

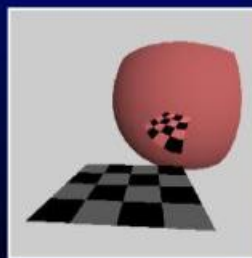
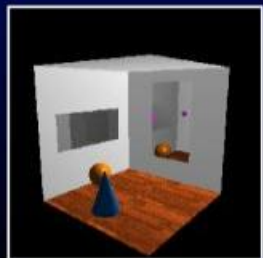
# Advanced Shading Techniques



## Reflection

- Planar reflectors
  - Stencil technique
  - Textured technique
- Curved reflectors
- Interreflections
- Refraction

## Reflection



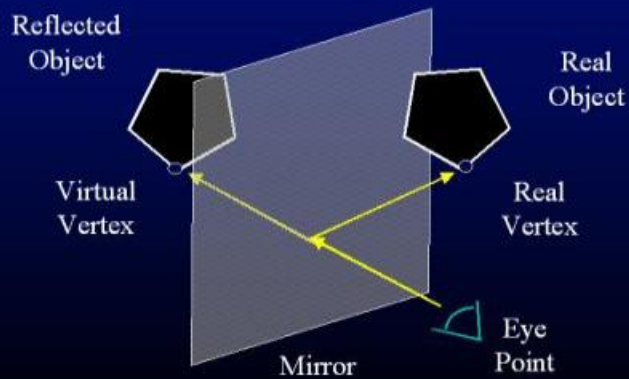
## Reflection



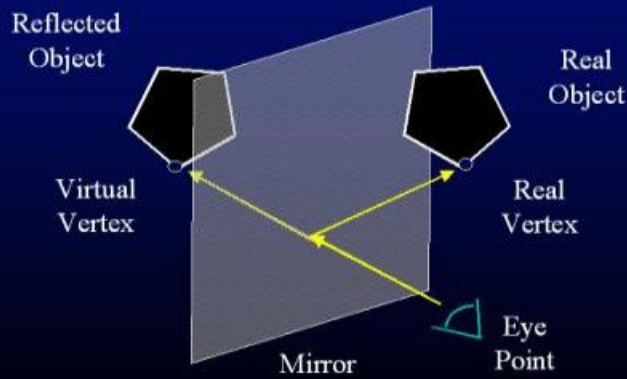
### Unifying concepts

- Ray-tracing too expensive for any reasonably sized image
- Approximate appearance of reflected objects
- Build second version of scene that looks reflected to eye
  - For each vertex in scene,
  - Calculate virtual vertex in reflected scene
- Blend that second scene with the first *somehow*

## Reflection



# Reflection



Mirror is XY plane at some  $-z$  point?

