Realistic Camera Model

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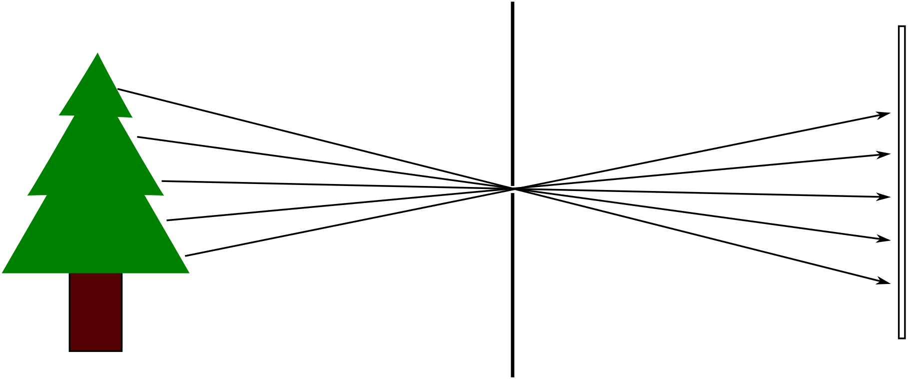
November 2, 2006

Outline

- Introduction
- Lens system
- Thick lens approximation
- Radiometry
- Sampling
- Assignment #2

Introduction

Until now we have only discussed the pinhole camera model, which is not phisically correct.



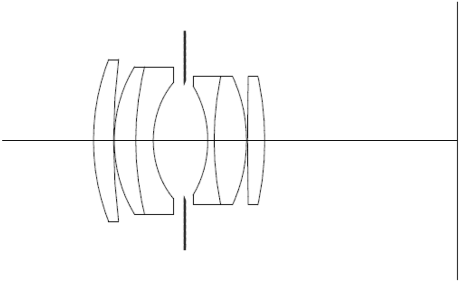
Why We Need Realistic Model

- Phisical correctness is our goal.
- Combining real images with synthetic ones is very common in digital visual effects.
- Machine vision and scientific applications need to simulate camera correctly.
- Users of 3D graphics system are familiar with cameras.

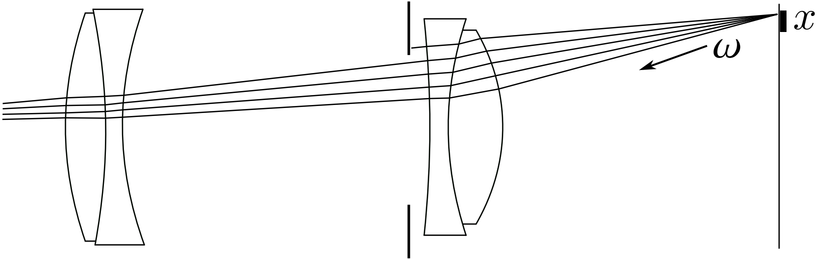
Lens Systems

Lens systems are typically constructed from a series of individual spherical lenses.

radius	thick	n_d	V-no	ap
58.950	7.520	1.670	47.1	50.4
169.660	0.240			50.4
38.550	8.050	1.670	47.1	46.0
81.540	6.550	1.699	30.1	46.0
25.500	11.410			36.0
	9.000			34.2
-28.990	2.360	1.603	38.0	34.0
81.540	12.130	1.658	57.3	40.0
-40.770	0.380			40.0
874.130	6.440	1.717	48.0	40.0
-79.460	72.228			40.0



Measurement Equation



$$R = \int\int\int\int L(T(x,\omega,\lambda);\lambda)S(x,t)P(x,\lambda)\cos\theta \; dx \; d\omega \; dt \; d\lambda$$

L: radiance
T: image to object space transformation
S: shutter function
P: sensor response characteristics

