



VU Rendering SS 2012

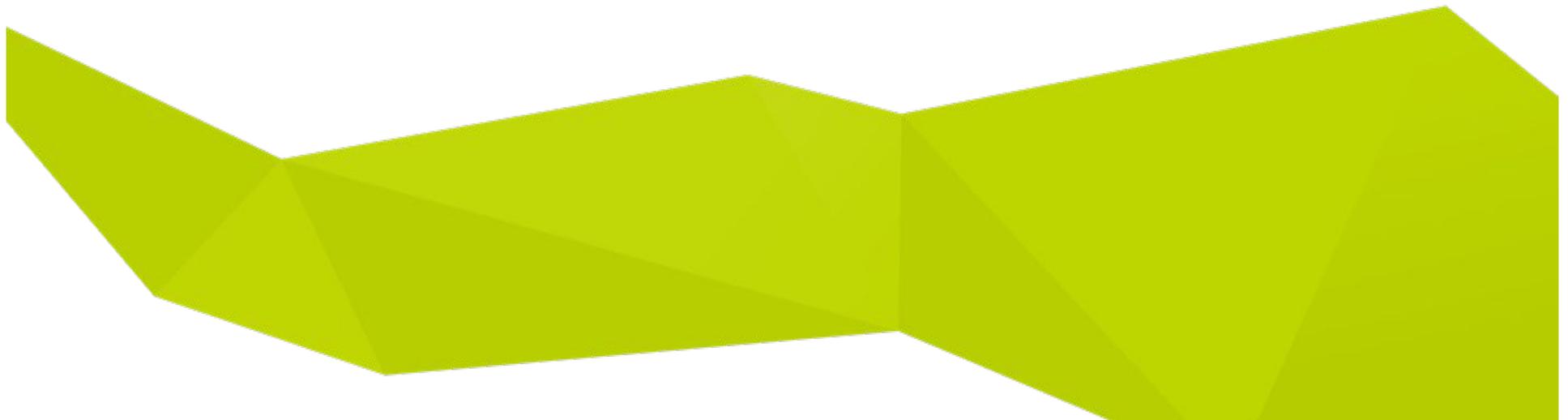
Unit 7: Cameras





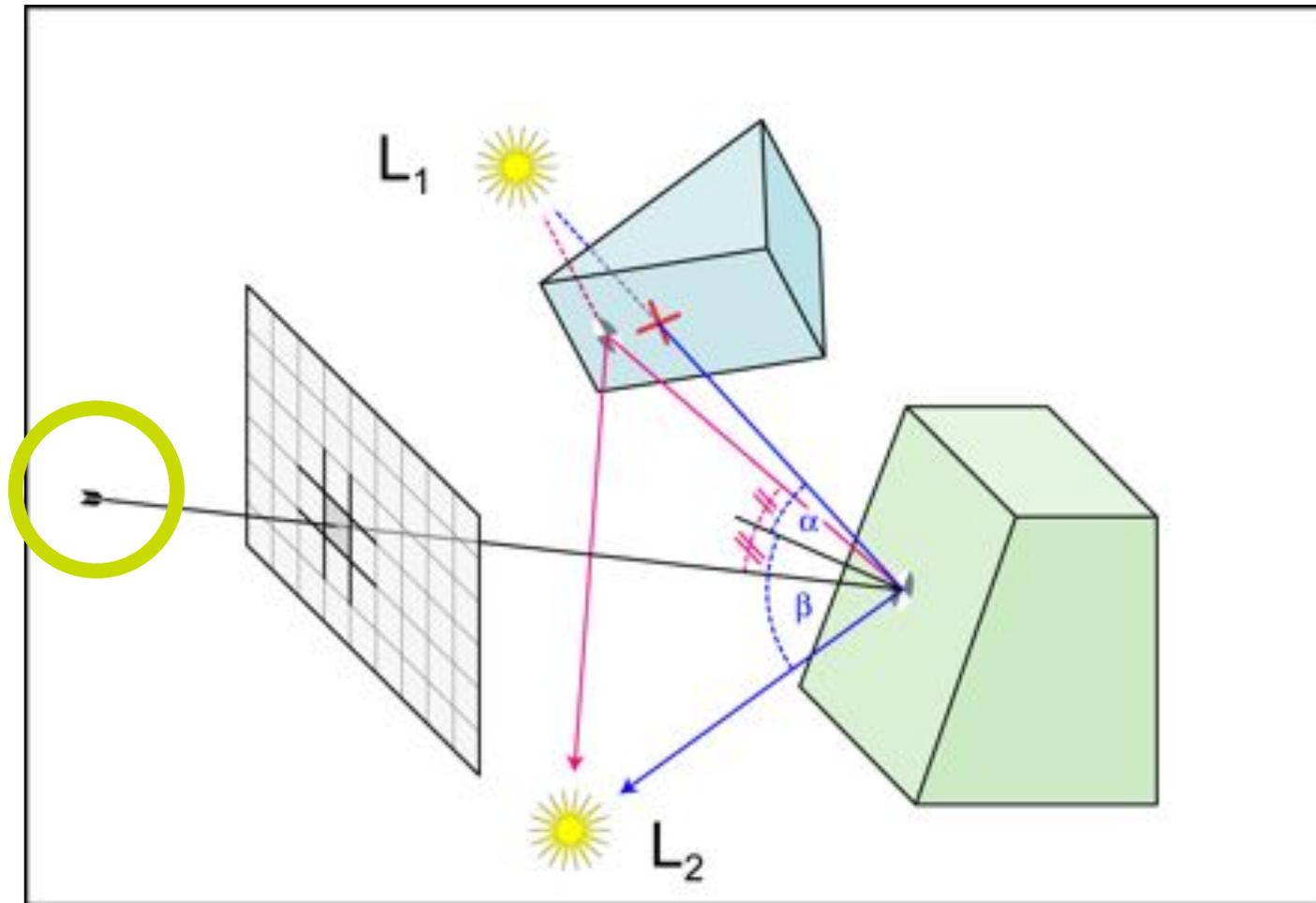
Overview

1. Pinhole camera
2. Thin lens camera
3. Simulating cameras by using Monte Carlo methods
4. Real Cameras
5. Stereo Demonstration





