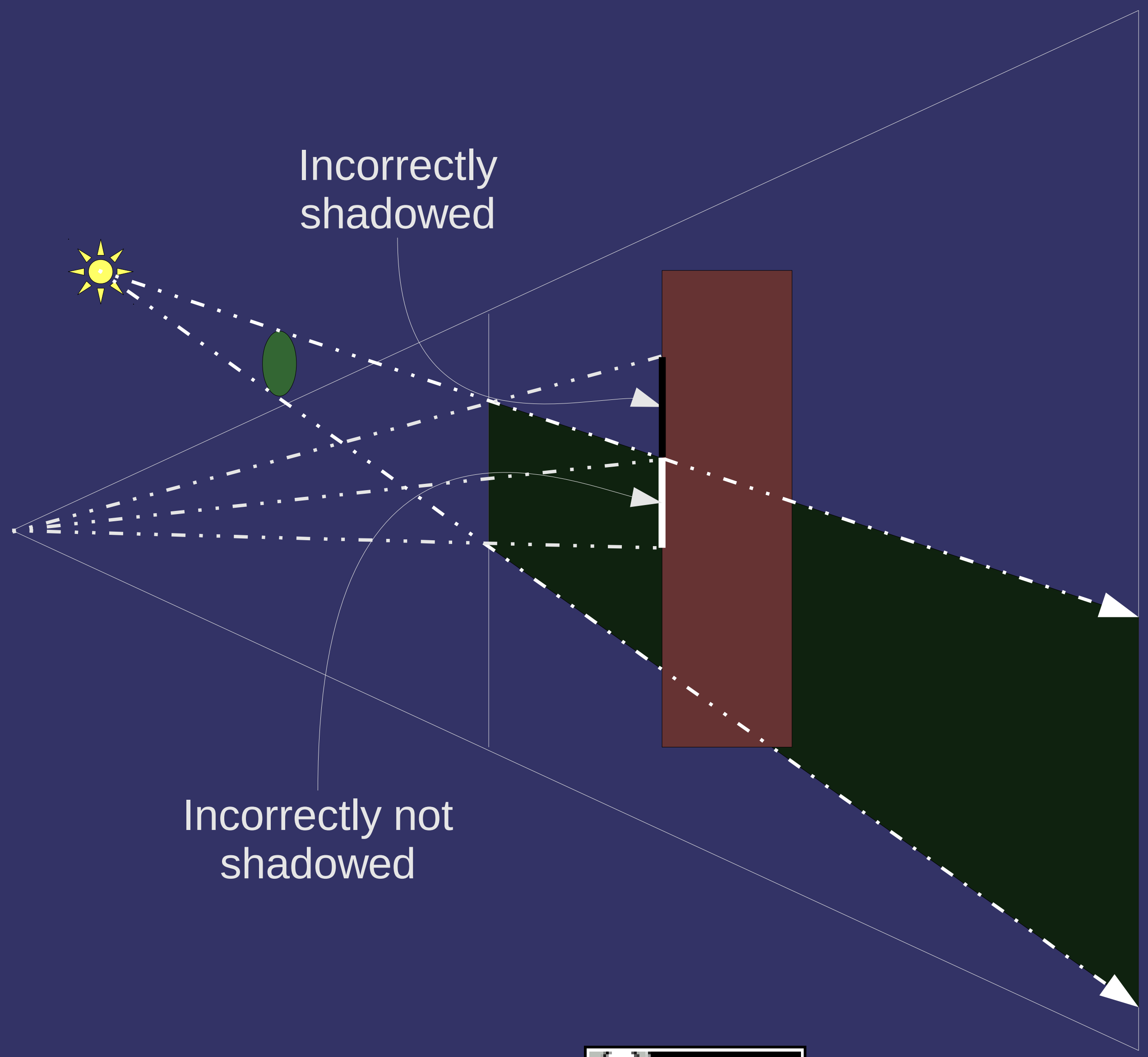
VGP353 – Week 6

- Agenda:
  - Fixing z-pass and z-fail with ZP+
  - Hardware based optimizations:
    - Depth clamping
    - Depth bounds testing

Z-pass Problems

- Z-pass has problems when the light and occluders are outside the view frustum
  - This *includes* the case where the camera is inside a shadow volume
  - Shadow volume geometry that is clipped by the near plane is the source of all the z-pass problems
- Partially solved by generating front-cap geometry
  - Generating this geometry is hard
  - This difficulty led to the invention of z-fail

