Computer Vision – TP1
Image Formation

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Outline

- ‘Computer Vision’?
- The Human Visual System
- Image Capturing Systems

Topic: Computer Vision?

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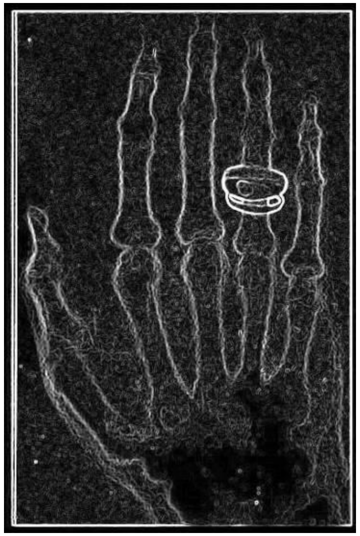
- The Human Visual System
- Image Capturing Systems

Computer Vision

"The goal of Computer Vision is to make useful decisions about real physical objects and scenes based on sensed images",

Shapiro and Stockman, "Computer Vision", 2001





Artificial Intelligence Index Report 2023

Stanford University
Human-Centered
Artificial Intelligence

TOP TAKEAWAYS

Industry races ahead of academia.

Until 2014, most significant machine learning models were released by academia. Since then, industry has taken over. In 2022, there were 32 significant industry-produced machine learning models compared to just three produced by academia. Building state-of-the-art AI systems increasingly requires large amounts of data, compute, and money, resources that industry actors inherently possess in greater amounts compared to nonprofits and academia.

Performance saturation on traditional benchmarks.

AI continued to post state-of-the-art results, but year-over-year improvement on many benchmarks continues to be marginal. Moreover, the speed at which benchmark saturation is being reached is increasing. However, new, more comprehensive benchmarking suites such as BIG-bench and HELM are being released.

AI is both helping and harming the environment.

New research suggests that AI systems can have serious environmental impacts. According to Luccioni et al., 2022, BLOOM's training run emitted 25 times more carbon than a single air traveler on a one-way trip from New York to San Francisco. Still, new reinforcement learning models like BCOOLER show that AI systems can be used to optimize energy usage.

The world's best new scientist … AI?

AI models are starting to rapidly accelerate scientific progress and in 2022 were used to aid hydrogen fusion, improve the efficiency of matrix manipulation, and generate new antibodies.

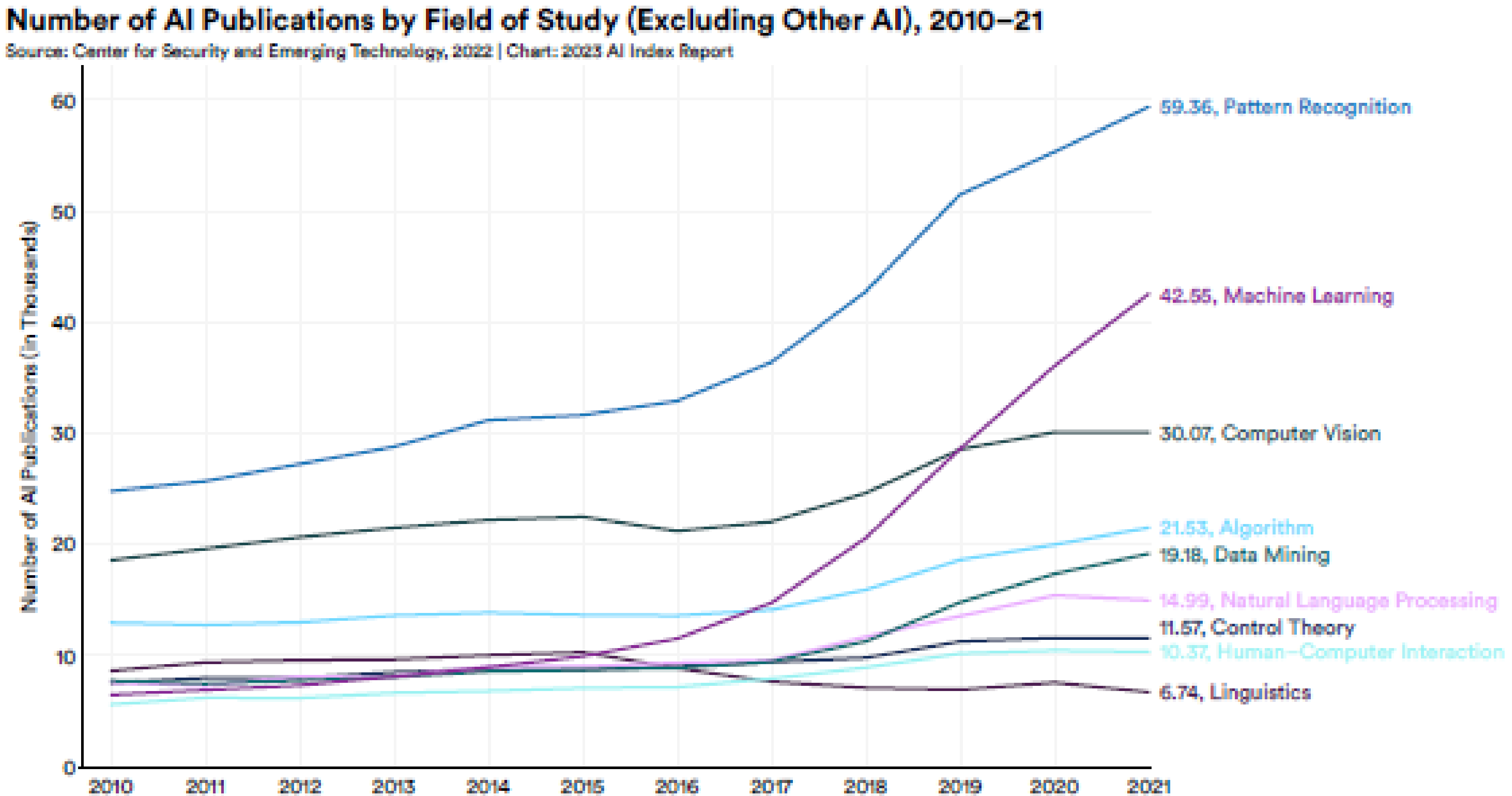
The number of incidents concerning the misuse of AI is rapidly rising.

According to the AIAAIC database, which tracks incidents related to the ethical misuse of AI, the number of AI incidents and controversies has increased 26 times since 2012. Some notable incidents in 2022 included a deepfake video of Ukrainian President Volodymyr Zelenskyy surrendering and U.S. prisons using call-monitoring technology on their inmates. This growth is evidence of both greater use of AI technologies and awareness of misuse possibilities.

The demand for AI-related professional skills is increasing across virtually every American industrial sector.

Across every sector in the United States for which there is data (with the exception of agriculture, forestry, fishery and hunting), the number of AI-related job postings has increased on average from 1.7% in 2021 to 1.9% in 2022. Employers in the United States are increasingly looking for workers with AI-related skills.