Raytracing Camera



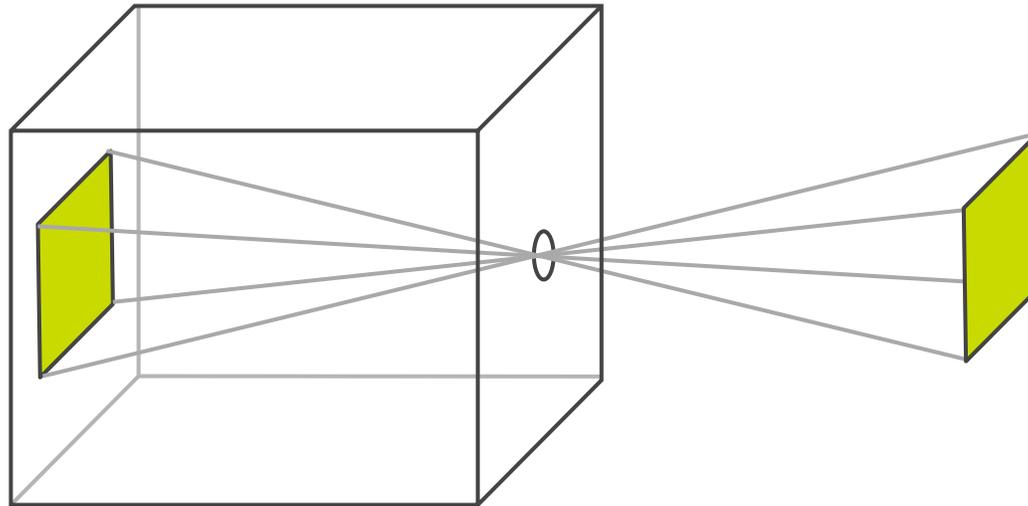


Camera Models

- 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



Pinhole Cameras

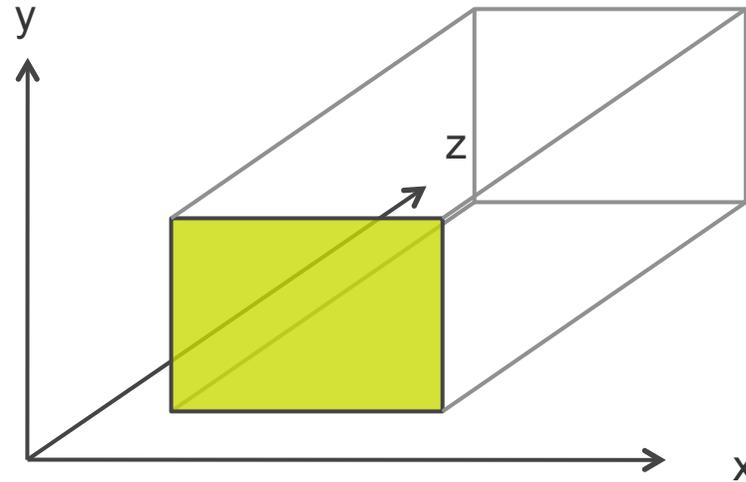


<http://personal.babelred.com>





Orthographic Camera



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

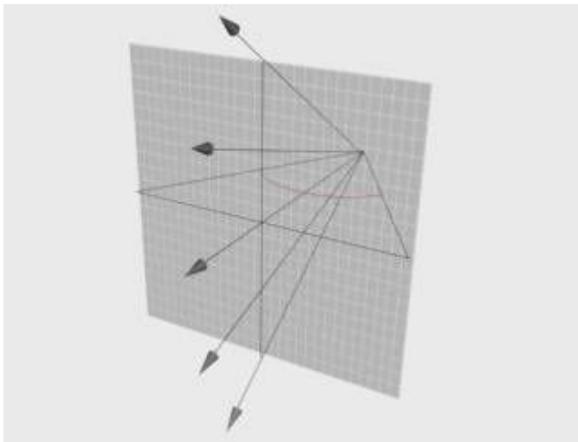
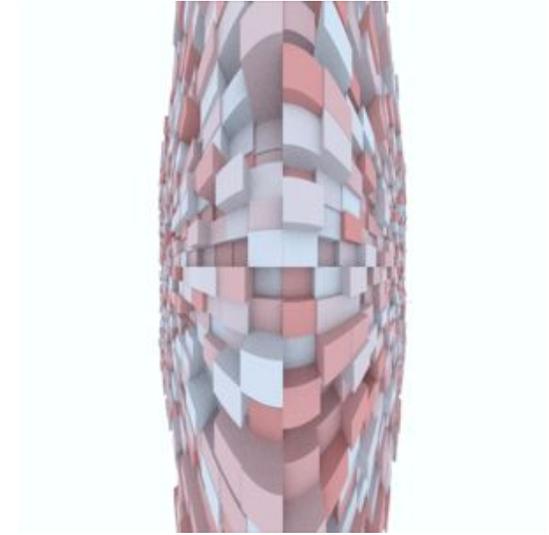
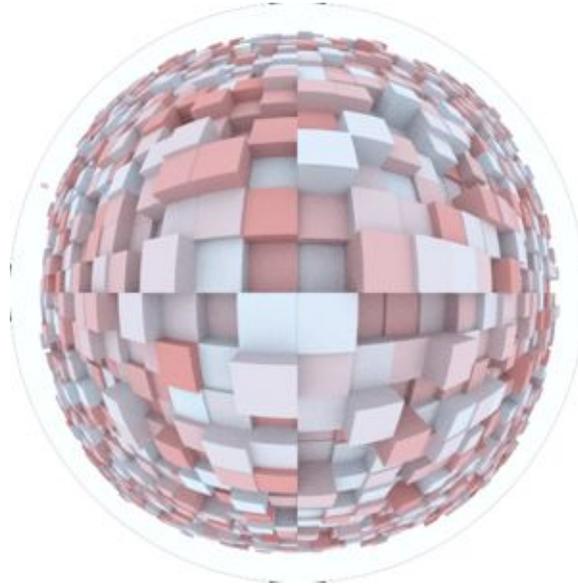
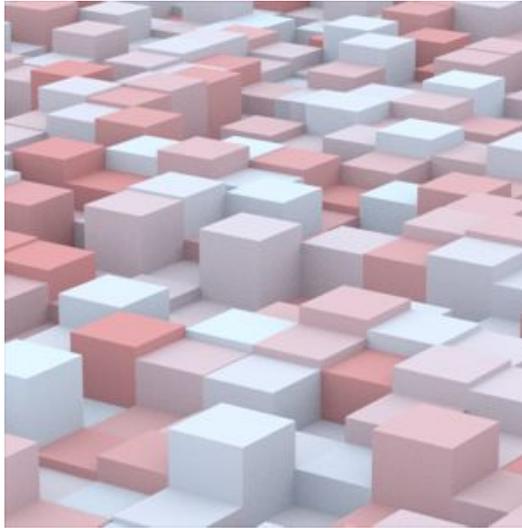


Orthographic vs. Perspective Camera

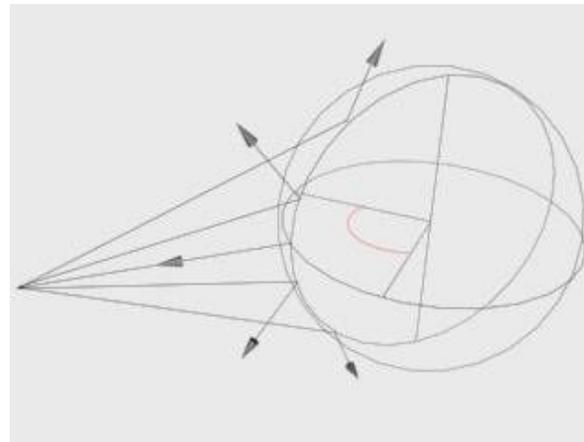




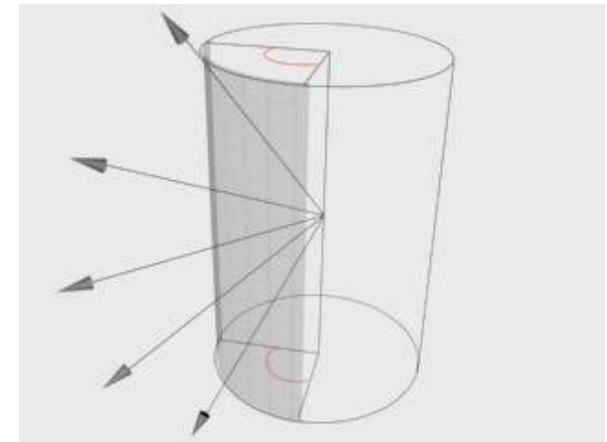
Other Cameras



Perspective



Fish Eye

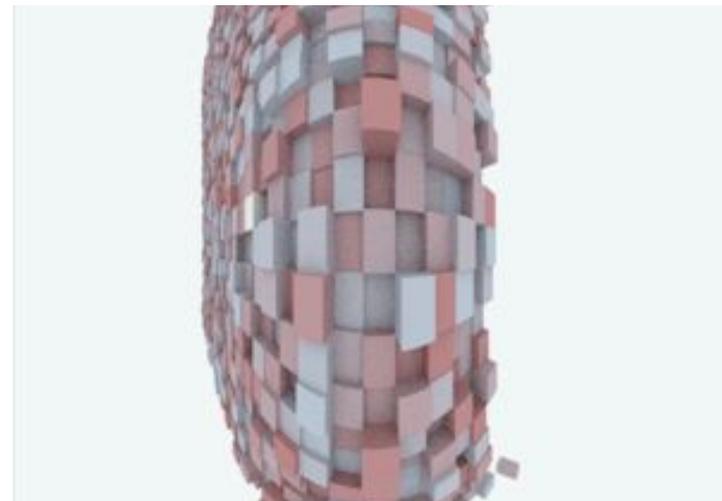
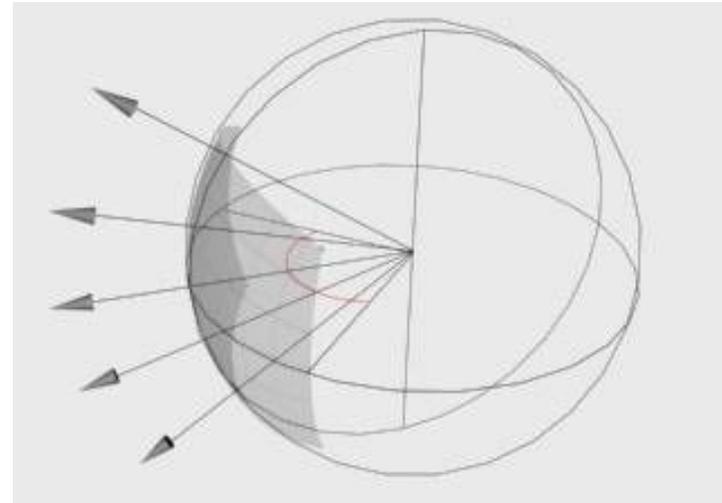