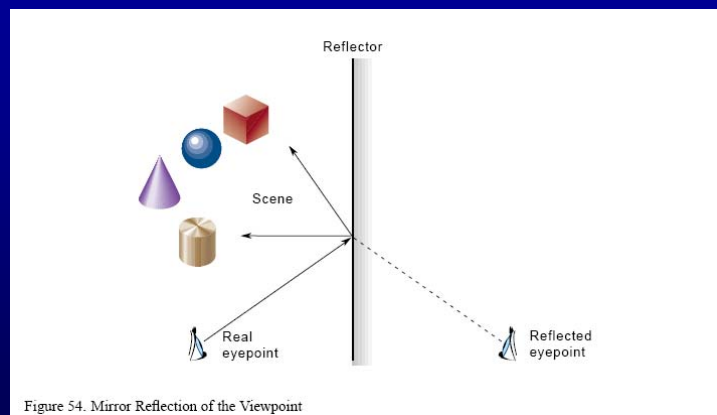


Figure 54. Mirror Reflection of the Viewpoint

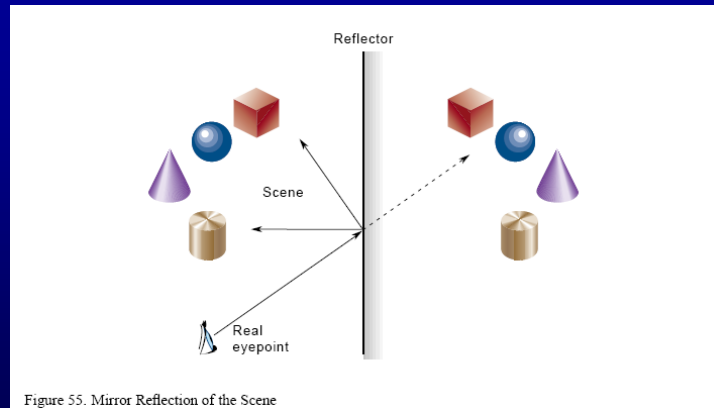


Figure 55. Mirror Reflection of the Scene

## Planar Reflectors



*Start with reflectors which lie in a plane*

- Mathematically straightforward
- Reflection math is the same for all vertices
- Define reflection matrix from plane

## Planar Reflections

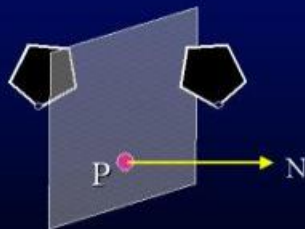


Dinosaur is reflected by the planar floor.

Easy hack, draw dino twice, second time has `glScalef(1,-1,1)` to reflect through the floor

But what if it's not the XY plane?

## Planar Reflectors



$$\begin{bmatrix} 1-2N_x^2 & -2N_xN_y & -2N_xN_z & 2(P \cdot N)N_x \\ -2N_xN_y & 1-2N_y^2 & -2N_yN_z & 2(P \cdot N)N_y \\ -2N_xN_z & -2N_yN_z & 1-2N_z^2 & 2(P \cdot N)N_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Reflection transformation  
matrix for  $P$  and  $N$   
(I.e. it's just a 4x4 matrix)

Just like shadows.....



Good



Bad

## Planar Reflectors



### *Stencil buffer implementation*

- Configure projection and viewing matrix, clear buffers
- Apply reflection transformation
- Draw scene normally (will be reflected) (skip mirror)
- Clear stencil to 0 and clear depth buffer
- Draw mirror polygon as stencil 1
- Clear color buffer everywhere stencil == 0

## Planar Reflectors



Original Scene



Reflected Scene



Reflected Scene  
Cleared Where not  
in Mirror

## Planar Reflectors



### *Stencil buffer implementation, cont'd*

- Remove reflection transformation
- Modulate reflected scene by mirror color & lighting
- Render remainder of scene normally (skip mirror)

## Planar Reflectors



Reflected Scene



Modulated by  
Mirror Parameters



Original Scene  
Rendered

## Planar Reflectors



### ***Projected texture implementation***

- Configure projection and viewing matrix, clear buffers
- Apply reflection transformation
- Draw scene normally (will be reflected) (skip mirror)
- Copy framebuffer into texture
  - Can save just rectangular region around mirror



## Planar Reflectors



Original Scene



Reflected Scene



Framebuffer  
Saved As  
Texture

## Planar Reflectors



### *Projected texture implementation, cont'd*

- Clear buffers
- Remove reflection transformation
- Set up texture projection identical to camera projection
- Render mirror, modulating with color and lighting
- Render scene normally (skip mirror)

# Planar Reflectors



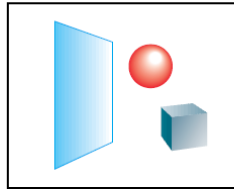
Framebuffer  
Saved As  
Texture



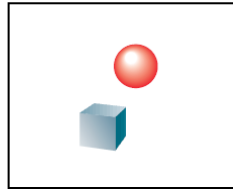
Mirror Drawn  
with Texture Projected  
from Viewpoint



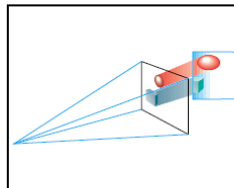
Original Scene  
Rendered



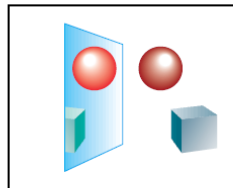
Original scene



Reflected objects



Reflected scene image  
projected onto reflector



Textured reflection  
and original scene

Figure 58. Masking Reflections Using Projective Texture

## Planar Reflectors



### *One last technique*

- If you scene has a background that fills window
- Draw reflected scene
- Clear depth
- Draw mirror modulated with reflection
- Draw background (will fill in areas around mirror)
- Draw unreflected scene