Computer Vision in AI Research



Fast Growing Field

- Technological evolution
  -> Deep neural networks
- Growing relevance to business contexts

- Consequences
  - Niche area -> Area of general interest
  - Change in programmatic content
  - Continuous education contexts

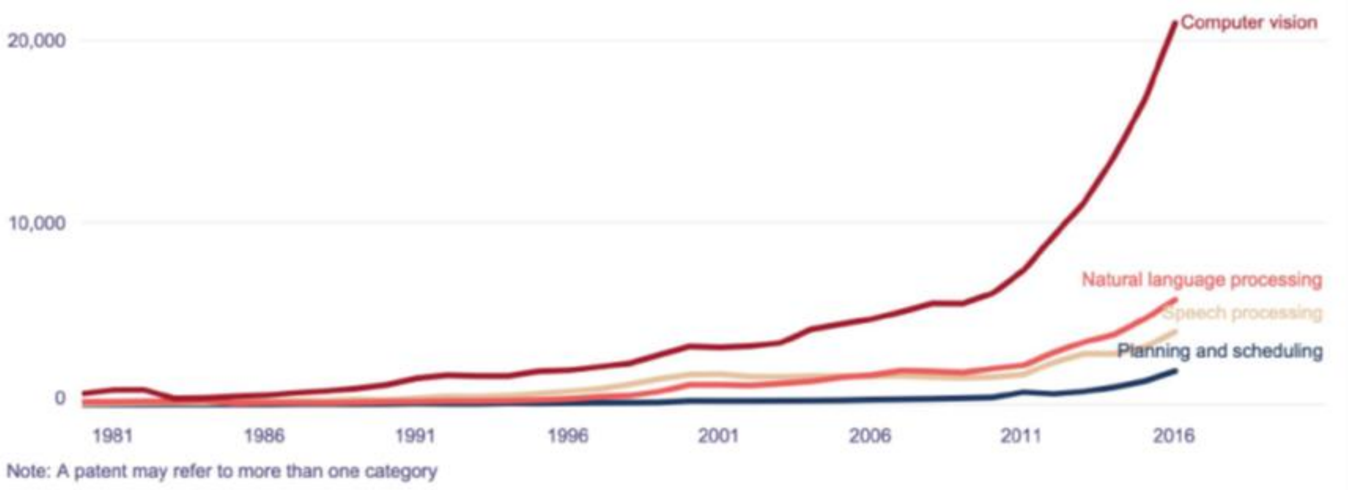
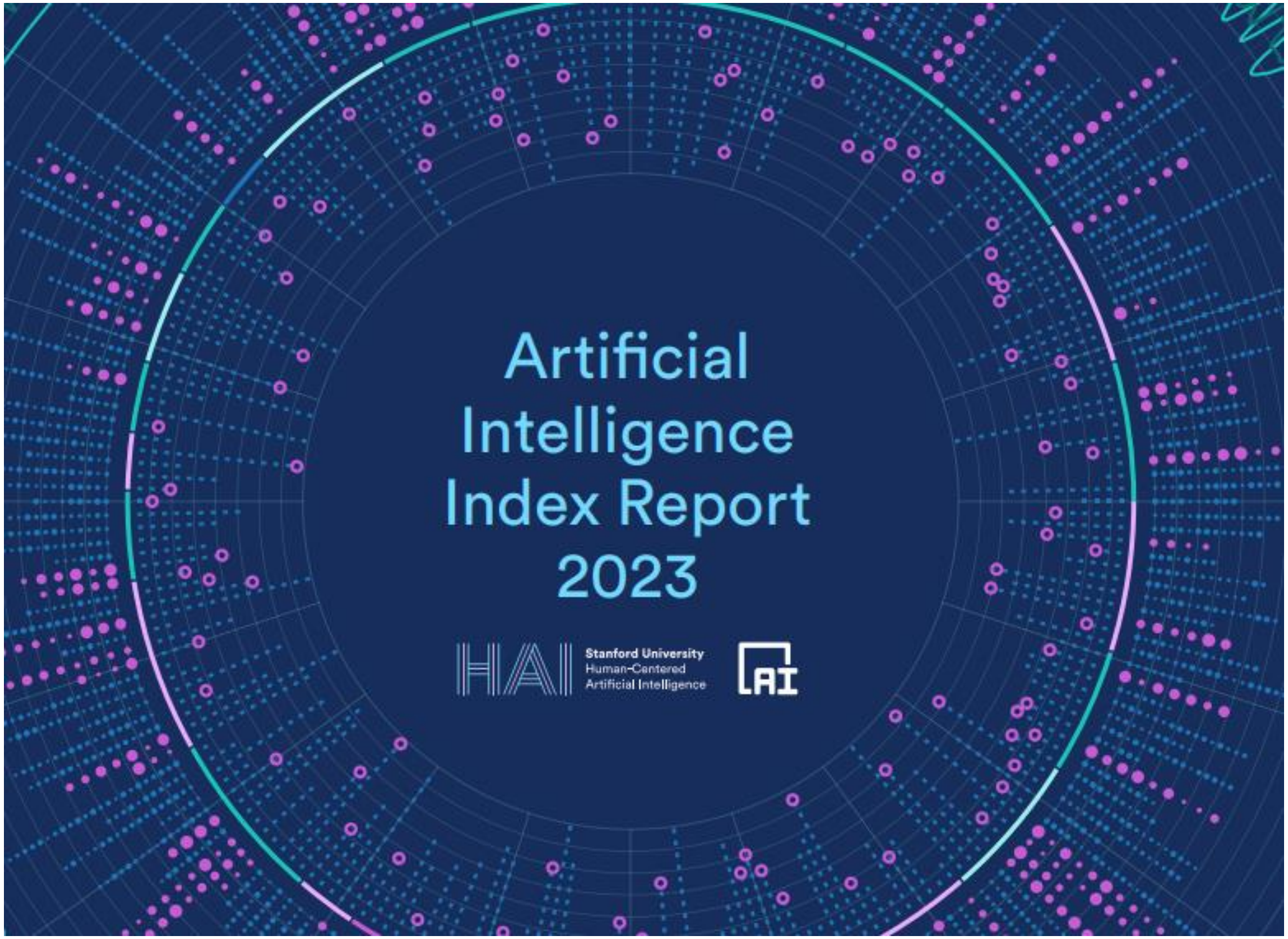
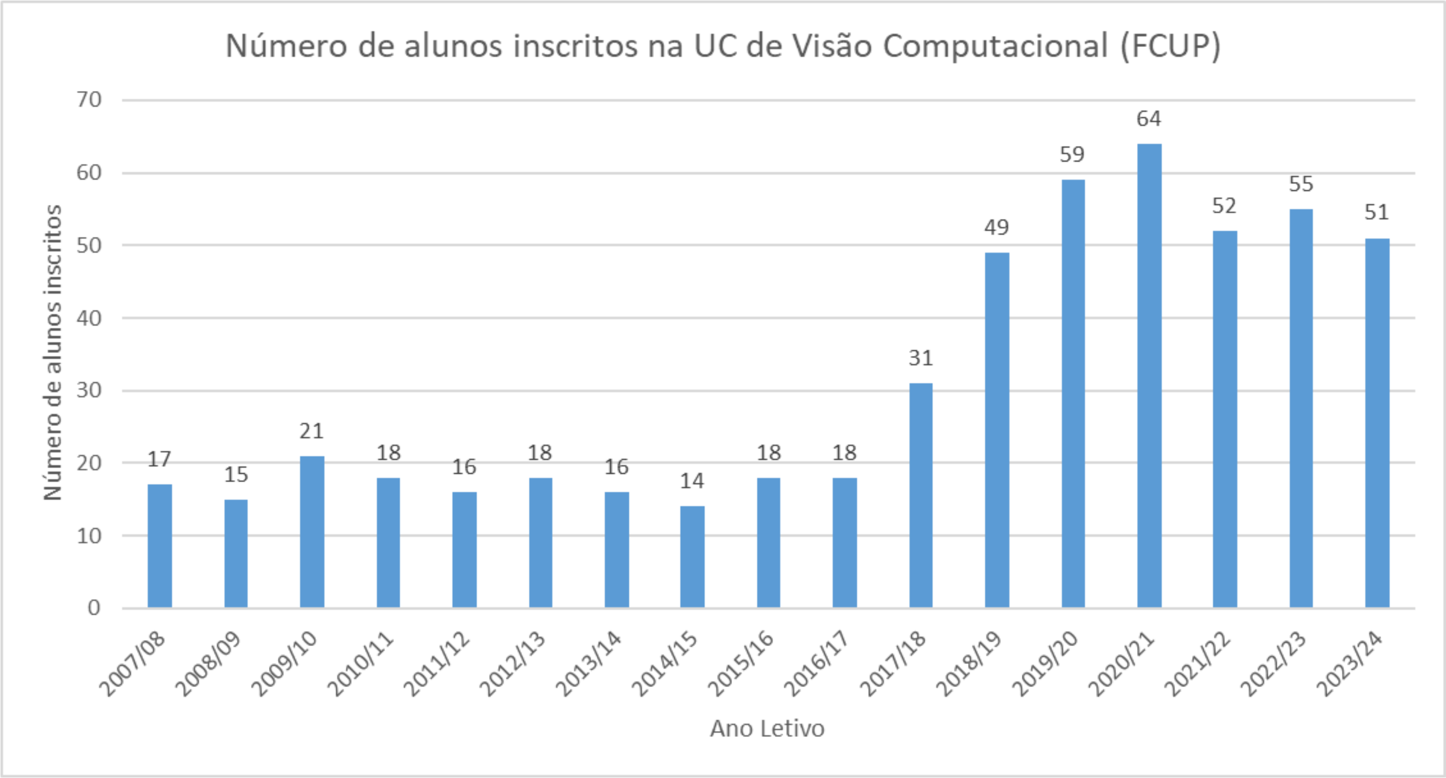


