



机器视觉测量与建模

Machine vision based surveying and modelling

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1

2. 图像处理的基础

- 2.1 图像的感知与获取
- 2.2 坐标转换基础
- 2.3 透视投影的相机模型
- 2.4 射影几何基础



2.1 图像的感知与获取

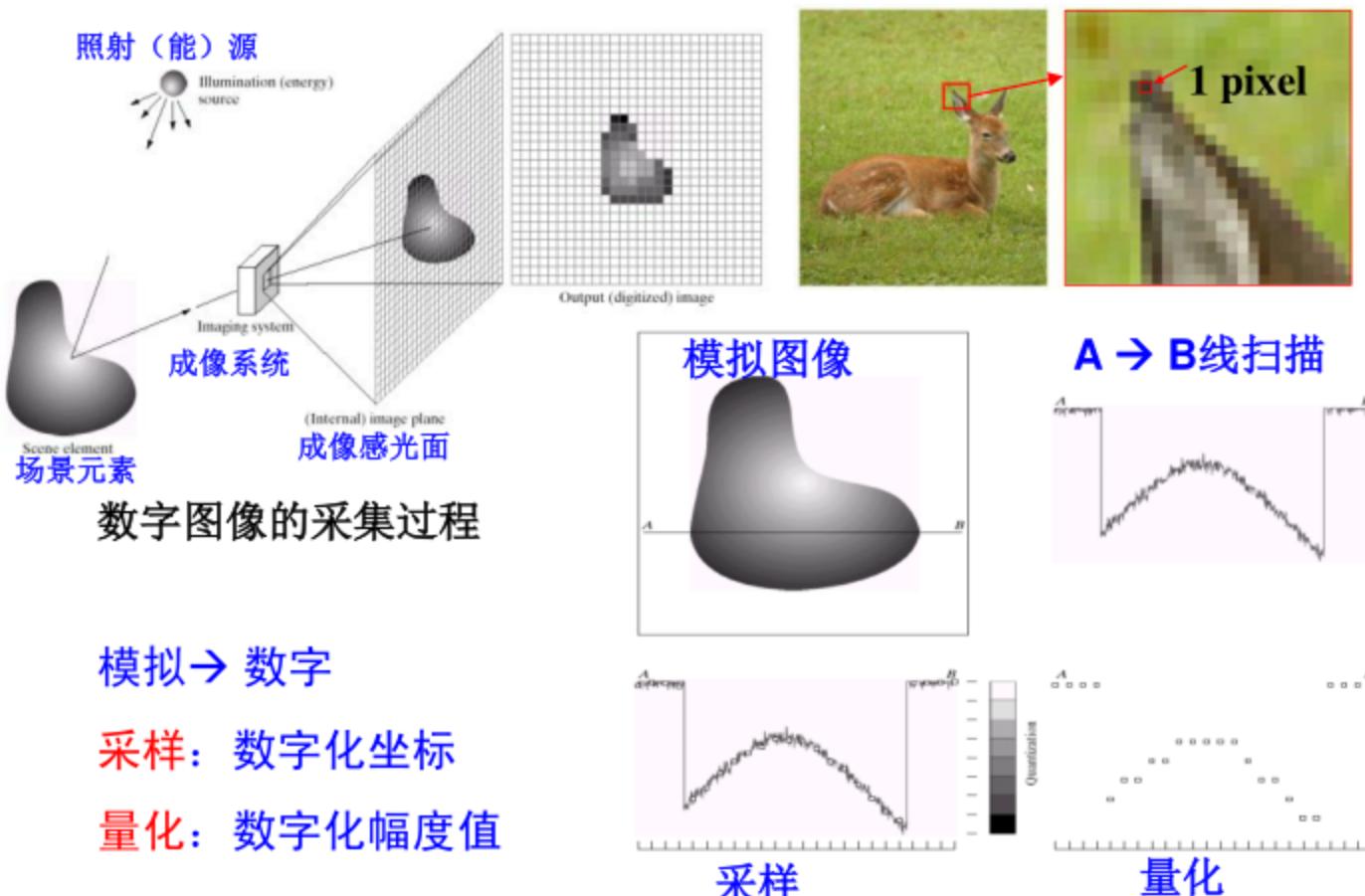


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3



2.1 图像的感知与获取



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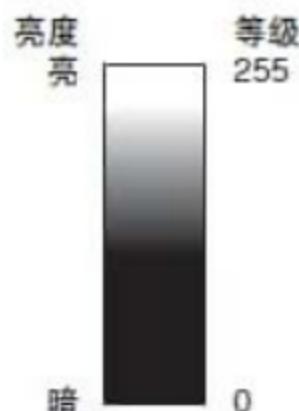
4

2.1 图像的感知与获取

- 用相机拍摄时，对象的光通过镜头在 sensor 上成像
- 光到达某个像素时，将根据光的强度产生相应的电荷
- 将该电荷的大小读取为电信号，即可获得各像素上光的强度

大部分图像传感器可以根据光强度将数据分为 256 个等级（8 位）。在最基本的黑白处理中，黑色（纯黑色）的数值为“0”，白色（纯白色）的数值为“255”，其它处于两者之间的颜色则根据光强度转换成其它数值。

