VGP352 – Week 10

- Agenda:
  - Quiz #3
  - Multiple render targets
  - Deferred shading
  - Discuss the final

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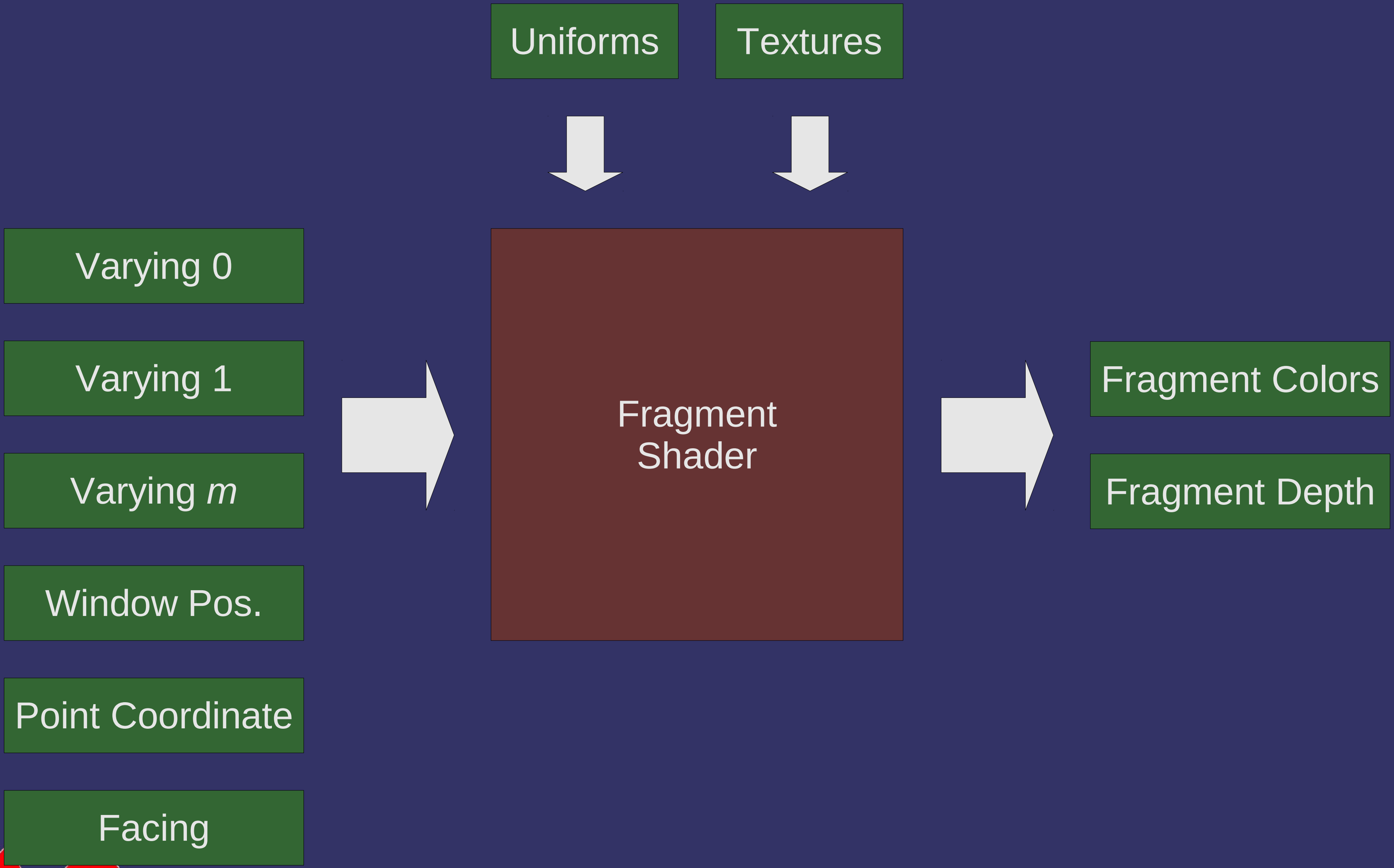
MRT

