CS 563 Advanced Topics in Computer Graphics
Camera Models

by Kevin Kardian

Introduction

- Pinhole camera is insufficient
  - Everything in perfect focus
  - Less realistic
- Different camera models are possible
  - Create varying images from the same scene
  - Simply generates rays differently

Camera Model Basics

- Each model stores very few values
  - Transforms between world and camera spaces
  - Distances to near and far clipping planes
  - Time values simulating camera shutter speed
- Coordinate Spaces
  - Object space
  - World space
  - Camera space
  - Screen space
  - Normalized device coordinate (NDC) space
  - Raster space

New Coordinate Spaces

- Camera space
  - Origin at the camera
  - z+ in the direction of viewing
  - y+ in the up direction

- Screen space
  - The camera space mapped to the image plane
  - z values are scaled to range [0,1]
  - These values correspond to points on the hither and yon planes

New Coordinate Spaces

- Normalized device coordinate (NDC) space
  - Scales all coordinates to range [0,1]
  - Note that y+ is in the down direction
- Raster space
  - Similar to NDC space
  - x,y coordinate values scaled to a different range
  - Based on the overall image resolution

Projective Models

- Subclass of normal camera models
- Projects objects from a space onto a screen
- Allows for depth of field
- Maintains several coordinate space transforms
  - CameraToScreen
  - WorldToScreen
  - RasterToCamera
  - ScreenToRaster
  - RasterToScreen

Orthographic Projection

- Projects a rectangular volume onto a screen
- Preserves parallel lines
- Maintains relative distance between objects
- Does not account for foreshortening

An Example

- Rendered using orthographic projection
- Note the lack of a vanishing point
- Platform edges remain parallel

Implementation Details

- Maps z values to range of [0,1]
  - First, aligns z = 0 to the hither plane
  - Then, scales values so that z = 1 matches the yon plane
- Creating sample rays
  - Sample points are taken from raster space
  - The point is transformed to a point on the hither plane
  - The ray points straight down the z axis
  - Finally, the ray is transformed to world space

Perspective Projection

- Projects a volume onto a screen
- This volume is not rectangular
- Does not maintain parallel lines
- Accounts for foreshortening
- More realistic view of object size and distance

An Example

- Rendered using perspective projection
- Note the illusion of a vanishing point
- Image appears to have depth

