

modeling

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overview

- what is modeling?
- object types
 - points, curves, surfaces, volumes
 - generative models, complex systems
- surface representations
 - polygon meshes
 - parametric surfaces
 - subdivision surfaces
- surface creation and modification
- component modeling

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what is modeling?

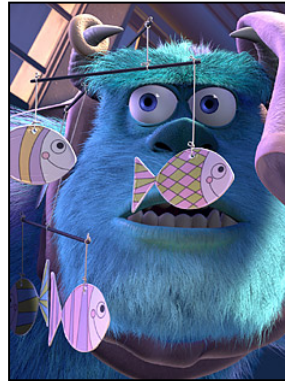
- definition of the geometry
- mathematical description of the shape

object types

- points
- created by
 - simulation
- applications
 - define complex systems

object types

- curves
- created by
 - human modeling
 - simulation
- applications
 - definition of surfaces
 - hairs/grass



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object types

- surfaces
- created by
 - human modeling
 - scanning
 - simulation
- applications
 - objects/characters



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object types

- surfaces
- created by
 - human modeling
 - scanning
 - simulation
- applications
 - objects/characters



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object types

- surfaces
- created by
 - human modeling
 - scanning
 - simulation
- applications
 - objects/characters



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object types

- surfaces
 - human modeling
 - scanning
 - simulation
- applications
 - objects/characters



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object types

- volumes
 - scanning (medical data)
 - simulation
- applications
 - atmospheric effects
 - fire/smoke/water



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object types

- generative models
 - vegetation

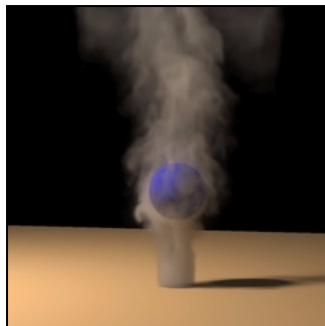


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object types

- complex systems
 - particle systems



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object types

- complex systems
 - crowds



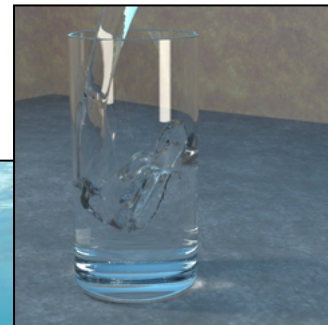
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object types

- complex systems
 - liquids



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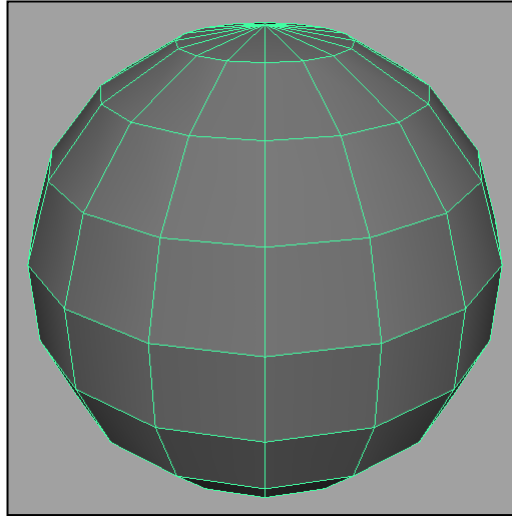
surface - what is it?

- very thin sheet (2D)
 - not a volume!
 - often can look at it only from the front

surface representations

- faceted models
 - polygon meshes
- smooth models
 - parametric surfaces (e.g. NURBS)
 - subdivision surfaces
- differ in the way they handle
 - smoothness (silhouettes/lighting)
 - easiness of modeling

polygon meshes

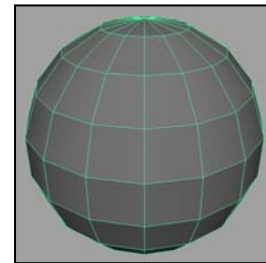


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polygon meshes

- collection of polygons
- not smooth
- easy to model any shape
- used by most low-level algorithms
 - convert parametric and subdivision surfaces to polygons for rendering
- used in interactive graphics (games)



