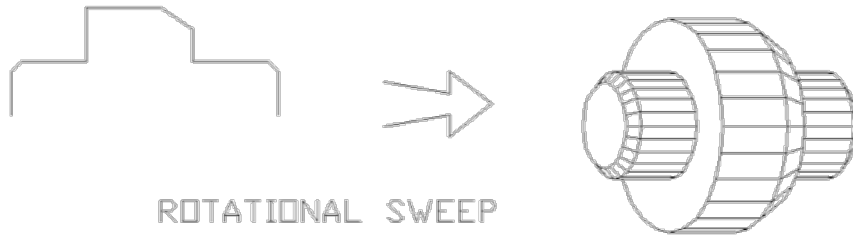
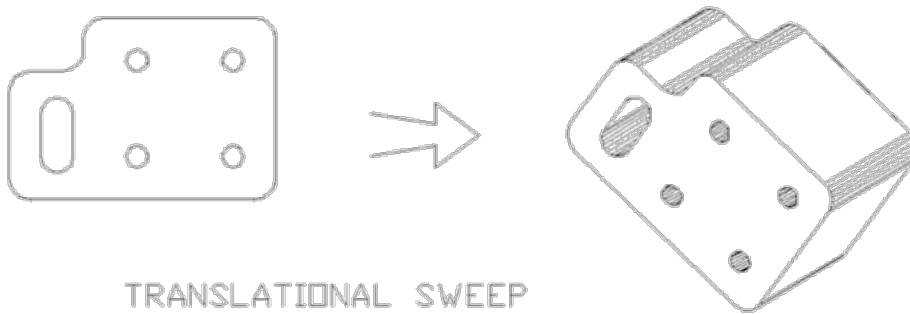


Early design tools reflected the heritage of drawing boards

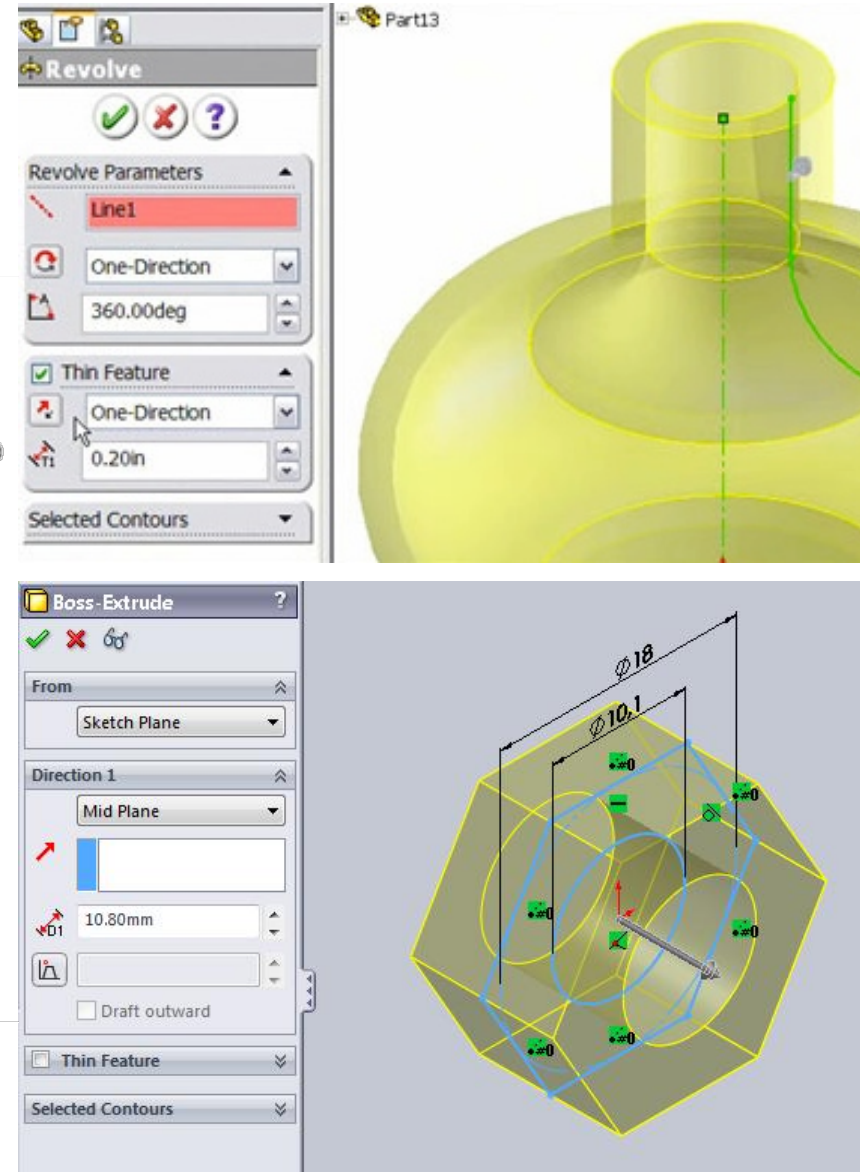
2D representations are based on edges and lines

