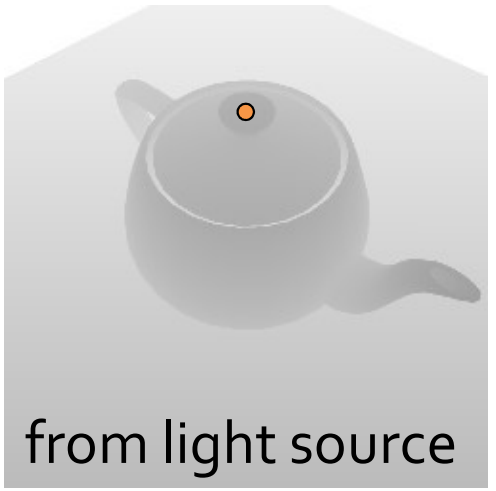
Shadow Mapping

Idea

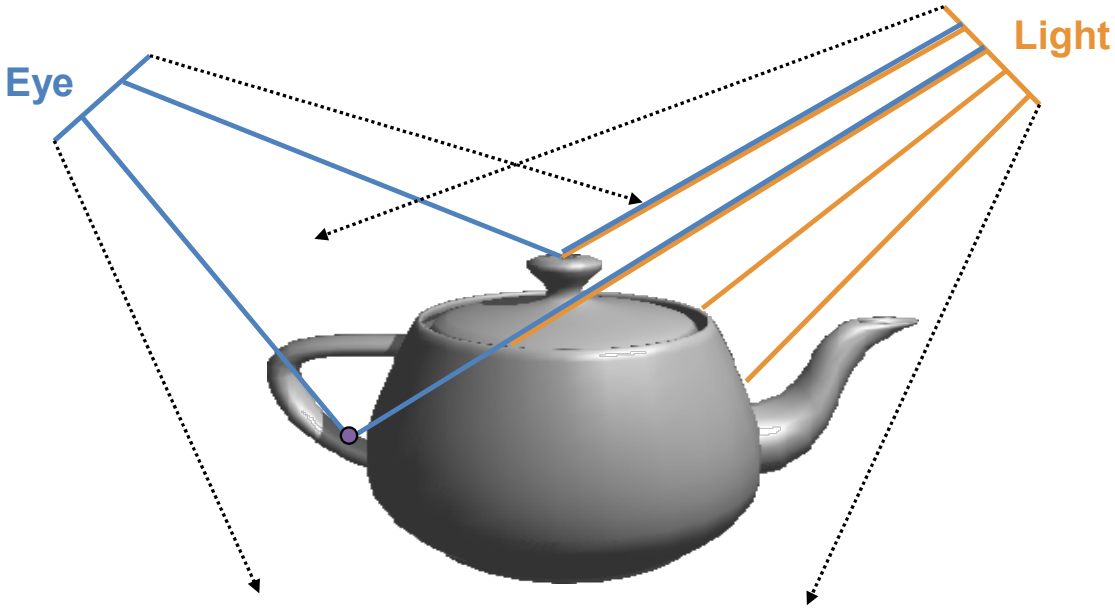
Idea

- What can be seen from the point-of-view of the light source is **lit**
- What is invisible from the point-of-view of the light source is in **shadow**
- How can we decide for a point if it is (in)visible to the light source?



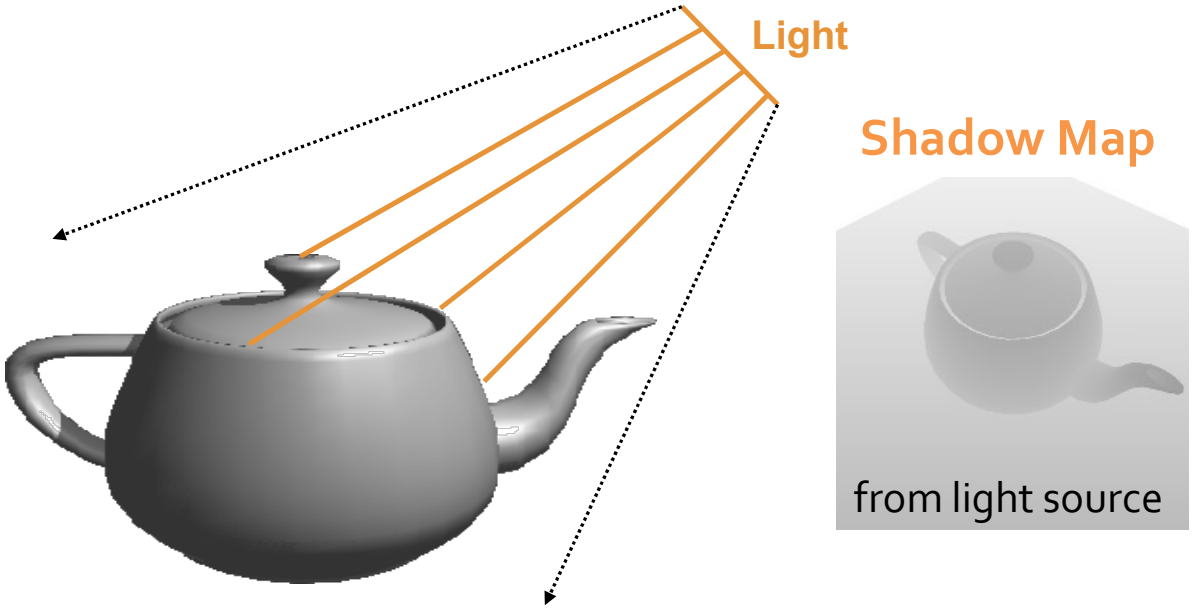
Point Visibility

- Tranform each point from the eye into the space of the light source
- Is the point farther away then the point seen from the light?
  - Then this point is in shadow



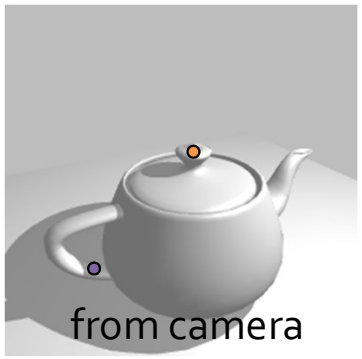
Shadow Mapping – First Pass

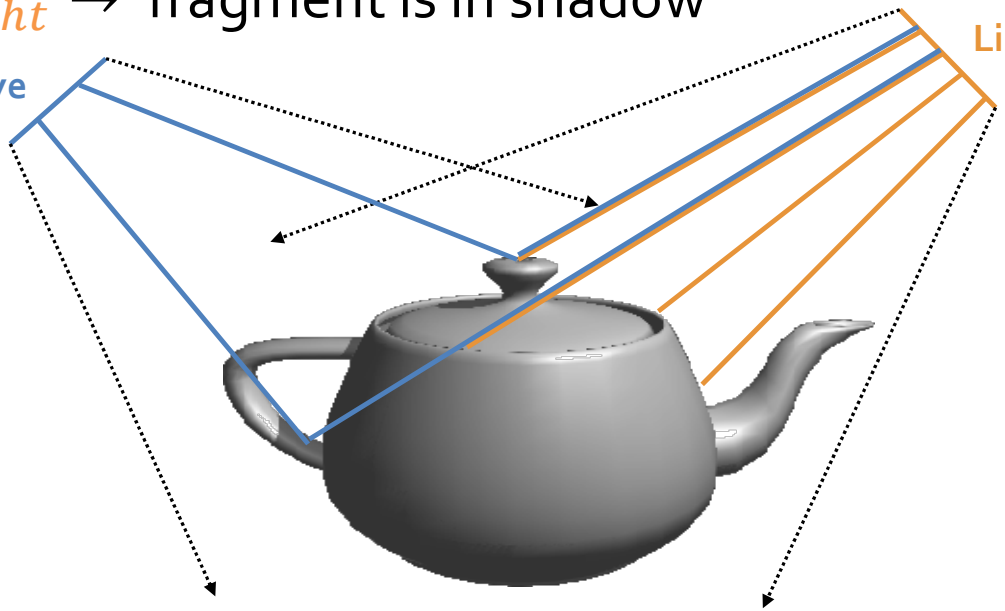
- Render scene from light-view and save depth values

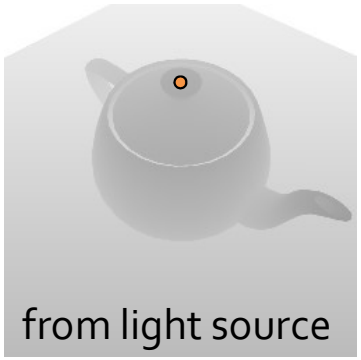


Shadow Mapping – Second Pass

- Render scene from eye-view
  - Transform each fragment to light source space
  - Compare z_{eye} with z_{light} value stored in shadow map
  - $z_{eye} < z_{light} \rightarrow$ fragment is in shadow







Why Shadow Maps?

