VGP353 – Week 5

- Agenda:
  - Quiz #2
  - Assignment #2 (shadow textures) due.
  - Finish shadow maps:
    - Percentage closer soft shadows (PCSS)
    - Parallel-split shadow maps (PSSMs)
  - Start assignment #3 (shadow maps)

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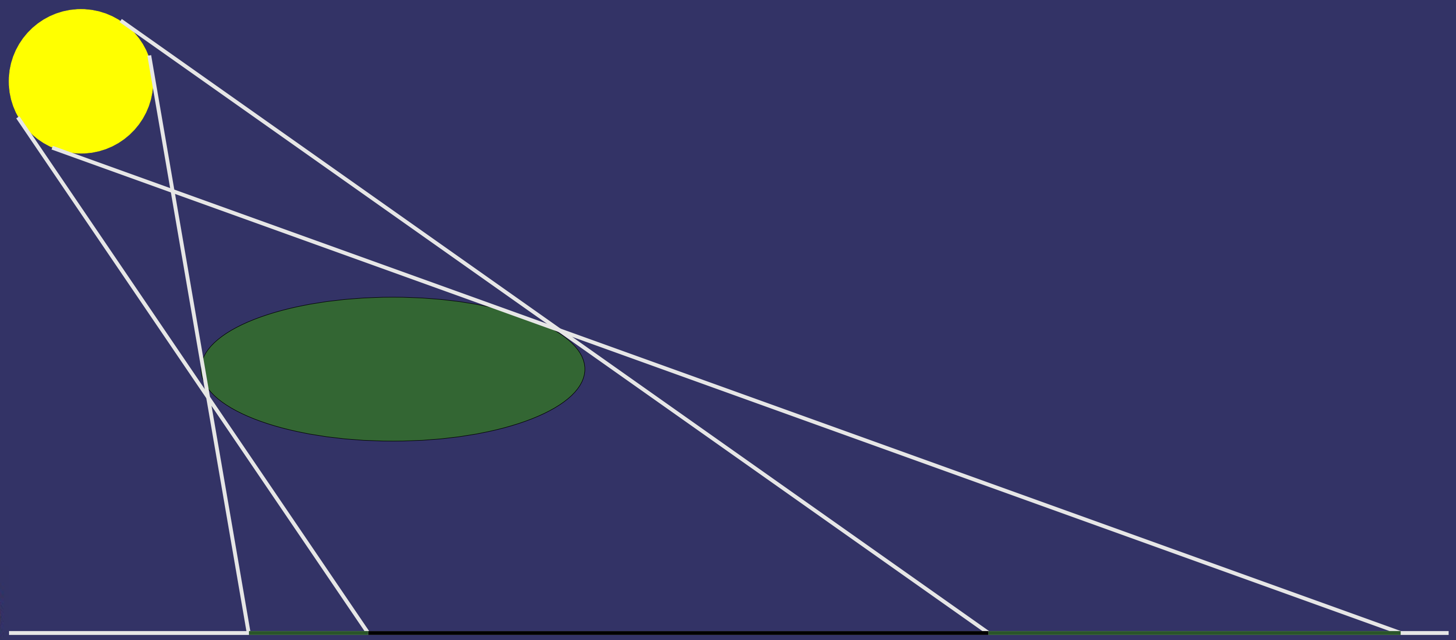
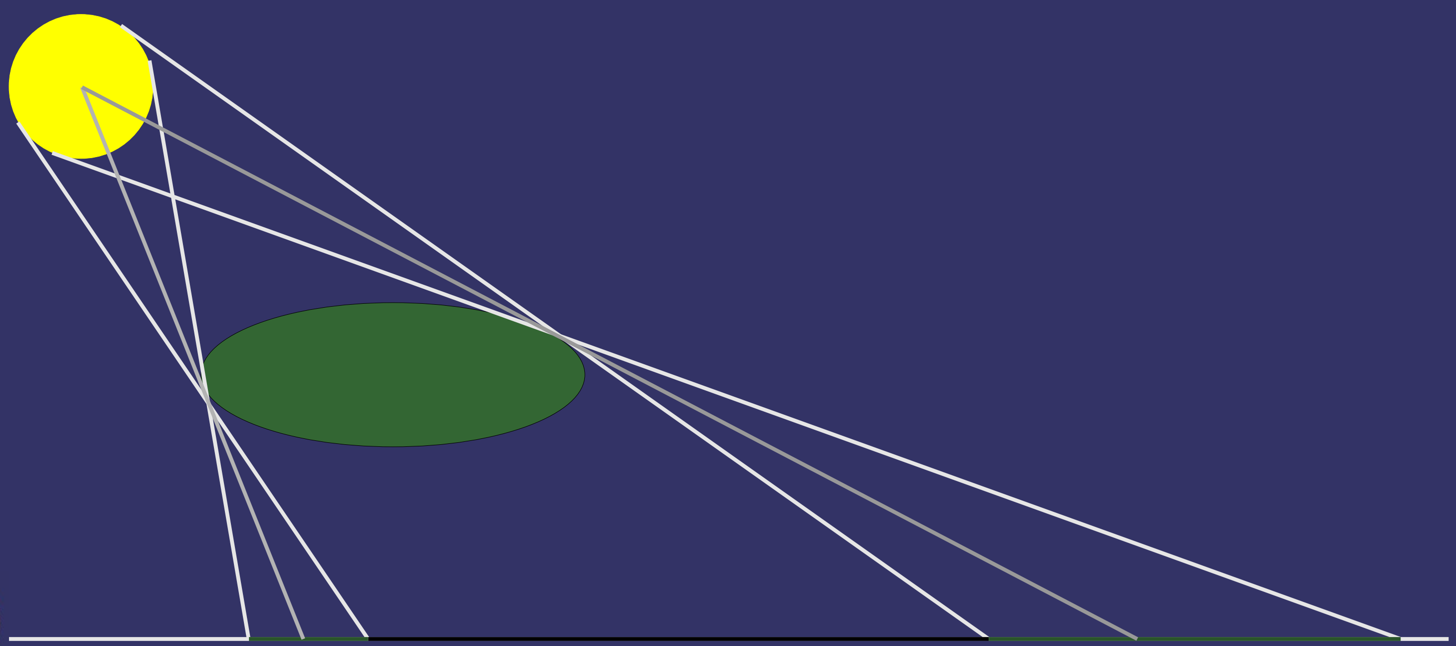
Soft Shadows

