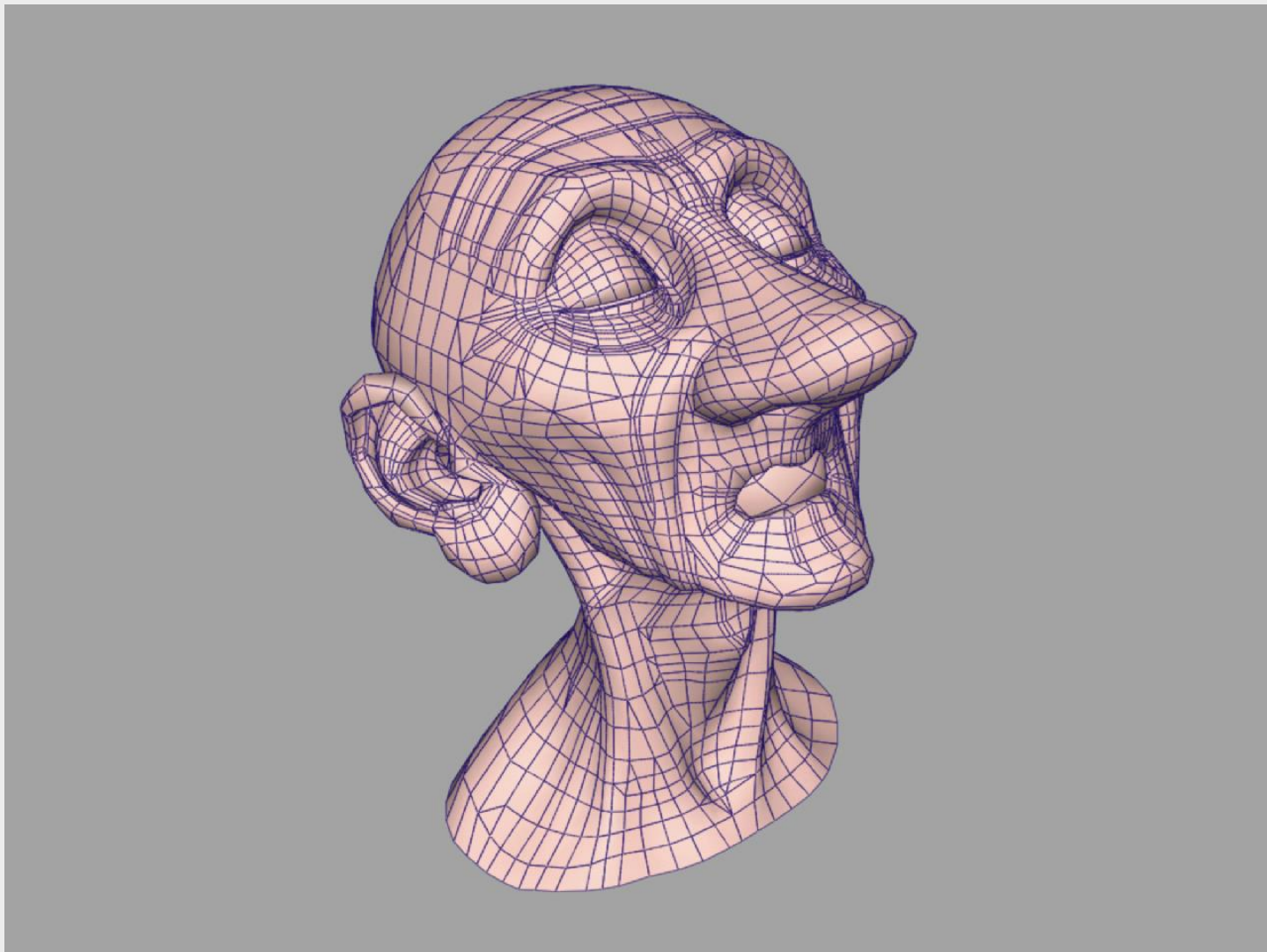


OBJECT REPRESENTATION

GERI'S GAME



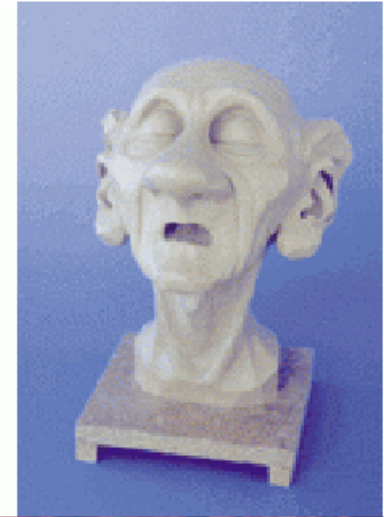
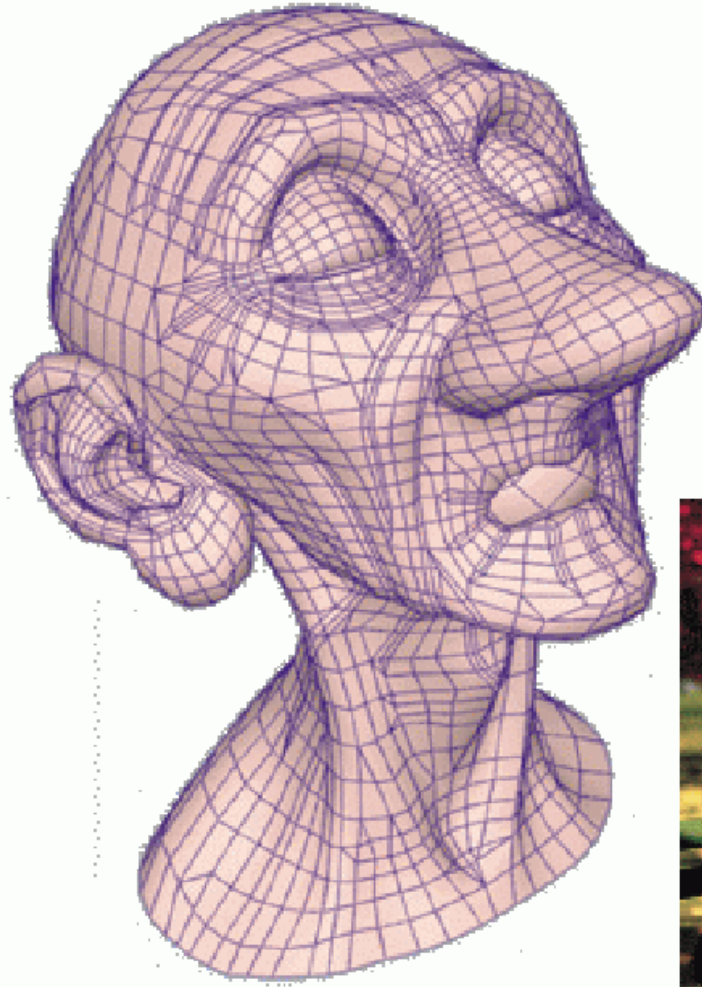
GERI'S GAME

PIXAR (1997)

SUBDIVISION
SURFACES

POLHEMUS
3D SCAN

OVER 700
CONTROLS



QUICK TEST #1

DESCRIBE THE PICTURE

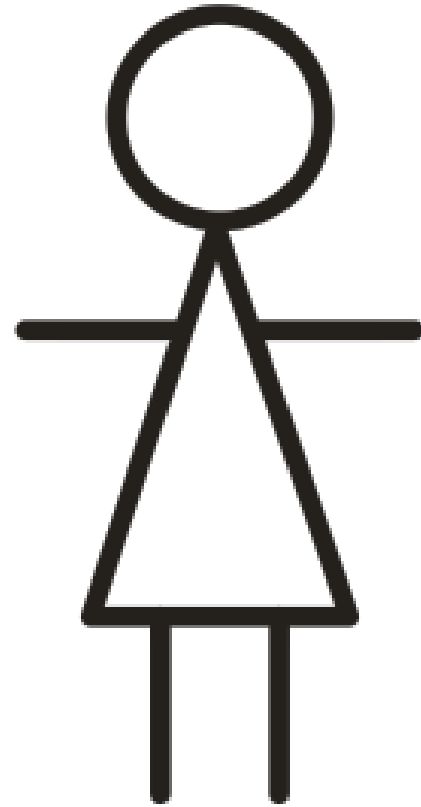
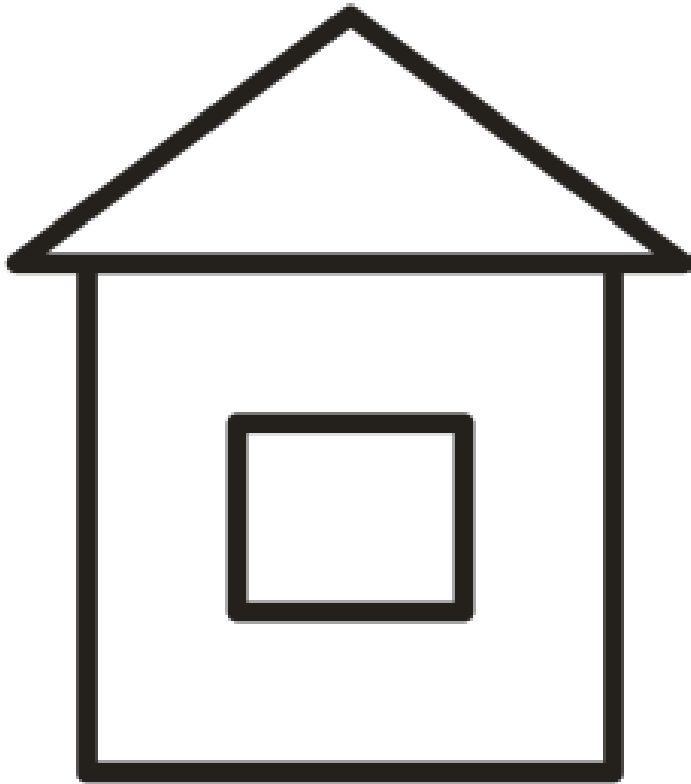