Figure 1 - Patents per year in Artificial Intelligence (WIPO, 2019)

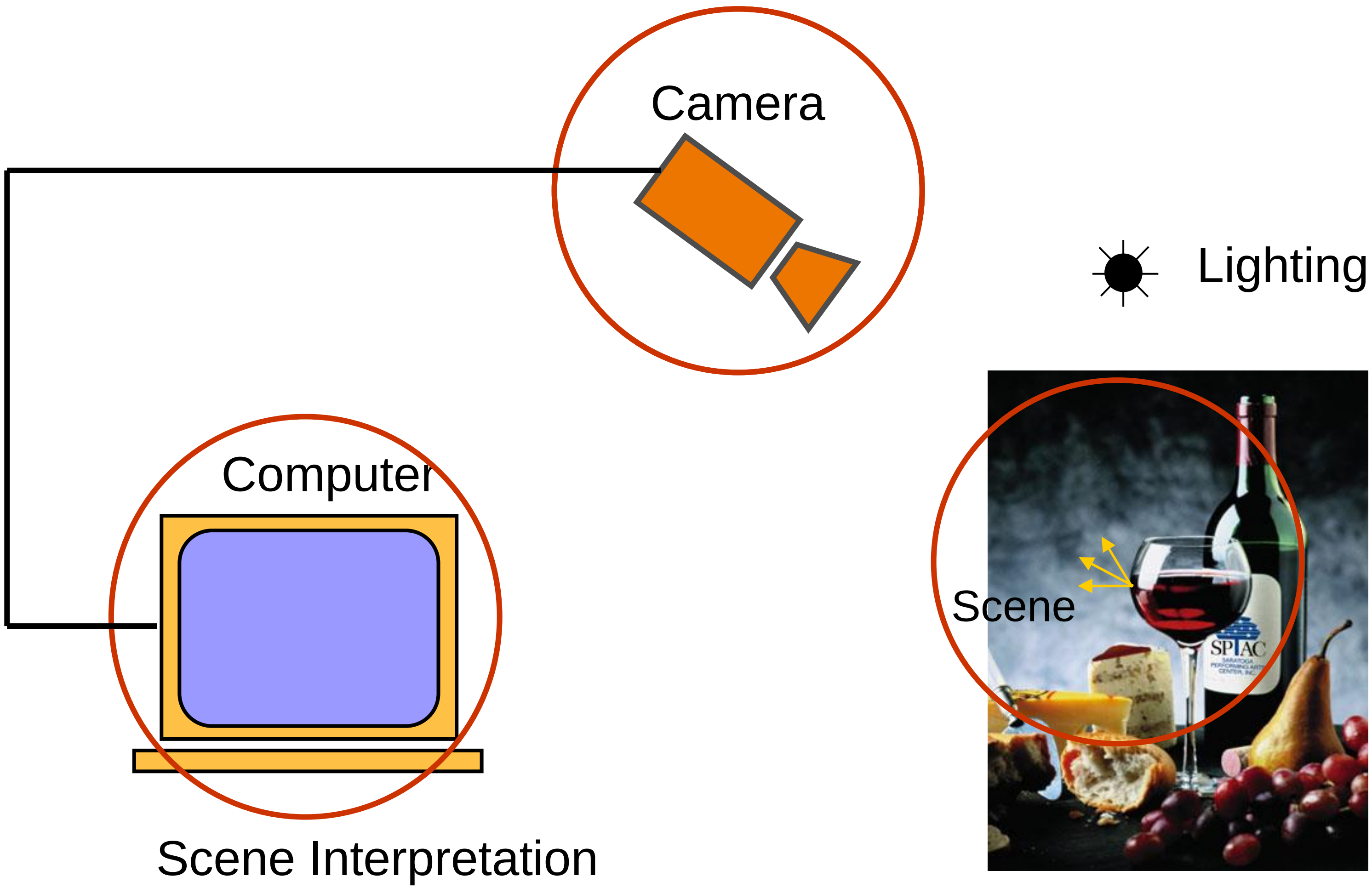
Computer Vision - Review pg 81 – pg 98



VC Students @ FCUP



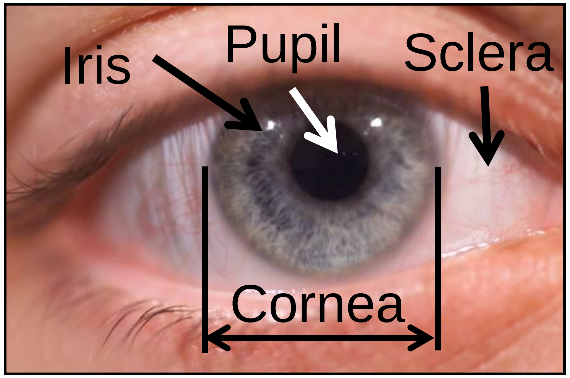
Components of a Computer Vision System

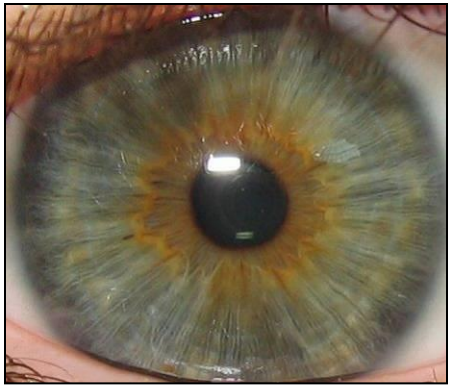