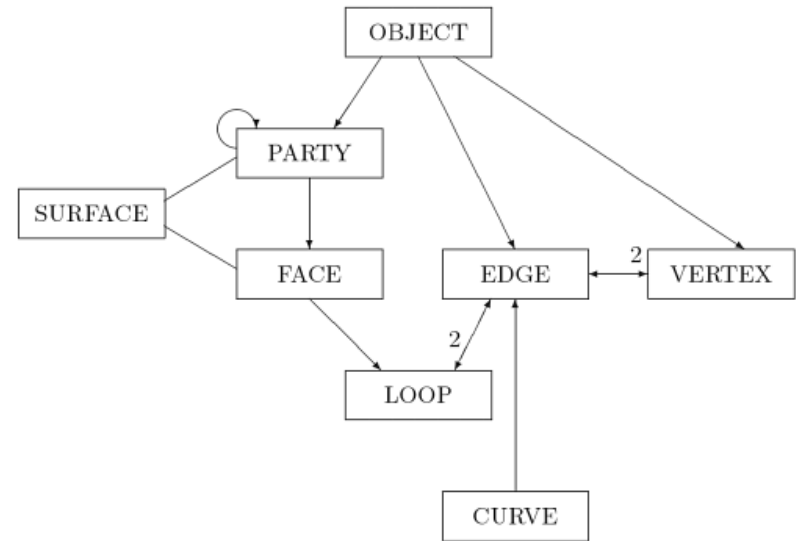
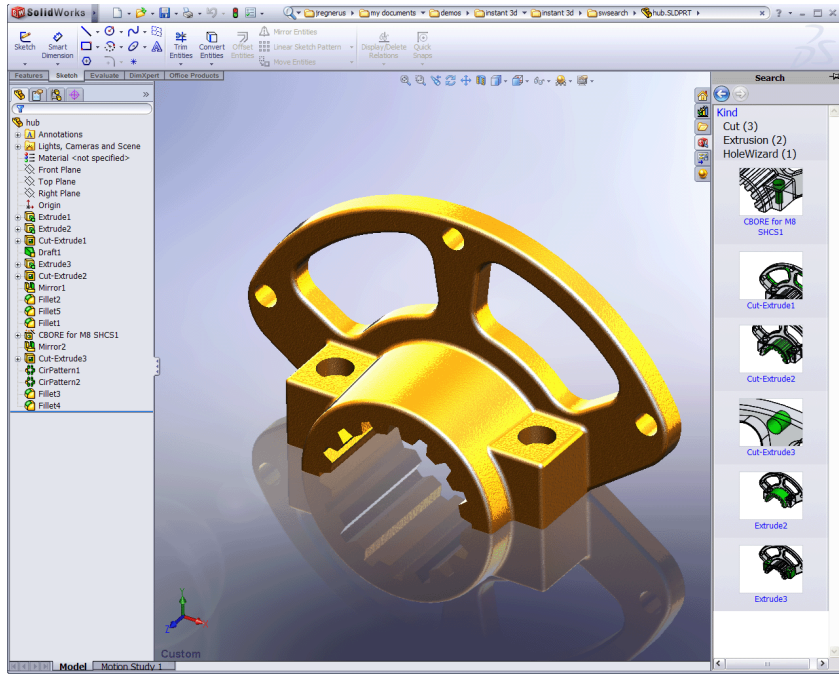


