How would you create CG models for these two abstract sculptures?

- "Solar Circle"
- "Pax Mundi"

Huddle and discuss with your neighbors!
Parametric Geometric Modeling

- Sculpture Generator I
- Minimal surfaces
- Generalized sweeps
- The SLIDE framework
- Design and implementation of a large sculptures
Brent Collins

Hyperbolic Hexagon II
Brent Collins: Stacked Saddles
Scherk’s 2nd Minimal Surface

Zero mean curvature everywhere

Alternating Tunnels
Scherk’s 2nd Minimal Surface ➔ Art

Normal “biped” saddles

Generalization to higher-order saddles (monkey saddle)
Scherk Tower

- 5-story core
- Monkey saddles
- Thick surface
- “Flare” added
Hyperbolic Hexagon by B. Collins

- 6 saddles in a ring
- 6 holes passing through symmetry plane at ±45°
- "wound up" 6-story Scherk tower

Discussion: What if ...
- we added more stories?
- or introduced a twist before closing the ring?
Solar Arch

- 12 stories
- 4th-order saddles
- 270° twist
Closing the Loop

straight
or
twisted
Brent Collins’ Prototyping Process

Armature for the *Hyperbolic Heptagon*

Mockup for the *Saddle Trefoil*

Time-consuming! (1-3 weeks)
Sculpture Generator I, GUI

Creates a family of highly specialized, parameterized shapes
Some of the Parameters in "SG1"
Base Geometry: One “Scherk Story”

- Taylored hyperbolas, hugging a circle
- Hyperbolic Slices ➔ Triangle Strips
The Basic Saddle Element

with surface normals

◆ precomputed -- then warped into toroid
Shape Generation:

- by stacking this basic hyperbolic element,
- twisting that stack along z-axis,
- bending (warping) it into an arch or loop.
Toroidal Warp into Collins Ring

8-story tower warped into a ring with a 360º twist added.
A Plethora of Shapes
Virtual Glass Scherk Tower with Monkey Saddles (Radiance 40 hours)

Jane Yen
True Minimal Surfaces?

- Not a true "minimal surface" (like a soap film)!
Ken Brakke’s *Surface Evolver*

- For approximating minimal surfaces:
  - Start with a crude polyhedral object
  - Subdivide triangles
  - Optimize vertices
  - Repeat the process
Minimality and Aesthetics

Are minimal surfaces the most beautiful shapes spanning a given edge configuration?
“Whirled White Web”  Séquin 2003

Maquette made with Sculpture Generator I

Minimal surface spanning three (2,1) torus knots
“Atomic Flower II” by Brent Collins

Minimal surface in smooth edge
(captured by John Sullivan)
Here, minimal surfaces seem aesthetically optimal.
To Make a Piece of Art,
It also Takes a Great Material Finish

PATINA BY STEVE REINMUTH
www.nada.kth.se/~asa/ray.html
"Minimal Surface City"
Minimum-Variation Surfaces (⇒ CS284)

The most pleasing smooth surfaces...
Constrained only by topology, symmetry, size.
Collins’ Fabrication Process

Layered laminated main shape

Wood master pattern for sculpture

Example: Vox Solis
Slices through *Minimal Trefoil*
One thick slice thru sculpture, from which Brent can cut boards and assemble a rough shape.

Traces represent: top and bottom, as well as cuts at 1/4, 1/2, 3/4 of one board.
Emergence of the *Heptoroid* (1)

Assembly of the precut boards: Heavy “staircasing”
Emergence of the *Heptoroid* (2)

Forming a continuous smooth edge
Emergence of the *Heptoroid* (3)

Smoothing the whole surface
The Finished
*Heptoroid*

- at Fermi Lab Art Gallery (1998)
“Scherk-Collins” Sculptures (FDM)
Hypersculpture: Family of 12 Trefoils
Extending the Notion of a “Saddle”

B = number of branches = the order of the saddles.
B = 1: A “one-leg saddle”? ➔ just a simple band.
Another Extension ...

Allow different kinds of "stretching" ...
Extending the Paradigm:  Totem 3

Bronze Investment Cast
Totem-4
Bronze, Dec. 2007
Carlo Séquin
Cohesion

SIGGRAPH’2003 Art Gallery
Going more then once around the loop ...

... results in an interwoven structure.
11 Stories, Monkey-Saddles, w=2:

cross – eye stereo picture
9-story Intertwined Double Toroid

Bronze investment casting
from wax original
made on 3D Systems’ *Thermojet*
Stepwise Expansion of Horizon

- Playing with many different shapes and
- experimenting at the limit of the domain of the sculpture generator,
- stimulates new ideas for alternative shapes and generating paradigms.
Sculpture Generator 1 as a Playground

The computer becomes an amplifier / accelerator for the creative process.

Another occasion where Sculpture Generator 1 became invaluable ...
Snowsculpting Championships: “Whirled White Web”  
(C. Séquin, S. Wagon, D. Schwalbe, B. Collins, S. Reinmuth)
Removing lots of snow ...

