Computer Animation: Art, Science and Criticism

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Lecture 5
Constructing and Editing a Polygon

- Create Polygon Tool.
- Append to Polygon Tool.
- Editing Vertex Positions.
**Mesh-CreatePolygonTool:** Click LMB on successive vertex positions. Use *Control-LMB* to initiate making a hole in the interior, if desired. Hit enter to complete the polygon.
**EditMesh-AppendToPolygonTool**: Click LMB on edge to be shared. Click LMB on successive vertices of new polygon. Hit enter to complete the polygon.
Editing Vertex Positions: Select vertices and move, rotate or scale them. Note that the result may be a non-planar polygon.
A vertex is a point in space.

An edge is a line segment connecting two vertices.

A polygon face is a closed sequence of connected edges.
  – Each edge has a direction.
    • Successive edges share vertices.
    • First and last edge share vertices.
  – Each face has a front and back, defined by a normal vector.

A polygon mesh is a collection of faces:
  – Two faces may share edges and vertices.
  – An open mesh has boundary edges.
  – A closed mesh has none.
  – The surface defined by the mesh need not be connected.
Constructing and Editing a Polygon Mesh

- **Constructing:**
  - Predefined polygon primitives.
  - Constructing and appending polygons.
  - Extrusion of a polygon.

- **Editing:**
  - Move operations on vertices, edges or faces.
  - Extrusion of a polygon face:
    - Normal direction or along a user-specified curve.
    - Keep faces together or not options.
Extruding a Polygon into a Polygon Mesh: Select polygon face and apply *EditMesh-ExtrudeFace*. Move, rotate or scale the face in object or world coordinates.
Extruding a Polygon along a Curve into a Polygon Mesh: Create a polygon. Create a curve not lying in a plane parallel to the polygon plane. Select the polygon and then the curve and invoke: \textit{EditMesh-Extrude [].} Set the number of divisions to make along the path and click \textit{Extrude}. You may use the manipulator tool to translate and scale the extrusion after it is created.
Polygon Mesh Display Options

• *Display–Polygons*:
  – Show or hide vertices.
  – Show or hide normal vectors.

• *Display–Polygons–CustomPolygonDisplay*:
  – Backface culling on: Only faces with normals pointing toward user may be selected.
  – Backface culling off: Any face may be selected.
Each polygon face has a front and a back. In this diagram, we have set the polygon display to indicate the front and back of each face by drawing a normal vector pointing in the front (outward) direction.
Polygon Backface Culling

The diagram on the left shows all eight polygon faces. In the diagram on the right, we have turned on backface culling. Only the polygons whose normals are pointing toward the camera are displayed, and only these polygons can be selected.
Extrusion

• Operates on face, edge or vertex.
• Extrusion path may be:
  – Normal to face.
  – Parallel to a world axis.
  – Along a specified curve.
• Option to keep faces together or not.
• Option to set number of divisions on path.
Invoke menu item: Create-PolygonPrimitives-Cube[] and enter options for two divisions along each axis and confirm. Go into component selection mode and press the SelectByComponentType (Faces) button. Then select a face and invoke menu item: EditMesh–Extrude[], select a number of divisions and confirm. Press the round button to toggle between extrusion in normal coordinates and extrusion in object coordinates.
Invoke menu item: *Create-PolygonPrimitives-Cube[]* and enter options for two divisions along each axis and confirm. Go into component selection mode and press the *SelectByComponentType (Lines)* button. Then select and edge and invoke menu item: *EditMesh–Extrude[]*, select a number of divisions and confirm. Press the round button to toggle between extrusion in normal coordinates and extrusion in object coordinates.
Invoke menu item: *Create-PolygonPrimitives-Cube[]* and enter options for two divisions along each axis and confirm. Go into component selection mode and press the *SelectByComponentType (Points)* button. Then select an edge and invoke menu item: *EditMesh–Extrude[]*, select a number of divisions and confirm.
Invoke menu item: *Create-PolygonPrimitives-Cube* and enter options for two divisions along each axis and confirm. Use the EP or CV curve tool to draw a curve whose starting point is at the center of a polygon face. Click RMB on the cube to bring up the marking menu. Select *Face* (select by face). Then select the polygon face and shift-select the curve. Then invoke *EditMesh–Extrude*[], select a number of divisions and confirm. You may use the manipulator tool to translate and scale the extrusion after it is created.
Extrusion with *EditMesh–KeepFacesTogether* (On)

(Extruding in normal coordinates.)
Extrusion with *EditMesh–KeepFacesTogether* (Off)

(Extruding in normal coordinates.)
Bevel and Chamfer

• Bevel:
  – Expands selected edge into a face.
  – Expands selected vertex and adjacent edges into faces.
  – Expands selected face into surface with one new face for each edge of the selected face.