- Real lights have area
  - Since the light has area, there are regions where only a portion of the light is occluded...this is the penumbra



Soft Shadows

- Real lights have area
  - Since the light has area, there are regions where only a portion of the light is occluded...this is the penumbra
  - Shadow maps represent part of the penumbra as umbra and part as unoccluded



Soft Shadows

- Size of penumbra region varies with:
  - Size of light
  - Distance between occluder and light
  - Distance between occluder and receiver

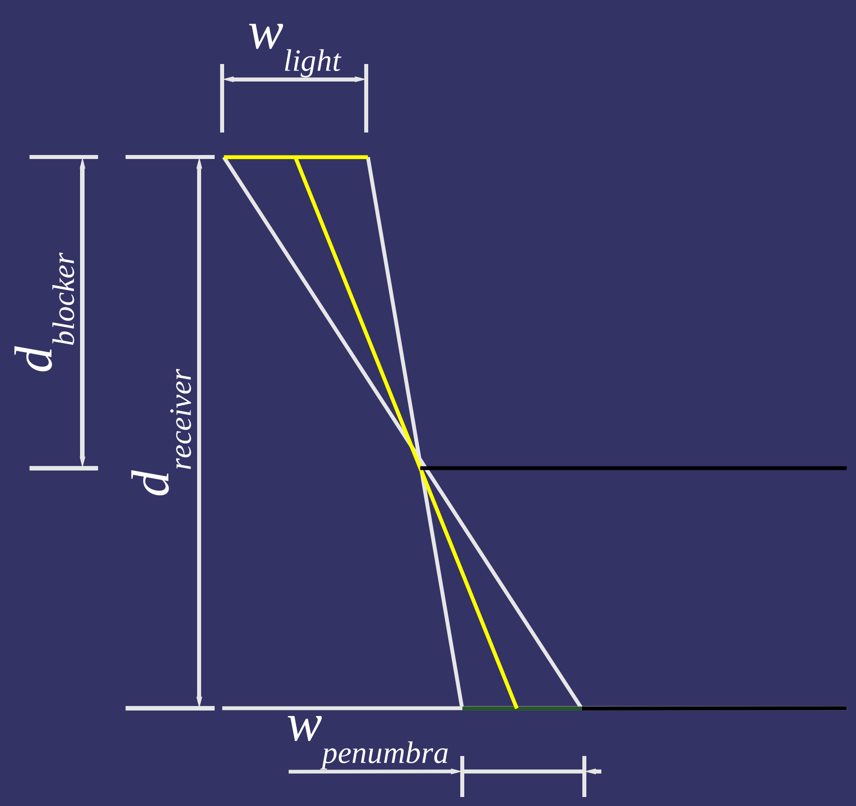
Soft Shadows

- Size of penumbra region varies with:
  - Size of light
  - Distance between occluder and light
  - Distance between occluder and receiver
- Using this information to perform *correct* light visibility calculations is hard
  - Make some simplifying assumptions!
  - Assume that all occluders, receivers, and lights are both flat and parallel to each other

Soft Shadows

- Estimate penumbra size using:

$$w_{penumbra} = \frac{(d_{receiver} - d_{blocker}) \times w_{light}}{d_{blocker}}$$

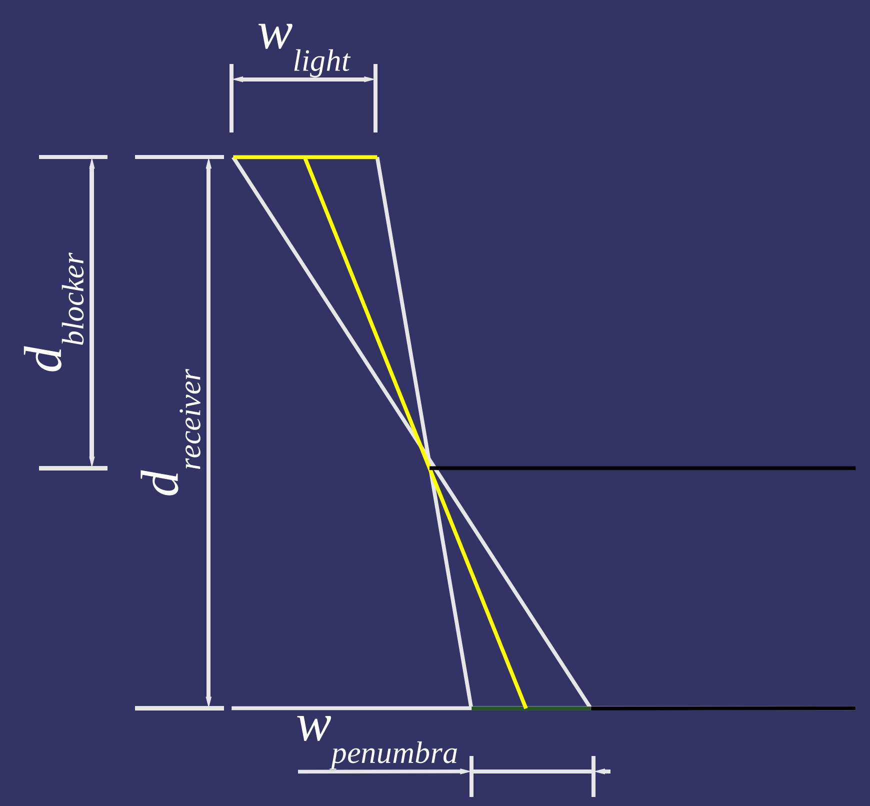


Soft Shadows

- Estimate penumbra size using:

$$w_{penumbra} = \frac{(d_{receiver} - d_{blocker}) \times w_{light}}{d_{blocker}}$$

- How do we determine $d_{blocker}$?