Implementation Details

- Plane of projection is actually at z = 1
  - One unit from the camera position

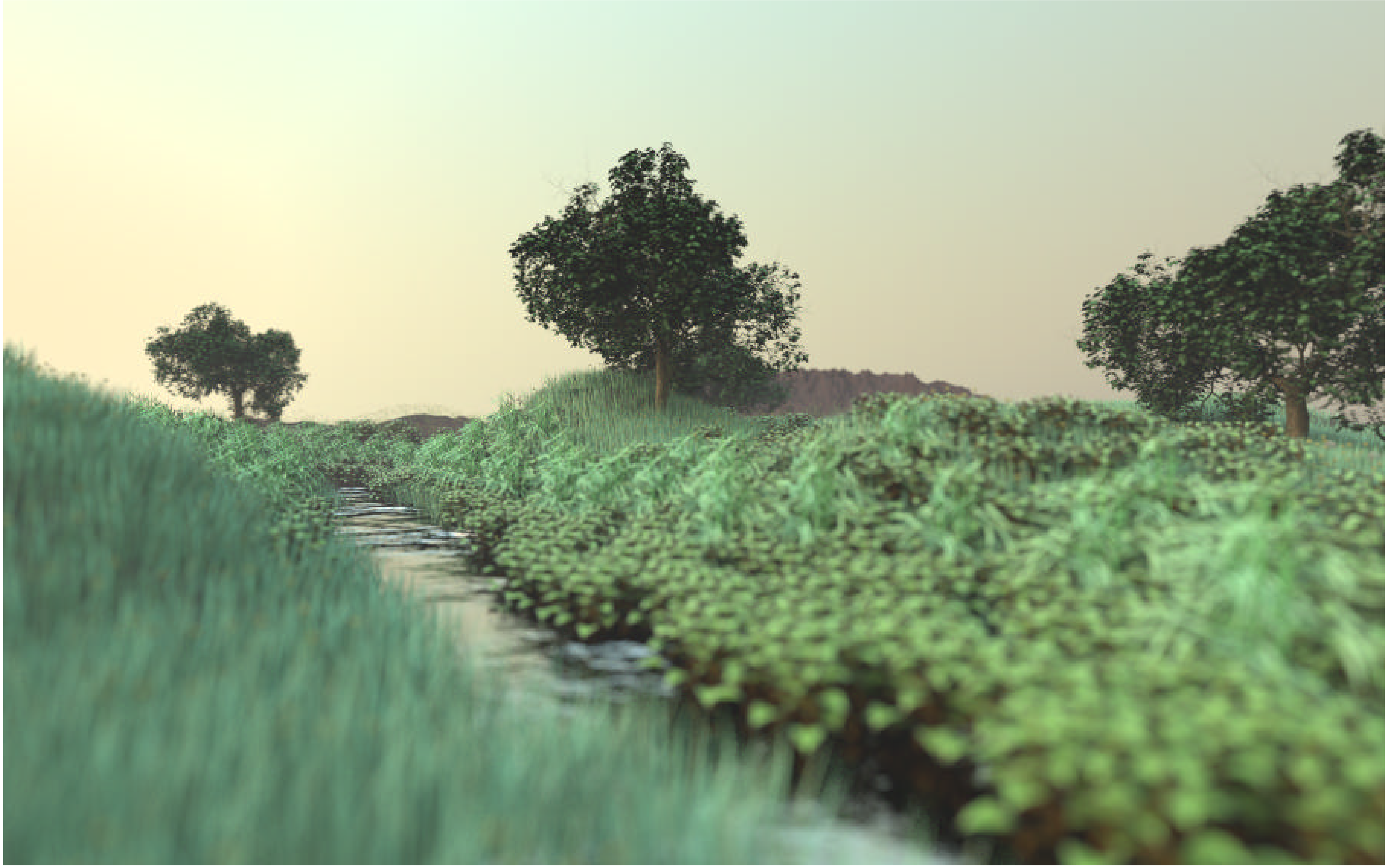
- Creating sample rays
  - Projecting sample points:
    - First, scale z values to a range of [0,1]
    - Then, divide x,y coordinate values by the scaled z
    - Finally, scale based on the fov angle to get x,y coordinates to a range of [-1,1]