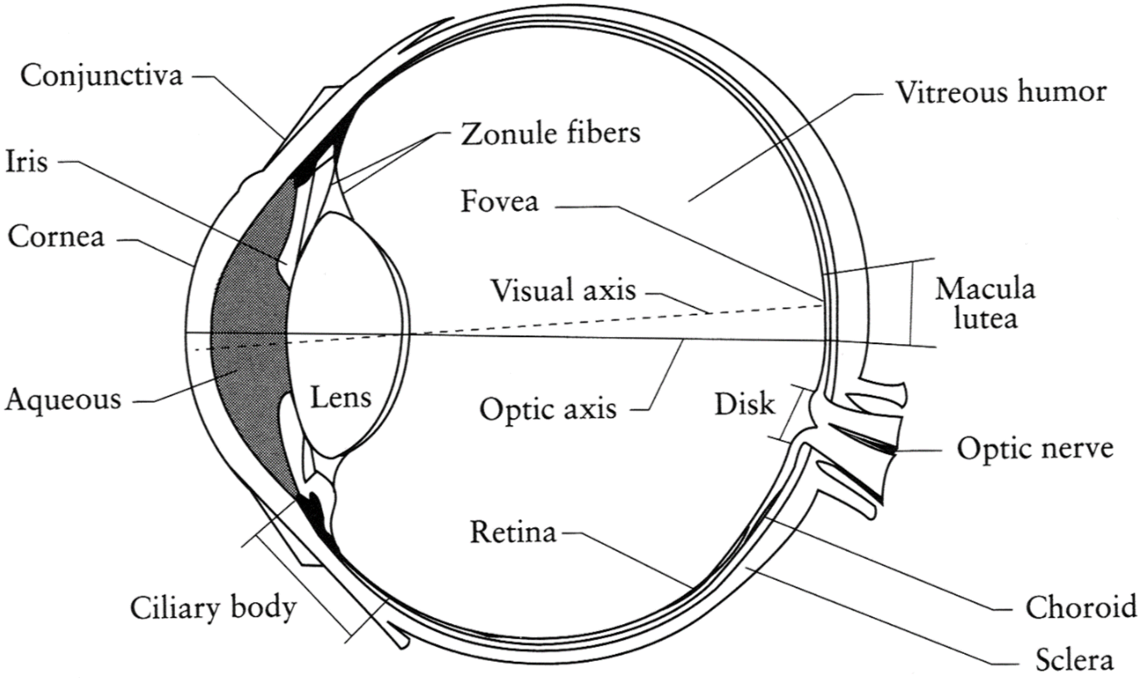
Topic: The Human Visual System

- ‘Computer Vision’?
- The Human Visual System
- Image Capturing Systems

Our Eyes



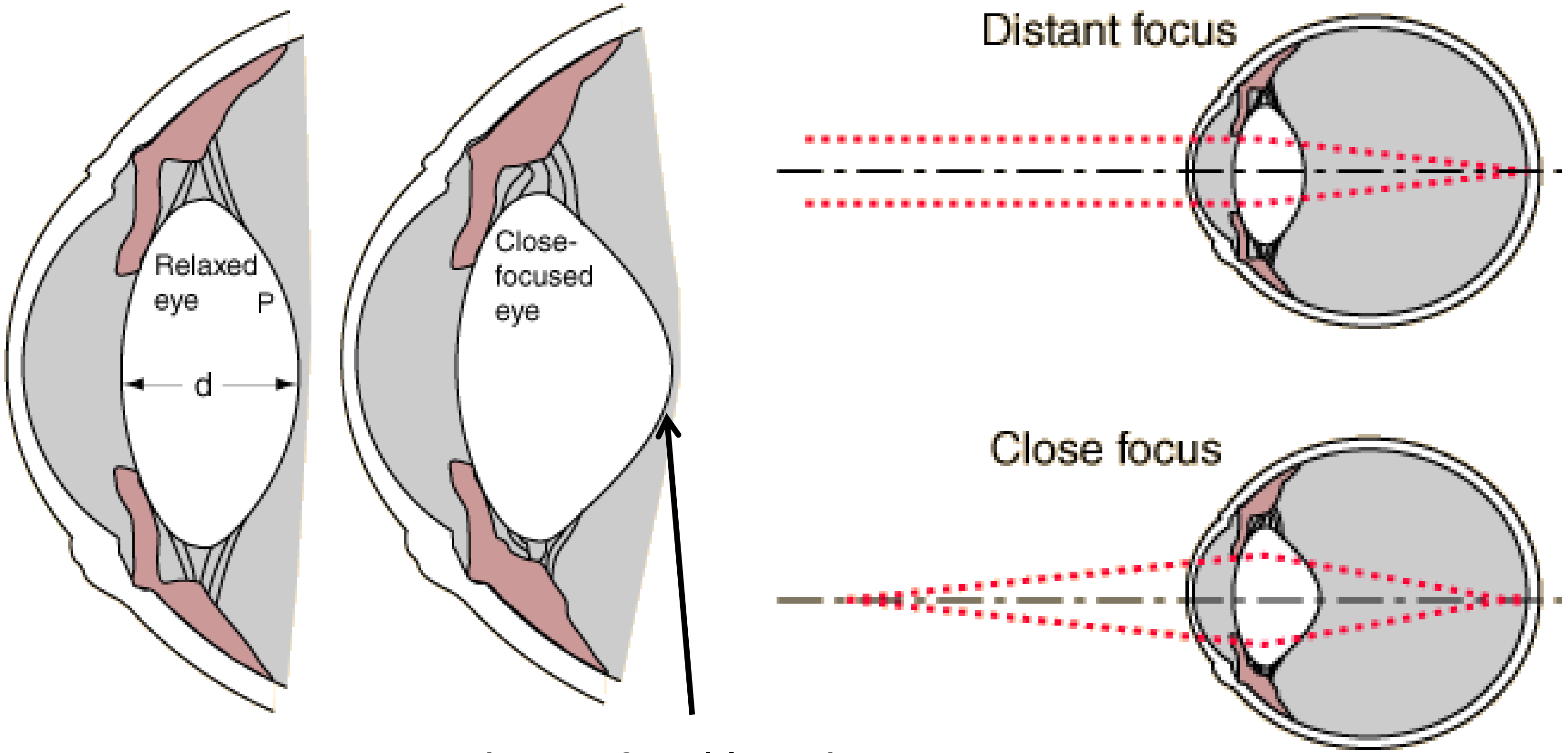




Iris is the diaphragm that changes the aperture (pupil)