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polygon meshes - examples



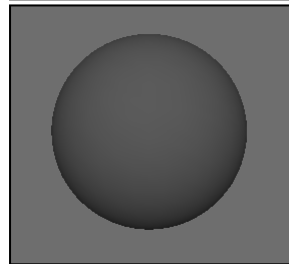
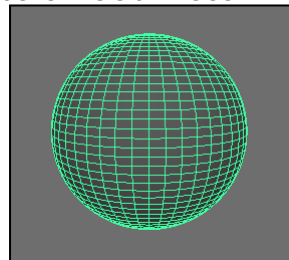
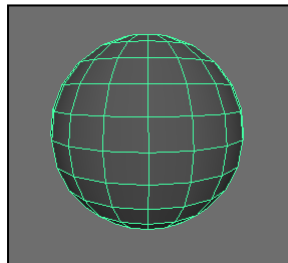
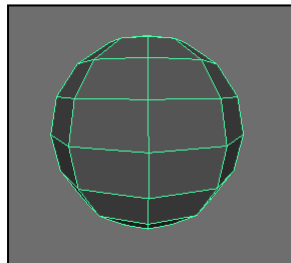
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polygon meshes - tessellation

- use more polygons to approximate smoothness
 - silhouettes, lighting

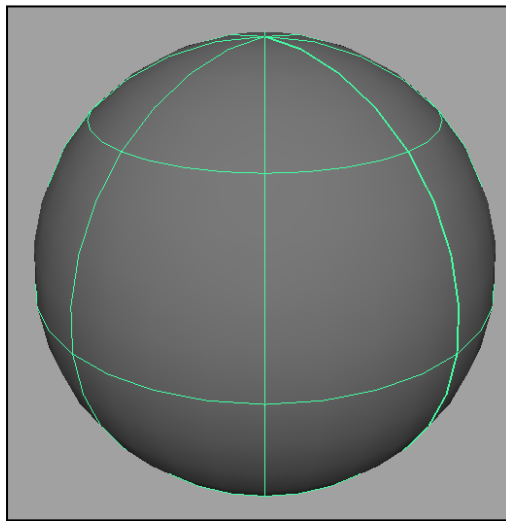


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polygon meshes - control

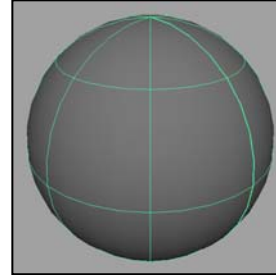
- change single polygons to change shape
 - create/delete polygons
 - move vertices → control points
- but might have lots of polygons for smoothness
 - lots of possible control points
 - very cumbersome

parametric surfaces



parametric surfaces

- smooth surfaces generated by simple control points
- smooth
- hard to model complex shapes
- used to model simple geometry



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parametric surfaces - examples



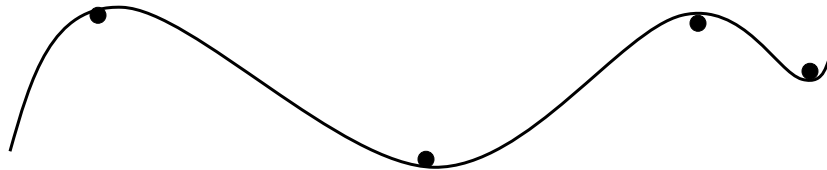
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parametric curves

- 1D equivalent to parametric surfaces
- also known as splines
- origin: strip of flexible metal
 - held in place by pegs or weights to constrain shape
 - traced to produce smooth contour



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parametric curves

- smoothness
 - in drafting spline, comes from properties of metal
 - in CG spline, comes from choosing smooth functions
- control
 - in drafting spline, comes from fixed pegs
 - in CG spline, comes from user-specified *control points*

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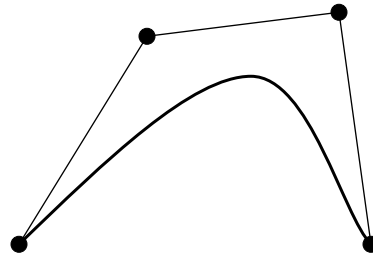
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parametric curves

- compute point on the curve by
 - computing a function for each control point
 - averaging the results

$$\mathbf{P}(t) = \mathbf{f}_1(t; \mathbf{P}_1) + \mathbf{f}_2(t; \mathbf{P}_2) + \mathbf{f}_3(t; \mathbf{P}_3) + \mathbf{f}_4(t; \mathbf{P}_4)$$

- various types
 - differ by type of control, interpolation function

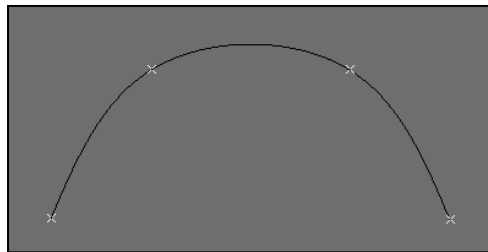


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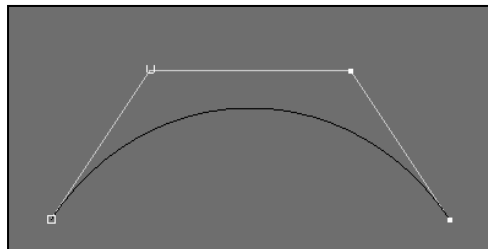
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parametric curves - interpolation

