2006-1252: CONCEPT MODELING WITH NURBS, POLYGON, AND SUBDIVISION SURFACES

James Wronecki, East Tennessee State University

James A. Wronecki is a designer/educator with diverse experience in design and digital media. He is an Assistant Professor at East Tennessee State University in the Technology Department's Digital Media Program. He received his Masters of Industrial Design from The University of the Arts in Philadelphia, PA. He has also served as an Instructor at The Art Institute of Atlanta, and as an Adjunct Professor at both The University of the Arts and Philadelphia University.

Concept Modeling with NURBS, Polygons, and Subdivision Surfaces

Introduction

Computer aided design (CAD) and computer aided industrial design (CAID) software programs provide effective NURBS based solid and surface modeling methods for engineers and designers. In the manufacturing pipeline, engineers use CAD for precision solid modeling, while industrial designers use CAID programs for technical surface modeling. Both solid and surface models and their corresponding methods can be complex and time consuming. In parallel, design visualization programs such as Alias Maya and Autodesk 3ds Max are used in entertainment industries to create animated films and digital games. These programs feature 3D modeling, photorealistic rendering, and animation tools that are useful for concept visualization and presentation. Design visualization programs typically have limited NURBS surface modeling tools derived from CAD and CAID programs. They also feature easy to use Polygon and Subdivision surface modeling tools and methods that are similar to sculpting with “digital clay”. In the engineering design process, design visualization programs can be used to quickly create concept models, render models, and produce animations for presentation.

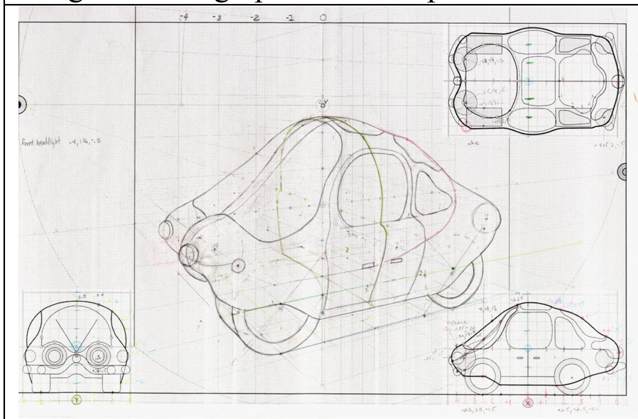
By researching and applying Maya’s NURBS, Polygon, and Subdivision modeling methods, the author presents an overview of each geometry type. The author also proposes a way to synergistically apply all three methods to rapidly create a 3D concept model. This tri part modeling methodology endeavors to intelligently use the specialized characteristics and capabilities of each method’s geometries. This tri part method is thought to be: simple as it can be easy to learn and use in both education and professional practice, straightforward as it goes from the general form to the specific details, and seamless as generated models can be imported without data loss into CAID programs.

The main goal of this three part method is to achieve form generation and shape exploration with greater ease, efficiency, and excellence. Using the methodology, the first concept model can be generated in a few hours by an experienced modeler. Variations on the first model can also be quickly made to create alternative concept study models.

This paper outlines three modeling methods by leading the audience through the workflow process of modeling a concept automobile. The paper is organized in three parts or stages called Phase 0: Concept Design, Phase I: NURBS, Phase II: Polygons, and Phase III: Subdivisions.

Phase 0: Concept Design

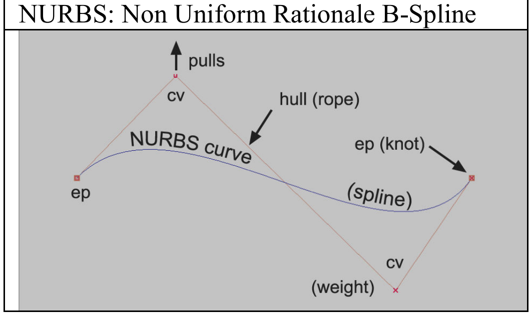
Image 0: Orthographic and Perspective



Before the modeling process begins, concept drawings were created in Phase 0. Here, the author designed a simple future concept car. The car was designed by sketching in three dimensions to create Top, Front, and Right Side Orthographic Views. The car was visualized in 3D by drawing a 30/60 angle of view with measured perspective techniques. Finally, orthographic sketches were imported into Maya's modeling views. At this point, the concept design stage ends and the tri-part modeling process begin.

