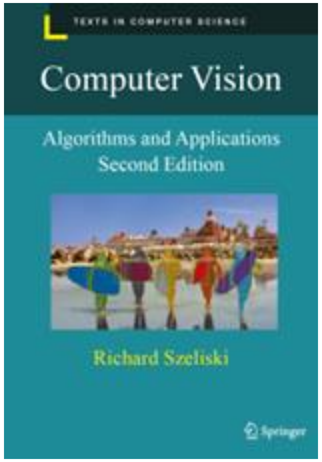
Image Processing & Computer Vision

501837-3 and 501838-3

Dr. Mohammed Alghamdi

Course Materials

- **Main textbook:** Computer Vision: Algorithms and Applications, 2nd edition by Richard Szeliski. can be downloaded for free here.



- **Other materials**—including videos, code, research papers, book chapters, and lecture notes—will be provided for each topic as we proceed.

Course Assessments

- Practical Lab: 10%
- Quizzes: 10% - We will have 3 quizzes
- Assignments or projects: 20% - We will have 2
- Midterm exam: 20% - in week 8
- Final exam: 40%

Course Policy Description

Students are expected to attend, and be on time, for every class. This demonstrates professionalism and consideration for your fellow students and your Instructor. Students who miss class and/or are late for class may experience an impact on their grade by missing around 5%.

Students are expected to turn in all assigned materials in a timely manner. All late assignments will be penalized by deducting -2 from the final mark for everyday being late.

Course Policy Description

Students are expected to demonstrate professionalism and courtesy by either silencing or turning off all cell phones and/or other alarm or audible indicator devices.

Absence of more than 20% of lectures or Lab will lead to a FORBIDDEN status.

All communications with the prof-in-charge should be through University Email. As well, All correspondance emails should be written professionally. Any behavior misconduct will not be tolerated.

An original official excuse should be approved by the department chair and submitted to the prof-in-charge.

Course Policy Description

You are encouraged to collaborate and study together, but each student must submit their own work. Identical assignments will result in a zero for all involved, and copying from others, including past students or online sources, will also receive a zero.

The Instructors reserve the right to add to, and/or modify any of the above policies as needed to maintain an appropriate and effective educational atmosphere in the classroom and the laboratory. In the case that this occurs, all students will be notified in advance of implementation of the new and/or modified policy

What is computer vision?

automatically identifying objects in images or video

Extracting latent information from visual data

technology that interprets light stimuli

computers seeing/learning things that the programmers who made them didn't tell them

Mimicking the human perception of sight with computational algorithms

train computers to understand the visual world

The study of understanding the world through visual perception

a simulation of eyes

Converting images to more understandable things like distance, edges, directions etc.

Computer getting information out of images/video

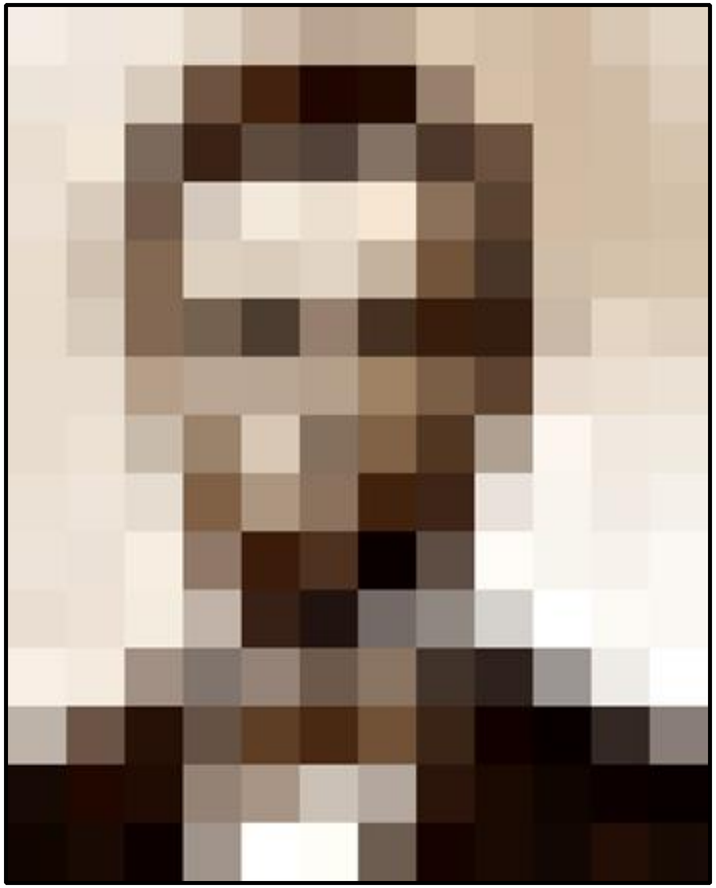
Giving the computer "eyes" to see and identify as humans would.

Teach computer to interpret and understand our world through images.

Every picture tells a story

Goal of computer vision is to write computer programs that can interpret images

What do computers see?



slide by Larry Zitnick

Can computers match (or beat) human vision?