- Multiple color outputs from the fragment shader
  - For practical purposes, requires the use of framebuffer objects
  - Slightly changes GLSL syntax

MRT


Uniforms
Textures
Varying 0
Varying 1
Varying *m*
Window Pos.
Point Coordinate
Facing
Fragment
Shader
Fragment Colors
Fragment Depth

Framebuffer Objects

- Attach one or more renderable objects to it
  - 1D, 2D, and 3D versions exist

```
void glFramebufferTexture2DEXT (GLenum target,
    GLenum attachment, GLenum textarget,
    GLuint texture, GLint level);

void glFramebufferRenderbufferEXT(
    GLenum target, GLenum attachment,
    GLenum renderbuffertarget,
    GLuint renderbuffer);
```

Selects how the buffer is used:

- Color buffer: `GL_COLOR_ATTACHMENT0`
- Depth buffer: `GL_DEPTH_ATTACHMENT`
- Stencil buffer: `GL_STENCIL_ATTACHMENT`

MRT – FBO Usage

- Use additional color attachments
  - e.g. `GL_COLOR_ATTACHMENT1`
  - Maximum number of attachments queryable with `GL_MAX_COLOR_ATTACHMENTS`
  - EXT_fbo requires that all color attachments have the same internal format
    - ARB_fbo / OpenGL 3.0 allow drivers to relax this restriction
    - The driver can still reject a particular combination
    - Most hardware can handle combinations with the same size internal formats
      - e.g. `GL_RGBA8` with `GL_RGBA_10_10_10_2`

MRT – Setting Draw Buffers

- Connect attachments with shader outputs:

```
void glDrawBuffers(GLsizei n,
    const GLenum *bufs);
```

  - `bufs` gives a list of attachments points to connect, in the specified order, with shader outputs
    - Shader output 0 gets the first listed attachment, output 1 gets the second, etc.
  - Maximum number of outputs queryable with `GL_MAX_DRAW_BUFFERS`

MRT – GLSL Usage

- `gl_FragColor` is but one output. What to do?
  - Replace with a new output that is declared as an array:

```
vec4 gl_FragData[];
```

  - Each element in `gl_FragData` corresponds to one of the outputs set by `glDrawBuffers`

References

Jones, Rob. “OpenGL Frame Buffer Object 201.” GameDev.net. December 14th, 2006. Accessed on June 10th, 2009. http://www.gamedev.net/reference/articles/article2333.asp

Deferred Shading

- Scenes with high depth complexity or many lights suffer from several problems:
  - Many passes to implement the lights
  - Lots of wasted fragment processing
  - Difficulty with per-batch storage for shadow maps
  - Difficulty with stencil shadows from multiple lights
  - etc.
  - End result: poor performance

Deferred Shading

- What if we could easily:
  - Light each pixel (not fragment) exactly once
  - Only apply lights to the fragments they affect
  - Reduce per-light cost in scenes with many lights

Deferred Shading

- General idea:
  - Render scene information needed for shading to an off-screen geometry buffer (G-buffer)
  - Draw per-light geometry to screen sampling from G-buffer to calculate shading

Deferred Shading – G-Buffer

- All per-fragment data required for shading:
  - Normal
  - Position
  - Diffuse / specular color
  - etc.
- Emit this during per-object rendering
  - Output this data instead of performing lighting calculations
  - Use MRT!