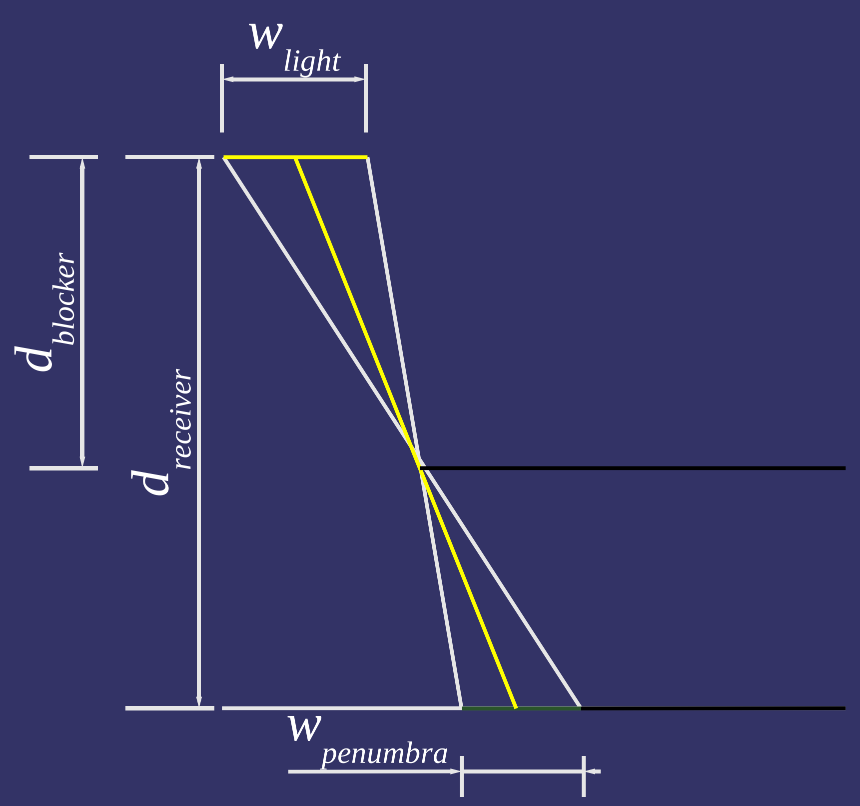


Soft Shadows

- Estimate penumbra size using:

$$w_{penumbra} = \frac{(d_{receiver} - d_{blocker}) \times w_{light}}{d_{blocker}}$$

- How do we determine $d_{blocker}$?
  - Search the shadow map for possible occluders



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Soft Shadows

- Examine a region around the point in the shadow map
  - Select region size based on light size and rendering budget
  - Sample values and *average* all depths less than the current fragment
    - Very similar to percentage closer filter (PCF)
- Use resulting average as $d_{blocker}$
  - $w_{penumbra}$ is the width of the PCF filter area

Soft Shadows

- Demo

Original image from
http://developer.nvidia.com/object/gdc_2005_presentations.html

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References

Randima Fernando. *Percentage-Closer Soft Shadows.* 2005. Game Developer's Conference. http://developer.download.nvidia.com/shaderlibrary/docs/shadow_PCSS.pdf

