VO Rendering
SS 2010

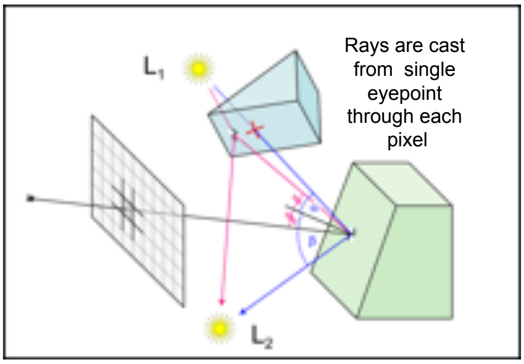
Unit 8: Cameras

Sources:

Overview

- Pinhole camera
- Thin lens camera
- Simulating cameras by using Monte Carlo methods
- Real Cameras
- Stereo Demonstration

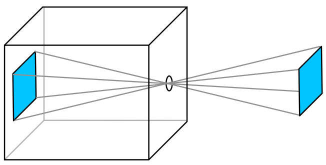
Raytracing Camera



Camera Models

- Perspective Camera
  - Perspective projection
- Orthographic Camera
  - Parallel projection
- Fisheye Camera
- …

Pinhole (Perspective) Camera

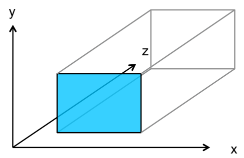


- Simplest device for taking photos
- Light enters through small hole and falls on film, hole = eye point
- Includes foreshortening
- Doesn‘t preserve distances or parallel lines

Pinehole Cameras

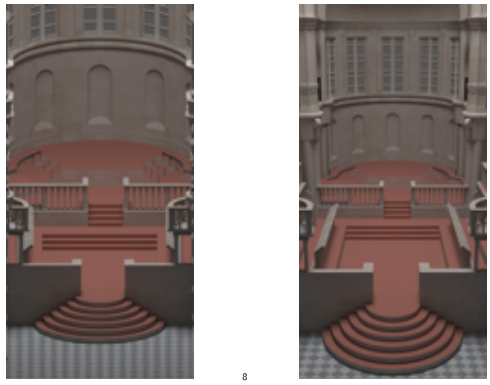


Orthographic Camera

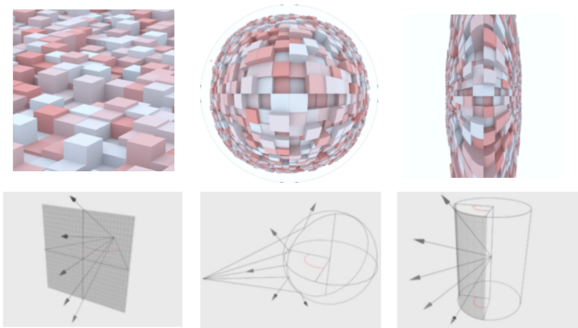


- Preserves relative distance between objects, parallel lines
- No foreshortening
- View volume = aligned box

Orthographic vs. Perspective Camera



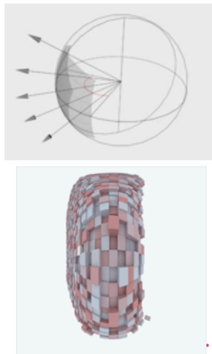
Other Cameras



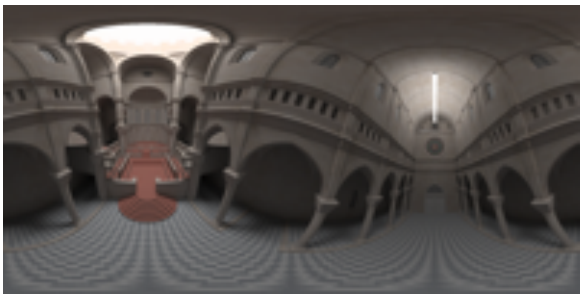
Perspective | Fish Eye | Cylindrical

Enviroment (Spherical) Camera

- Rays are traced in all directions around a point
- 2D view of everything that is visible from that point
- All rays have same origin
- Useful for environment lighting