  - Sample rays all point from the origin to this projection

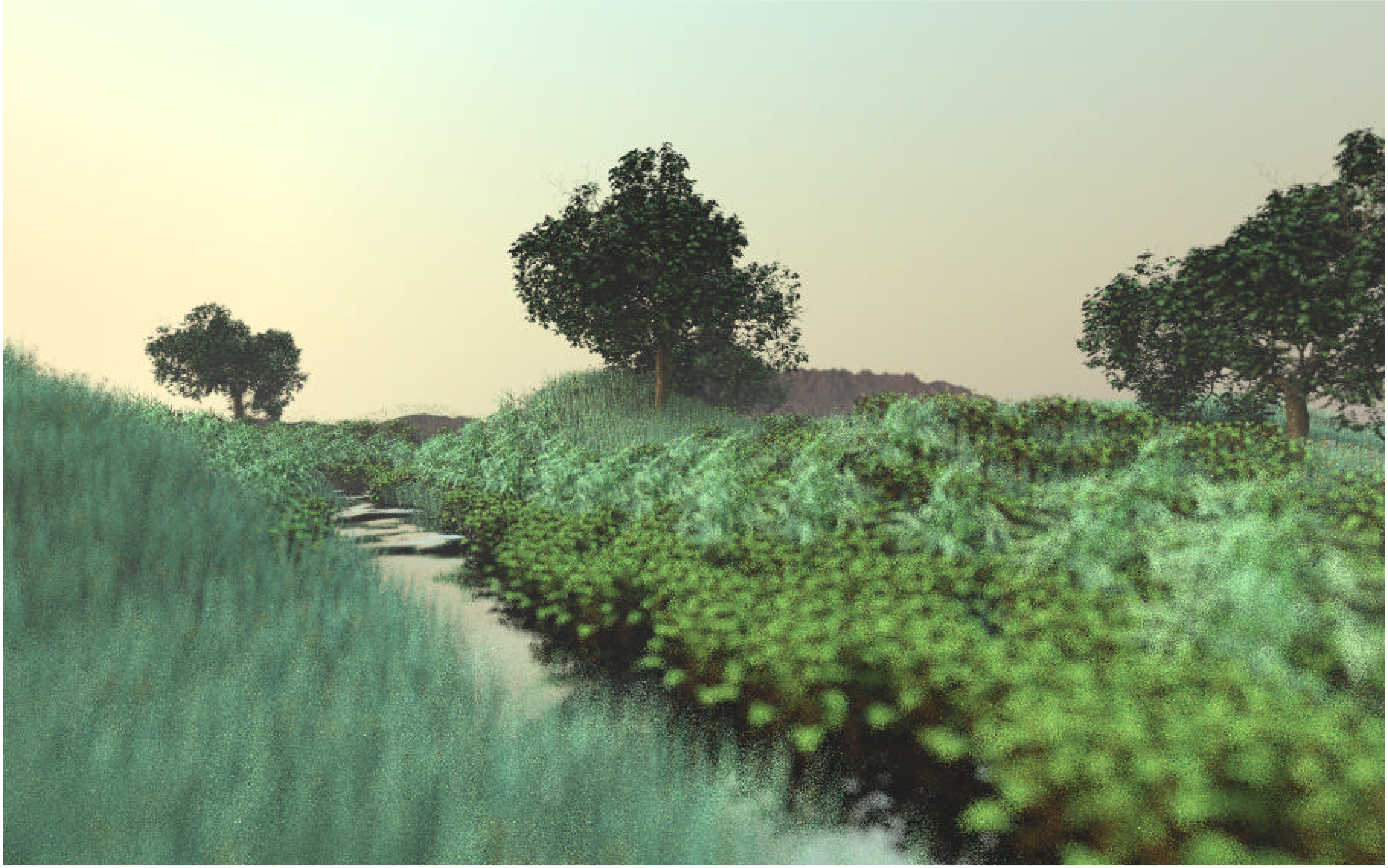
Depth of Field

- Actual lenses do not have perfect focus
- Circle of confusion
  - The image area onto which a single point is projected
  - Based on lens radius and focal distance
  - Focal distance - the distance at which the circle of confusion has no radius
- Large number of samples required for each pixel

Undersampling



Undersampling



Creating Sample Rays

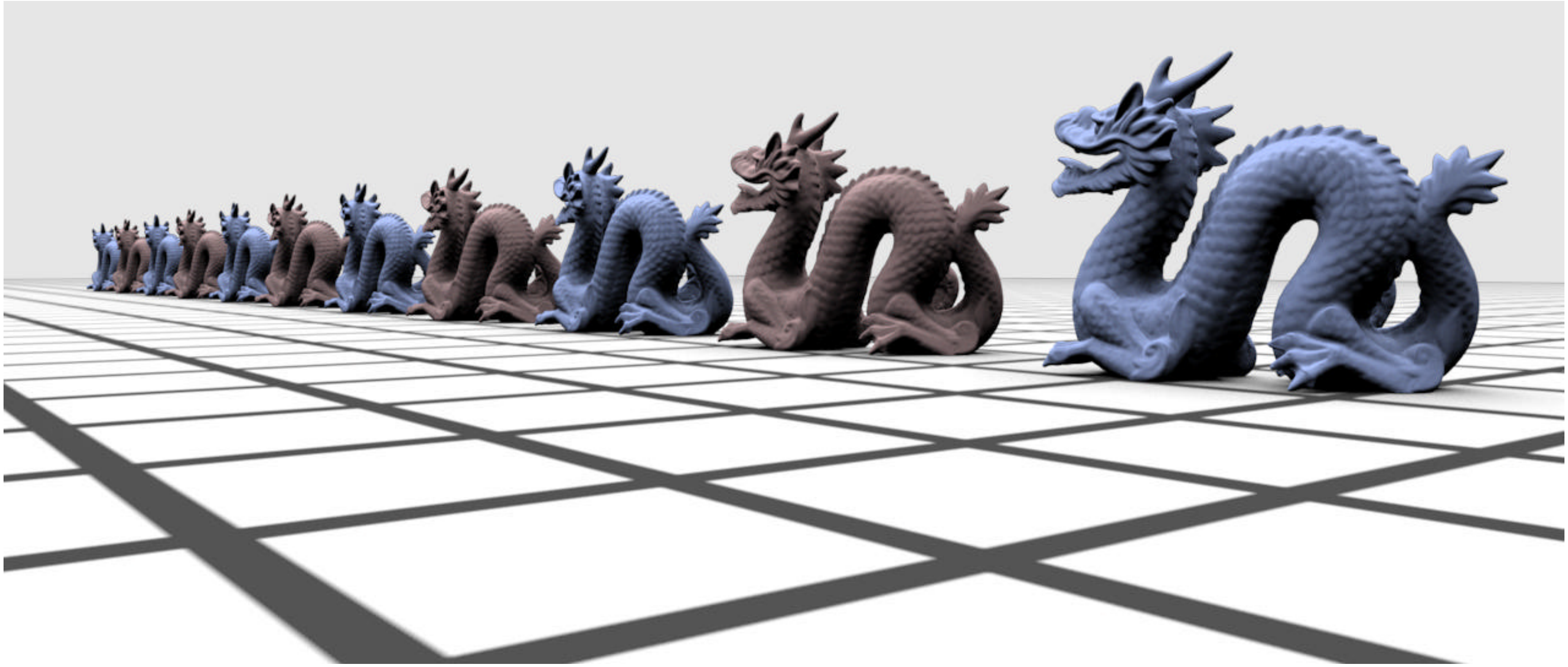
Cook, Porter, Carpenter (1984)