- interpolating



- approximating



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parametric curves - basis functions

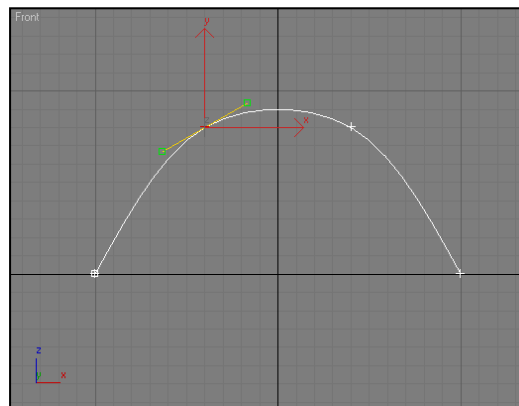
- functions to generate curve from control points
- degree: typically cubic
 - good control, smoothness and efficiency
- classes
 - basic: e.g. Hermite, Bezier
 - control: Points + Tangents or Points
 - only 4 control points → stitch curves (done for you)
 - rational splines: e.g. NURBS
 - control: points
 - as many controls as needed
 - mathematical representation makes tools easier

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parametric curves - control

- curve points + tangents

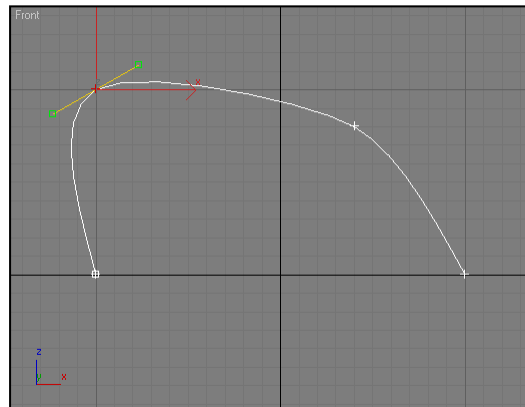


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parametric curves - control

- curve points + tangents

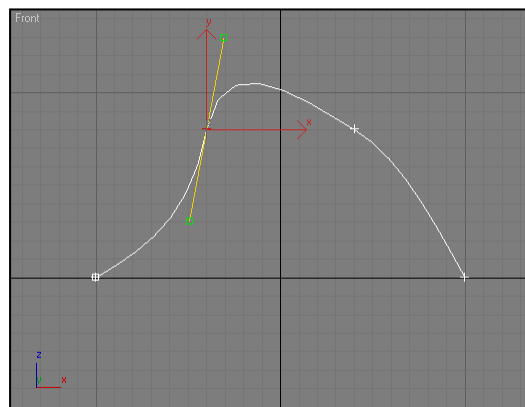


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parametric curves - control

- curve points + tangents

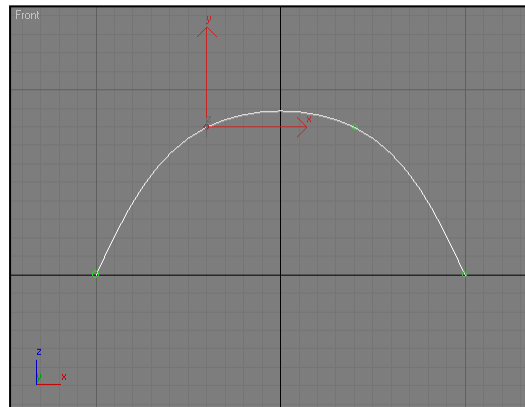


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parametric curves - control

- control points: interpolating