Cylindrical



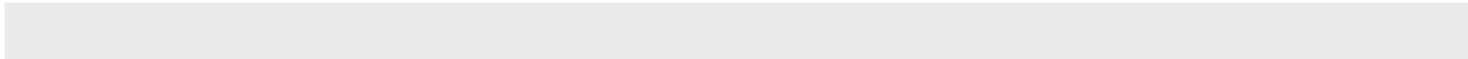
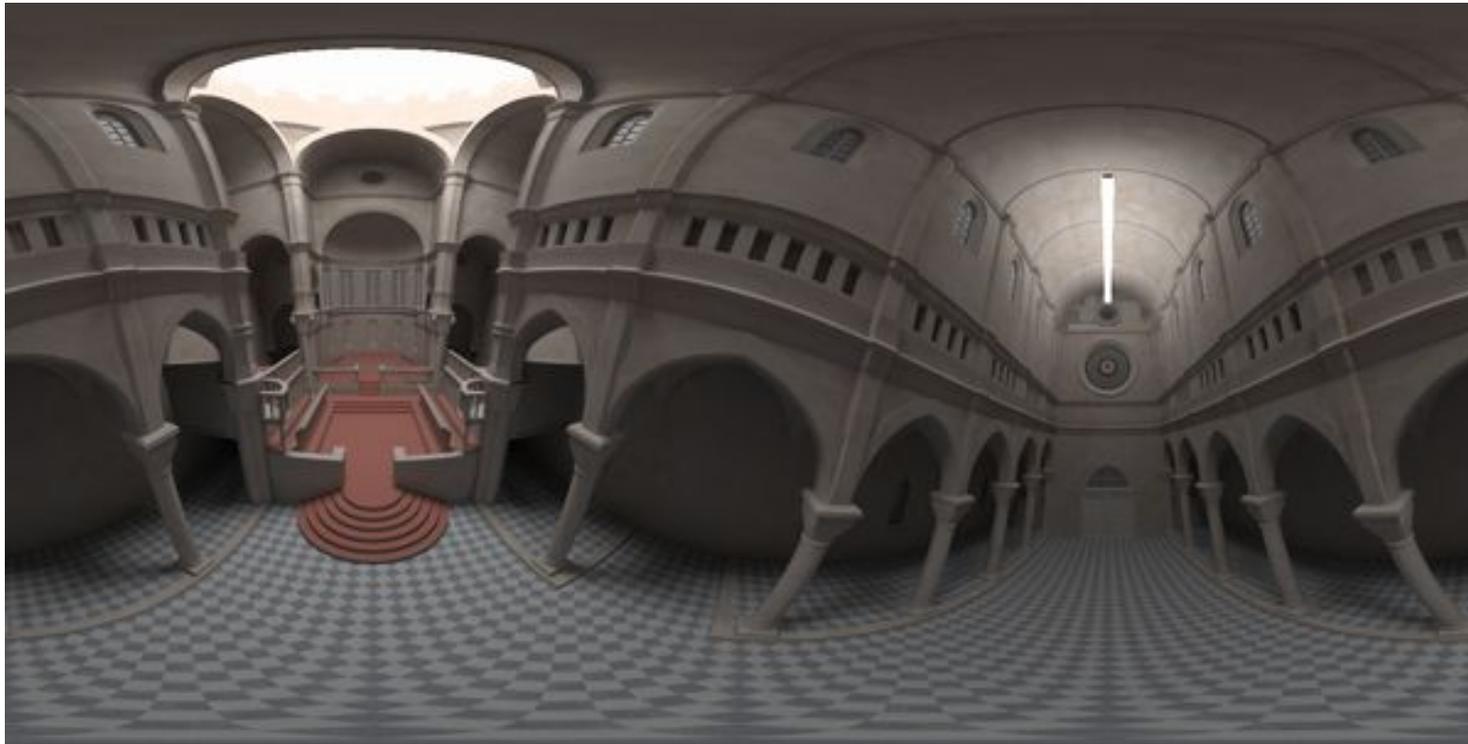
Environment (Spherical) Camera

- 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





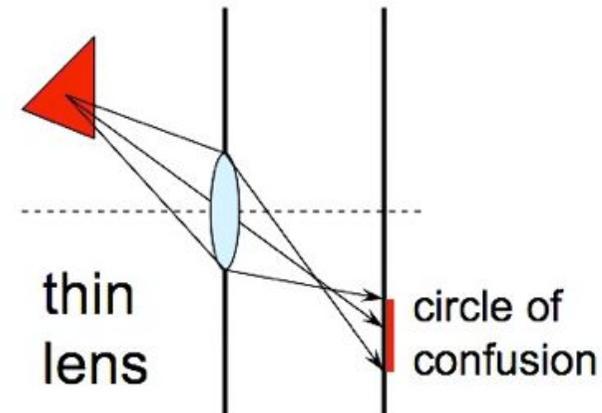
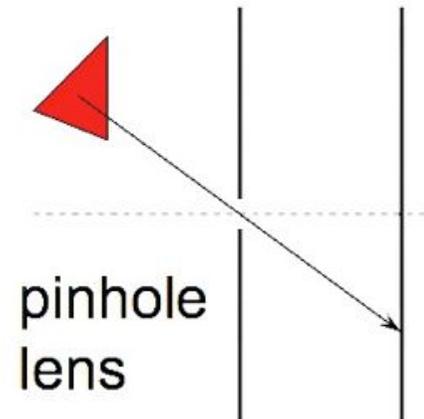
Enviroment (Spherical) Camera Example





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!



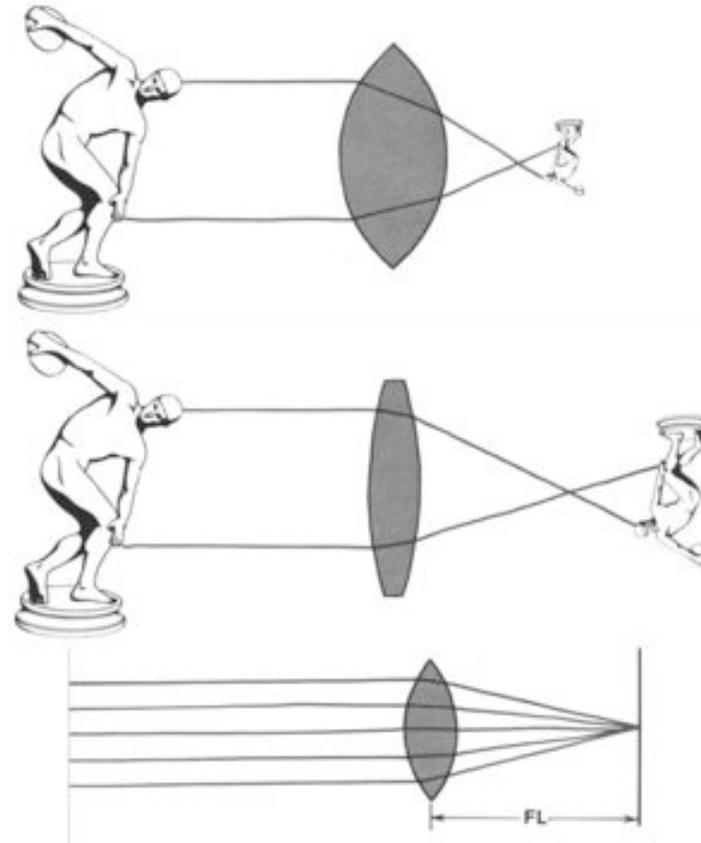
Thin Lens Assumption

- 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

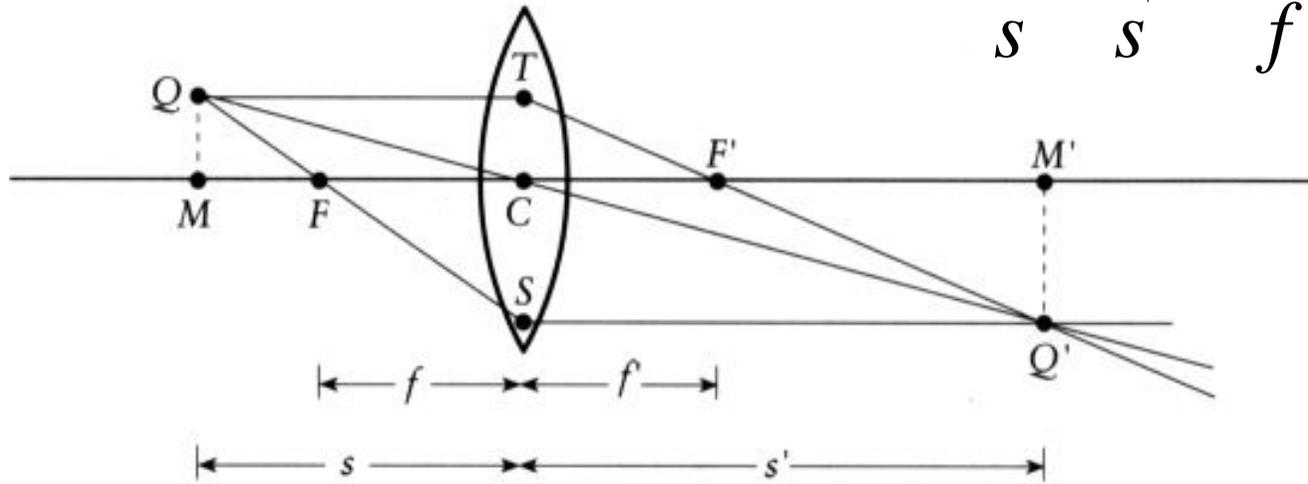
- Parallel rays that fall through the lens are focused in F
- Small f - wide angle lens, large f - tele lens