Enviroment (Spherical) Camera Example



Pinhole Concept Drawbacks

- Sharp for all parts of a scene
- Idealized concept → not realistic!
- Real cameras need an aperture and a lens

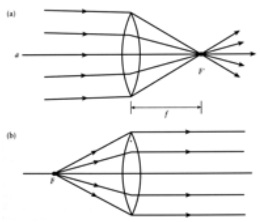
Aperture

- The - for physical reasons - always nonzero diameter of the narrowest point in the imaging system
- The physical reason is that at least some light has to reach the film
- In real cameras the aperture has variable width and is usually determined by a mechanical iris
- Without an accompanying lens an iris cannot generate an image!

Thin Lens Assumption

- For sophisticated CG renderings with depth of field effects, a more realistic concept of lens systems than a pinhole camera is needed
- For most purposes, it is sufficient to assume a planar lens with negligible curvature and fixed index of refraction
- „Fat“ lenses have to be explicitly simulated

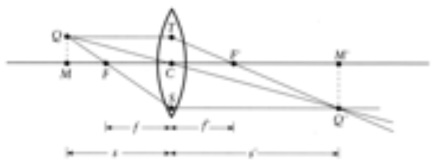
Focal Length Definition



- Parallel rays that fall through the lens are focused in F
- Small f – wide angle lens, large f – tele lens

Imaging Through a (Thin) Lens

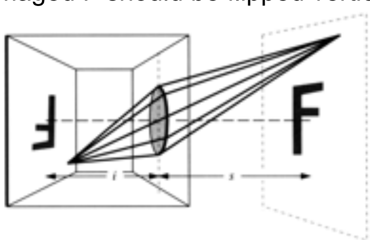
- Lens inverts image
- Virtual image is created at s‘



$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Thin Lens Camera

- (The imaged F should be flipped vertically)



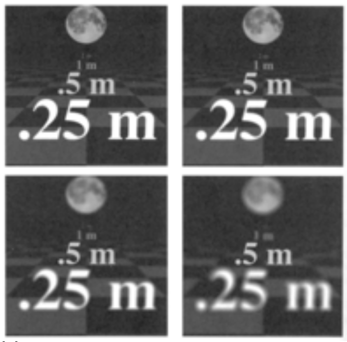
Thin Lens Camera Implications

- It is possible to perfectly focus any plane source image onto the receiving film
- It is not possible to simultaneously focus objects which are at different depths!
- However, the resolution of the receiver is always limited (film, CCD, raster image)
- The lens can be setup to have large ranges of the image in focus at the same time

Depth of Field

- The resulting effect - only certain parts of a scene are in focus - is known as depth of field
- The extent of this can be controlled through the aperture setting
- Aperture is small: image is sharper over a wider range, but longer exposure is needed
- Aperture is big: fast exposure, low DOF

Depth of Field Example #1



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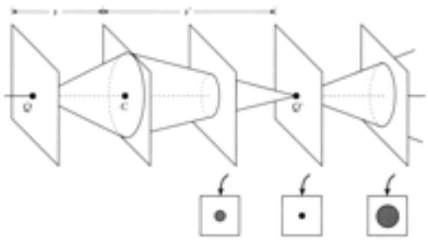
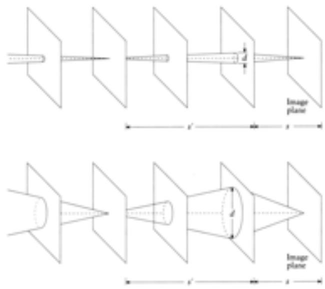
Circle of Confusion #1



- In the order of 0.03 mm for real cameras in focused areas

Circle of Confusion #2

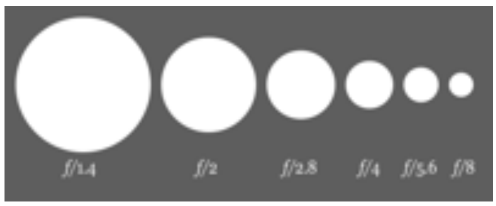


- Smaller apertures yield sharper images!