- Get a random sample point on the lens

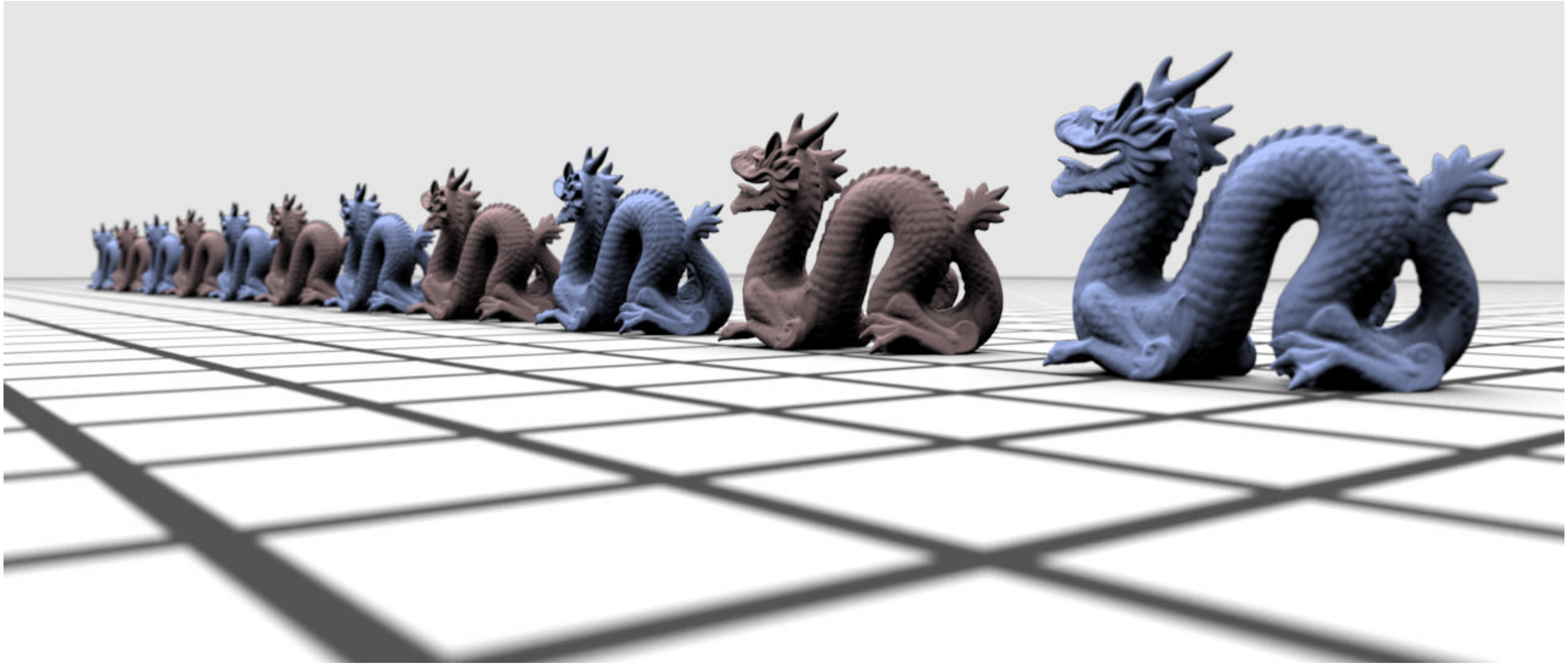
- Observation: Light through the center of a lens isn't refracted
  - Generate this non-refracted ray
  - Find where it intersects the focal plane

