Exploring Visualizations

An Overview of a Seminar in 3D Modeling and Printing

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Summer 2015

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3D Modeling Workshop

During the 2014-15 Year, I ran a workshop meant to introduce faculty, grads, and undergrads to 3D modeling and 3D printing.

- The Goal of the Workshop: To Make the participants able to design their own ideas and print them.
- One session, 1-2 hours a week
- Ran in a workshop manner - Not lecture
- Projects (ideally) take a single workshop, but many went for longer
- Used Rhino 5 for Windows (30 license school lab $975)
- Local company, owned by an alumnus, let us use his Makerbot Replicator 2 at cost of material

This Talk's Goals

The Goal of this talk is to give you an outline for a workshop you want to run.

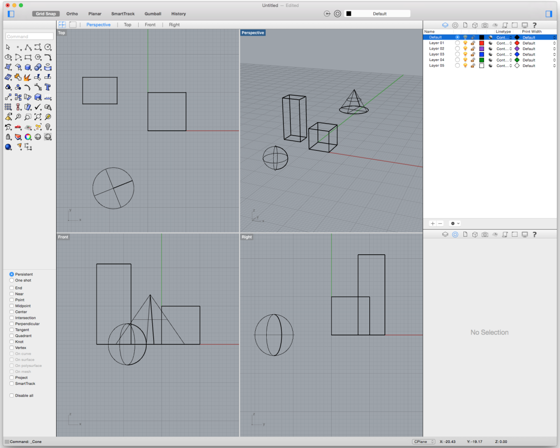
Or to let you get some ideas of things you want to make yourself.

Let everyone realize how useful customizable 3D models can be for a mathematician in research or teaching.

The beginning of the workshop focused on users becoming familiar with the GUI and basic creation tools available to them.

- Understanding how the viewports work and rotating/panning them
- Placing objects: Points, lines, etc
- Working in a digital 3D environment
- This is a long process - About half a semester
- The following projects were designed to make the user comfortable in this new world

GUI


Untitled — Edited
Grid Snap
Ortho
Planar
SmartTrack
Gumball
History
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Tangent
Quadrant
Knot
Vertex
On curve
On surface
On polysurface
On mesh
Project
SmartTrack
Disable all
Name
Linetype
Print Width
Layer 01
Layer 02
Layer 03
Layer 04
Layer 05
No Selection
Command: _Cone
CPlane
X: -20.43
Y: -19.17
Z: 0.00

Castle - Day 1

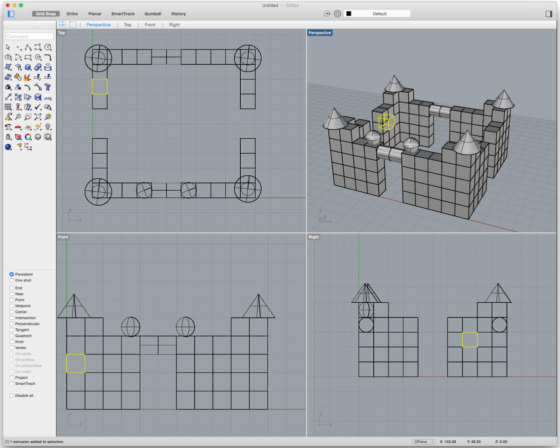
The first project was not meant to be printed. Commands they learn:

- Create cubes, spheres, cones, cylinders, etc
- Copy and Paste
- Move

Directions: Build a *SWEET* Castle with the shapes you can now create.

