

Cameras, Radiometry and Lights

Computer Vision I
CSE 252A
Lecture 5-Part I

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Announcements

- Assignment 1 Posted to the web page: Due 1/31/04
- Read Chapter 4 of Forsyth & Ponce

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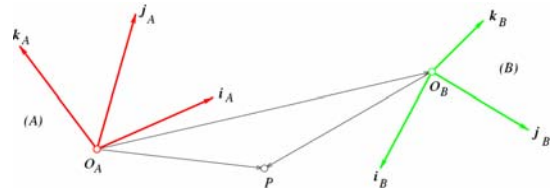
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Last lecture in a nutshell

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Coordinate Changes: Rigid Transformations



Euclidean
$${}^B P = {}^B R {}^A P + {}^B O_A$$

Homogeneous
$$\begin{bmatrix} {}^B P \\ 1 \end{bmatrix} = \begin{bmatrix} {}^B R & {}^B O_A \\ \mathbf{0}^T & 1 \end{bmatrix} \begin{bmatrix} {}^A P \\ 1 \end{bmatrix}$$

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Some points about SO(n)

- $SO(n) = \{ R \in \mathfrak{R}^{n \times n} : R^T R = I, \det(R) = 1 \}$
 - $SO(2)$: rotation matrices in plane \mathfrak{R}^2
 - $SO(3)$: rotation matrices in 3-space \mathfrak{R}^3
- Forms a Group under matrix product operation:
 - Identity
 - Inverse
 - Associative
 - Closure
- Closed (finite intersection of closed sets)
- Bounded $R_{ij} \in [-1, +1]$
- Does not form a vector space.
- Manifold of dimension $n(n-1)/2$
 - $\text{Dim}(SO(2)) = 1$
 - $\text{Dim}(SO(3)) = 3$

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SO(3)

- Parameterizations of $SO(3)$
- 3-D manifold, so between 3 parameters and $2n+1$ parameters (Whitney's Embedding Thm.)
 - Roll-Pitch-Yaw
 - Euler Angles
 - Axis Angle (Rodrigues formula)
 - Cayley's formula
 - Matrix Exponential
 - Quaternions (four parameters + one constraint)

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Camera parameters

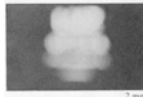





- Issue
 - camera may not be at the origin, looking down the z-axis
 - extrinsic parameters
 - one unit in camera coordinates may not be the same as one unit in world coordinates
 - intrinsic parameters - focal length, principal point, aspect ratio, angle between axes, etc.

$$\begin{pmatrix} U \\ V \\ W \end{pmatrix} = \begin{pmatrix} \text{Transformation} \\ \text{representing} \\ \text{intrinsic parameters} \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} \text{Transformation} \\ \text{representing} \\ \text{extrinsic parameters} \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ T \end{pmatrix}$$

3 x 3 4 x 4

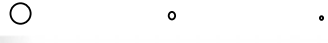
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Pinhole Camera Images with Variable Aperture

2 mm			1mm
	2 mm	1 mm	
.6 mm			.35 mm
	0.6 mm	0.35 mm	
.15 mm			.07 mm
	0.15 mm	0.07 mm	

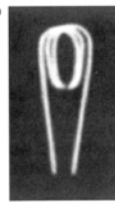
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Limits for pinhole cameras

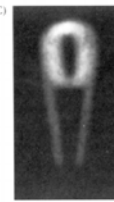




(A)



(B)

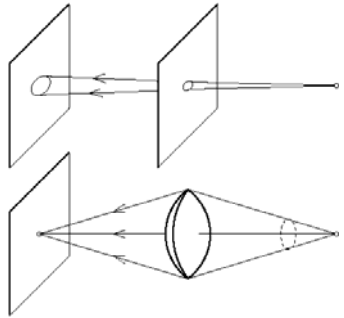


(C)

2.18 DIFFRACTION LIMITS THE QUALITY OF PINHOLE OPTICS. These three images of a bulb filament were made using pinholes with decreasing size. (A) When the pinhole is relatively large, the image rays are not properly converged, and the image is blurred. (B) Reducing the size of the pinhole improves the focus. (C) Reducing the size of the pinhole further worsens the focus, due to diffraction. From Ruechardt, 1958.

