Adventures with the GPU

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My goals for this talk

• Provide resources and motivation to get started with shader programming roice3.org/icerm

• A few mathematical detours

• Share fun with @TilingBot and a resulting art piece

• Tons and tons of pictures and animations! Maybe too many
What is a shader?

Shaders are little programs that run on the GPU. These programs run at certain points of the graphics pipeline.

```c
void mainImage( out vec4 fragColor, in vec2 fragCoord )
{
    // Normalized pixel coordinates (from 0 to 1)
    vec2 uv = fragCoord/iResolution.xy;

    // Time varying pixel color
    vec3 col = 0.5 + 0.5*cos(iTime+uv.xyx+vec3(0,2,4));

    // Output to screen
    fragColor = vec4(col,1.0);
}
```
From primitives to shaders
From **primitives** to shaders
From primitives to shaders
From primitives to shaders
Spherical Image

A shader to rotate around a spherical image

Views: 0, Tags: image, spherical
Shader #2:
Isometry classes of hyperbolic space

\[ F(z) = \frac{az + b}{cz + d} \]

\[ \hat{\mathcal{C}} = \mathcal{C} \cup \{\infty\} \]

Group of Möbius Transformations

\[ PSL(2, \mathcal{C}) \cong PGL(2, \mathcal{C}) \]
This is not a cone
It’s a cylinder in UHS model: Elliptic Isometry
Hyperbolic Isometry
Hyperbolic Isometry
Loxodromic Isometry
Loxodromic Isometry
This is not a plane
It’s a horosphere: Parabolic Isometry
Raymarching

See “Ray Marching and Signed Distance Functions” by Jamie Wong

Credit: GPU Gems 2: Chapter 8
Quaternions!

\[ z \mapsto \frac{az + b}{cz + d}, \quad z \in \hat{\mathbb{C}} \]

\[ w = z + yj, \quad y \in \mathbb{R}^+ \]

\[ w \mapsto \frac{aw + b}{cw + d} \]
Shader #3: Spherical Images
Shader #4: Hyperbolic VR using Raymarching

Folding AND Raymarching, see Henry’s NSF video!
Utilities

- Shadertoy-render
- ffmpeg
- Pov-Ray
- LinqToTwitter

Again, links (and scripts) at: roice3.org/icerm
In my experience...

Advantages
• Fast!
• Motion
• Quality
• Fractals
• WebGL
• Lots of Examples

Disadvantages
• Hardware
• Debugging
• Optimization
• Low-level
• Code libraries
“The explorer who will not come back or send back his ships to tell his tale is not an explorer, only an adventurer.”

-Ursula K. Le Guin, *The Dispossessed: An Ambiguous Utopia*
@Tilingbot
The Real Shader #1: Hyperbolic Wythoff explorer
by Matt Zucker, mzucker.github.io
Regular and Rectified
Uniform Tilings

Bitruncation

5

7
Uniform Tilings

Cantellation

5

Cantellation

7
Uniform Tilings

Omnitruncation

5

7
Duals to Uniform (Catalan Tilings)
Rotating in a conformal square

Snub \{8,8\}
In a rotating conformal square

Omnitruncated \{6,9\}
Excellent illustration of the Koebe distortion theorem

#Hyperbolic #tiling shown in a rotating conformal square projection. Omnitruncated {6,9}.
Liquid Plutonium
@LiquidPlutonium

Replying to @TilingBot

Lol 69

4:21 PM · 3/17/19 · Twitter for Android
Rotating in the band model

Truncated \{6,4\}
In a rotating band model

Truncated \{8,4\}
Limit Rotations

Omnitruncated \{4,\infty\}

Truncated \{3,\infty\}
Joukowsky projection

named after Nikoli Zhukovsky

\[ z = \frac{1}{2} \left( \zeta + \frac{1}{\zeta} \right) \]
The best internal representation?
Thank you!

roice3.org/imerm