



SIGGRAPH2004

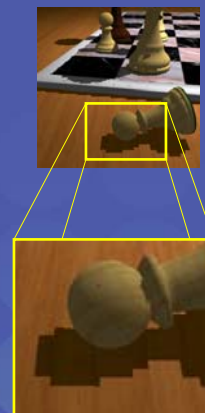
## Perspective Shadow Maps

Marc Stamminger, University of Erlangen-Nuremberg

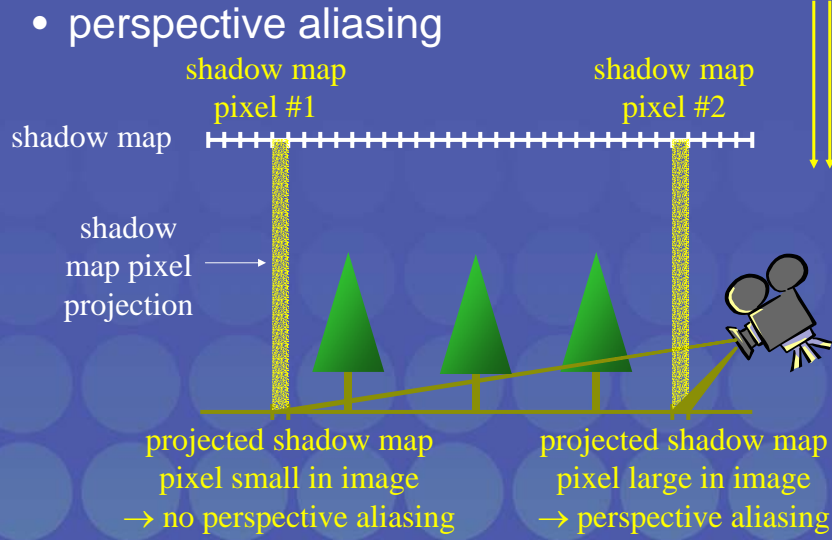
### Shadow Map Aliasing



- in particular for large scenes
- shadow maps impossible for infinite scenes

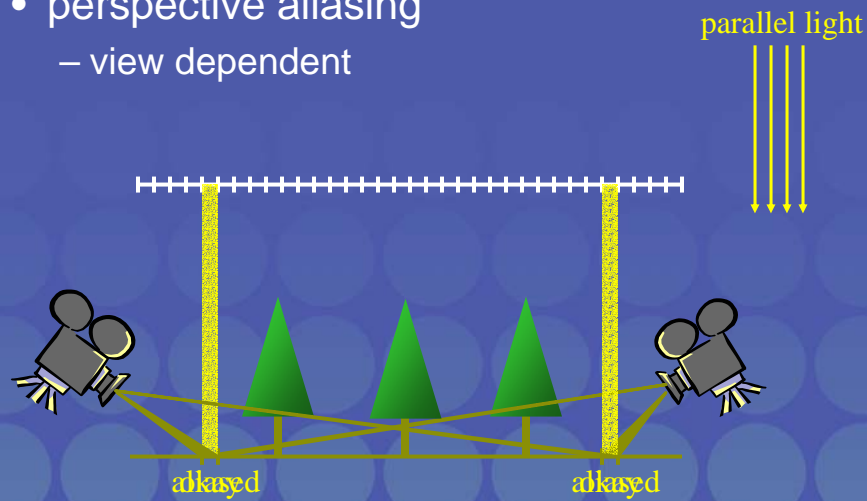


# Shadow Map Aliasing



# Shadow Map Aliasing

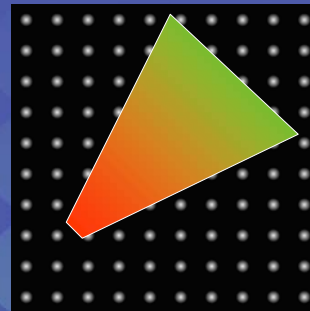
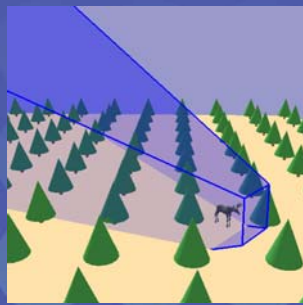
- perspective aliasing  
– view dependent



## Shadow Map Aliasing



- perspective aliasing
  - view dependent
  - close to camera: perspective aliasing
  - distant regions: oversampling