Retina is the sensor where the fovea has the highest resolution

Focusing



shorter focal length

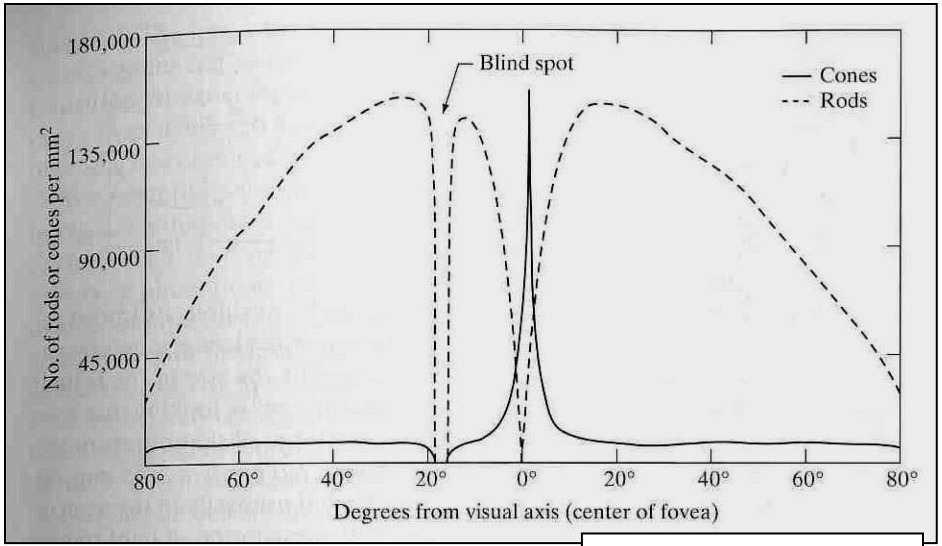
Changes the focal length of the lens

Blind Spot in the Eye

Close your right eye and look directly at the "+"

Colour

- Our retina has:
  - **Cones** – Measure the frequency of light (colour)
    - 6 to 7 millions
    - High-definition
    - Need high luminosity
  - **Rods** – Measure the intensity of light (luminance)
    - 75 to 150 millions
    - Low-definition
    - Function with low luminosity



Gonzalez & Woods

We only see colour in the centre of our retina!

Topic: Image Capturing Systems

- ‘Computer Vision’?
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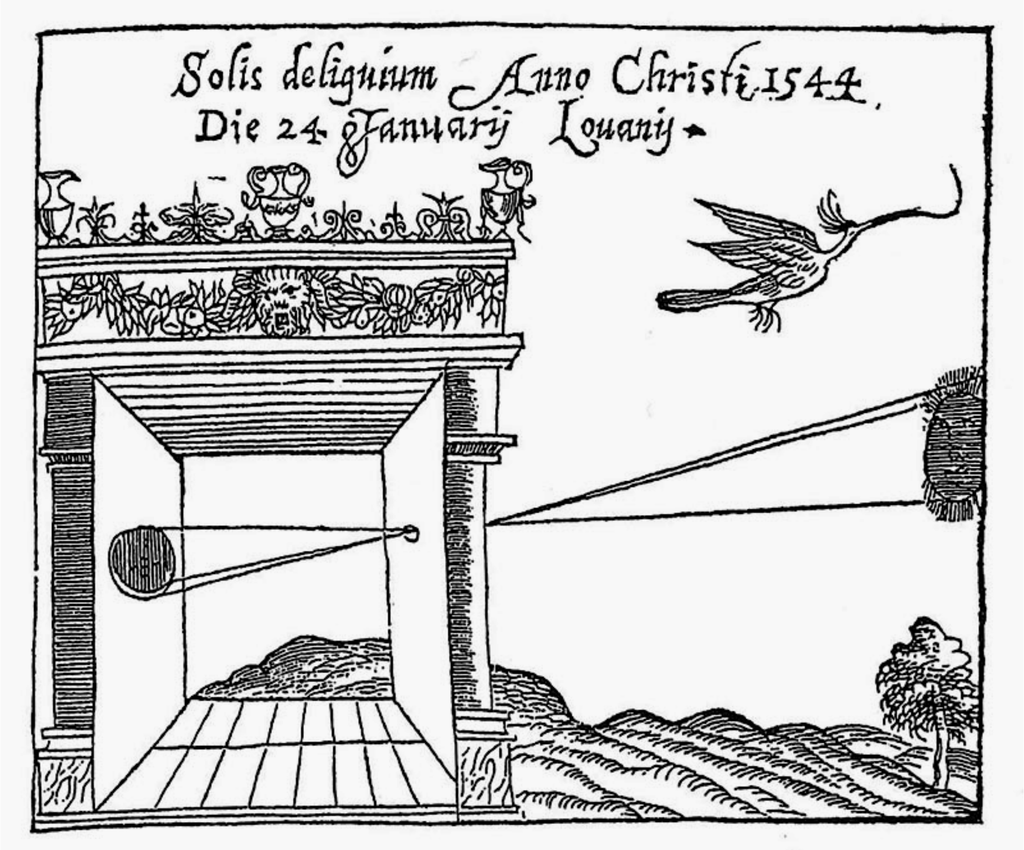
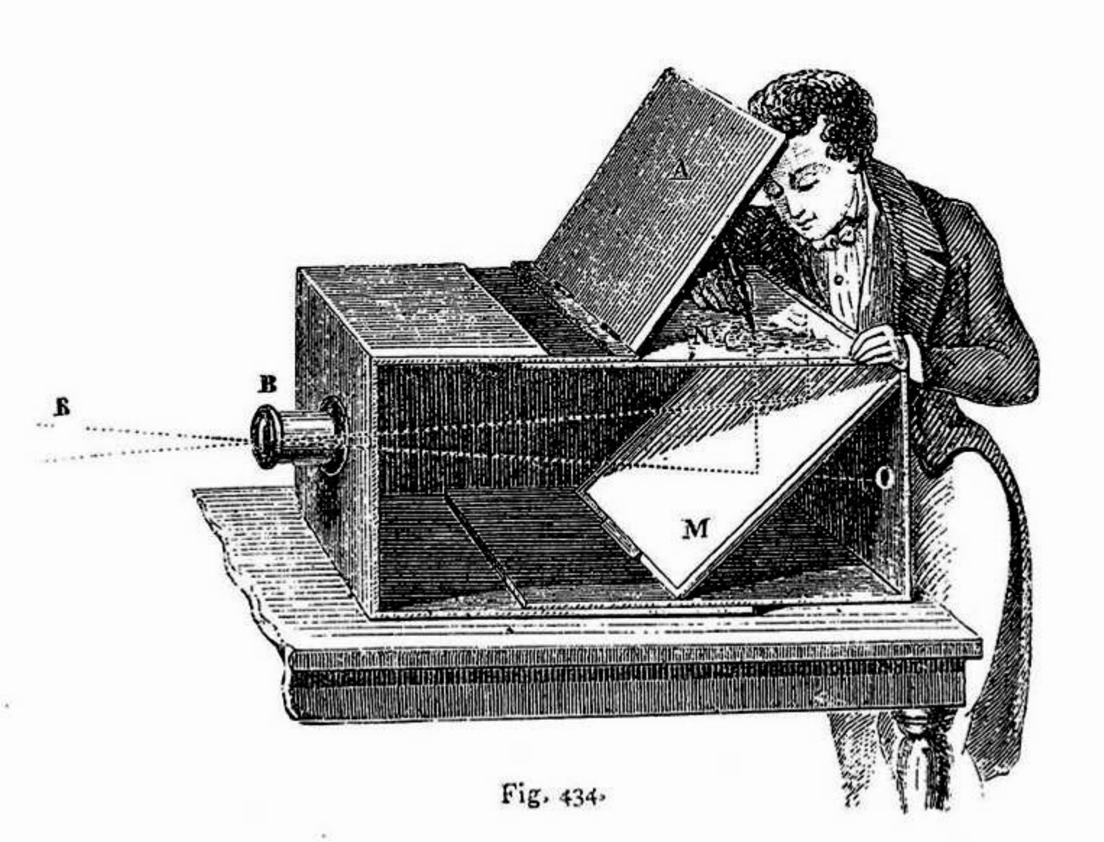
A Brief History of Images