• Chamfer:
  – Replaces selected vertex with a face.
  – The number of sides of the face is the number of edges incident on the vertex.
EditMesh–Bevel
EditMesh–Bevel
EditMesh–Bevel
EditMesh–ChamferVertex
Refining a Polygon Mesh

• Subdivide Polygon:
  – Splits selected faces into multiple polygons.
  – Quad and triangle options.

• Split Polygon:
  – User draws new edge connecting two existing edges.
  – Polygon splits in two along new edge.

• Mesh geometry is unchanged, if all polygons are planar.
EditMesh–AddDivisions(Quad)
EditMesh–SplitPolygonTool

User draws a new edge between two selected edges.
Extracting and Merging Sets of Faces

- Set EditMesh to KeepFacesTogether.
- Invoke: EditMesh–DuplicateFace (with Separate option).
- Click LMB on the manipulator toggle button to switch to world coordinates, and drag the copy away from the original.
- Cut a face out of the original mesh where the copy will be joined.
- Move the copy to the location where it will be joined.
- Select the original mesh and the copy.
- Invoke: Mesh–Combine to make the copy and original into one mesh.
- Use EditMesh–MergeEdgeTool to join extracted or duplicated faces to boundary edges in the combined mesh.
Select a set of faces and apply *EditMesh–DuplicateFace*. Click on the circle to toggle into world coordinates. Then move the duplicate set to a new position. Drag a selection box around all (and only the new faces) and invoke Mesh-Combine to make them a single surface.

demo-05-duplicate-combine-merge1.mb

demo-05-duplicate-combine-merge2.mb
Cut a face out of the old surface. Move the new surface to a location where it meets the hole in the old surface. Select both surfaces and invoke *Mesh-Combine* to make them one surface. Then invoke *EditMesh-MergeEdgeTool*. Select one edge along the joint. Then shift select its mate and press enter. Repeat for all other pairs of matching edges along the joint.

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demo-05-duplicate-combine-merge2.mb

demo-05-duplicate-combine-merge3.mb
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Averaging and Smoothing

• Averaging:
  – Moves vertices, but does not change mesh topology.
  – New vertex position is a weighted average of positions of selected vertices.

• Smoothing:
  – Refines mesh topology.
  – Moves vertices to new positions to create a smoother surface.
Mesh-AverageVertices
Mesh-Smooth
Non-Manifold and Invalid Geometry

• Non-Manifold:
  – A manifold mesh can be cut at selected edges and unfolded into a planar surface.
  – A non-manifold mesh does not have this property:
    • E.g., Three faces sharing an edge.
    • E.g., Two faces sharing a vertex, but not an edge.
    • E.g., Adjacent faces with opposite normals.

• Invalid Geometry:
  – Vertex not in any edge.
  – Edge not in any face.

• Some tools work on only a valid manifold.
• Use Cleanup tool to make a mesh a valid manifold.
Exercise: Animated Extrusion

- Make a NURB circle lying in the XZ plane.
- Make a NURB curve going up the Y axis from the circle center and then curving off.
- In the Surfaces menu set, invoke Surfaces-Extrude[] and reset settings and choose "Partial". Select the circle and then select the curve and LMB click Extrude.
- In the channel box, animate the maxValue of subCurve2 from 0 to 1 over frames 1 to 100.
- Select extrudedSurface1 and invoke Modify-Convert-NURBsToPolygons[] and choose TellelationMethod "General" and set #U 9 and #V 20 and "Tesselate".
- Invoke the panel menu item: Show-IsolateSelect-ViewSelected. Now you should see only the polygon surface you created.
- Select the 8 edges around the hole at the moving end of the polygon tube. In the Polygons menu set, select Mesh-FillHole. Now there's a cap.
- Select the nurbsToPoly1surface and invoke Polygons-Smooth.
Making a Polygon Mesh Head

• Create polygon primitive cube.
• Move rows and columns of vertices.
• Delete edges in eye sockets.
• Make inward extrusions for eyes and mouth.
• Use *Average* tool to round the crown.
• Move individual vertices to refine the face.
demo-05-polyhead-01.mb
demo-05-polyhead-03.mb
demo-05-polyhead-04.mb
Making a Polygon Mesh Body

- Create polygon primitive cube.
- Use *Bevel* tool to round the top and bottom.
- Use *Extrude Face* tool to create arms.
- Use *Extrude Face* tool to create legs.
- Use *Extrude Face* tool to create feet.
- Move individual vertices to refine the body.
demo-05-sl-male-skin.mb
demo-05-sl-female-skin.mb
NURB v. Polygon Mesh

• NURB:
  – Smooth.
  – Fixed rectangular grid topology.
  – Cannot be refined locally.

• Polygon Mesh:
  – Not smooth.
  – Variable topology.
  – Can be refined locally.
Subdivision Surfaces
(Best of both worlds?)