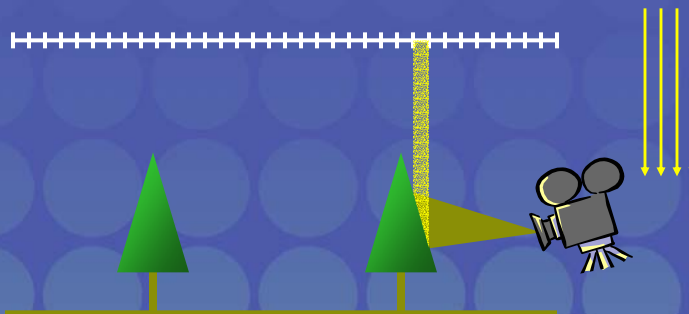


## Shadow Map Aliasing



- projection aliasing
  - depends on angle of light incidence
  - very local

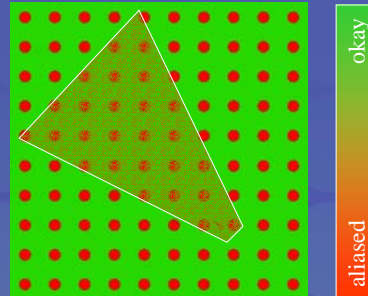
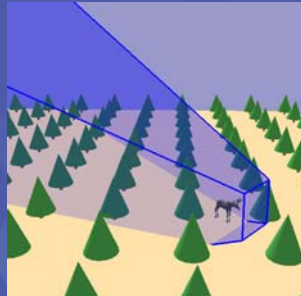
parallel light



## Shadow Map Aliasing



- projection aliasing
  - very local



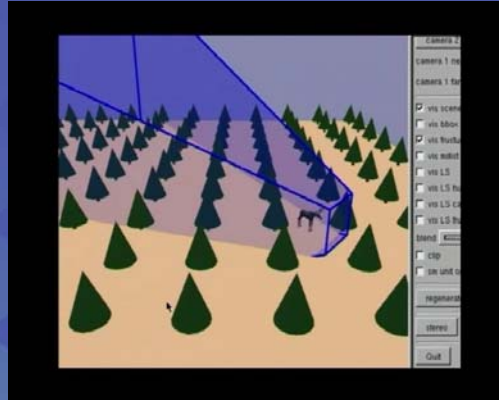
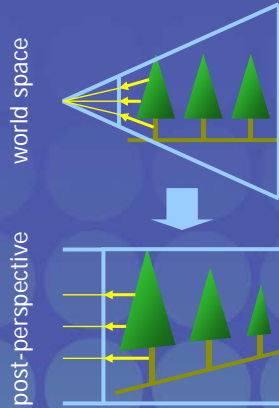
## Perspective Shadow Maps



- Idea:
  - generate and apply shadow map in post-perspective space (clip space)
  - „Perspective Shadow Maps“ see the world after the perspective projection
    - account for perspective aliasing
    - cannot account for projective aliasing

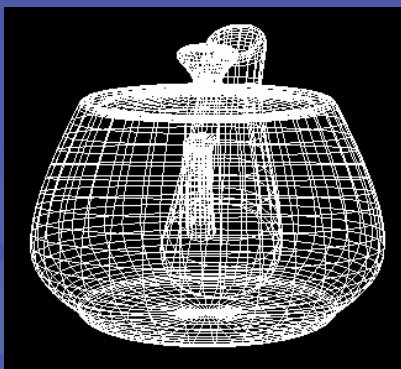
# Post-Perspective Space

- perspective transformation  
(gl uPerspect i ve)