Z-pass Problems



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  - Front-facing (w.r.t. the light) occluder geometry projected onto the camera's near-plane
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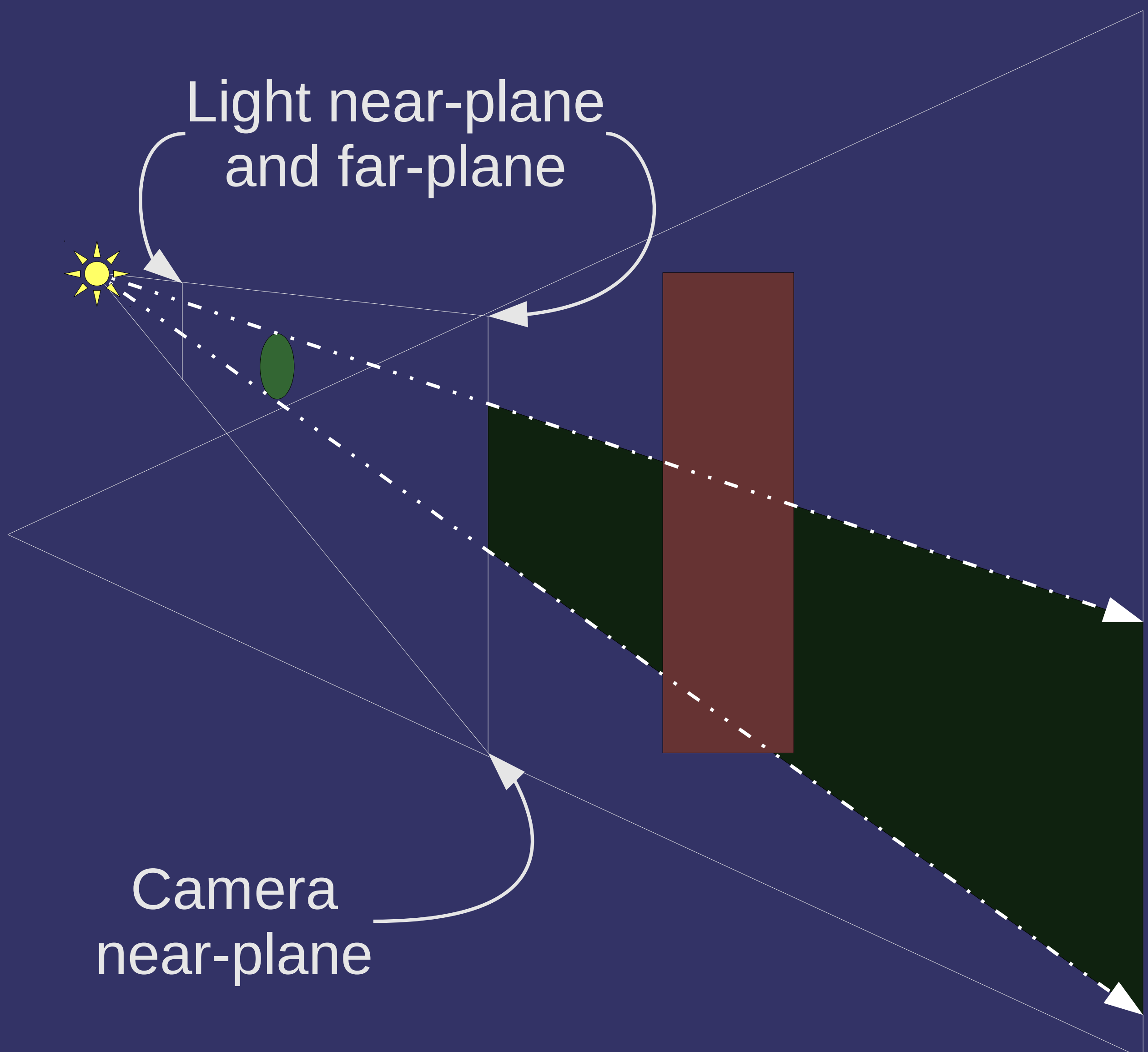
  - Why not *do* just that: project front-facing occluder geometry on the the camera's near-plane
- ZP+ Algorithm:
  1. Position eye at light
  2. Orient view frustum parallel (or anti-parallel) to the camera frustum
  3. Set far-plane to match the camera's near-plane
  4. Draw front facing geometry into stencil buffer