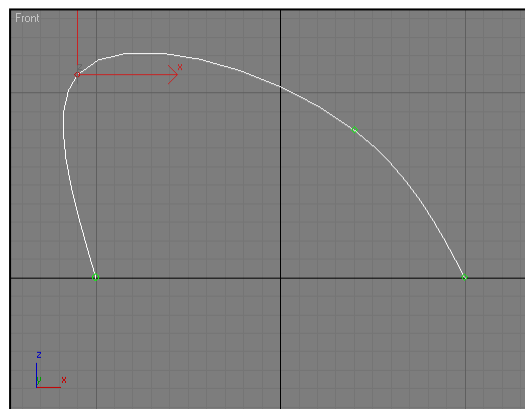


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parametric curves - control

- control points: interpolating

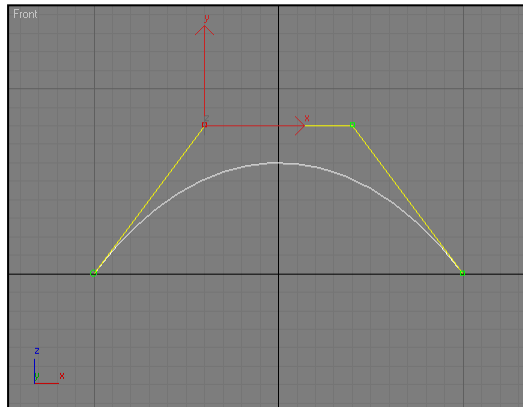


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parametric curves - control

- control points: approximating

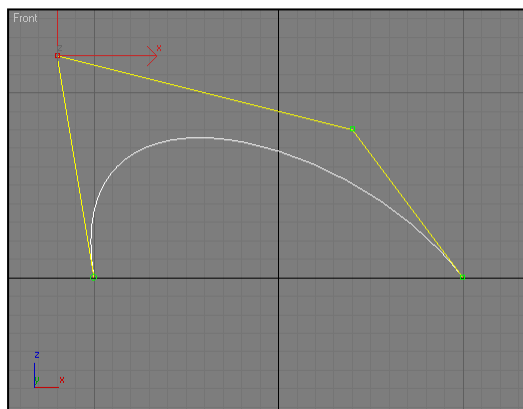


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parametric curves - control

- control points: approximating

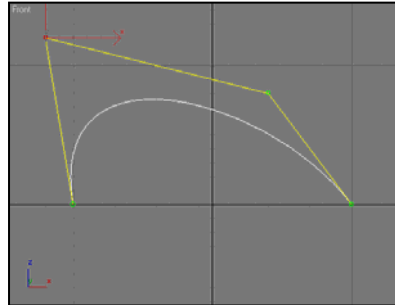
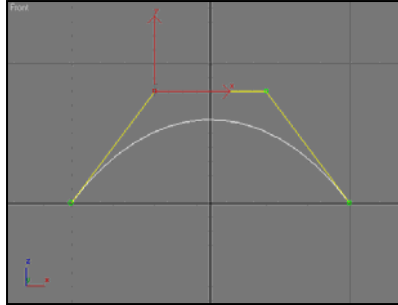


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parametric curves - control hull

- approximating: curve is inside the control hull
 - very important for surfaces

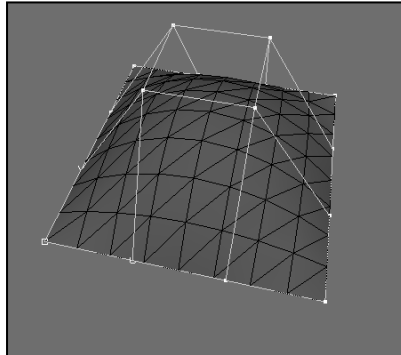
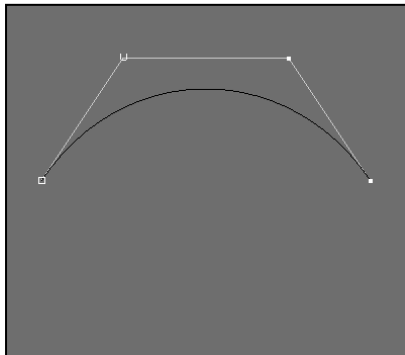


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parametric curves vs. surfaces

- curves
 - array of control points
- surfaces
 - grid of control points

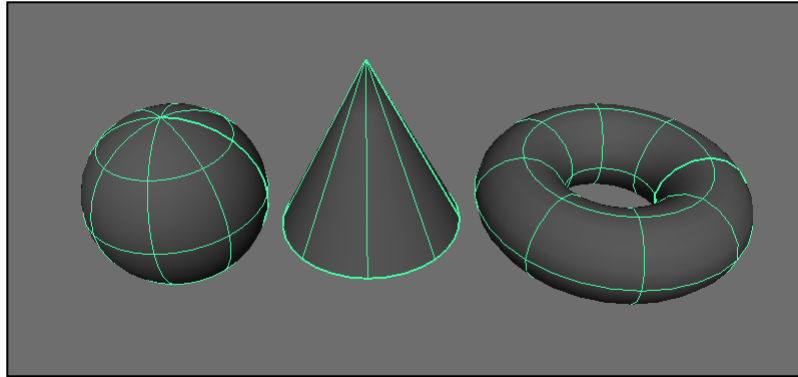


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parametric surfaces - examples