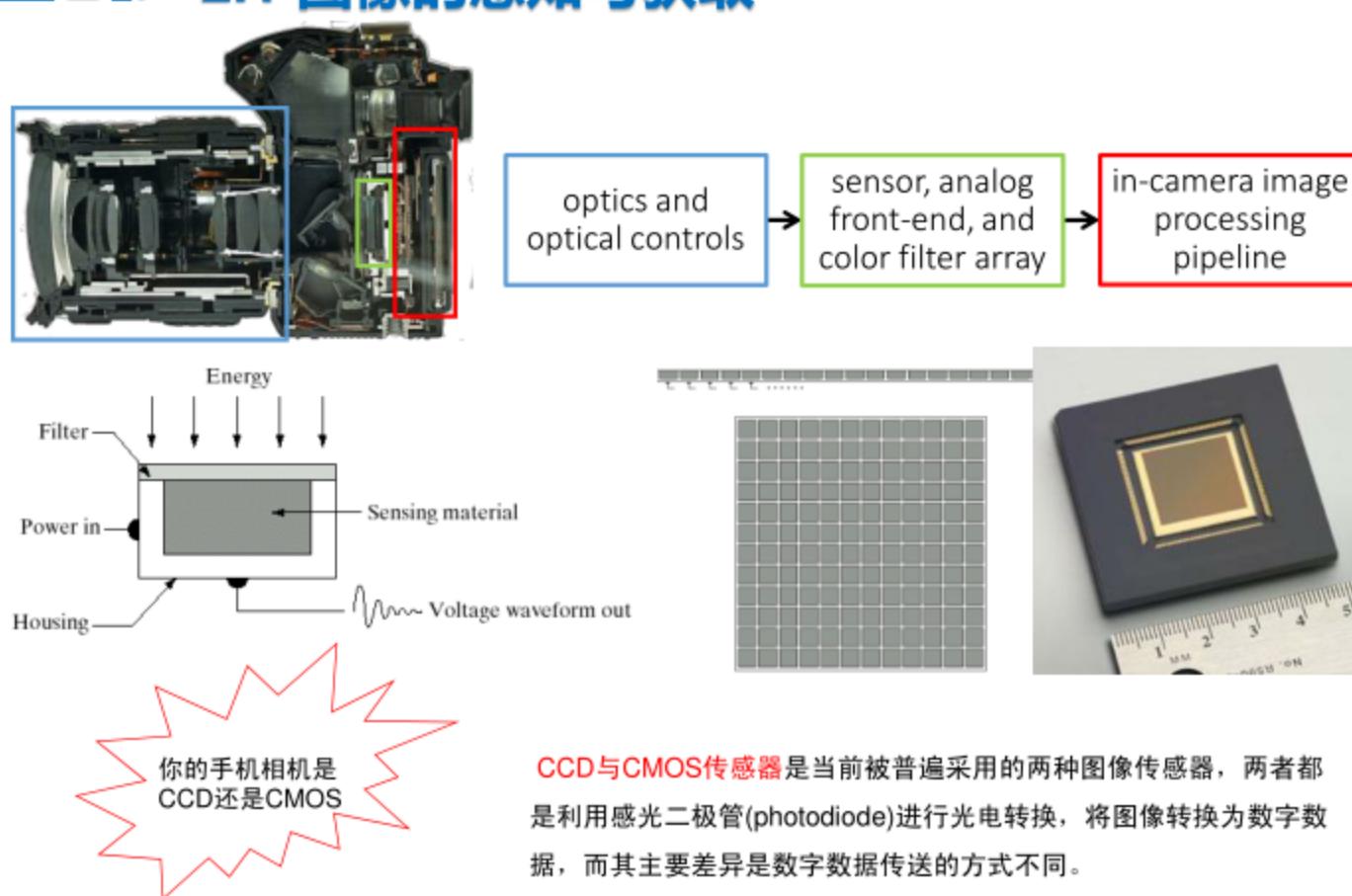
每一个像素都有一个位于“0”（纯黑色）与“255”（纯白色）之间的数值。



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5

2.1 图像的感知与获取



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6

2.1 图像的感知与获取



CCD

Charge Coupled Device (电荷耦合元件)，一种将图像转换为电信号的半导体元件。

separate photo sensor at regular positions
area CCDs and linear CCDs

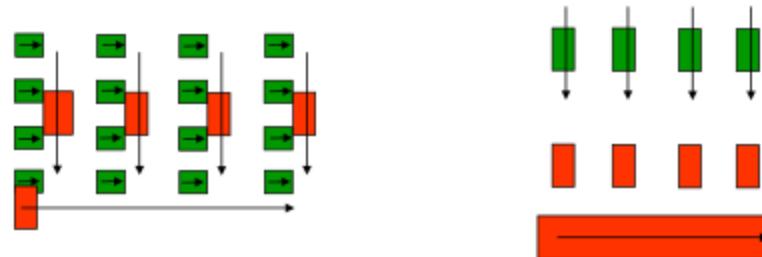
area architectures :

interline transfer

and

frame transfer

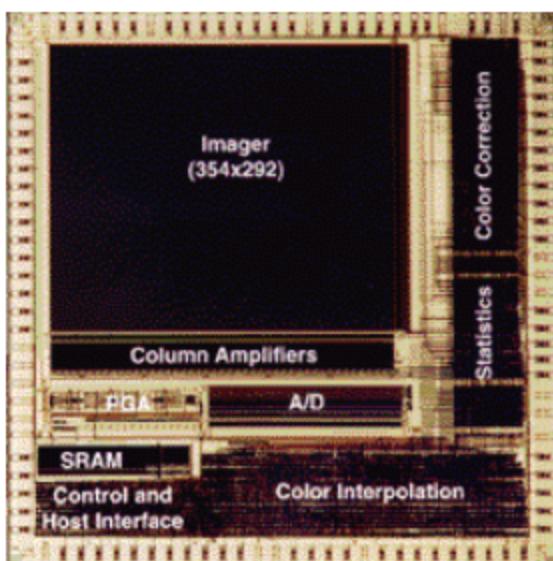
photosensitive
storage



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7

2.1 图像的感知与获取



CMOS

Same sensor elements as CCD

Each photo sensor has its own amplifier

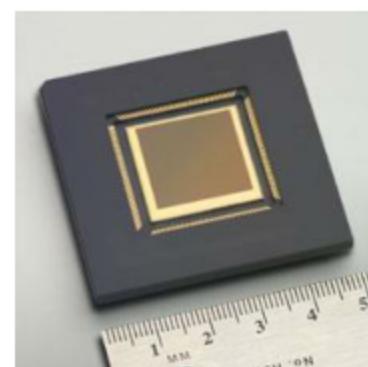
More noise (reduced by subtracting 'black' image)

Lower sensitivity (lower fill rate)

Uses standard CMOS technology

Allows to put other components on chip

'Smart' pixels



Foveon
4k x 4k sensor
0.18 μ process
70M transistors

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8



CCD vs. CMOS

视频19分钟

https://www.bilibili.com/video/BV1Qt421a7S4/?spm_id_from=333.337.search-card.all.click&vd_source=7d1d23b0822743a868a1515c73cf4bc5

- 1. 灵敏度差异：由于CMOS传感器的每个象素由四个晶体管与一个感光二极管构成(含放大器与A/D转换电路)，使得每个象素的感光区域远小于象素本身的表面积，因此在象素尺寸相同的情况下，CMOS传感器的灵敏度要低于CCD传感器。
- 2. 成本差异：由于CMOS传感器采用一般半导体电路最常用的CMOS工艺，可以轻易地将周边电路(如AGC、CDS、Timing generator、或DSP等)集成到传感器芯片中，因此可以节省外围芯片的成本；除此之外，由于CCD采用电荷传递的方式传送数据，只要其中有一个象素不能运行，就会导致一整排的数据不能传送，因此控制CCD传感器的成品率比CMOS传感器困难许多，即使有经验的厂商也很难在产品问世的半年内突破50%的水平，因此，CCD传感器的成本会高于CMOS传感器。
- 3. 分辨率差异：CMOS传感器的每个象素都比CCD传感器复杂，其象素尺寸很难达到CCD传感器的水平，因此，当我们比较相同尺寸的CCD与CMOS传感器时，CCD传感器的分辨率通常会优于CMOS传感器的水平。例如，目前市面上CMOS传感器最高可达到210万象素的水平(OmniVision的OV2610，2002年6月推出)，其尺寸为1/2英寸，象素尺寸为4.25μm
- 4. 噪声差异：由于CMOS传感器的每个感光二极管都需搭配一个放大器，而放大器属于模拟电路，很难让每个放大器所得到的结果保持一致，因此与只有一个放大器放在芯片边缘的CCD传感器相比，CMOS传感器的噪声就会增加很多，影响图像品质。
- 5. 功耗差异：CMOS传感器的图像采集方式为主动式，感光二极管所产生的电荷会直接由晶体管放大输出，但CCD传感器为被动式采集，需外加电压让每个象素中的电荷移动，而此外加电压通常需要达到12~18V；因此，CCD传感器除了在电源管理电路设计上的难度更高之外(需外加 power IC)，高驱动电压更使其功耗远高于CMOS传感器的水平。
- 综上所述，CCD传感器在灵敏度、分辨率、噪声控制等方面都优于CMOS传感器，而CMOS传感器则具有低成本、低功耗、以及高整合度的特点。不过，随着CCD与CMOS传感器技术的进步，两者的差异有逐渐缩小的态势，例如，CCD传感器一直在功耗上作改进，以应用于移动通信市场(这方面的代表业者为Sanyo)；CMOS传感器则在改善分辨率与灵敏度方面的不足，以应用于更高端的图像产品。

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9

9

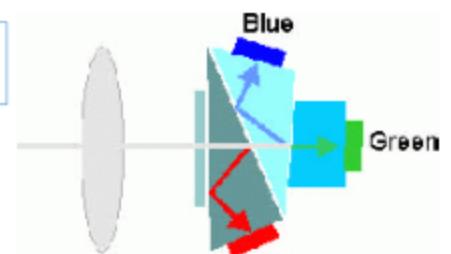


2.1 图像的感知与获取

彩色成像摄像机的工作原理

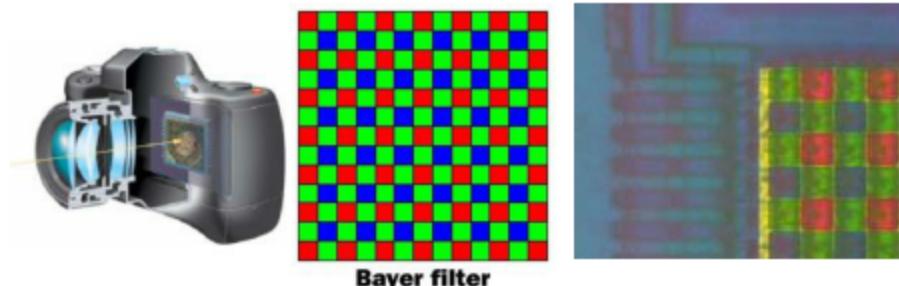
1. Prism棱镜(with 3 sensors)

Separate light in 3 beams using dichroic prism.
Requires 3 sensors & precise alignment. Good
color separation