QUICK TEST #2

DESCRIBE THE PICTURE



DESCRIBE THE PICTURE



SEMANTIC VS. NUMERIC

HUMANS - SEMANTIC REPRESENTATION

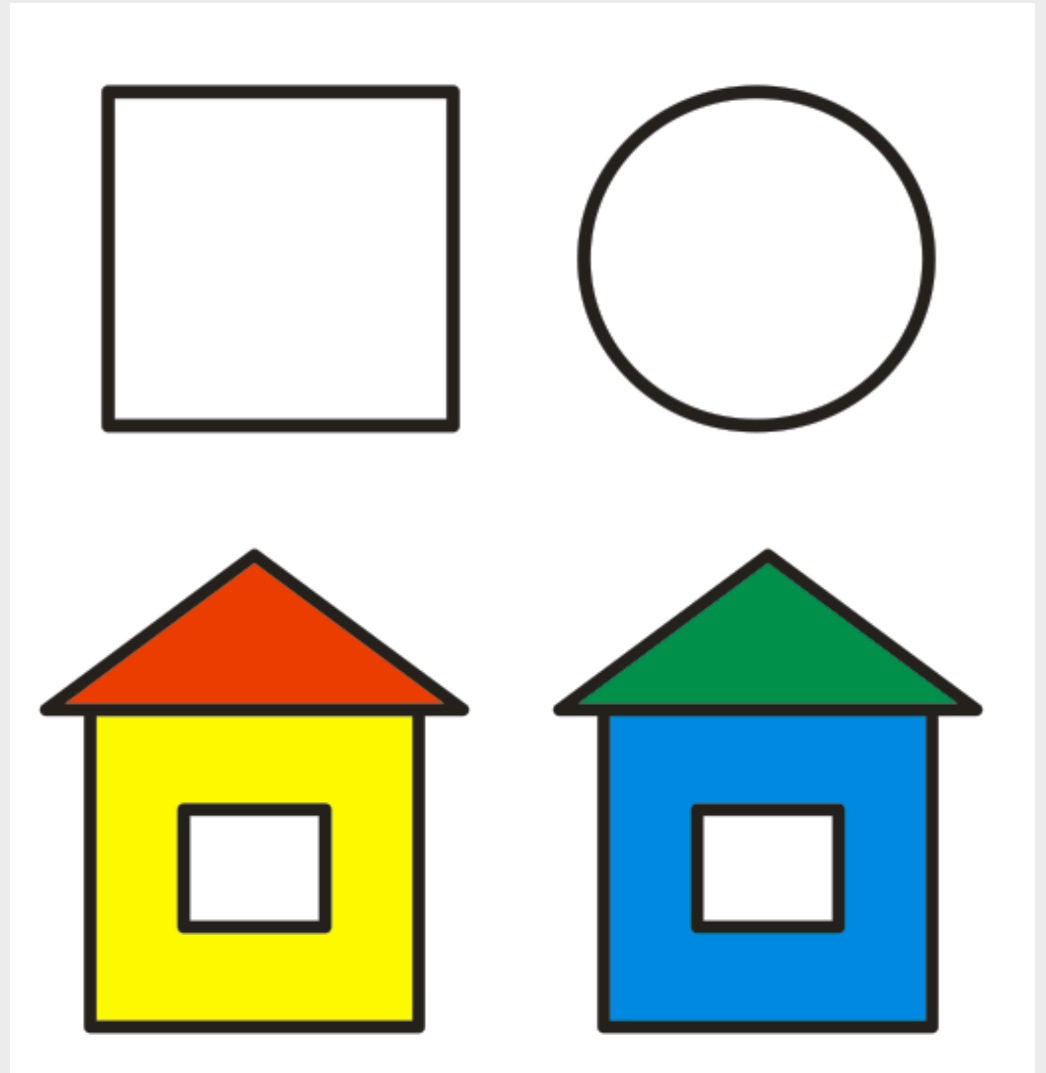
concepts, notions, meanings, emotions...
imprecise, ambiguous

COMPUTERS - NUMERIC REPRESENTATION

exact, mathematical, straightforward

DETAILED REPRESENTATION

WHAT OBJECT
PROPERTIES
ARE THERE?



OBJECT PROPERTIES - ADVANCED

PHYSICAL OBJECT PROPERTIES

mass, stiffness, elasticity

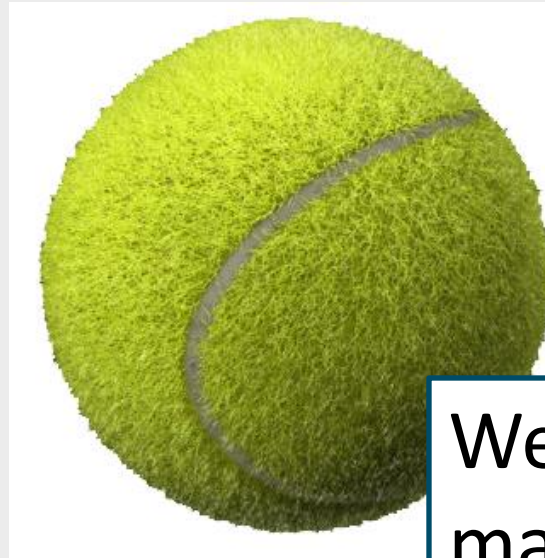
MATERIAL PROPERTIES

shininess, roughness

light behavior

friction

etc.



We'll deal with materials later

OBJECT DEFINITION

GEOMETRY

plus model transformation (local \rightarrow global)

MATERIAL

color, shininess, index of refraction

TEXTURE MAPPING

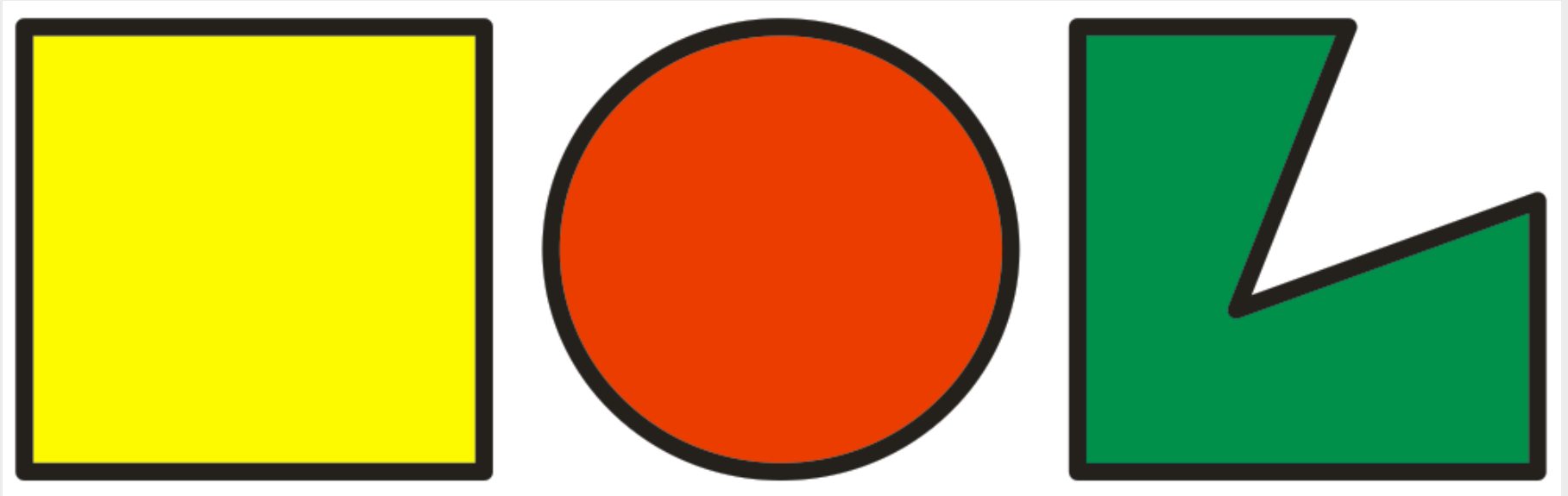
UV mapping, wrapping of texture around the object

BODY PROPERTIES

weight, elasticity...