Deferred Shading – G-Buffer

- Example G-buffer layout:
  - 2 RGBA16F outputs:

Diffuse (red)	Diffuse (green)	Diffuse (blue)	m
Normal (X)	Normal (Y)	Normal (Z)	n

  - m is the Cook-Torrance roughness
  - n is the index of refraction

Deferred Shading – G-Buffer

- Tough choices:
  - Explicitly store position or derive from screen X/Y and depth value?
  - Explicitly store the normals Z or derive from its X and Y?
  - One of the most important parts of designing a deferred shading engine is selecting the parameters and the packing

Deferred Shading – G-Buffer

- CryEngine 3 stores normals in 2 components
  - Encode:

```
normal_g = normalize(normal.xy) *
    sqrt((normal.z / 2.0) + 0.5);
```

  - Decode:

```
normal.z  = (length(normal_g.xy) * 2.0) — 1.0;
normal.xy = normalize(normal_g.xy) *
    sqrt(1.0 – (normal.z * normal.z);
```

  - Very similar to the mapping for spherical reflection maps
  - More expensive to compute, but has better precision

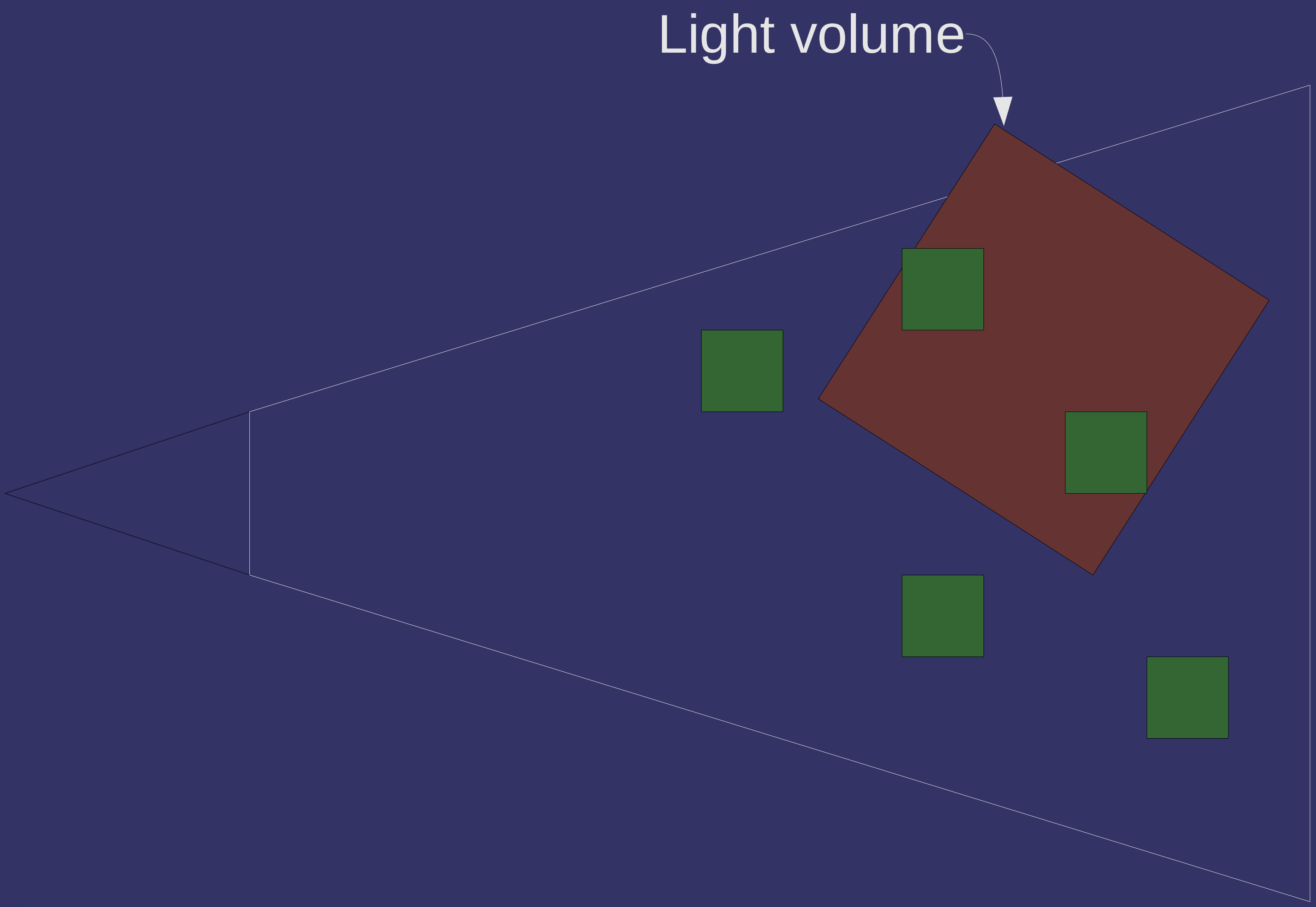