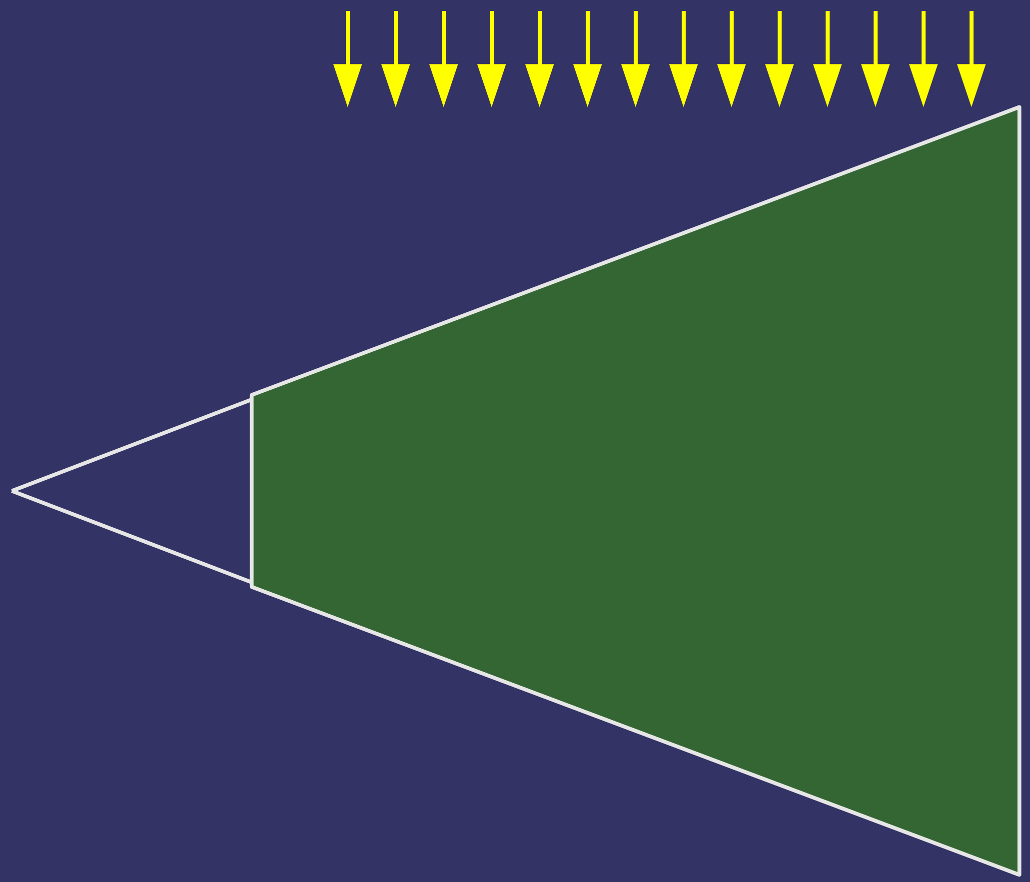
Break

Perspective Shadow Maps

- Some significant problems:
  - Shadow map *quality* is view-dependent
  - Several special cases that must be handled depending on light direction / position
  - Difficulties handling shadow casters behind the camera
- Introduced some good ideas:
  - Re-parameterizing the scene based on the camera / light frusta