Camera Obscura, Gemma Frisius, 1544

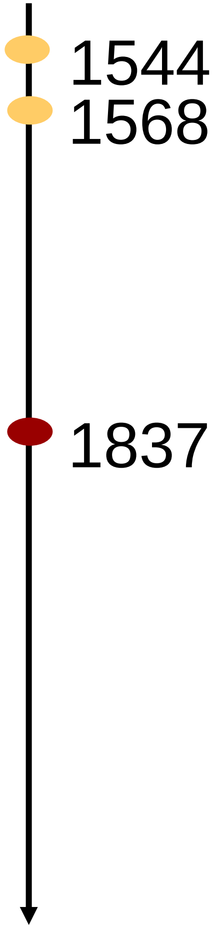
A Brief History of Images



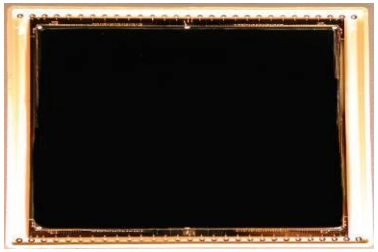
Lens Based Camera Obscura, 1568

A Brief History of Images

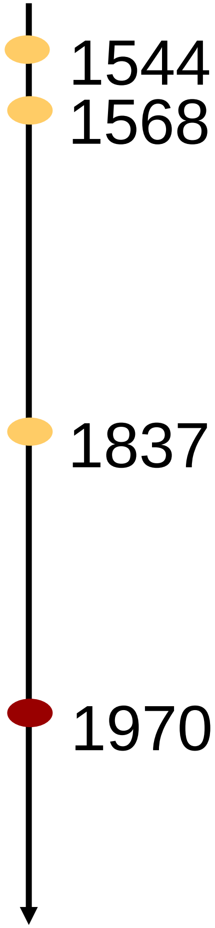
Still Life, Louis Jaques Mande Daguerre, 1837