Imaging Through a (Thin) Lens

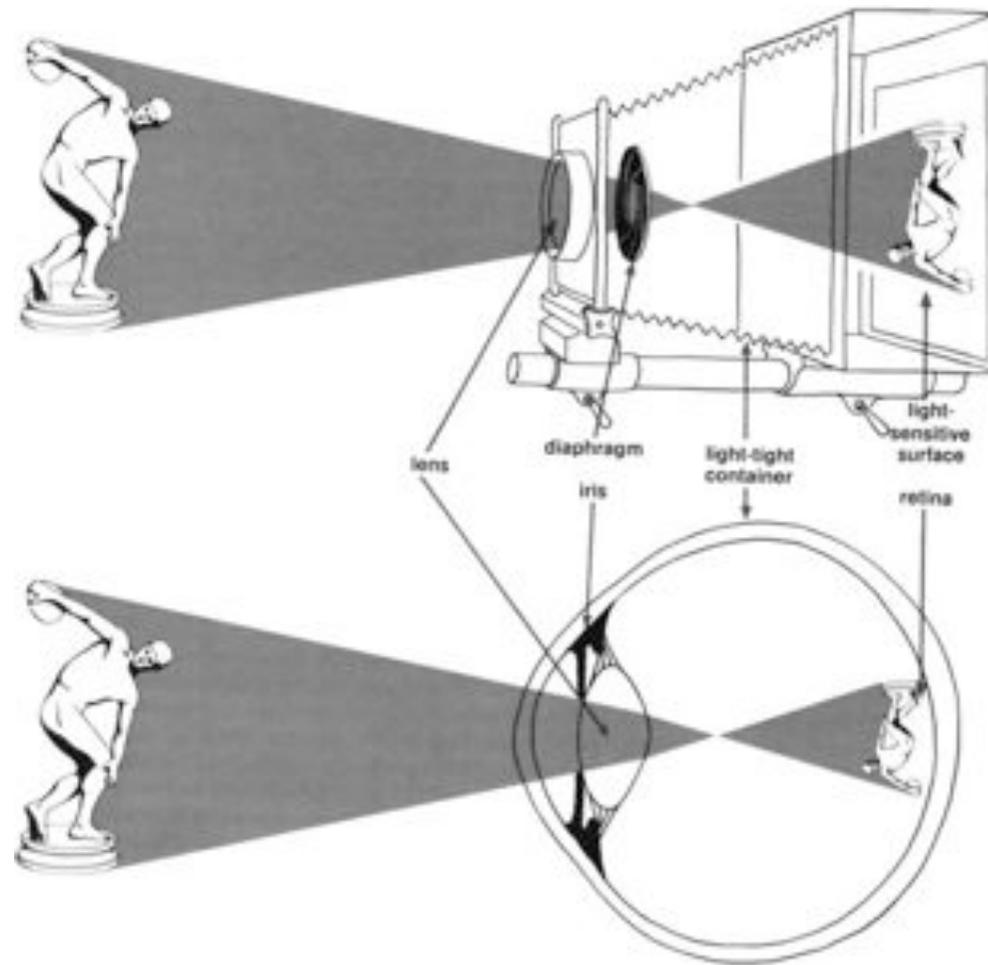
$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$