Main skill they acquire: Intuition about 3D space they are working in

Castle - Day 1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Point
Midpoint
Center
Intersection
Perpendicular
Tangent
Quadrant
Knot
Vertex
On curve
On surface
On polysurface
On mesh
Project
SmartTrack
Disable all
1 extrusion added to selection.
CPlane
X: 133.08
Y: 48.30
Z: 0.00

Commands they learn:

- Boolean operations: Difference, Intersection, Union
- Rotate

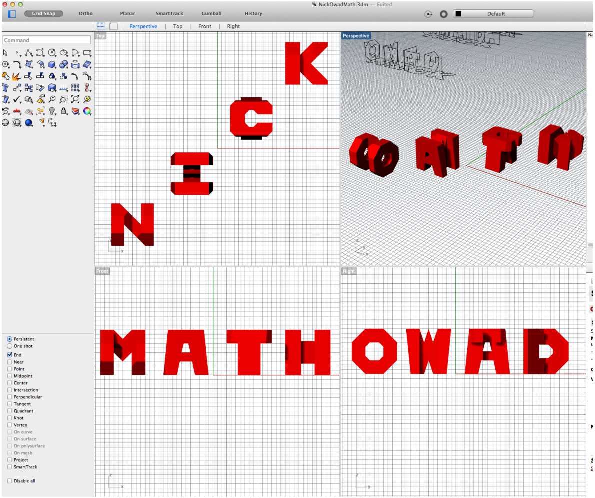
Direction 1: Build a rectangluar prism that has a square hole, circle hole, and triangle hole (all the "same" size).

Direction 2: Build a single object that can pass through each hole and fill it completely. (Hint: This is possible.)

Part two of this project:

Directions: Pick 3 words of the same length, n, and "do the same thing." That is, create n blocks which have 3 letters on each block so that from the 3 directions they are all visible.

Failure - Much to complicated for the second project.


NickOwadMath.3dm — Edited
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On polysurface
On mesh
Project
SmartTrack
Disable all

Extrusions - Replacement Day 2

What to do instead:

Extrustions!

Commands they learn:

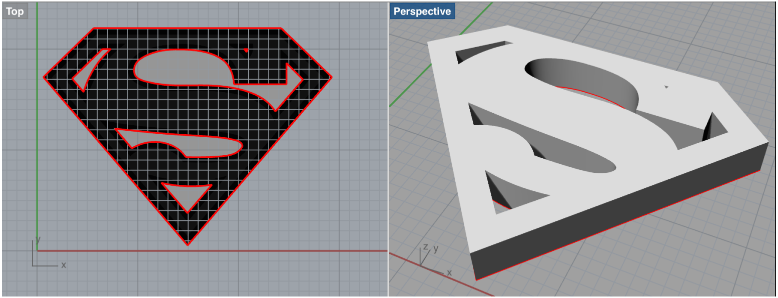
- Placing bitmaps
- Extrude curve
- Trim
- Join

Directions: Come to class with a picture (Symbol, Emblem, etc.) Draw the outline with interpolated curves.

MUST BE A SINGLE CLOSED CURVE!

Extrude it.

Extrusions - Replacement Day 2



Exploring Visualizations

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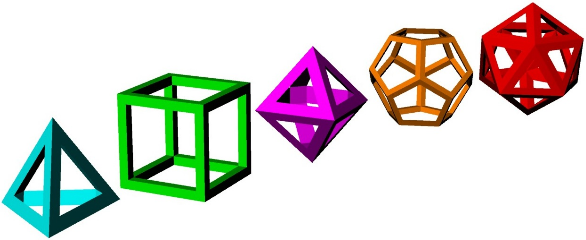
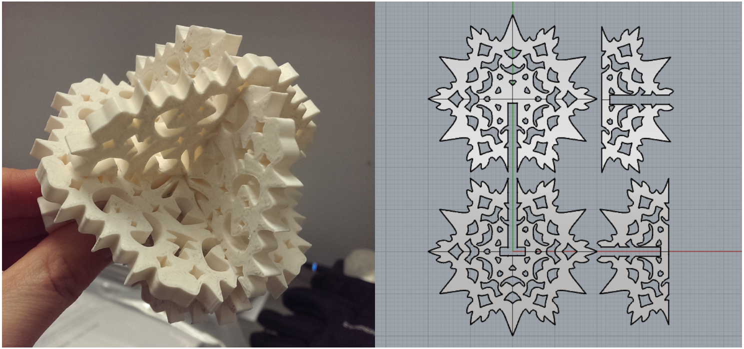
Platonic Solids

- Commands: Array (polar), 3D rotate, Osnap
- Lots of ways to actually build the models: from faces, vertices, etc
- Spent a month just on these 5 shapes



Pumpkins and Snowflakes



Modeling with Python

Disclaimer: I am a novice programmer.