  - Quantitatively determining when aliasing will occur

Parallel-Split Shadow Maps

- PSSMs solve most of these problems



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Parallel-Split Shadow Maps

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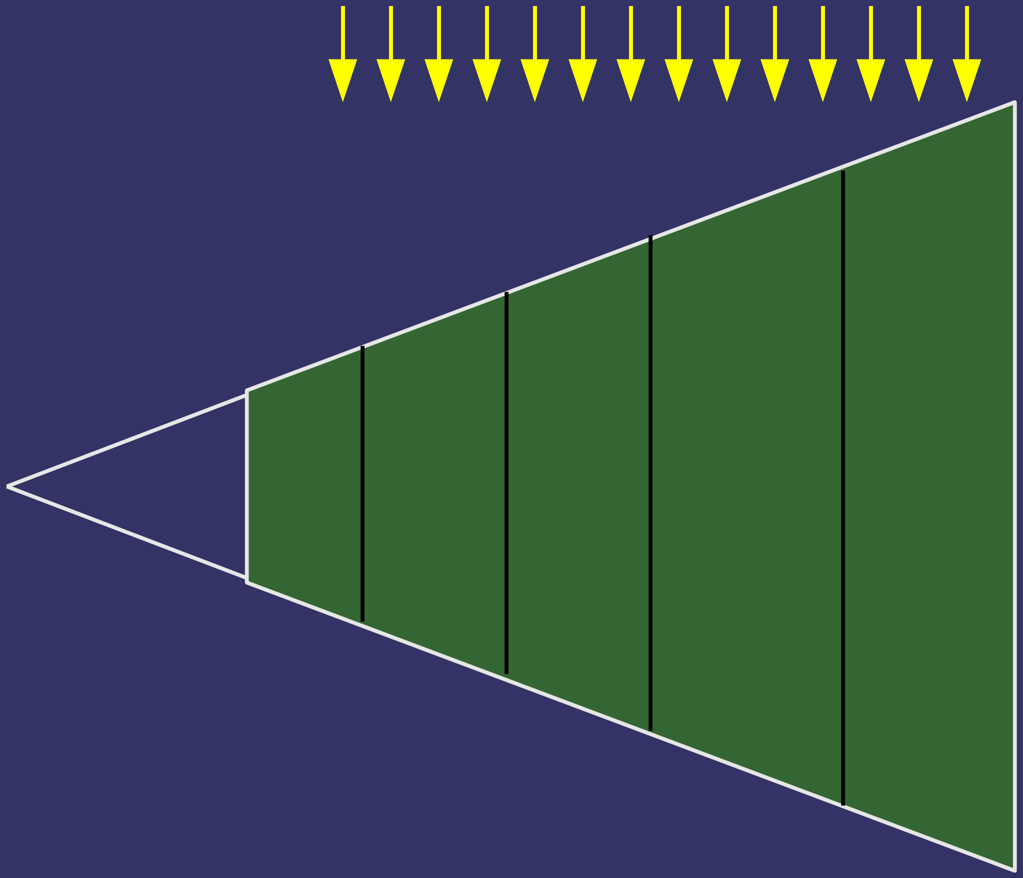
  - Split view frustum into n parts with planes parallel to the near / far plane