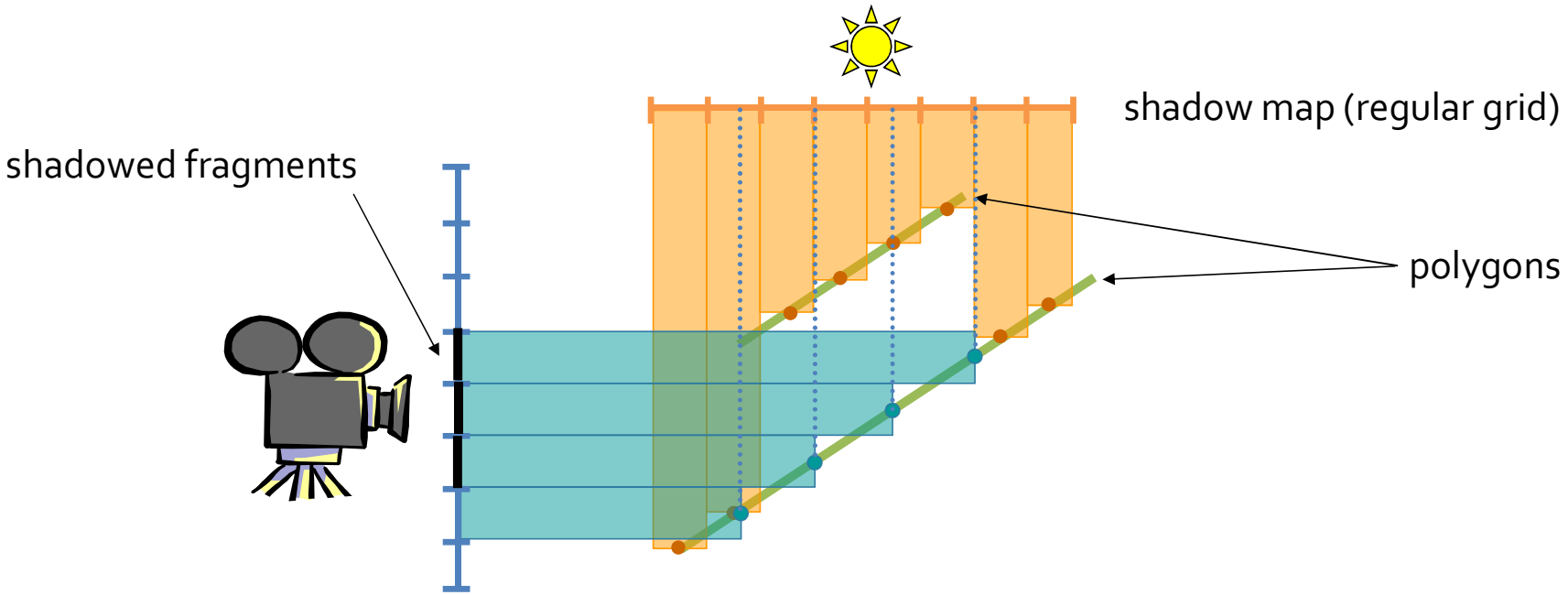
- **Independent** of scene complexity
  - Not as fill-rate limited as shadow volumes
- Only **one** additional (depth only) **render pass**
- Handle **self-shadowing** correctly
- Handle arbitrary **shadow caster/receiver** constellations
- Problems?

Shadow Mapping

Aliasing

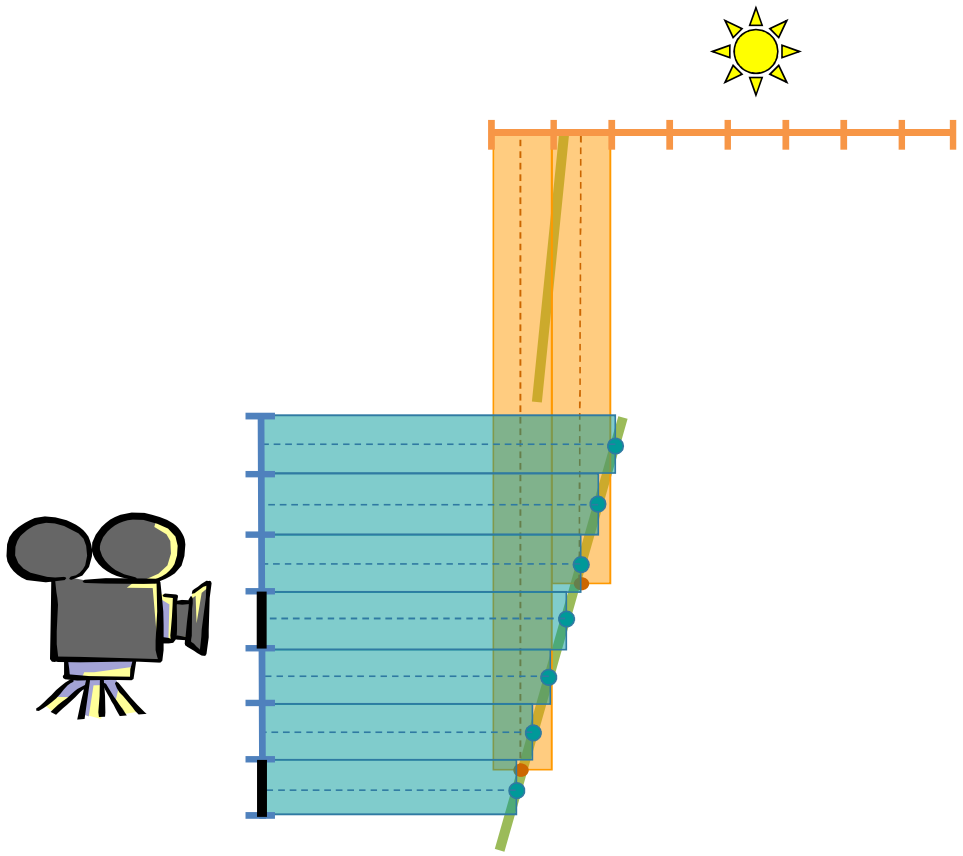
Shadow Map as Signal Reconstruction

- Initial sampling: shadow map rendering
- Reconstruction: nearest neighbor, PCF, …

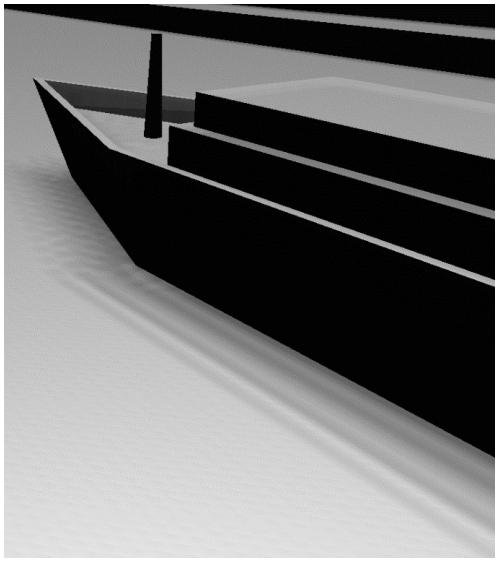


Shadow Map as Signal Reconstruction

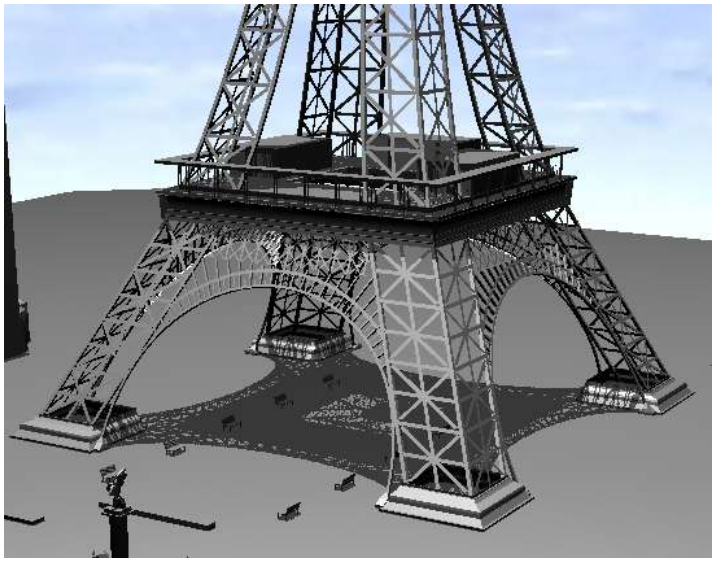
- Shadow map samples only correct at center
- Wrong results too little sampling information in shadow map