2D OBJECTS

LET'S DEFINE THESE OBJECTS



2D OBJECTS

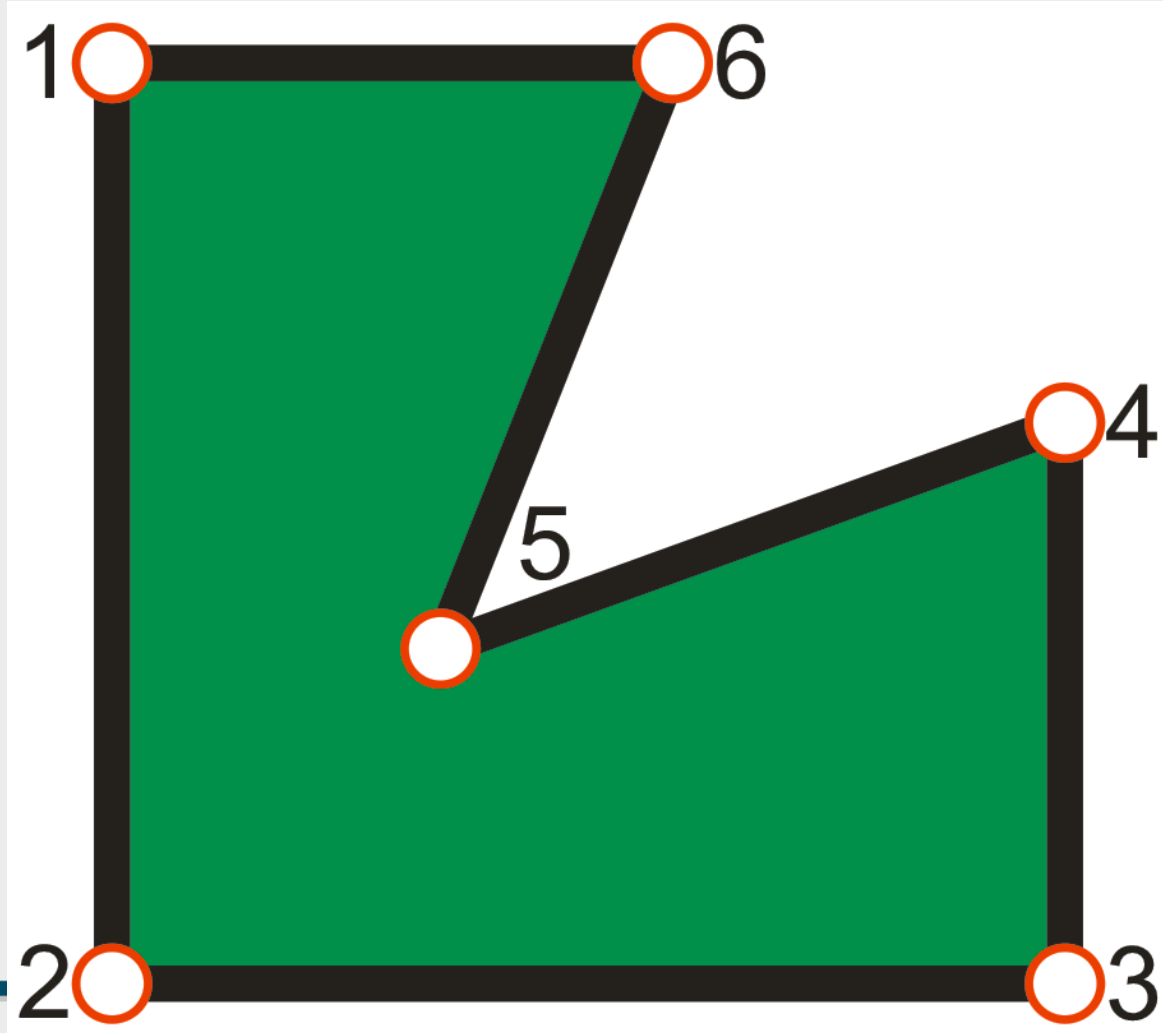
POLYGONS

CONTROL VERTICES

x,y coordinates
in order
CCW

EDGES

width
shape
style (solid,
dotted etc.)



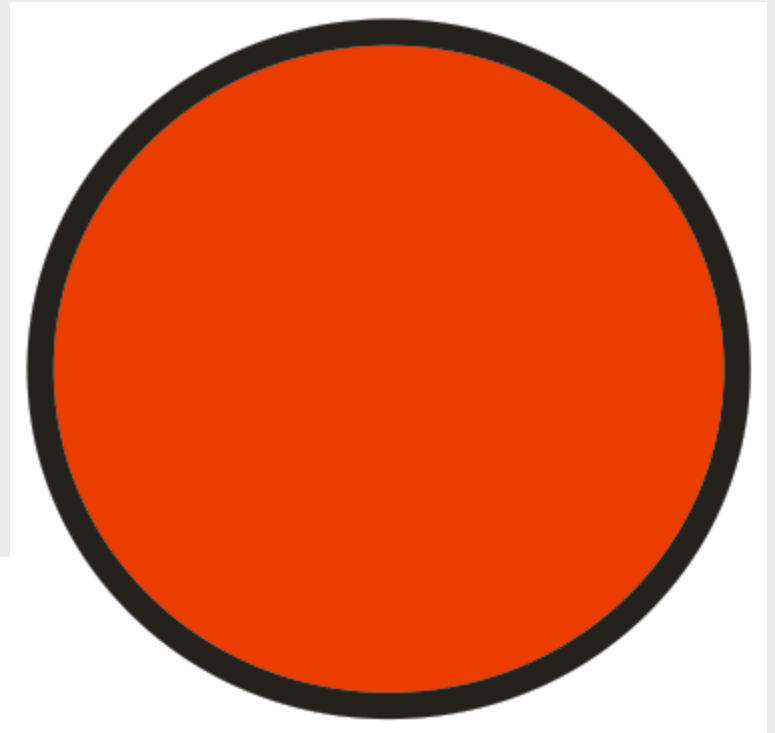
CURVES

PRIMITIVE SHAPES

Circle, Ellipse, ...

GENERAL SHAPES

Parametric curves



PARAMETRIC CURVES

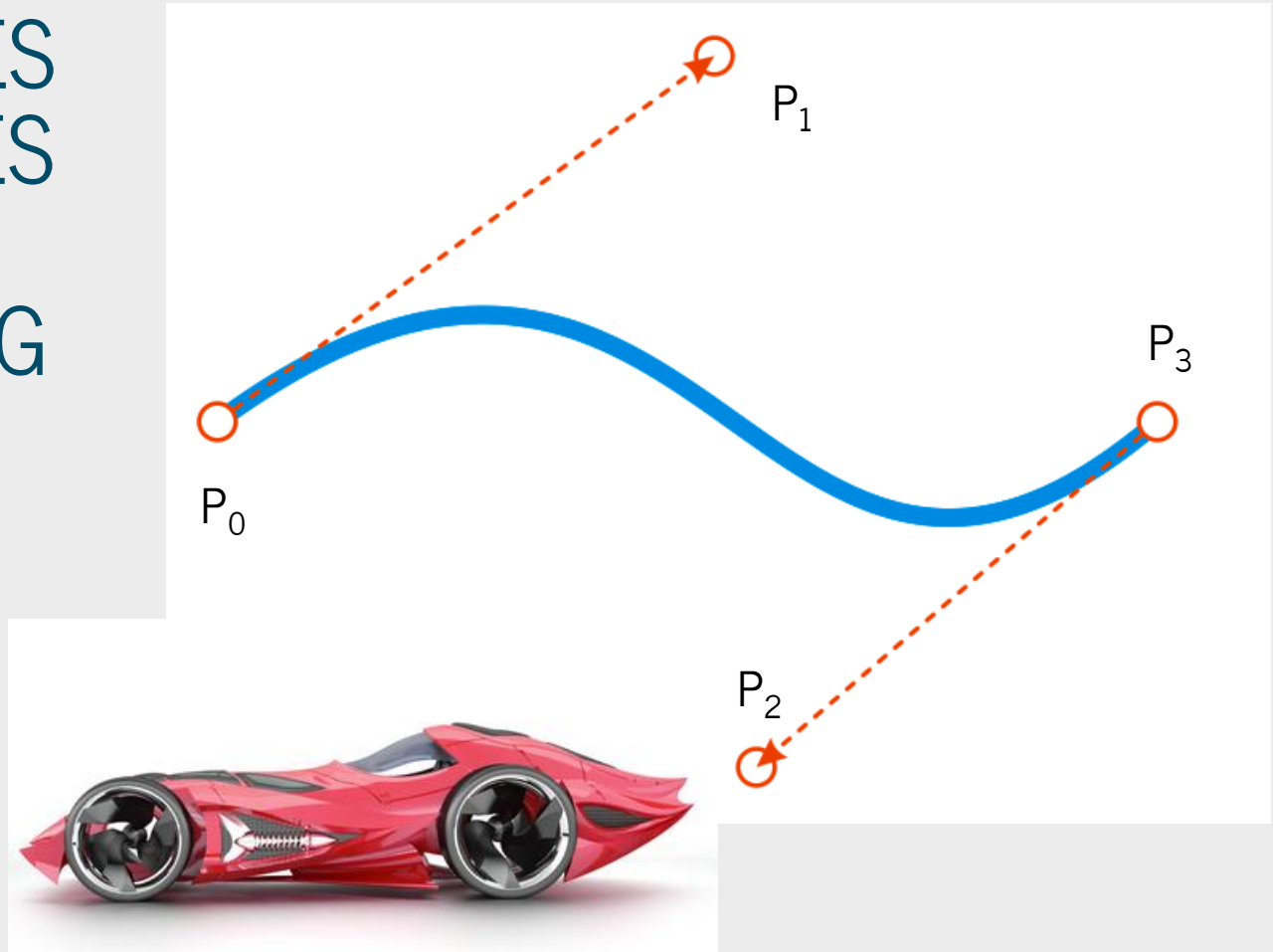
BEZIER CURVES
SPLINE CURVES

CAD MODELING

Cars

Shoes

Product design

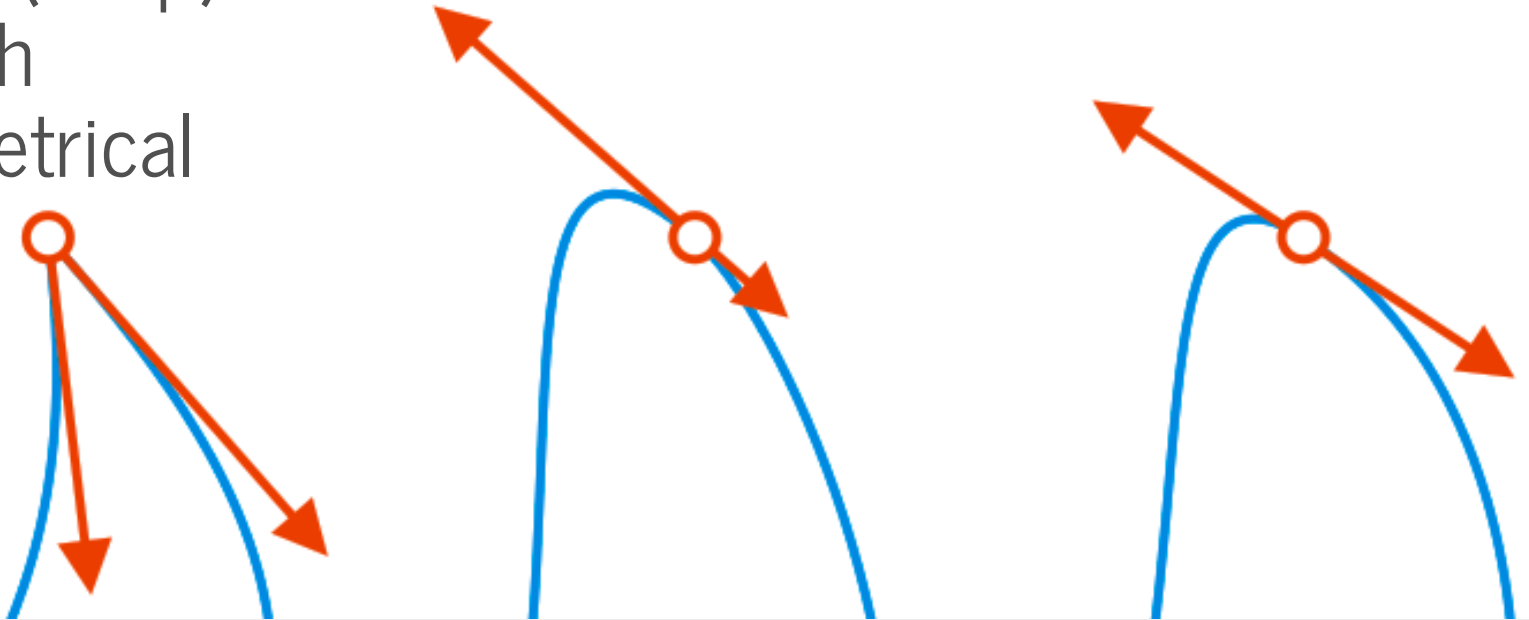


$$\mathbf{B}(t) = (1 - t)^3 \mathbf{P}_0 + 3(1 - t)^2 t \mathbf{P}_1 + 3(1 - t) t^2 \mathbf{P}_2 + t^3 \mathbf{P}_3, \quad t \in [0, 1].$$