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



Thin Lens Camera





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



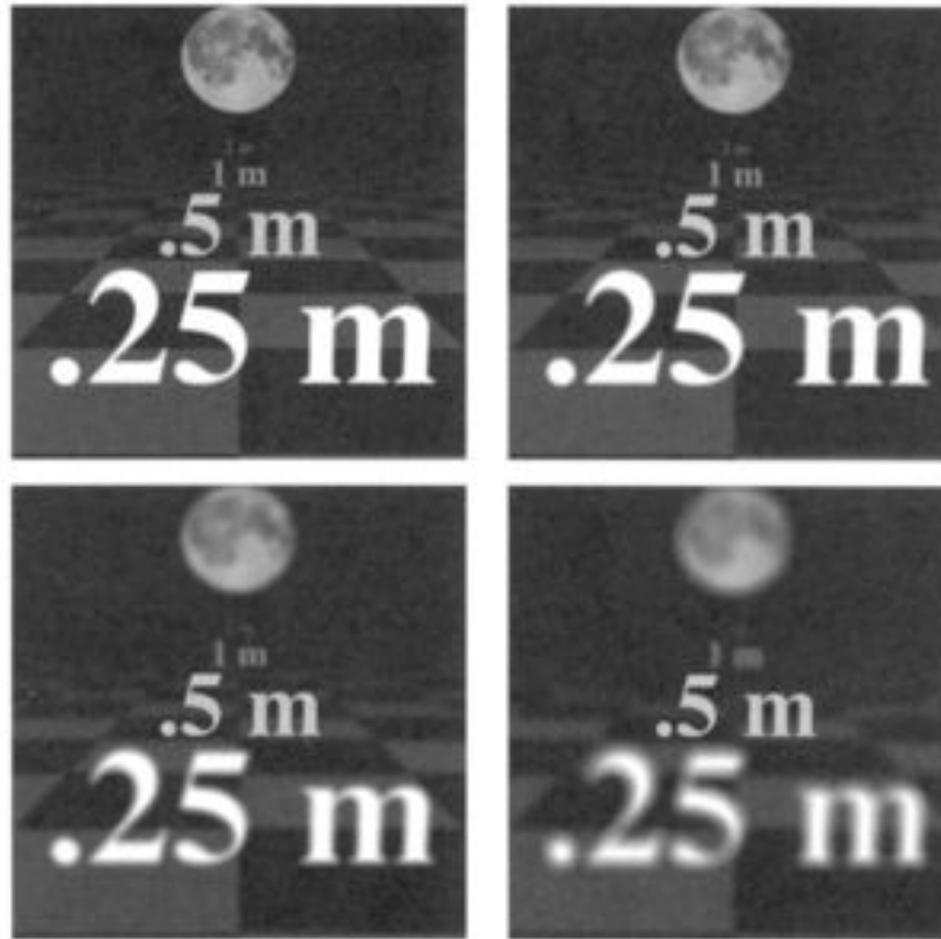
Depth of Field



- 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

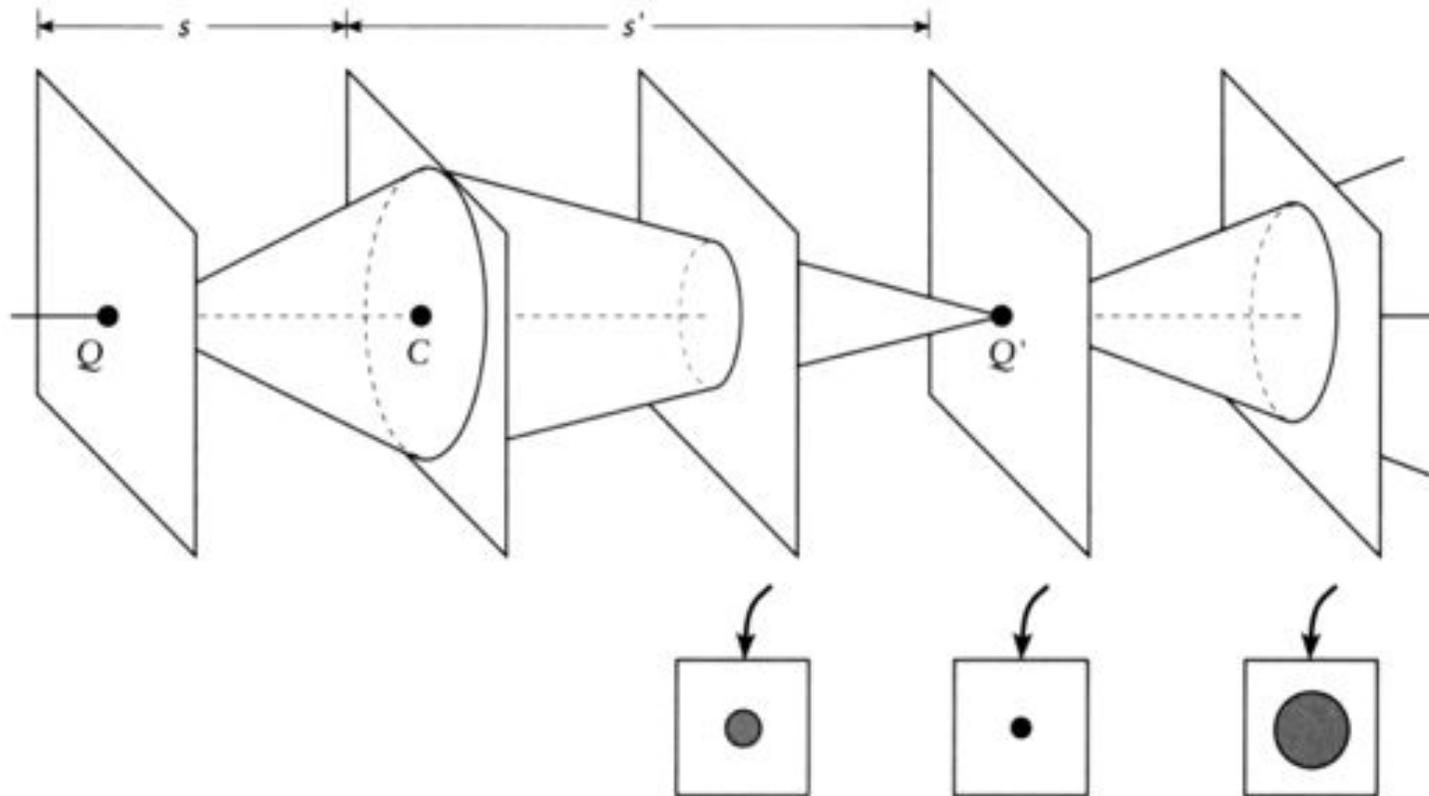


Depth of Field Example #1





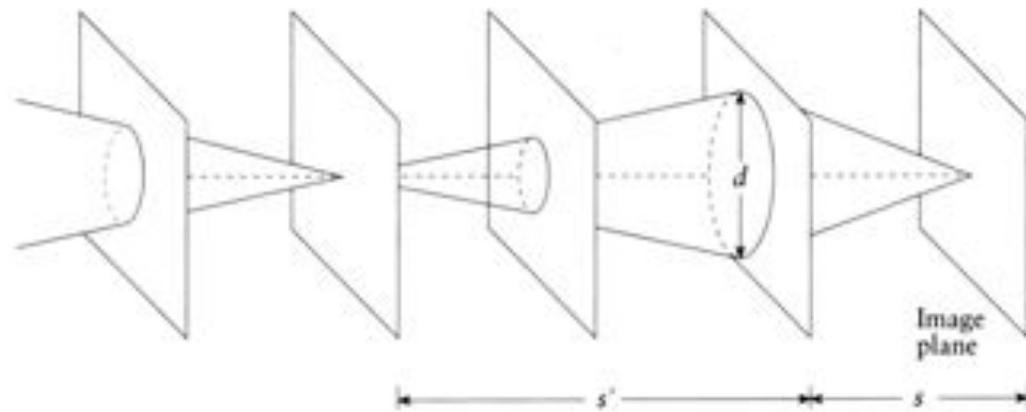
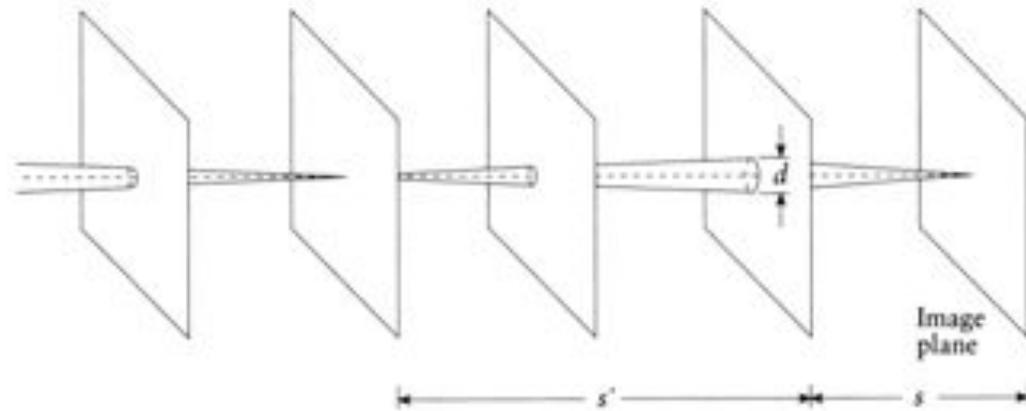
Circle of Confusion #1



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



Circle of Confusion #2



Smaller apertures yield sharper images!

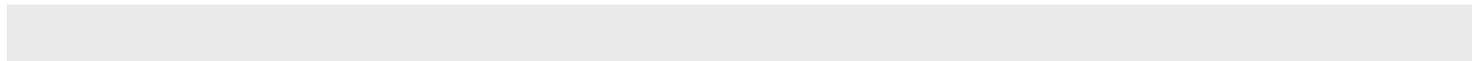
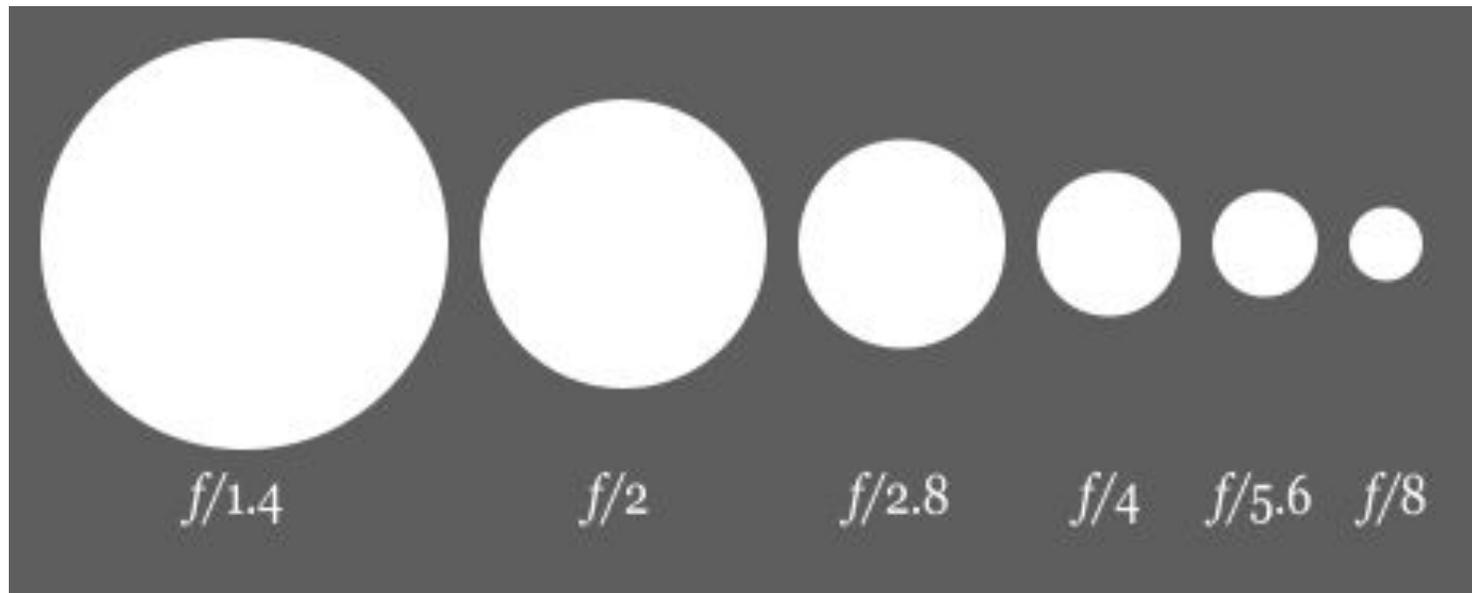


Aperture Numbers

- Given as f-stops on modern equipment
- $f\text{-stop} = F/D$ (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 exposure 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

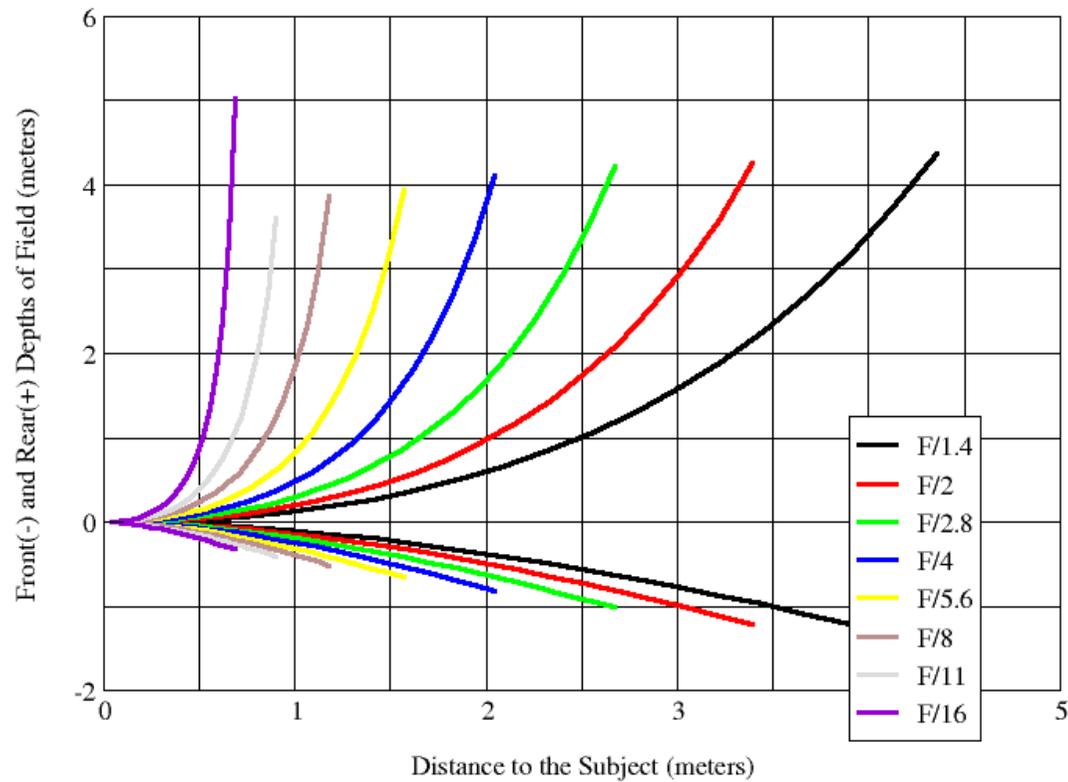




Wide Angle DOF Plot

Depth of Field for a 20 mm Lens ($c = 33 \mu\text{m}$)

www.dof.pcraft.com, by Nicholas V. Sushkin (1995-2001)