ZP+



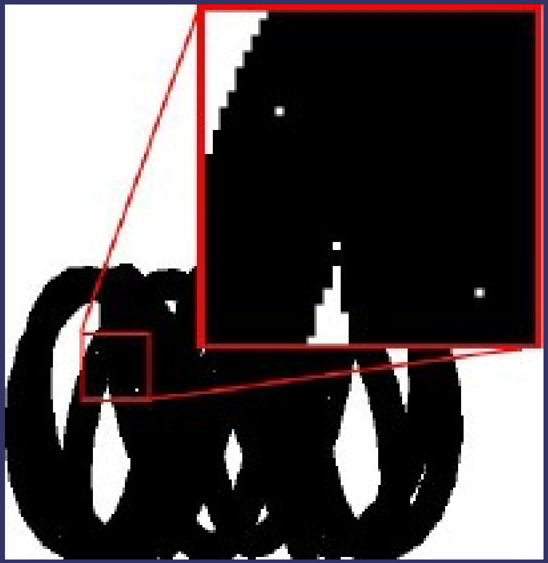
ZP+

- Projection matrix is:

$$P_l = \begin{pmatrix} \frac{2\alpha f}{c_{width}} & 0 & -2\frac{\Delta_x}{c_{width}} & 0 \\ 0 & \frac{2f}{c_{height}} & -2\frac{\Delta_y}{c_{height}} & 0 \\ 0 & 0 & \frac{n+f}{n-f} & \frac{2n+f}{n-f} \\ 0 & 0 & -1 & 0 \end{pmatrix}$$

ZP+

- Since geometry is drawn with different projections, rounding errors can cause slight cracks to appear:



  - Not a significant problem in practice
  - Can be solved, see paper for details

References

Hornus, Samuel; Hoberock, Jared; Lefebvre, Sylvain; Hart, John C., "ZP+: Correct Z-Pass Stencil Shadows." In *Proceedings of ACM Symposium on Interactive 3D Graphics and Games*. ACM Press, April 2005. http://artis.imag.fr/Publications/2005/HHLH05/