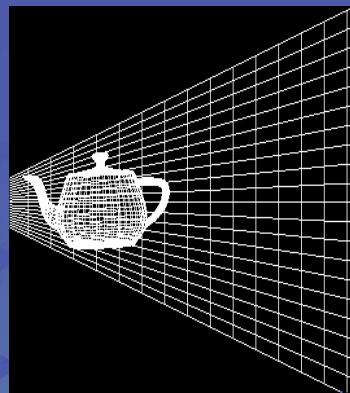


# Post-Perspective Space

- properties of perspective transformation



camera view

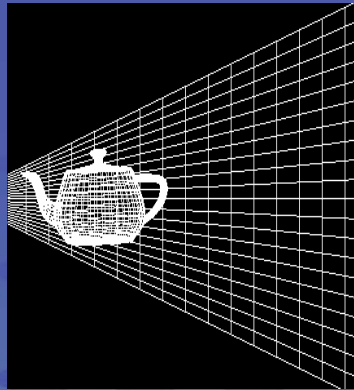


view frustum from side

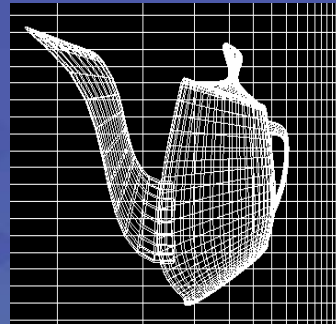
## Post-Perspective Space



- properties of perspective transformation



view frustum from side



after perspective transformation

## Post-Perspective Space



- properties of perspective transformation
- demo:
  - rotate object
  - move object forwards/backwards
  - change field of view
  - change near/far value

PERSPECTIVE

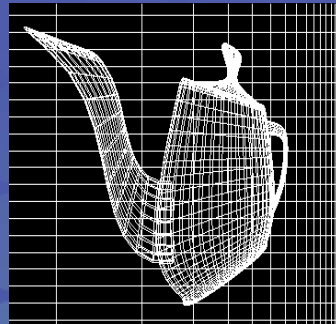
demo  
application

## Post-Perspective Space



- properties of perspective transformation
  - objects close to camera are enlarged
  - distant objects are shrunk

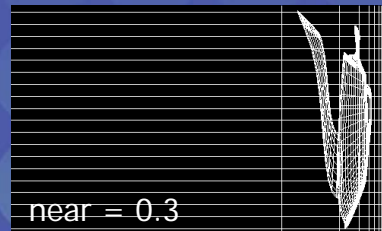
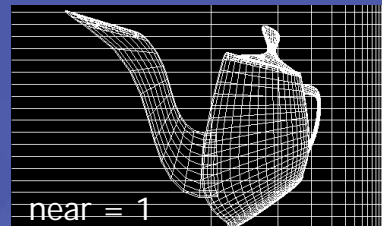
← camera



## Post-Perspective Space

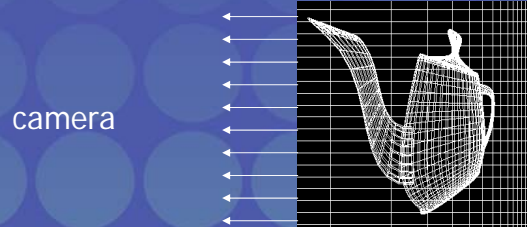
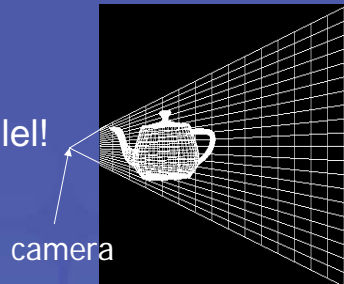


- properties of perspective transformation
  - non-linear mapping:  
 $z \rightarrow 1 - 1/z$
  - near-value critical!
    - too little near value
      - post-perspective cube mostly empty
      - waste of depth precision
    - far value not critical
      - little influence
      - can become infinity!



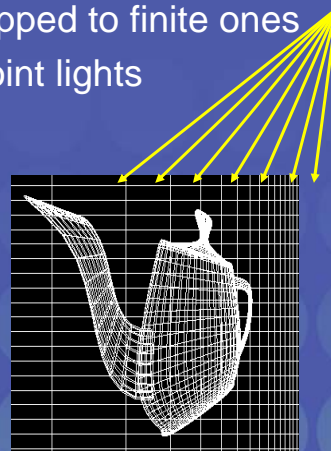
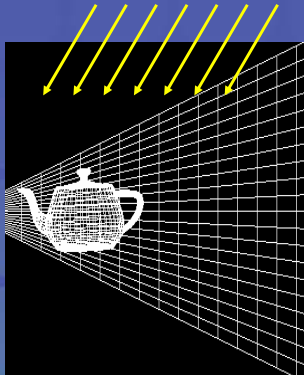
## Post-Perspective Space

- properties of perspective transformation
  - camera rays become parallel!
  - camera moved to infinity