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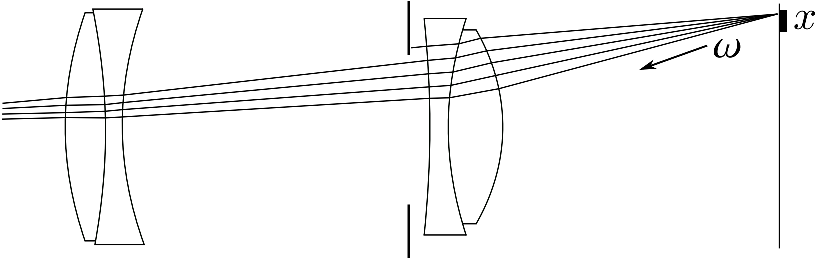

$$R = \Delta t \cdot \int \int L(T(x,\omega)) \cos\theta \; dx \; d\omega$$

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Solution: Monte Carlo method:

$$\int_\Omega f(x)dx \approx [\frac{1}{N}\sum_{i=1}^{N} f(x_i)] \cdot \int_\Omega dx$$

where $x_1, x_2, \ldots, x_N$ are uniform distributed random samples in Ω.

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4. Set the pixel value to the average of radiance.

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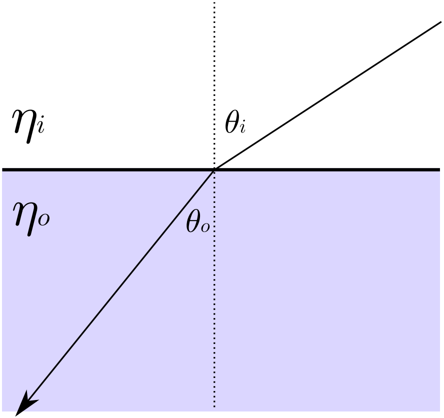
    2. Compute the new direction by Snell's law if the medium is different.

Snell's Law



$$\eta_i \sin\theta_i = \eta_o \sin\theta_o$$

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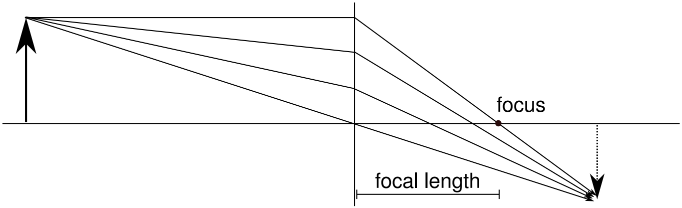
- Thick lens approximation has additional parameter of thickness.

Thin Lens and Thick Lens



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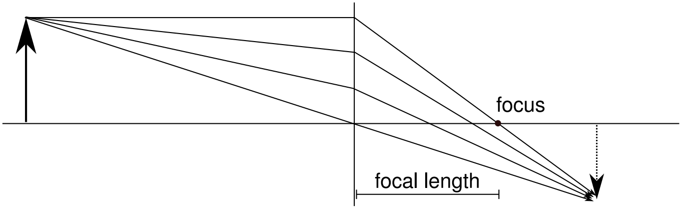
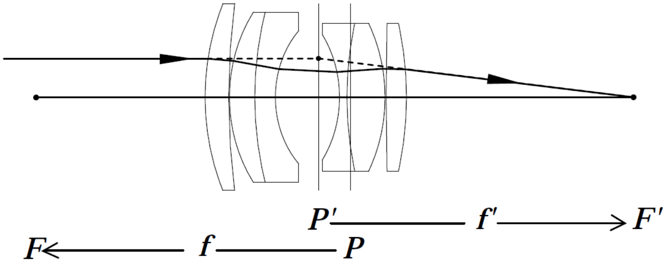
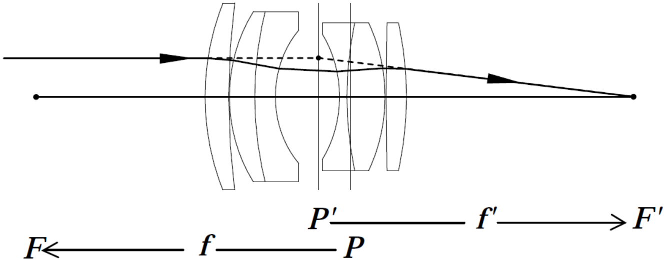