Day 1
Day 2: Making a Torus
End of Day 2

The Torus
Day 3, am: Drawing Flanges
Day 3, pm: Carving Flanges, Holes
Day 4: Geometry Refinement
End of Day 4: Desired Geometry
Day 5, am: Surface Refinement
Judgement Time: Whirled White Web
12:41 pm -- 42° F
“WWW” Wins Silver Medal
Large and **Durable** Sculpture!

- Need a material more permanent than snow...
2006: Commission for a Big Sculpture!

- Scale up original “Pax Mundi” (to 6ft diam.)
- Less than 1500 pounds
- Budget 50’000 $
- Due in 4 months (Nov. 2006)
- Collaboration: Collins, Reinmuth, Séquin

My task:
Create the digital file for a mold master
Another Inspiration:
Brent Collins’ *Pax Mundi* (1997)
How Would You Model This?

- Conceptual associations?
- Potentially useful modeling paradigms?
- Generating principle?
- Use of geometrical parameters?
Keeping up with Brent ...

- *Pax Mundi* cannot be done with *Sculpture Generator I*

- Needs a more general program!

- First:
  Need to understand what is going on
Sculptures by Naum Gabo

Pathway on a sphere:
Edge of surface is like seam of tennis- or base-ball;

==> 2-period Gabo curve.
2-period “Gabo Curve”

- Approximation with quartic B-spline with 8 control points per period, but only 3 DOF are used (symmetry!).
4-period “Gabo Curve”

Same construction as for 2-period curve
Pax Mundi Revisited

- Can be seen as:
  - Amplitude modulated, 4-period Gabo curve
SLIDE-GUI for “Pax Mundi” Shapes

Good combination of interactive 3D graphics and parameterizable procedural constructs.
Tennis ball –
or baseball –
seam
used as
sweep curve.
Viae Globi Family (Roads on a Sphere)

2  3  4  5  periods
Via Globi 5  (Virtual Wood)

Wilmin Martono
Modularity of **Gabo Curve Generator**

- **Sweep Curve Generator:**
  - Gabo Curves as B-splines

- **Cross Section Fine Tuner:**
  - Parameterized shapes

- **Sweep / Twist Controller**
How do we orient, move, morph ... the cross section along the sweep path?

- Natural orientation with Frenet frame
- Torsion Minimization:
  - Azimuth: tangential / normal
  - $900^\circ$ of twist added.
Extension: Free-form Curve on a Sphere

Spherical Spline Path Editor (Jane Yen)

Nice smooth interpolating curves through sparse data points
Many Different Viae Globi Models
Paradigm Extension: Sweep Path is no longer confined to a sphere!
The Beauty of Knots

Trefoil Knot

Music of the Spheres (Brent Collins)
Figure–8 Knot
Free-form 3D Space Curves

Figure-8 knot
Figure-8 Knot
Bronze, Dec. 2007

Carlo Séquin
Chinese Button Knot (9_{40})
Chinese Button Knot
Bronze, Dec. 2007
Carlo Séquin
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My task:
Create the digital file for a mold master
Target Geometry
Emulation; Define Master Pattern

- Master to make a mold from.
- Use 4 copies.
Subdivide into Two Master Segments
Joe Valasek’s  CNC Milling Machine
Machined Master Pattern #2
(Cut) Master → Silicone Rubber Mold
Mold ➔ Several (4) Wax Copies
Spruing the Wax Parts for Casting
Ceramic Slurry Shell Around Wax Part
Shell Ready for Casting
Casting with Liquid Bronze
Bronze Cast Slowly Cooling Off
Cracking the Ceramic Shell
The Freed Bronze Cast
Assembly of Pieces
Grinding the Welded Seams,
Polishing the Surface
Applying Patina
Front Door

H&R Block Building
The Final Destination
Steve  Tightening the Bolts
A New Commission ...

- 10 ft diameter
- amber-tinted polyester resin
- to be hung in an atrium below skylight
Sculpture Design

- branches = 4
- storeys = 11
- height = 1.55
- flange = 1.00
- thickness = 0.06
- rim_bulge = 1.00
- warp = 330.00
- twist = 247.50
- azimuth = 56.25
- mesh_tiles = 0
- textr_tiles = 1
- detail = 8

bounding box:
- xmax = 6.01,
- ymax = 1.14,
- zmax = 5.55,
- xmin = -7.93,
- ymin = -1.14,
- zmin = -8.41
Breckenridge Competition (1997)
FDM Maquette of Solar Arch

2nd place
Solar Arch – Small Bronze
Two Modules Assembled
Two times Three Modules
Merging the Two Half-Circles
Always Some Tense Moments ...
Millennium Arch by Night
Some Observations

- Interactive graphics ==> enhanced creativity
- Speed is not my primary concern.
- I would like a more expressive user interface – particularly for the first stages of capturing an idea and getting it into the computer.
- I am still using paper, wire, styrofoam, etc ... to explore new ideas.
QUESTIONS ?