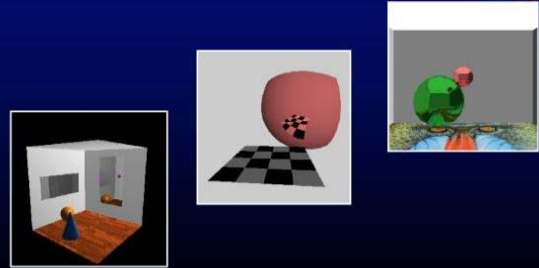## Advanced Shading Techniques

Reflection

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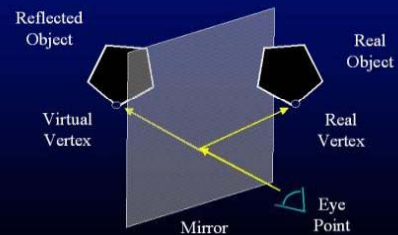- Refraction

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Reflection
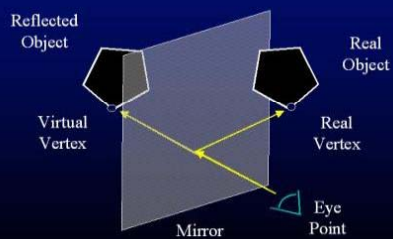

Reflection

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
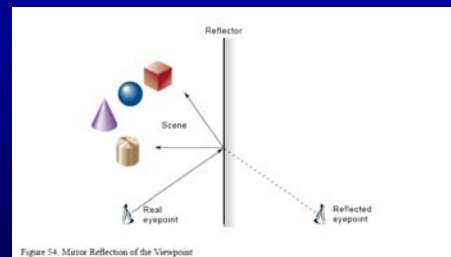

Mirror is XY plane at some –z point?

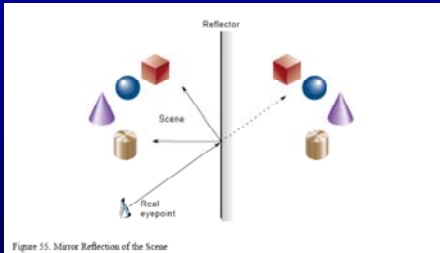Figure 54. Mirror Reflection of the Viewpoint

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
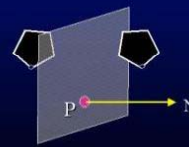

Planar Reflections

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

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

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
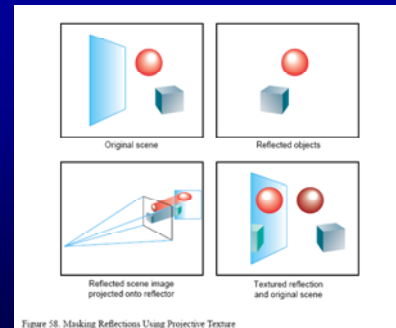from Viewpoint

Original Scene
Rendered

Original scene   Reflected objects

Reflected scene image   Textured reflection
projected onto reflector   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
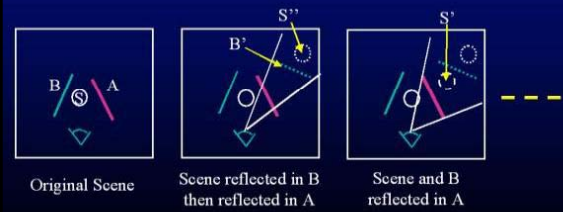
Interreflections

Adding More Reflection Bounces

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

Interreflections

Adding More Reflection Bounces

Original Scene

Scene reflected in B then reflected in A

Scene and B reflected in A

Recursive Planar Mirrors

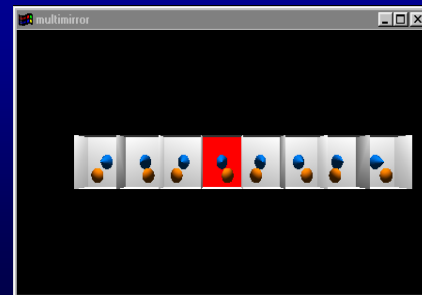**Basic idea of planar reflections can be applied recursively. Requires more stencil bits.**

The Trick (bird's eye view)

Demo