2D drawings can be extruded, revolved, lofted into 3D shapes



These operations mimic machining techniques

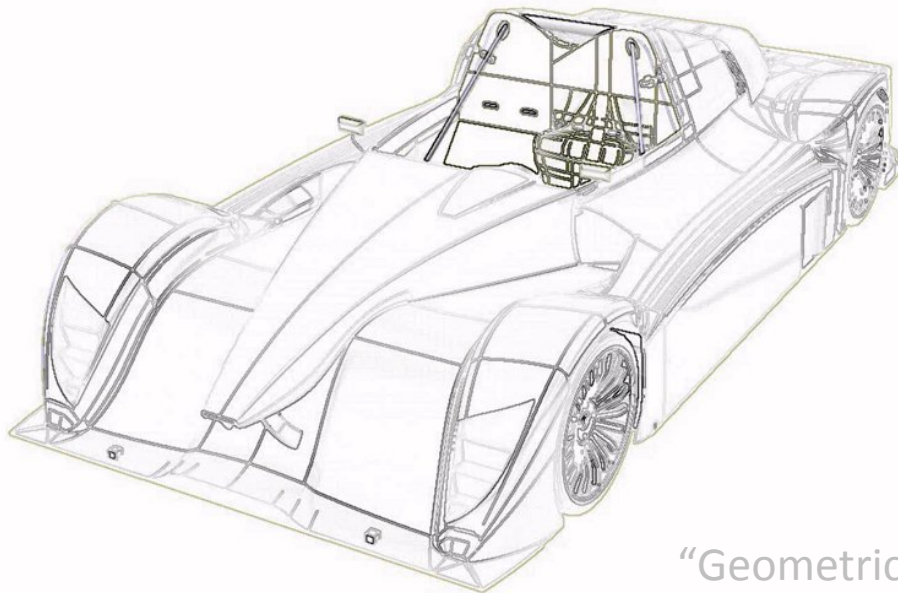




Gradual evolution
from drafting

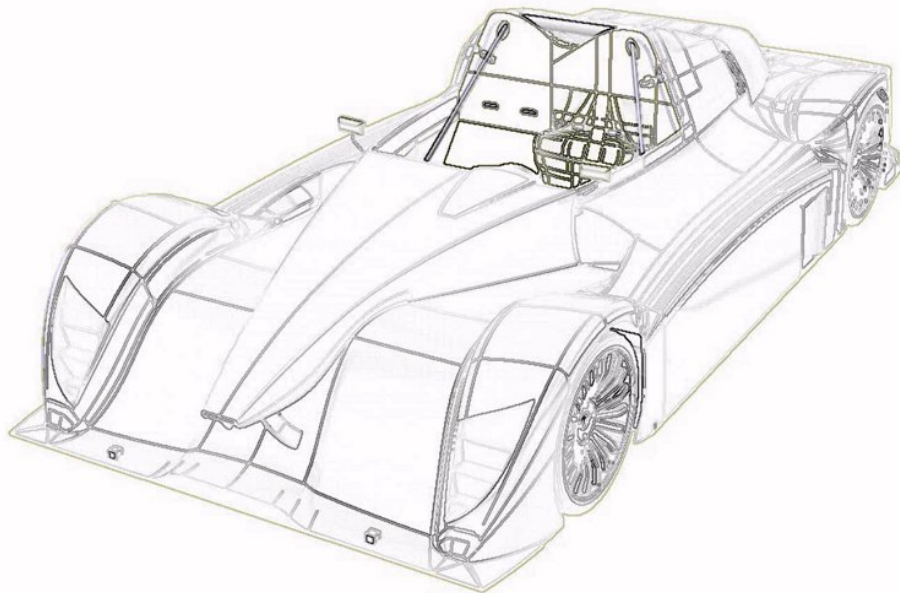
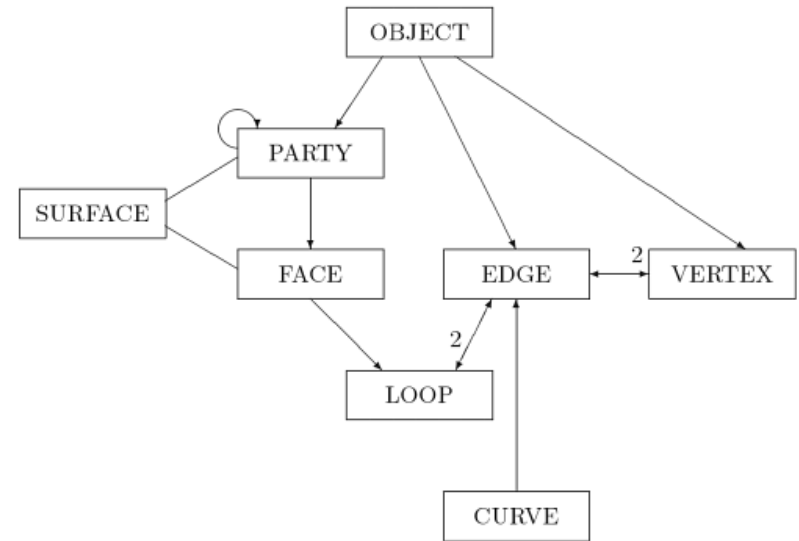
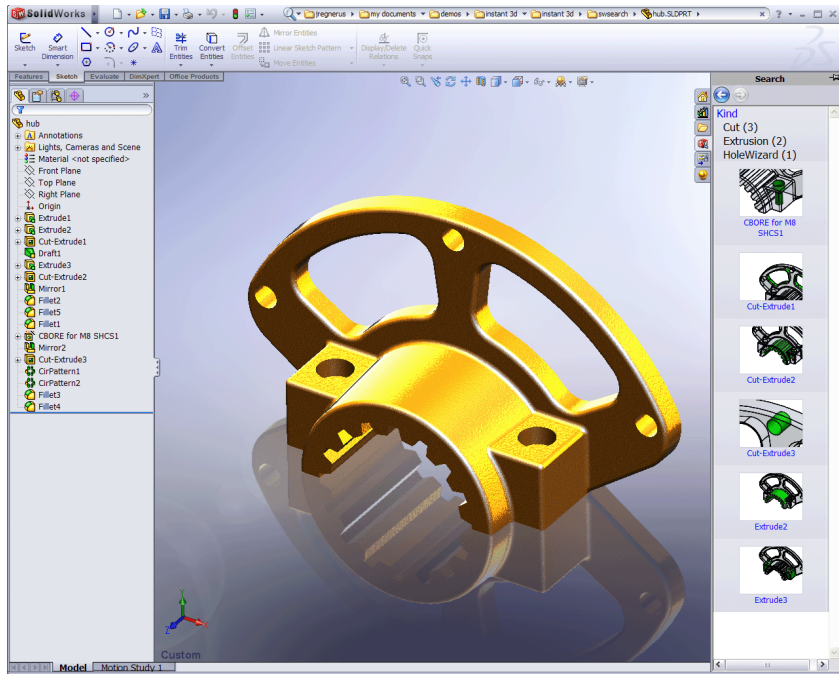
+ Limited rendering
hardware