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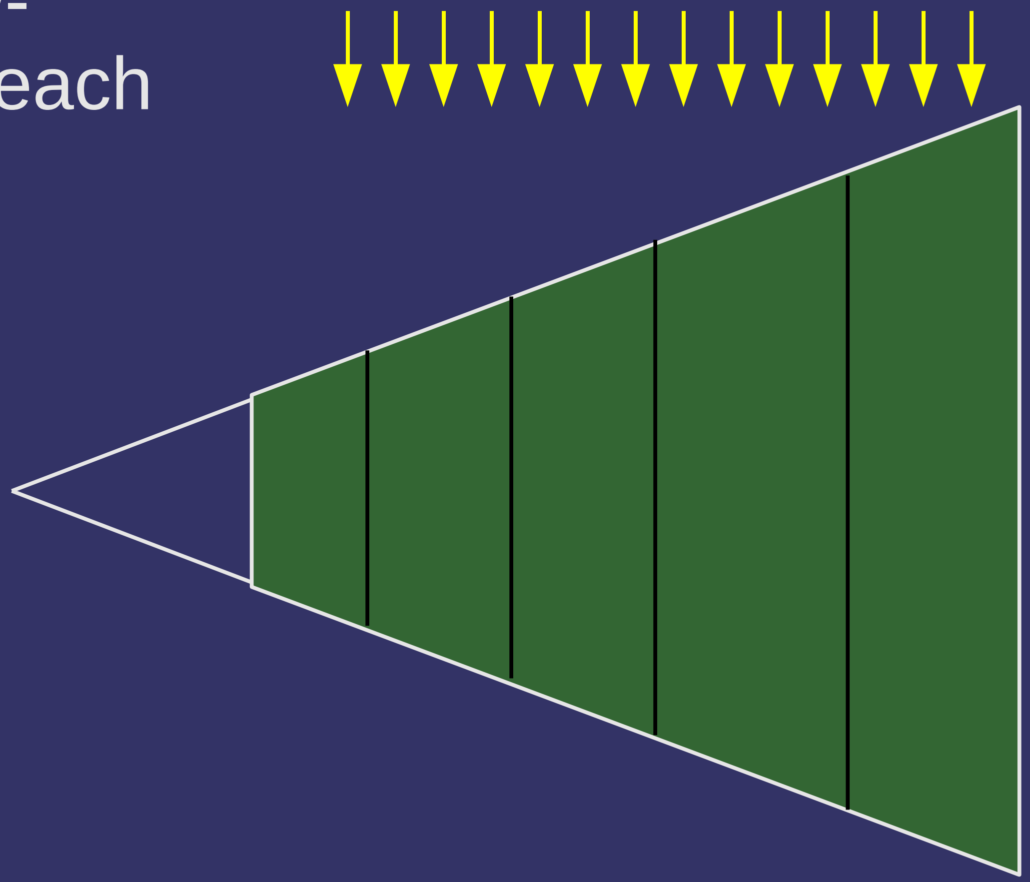
  - Calculate light's view-projection matrix for each split region



