Resolution Independent NURBS Curves Rendering using Programmable Graphics Pipeline

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Motivation

• Visualize NURBS Curves:
  • Resolution independence
  • Fast Rendering, and pre-processing.
• Minimal memory storage.
• Resolution independent UI and CAD drawing in a 3D Scene.
• On embedded devices!
Background

• NURBS Curves:
  • Provides additional DoF namely, Weights.
  • Fewer Control Points to describe complex shapes
  • Widely used in CAD.

• NURBS Visualization:
  • Heavy pre-processing.
  • Common approach: Convert to Bezier data.
  (SVG...) - Post Design Visualization

\[ C(x) = \frac{\sum_{i=0}^{n} N_{i,D}(x)w_i P_i}{\sum_{j=0}^{n} N_{j,D}(x)w_j} \]
Related Work

GPU NURBS Rendering, using textures

Direct evaluation of nurbs curves and surfaces on the gpu, Krishnamurthy et al. 2007

Images from referenced authors/papers

Resolution Independent, Bezier Curves

Resolution independent curve rendering using programmable graphics hardware, Loop Blinn 2005
Our Method: Input

- Set of outlines (shape's boundaries).
  - Vertices are of two types: off-curve, on-curve.
  - Each vertex has x, y, z, w as attributes.
Our Method: Input

• Convert curved parts of the outlines to a set of triplets.
  • Each triplet has one off-curve → *curved* triangle
• The inner regions → *non-curved* triangles. (Triangulation)
Modified Delaunay Triangulation.

4 Outlines

For each outline:
- Triangulation done Independently.
- No cleanup phase.
- No extra triangles.

3 Loops
Rendering – Quadratic Curve

• Let the control points be:

\[ p_0 = [0 \ 0 \ w_0], \quad p_1 = [\frac{1}{2} \ \frac{1}{2} \ w_1] \quad \text{and} \quad p_2 = [1 \ 0 \ w_2] \]

• Perform a Triple Knot insertion.

\[ K = [0 \ 0 \ 0 \ 1 \ 1 \ 1] \]

• Assign \( P_i \) as texture Coordinates to each \textit{curved} triangle
Rendering – Quadratic Curve

• Derive the implicit form of the curve.

\[ f = v - \frac{w_1 u (1 - u)}{(w_0 - 2w_1 + w_2)u^2 + 2(w_1 - w_0)u + w_0} \]

• Using the implicit function we can check if a fragment is in \((f < 0)\) or out.

• Setting \(P_1=[1/2\quad -1/2]\) for out, we can always render in.
Rendering – Quadratic Curve

- Each curved triangle can be manipulated using $W_1$

  Equiv to LoopBlinn2005

- We note that the Curve is Aliased.
Rendering Regions: Frag. Shader

- Compute $\nabla g(x, y)$ using the chain rule:

$$\nabla g = \begin{bmatrix}
g^x_y - \frac{w_1((w_0-w_2)u^2-2w_0u+w_0)g^x_x}{(\alpha u^2+2\beta u+w_0)^2} \\
g^y_y - \frac{w_1((w_0-w_2)u^2-2w_0u+w_0)g^y_x}{(\alpha u^2+2\beta u+w_0)^2}
\end{bmatrix}$$

where

$$\alpha = w_0 - 2w_1 + w_2, \quad \beta = w_1 - w_0$$
Anti Aliasing

• Compute the signed distance:

\[ e(u, v) = \frac{1}{2} - \text{sign}(v) \frac{f}{\|\nabla g\|} \]

• Classify:

\[ \text{class}(u, v) = \begin{cases} 
\text{in} & \text{if } e(u, v) \geq 1 \\
\text{out} & \text{if } e(u, v) \leq 0 \\
\text{boundary} & \text{otherwise.}
\end{cases} \]
Anti Aliasing

• For curved triangles – done.
• Non curved:
  • MSAA – General Case.
  • VBAA – Two pass rendering

The quick brown fox jumps over the lazy dog
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Implementation - API

• Part of Jogl Open Source Project!
• Graph API: RI shapes, Text and User Interface

http://jogamp.org

Application

- P&ID visualization: (Desktop & Mobile)
Conclusion & Future Work

- Presented a method for rendering NURBS curve
  - Resolution Independent
  - Mobile ready! (OpenGL ES2 impl)
  - No heavy preprocessing and memory usage.
- Future work:
  - Resolution Independent User Interface and UI Design tool.
  - Resolution independent P&ID viewer
Thank you!