Phase I: NURBS

NURBS: Non Uniform Rationale B-Spline

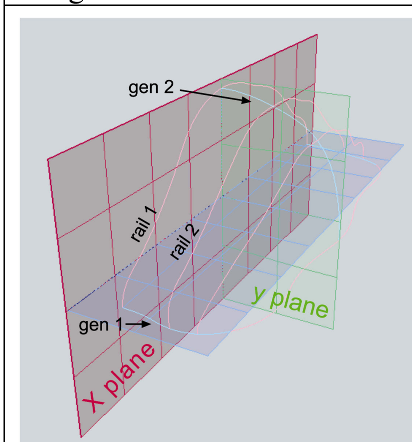


<u>NURBS Curves</u>

The NURBS phase begins by creating NURBS curves that match the profile curves of the concept car. In image 0, the profile curves are shown in bold in the Top, Front, and Side orthographic multi-views. By first positioning edit points and then manipulating control vertices any three dimensional curve can be created.

Derived from ship-building practices, NURBS curves, like curved "wood" *splines,* are formed by using *hulls* or "ropes" tied to a curve at *edit points (ep)* or "knots" that pull with *control vertices (cv) or* "weights" that bend the curve. Knots or edit points are attached directly to the curve's end points or *on* points along a curve. Control vertices are weighted control points that reside *off* the curve, and on hulls, that influence the smoothness of a curve by pulling on edit points.

Image 1a: NURBS Curves



Maya can create NURBS curves that reside on live surfaces, on grided orthographic planes, or at any point in 3D space. However, when using orthogonal modeling views, flat 2D curves are drawn on the Side (red X plane), Front (green Y plane) or Top (blue Z plane) construction planes. Scanned digital images can also be placed on these orthographic planes as either image planes or as textured image maps.

With scaled top, front, and side reference images on each plane it is a simple matter to create 2D profile curves by tracing the sketched curve on orthographic planes. Since this model example is symmetrical, or the same on both sides of the x plane, only half of the profile curves need to be made.

Quality Surfaces

In this stage, the profile NURBS curves will be used to construct *quality* 3D NURBS surfaces using the Birail surface creation tool. To ensure that quality curves and surfaces are constructed, and the proper function of the Birail tool, the Surface Rules and Birail Guidelines listed below must be followed. The term *quality,* defined here, refers to the ability of curves and surfaces to describe the general form of the concept being modeled with *even* contour lines, called isoparms, and *exact* four sided surfaces, called patches. This quality can be referred to as *exact shape* quality and *even surface* quality. Shape quality refers to how *exactly* and *effectively* the curves and surfaces match the orthographic drawings and perspective shape drawn by the designer in Phase 0. Surface quality refers to how *evenly* and *efficiently* the surface patches describe the surface. Therefore, *quality* surfaces precisely define the general shape of the object with the fewest number of isoparms and surface patches spread evenly throughout the form.

Surface Rules and Birail Guidelines

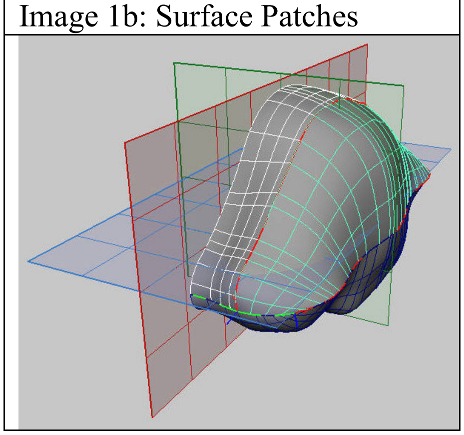
1st rule: Profile and rail curves need a limited and equal number of edit points (ep's) to ensure efficient curve parameterization and even distribution of surface isoparms.
2nd rule: Align the ep's for each curve such that the created surface isoparms wrap around the shape of the model in even cross sections.
3rd rule: In order for the birail tool to create a surface each profile curve must intersect, or touch, its corresponding rail curve at a given location.

By following these rules and guidelines, the NURBS profile curves and the by Birail tool were used to run X # of generation or profile curves along two rail curves (see image 1a).

NURBS Surfaces

The resulting surface patches have isoparms that reside at curve edit points and effectively wrap around the half the model. The surface patches were aligned to make them curvature continuous to one another so they appear seamless. The patches were attached, after ensuring that the patches: U and V directions go in the same direction, normals face out, and edges are stitched. With one single surface patch describing half the shape of the car it is mirrored to finish the basic form.

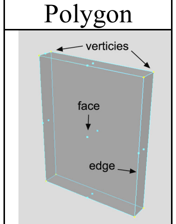
Image 1b: Surface Patches



Phase II: Polygons

Polygons are closed shapes defined by groups of ordered vertices that form straight lines called edges. Useful polygons are typically either three sided or four sided. The area enclosed by polygon edges is called a face which can be either planer (flat) or non-planer. Polygon vertices can be moved. Polygon edges and faces can be both moved and extruded.