INTERPOLATION PARAMETRIC CURVES

CONTROL VERTICES + TANGENT VECTORS

corner (cusp)
smooth
symmetrical



USUALLY CUBIC SPLINES - GOOD
MANIPULATION

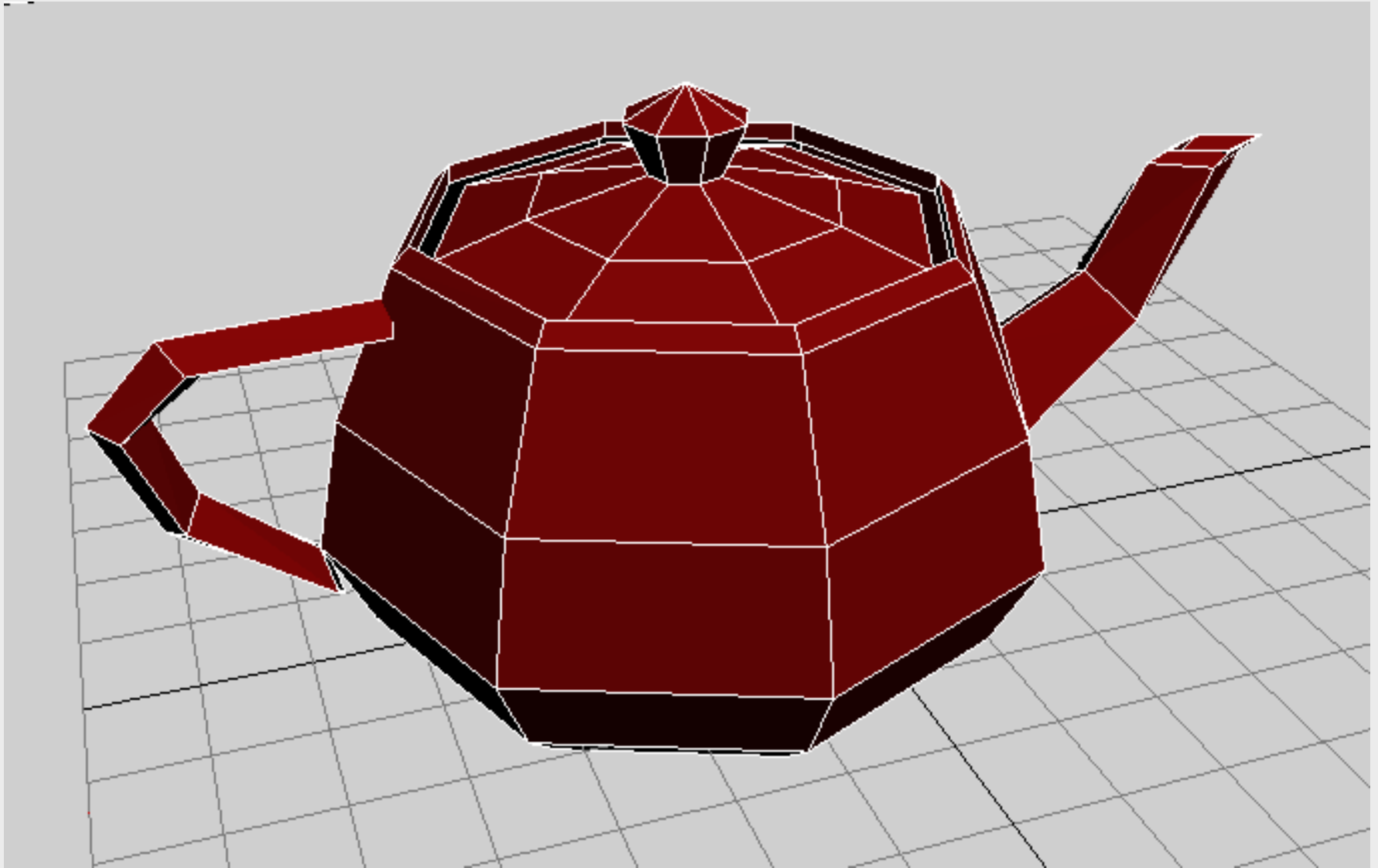
PARAMETRIC \rightarrow POLYGONAL



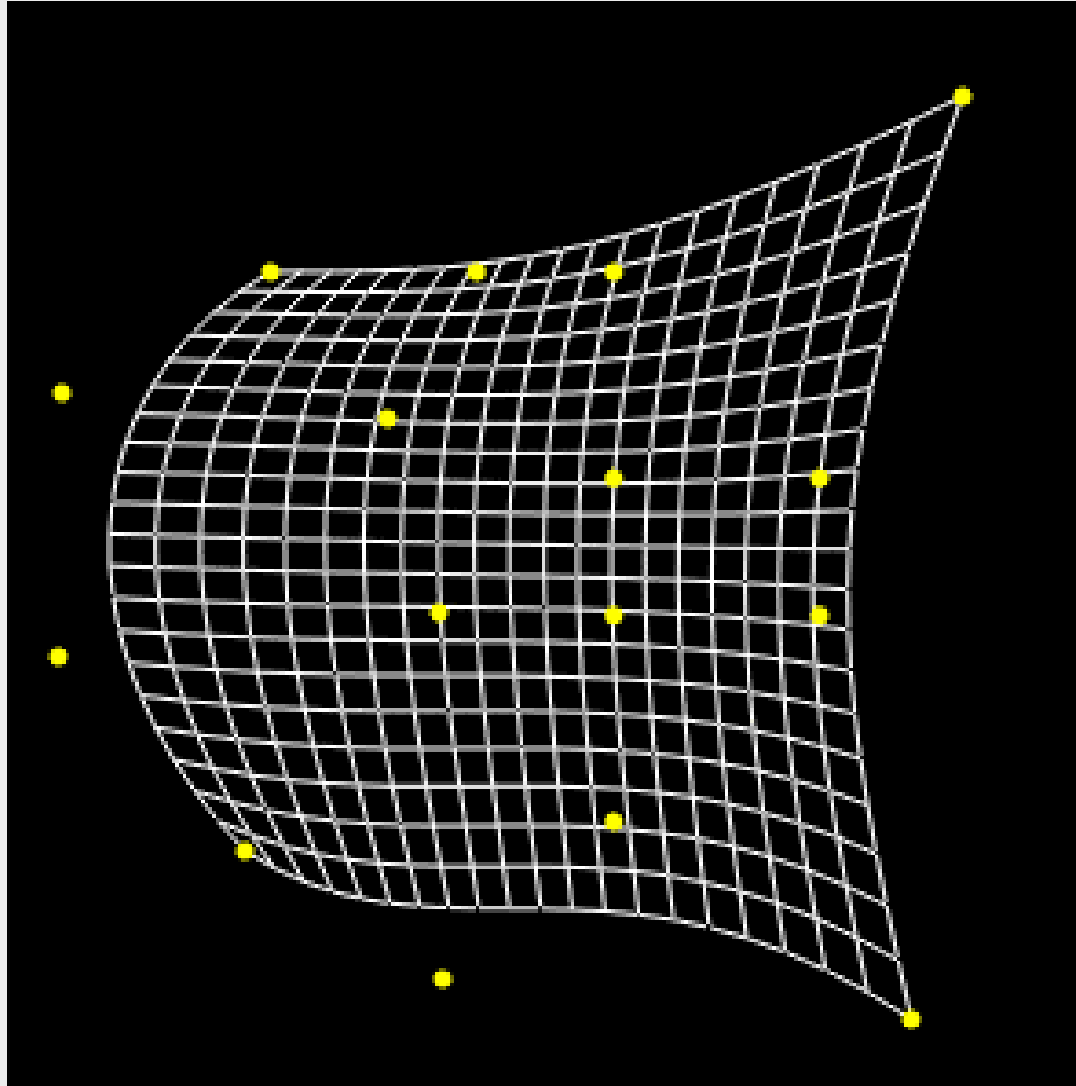
$$\mathbf{B}(t) = (1-t)^3\mathbf{P}_0 + 3(1-t)^2t\mathbf{P}_1 + 3(1-t)t^2\mathbf{P}_2 + t^3\mathbf{P}_3, \quad t \in [0, 1].$$