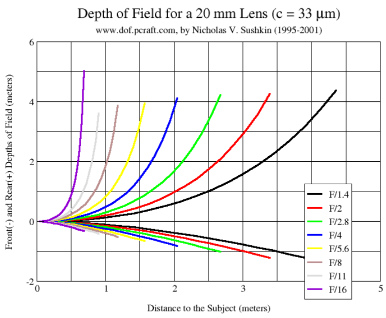
Aperture Numbers

- Given as f-stops on modern equipment
- f-stop = F/D (focal length / diameter)
- Standard sequence: f/1.4, f/2, f/2.8, f/4, f/5.6, f/8, f/11, f/16, f/22, f/32, f/45
- Film exposue is proportional to the square of the f-stop
- It is convenient to work with doubling brightness values, so the standard f-stops differ by sqrt(2)

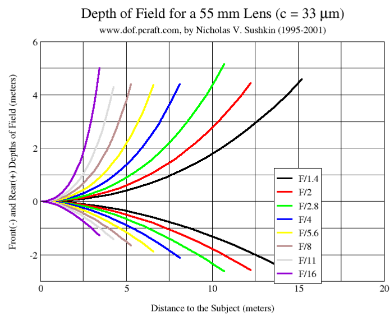
F-stop Visualisation



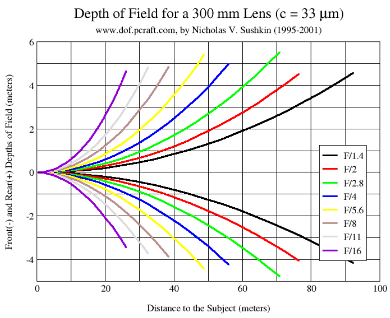
Wide Angle DOF Plot



Standard DOF Plot



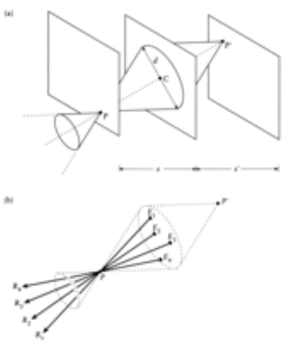
Tele Lens DOF Plot



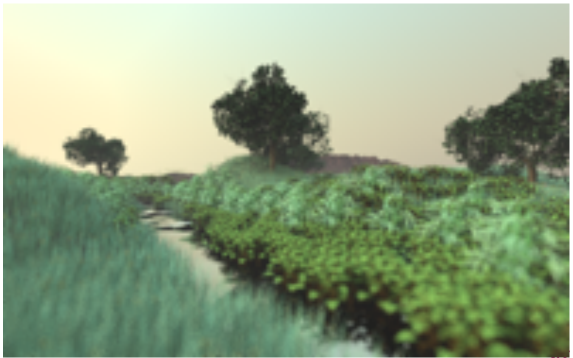
DOF Example #2

How to Generate DOF Effects

- Random samples are generated in the aperture area
- Rays are cast from there through the projected eye-point
- Application: path tracers



DOF Undersampling



DOF Example #3

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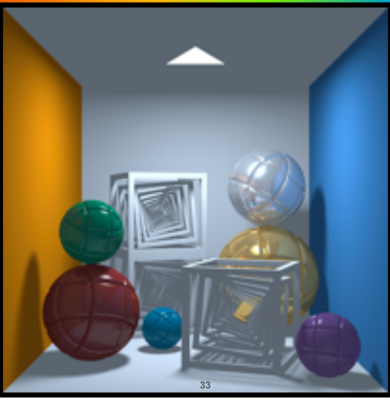
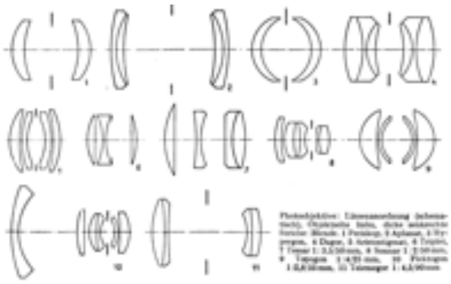
DOF Animation