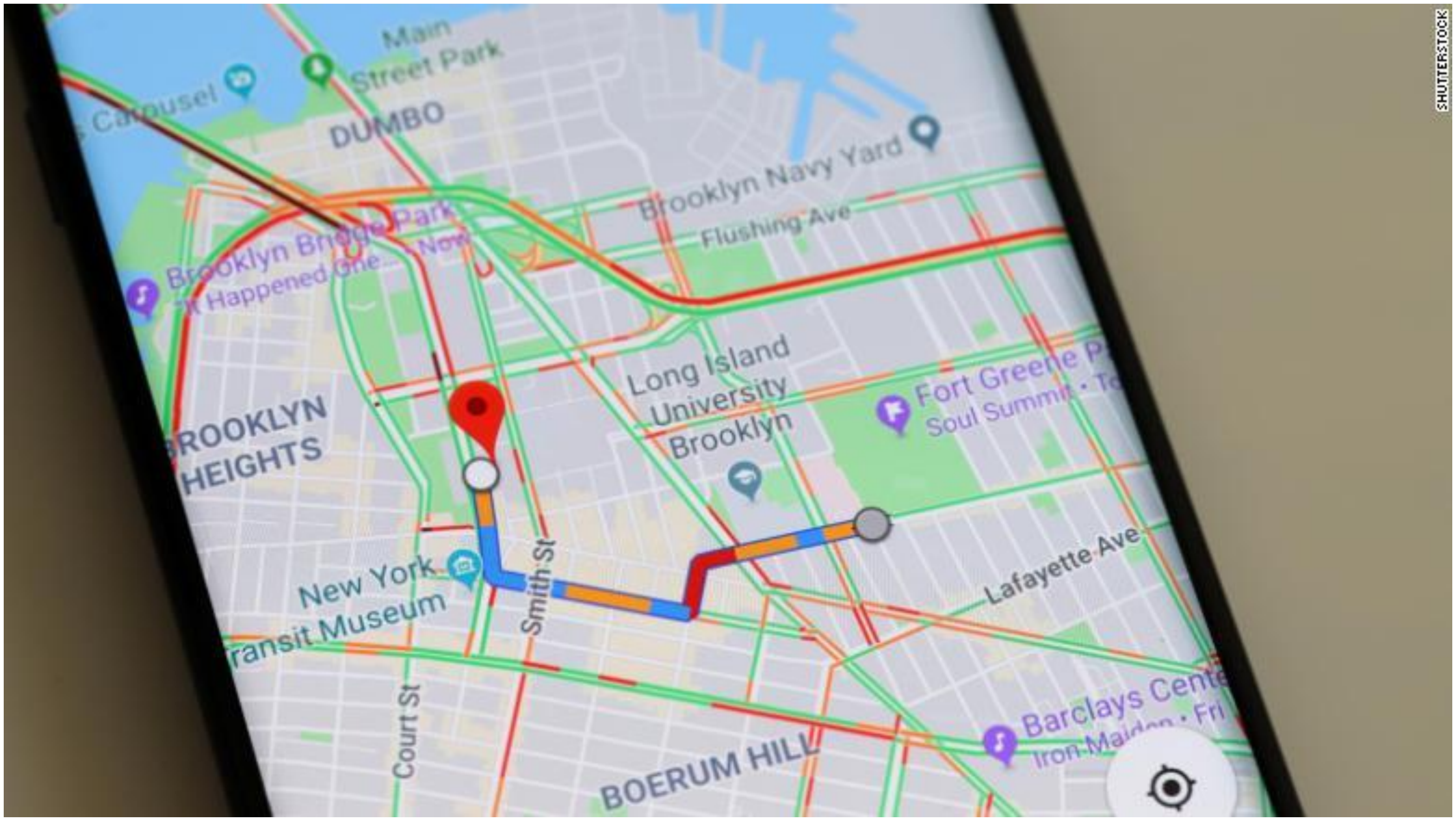
Yes and no (but mostly no!)

- humans are much better at “hard” things
- computers can be better at “easy” things

3D Maps

Apple Maps

2D Maps



Google Maps

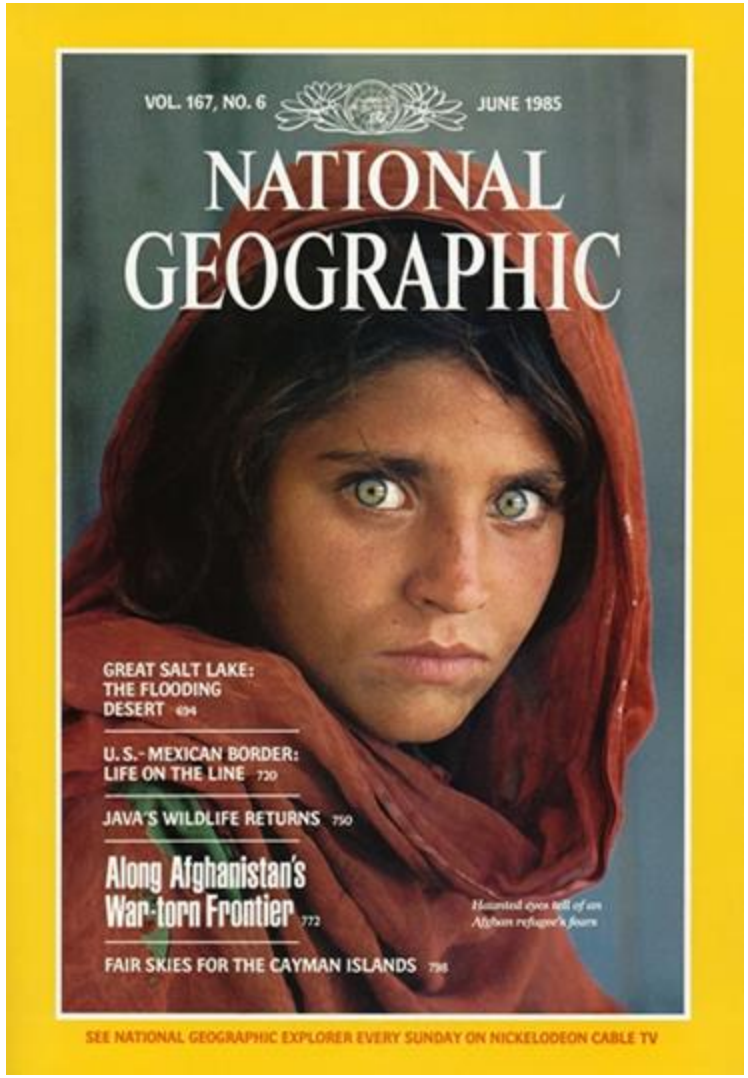
3D photos

3D Photos on Facebook

Estimate depth from photo to create animation

https://ai.facebook.com/blog/-powered-by-ai-turning-any-2d-photo-into-3d-using-convolutional-neural-nets/