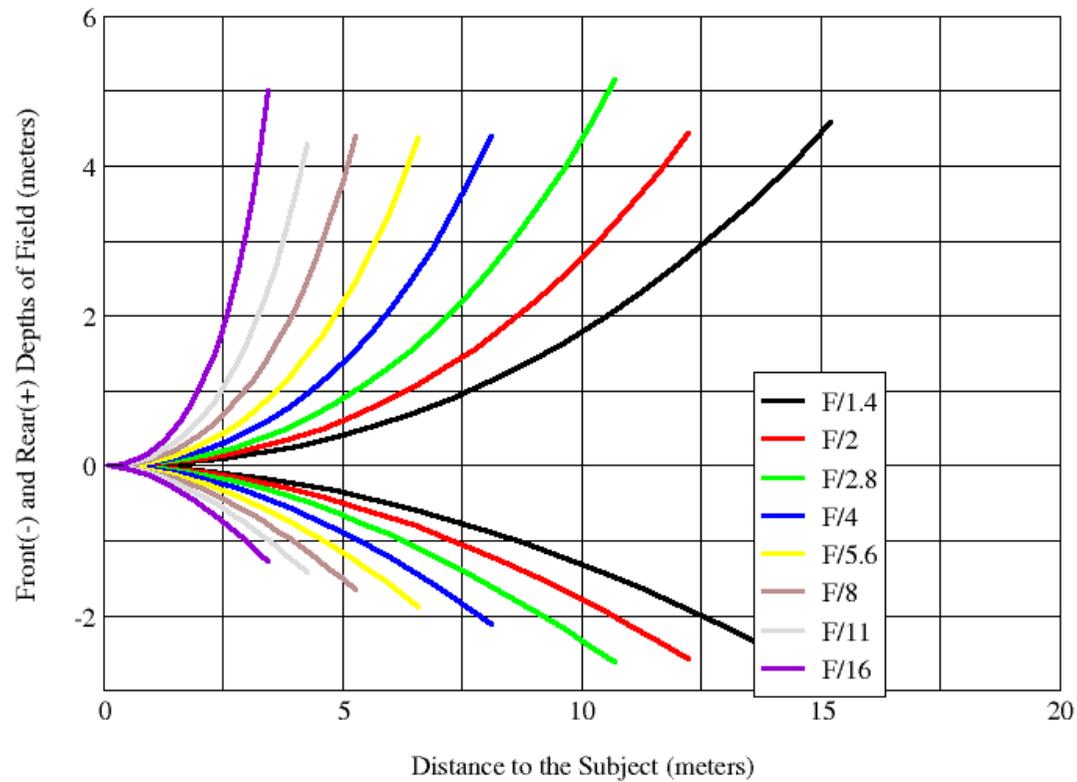




Standard DOF Plot

Depth of Field for a 55 mm Lens ($c = 33 \mu\text{m}$)

www.dof.pcraft.com, by Nicholas V. Sushkin (1995-2001)

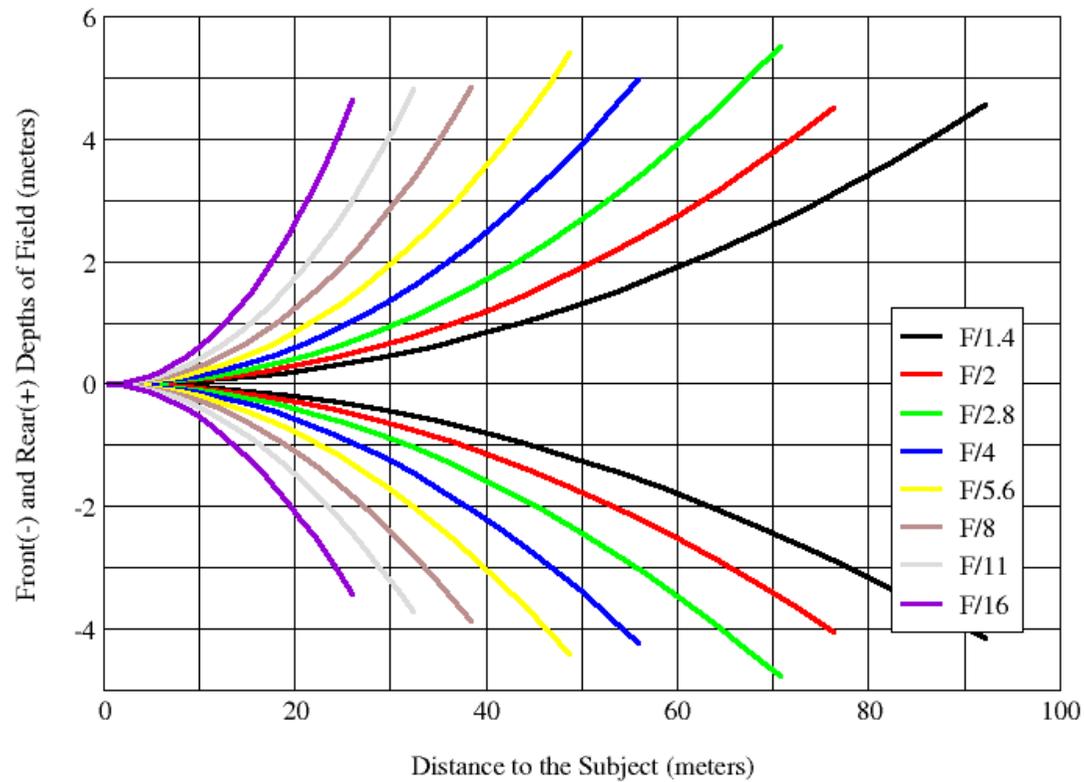




Tele Lens DOF Plot

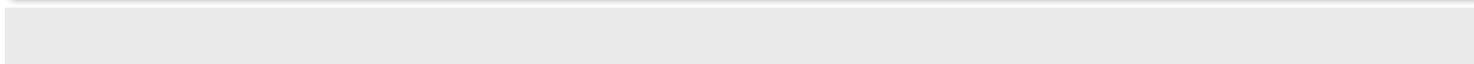
Depth of Field for a 300 mm Lens ($c = 33 \mu\text{m}$)

www.dof.pcraft.com, by Nicholas V. Sushkin (1995-2001)





DOF Example #2





DOF Example





Ray Traced DOF





Accumulated-Buffer DOF



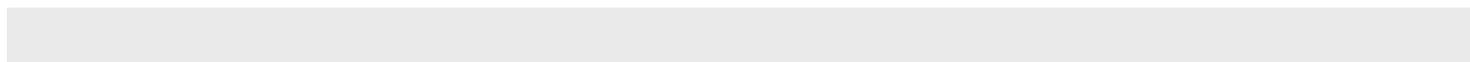


Layered Depth of Field





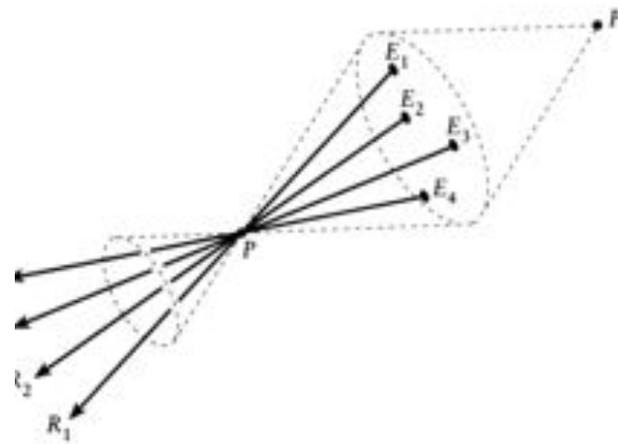
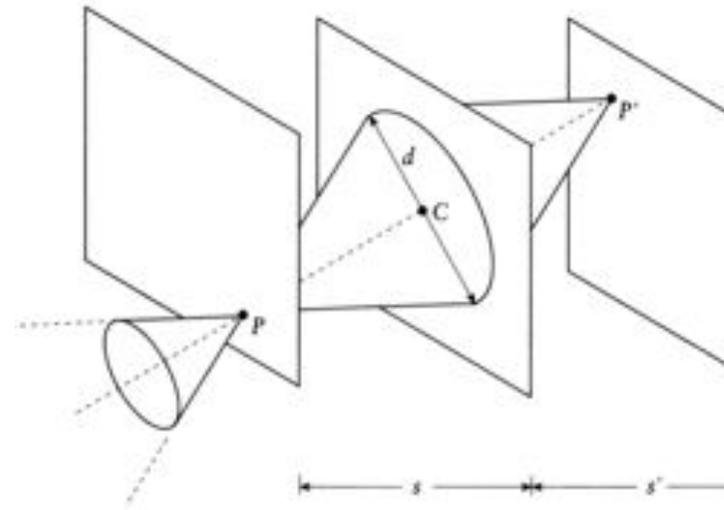
Forward-Mapped Z-Buffer Depth of Field