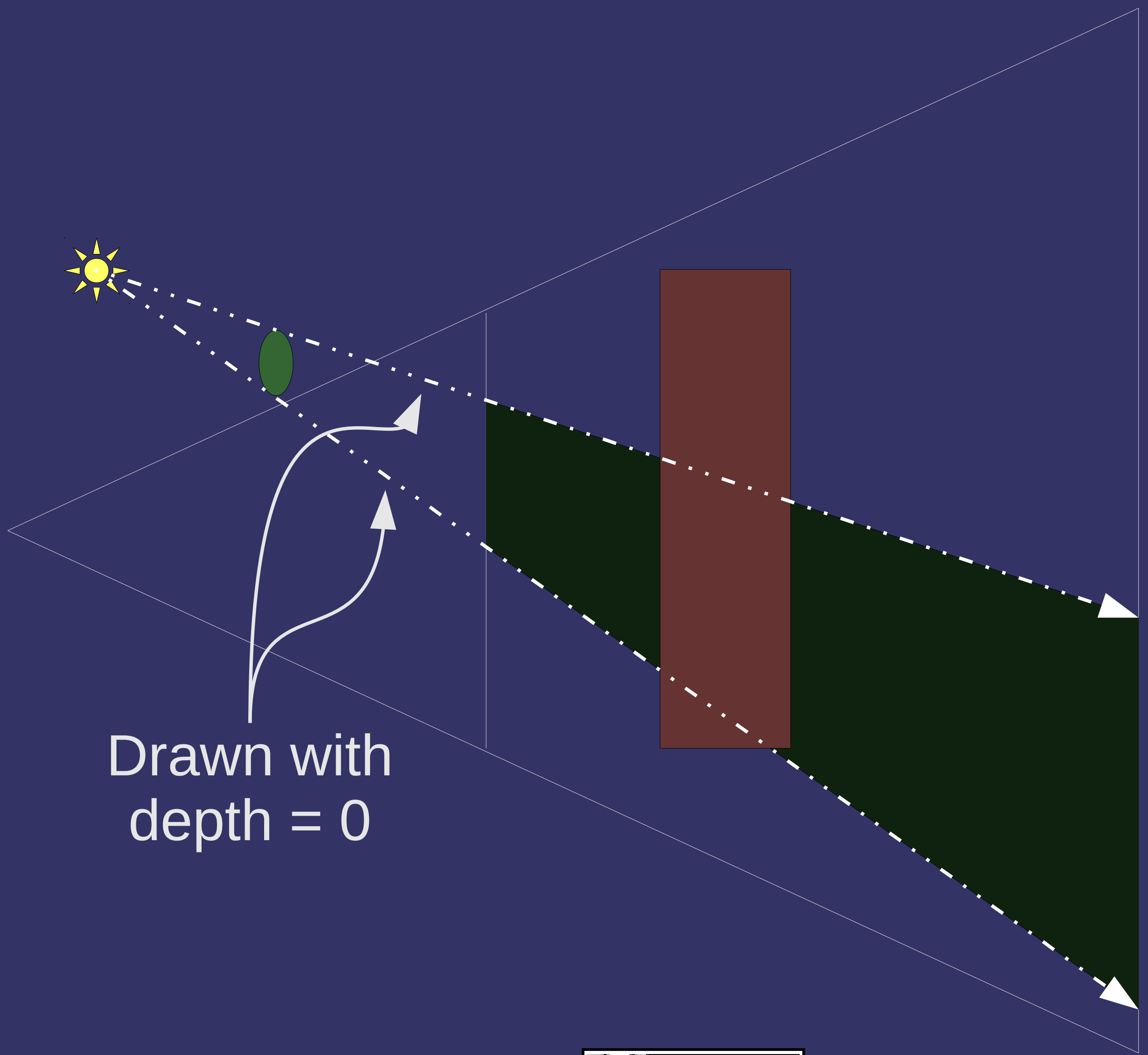
Hardware Optimizations

- Several hardware features exist to help accelerate shadow volume rendering
  - Depth clamping
  - Scissor testing
  - Depth bounds testing

Depth Clamp

- Fragments with interpolated depth values less than 0.0 or greater than 1.0 get a depth value clamped to [0, 1]
  - These are the fragments that would be clipped by the near- or far-plane
  - Eliminates need for front- and back-caps on shadow volumes
    - See ZP+ paper for more details
- Part of OpenGL 3.2
  - Also `GL_ARB_depth_clamp` and `GL_NV_depth_clamp`

Depth Clamp



Scissor Testing

- Spot lights only affect some areas of the screen
  - We end up drawing shadow volumes even where there is no light to be shadowed!
- Use scissor test to eliminate drawing of useless shadow volumes
  - Calculate x/y region of the *window* where a light can be seen
  - Set scissor rectangle to just this region
  - Fragments outside the region will be clipped

Depth Bounds Testing

- Extra per-fragment test before stencil test
  - Discards fragment if the *existing* depth value is outside a predefined range
  - Acts like a scissor test for depth
- Part of OpenGL 3.2
  - Also `GL_EXT_depth_bounds_test`

Depth Bounds Testing

```
calculate_light_screen_space_volume(light,
                                    &x_min, &x_max,
                                    &y_min, &y_max,
                                    &z_min, &z_max);

glEnable(GL_DEPTH_BOUNDS_TEST_EXT);
glEnable(GL_SCISSOR_TEST);

glDepthBounds(z_min, z_max);
glScissor(x_min, y_min, x_max - x_min, y_max - y_min);

do_shadows(light, objects);
```

Optimizing Shadow Volumes

- We've reduced the fill-rate a *lot* but we still...
  - Render a lot of volumes that don't produce visible shadows
  - Render a lot of volumes that do produce visible shadows in areas where they don't produce shadows
  - Render a lot of volumes from casters that are themselves completely in shadow

Optimizing Shadow Volumes

- Improve fill-rate usage two ways:
  - Cull volumes from casters that cast shadows not visible to the eye
  - Clamp shadow volume to the regions containing possible receivers

Shadow Volume Culling

- Compute two sets of objects:
  - Potential shadow receivers (PSR): Objects that may be visible to the camera
  - Potential shadow casters (PSC): Objects that may be visible to the light
- Use occlusion queries:
  - Render the scene once from the view of the light
  - Disable depth writes
  - Render object bounding boxes with occlusion queries
    - BBs with non-occluded pixels represent potentially visible objects

Shadow Volume Clamping

- Two steps:
  - Calculate continuously occupied intervals in object space
  - Reduce to discrete intervals in image space

Continuous Clamping

- From the point-of-view of the light:
  - Project each AABB into the lights near plane
    - The projections are squares
  - Determine which projections overlap
    - For each caster-receiver overlap, determine the depth interval occupied
    - The paper describes the occupied interval calculation in more detail
  - This is performed entirely on the CPU

Discrete Clamping

- From the point-of-view of the light:
  - Slice the view frustum into segments using “similarly oriented” planes
    - Planes roughly parallel to the light's near plane that pass through the camera are a good choice
  - Render slices back-to-front
    - The borders of the slice are clip planes
    - Project the caster onto the far plane
    - Render objects using occlusion query
    - If no pixels pass, the slice is empty
  - This is performed on the GPU

References

Lloyd, B., Wendt, J., Govindaraju, N., and Manocha, D. 2004. CC Shadow Volumes. In *ACM SIGGRAPH 2004 Sketches* (Los Angeles, California, August 8 - 12, 2004). R. Barzel, Ed. SIGGRAPH '04. ACM, New York, NY, 146. http://gamma.cs.unc.edu/ccsv/

Next week...

- Quiz #3
- Ambient occlusion
- Read:

Iones, A., Krupkin, A., Sbert, M., and Zhukov, S. 2003. Fast, Realistic Lighting for Video Games. *IEEE Computer Graphics and Applications*. 23, 3 (May. 2003), 54–64. http://ima.udg.edu/iiia/GGG/UsersDocs/mateu/obscurances.pdf

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