ART Example



Reality: Lens Types

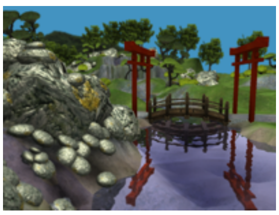


- All real lens systems are compromises between conflicting goals

Real Camera Lens Errors

- Spherical Aberration, Astigmatism & Coma lower image sharpness
- Distortion affects the image geometry (pincushion & barrel)
- Field curvature is due to lens curvature: local lack of sharpness
- Chromatic aberration (coloured fringes) occurs near the edges
- Diffraction upper-bounds the imaging capabilities of a given lens

Introduction to Stereo Projection



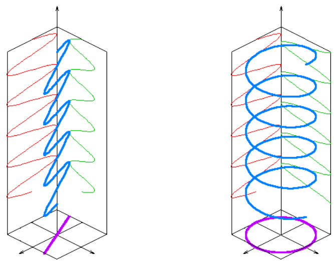
Motivation

- Powerful modern hardware enables rendering a scene more than once a frame
- New beamer setup enables stereo rendering at institute

Overview

- Physical properties of stereo setup
- Basics
- Stereo techniques
- Demo

Linear vs Circular Polarization



Physical properties of stereo setup

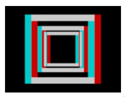
- 2 beamers with filters for circular polarized light
  - left-hand and right-hand circular polarization
- 1 retroreflective screen
  - Preserves polarization state

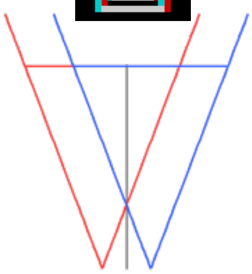
Basics

- Render scene twice
  - For each eye with eye-offset
    - Typical 6.3 cm
  - Modification of view-matrix necessary
  - Optional modification of projection-matrix
- Result
  - Parallax at objects
    - Related to distance to projectionplane

Stereo techniques (1/3)

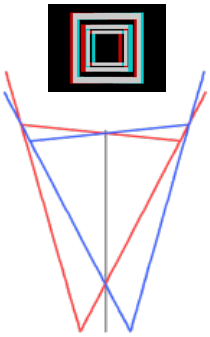
- Offset
  - Shift view-matrix
  - No change at projection
  - NVIDIA Stereo-Driver works this way





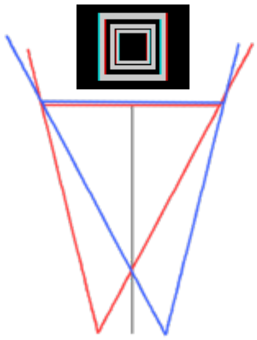
Stereo techniques (2/3)

- Toe – In
  - Shift view-matrix and rotate towards focus point
  - No change at projection
  - Appears right but might cause discomfort
    - Vertical parallax



Stereo techniques (3/3)

- Offaxis
  - Shift view matrix
  - Create asymmetric projection
  - Correct method, no vertical parallax
  - Less stressfull



Projection matrix revisited (1/2)

- Transforms points in viewfrustum to coordinates in [-1, 1]
  - Asymmetric frustum
    - n – near
    - f – far
    - r,l – right, left
    - t,b – top, bottom

$$\begin{pmatrix} \frac{2*n}{r-l} & 0 & \frac{r+l}{r-l} & 0 \\ 0 & \frac{2*n}{t-b} & \frac{t+b}{t-b} & 0 \\ 0 & 0 & \frac{-(f+n)}{(f-n)} & \frac{-2*n*f}{f-n} \\ 0 & 0 & -1 & 0 \end{pmatrix}$$

Demo

Questions & Answers

Rendering VO Unit 7

The End

Thank you for your attention!