= 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

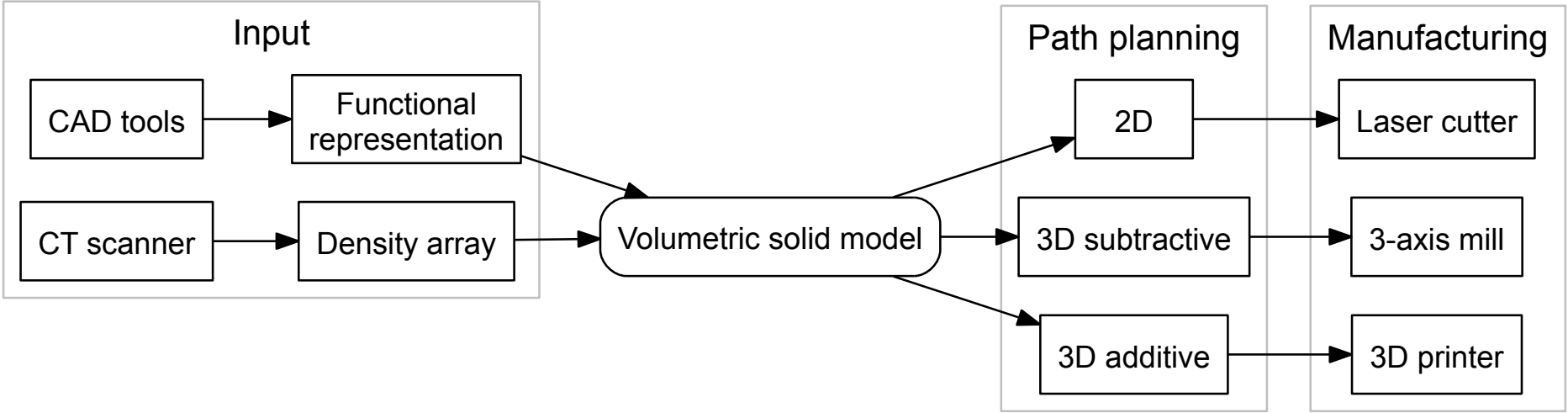
Solution

Hierarchical, volumetric solids

End-to-end CAD/CAM workflow

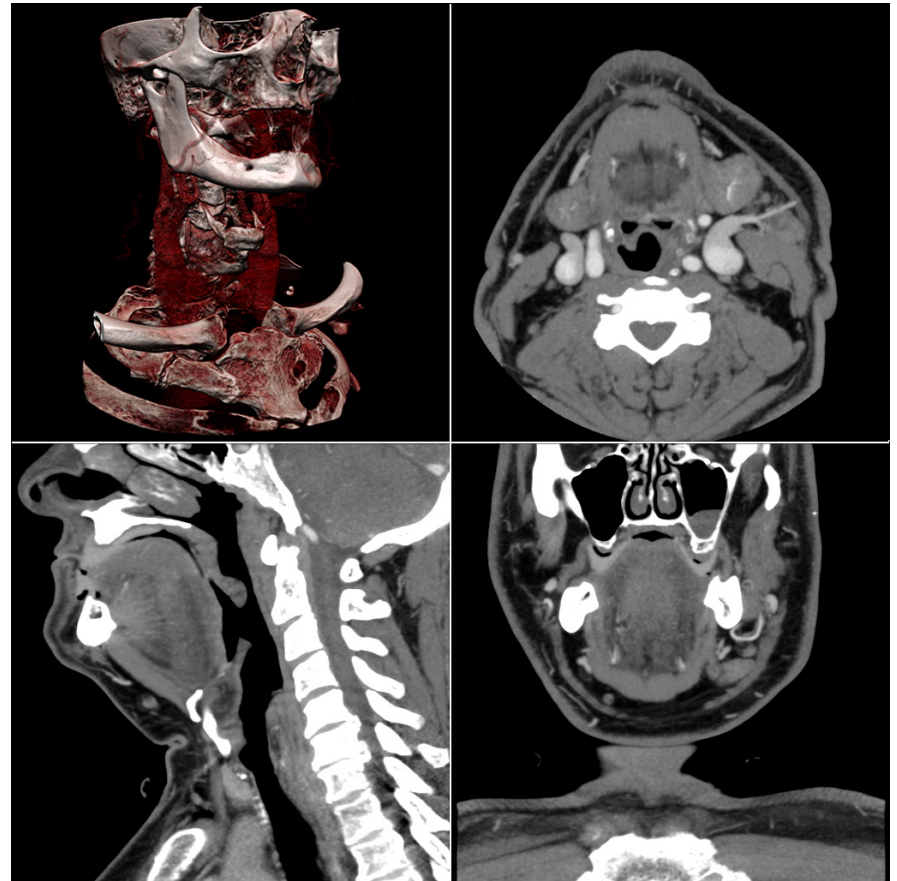


Matt Keeter



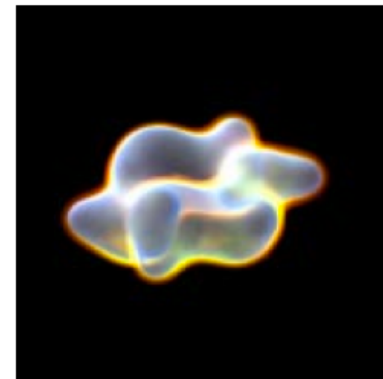
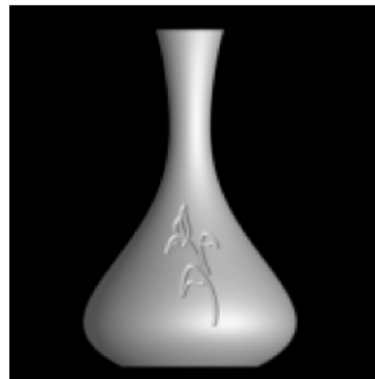