3D GEOMETRY

FROM 2D POLYGONS TO 3D POLYHEDRA



FROM 2D CURVES TO 3D SURFACES



BOUNDARY REPRESENTATION

ONLY THE SURFACE OF THE OBJECT

NO INFORMATION ABOUT THE INSIDES

POINT CLOUD

WIREFRAME

POLYGONAL MESH

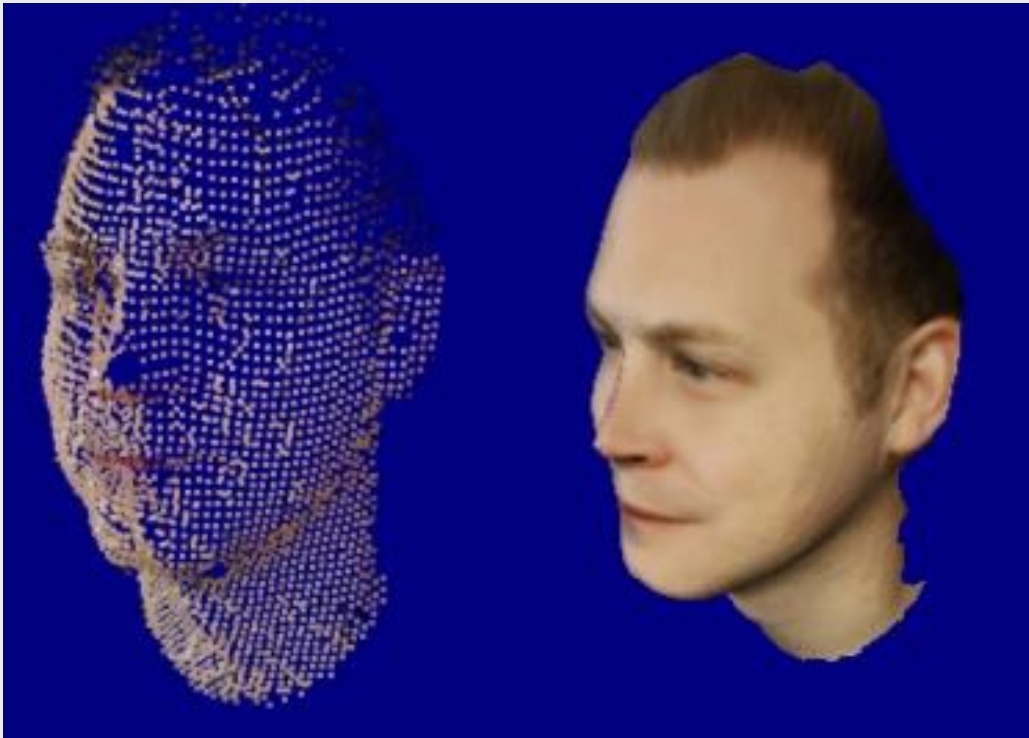
PARAMETRIC SURFACES

SUBDIVISION SURFACES

IMPLICIT SURFACES

POINT CLOUD

SET OF POINTS ON OBJECT SURFACE
USUALLY OBTAINED BY 3D SCANNING
CONNECTIVITY INFORMATION?

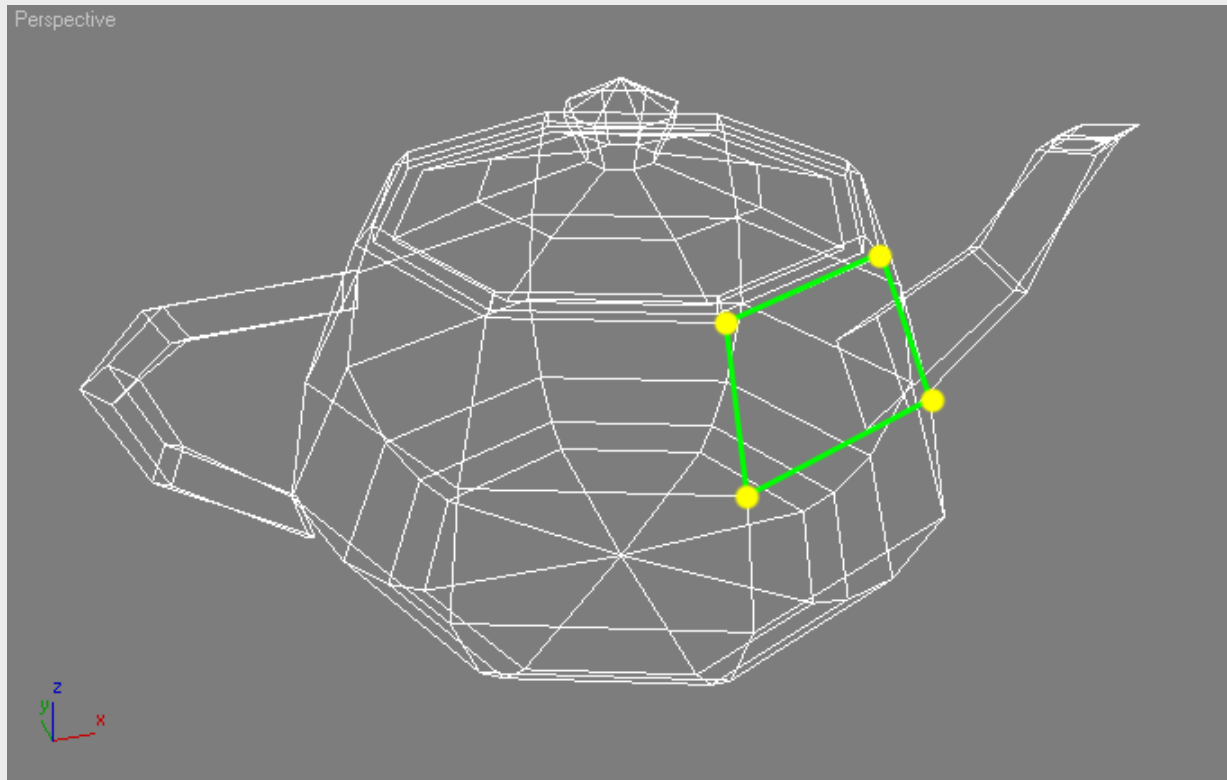


<http://www.photomodeler.com>

WIREFRAME

SET OF VERTICES
EDGES

$V(X,Y,Z)$
 $E(V_I, V_J)$



POLYGONAL REPRESENTATION

POLYGONAL
MESH

VERTICES

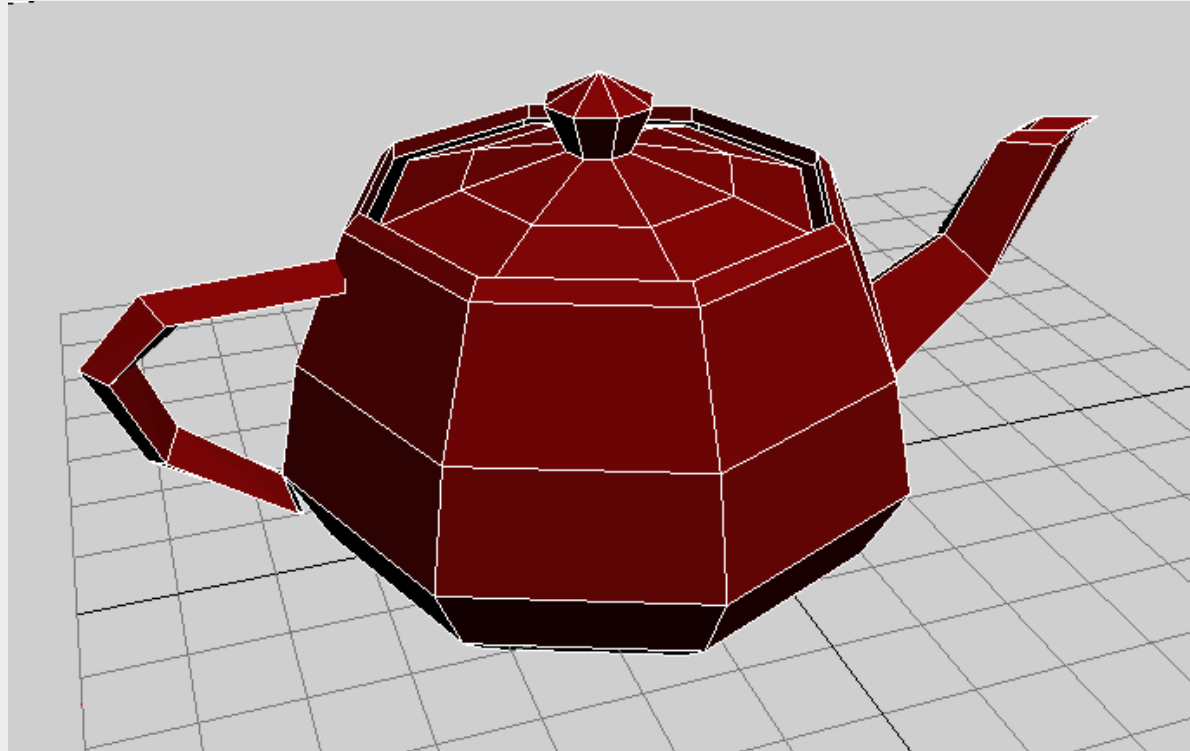
$V(x,y,z)$

FACES

$F(V_1, V_2, \dots V_n)$

(EDGES)