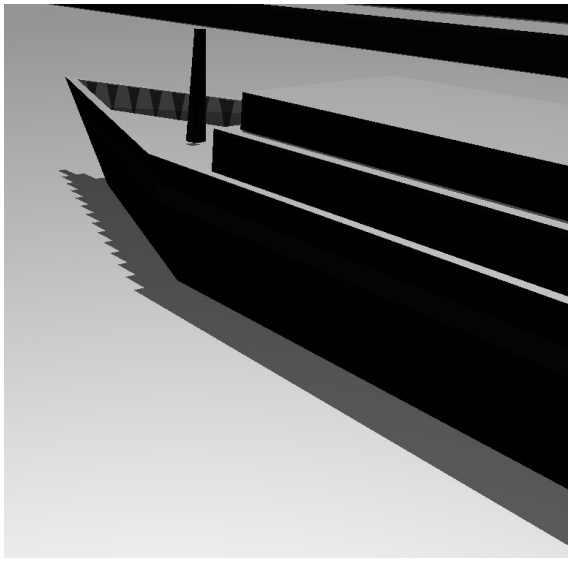
Main Types of Error



Undersampling
Too low initial sampling frequency



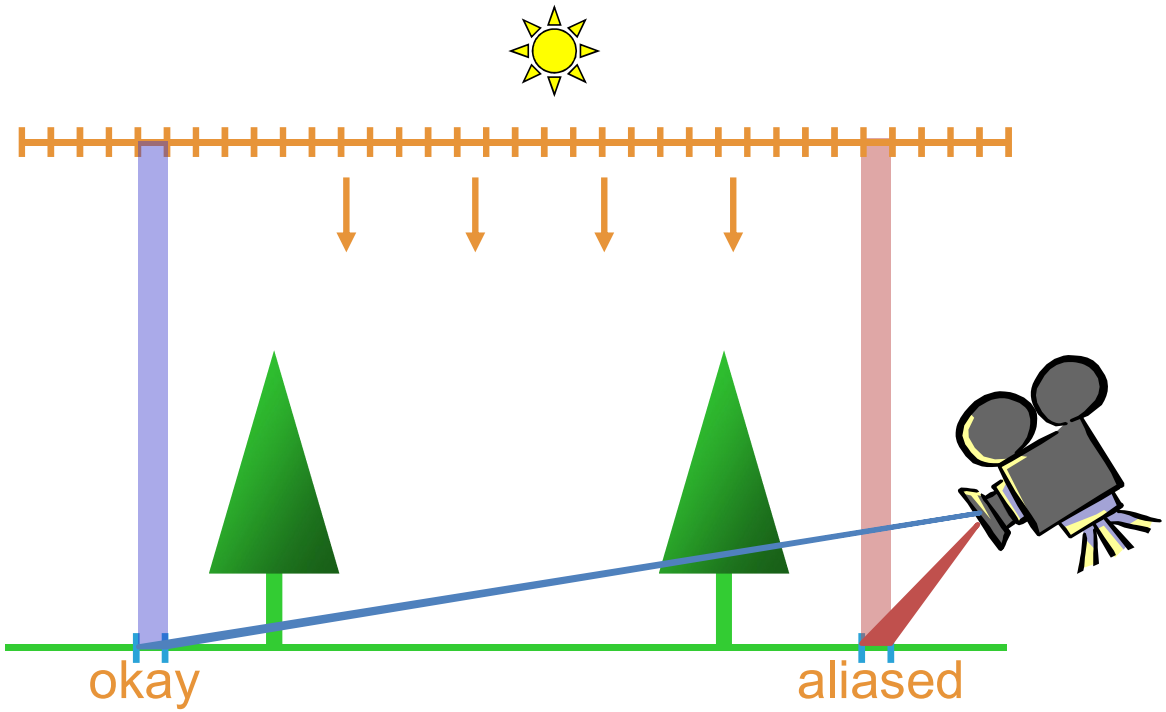
Oversampling
No band-limiting

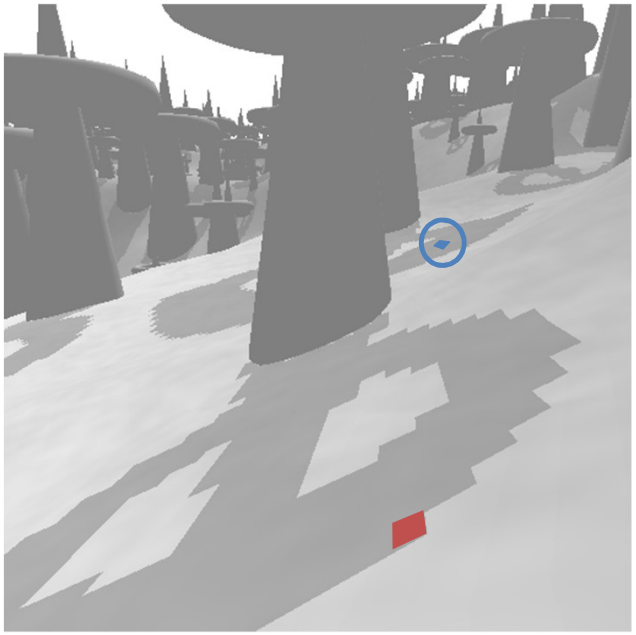


Reconstruction error
Staircase artifacts

Undersampling – Perspective Aliasing

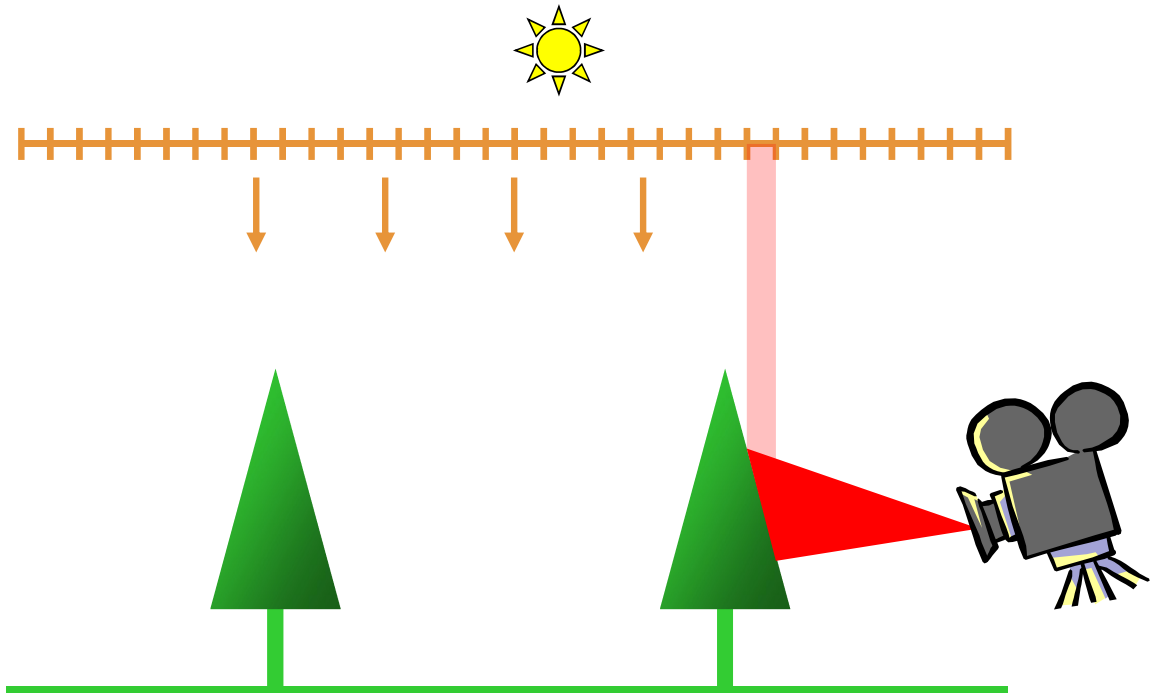
- **Sufficient** resolution far from the observer
- **Insufficient** resolution near the observer