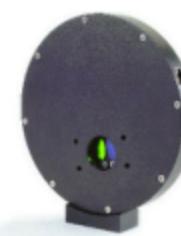
2. Filter mosaic滤光片

Coat filter directly on sensor



3. Filter wheel滤轮

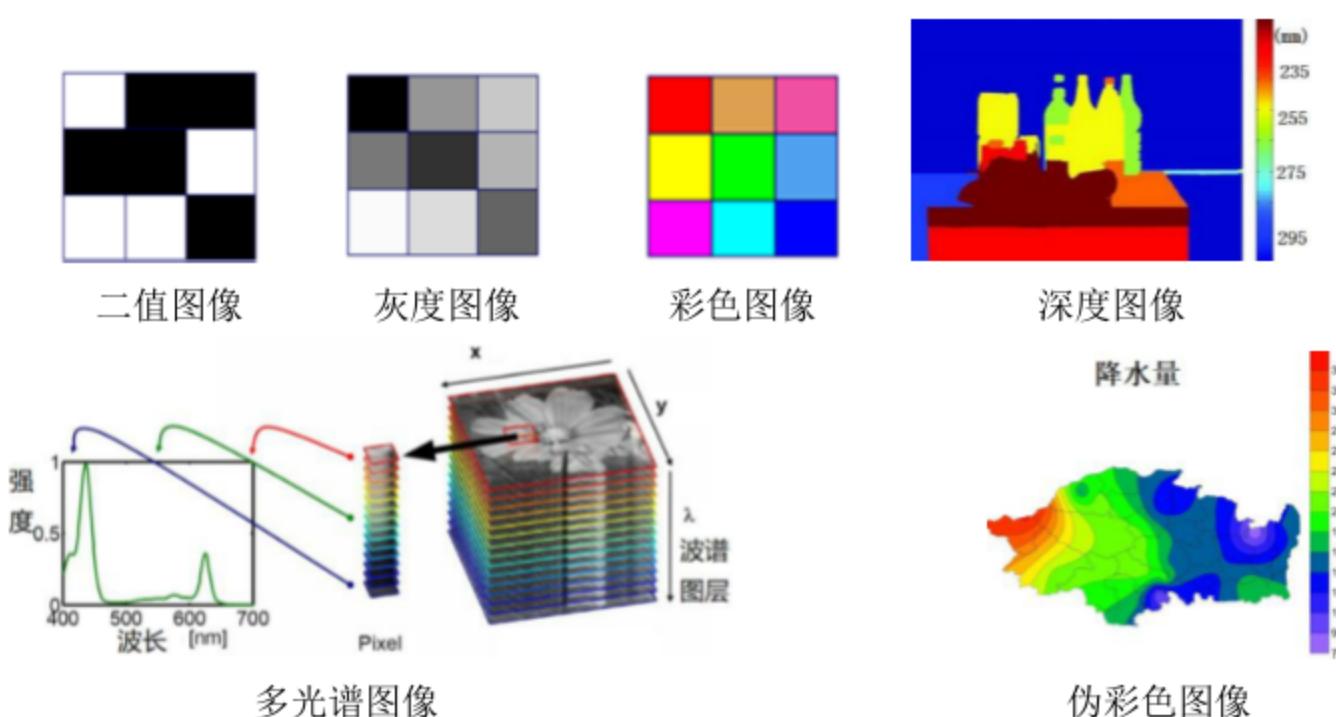
Rotate multiple filters in front of lens. Allows more than 3
colour bands.. Only suitable for static scenes



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10

2.1 图像的感知与获取



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11

2.1 图像的感知与获取

Pinhole imaging 小孔成像

Pinhole camera 又称为 camera obscura 暗箱(早期的照相机)

First mention ...



Chinese philosopher Mozi
中国哲学家墨子
(470 to 390 BC)

First camera ...



Greek philosopher Aristotle
哲学家亚里士多德
(384 to 322 BC)

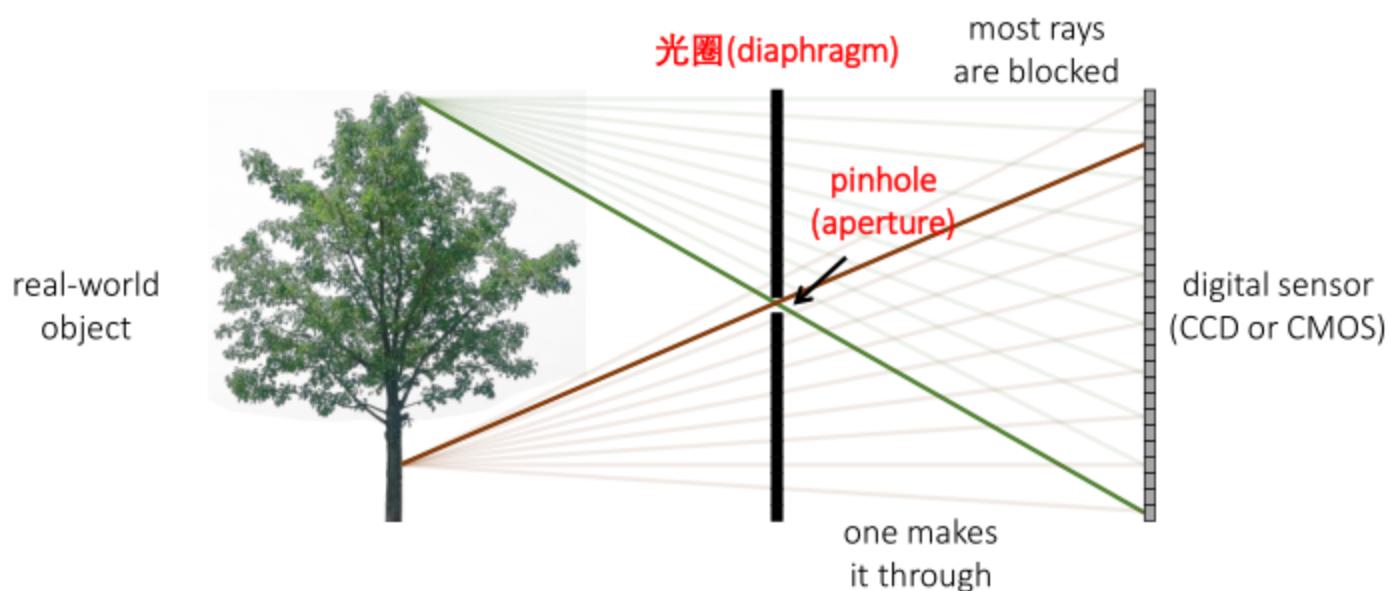
Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

12



2.1 图像的感知与获取

Pinhole imaging 小孔成像



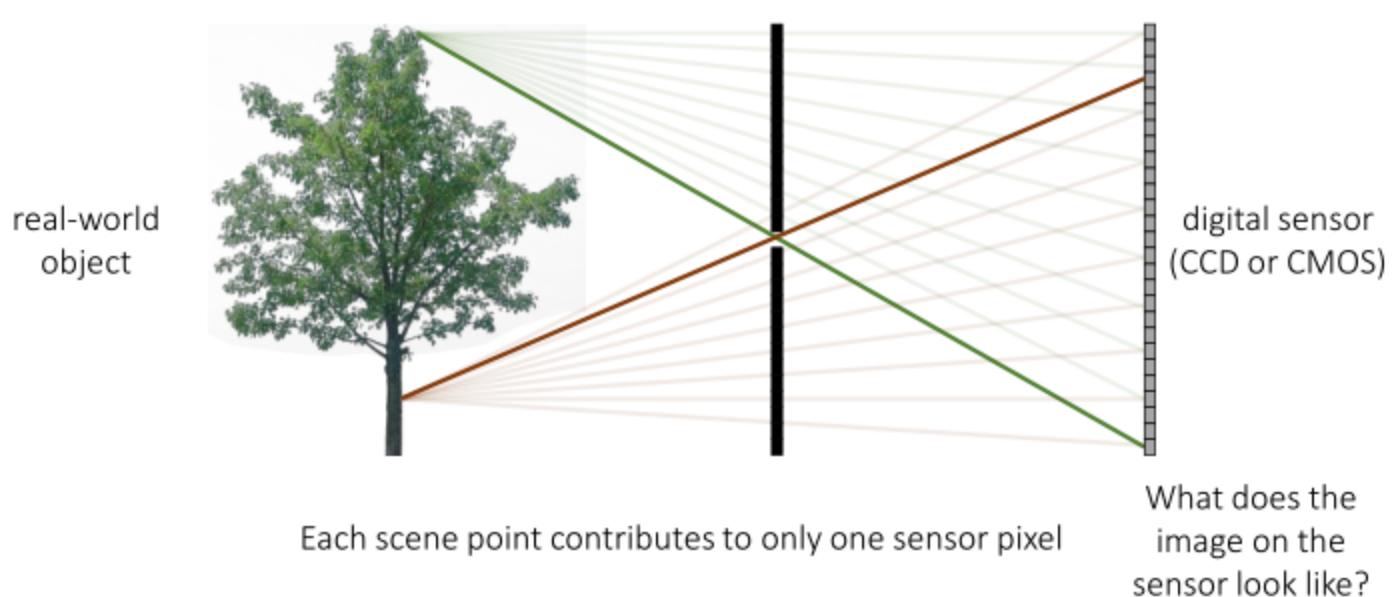
Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