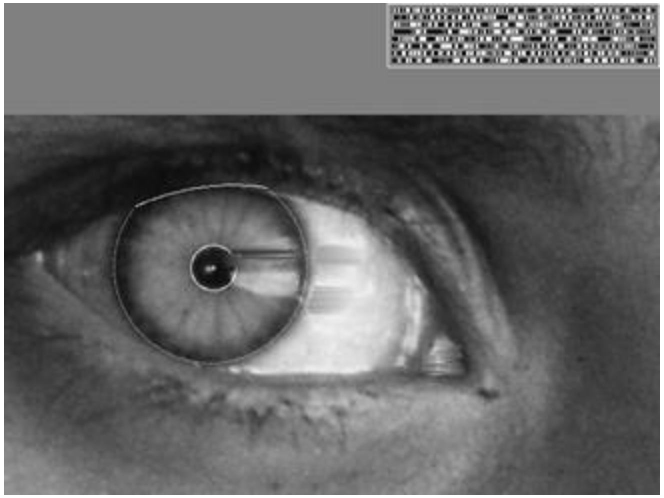
Face recognition

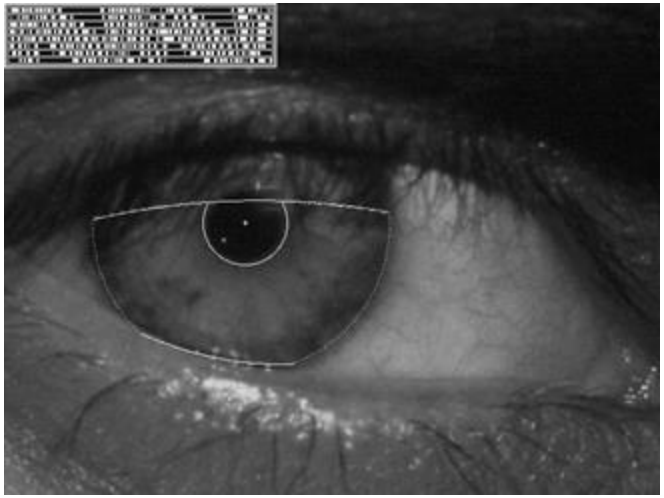


Who is she?