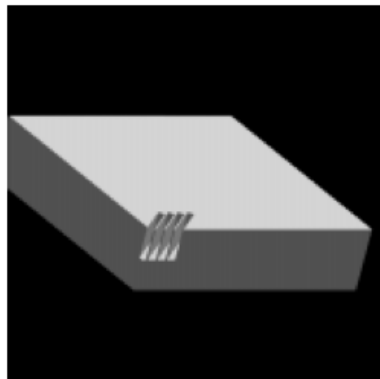
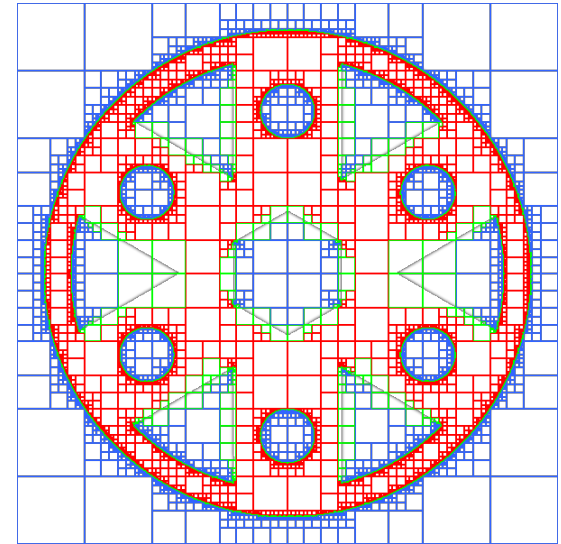
Lattice Representations

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



Hierarchical Representation

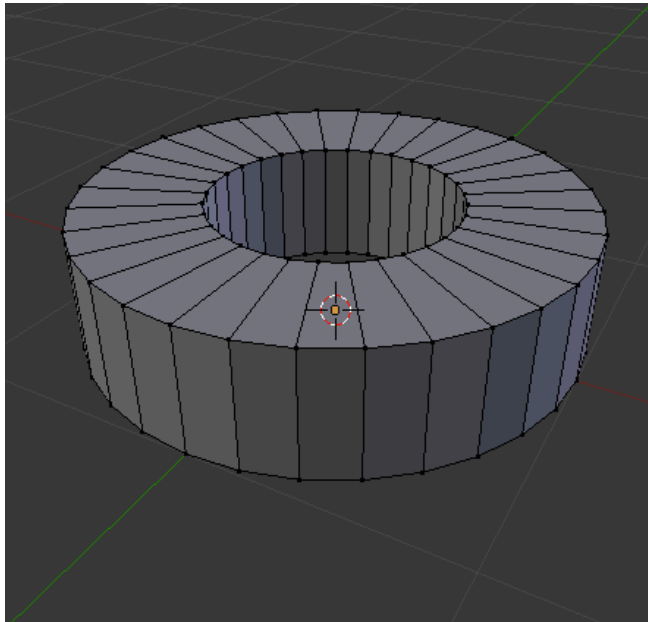
- Adaptively sampled distance fields (ASDFs)
- Hierarchical, space-efficient volumetric representation