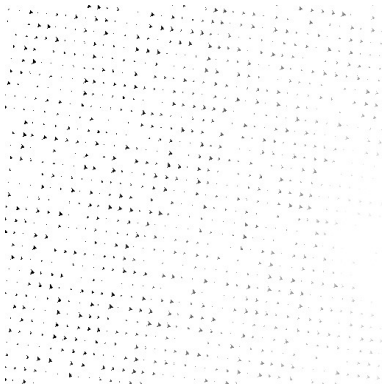


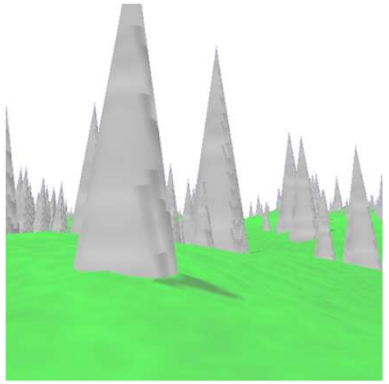


Undersampling - Projection Aliasing

- Shadow receiver ~ **orthogonal** to shadow map





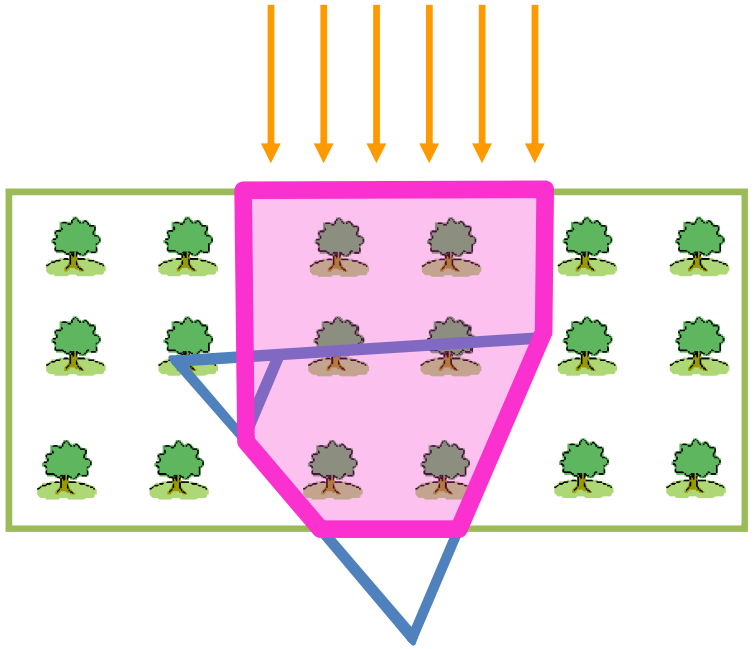


Shadow Mapping

Fighting Undersampling – Focusing

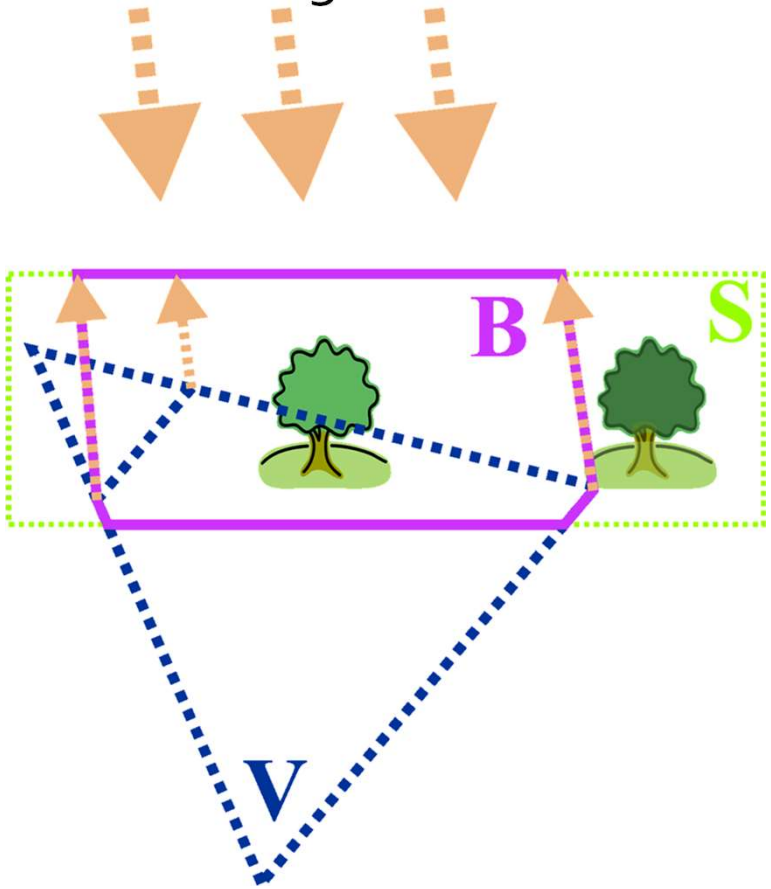
Focus the Shadow Map

- Only include relevant objects
  - Shadow casters
  - Light source frustum
  - View frustum
- Better use of shadow map resolution
- Brabec et al. 2002