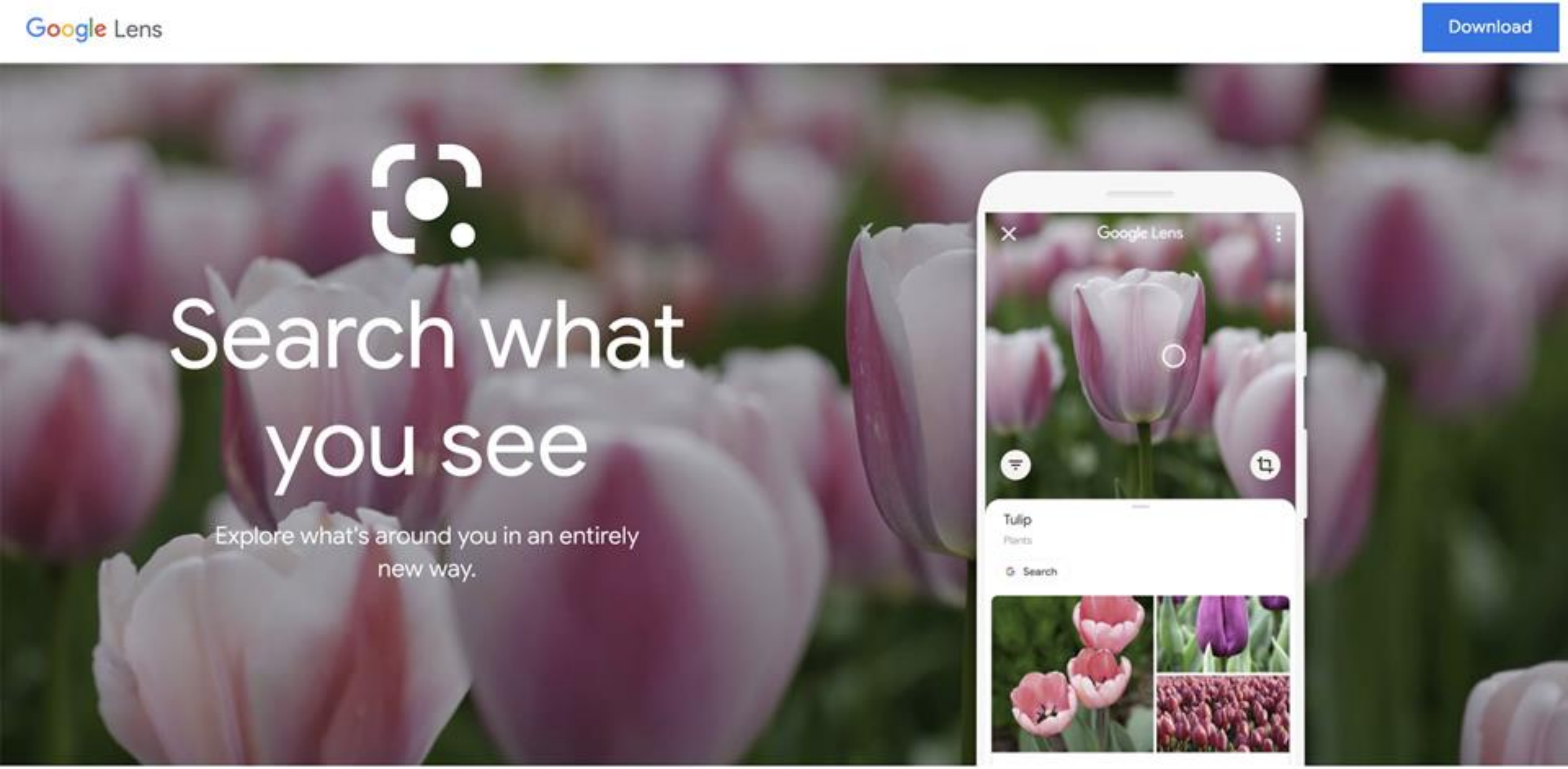
Vision-based biometrics

"*How the Afghan Girl was Identified by Her Iris Patterns*" Read the story





Object recognition



Special effects: shape capture

The Matrix movies, ESC Entertainment, XYZRGB, NRC

Sports

Sportvision first down line
Nice explanation on www.howstuffworks.com

Games

Microsoft's XBox Kinect