$E(V_i, V_j)$



PARAMETRIC SURFACES

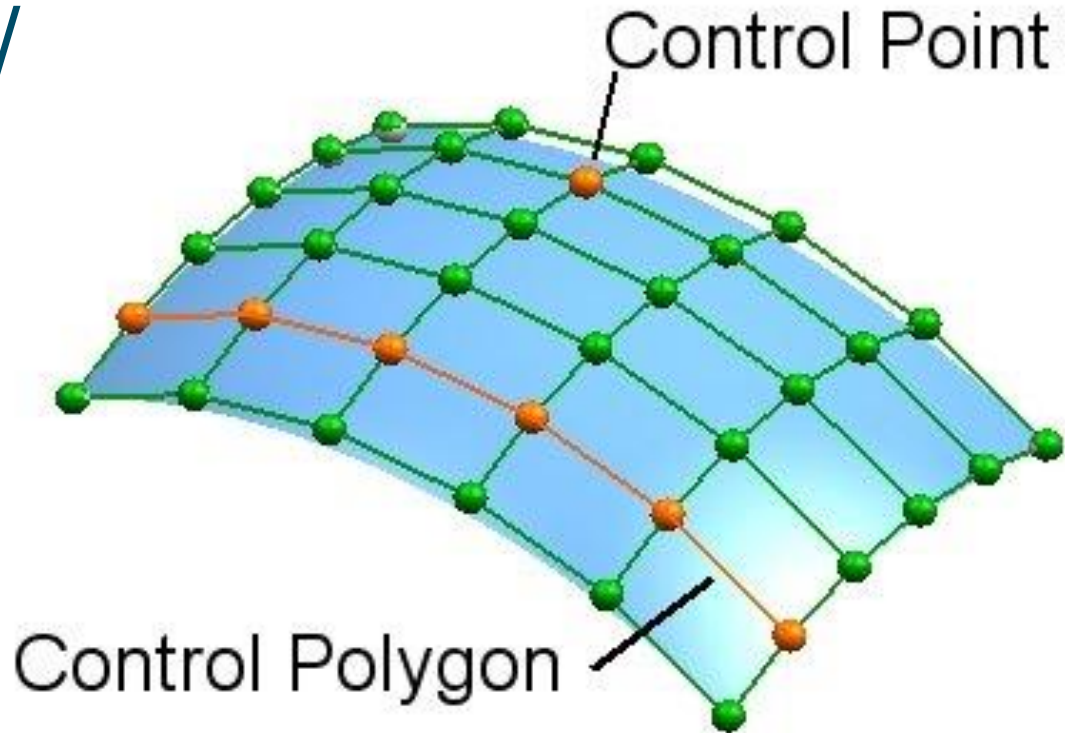
SMOOTH

3D GENERALIZATION OF PARAMETRIC CURVES

M * N CONTROL POINTS

PARAMETERS U,V

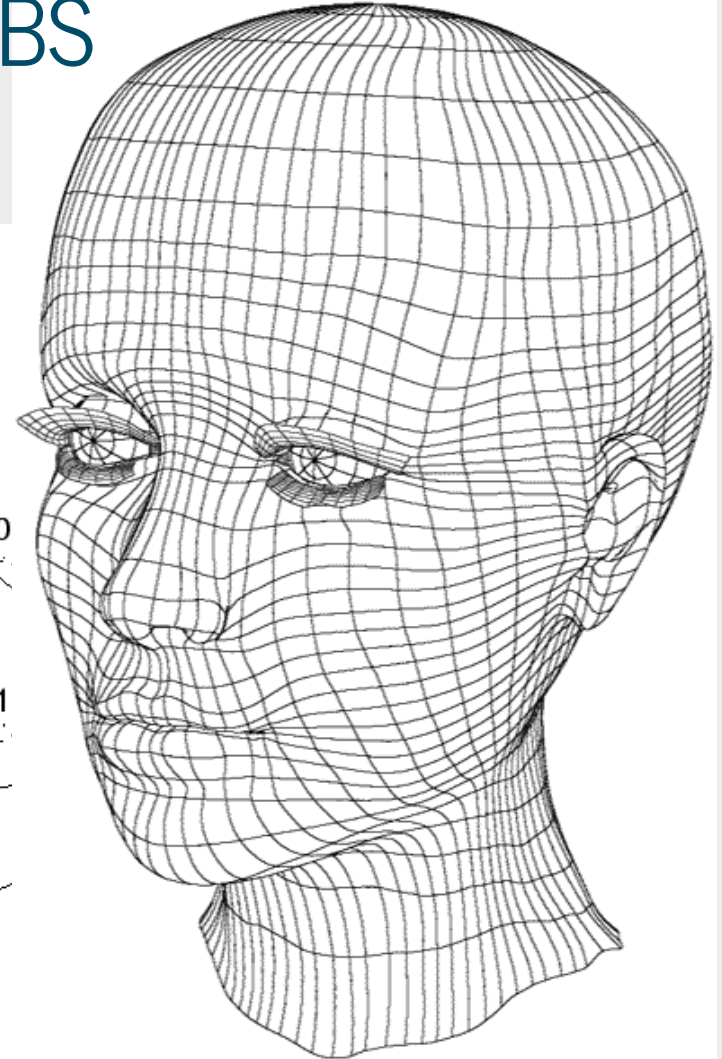
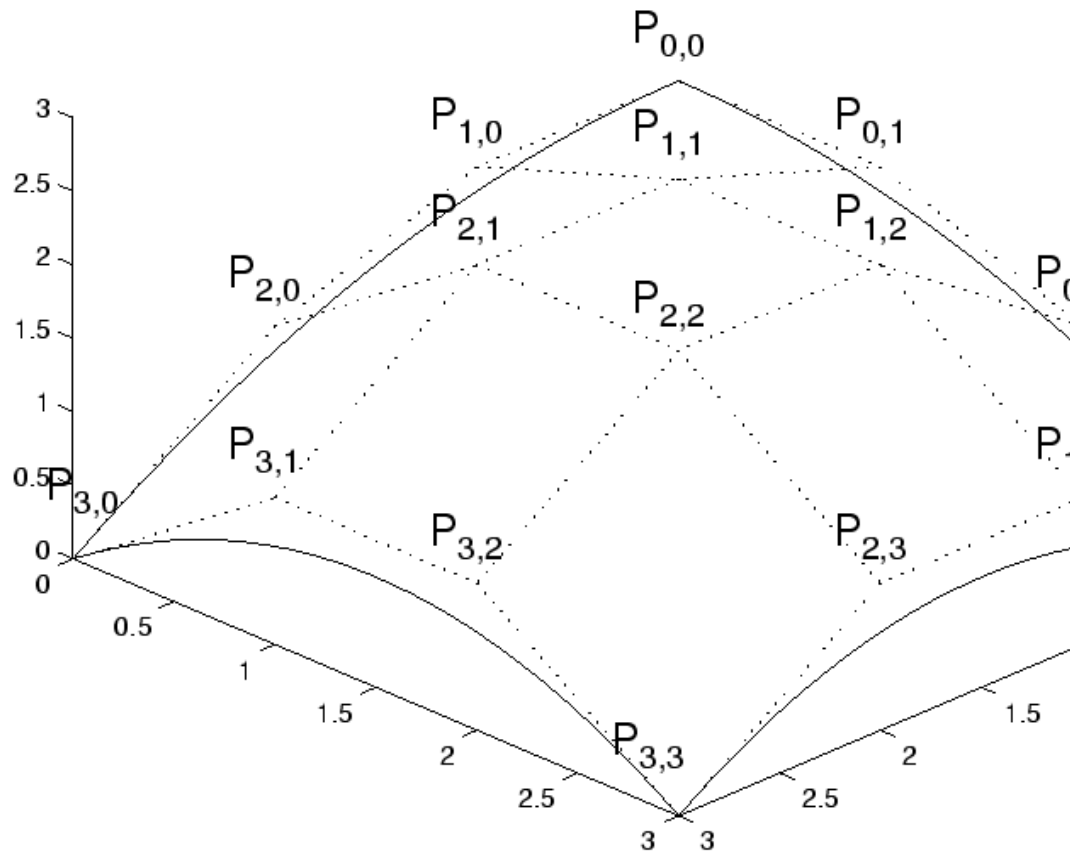
$$C(X,Y,Z) = F(U,V)$$