- Sample ray originates at the sample point and points towards this intersection

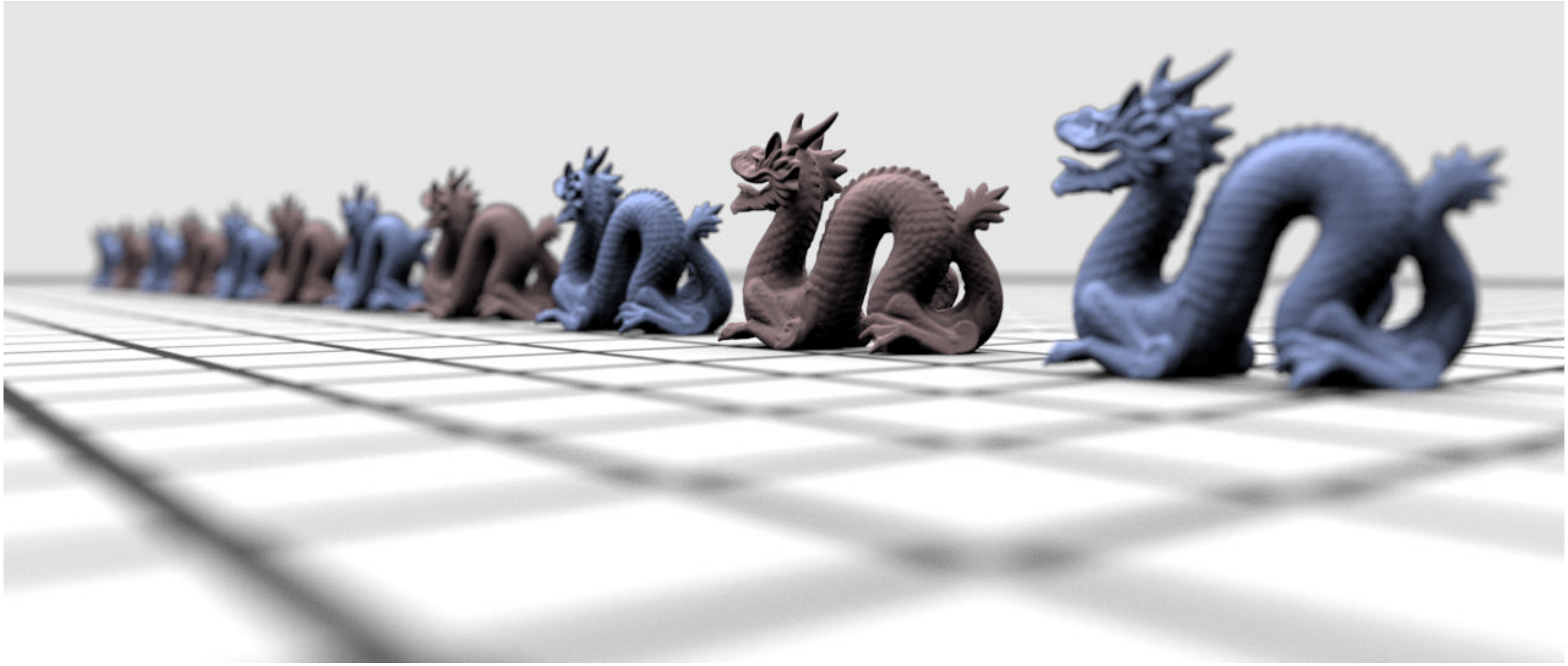
Example 1



Example 2



Example 3



Example 4

Postprocessing Discussion

- Consider calculating the size of any give circle of confusion
- It is apparent that this can be done after ray tracing
- Each location on the scene can be “blurred” based on how focused it should appear
- Where are the flaws in this approach?
- How/why do these not apply to Cook et al’s approach?