Deferred Shading – Lighting

- For each light, draw simplified bounding geometry
  - Perform lighting for each fragment drawn
    - Only light the areas of the scene that need lighting
    - Read from G-buffer at the screen X/Y position
    - Add calculated lighting to existing values
  - Examples:
    - Directional light: box
    - Point light: sphere
    - Spot light: cone

Deferred Shading – Lighting

- Optimize by letting the early stencil test discard many fragments
  - Draw the light volume once:
    - Disable color writes
    - Set depth function to `GL_LESS` and stencil function to `GL_ALWAYS`
    - Set Z-fail stencil operation to `GL_REPLACE` and all others to `GL_KEEP`
  - Draw the light volume again:
    - Enable color writes
    - Set depth function to `GL_LEQUAL` and stencil function to `GL_EQUAL`
    - Set all stencil operations `GL_KEEP`

Deferred Shading – Lighting



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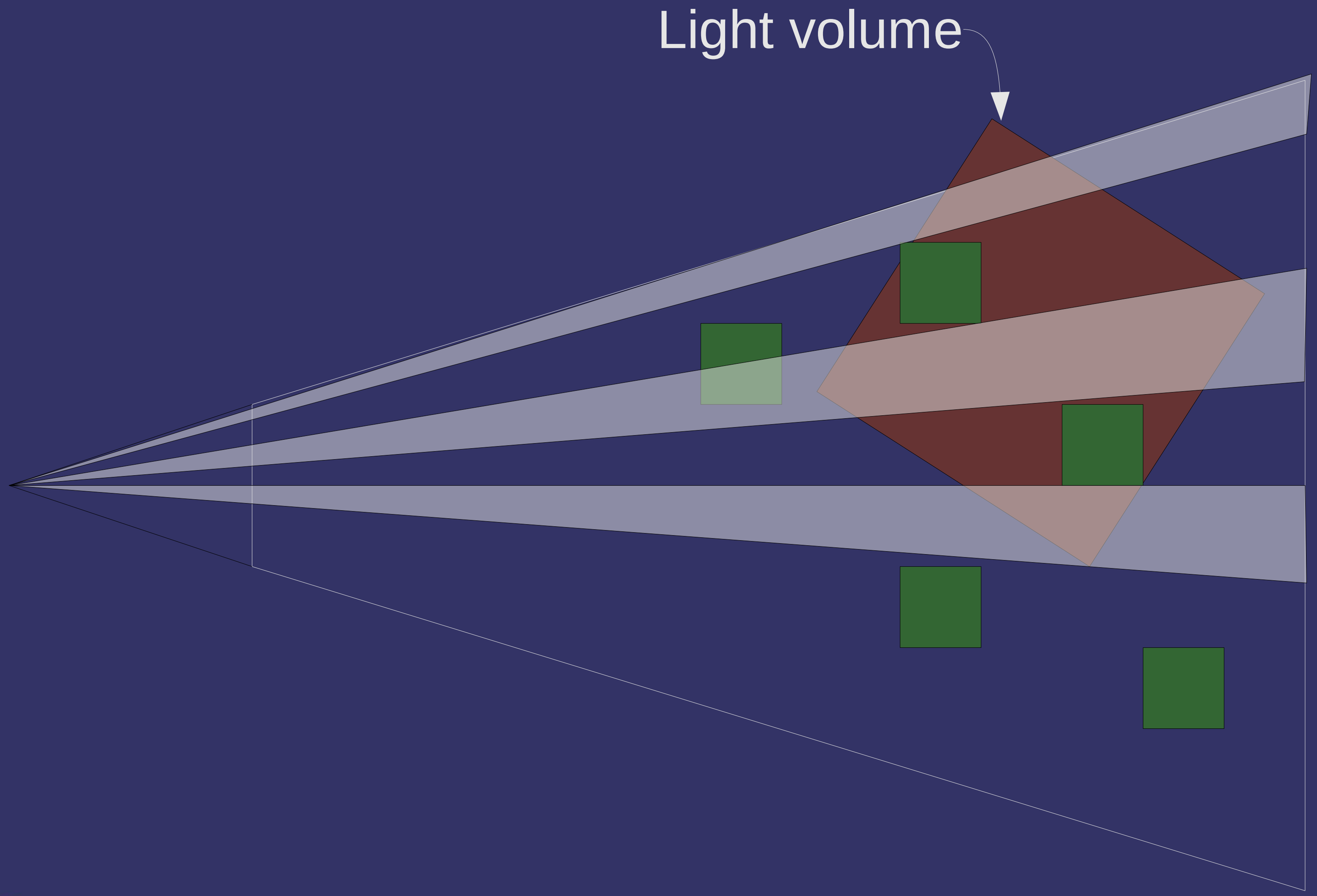
Deferred Shading – Lighting