<http://cadauno.sourceforge.net/>

PARAMETRIC SURFACES EXAMPLES

CUBIC BEZIER SURFACE, NURBS



PARAMETRIC VS. POLYGONAL

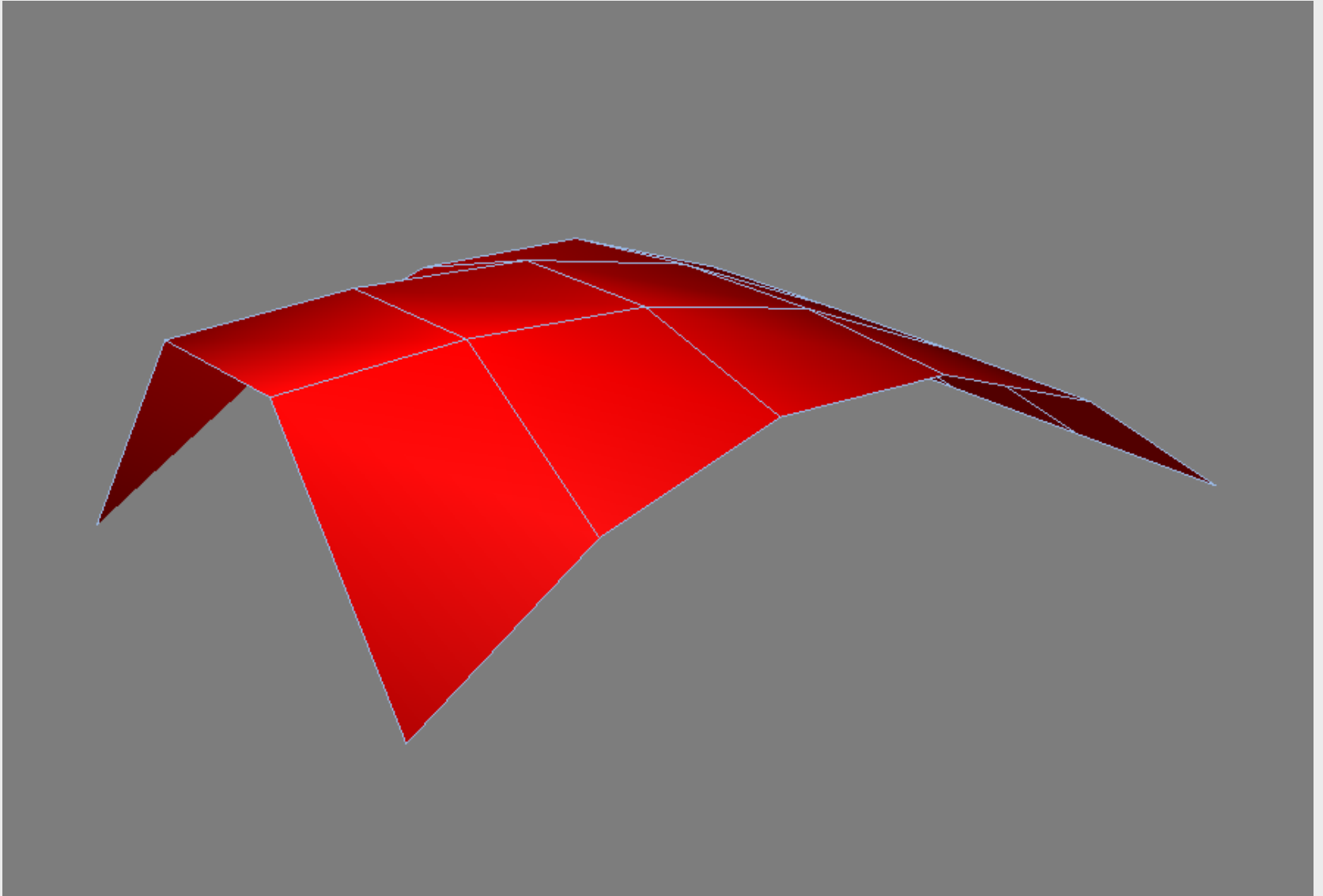
PARAMETRIC

smooth, re-parametrizable
harder rendering
precise rendering

POLYGONAL

discrete, hard to re-parametrize
faster rendering or rasterization
approximation

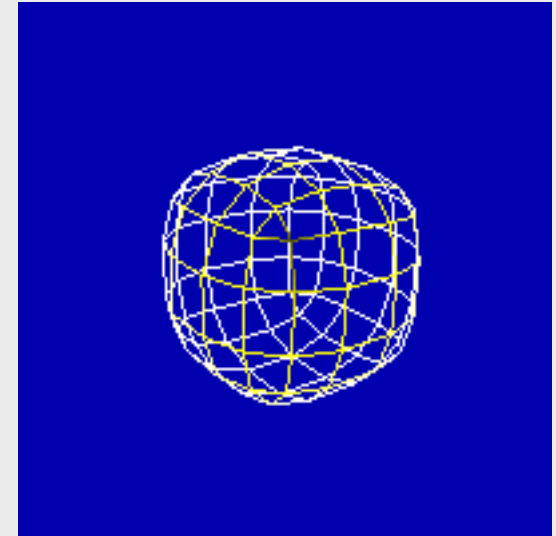
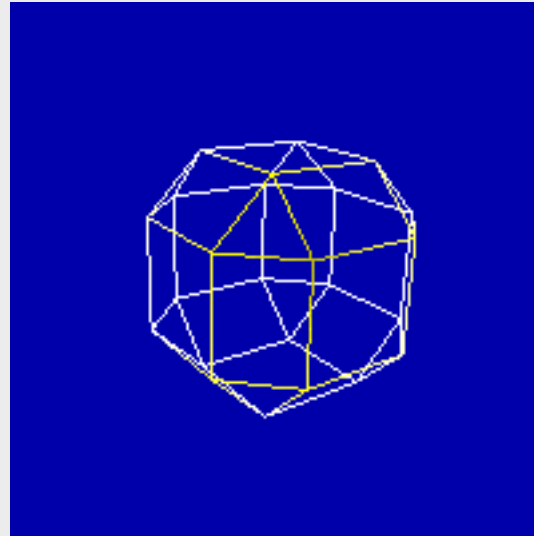
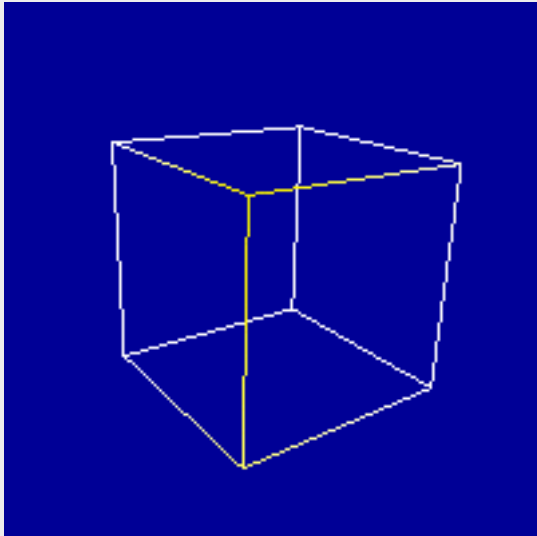
PARAMETRIC \rightarrow POLYGONAL



SUBDIVISION SURFACES

RECURSIVE SUBDIVISION OF A POLYGONAL
MODEL

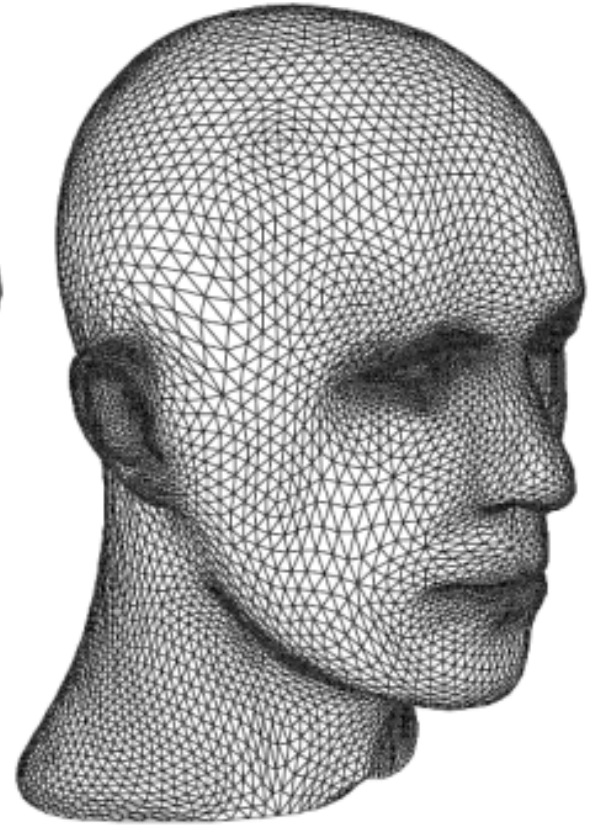
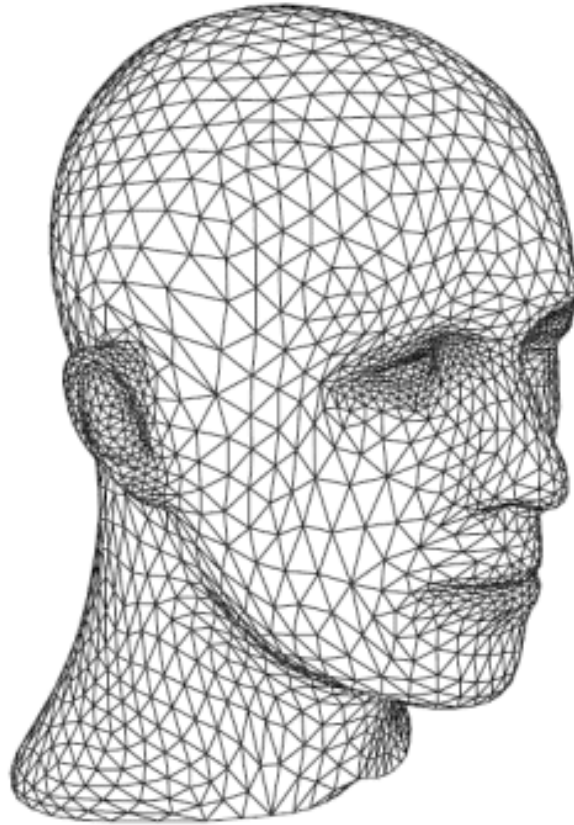
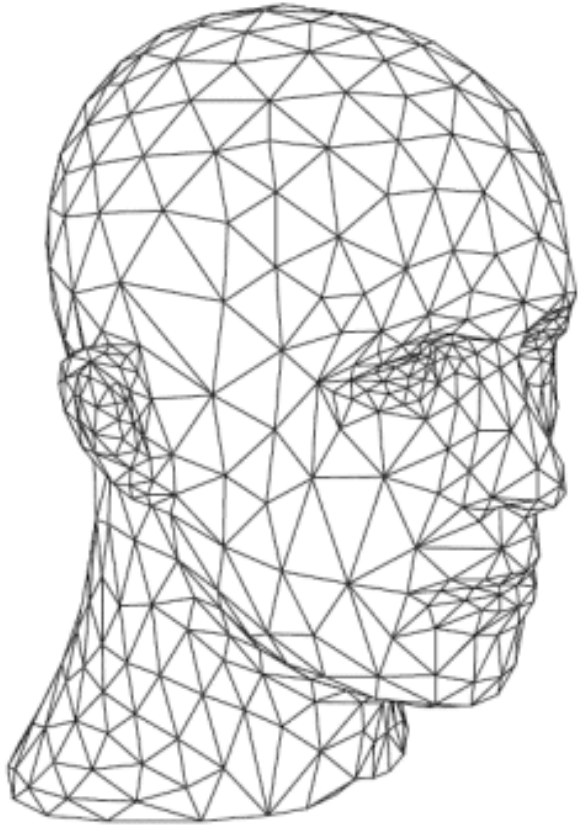
LIMIT SURFACE = SMOOTH



EASY MODELING, SMALL DATA SIZE

[HTTP://WWW.HOLMES3D.NET/GRAPHICS/SUBDIVISION/](http://www.holmes3d.net/graphics/subdivision/)

SUBDIVISION EXAMPLE



“REAL WIREFRAME”

BENEDICT RADCLIFFE’S TOYOTA COROLLA



OTHER

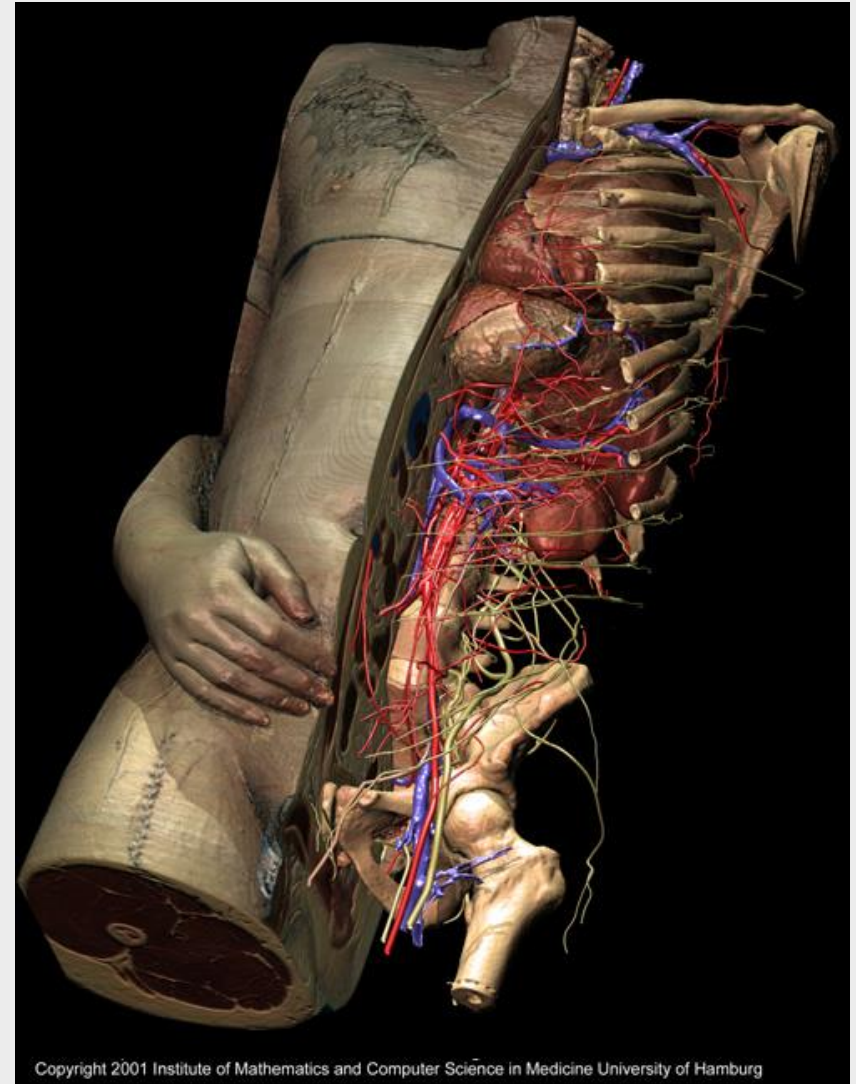
3D

REPRESENTATIONS

VOLUMETRIC REPRESENTATION

NOT ONLY BOUNDARY
BUT ALSO THE INSIDES
OF THE OBJECT

MEDICINE
PHYSICS
SIMULATIONS
ANIMATION



VOXELS

VOLUME ELEMENTS, "3D PIXELS"