13



2.1 图像的感知与获取

Pinhole imaging 小孔成像



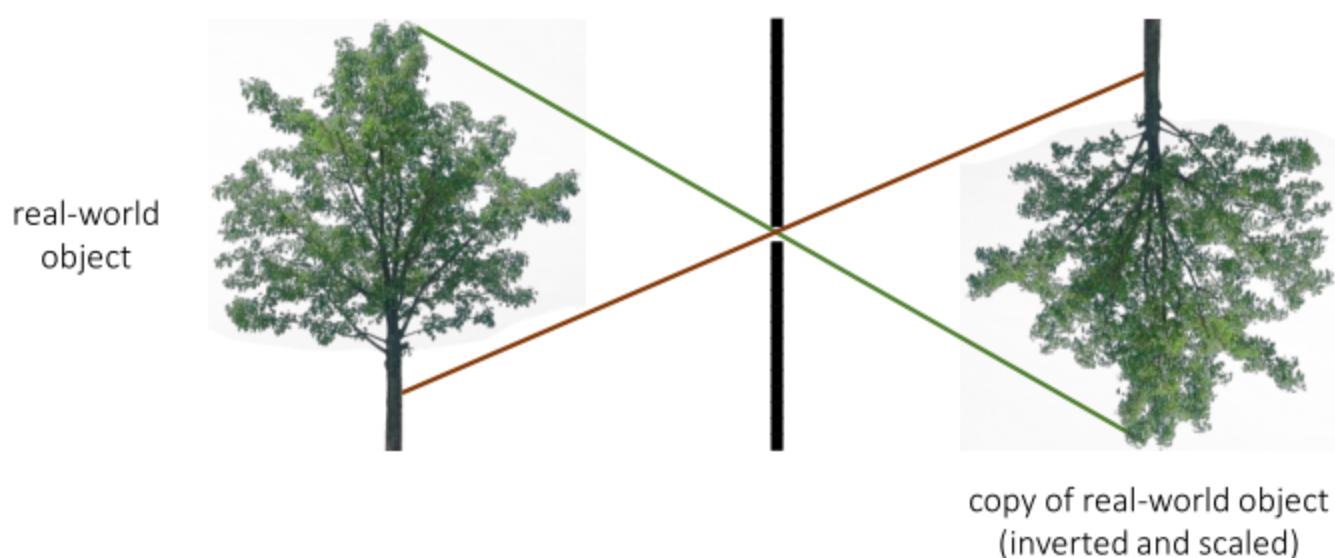
Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

14



2.1 图像的感知与获取

Pinhole imaging 小孔成像



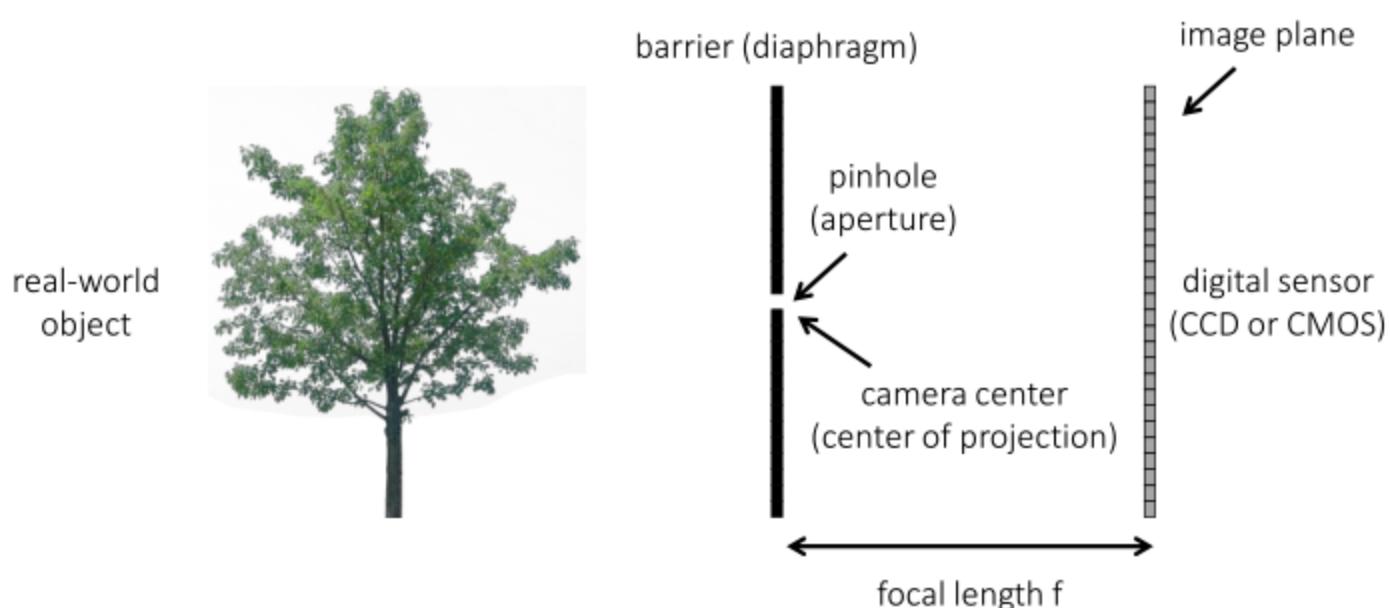
Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

15



2.1 图像的感知与获取

Pinhole camera terms



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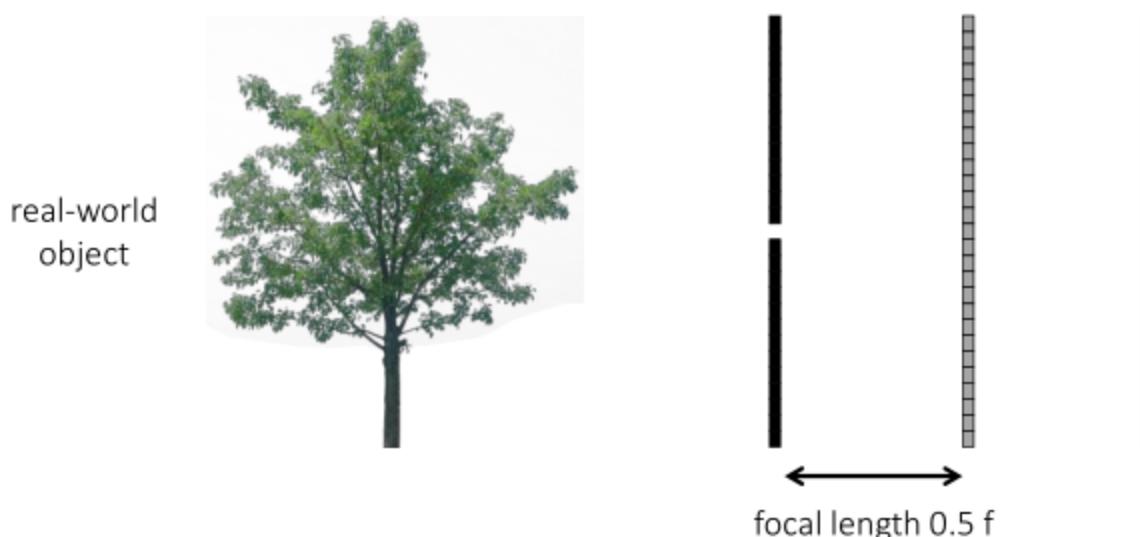
16



2.1 图像的感知与获取

Focal length

What happens as we change the focal length?