A Brief History of Images



Silicon Image Detector, 1970

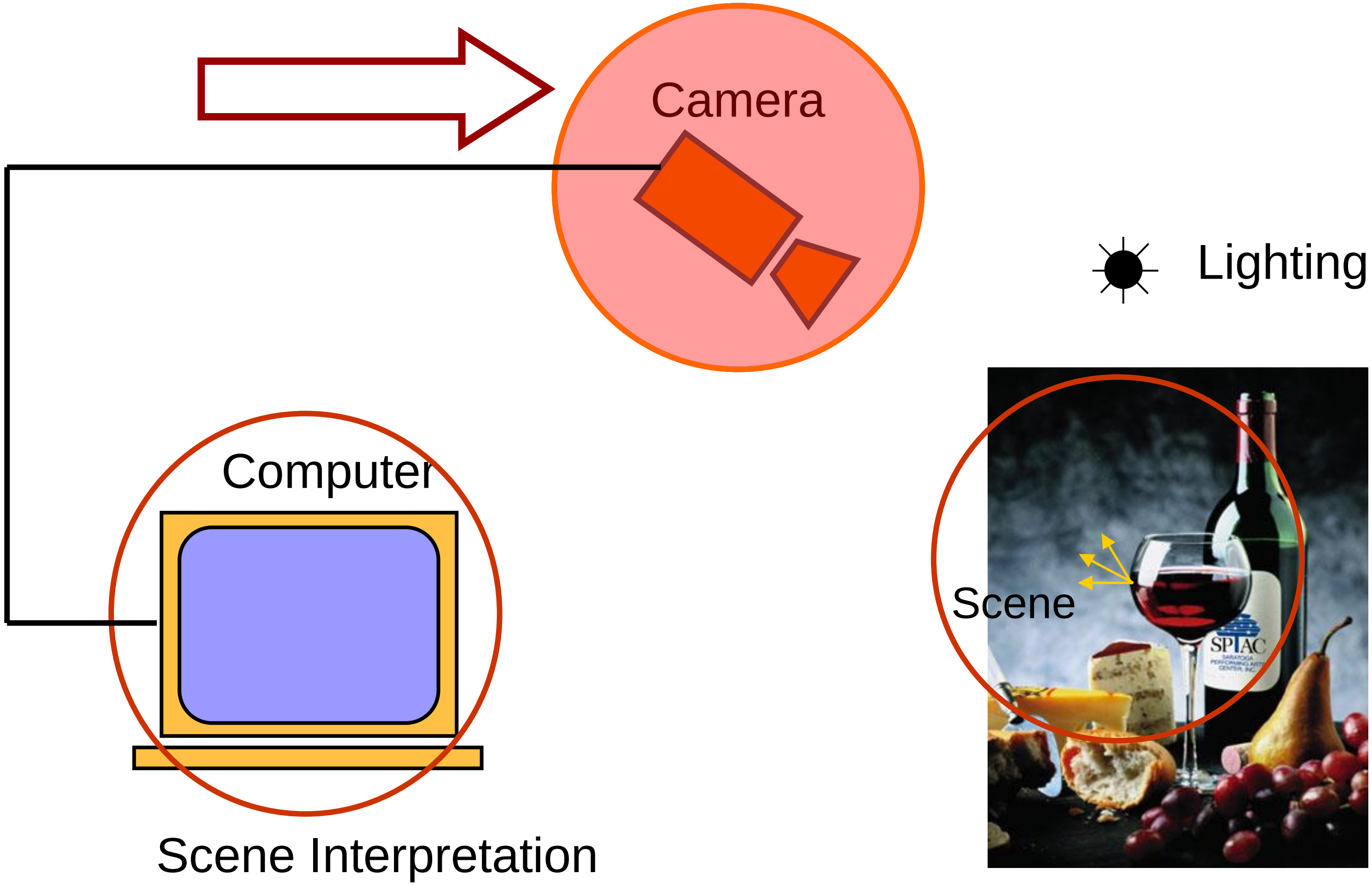


A Brief History of Images

Digital Cameras

1544
1568
1837
1970
1995

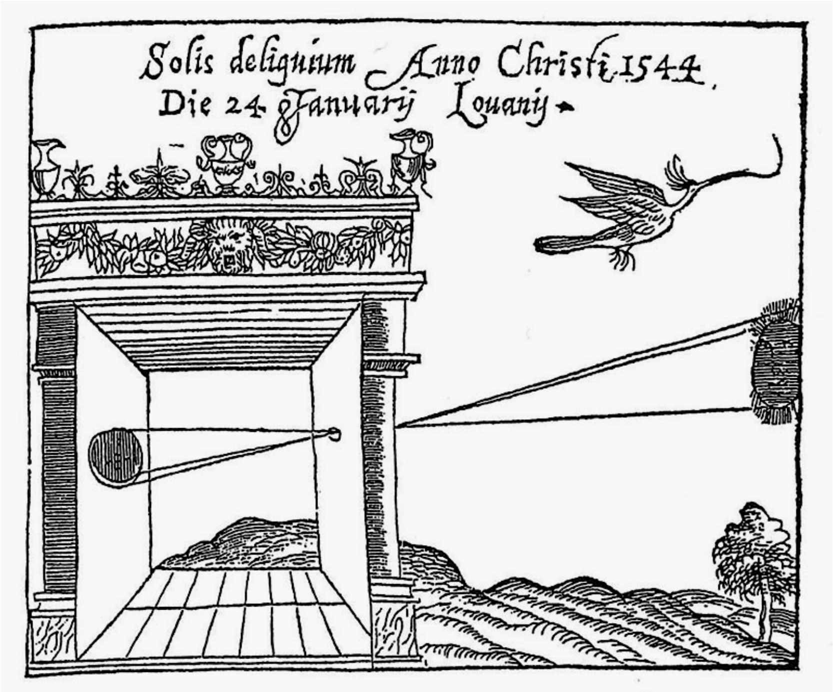
Components of a Computer Vision System



Pinhole Camera

- Basically a pinhole camera is a box, with a tiny hole at one end and film or photographic paper at the other.

- Mathematically: out of all the light rays in the world, choose the set of light rays passing through a point and projecting onto a plane.



Pinhole Photography

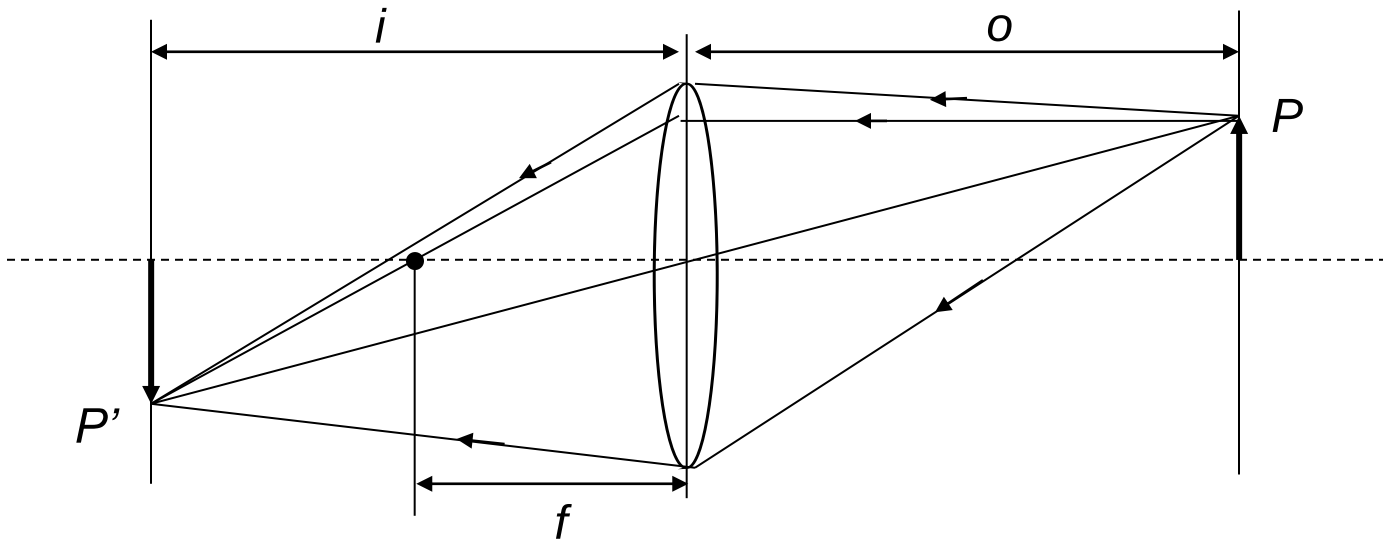
©Charlotte Murray Untitled, 4" x 5" pinhole photograph, 1992