Distributed Ray Tracing

Cook, Porter, Carpenter (1984)

- Approach was to achieve improvements by varying sample rays in time
- With extra samples, each spatial location could be sampled at several instants of time
- Instead, separate locations are sampled at varying times
- Oversampling still occurs
- Same result is achieved with fewer total samples

Motion Blur

Potmesil (1983)

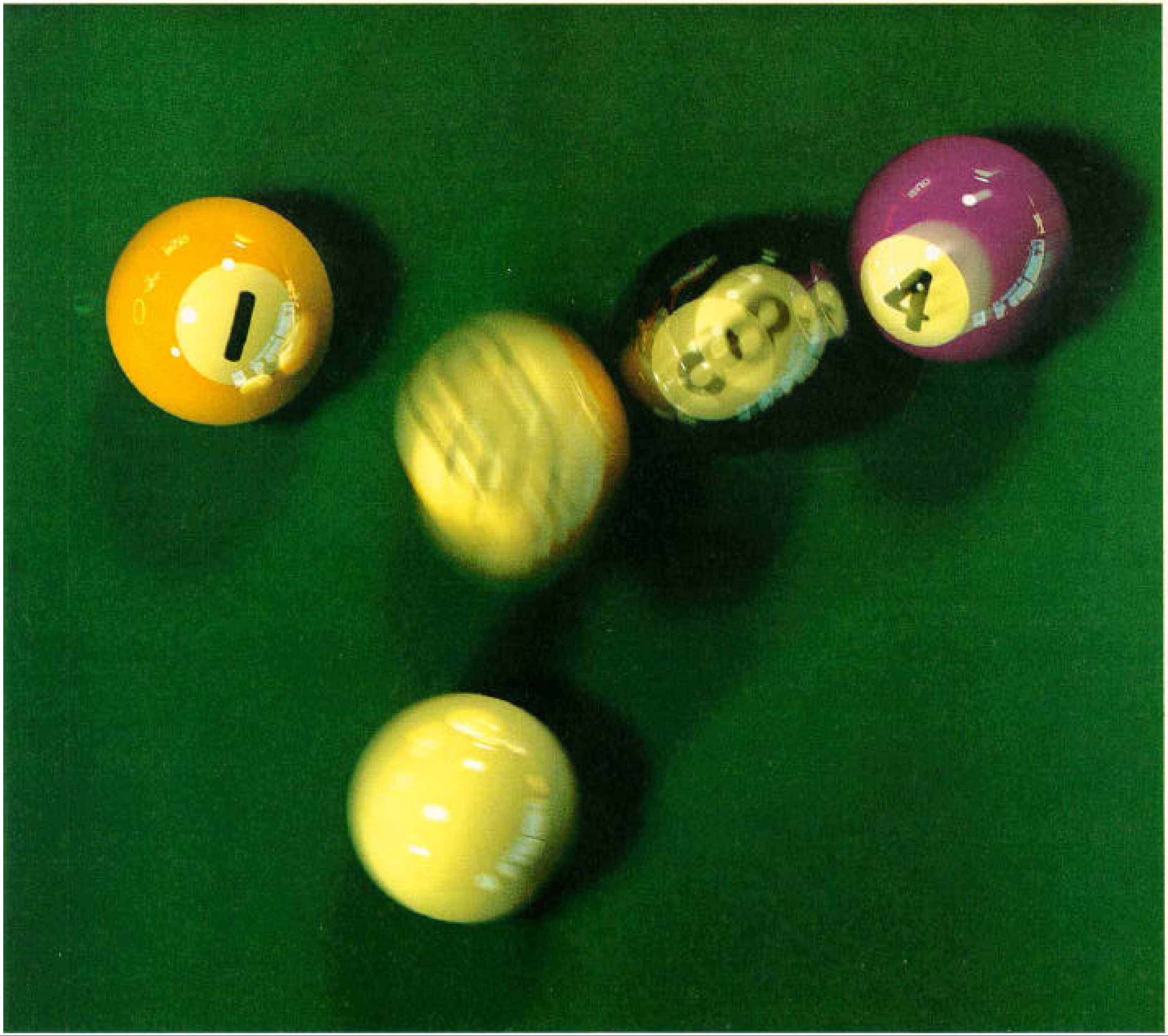
- A preprocessing approach
- Attempting to render an image then apply blur is flawed
- Hidden surfaces may be revealed by motion
- What about background surfaces that are also in motion?
- What about other visual effects?
- Solution: Account for motion blur at the time of sampling

Motion Blur

Cook, Porter, Carpenter (1984)

- A distributed approach
- Different parts of an object are sampled at different times
- The object as a whole is captured in motion
- Accounts for various effects because their changes are captured as well
  - Visibility
  - Shading
  - Shadows
  - Depth-of-field
  - Reflections