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

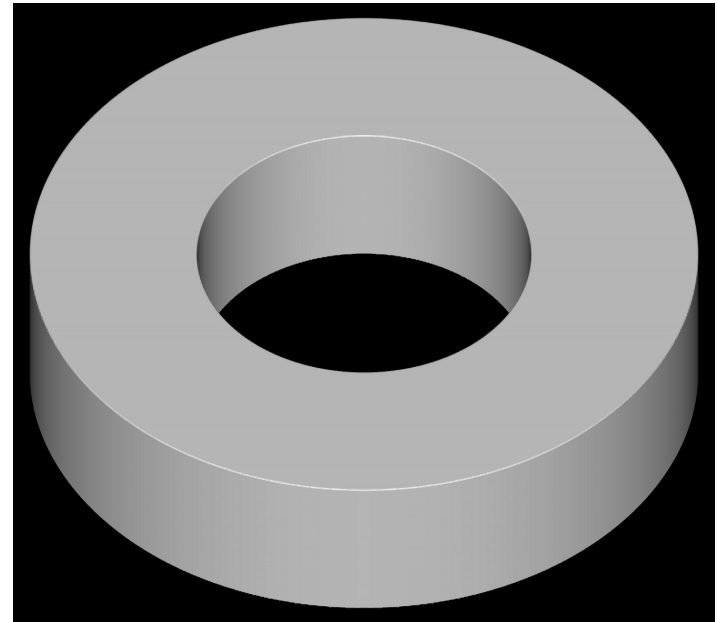
CAD without B-Reps

Boundary Representation



128 vertices, 256 edges, 128 faces

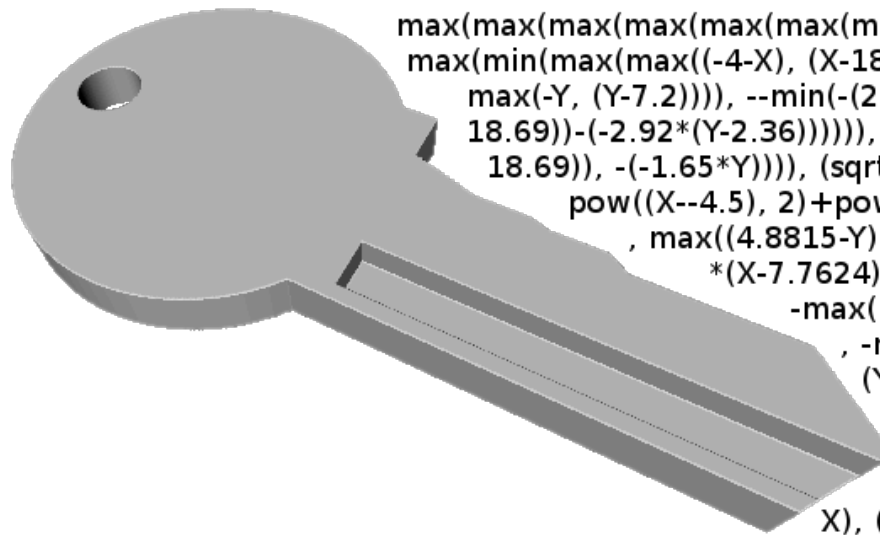
Functional Representation



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

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

CAD without B-Reps

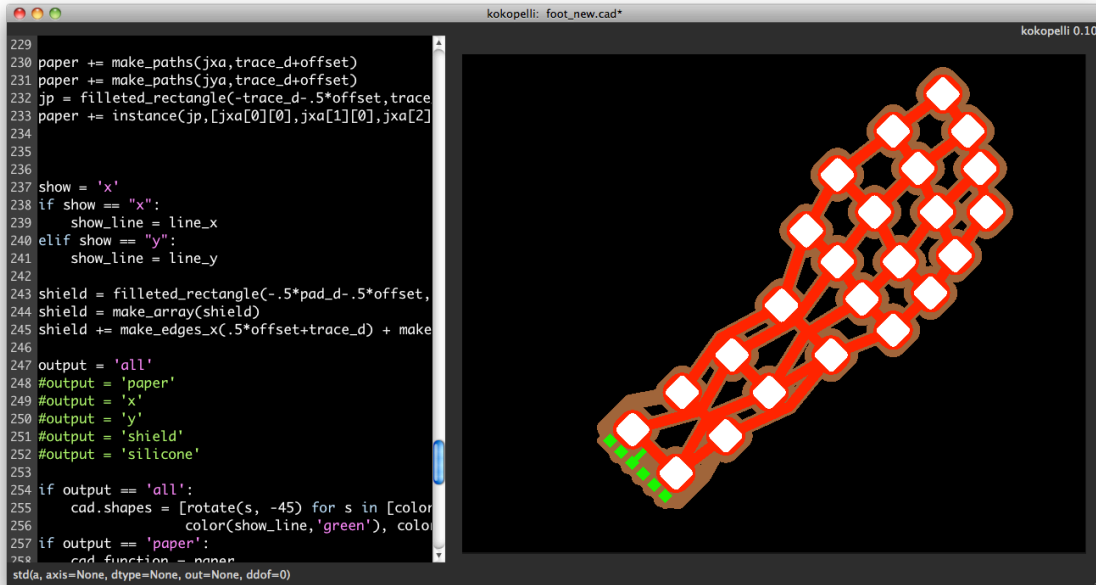


```
max(max(max(max(max(max(max(max(max(max(max(max(max(min (max(
max(min(max(max((-4-X), (X-18.69)), max(-Y, (Y-5.52))), max(max((-4-X),(X-5.59)),
max(-Y, (Y-7.2))), --min(-(2.92*(Y-5.52)), min((-3.16*(X-18.69)), ((3.16*(X-
18.69))-(-2.92*(Y-2.36))))), --min(((2.13*(X-17.04))-(1.65*Y)), min((-2.13*(X-
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])
```