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





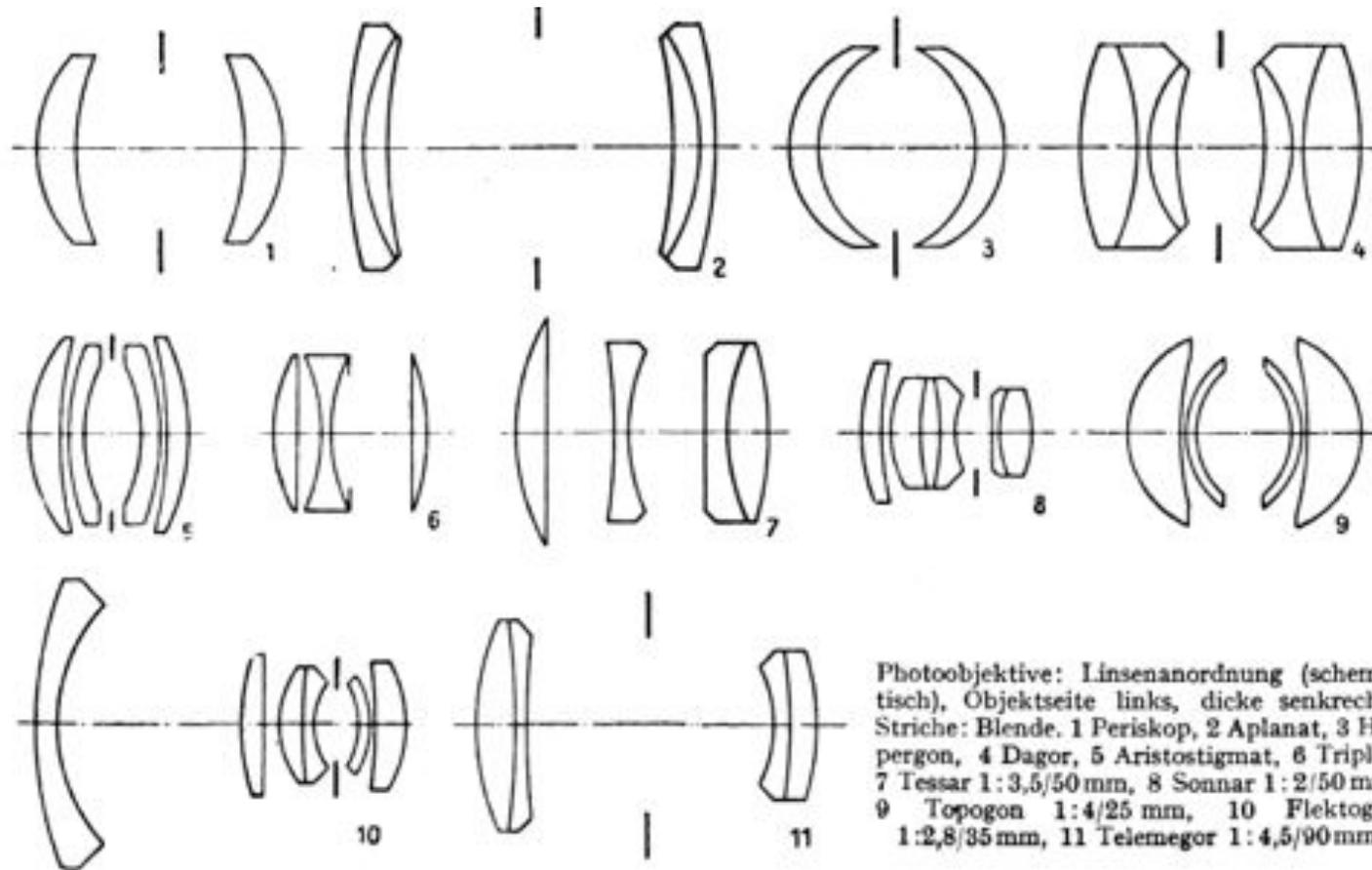
DOF Animation

**Depth-of-Field Rendering
by Pyramidal Image Processing**

Martin Kraus, Magnus Strengert



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
- Beamer setup enables stereo rendering at institute





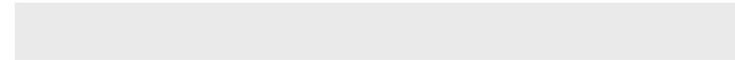
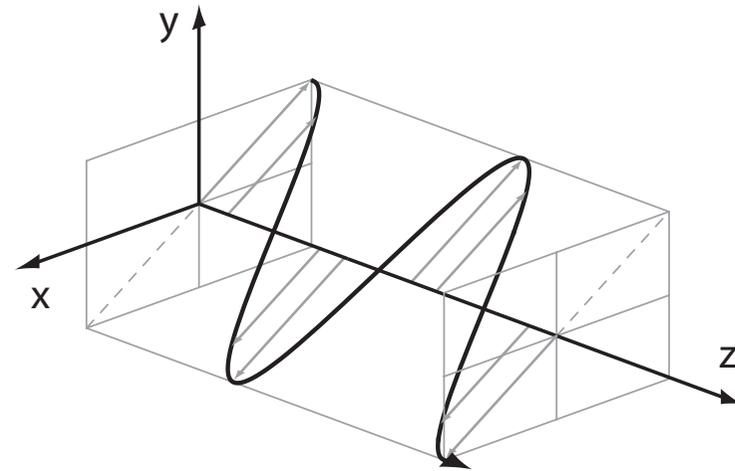
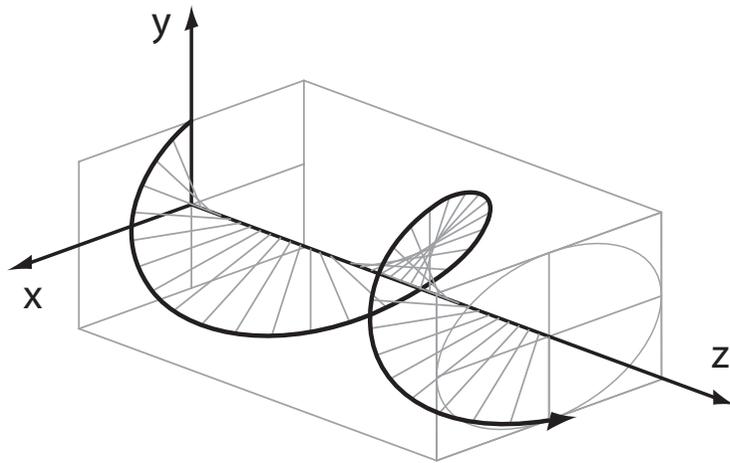
Physical properties of stereo setup

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





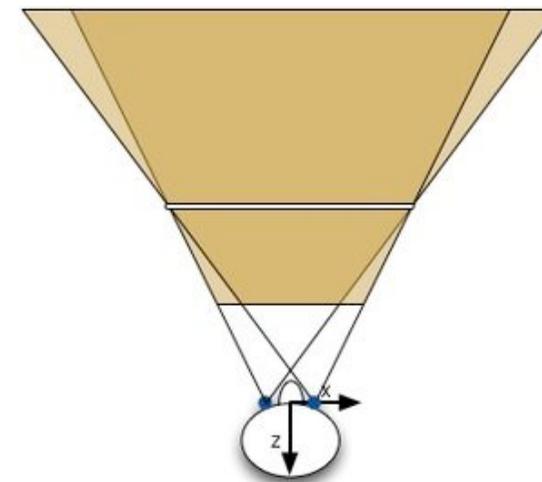
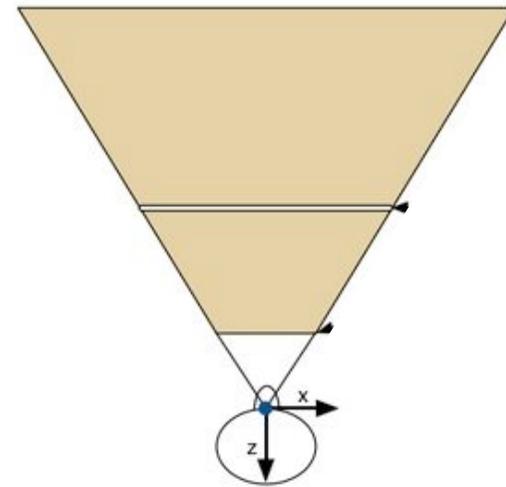
Linear vs Circular Polarization