• Represent surface as a polygon mesh.
• Include rules for refining the mesh.
• Define the surface to be the limit of infinite series of refinements.
Subdividing a Surface

(Catmill – Clark)

For each face, create a new vertex that is a weighted sum of the vertices of the edges of the face.

For each edge, create a vertex that is a weighted sum of the vertices of the faces on either side of the edge.
Subdividing a Surface

(Catmill – Clark)

For each vertex, create a new vertex that is a weighted sum of the vertices on surrounding faces.

Special rule for subdividing boundary edges.
Subdividing a Surface

(Catmill – Clark)

Limit surface is bi-cubic uniform B-Spline.
Original vertices are control points.
Creating a Subdivision Surface

• Subdivision surface primitives.

• Conversion of an existing polygon mesh.
Subdivision Surface Editing Modes

• Polygon proxy mode.
  – Edit the polygon mesh from which the surface was created.
  – Use all polygon mesh editing tools.

• Standard mode:
  – Edit original mesh.
  – Edit any refined mesh or portion thereof.
  – Limited set of polygon mesh editing tools.
Create a polygon cone with 3 height divisions, 4 axis divisions and 1 division of the cap. Then invoke the menu item: *Proxy-SubdivisionProxy*.
Create a polygon cone with 3 height divisions, 4 axis divisions and 1 division of the cap. Then invoke the menu item: **Modify-Convert-PolygonsToSubDivs**. Then invoke the menu item: **Display-SubdivisionSurfaceComponents** (Edges and Vertices) to see the controlling polygon and its vertices.

demo-05-subdivision-cone-proxy2.mb
Select the polygon cone proxy. Then press and hold RMB to bring up the marking menu and go into face selection mode. Select the faces on the lower third of the cone and the bottom. (Left picture.) Then invoke menu item: *EditMesh-AddDivisions*. (Right picture.)

demo-05-subdivision-cone-proxy-refinement.mb
Select the subdivision surface. Then go into component mode and select the vertex at the apex. Use the Move tool to move the vertex downward.

demo-05-subdivision-cone-standard-manipulation.mb
Refinement of Selected Components

- Available in Standard Mode.
- User selects a set of vertices, faces or edges.
  - In the original mesh.
  - Or a previously refined mesh.
- System makes the refinement of the selected components available for editing.
- Does not change the subdivision surface itself.
Go into component mode and select the 5 vertices at the top. Press and hold RMB and invoke *RefineSelected*. Instead of the 5 selected vertices we now see 25 new vertices, giving us finer control over the shape.

demo-05-subdivision-cone-standard-refinement.mb
Display Level

- Works in Standard Mode.
- Set to Level 0 to show and edit the proxy mesh.
- Set to Level 1, 2, ..., N, ... to show and edit a refined mesh that was created previously.
The original 5 vertices are still there. First click on the gray background to deselect everything. Then press RMB to bring up the marking menu and select DisplayLevel-0. Now we see the original 5 vertices. We can still manipulate them for coarse-grained control over the shape. Now press RMB to bring up the marking menu and select DisplayLevel-1. Now we see the 25 new vertices. We can manipulate them for fine grained control over the shape.
Creasing a Subdivision Surface

- Press and hold RMB to bring up the marking menu.
- Choose “Edges” to go into edge selection mode.
- Select a sequence of edges along the subdivision surface.
- Invoke menu item: *EditMesh-CreaseTool*.
- Now the surface has a crease:
  - I.e. A line along which the surface is non-smooth.
  - I.e. A line along which the surface tangents are discontinuous.
- CV influences do not cross the crease line.
Collapsing a Subdivision Hierarchy

• Works in Standard or Polygon Proxy Mode.
• User selects number N of levels to collapse.
• System generates the Nth-level refined mesh.
• Nth-level refined mesh becomes the new polygon proxy mesh.
• Now all Polygon Mesh editing tools can be applied to the Nth-level refined mesh.
Creating a Subdivision Hand

- Start with a subdivision sphere, scaled down in the Y direction.
- Use *EditMesh-SplitPolygonTool* in Polygon Proxy Mode to make faces where fingers and thumb attach to hand.
- Use *EditMesh-Extrude* to extrude fingers and thumb.
- Move vertices in the proxy polygon to give the hand a fuller shape.
- Select and refine vertices near a finger tip to model a fingernail.
- Put a crease along the edge of the fingernail.
demo-05-subdivision-hand-01.mb
demo-05-subdivision-hand-04.mb
demo-05-subdivision-head-choi.mb
Converting a Polygon Mesh to a Subdivision Surface

• Select polygon mesh object.
• Invoke: Modify-Convert-PolygonsToSubdivs.
• Now the polygon mesh has become the proxy for a new subdivision surface.