- good results for man-made objects

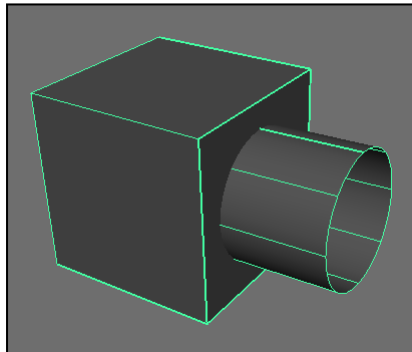


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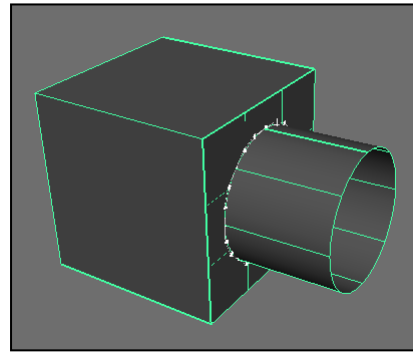
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parametric surfaces - joining

- fundamental problem: stitching
 - typical in organic deforming models, e.g. characters
 - think about cloths



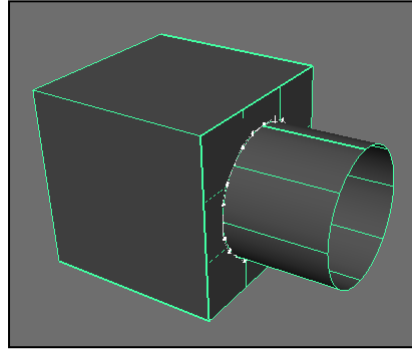
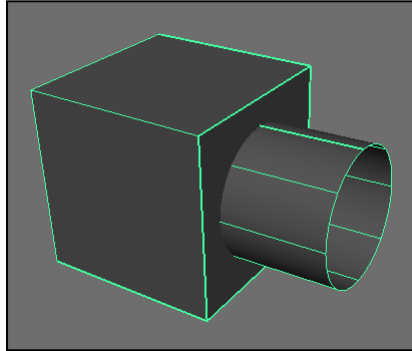
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parametric surfaces - topology

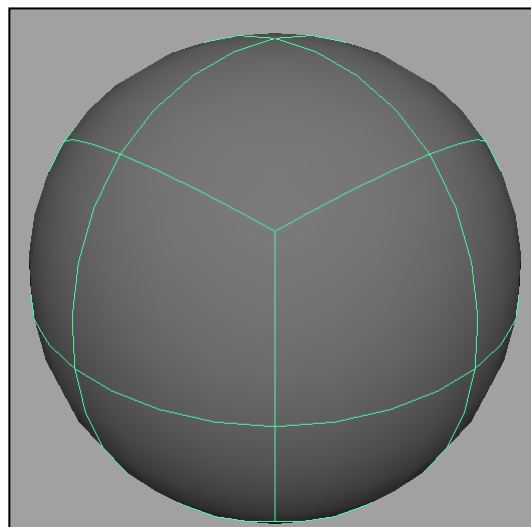
- fundamental problem: topology
 - NURBS are fundamentally a collection of 4 sided sheets!



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subdivision surfaces

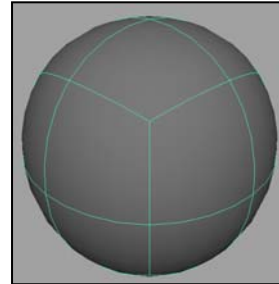


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subdivision surfaces

- polygons: not smooth, but easy
- parametric: smooth, but hard
- subdivision surfaces
 - “smooth polygon meshes”
 - control using a polygon mesh
 - with additional control for sharp features
 - no stitching problems!
- used for most geometry and all characters



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subdivision surfaces - examples



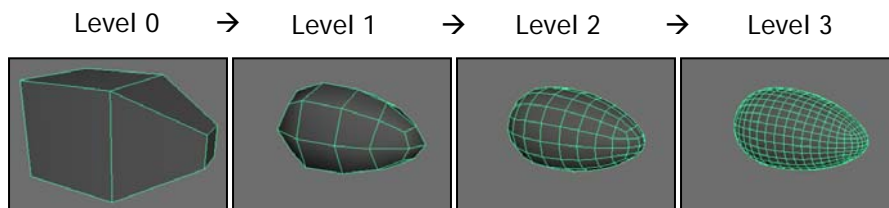
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subdivision surfaces - interpolation

- take a polygon mesh
- apply a subdivision rule
 - different types exists
- keep smoothing until good enough (infinity)



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subdivision surfaces - interpolation