DISCRETE

BINARY VALUES
FLOAT VALUES



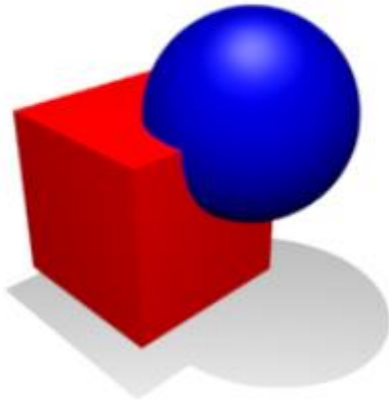
CONSTRUCTIVE SOLID GEOMETRY

PRIMITIVES + BOOLEAN OPERATORS ON SETS
AND, OR, NOT

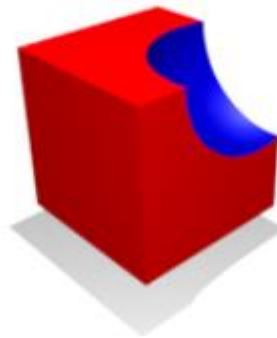
CAREFUL ABOUT SINGULARITIES - MANIFOLDS

Operations in constructive solid geometry

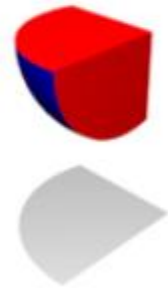
Boolean union



Boolean difference



Boolean intersection



CSG CONTINUED

HIERARCHY

Leaves = primitives

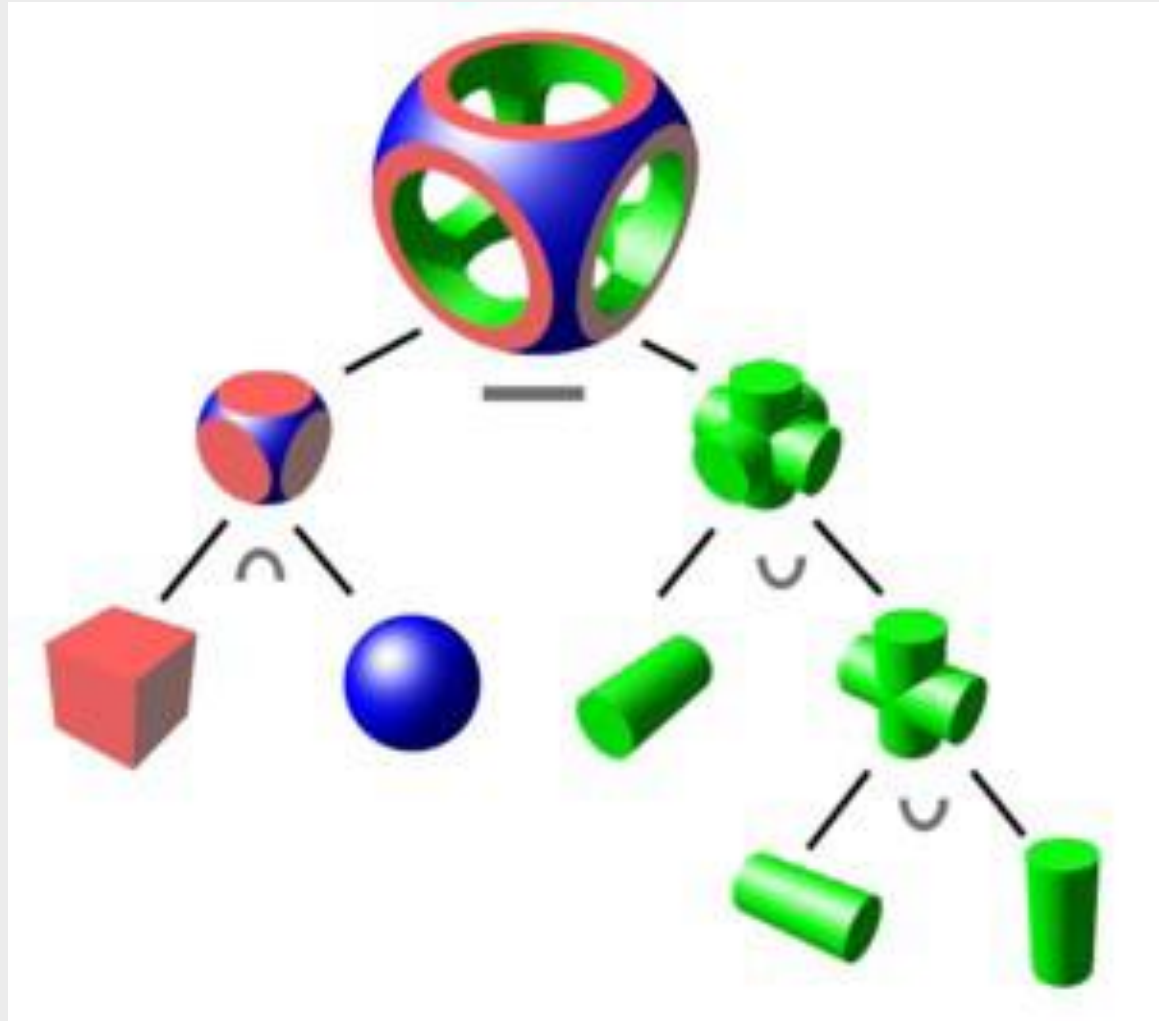
Nodes = operators

VOLUME-REP

Good

BOUNDARY-REP

Difficult

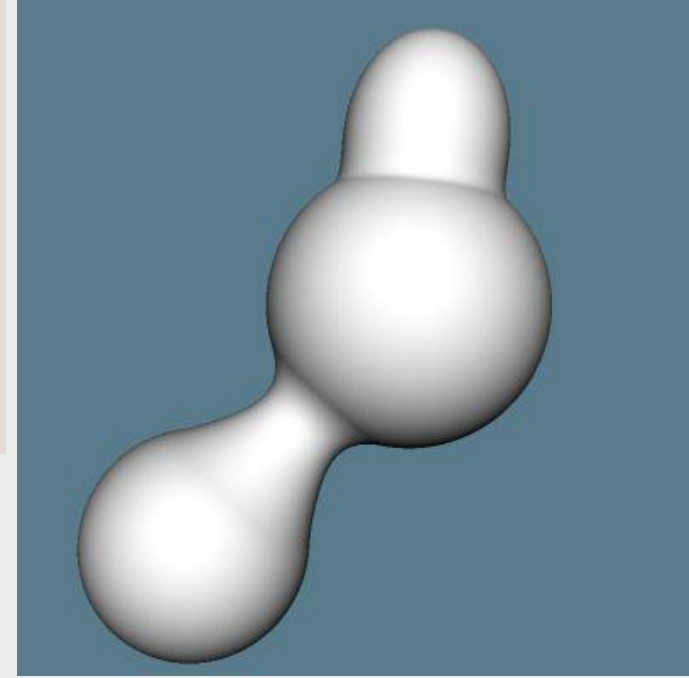
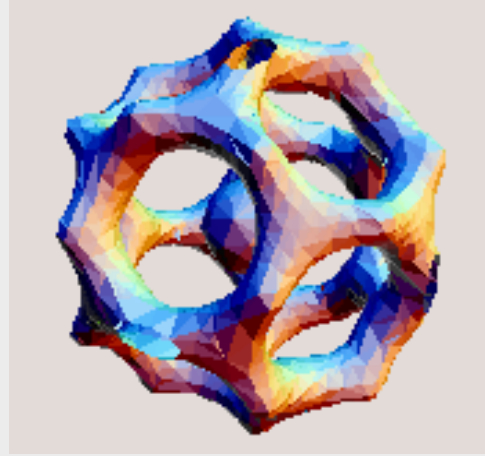


IMPLICIT SURFACES

$$F(X,Y,Z) = 0$$

SPHERE:

$$x^2 + y^2 + z^2 - r^2 = 0$$



METABALLS:

$$\sum_m R / ((x - x_m)^2 + (y - y_m)^2 + (z - z_m)^2) - c = 0$$

EXAMPLES:

[HTTP://IAT.UBALT.EDU/SUMMERS/MATH/PLATSOL.HTM](http://IAT.UBALT.EDU/SUMMERS/MATH/PLATSOL.HTM)

VIDEO



<http://youtu.be/k27ZVOp1PW4>

FUNCTIONAL REPRESENTATION

F-REP ~ GENERALIZATION OF CSG & IMPLICIT
MORE NODE FUNCTIONS - OPERATORS

e.g. object blending



```
center = [0, 0.5, 0];
se = hfSuperell(x, center, 8, 2.5, 8, 0.3, 0.3);

center = [0, -0.5, 0];
el_cly = hfEllCylZ(x, center, 4, 2);

wrist = el_cly & (8-x[3]) & (x[3]+20);

center = [0, 3.5, 0];
el1 = hfEllipsoid(x, center, 8, 1, 8);

center = [-2, 3.5, 0];
el2 = hfEllipsoid(x, center, 8, 1, 8);

center = [2, 3.5, 0];
el3 = hfEllipsoid(x, center, 8, 1, 8);

center = [-0.5, 3.5, -2];
el4 = hfEllipsoid(x, center, 8, 1, 8);

el = el1 | el2 | el3 | el4;

palm = hfBlendUni(se, wrist, 5, 2, 2) \ el;
```