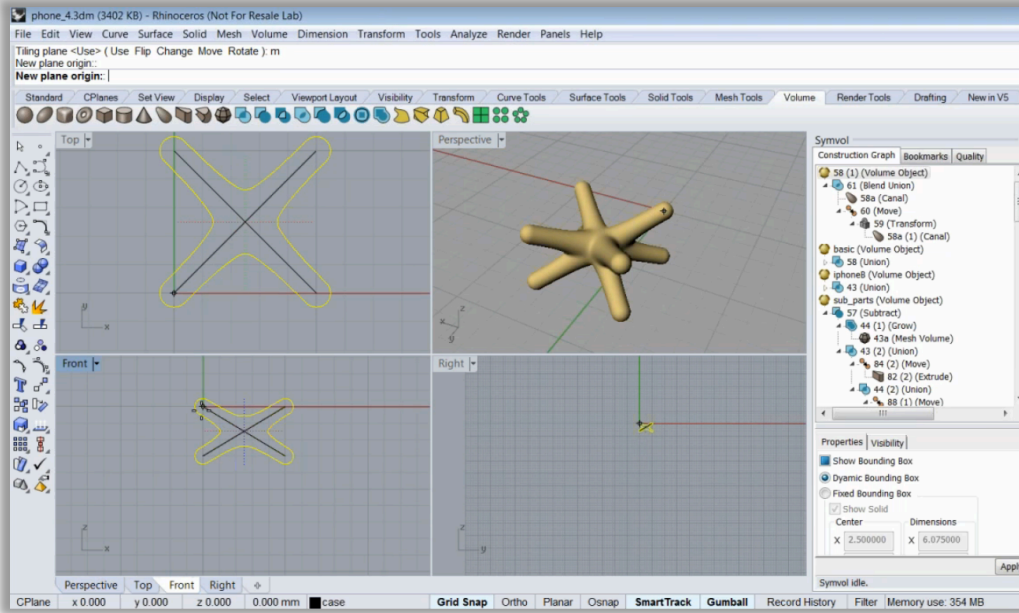
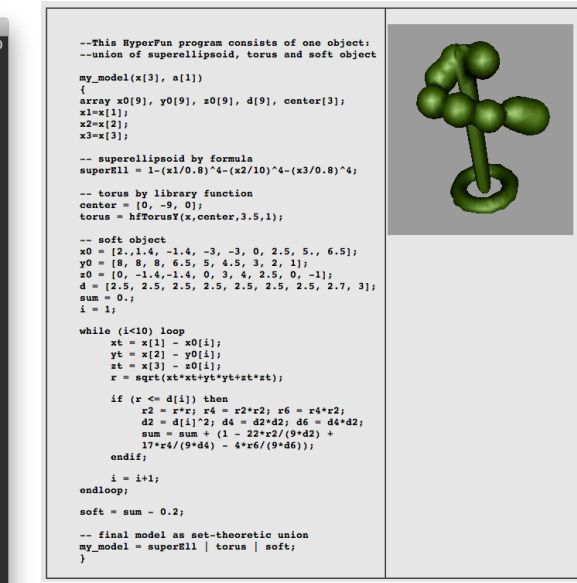
TSA master key

Will Langford & Matt Keeter, 2012

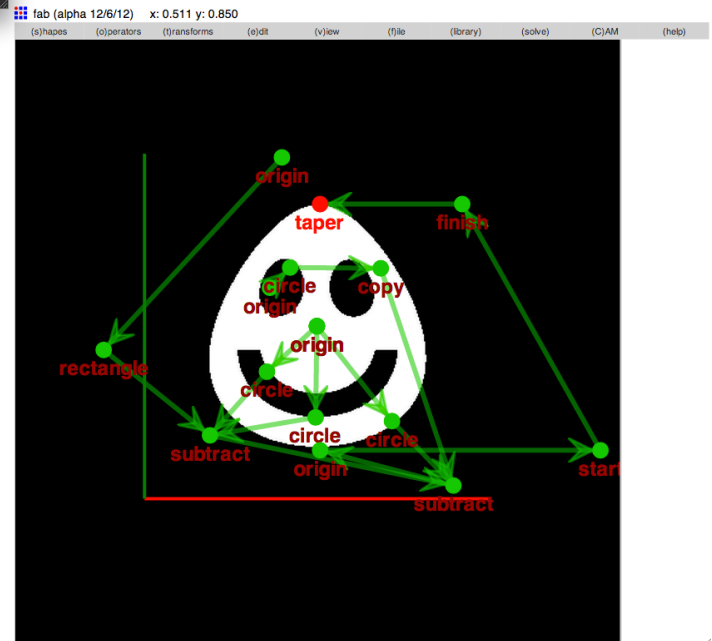
kokopelli (Matt Keeter)



Hyperfun (DMG)