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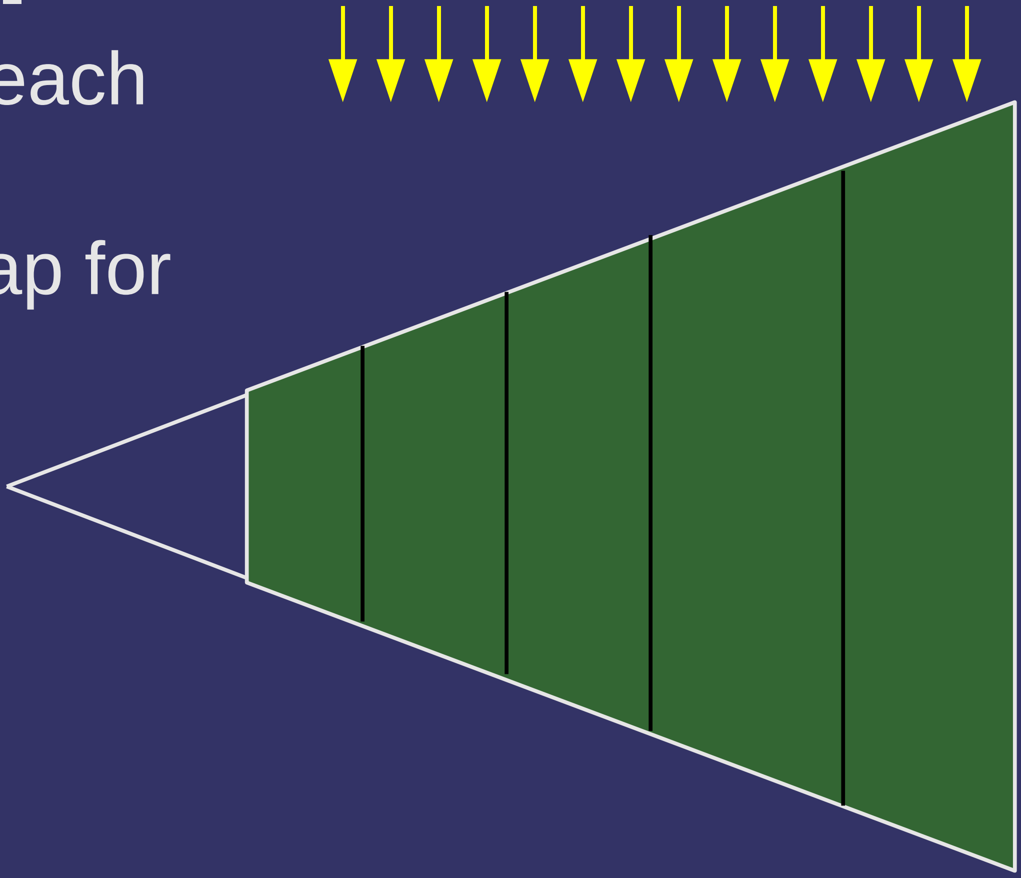
  - Split view frustum into n parts with planes parallel to the near / far plane
  - Calculate light's view-projection matrix for each split region
  - Generate shadow map for each split regions



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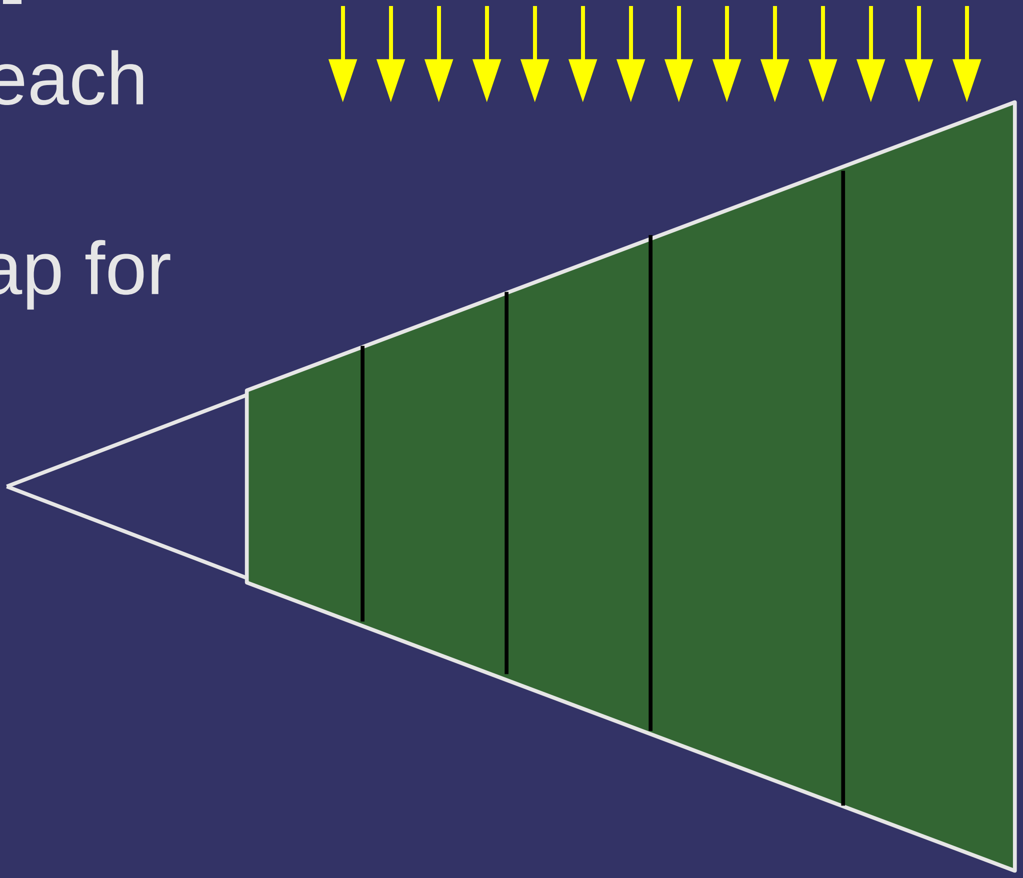
Parallel-Split Shadow Maps