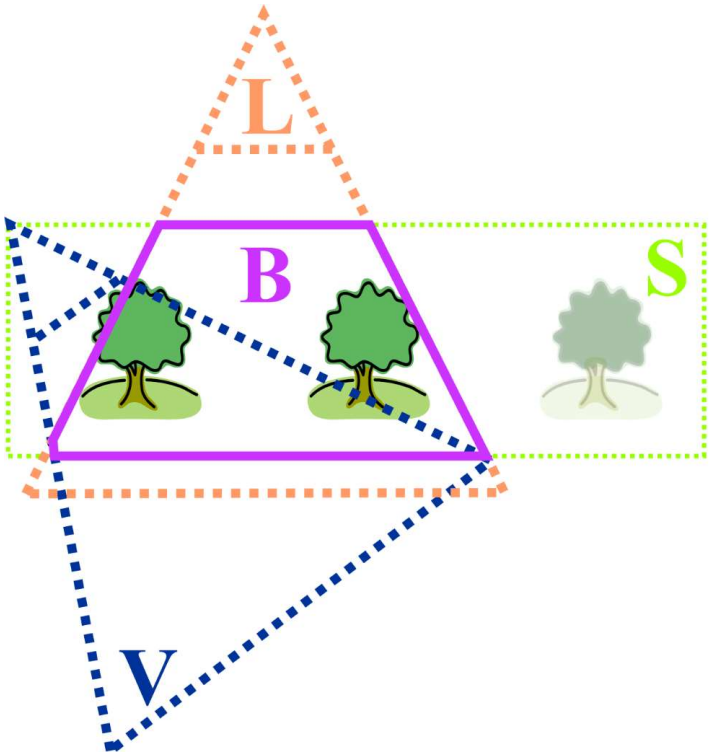


Focus the Shadow Map

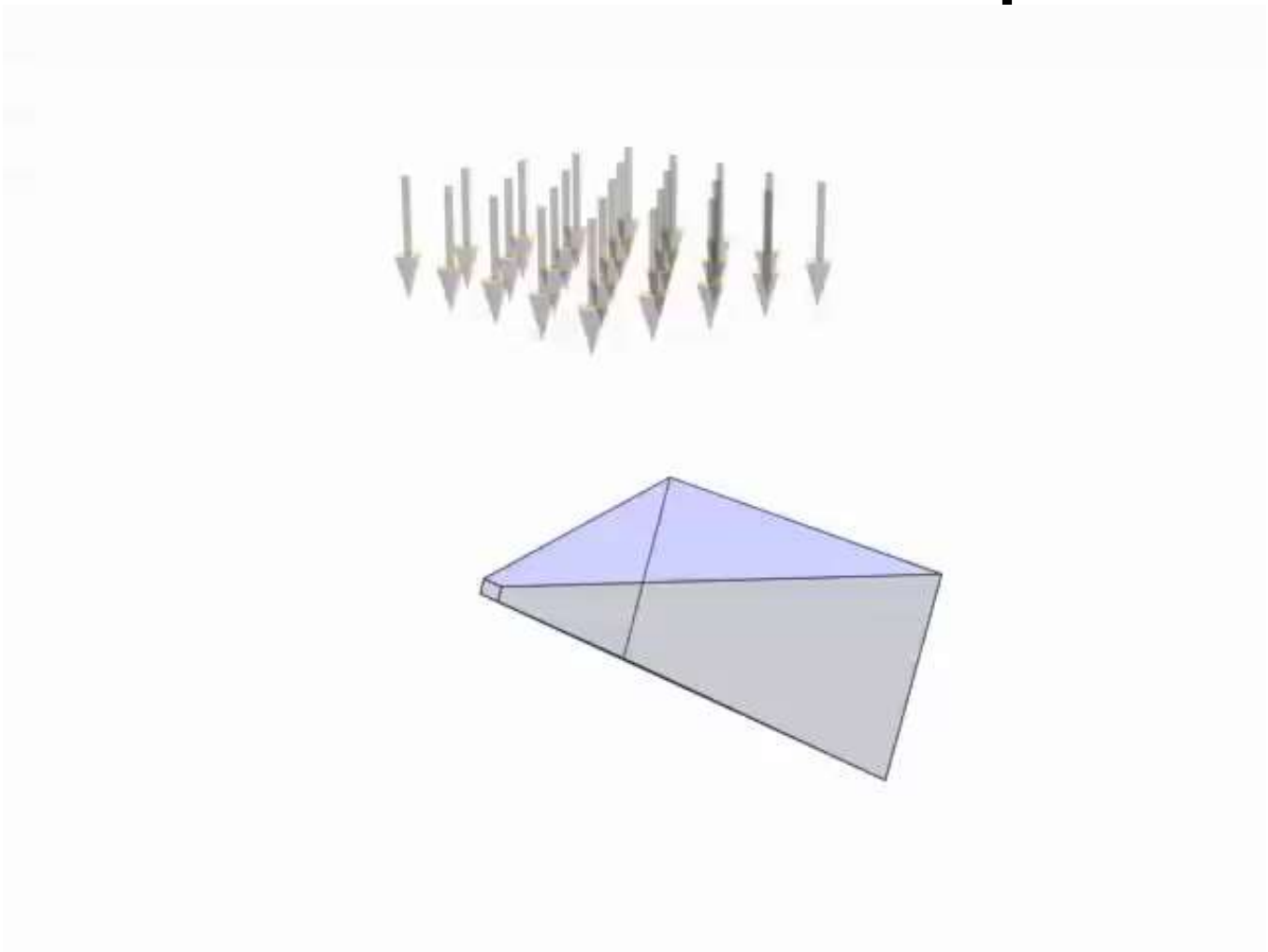
- Directional light



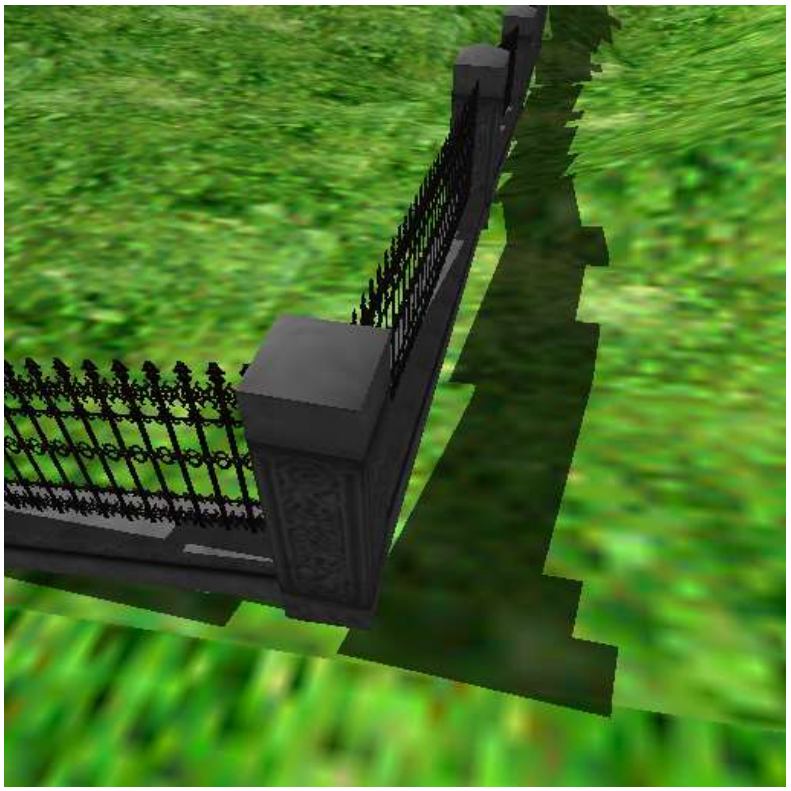
- Point light



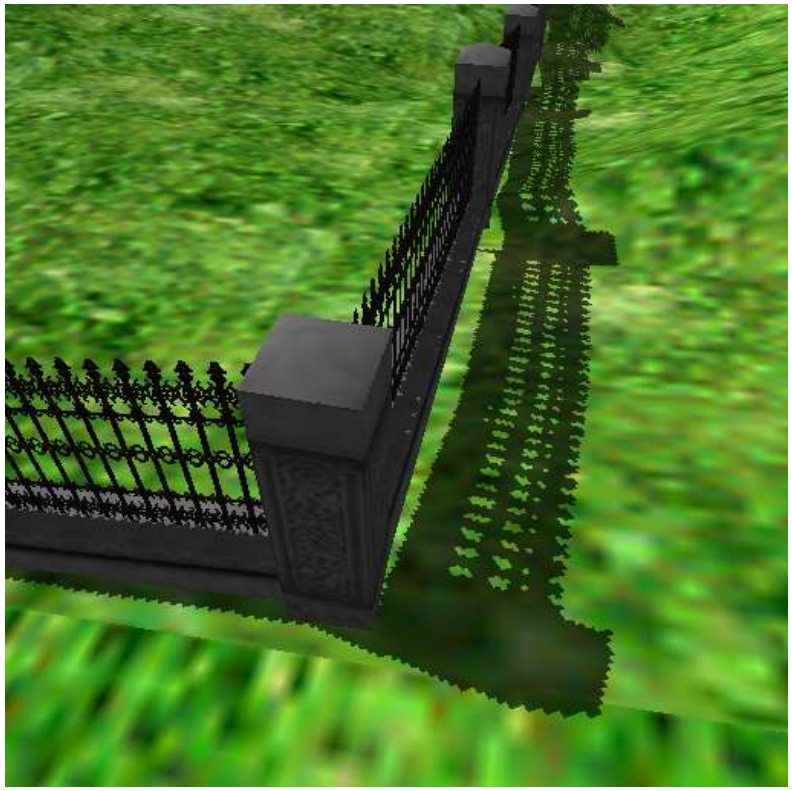
Focus the Shadow Map



Focus the Shadow Map

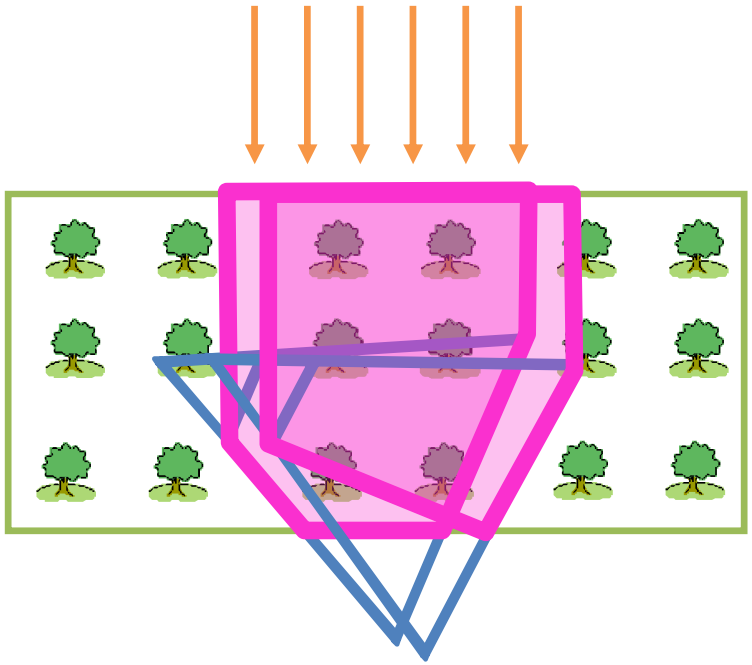


Unfocused

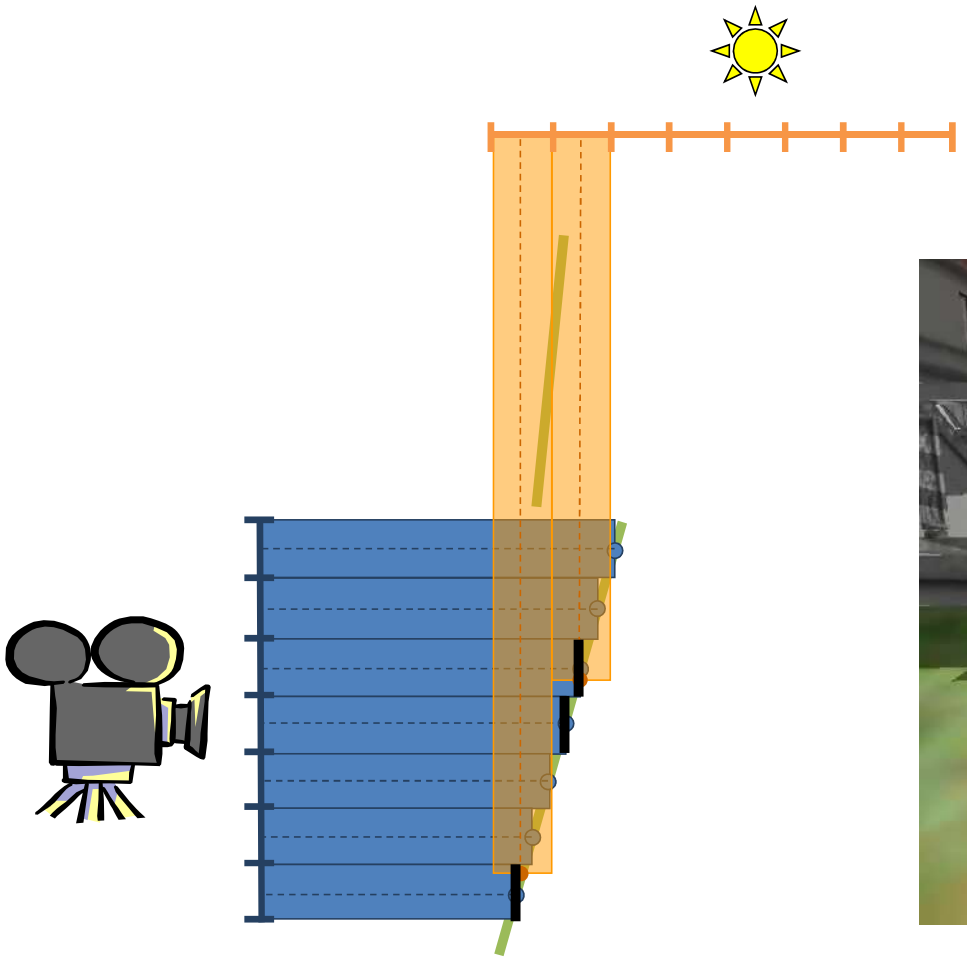