## Post-Perspective Space

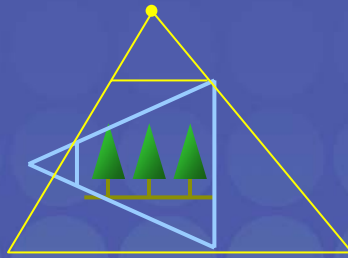
- vice versa:
  - infinite points can be mapped to finite ones
  - parallel lights become point lights



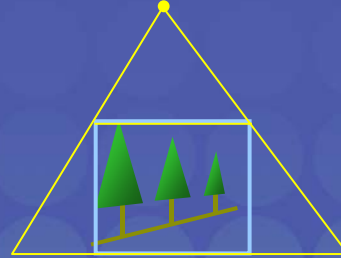


# PSM idea

- uniform shadow map
- perspective shadow map



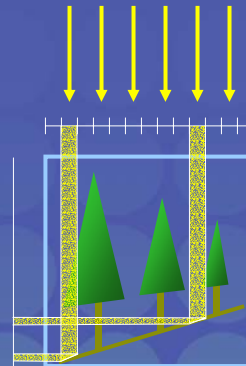
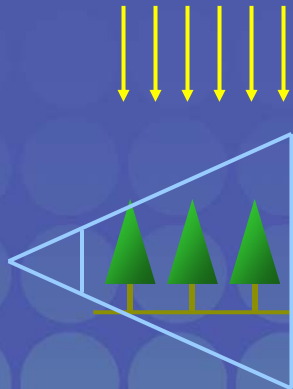
world space



post-perspective

# Perspective Shadow Maps

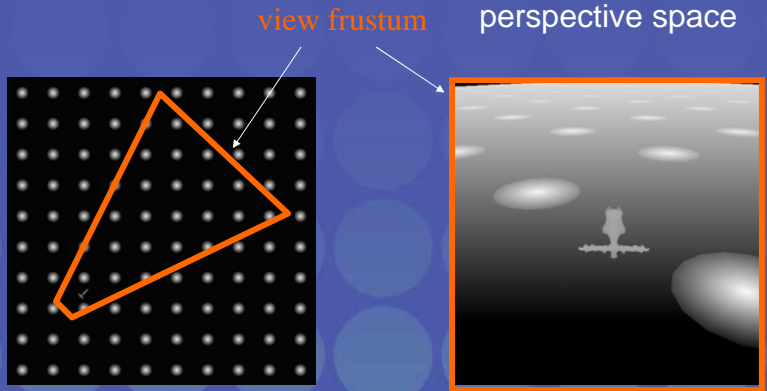
- standard shadow map
- perspective shadow map



# Perspective Shadow Maps



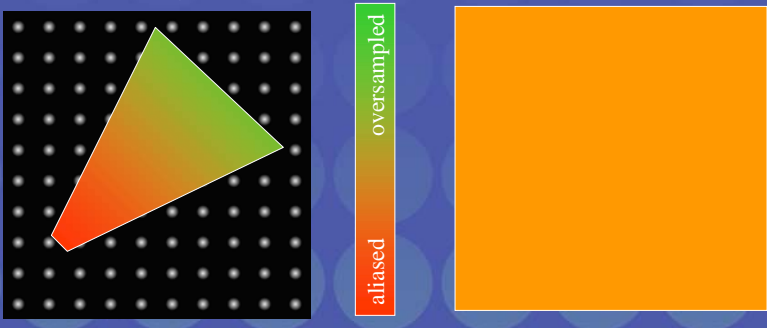
- standard shadow map
  - sees normal world
- perspective shadow map
  - sees world in post-perspective space