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17

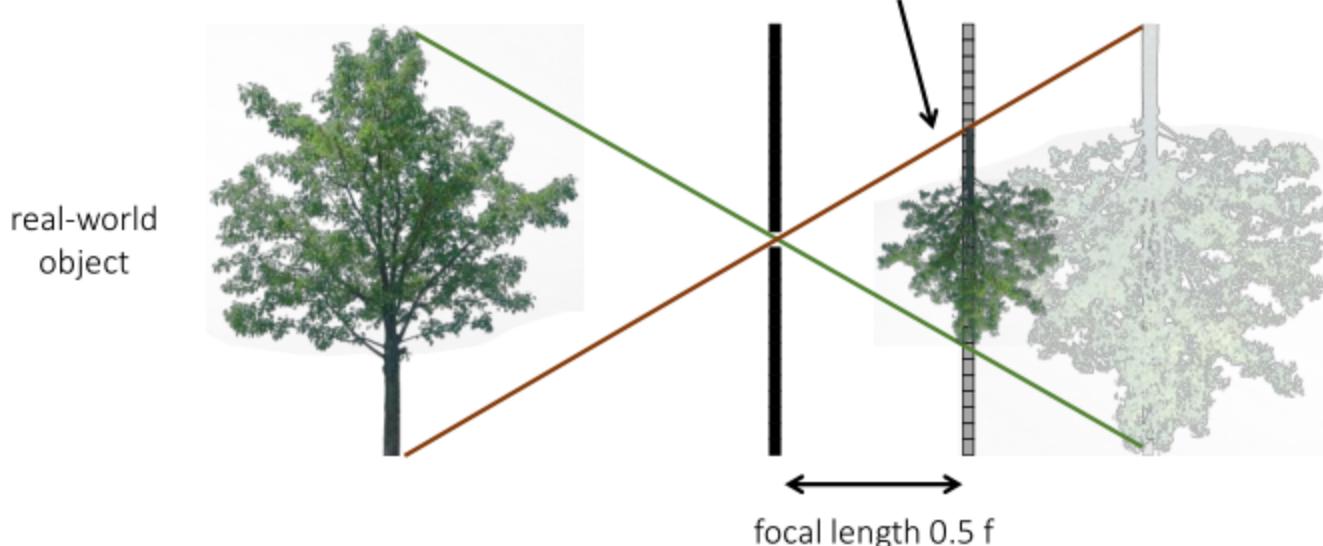


2.1 图像的感知与获取

Focal length

What happens as we change the focal length?

object projection is half the size



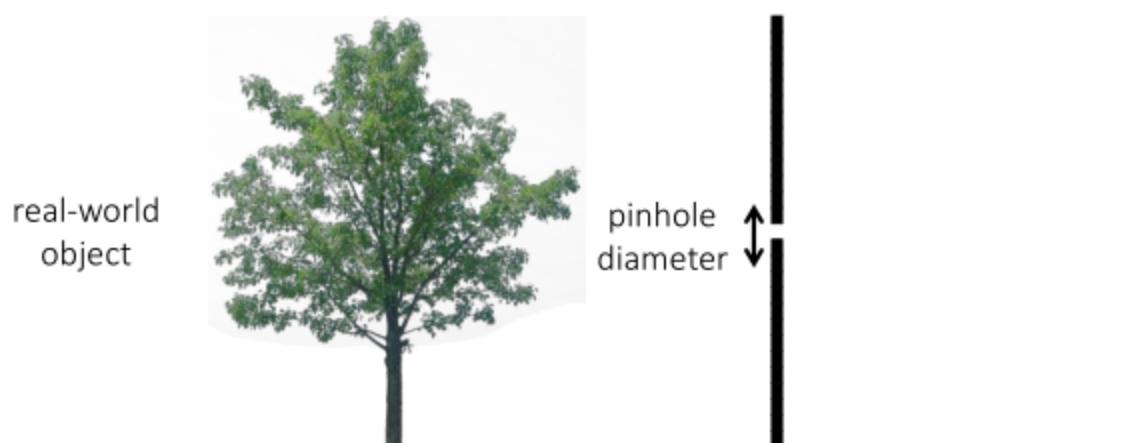
Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

18



2.1 图像的感知与获取

Pinhole size



Ideal pinhole has infinitesimally small size

- In practice that is impossible.

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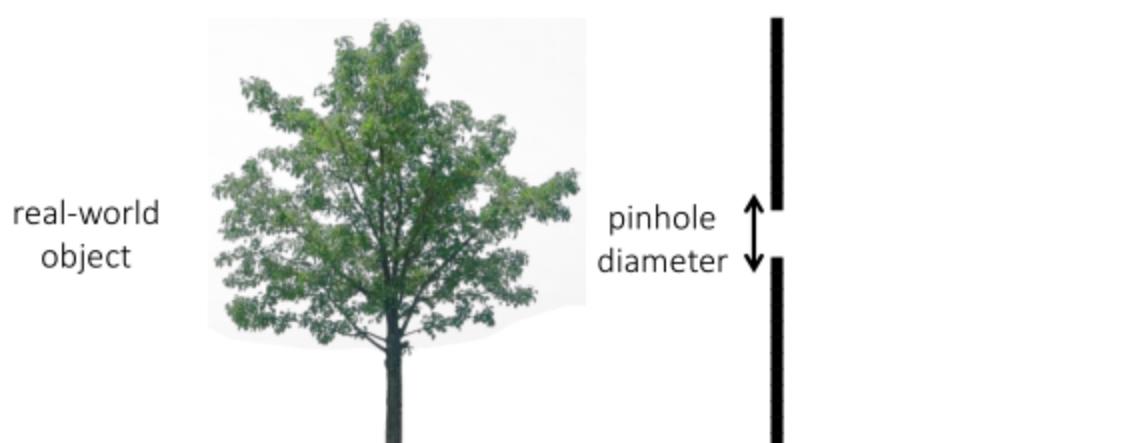
19



2.1 图像的感知与获取

Pinhole size

What happens as we change the pinhole diameter?



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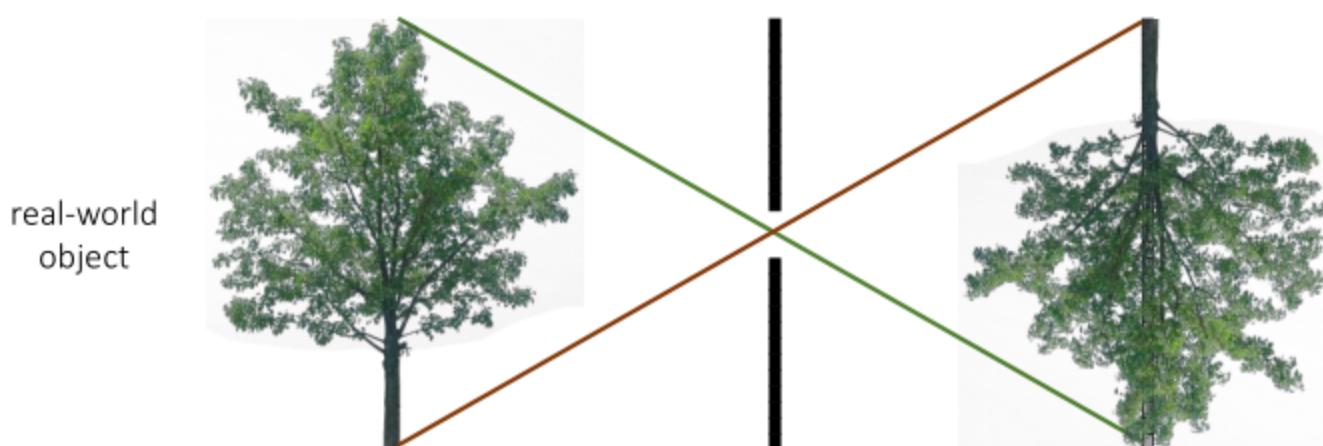
20



2.1 图像的感知与获取

Pinhole size

What happens as we change the pinhole diameter?



Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

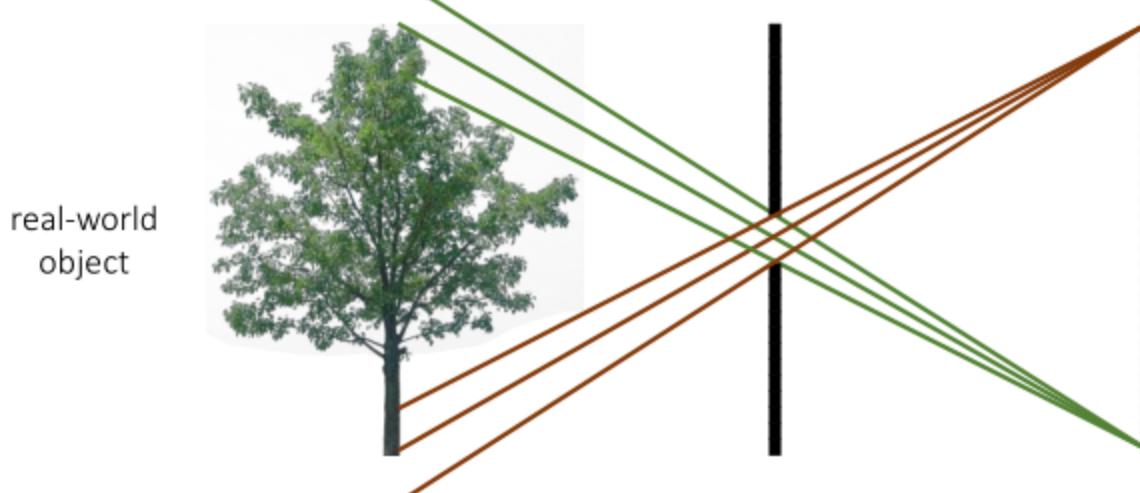
21



2.1 图像的感知与获取

Pinhole size

What happens as we change the pinhole diameter?



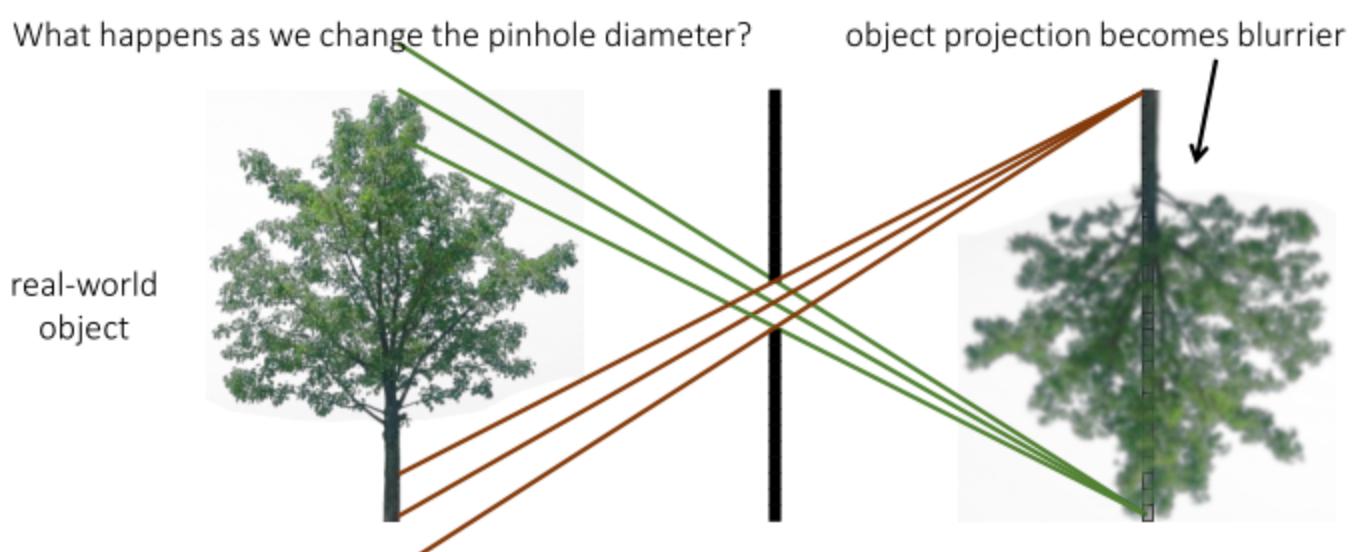
Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

22



2.1 图像的感知与获取

Pinhole size



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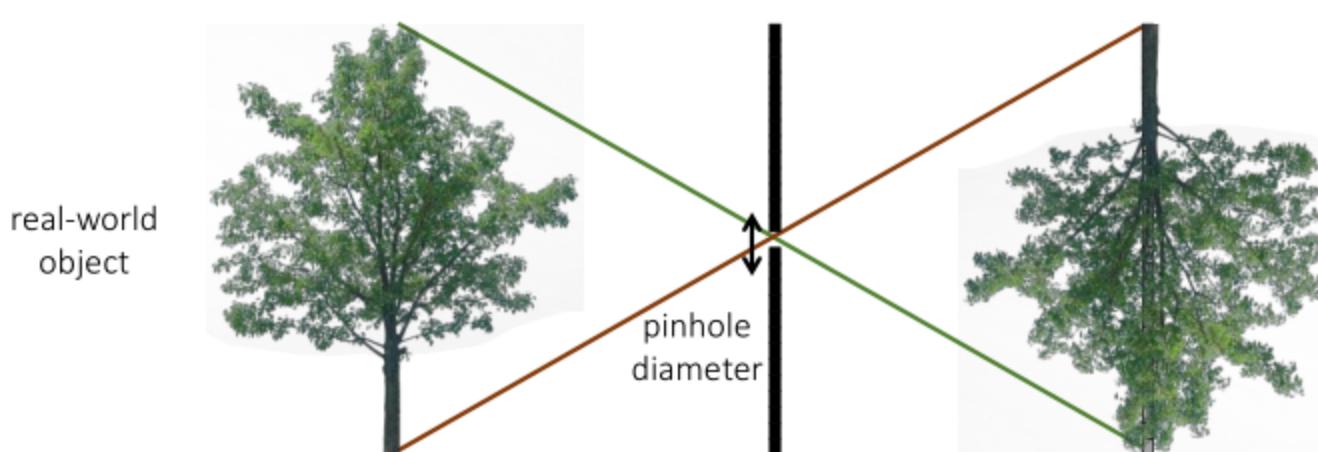
23



2.1 图像的感知与获取

Pinhole size

What happens as we change the pinhole diameter?



Will the image keep getting sharper the smaller we make the pinhole?

是不是小孔越小，图像越清晰？

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24

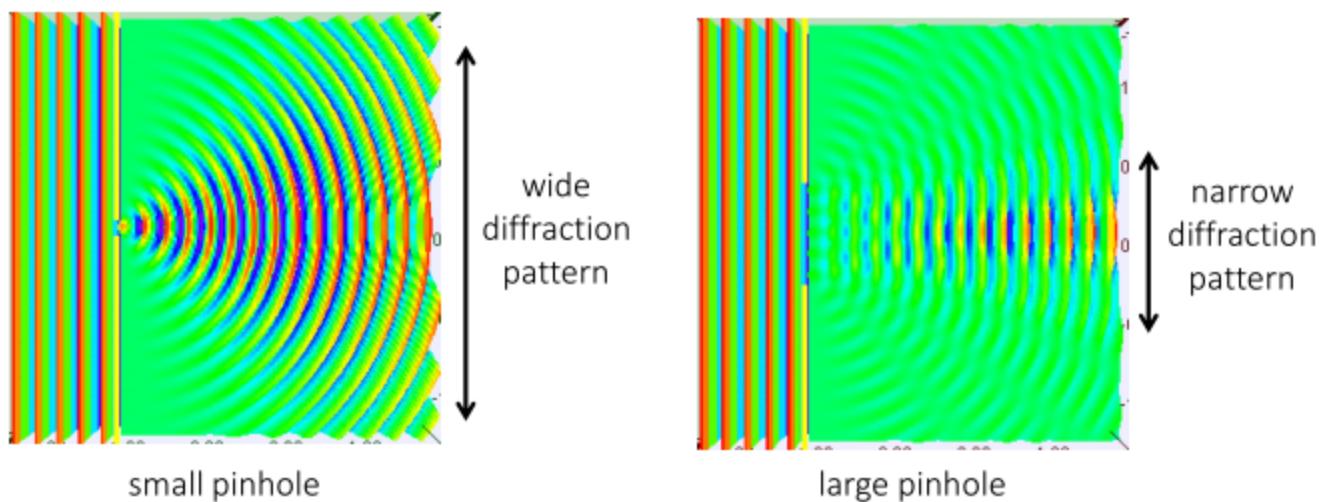


2.1 图像的感知与获取

Diffraction limit

Diffraction pattern = Fourier transform of the pinhole.

- Smaller pinhole means bigger Fourier spectrum.
- Smaller pinhole means more diffraction.