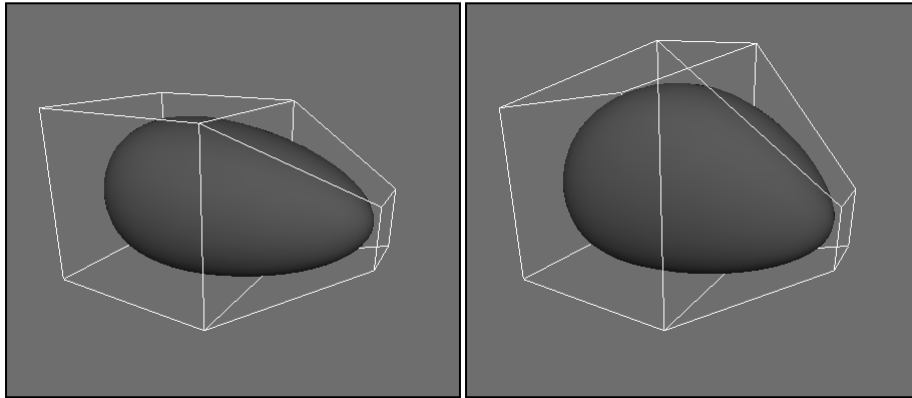
- limit surface of the polygon mesh under the given subdivision rule
- subdivision vs. polygons
 - subdivs are inherently smooth
 - subdivs use polygons as control meshes
- can be interpolating or approximating
 - latter used in practice

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subdivision surfaces - control

- modify polygon mesh

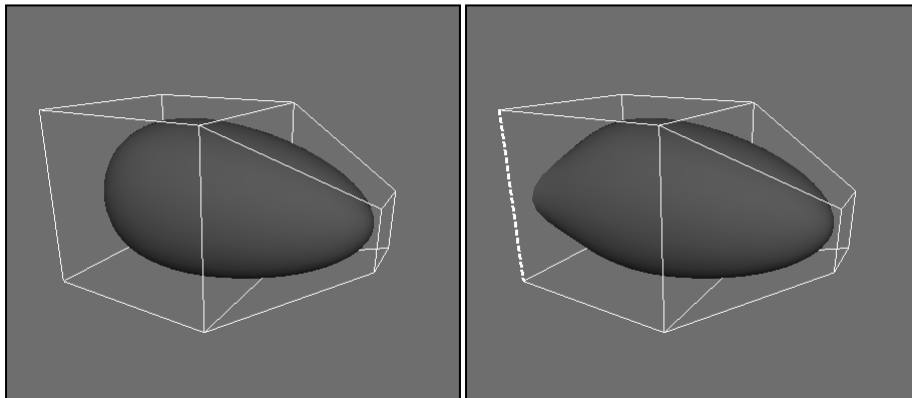


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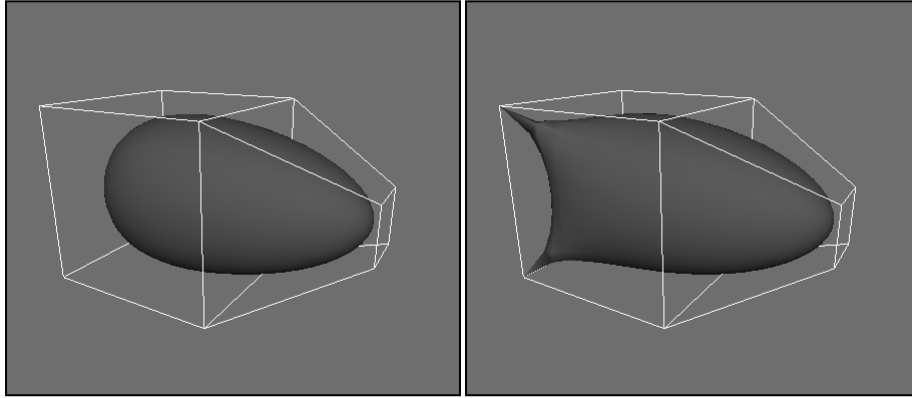
subdivision surfaces - sharp features