Finding Thick Lens Approximation



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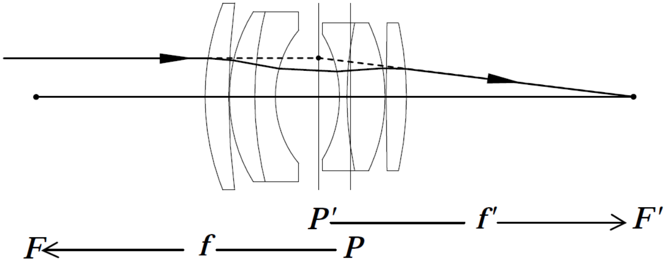

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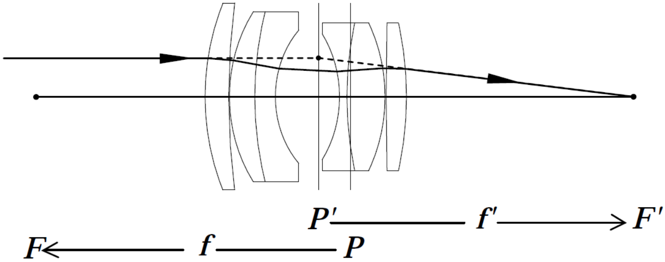

1. Shoot a ray parallel to the axis to find the focus.
2. Find the principal plane by intersecting the refracted ray and parallel one.
3. Find the secondary principal plane by tracing from another side.

Application of Thick Lens Approximation

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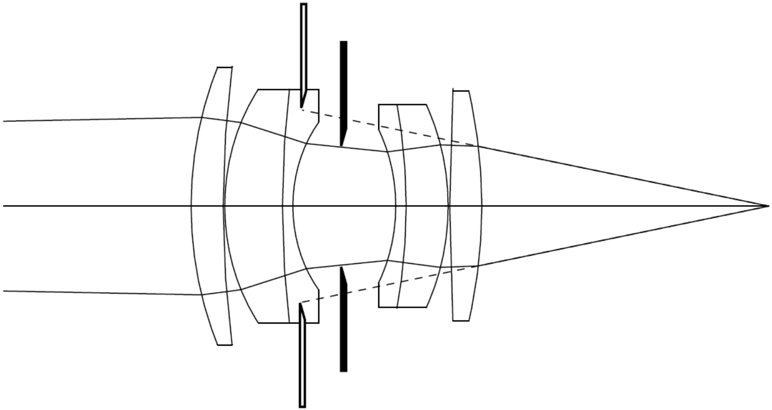
Exit Pupil (1/2)



The exit pupil is the effective aperture stop in the image space which allows ray incidence.

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- You may also use the aperture of the nearest lens as the exit pupil.

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- Assume that the irradiance is constant over the exposure period:

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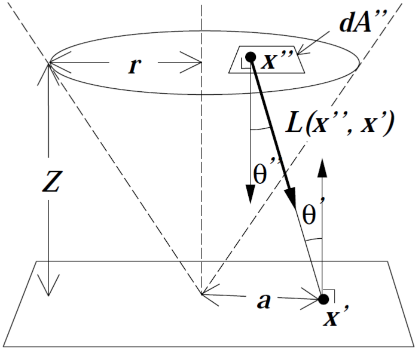
- Let

$$E(x') = \int L(T(x', \omega)) \cos\theta' \; d\omega$$

$$R = \Delta t \cdot \int E(x') \; dx'$$

Integral over the Exit Pupil



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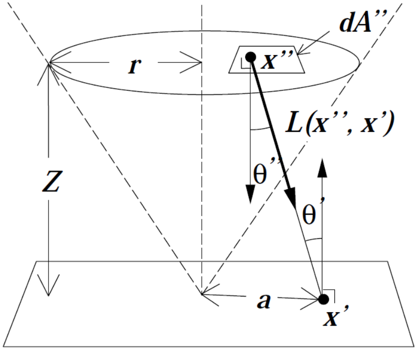

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$$d\omega = \frac{\cos\theta''}{r^2} dA''$$