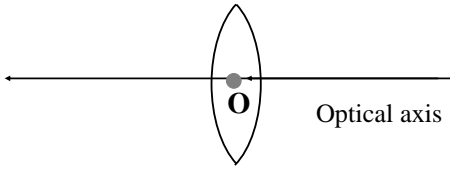
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The reason for lenses



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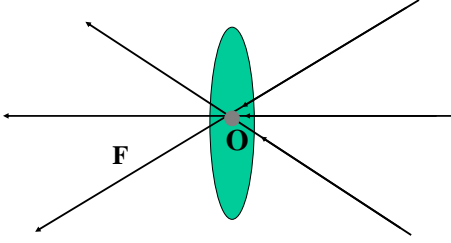
Thin Lens



- Rotationally symmetric about optical axis.
- Spherical interfaces.

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Thin Lens: Center



- All rays that enter lens along line pointing at **O** emerge in same direction.

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Thin Lens: Focus

Parallel lines pass through the focus, F

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Thin Lens: Image of Point

All rays passing through lens and starting at P converge upon P'

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Thin Lens: Image of Point

$$\frac{1}{z'} - \frac{1}{z} = \frac{1}{f}$$

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Thin Lens: Image Plane

Image Plane
A price: Whereas the image of P is in focus, the image of Q isn't.

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Thin Lens: Aperture

- Smaller Aperture -> Less Blur
- Pinhole -> No Blur

Image Plane

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Field of View

Image Plane

Field of View

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Deviations from the lens model

Deviations from this ideal are **aberrations**

Two types

1. geometrical

- spherical aberration
- astigmatism
- distortion
- coma

2. chromatic

Aberrations are reduced by combining lenses



Compound lenses

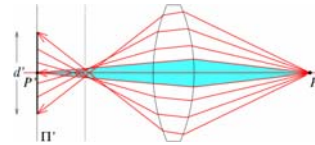
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Spherical aberration

rays parallel to the axis do not converge

outer portions of the lens yield smaller focal lengths

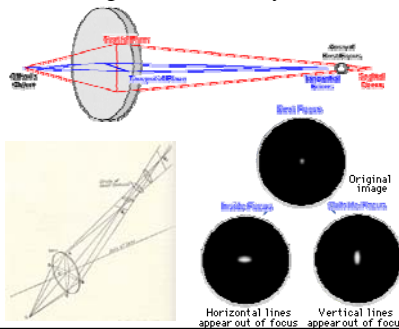


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Astigmatism

Different focal length for inclined rays



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Horizontal lines appear out of focus
Vertical lines appear out of focus

Distortion

magnification/focal length different for different angles of inclination



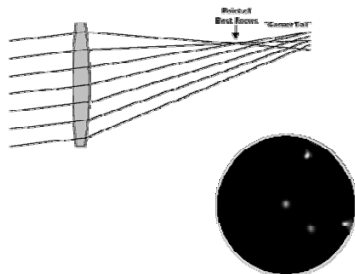
Can be corrected! (if parameters are known)

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Coma

point off the axis depicted as comet shaped blob



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Chromatic aberration

(great for prisms, bad for lenses)

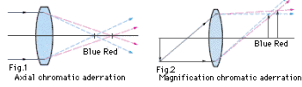


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Chromatic aberration

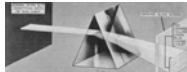
rays of different wavelengths focus in different planes



The image is blurred and appears colored at the fringe.

cannot be removed completely

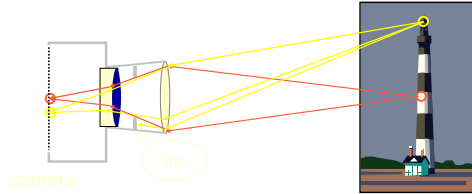
sometimes *achromatization* is achieved for more than 2 wavelengths



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Spatial Non-Uniformity



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