- sometimes need sharp features
- creases: edge



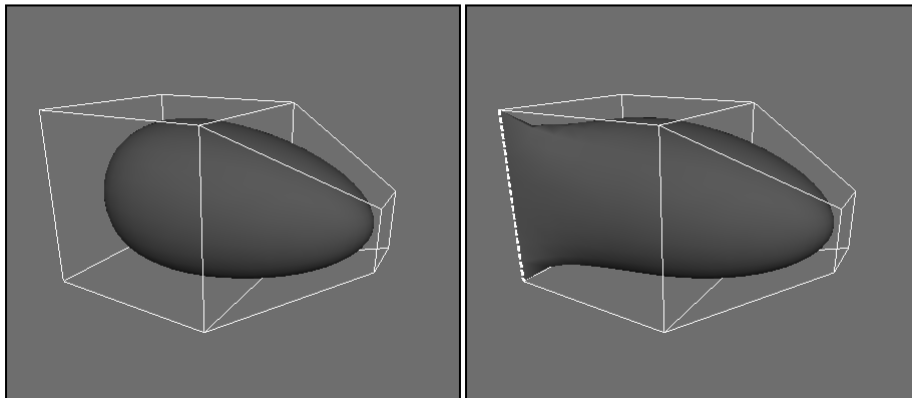
subdivision surfaces - sharp features

- sometimes need sharp features
- creases: vertex



subdivision surfaces - sharp features

- sometimes need sharp features
- creases: edge and vertex



surface creation

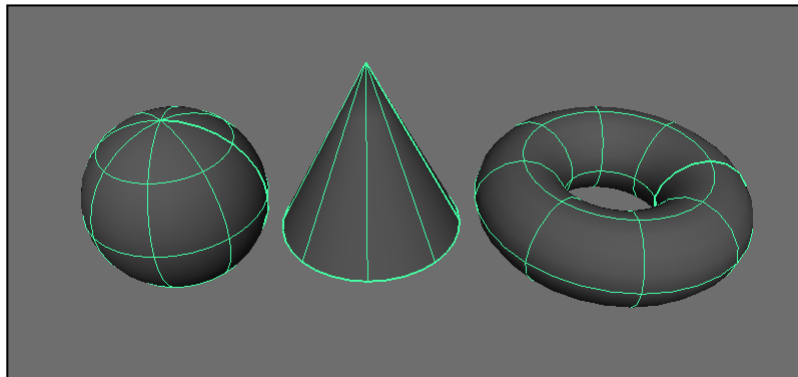
- construct starting surface
 - primitives
 - curve to surface: extrusion, revolution, ...
- modify the whole object
 - global deformations: e.g. bend, twist
 - deformation stacks
- modify objects' components
 - most used method for characters
 - polygonal/subdivision modeling

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surface creation: primitives