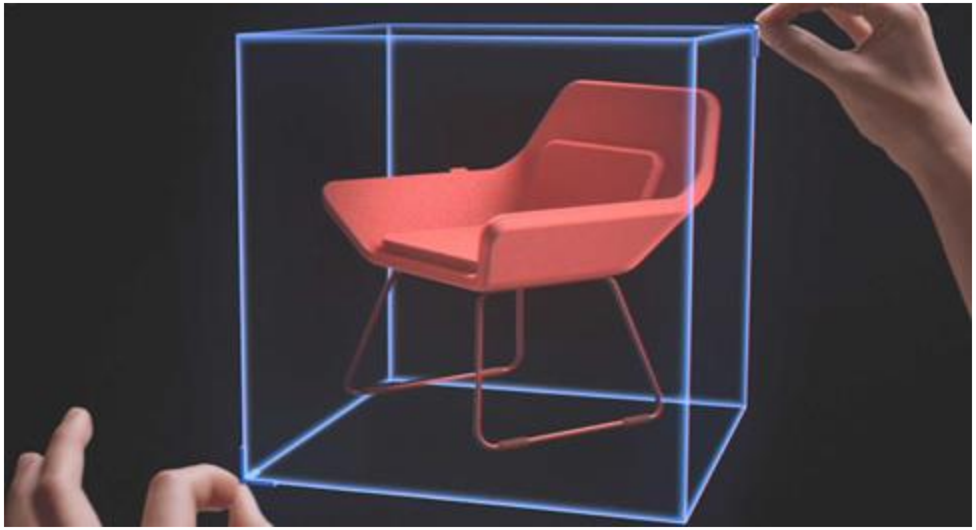
Virtual Reality

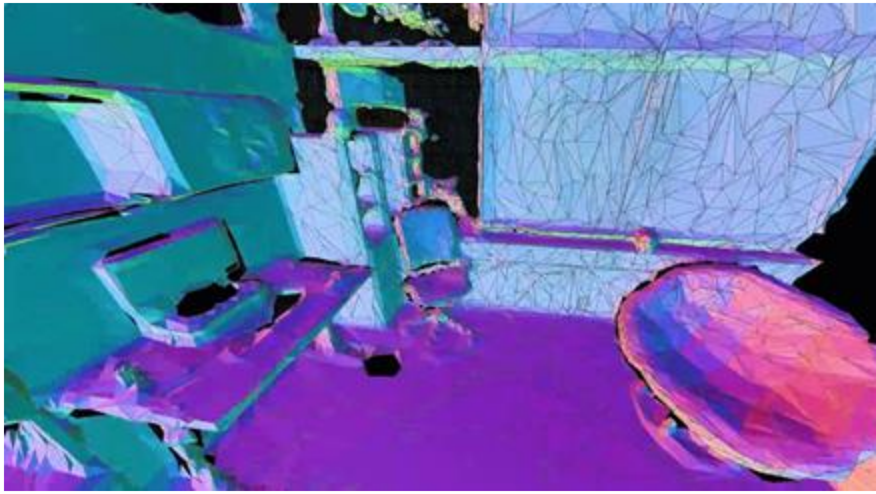
Oculus Quest, Beat Saber

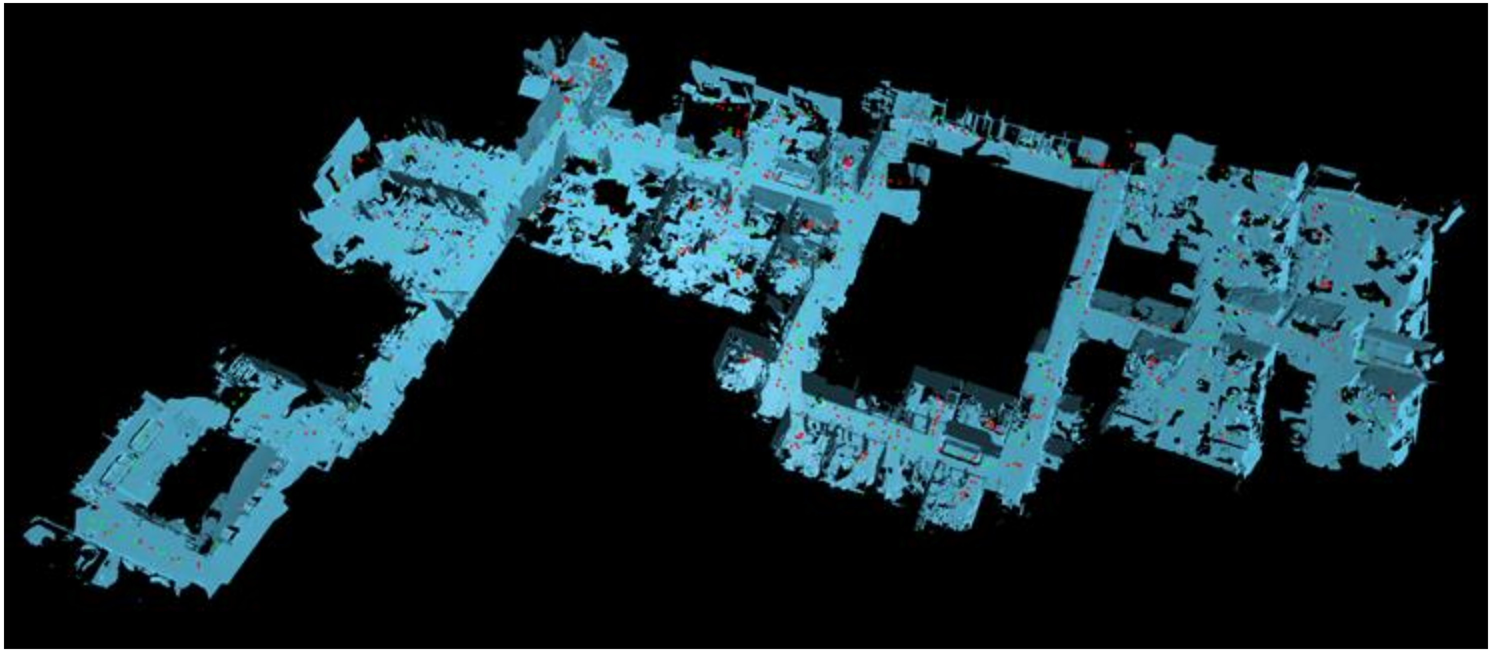
Augmented Reality

Microsoft Hololens 2

Augmented Reality

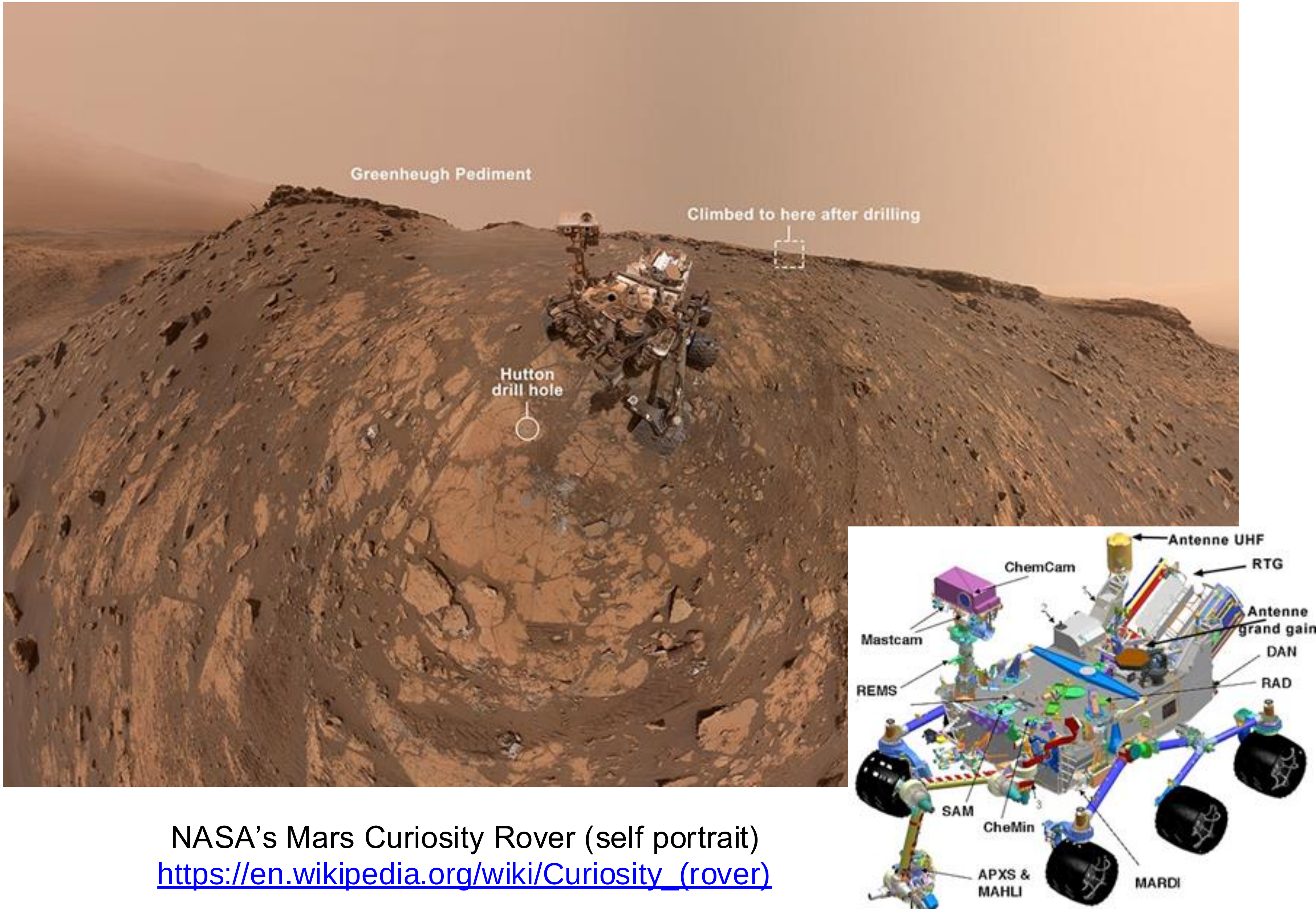






Body Tracking

Robotics



NASA's Mars Curiosity Rover (self portrait)
https://en.wikipedia.org/wiki/Curiosity_(rover)