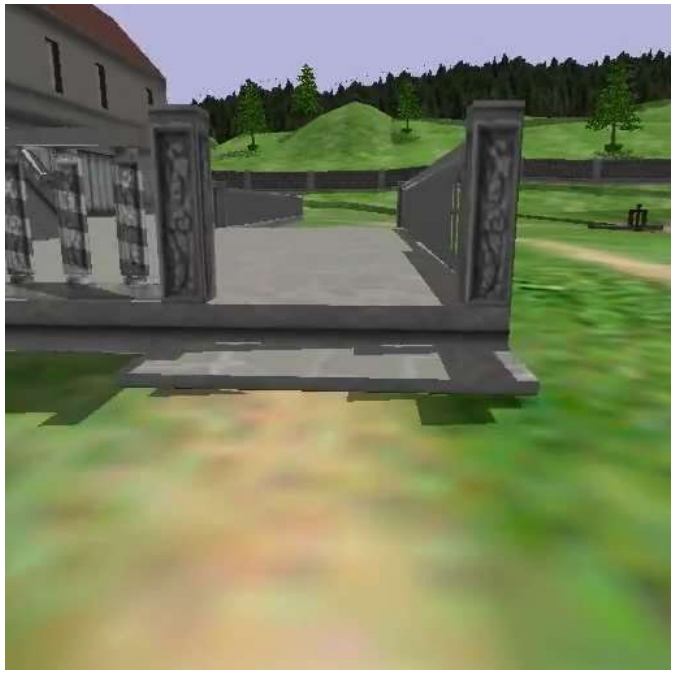
Focused

Fitting – Temporal Aliasing

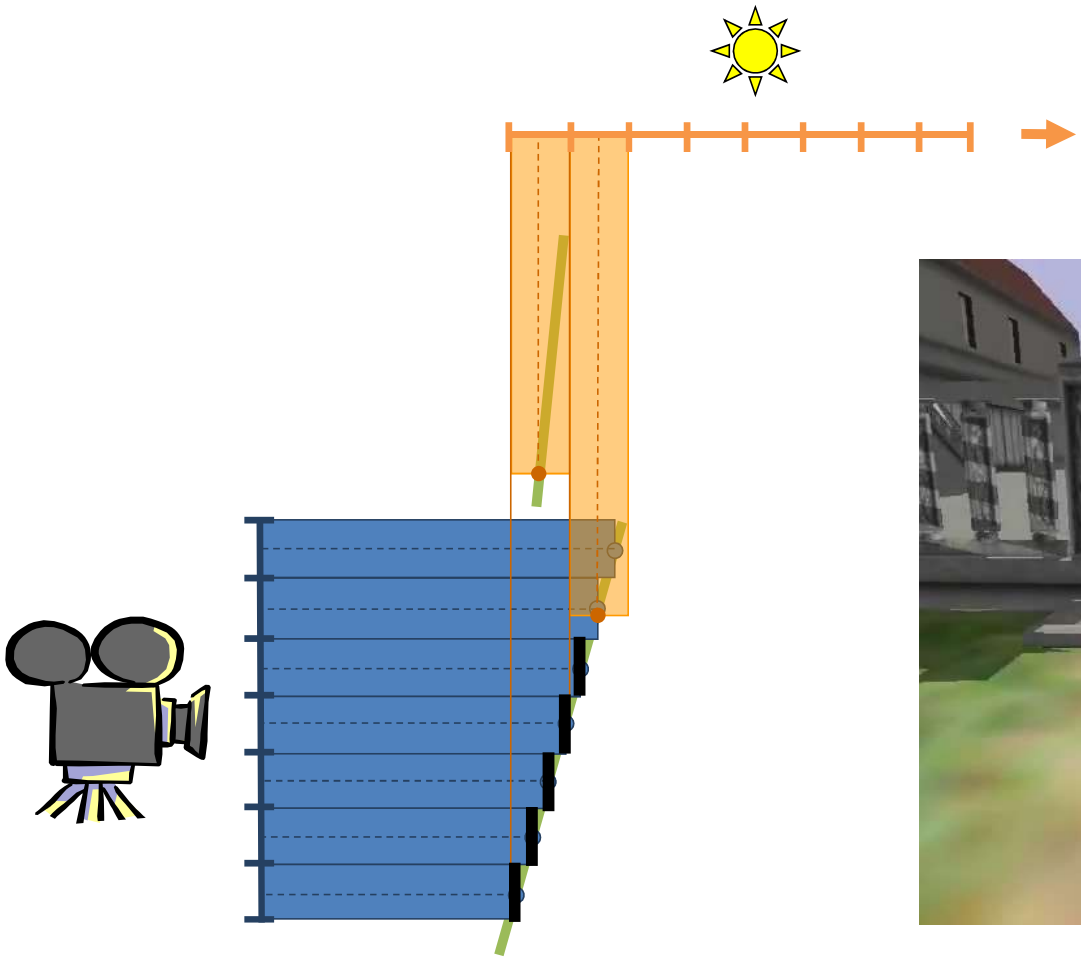


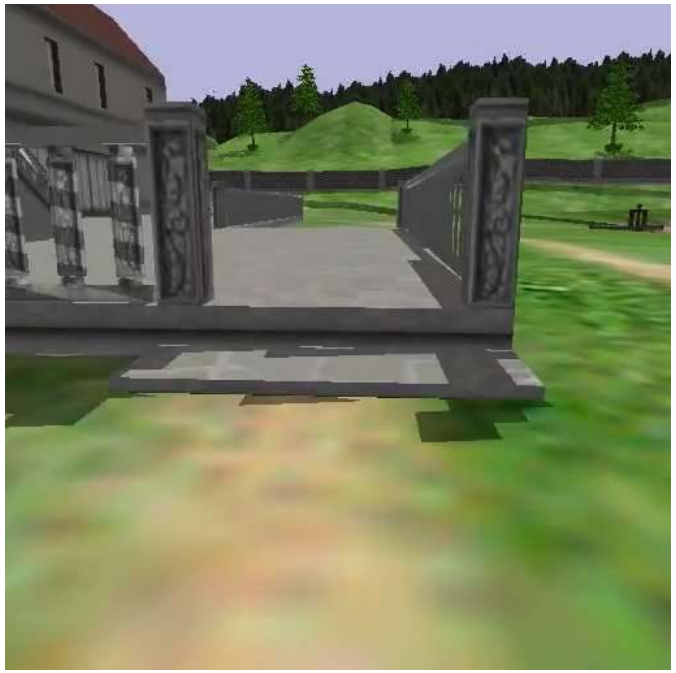
Fitting – Temporal Aliasing



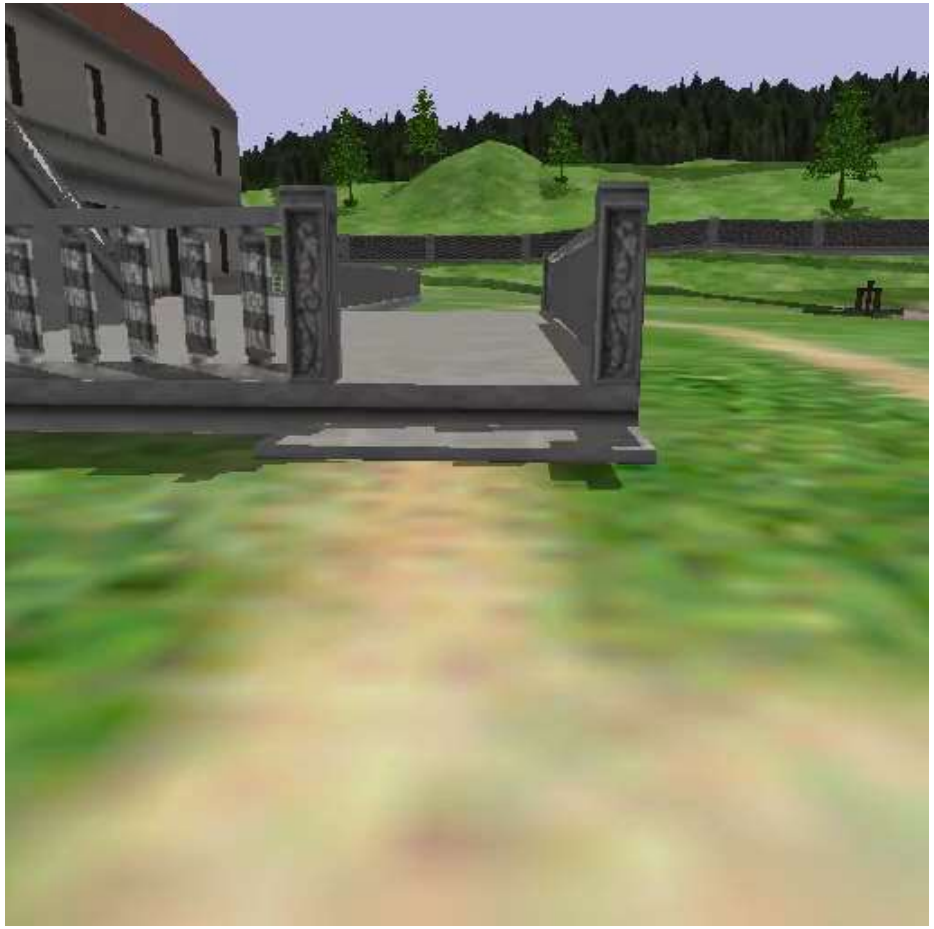


Fitting – Temporal Aliasing





Fitting – Temporal Aliasing



Fitting vs Temporal Aliasing

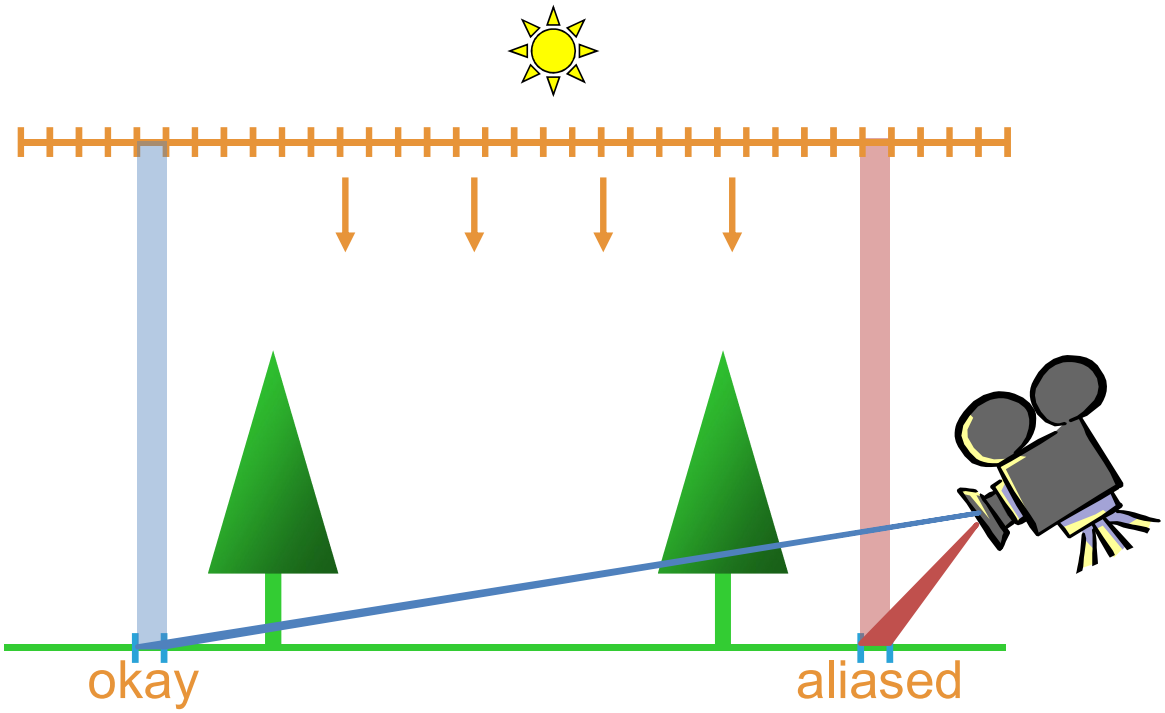
- Commonly used