Basics

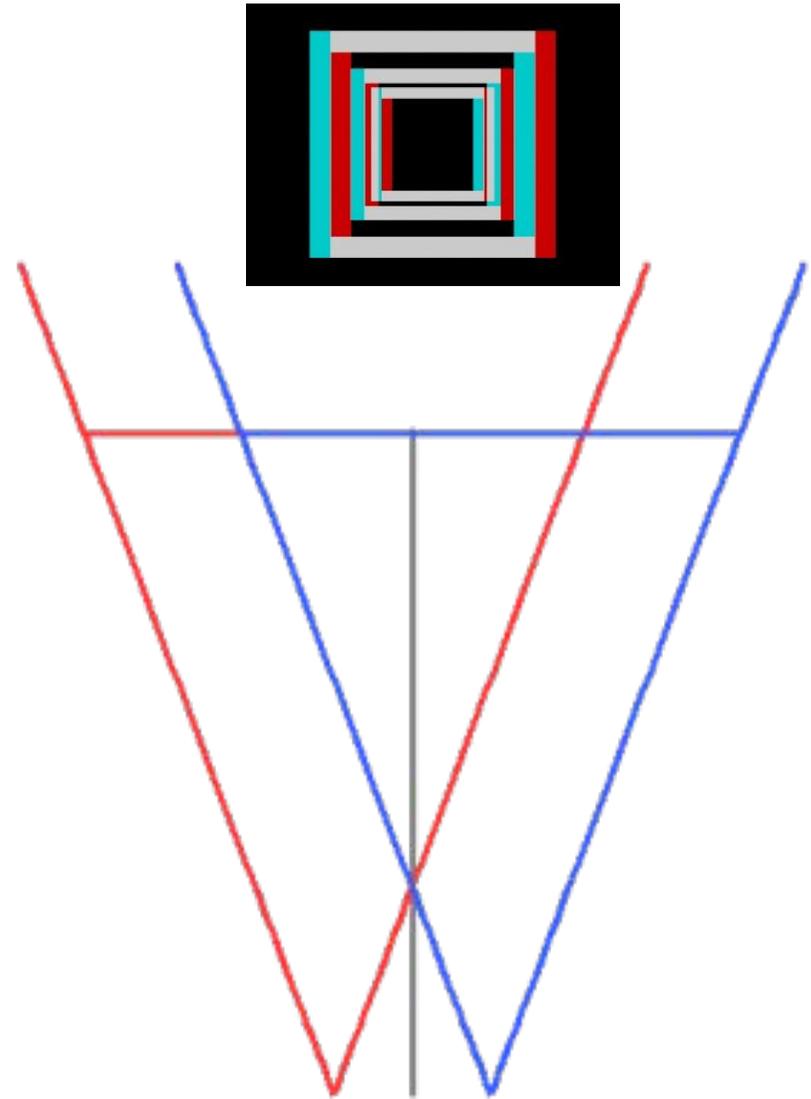
- Render scene twice
 - For each eye with eye-offset
 - Typical 6.3 cm
 - Modification of view-matrix necessary
- Optional modification of projection-matrix
- Result
 - Parallax at objects
 - Related to distance to projection plane





Stereo techniques (1/3)

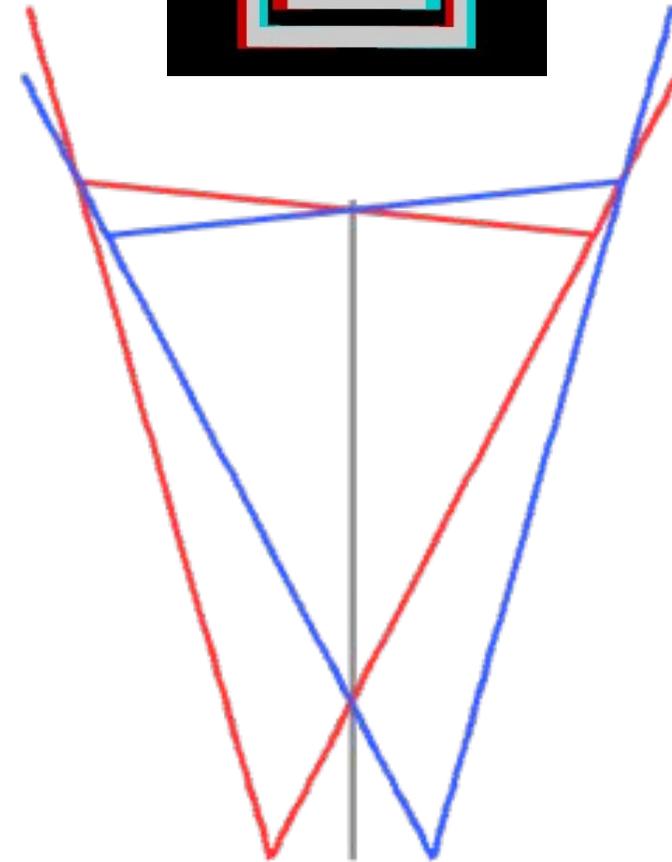
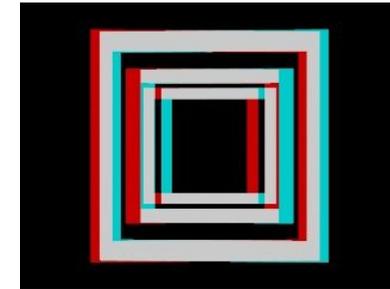
- Offset
 - Shift view-matrix
 - No change at projection
- NVIDIA Stereo-Driver works this way





Stereo techniques (2/3)

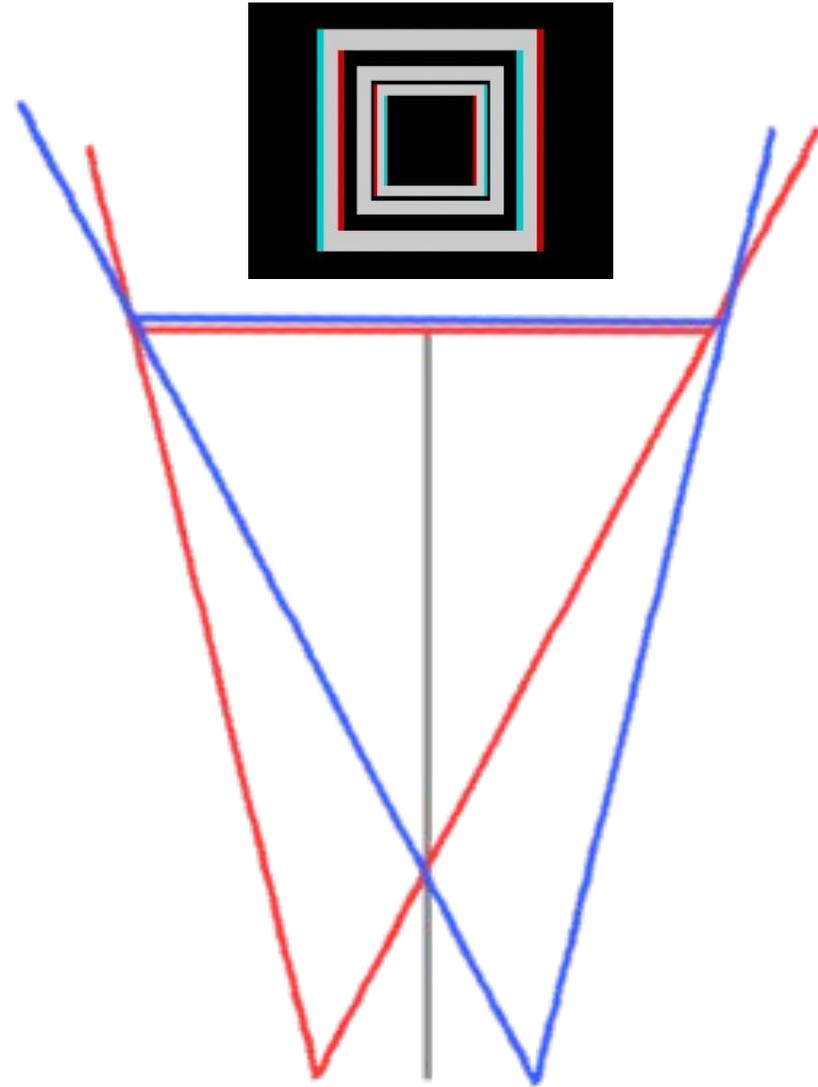
- Toe - In
 - Shift view-matrix and rotate towards focus point
 - No change at projection
- Appears right but might cause discomfort
 - Vertical parallax





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

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



The End
Thank you for your attention!