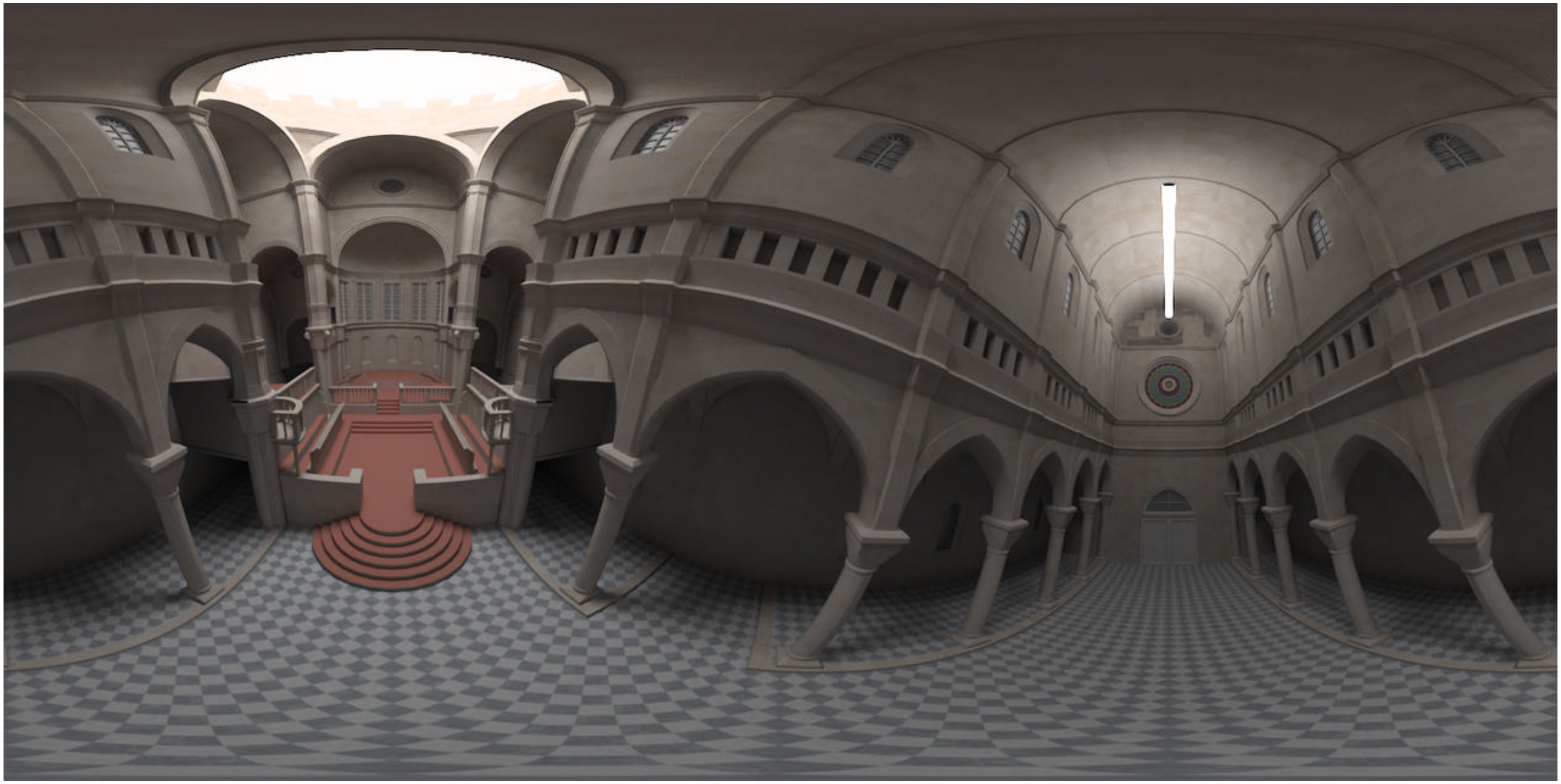
An Example



Environment Camera

- Images rendered using ray tracing have more flexibility
- Consider a point suspended in space
- Send rays in all directions from that point
- Scene maps to an image on a spherical plane
- Image manipulated to give a 2D view on a flat plane

An Example



Implementation Details

- 180 deg. field of vision from top to bottom
- 360 deg. field of vision from left to right
- Note that this camera cannot use linear projections
  - There is no projection matrix
- Creating sample rays
  - All sample rays have the same origin
  - Sample points are converted to spherical coordinates
  - Coordinates are scaled to the appropriate ranges