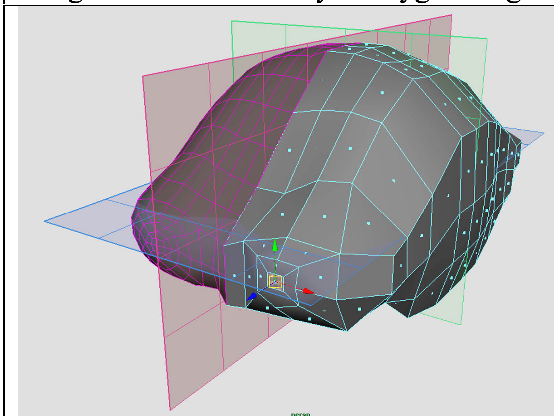
Polygon



A polygon object composed of set of combined or joined polygons is called a mesh. An object composed of disjointed sets of polygon geometries is called a shell. Shells can be joined to form a single polygon mesh by first using Combine and then either the Merge Vertices or Merge Edges tools.

Polygon Cage

Image 2: Smooth Proxy / Polygon Cage



In the polygon phase, a simple polygon mesh is created by either: a) converting and editing the NURBS surface, b) creating a simple polygon mesh directly from NURBS curves by setting polygon output options in NURBS surface tools, or by c) using the "box method" to sculpt the surface using polygon tools and the first NURBS surface as a reference. The resulting polygon mesh should be a single surface mesh and be composed of quad or 4 sided polygon faces. The polygon mesh is called a cage. The cage needs to be simple and have the fewest number of faces vertices, edges, as possible.

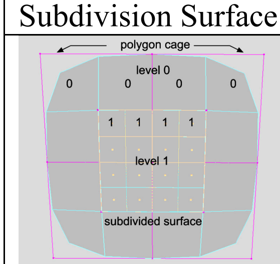
Smooth Proxy / Symmetrical Modeling

A polygon cage can be smoothed to form organic shapes. A simple box-like cage can be easily sculpted while a smooth proxy version automatically displays smooth surface results. In Maya, this function is called Smooth Proxy in other packages it is known as meshsmooth. Maya's smooth proxy options can be set to allow simple polygon cage sculpting on one side of the axis of symmetry and automatic viewing of the mirrored smooth mesh on the other. In the concept car example, a semitransparent polygon cage and smooth proxy were quickly and easily sculpted with option c) box method by using the first NURBS surface as a visual shape reference.

Once half the model is sculpted and edited satisfactorily, a full smooth version and single surface mesh was created using the Mirror Geometry tool. The polygon cage was then duplicated and edited to rapidly sculpt a variety of alternative concept study models.

Phase III: Subdivision Surfaces

Subdivision Surface

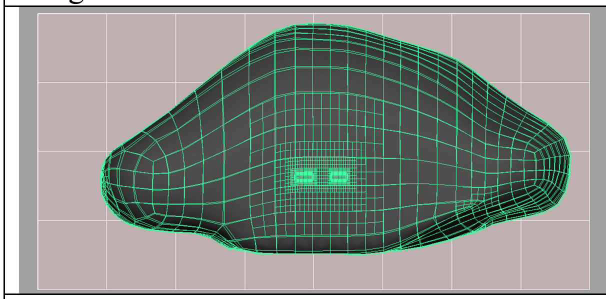


A smoothed polygon cage can be converted to a subdivision surface to add details to a concept model. Subdivision surfaces are a hybrid that provides smooth organic NURBS modeling features with the detail and extrusion capabilities of polygon modeling. Subdivision surfaces add levels of detail to specific areas to model complex surface details. The based subdivision surface is called level zero and is course or rough. Level 0 subdivision surfaces resemble a smoothed polygon. However, up to 12 additional subdivisions of polygon faces, called levels, of increasing fineness can be added to refine the surface shape and add surface details. Subdivision surfaces levels are like subdivided polygons that can also be creased to form a hard or edge.

Subdivision Modes

There are two modes for a subdivision surfaces called polygon mode and standard mode. In polygon mode, all polygon tools and options are available and the surface is editable as a Level 0 or base polygonal mesh. In standard mode, the surface can be subdivided where detail is needed. Subdivided edges can be set to have either a full crease (hard edge or vertex) or partial crease (smooth edge or vertex).