## Planar Reflectors



### *Shiny marble, etc...*

- Mirror can have color, texture, lighting, etc
- Stencil: Draw modulated by reflection in framebuffer
- Texture: Draw modulated with reflection texture
  - May need multipass or multitexture

## Planar Reflectors



### *Implementation issues*

- Can cull to a frustum that bounds mirror polygon
- Need clipping plane in plane of mirror
  - Stuff transformed to front of mirror shouldn't be rendered
  - Can also create skewed projection so near plane clips
- Magnification/minification special effect:
  - Hack for slight concavity/convexity
  - Translate reflected scene perpendicular to mirror

## Planar Reflectors



### *Implementation issues*

- Texture implementation may be slow: fb copy to texture
- Stencil buffer implementation requires... stencil buffer!
- Could draw mirror into stencil up front, but:
  - Stencil enabled during entire reflected scene
  - Could just draw with clip planes if mirror = quad

## Interreflections



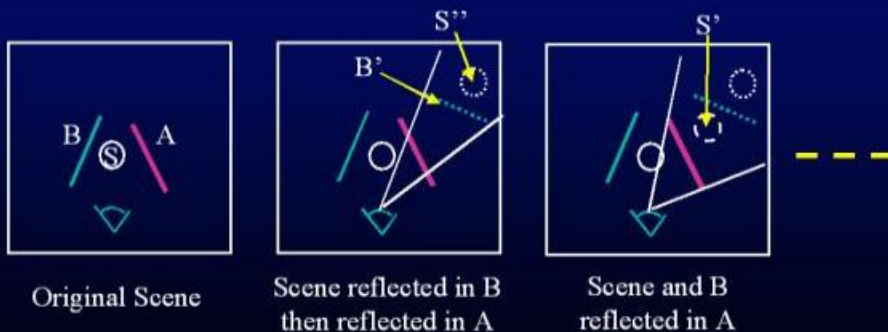
### Adding More Reflection Bounces

- Limit reflections to  $n$  bounces, handle recursively
  - Render scene reflected in A
    - <sup>2</sup> Render scene reflected in both B and A, clipping to intersection of A and B on screen
    - <sup>2</sup> Add in scene reflected in A, clipping to A
  - Render scene reflected in B, ...
  - Add in original scene

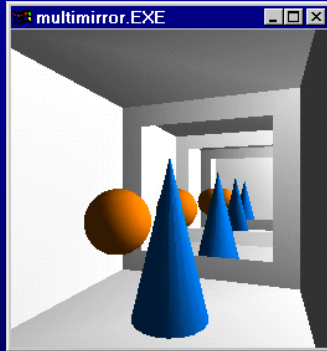
## Interreflections



### Adding More Reflection Bounces

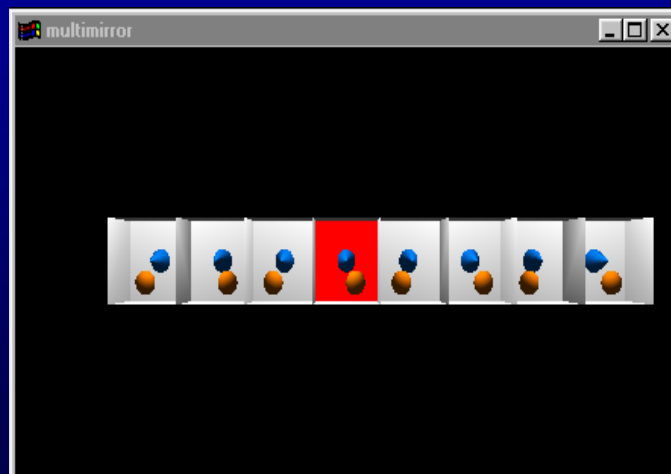


## Recursive Planar Mirrors



Basic idea of planar reflections can be applied recursively. Requires more stencil bits.

## The Trick (bird's eye view)



**Demo**