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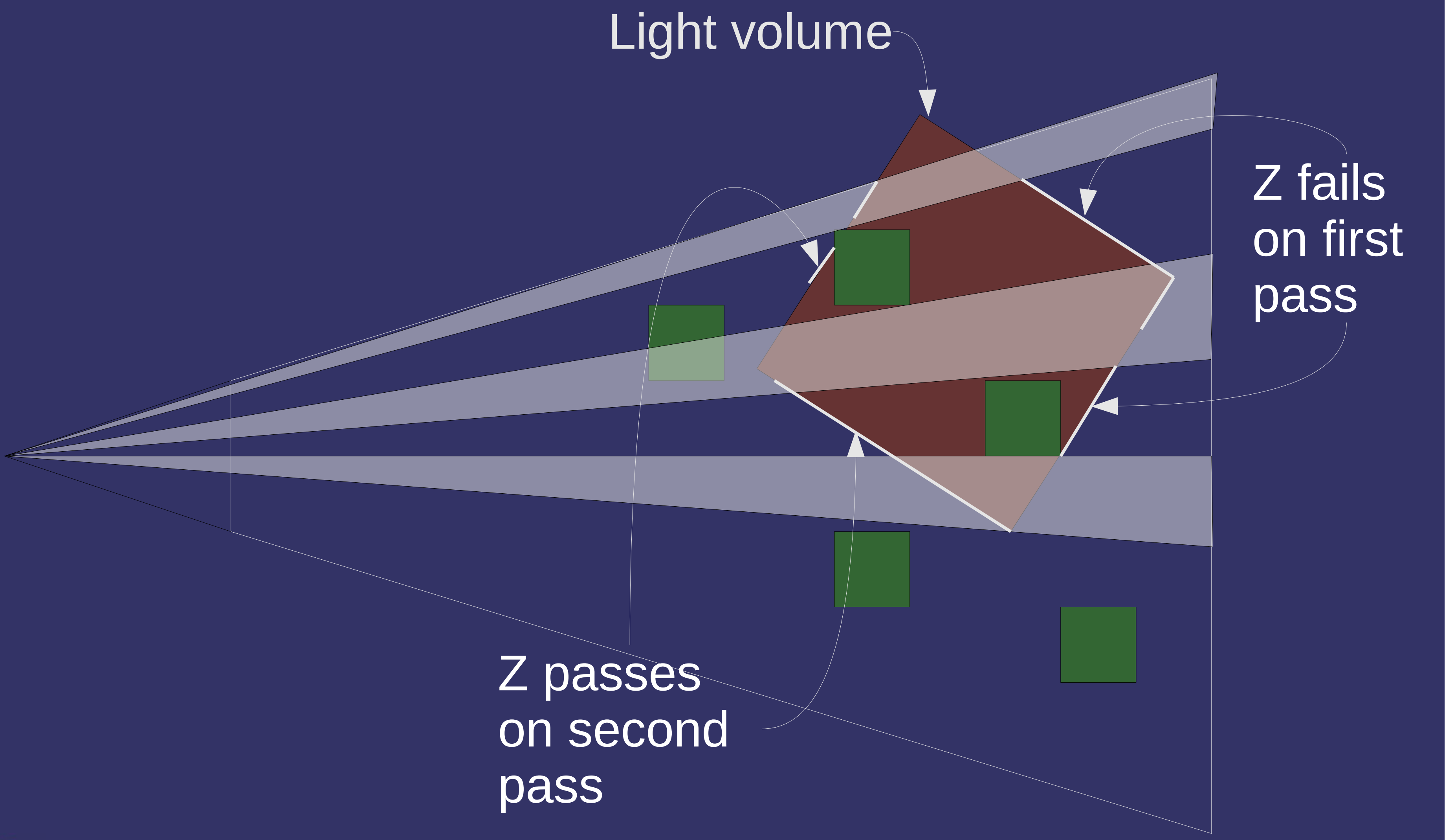
Deferred Shading – Lighting