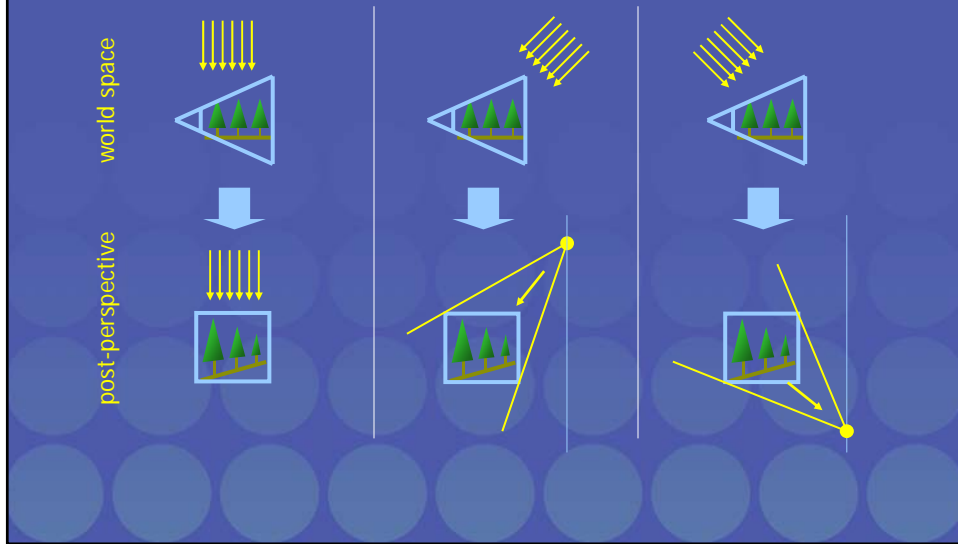
# Perspective Shadow Maps



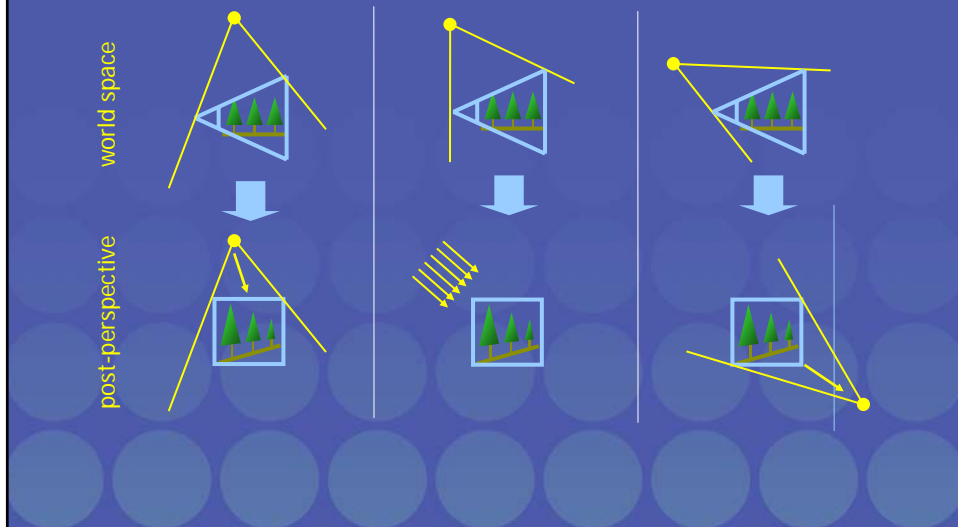
- standard shadow map
  - perspective aliasing close to camera
  - oversampling in distant regions
- perspective shadow map
  - uniform perspective aliasing over entire frustum



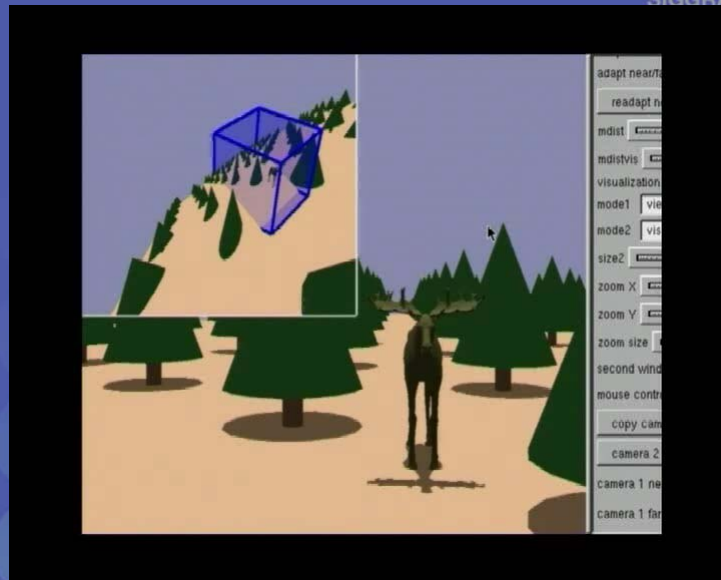
# Parallel Light Transformation



# Point Light Transformation

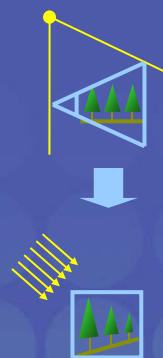


# Point Light Transformation



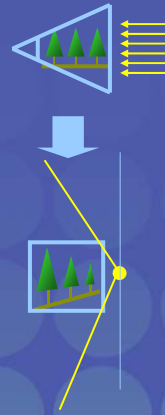
## Discussion

- ideal case:  
parallel light in post-  
perspective space  
(→ no perspective aliasing)
  - directional light parallel  
to image plane
  - point light in camera  
plane (miner's lamp)