- Better use of shadow map resolution
- One cause for temporal aliasing
- Temporal aliasing noticeable because of insufficient resolution → warping

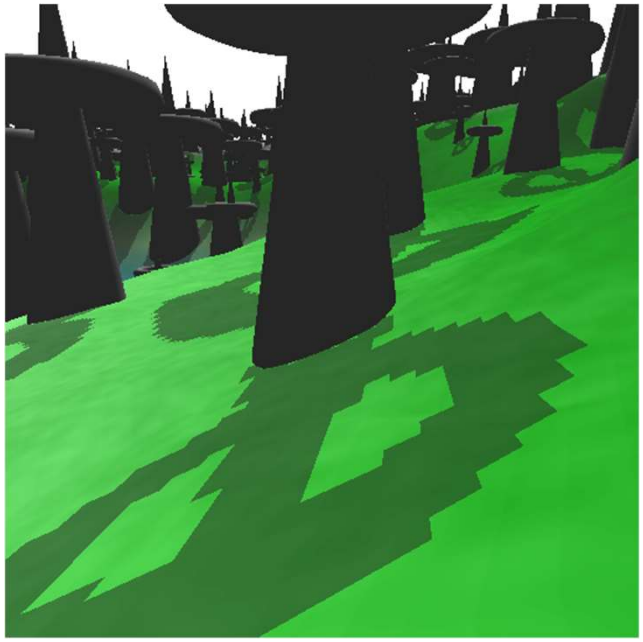
Shadow Mapping

Fighting Undersampling – Warping

Solution for Perspective Aliasing

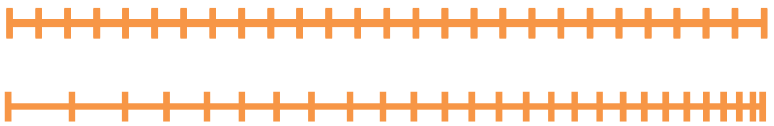
- **Insufficient** resolution near the observer