Light volume

Z fails on first pass

Z passes on second pass

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Deferred Shading – Drawbacks

- What could go wrong?

Deferred Shading – Drawbacks

- What could go wrong?
  - Transparency effects won't work
  - Traditional anti-aliasing (multisampling) has problems

References

Hargreaves, S., Harris, M. “Deferred Shading.” Nvidia 6800 Leagues Under the Sea. June 2004. http://developer.nvidia.com/object/6800_leagues_deferred_shading.html

Fabio Policarpo, Francisco Fonseca, *Deferred shading tutorial*. Pontifical Catholic University of Rio de Janeiro. 2005. http://www710.univ-lyon1.fr/~jciehl/Public/educ/GAMA/2007/Deferred_Shading_Tutorial_SBGAMES2005.pdf

Shishkovtsov, Oles. "Deferred Shading in S.T.A.L.K.E.R." in Fernando, Randima (editor) GPU Gems 2, Addison Wesley, 2005. http://http.developer.nvidia.com/GPUGems2/gpugems2_chapter09.html

Mittring, M. “A bit more deferred – CryEngine3.” Triangle Game Conference 2009. http://www.crytek.com/technology/presentations/

Global Illumination

- Can deferred shading be used to implement global illumination?
  - Yes, but...
    - Only for a single “bounce”
    - Only for diffuse inter-reflections
- Deferred shading makes using many lights very cheap
  - Where many can mean 100's
  - Generate a bunch of fake lights that represent the reflection of light from surfaces
    - Call these *virtual point lights* (VPLs)

Virtual Point Lights

- Generate VPLs:
  - Trace paths from each light to first intersection
    - This determines the position of the VPL
    - Treat all VPLs as 180° spot lights
  - Calculate reflection at intersection
    - This determines the intensity of the VPL

References

Samuli Laine, Hannu Saransaari, Janne Kontkanen, Jaakko Lehtinen, and Timo Aila. "Incremental Instant Radiosity for Real-Time Indirect Illumination." Eurographics Symposium on Rendering 2007. http://www.tml.tkk.fi/~timo/

Next week...

- The final

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