Smart cars

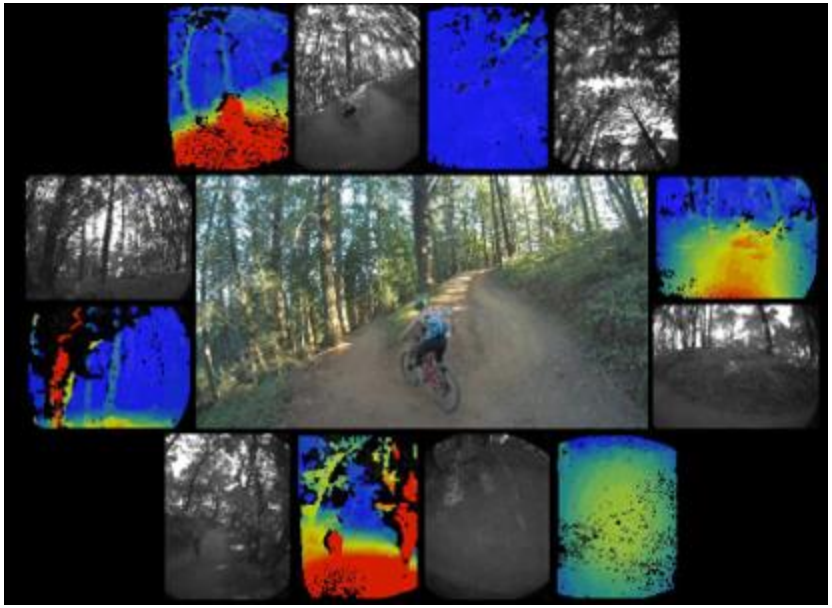
Slide content courtesy of Amnon Shashua

[Mobileye]