Image Size inversely proportional to Distance

Reading: http://www.pinholeresource.com/

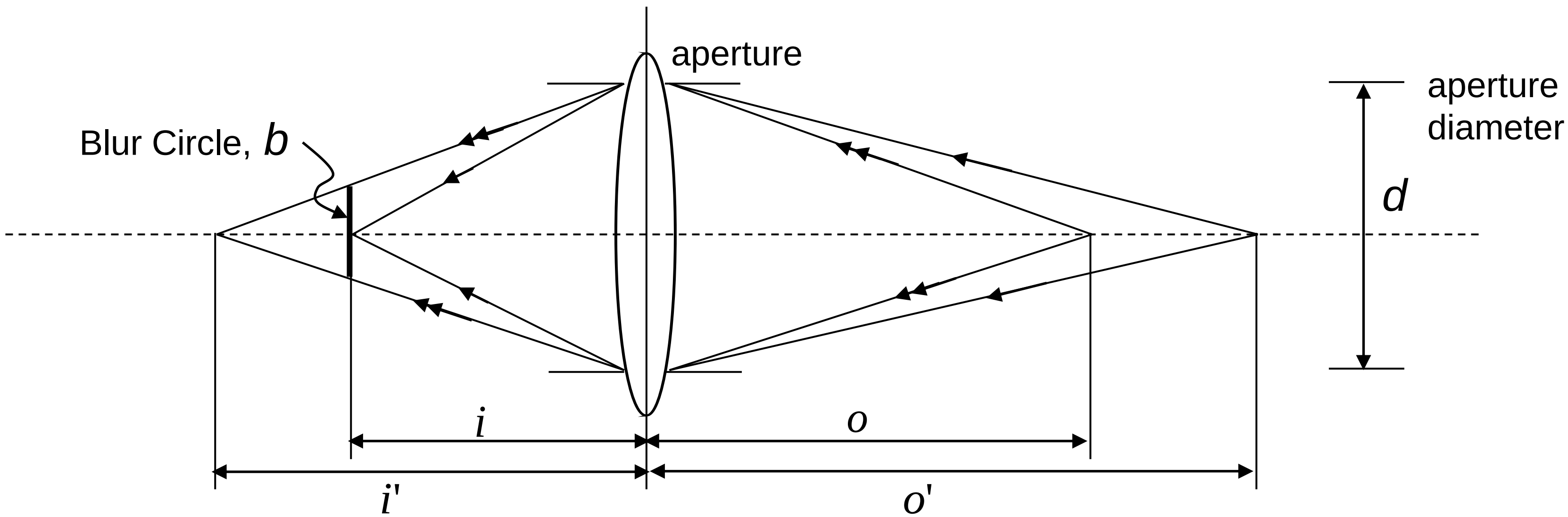
Image Formation using Lenses

- Lenses are used to avoid problems with pinholes.
- Ideal Lens: Same projection as pinhole but gathers more light!



- Gaussian Thin Lens Formula: $$\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$$
- *f* is the focal length of the lens – determines the lens's ability to refract light

Focus and Defocus



- Gaussian Law:

$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$$

$$\frac{1}{i'} + \frac{1}{o'} = \frac{1}{f}$$

$$\Rightarrow \quad (i' - i) = \frac{f}{(o' - f)} \frac{f}{(o - f)} (o - o')$$

- In theory, only one scene plane is in focus

Depth of Field

- Range of object distances over which image is <u>sufficiently well</u> focused
- Range for which *blur circle* is less than the resolution of the sensor

http://images.dpchallenge.com/images_portfolio/27920/print_preview/116336.jpg

Image Sensors

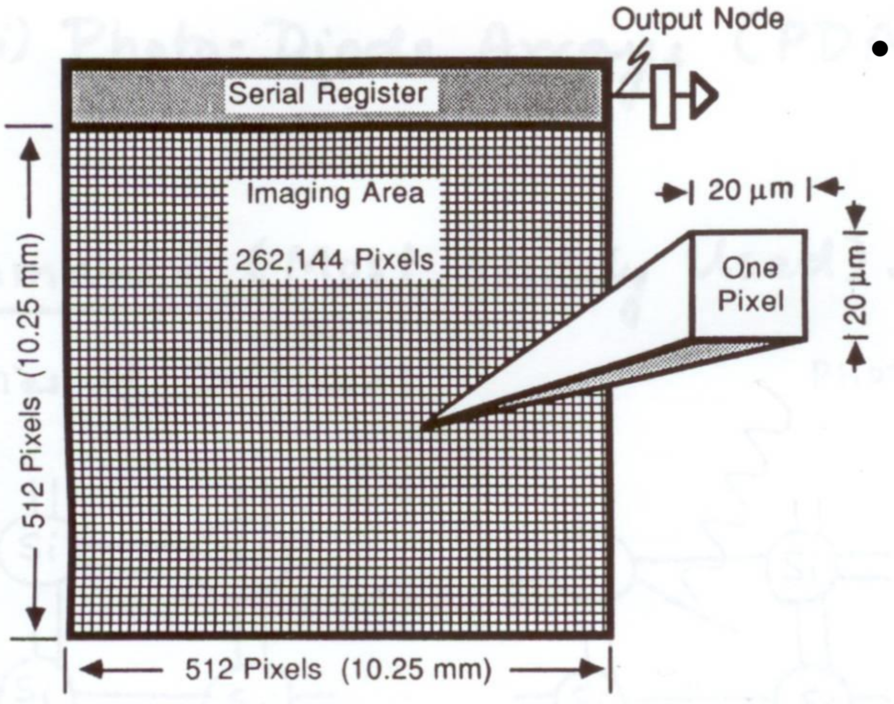
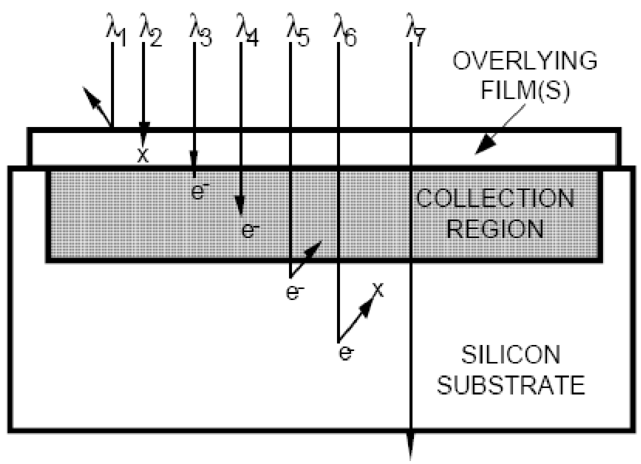


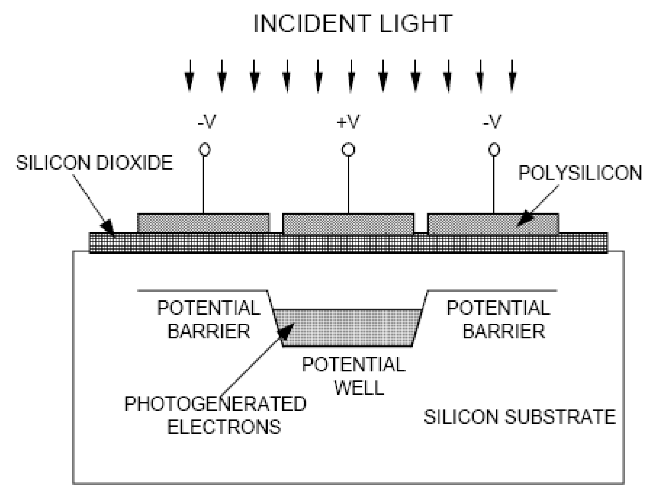
FIG. 4. Typical 512 × 512 CCD.

- Considerations
  - Speed
  - Resolution
  - Signal / Noise Ratio
  - Cost

Image Sensors

- Convert light into an electric charge



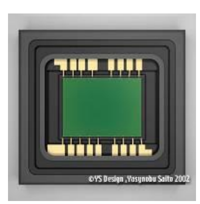


CCD (charge coupled device)

Higher dynamic range

High uniformity

Lower noise

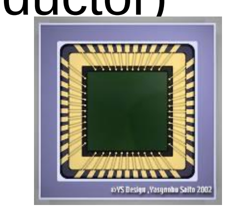


CMOS (complementary metal Oxide semiconductor)

Lower voltage

Higher speed

Lower system complexity



Resources

- Szeliski, “Computer Vision: Algorithms and Applications”, Springer, 2022
  - Chapter 1 – “Introduction”
  - Chapter 2 – “Image Formation”