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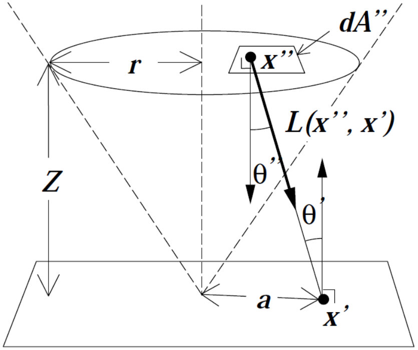

$$E(x') = \int_{x'' \in D} L(x'', x') \frac{\cos\theta' \cos\theta''}{||x'' - x'||^2} \, dA''$$

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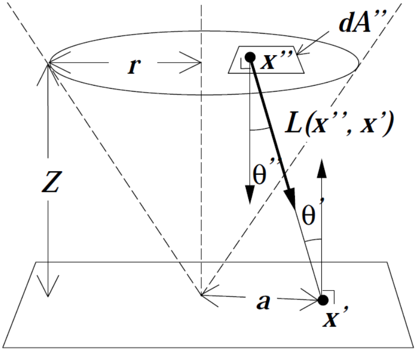

$$E(x') = \frac{1}{Z^2} \int_{x'' \in D} L(x'', x') \cos^4 \theta' \, dA''$$

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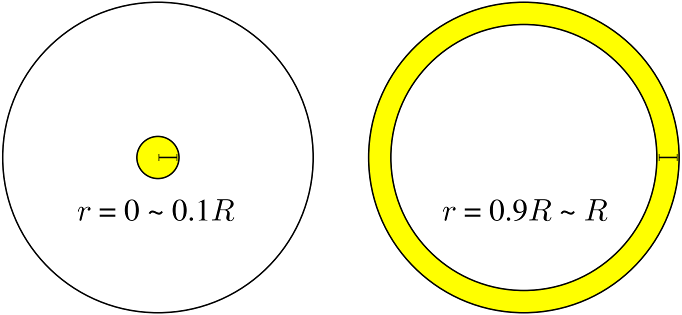
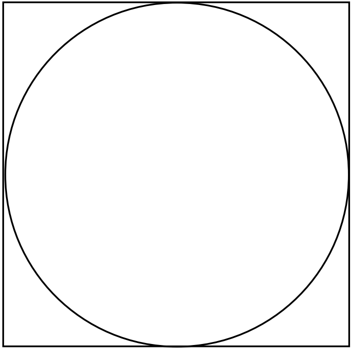
  - The result is not uniform due to coordinate transformation.



A Simple Method: Rejection

1. Uniformly sample a point in the bounding square of the disk.
2. If the sample lies outside the disk, reject it and sample another one.



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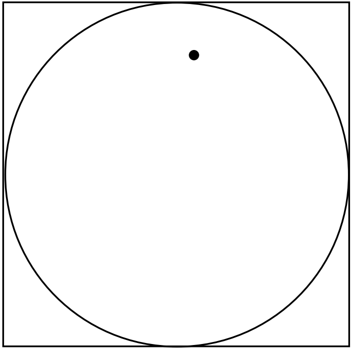

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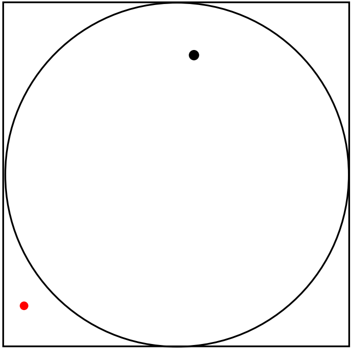

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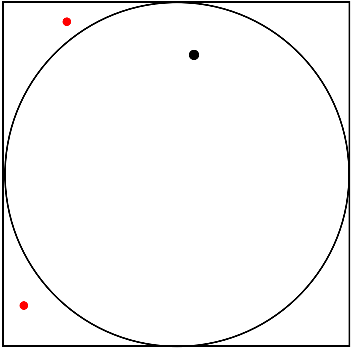