- Vision systems currently in high-end BMW, GM, Volvo models

Self-driving cars

Drones

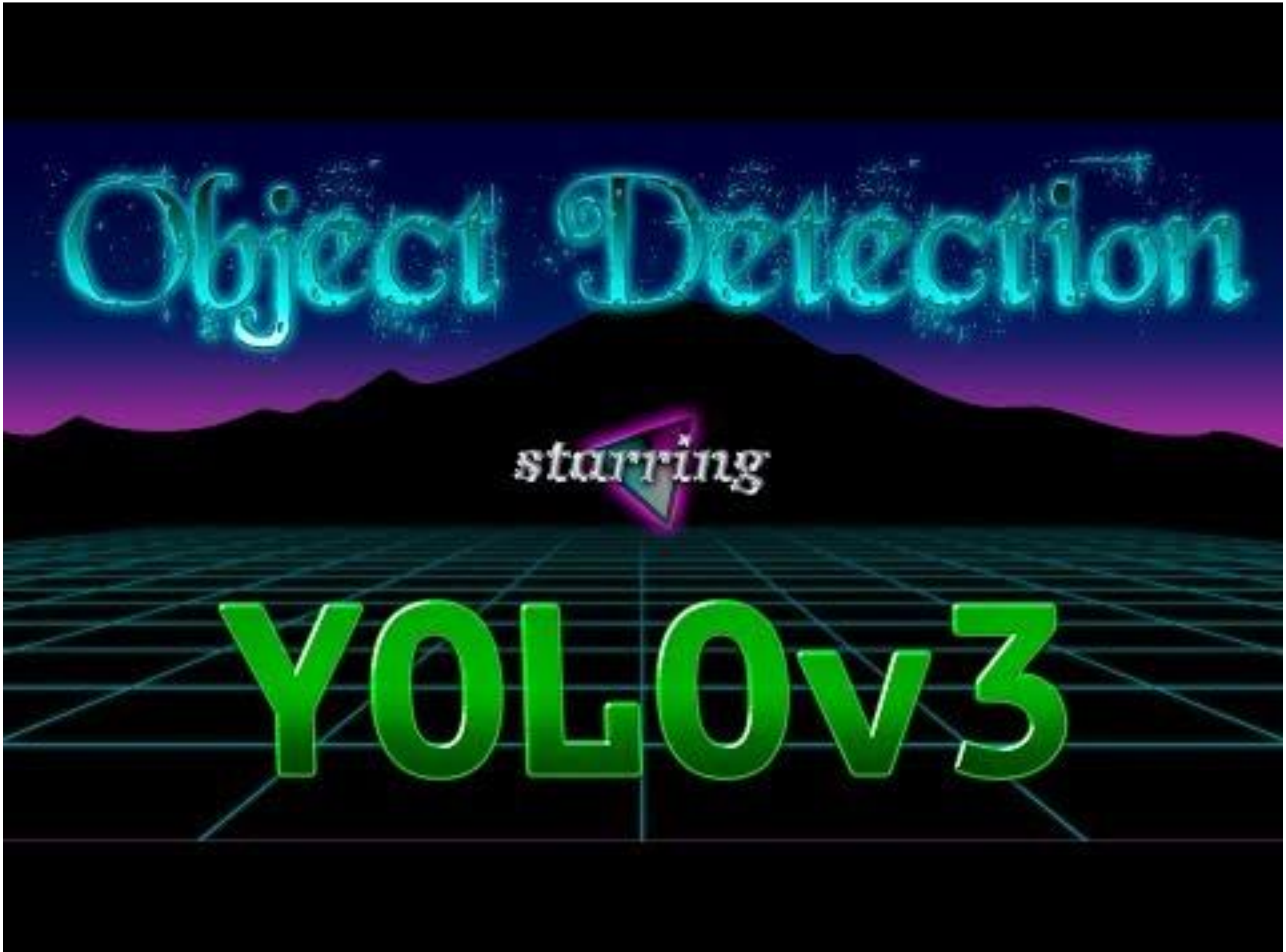


https://www.skydio.com/

Research: Timelapse

Research: Neural Rendering

Research: Yolo



Research: StyleGan

Filtering

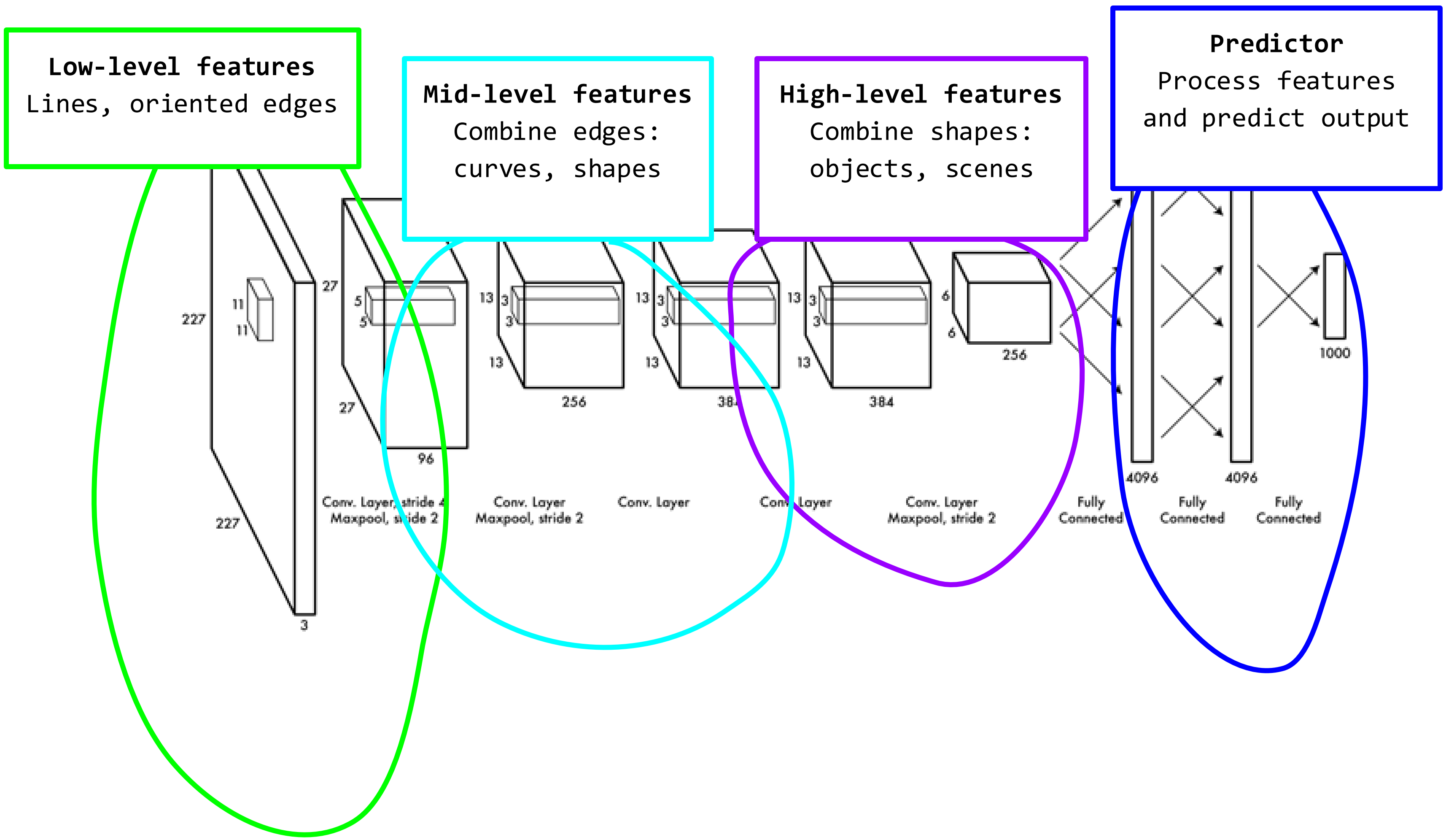
(a) Original image