- PSSMs solve most of these problems
  - Split view frustum into m parts with planes parallel to the near / far plane
  - Calculate light's view-projection matrix for each split region
  - Generate shadow map for each split regions
  - Apply shadow maps to scene



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Parallel-Split Shadow Maps

- Aliasing occurs when $d > d_i$

$$d = d_s \frac{r_s}{r_i} \frac{N \cdot V}{N \cdot L}$$

  – Rename r_i as z, and call dz the change in z relative to one unit in ds

$$d = \frac{dz}{z\,ds} \frac{N \cdot V}{N \cdot L}$$

  – Ignoring perspective aliasing, this means that we want dz / zds to be constant over the entire view

    – Call this constant ρ

Parallel-Split Shadow Maps

- Optimal shadow map distribution is:

$$\frac{ds}{z\,dz} = \rho \Rightarrow \mathrm{s}(z) = \int_0^s ds = \frac{1}{\rho}\int_n^z \frac{1}{z}\,dz = \frac{1}{\rho}\ln\left(\frac{z}{n}\right)$$

  - Since $\mathrm{s}(f) = 1$, $\rho = \ln(\mathrm{f} / \mathrm{n})$

Parallel-Split Shadow Maps

- Current hardware can't do this non-linear z transform
  - Discretely perform the mapping in steps at the split planes

$$s_i = s(C_i^{\log}) = \frac{1}{\ln(f/n)} \ln\left(\frac{C_i^{\log}}{n}\right)$$

  - Each split gets 1 / m of total texture resolution, substituting i / m for s_i

$$C_i^{\log} = n\left(\frac{f}{n}\right)^{i/m}$$

Parallel-Split Shadow Maps

- Alternately, the view frustum could be divided into equally sized pieces

$$C_i^{uni} = \frac{(f - n) \times i}{m} + n$$

Parallel-Split Shadow Maps

- Neither split strategy work very well
  - Logarithmic splitting groups split-planes too close to the near plane
  - Uniform splitting doesn't group split-planes close enough to the near plane

Parallel-Split Shadow Maps

- Neither split strategy work very well
  - Logarithmic splitting groups split-planes too close to the near plane
  - Uniform splitting doesn't group split-planes close enough to the near plane
- Instead, use a hybrid of the two

$$C_i = \lambda C_i^{\log} + (1 - \lambda) C_i^{uni}$$

  - λ is tunable parameter
  - The paper calls this the *practical split scheme*

Parallel-Split Shadow Maps

- Light transformation matrices are determined much like before
  - Calculate view-projection matrix for light relative to whole view frustum
  - Transform each split region to light's post-projection space
  - Calculate AABB for transformed split region
  - Use AABB to calculate "crop" transformation to scale and center split region to full view

Parallel-Split Shadow Maps

- To apply shadows, the shader must determine which region contains the current fragment
  - Determine the split-plane, C_s, nearest the camera but farther away than the current fragment
  - C_s determines which shadow map to apply
  - The light transforms, C_i distances, and shadow maps (samplers) must be provided to the shader as arrays of uniforms
    - m is a compile-time constant

Parallel-Split Shadow Maps

- Only directional lights have been dealt with so far

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- Only directional lights have been dealt with so far
  - Light transformations for each split region are calculated from the light's post-projection space
  - For point lights, transform by the light's view-projection matrix *first*
    - This effectively converts the point-light to a directional light!

References

Zhang, F., Sun, H., Nyman, O. “Parallel-Split Shadow Maps on Programmable GPUs,” in *GPU Gems 3,* ed. Hubert Nguyen, pp. 202 – 237. Boston, MA: Addison-Wesley, 2008. http://appsrv.cse.cuhk.edu.hk/~fzhang/pssm_project/

Wimmer, M., Scherzer, D., and Purgathofer, W. “Light Space Perspective Shadow Maps,” in *Proceedings of Eurographics Symposium on Rendering*, pp. 143 - 151. Norrköping, Sweden: Eurographics Association, 2004. http://www.cg.tuwien.ac.at/research/vr/lispsm/

Next week...

- Shadow volumes

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