But I managed to get some nice results with a little help:

- Henry Segerman
- Google: Python Rhino tutorials
  One I used: vimeo.com/28619851
- Rhino.Python Programmer's Reference
  4.rhino3d.com/5/ironpython/index.html

This talk will be much more Rhino specific now.

Graphs

We will be building the graphs the same way most graphing applications do:

Plot a bunch of points and connect them.

Rhino uses nurbs (Non-Uniform Rational Basis Splines).

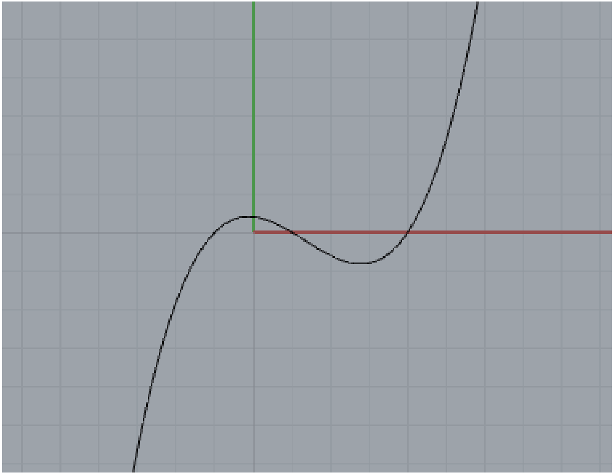
Fancy way to say: connect the points with polynomial curves so they are smooth.

Rhino command: AddInterpCurve

The code from Henry that we use:

```
import sys, os
import rhinoscriptsyntax as rhino
from math import *

def draw_parametric_curve(function, param_range, num_points = 64):
  curve_pts = []
  for i in range(num_points):
    x = param_range[0] + (param_range[1] - param_range[0]) * float(i)/float(num_
    point = function(x)
    if point != None:
      curve_pts.append( rhino.AddPoint(point) )
  out = rhino.AddInterpCurve(curve_pts)
  rhino.DeleteObjects(curve_pts)
  return out


def cubic(x):
        return [x,.1*(x+1)*(x-1)*(x-4),0]


draw_parametric_curve(cubic, (-5,10))
```

The result:



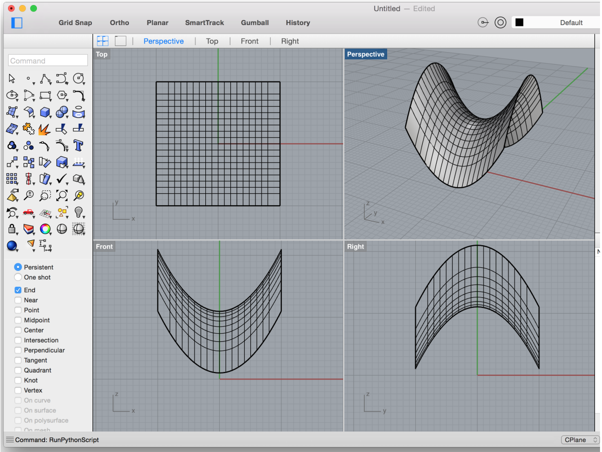
Graphs

For surfaces, graph:

$$z = \frac{1}{10}\left(x^2 - y^2\right)$$

```
import rhinoscriptsyntax as rs

count = 21,21

def s(x,y):
        return (.1*((x-10)**2-(y-10)**2)+11)


points = []

for i in range(count[0]):

    for j in range(count[1]):

        pt = i-10, j-10, s(i,j)

        points.append(pt)

rs.AddSrfPtGrid(count, points)
```