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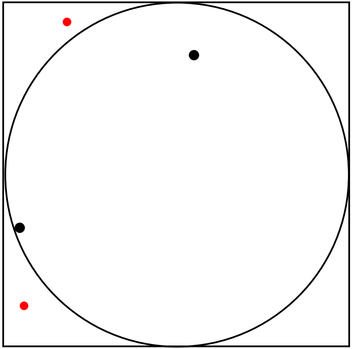

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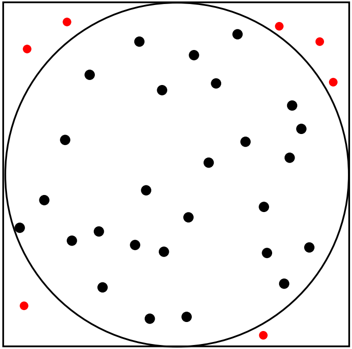

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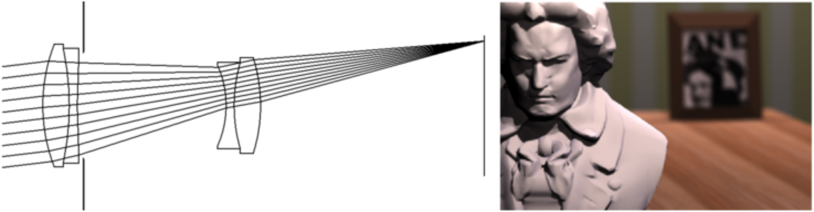
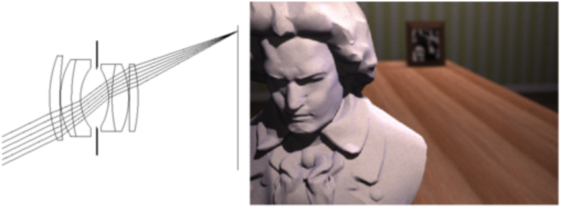
- This produce uniform samples on a disk after coordinate transformation. We will prove it later in chapter 14 “Monte Carlo integration”.

Results



200mm Telescope

Results



50mm General

Results

35mm wide-angle

Results

16mm Fisheye

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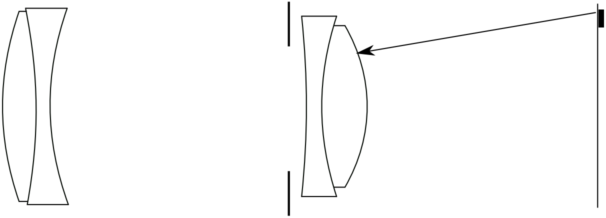
  - You need to fill the content of `ray` and return a value for its weight.

Inside GenerateRay()



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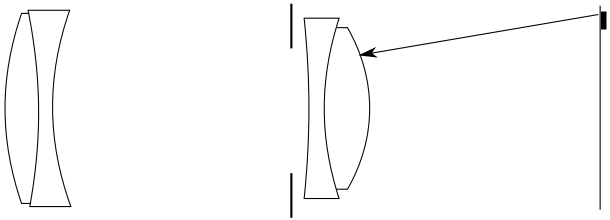

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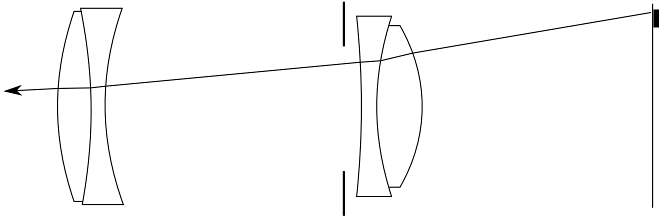

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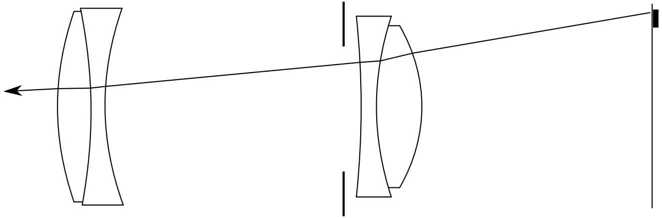

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- My email address:
  littleshan@cmlab.csie.ntu.edu.tw
  littleshan@gmail.com