衍射角越大, 衍射级次越高, 空间频率也越高。然后这些不同频率的衍射光通过傅里叶透镜在后焦面上形成一个初级干涉图

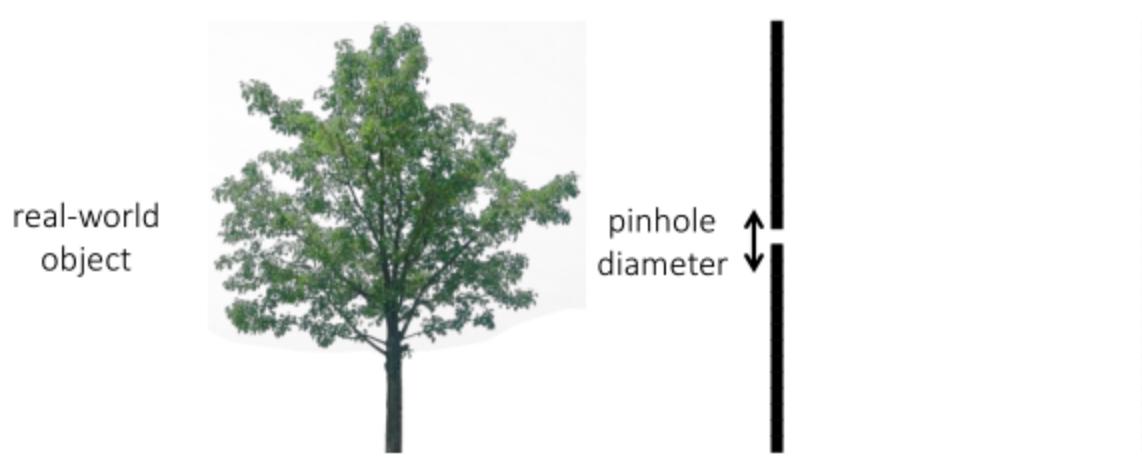
Ref: Ioannis (Yannis) Gkioulekas <http://www.cs.cmu.edu/~igkioule>

25



2.1 图像的感知与获取

What about light efficiency?



- What is the effect of doubling the pinhole diameter?
- What is the effect of doubling the focal length?

- 2x pinhole diameter → 4x light
- 2x focal length → 1/4x light

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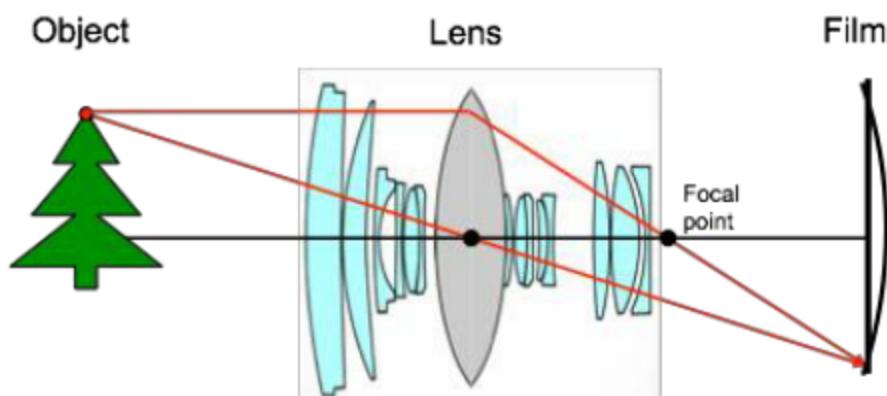
26



2.1 图像的感知与获取

Thin lenses are a fiction

The thin lens model assumes that the lens has no thickness, but this is rarely true...



To make real lenses behave like ideal thin lenses, we have to use combinations of multiple lens elements (compound lenses).

注：即使有多个镜头，整个光学系统可以（平行）描述使用一个单一的焦距和光圈数。

27



2.1 图像的感知与获取

Thin lenses are a fiction

The thin lens model assumes that the lens has no thickness, but this is rarely true...



To make real lenses behave like ideal thin lenses, we have to use combinations of multiple lens elements (compound lenses).

28



2.1 图像的感知与获取

视频播放

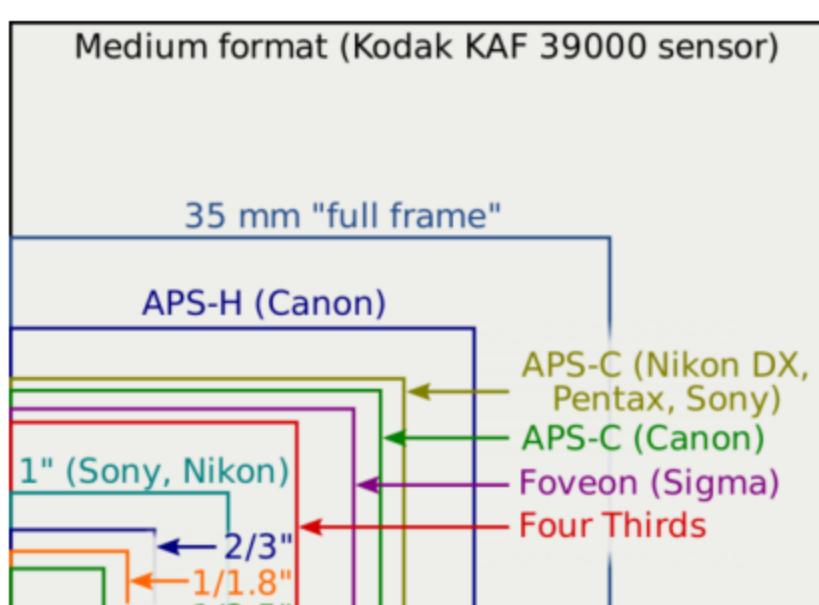


29



2.1 图像的感知与获取

了解：Field of view also depends on sensor size



英寸的符号是”。1英寸等于2.54厘米，12英寸为1英尺，36英寸为1码。

- “Full frame” corresponds to standard film size.
- Digital **sensors** come in smaller formats due to manufacturing limitations (now mostly overcome).
- Lenses** are often described in terms of field of view on film instead of focal length.

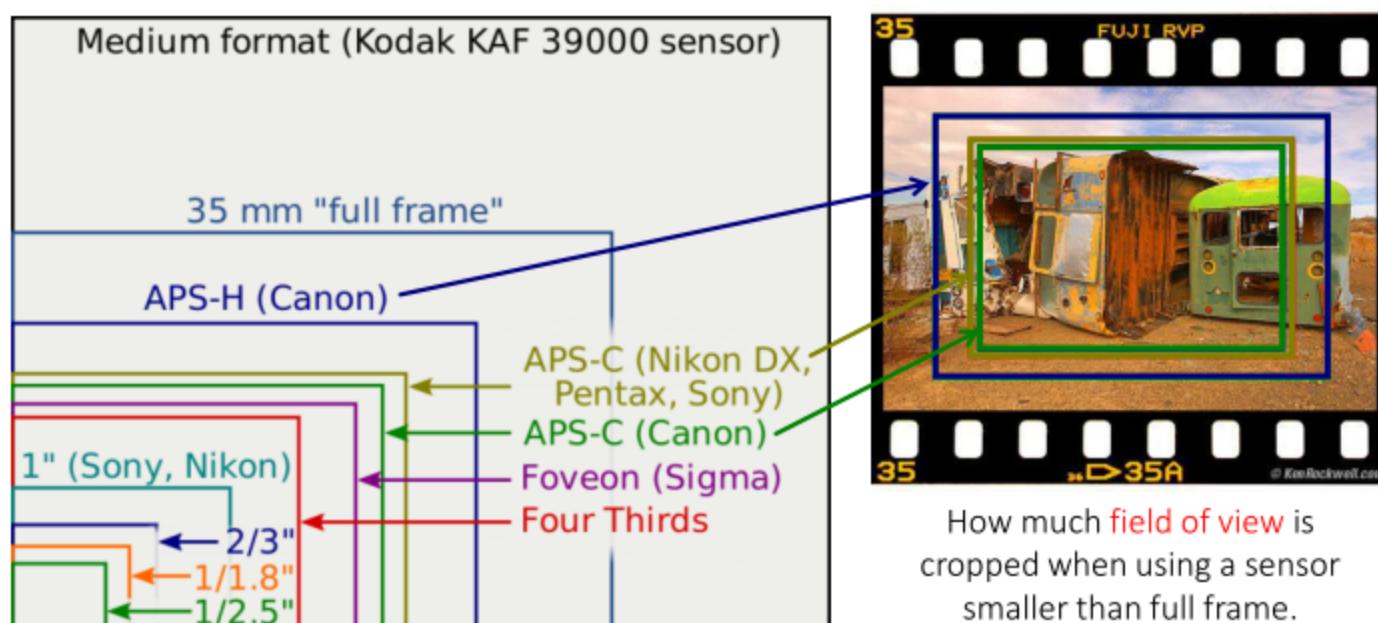
等效焦距是指在使用不同画幅（传感器大小）的相机时，为了获得相同画面视角的照片，所需要选择的焦距。