Surface result:



Lets talk about approximating

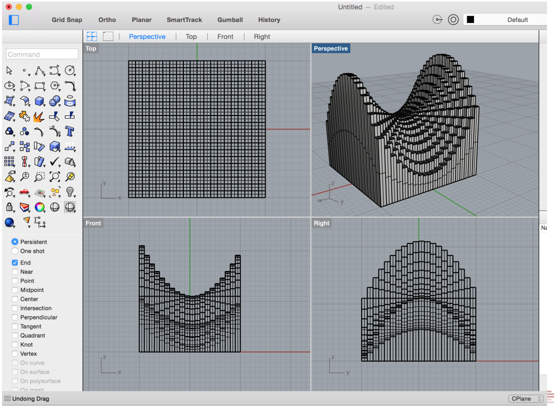
$$\int_{x=-10}^{10}\int_{y=-10}^{10}\frac{1}{10}\left(x^2-y^2\right)\,\mathrm{d}y\mathrm{d}x$$

```
import rhinoscriptsyntax as rs
from math import*

def s(x,y):
        return (.1*((x-10)**2-(y-10)**2)+11)


count = 20,20

for i in range(count[0]):
        for j in range(count[1]):
                rs.AddBox([ [i-10,j-10,0], [i-9,j-10,0],
                        [i-9,j-9,0], [i-10,j-9,0],
                        [i-10,j-10,s(i,j)], [i-9,j-10,s(i,j)],
                        [i-9,j-9,s(i,j)], [i-10,j-9,s(i,j)] ] )
```

Integration

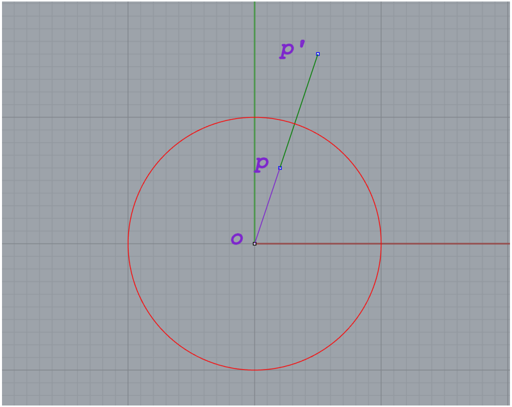
Lets talk about approximating

$$\int_{x=-10}^{10} \int_{y=-10}^{10} \frac{1}{10}\left(x^2 - y^2\right) \mathrm{d}y\mathrm{d}x$$



Hyperbolic Geometry

Given a point P, we can invert it about a circle of radius r and obtain a new point P' by the simple relation $OP \times OP' = r^2$.

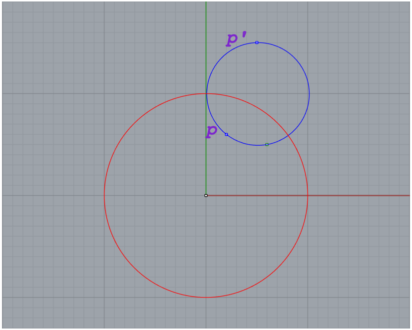


Inverting a point about a circle


```
import rhinoscriptsyntax as rs
from math import*

basecircle = rs.GetObject("Select circle to invert about"

if rs.IsCircle(basecircle):

    radius = rs.CircleRadius(basecircle)

    center = rs.CircleCenterPoint(basecircle)

point = rs.GetObject("Select point to invert")

if rs.IsPoint(point):

        dist = rs.Distance( point, center)

a = (radius / dist ) ** 2


rs.ScaleObject( point, center, (a,a,a), True )
```

Inverting a point about a circle

Lines in hyperbolic geometry are circles that intersect our red circle perpendicularly. For every two points there is a unique line that passes through them. To draw the line, we just invert one of the two given points, and draw the unique circle formed by those three points.



Thank you!