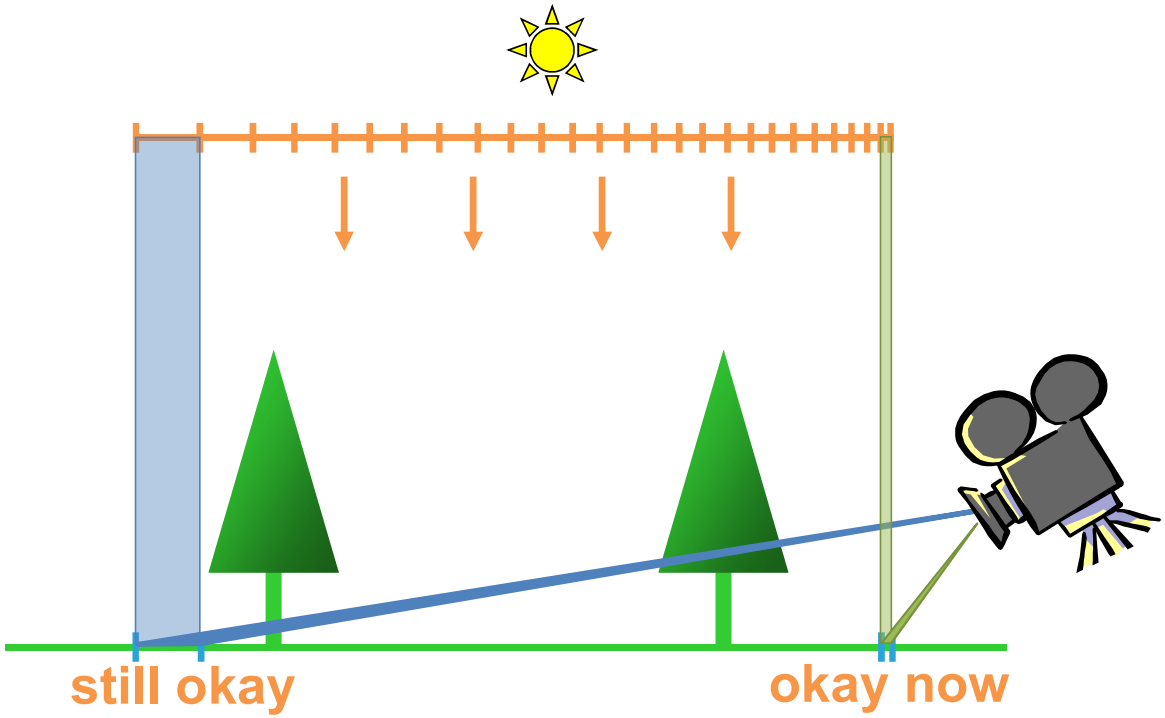
Solution for Perspective Aliasing

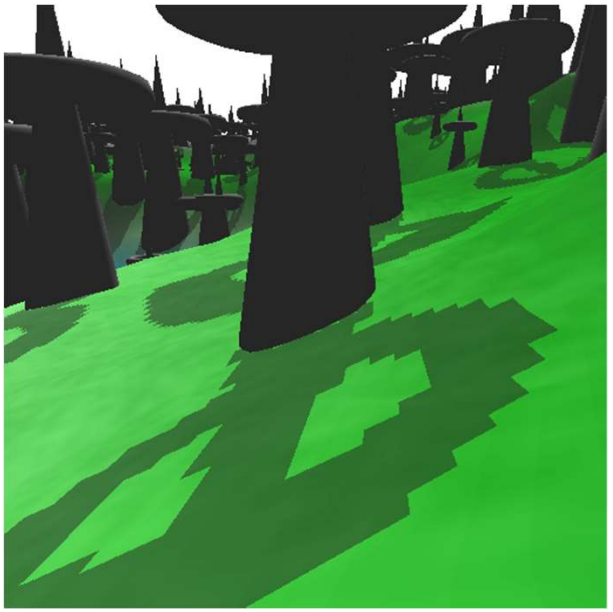
- **Insufficient** resolution near the observer
- **Redistribute** values in shadow map



Solution for Perspective Aliasing

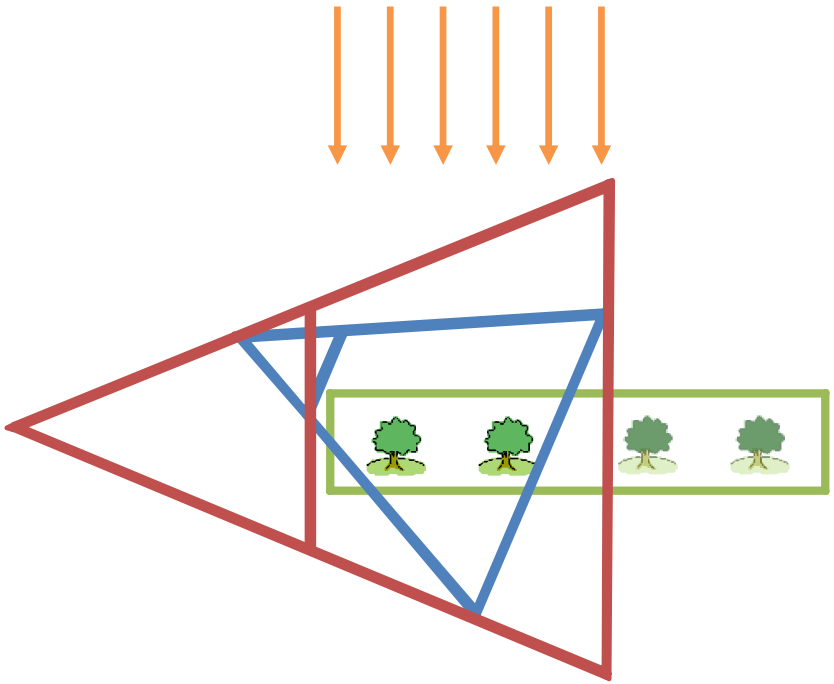
- **Sufficient** resolution near the observer
- **Redistribute** values in shadow map



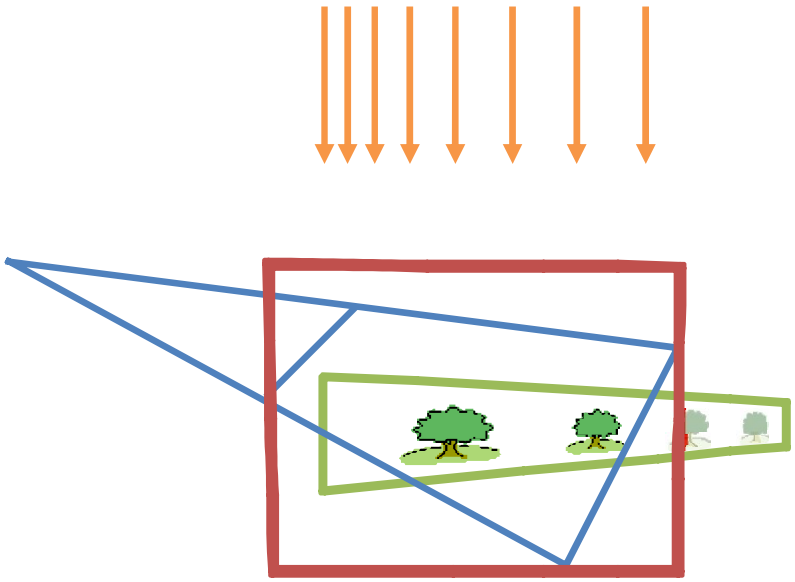


Shadow Map Warping

- Uniform shadow map



- Warped shadow map



additional perspective frustum