Image 3: Subdivision Car Surface



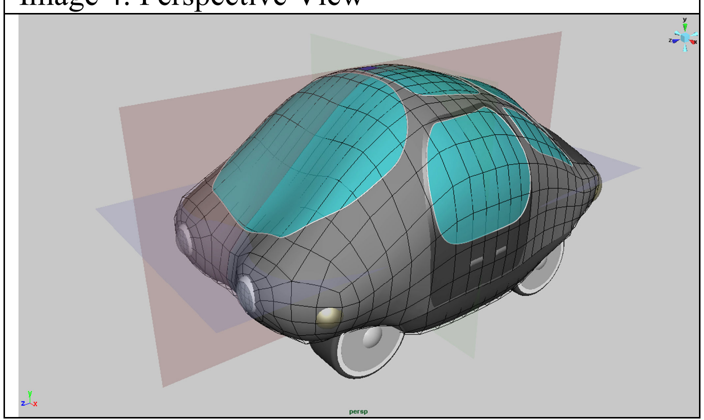
Wronecki, 2006

Car Details

To quickly create door handles on one subdivision surface concept model, a side orthographic reference view was used to determine which polygon faces to select and subdivide. Subdivided edges surrounding the door handles were then selected and set to have a hard crease using the Full Crease tool. These subdivided faces were selected and moved to quickly form the general shape of the door handles. The hard crease stopped the surrounding surface from pulling out with the handle. In Maya 7, the ability to crease polygon surfaces edges has been added. Polygon mode surface edges can also be manually subdivided with the Split Polygon tool. However, manual splitting of polygons tends to distort the topology of the smooth polygon surface mesh.

Car Windows and Doors

Image 4: Perspective View



To create windows and doors for the car, flat 2D NURBS curves were created by tracing orthographic views onto the X, Y, and Z planes. With the flat 3D window and door curves were projected onto the 3D car surface to create *curves on surface* (cos). However, since curves can only be projected onto NURBS surfaces, the subdivision surface was converted to a NURBS surface for final detail modeling.

With 3D window curves on the NURBS surface, the windows and doors were quickly created using the Trim tool. The Trim Edge selection tool was used to select the trimmed edge. The Duplicate Surface Curves tool created the actual window/door border edge curves. Finally, a circle was extruded along these border curves to create the window and door surface trim.

Lights

Primitive shapes were used and edited to create details such as car lights. Boolean operations can be performed to attach primitive shapes to single surface NURBS and Polygon models. In Maya, Boolean operations cannot be performed on trimmed surfaces.

Model Conversions

In Maya, polygon surfaces can only be converted to Subdivision Surfaces. Converting Subdivision to NURBS surfaces breaks apart single surface meshes into multiple NURBS surface patches that need to be re-attached. NURBS surfaces can be imported into either CAD or CAID software and used as either surface references or modeling geometries.

Rendering

With built in U V coordinates material shaders and textures can be dragged and dropped onto NURBS surfaces patches. Each patch can have one material shader. Polygons and subdivision meshes can have different shaders and textures assigned to selected faces. U V coordinates for polygons, however must be manually described using a set of Polygon U V tools. When texturing polygon meshes post modeling U V texture mapping methods must be performed.

Conclusions

The tri part modeling methodology presented in this paper requires a good working knowledge of all three surface modeling techniques. However, its methods do afford creative power and flexibility by synergizing the unique characteristics and capabilities of each surfacing technique.

NURBS curves are effective for accurately creating surfaces that efficiently describe a specific shape outline. Alternative concept shapes can be formed with NURBS surfaces by transforming the profile construction curves with history or by modifying surface cv's. NURBS patch modeling however, is precise, complex, and often difficult to manage.

Polygon modeling is simple and straightforward. Polygon surface cages enable the user to simply sculpt a single surface by moving and extruding edges and faces. The smoothed versions of polygons have built in curvature continuity providing smooth organic shapes with no seams. Students find that sculpting and editing a simple polygon cage and single mesh is often easier that stitching, aligning, and attaching NURBS surface patches.

Subdivision surfaces enable the user to add various level of detail by creating additional subdivided polygon faces where needed. Subdivision surfaces are edited with polygon tools.

The accuracy of NURBS, simplicity of polygons, and details of subdivision surfaces enables concept models and alternative form study models to be made quickly and intuitively. With 3D concept models engineering designers can communicate their visualized ideas early on in design reviews and create photorealistic renders later on for marketing and sales presentations.

Bibliography

1. Alias Systems (2004) NURBS Modeling. Alias Toronto, Canada
2. Alias Systems (2004) Polygon Modeling. Alias Toronto, Canada
3. Alias Systems (2004) Subdivision Surface Modeling. Alias Toronto, Canada