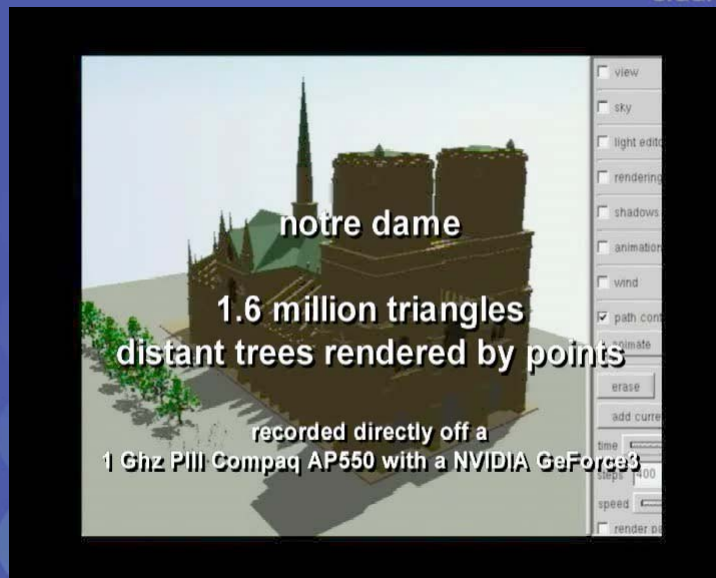


## Discussion

- worst case:  
point light in post-  
perspective space  
close to unit cube  
(→ severe new distortions)
  - e.g. parallel light from  
front or behind



## Results



## Problems of original paper



- robustness
  - quality changes for moving lights/camera
  - „swimming“ shadows
  - depth bias
  - constructions of original paper lead to singularities
  - idea is simple, but robust implementation awkward

## Issues and extensions

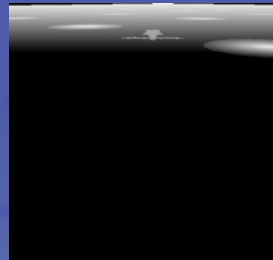
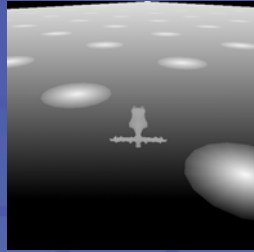


- camera near/far selection
- shadows from the back
- deep light sources
- usage of cube maps
- generalization

## Near/Far Selection



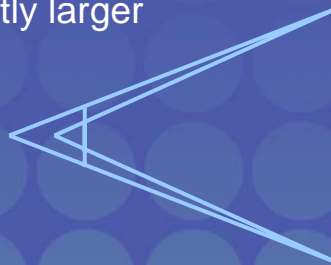
- close near plane → strong perspective distortion



## Near/Far Selection



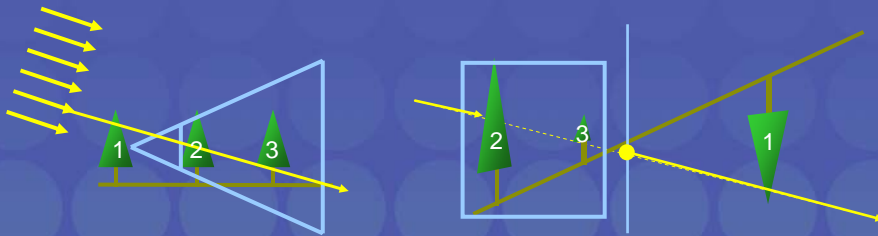
- solutions:
  - select near plane as far as possible (e.g. read back depth buffer → slow)
  - virtually move camera back, compute psm for slightly larger frustum
  - move near plane forward to original plane [Kozlov04]