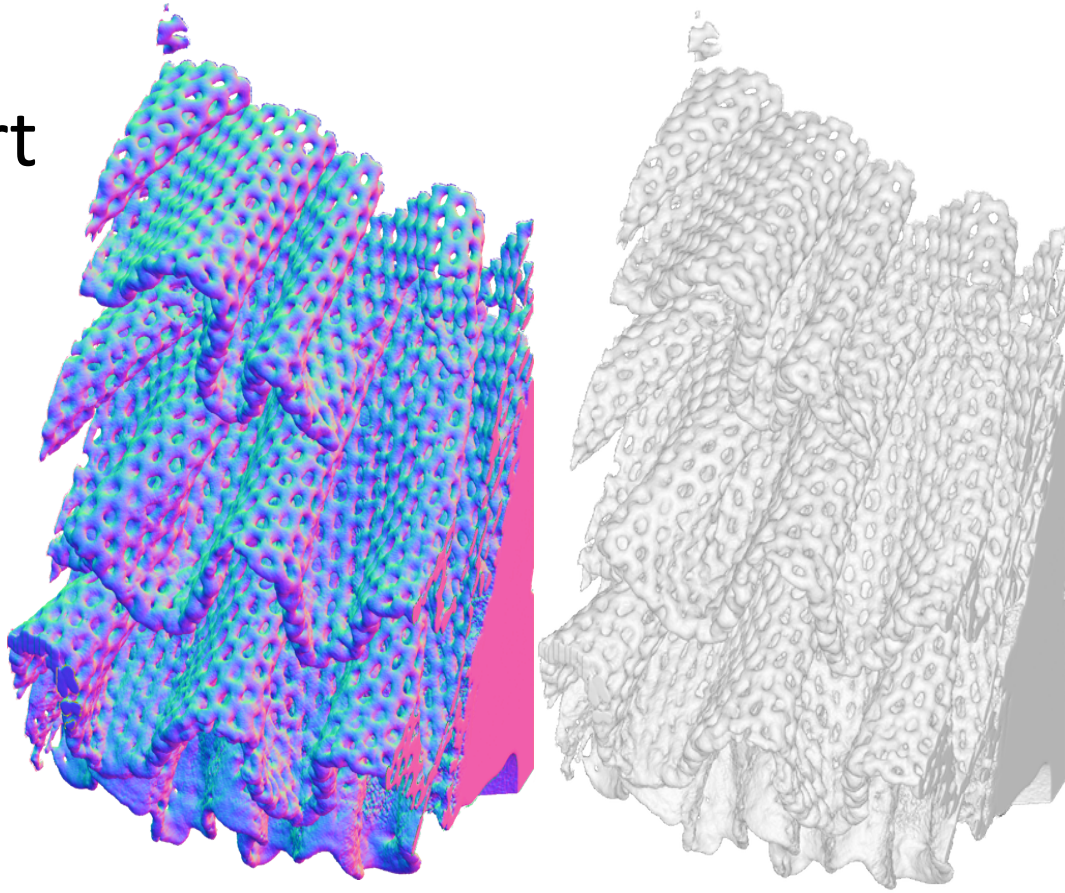
Symvol™ for Rhino (Uformia)



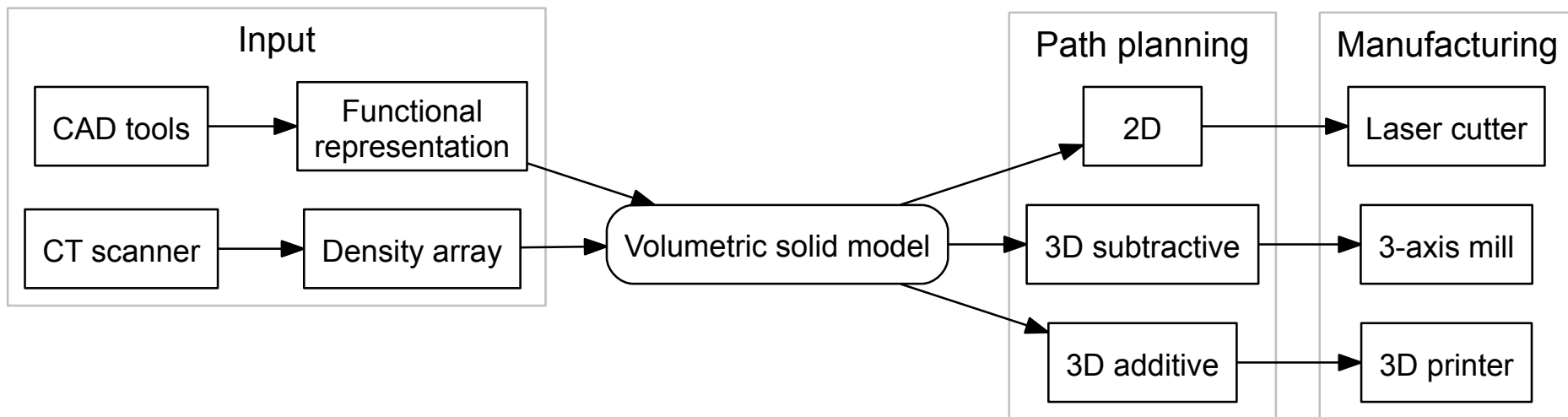
fabserver (Neil Gershenfeld)

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

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