- basic geometric primitives

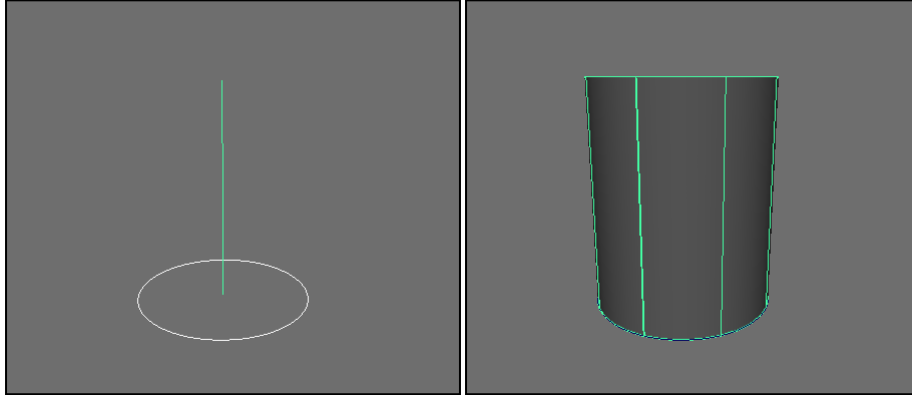


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surface creation: extrusion

- start with a shape and a path
- pull the shape along the path

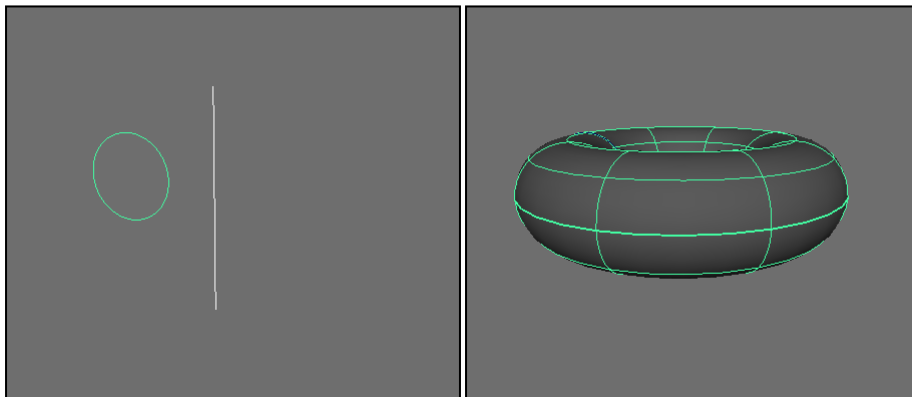


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surface creation: revolve

- start with a shape and an axis
- rotate the shape around the axis

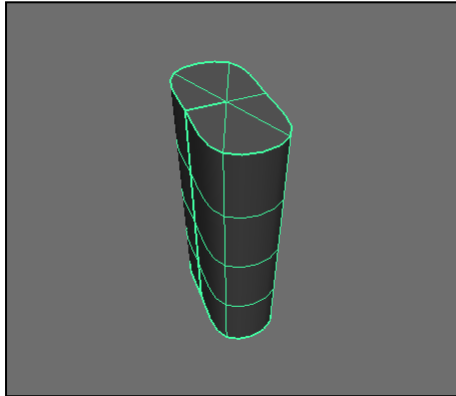


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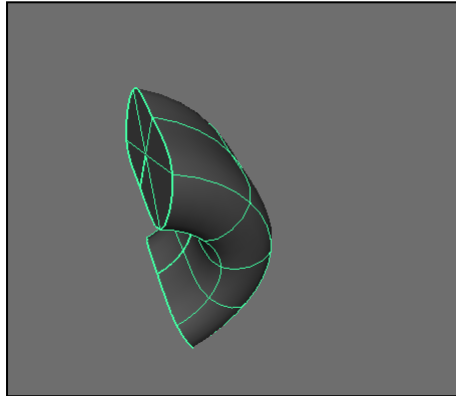
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surface modification: deformation

- global deformation based on procedural controls
- bend



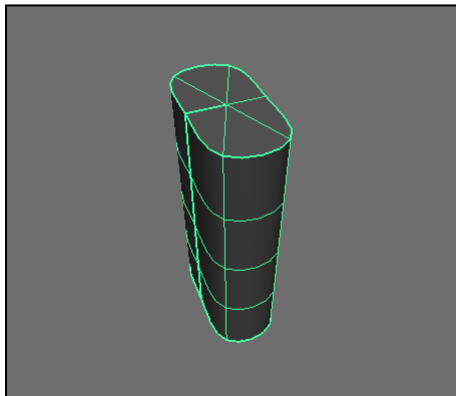
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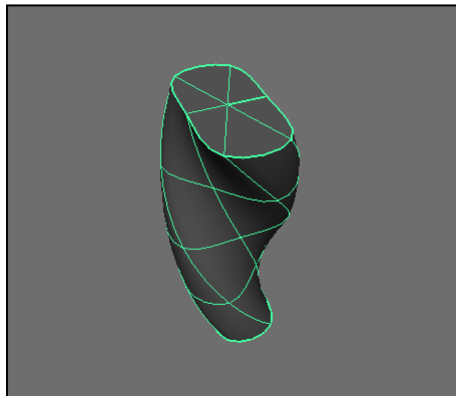
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surface modification: deformation

- global deformation based on procedural controls
- twist



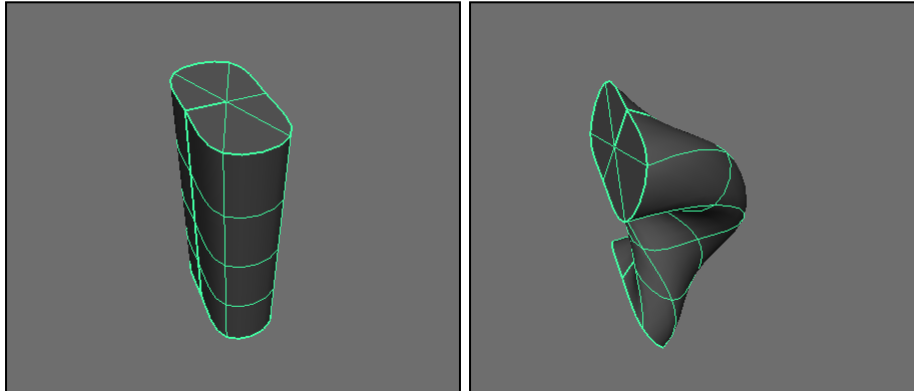
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surface modification: deformation

- global deformation based on procedural controls
- twist then bend

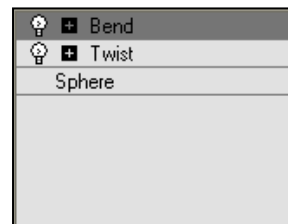


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surface modification: stacks

- keep around all the modifications
 - can edited a previous twist even after I apply bend
 - can edited all parameters at once
- basic concept in all packages
- makes editing way more efficient
 - in this case undo/redo would not work
- necessary for animating shapes



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component modeling

- probably the most used technique in industry
 - necessary for organic shapes
- start with simple surface
- change components
 - surfaces types: control points
 - polygon/subdivision types: vertices, edges, faces
 - transformations: move, rotate, scale, create, etc.
- requires a lot of practice
- will be covered with examples in the lectures