## Shadows From the Back



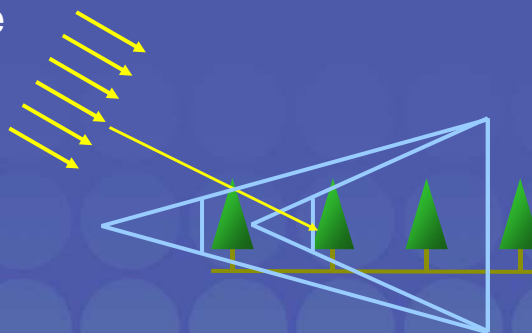
- object behind viewer casts shadow
- wrap around at infinity



## Shadows From the Back



- solution 1:  
virtually move  
back camera  
until  
no shadows  
from  
behind

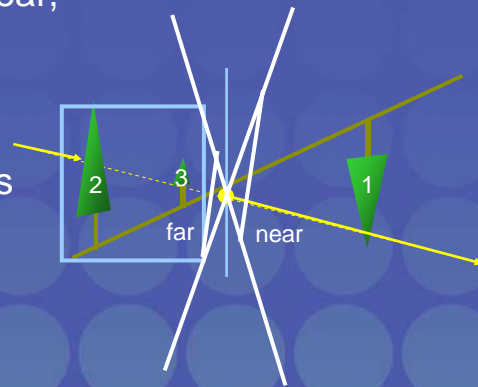




## Shadows From the Back



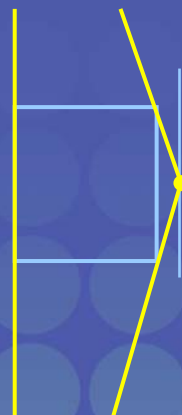
- surprising solution 2 [Kozlov04]:  
set near plane to a negative value
  - eye rays start at  $-near$ ,  
go to  $-\infty$ ,  
wrap to  $\infty$   
and end at  $far$
  - sign of homogenous  
w happens to be  
correct!



## Deep Light Sources



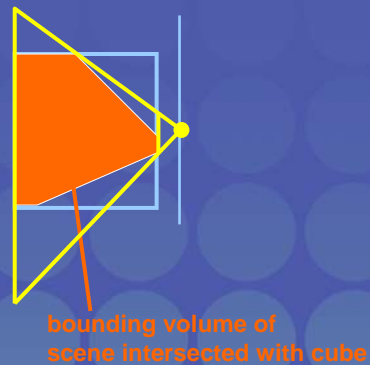
- deep lights
  - close to post-persp. cube
  - wide frustum
  - large distortions



## Deep Light Sources



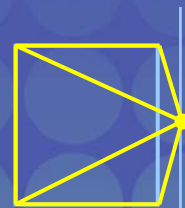
- however:
  - scene's bounding box shrinks towards the far plane
  - intersection of bounding box and cube much smaller close to light



## Cube Maps



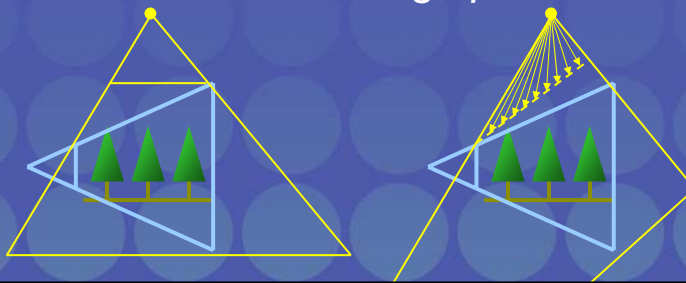
- [Kozlov04]: use cube maps to better sample the unit cube
  - one shadow map for every backfacing side of the unit cube
  - can be achieved with cube maps:  
 $\text{text.coord} = \text{vertex coord} - \text{light pos}$
  - much better quality
  - also useful for point lights
  - generation of cube maps requires multiple passes



## Thesis of Hamilton Yu-Ik Chong



- generalization of PSM idea
- observation:  
*shadow maps have a degree of freedom that have been unused before PSMs: the orientation of the image plane*



## Thesis of Hamilton Yu-Ik Chong



- optimal angle for single plane geometry
  - project camera to plane (parallel to image plane)  
→ C
  - light plane parallel to connection of light and C
  - minimal perspective aliasing on plane