30



2.1 图像的感知与获取

Crop factor

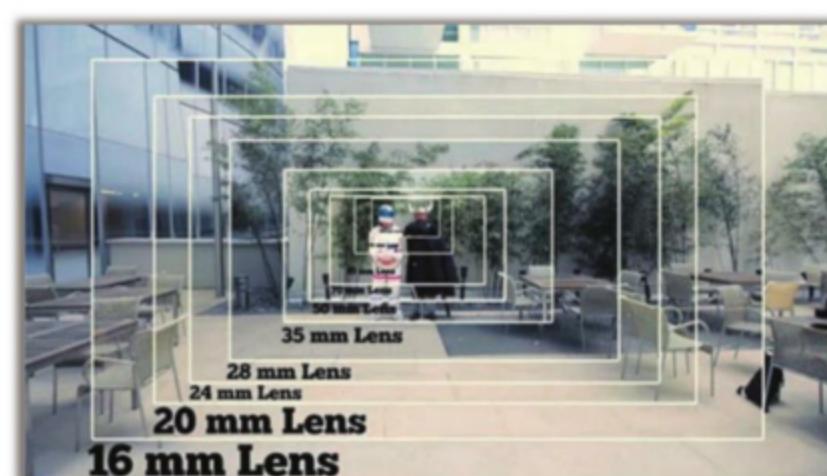
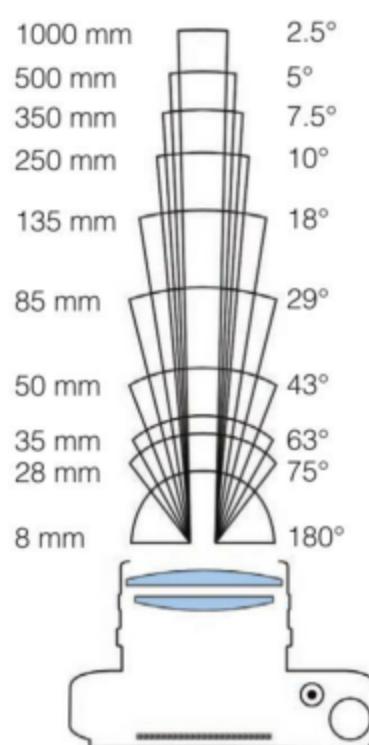


31



2.1 图像的感知与获取

Field of view



Andrew McWilliams

32

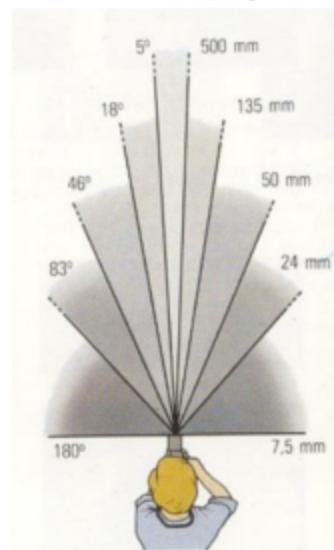
32



2.1 图像的感知与获取

Field of view

Increasing the lens focal length is similar to cropping



$f = 25 \text{ mm}$



$f = 50 \text{ mm}$



$f = 135 \text{ mm}$



Is this effect identical to cropping?

33



2.1 图像的感知与获取

The lens on your camera



34



2.1 图像的感知与获取

Perspective distortion



long focal length



mid focal length



short focal length

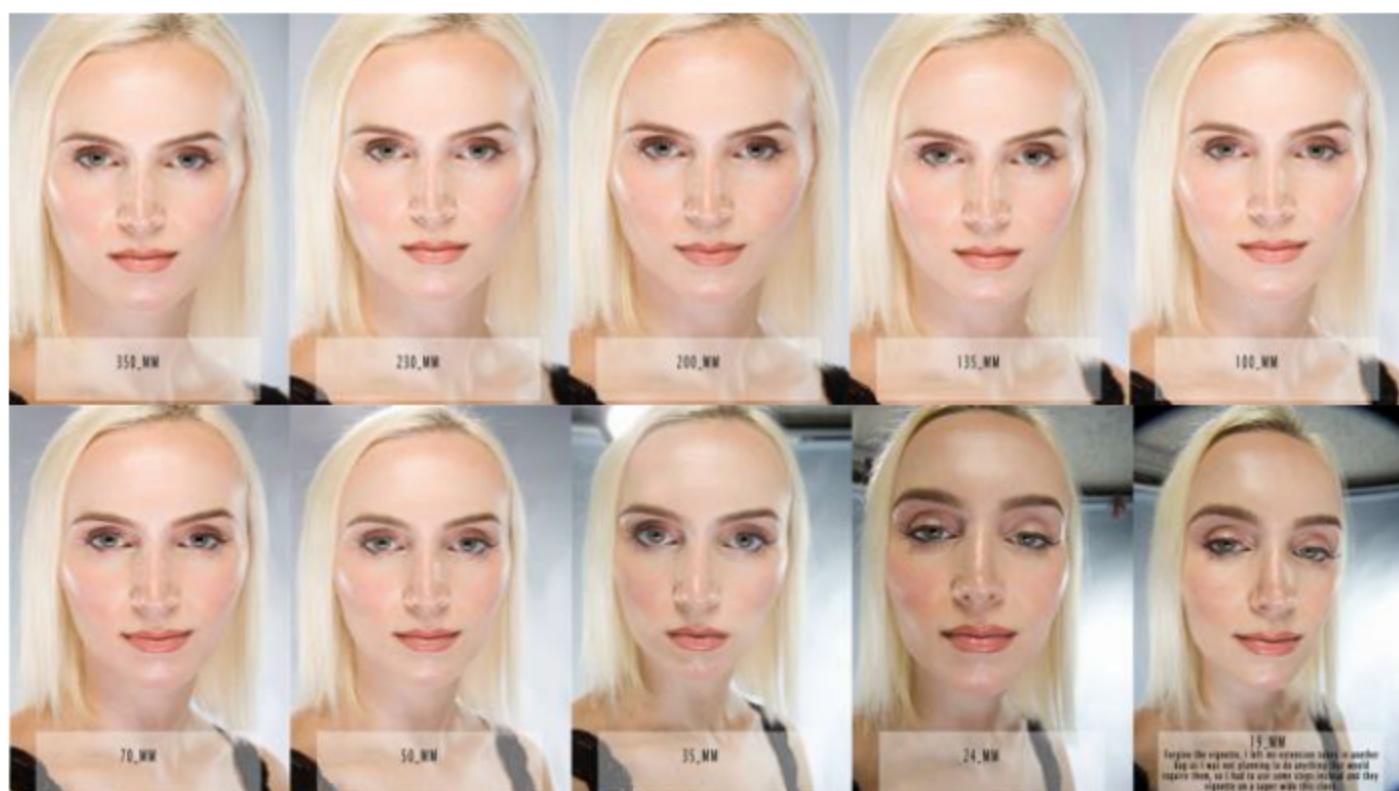
What is the best focal length for portraits?

35



2.1 图像的感知与获取

Perspective distortion



36



2.1 图像的感知与获取

Wide-angle lenses

Lenses with focal length **35 mm or smaller**.



They tend to have large and curvy frontal elements.

37



2.1 图像的感知与获取

Wide-angle lenses

Ultra-wide lenses can get impractically wide...



Fish-eye lens: can produce (near) hemispherical field of view.



38



2.1 图像的感知与获取

Telephoto lenses

Lenses with focal length 85 mm or larger.

Technically speaking, “telephoto” refers to a specific lens design, not a focal length range. But that design is mostly useful for long focal lengths, so it has also come to mean any lens with such a focal length.



Telephotos can get very big...



800mm f5.6 L IS



600mm f4 L IS II



200-400mm f4 L IS



500mm f4 L IS II



400mm f2.8 L IS II



300mm f2.8 L IS II

39



2.1 图像的感知与获取

Telephoto lenses

- What is this?
- What is its focal length?

About 57 meters.



Telephotos can get very big...

40