(b) Average filtering

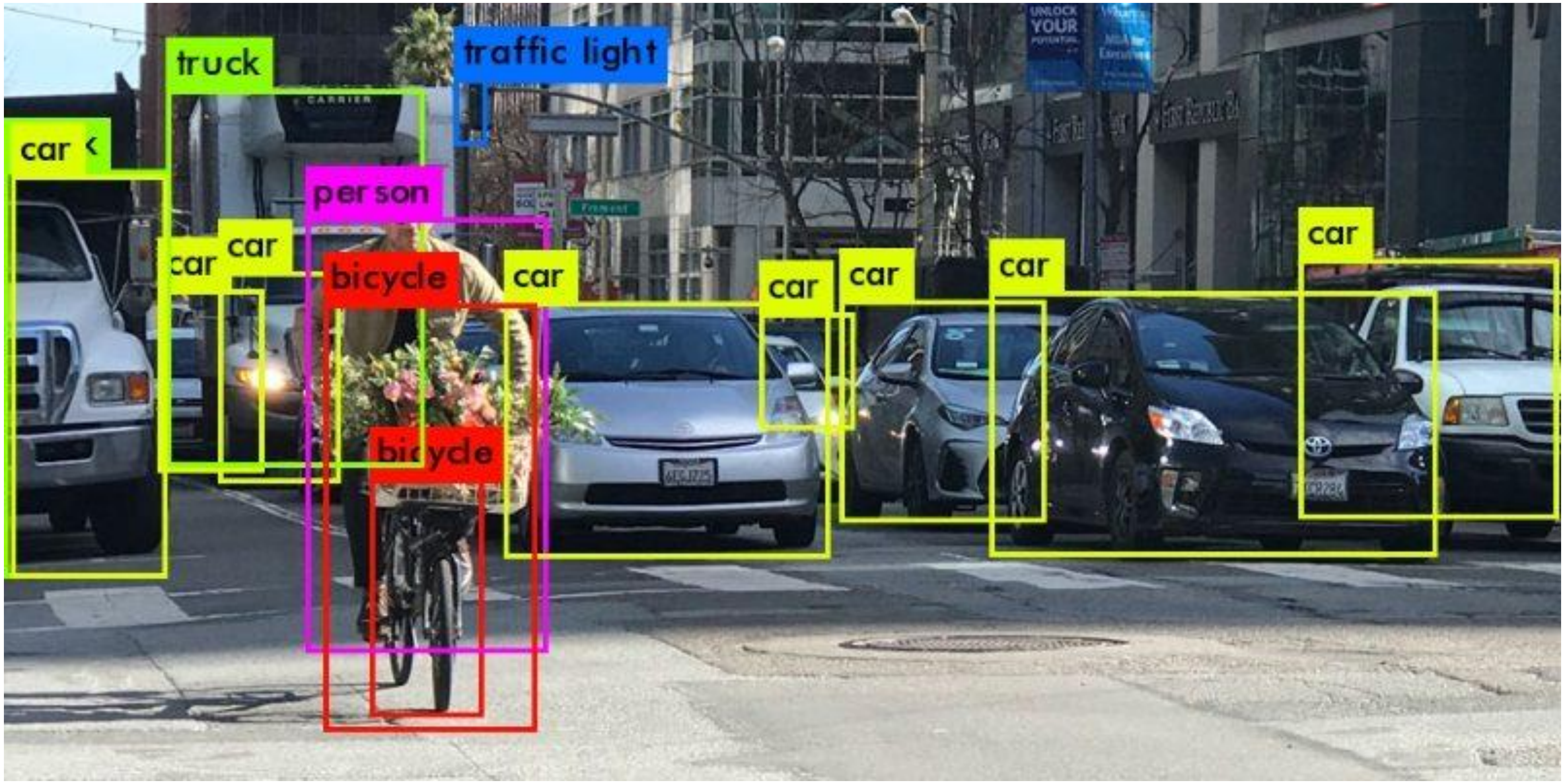
(c) Using a 9×9 filter

(d) Using a 25×25 filter

Machine Learning for Computer Vision



Object Detection

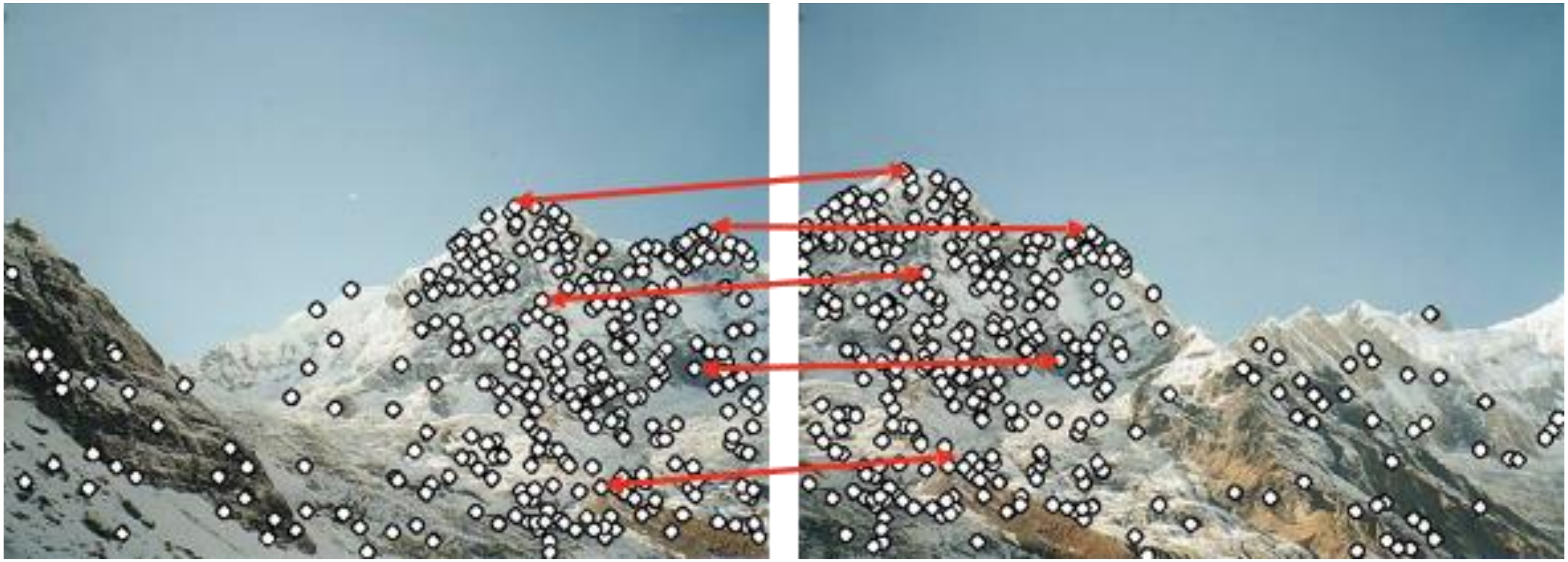


https://heartbeat.fritz.ai/introduction-to-basic-object-detection-algorithms-b77295a95a63

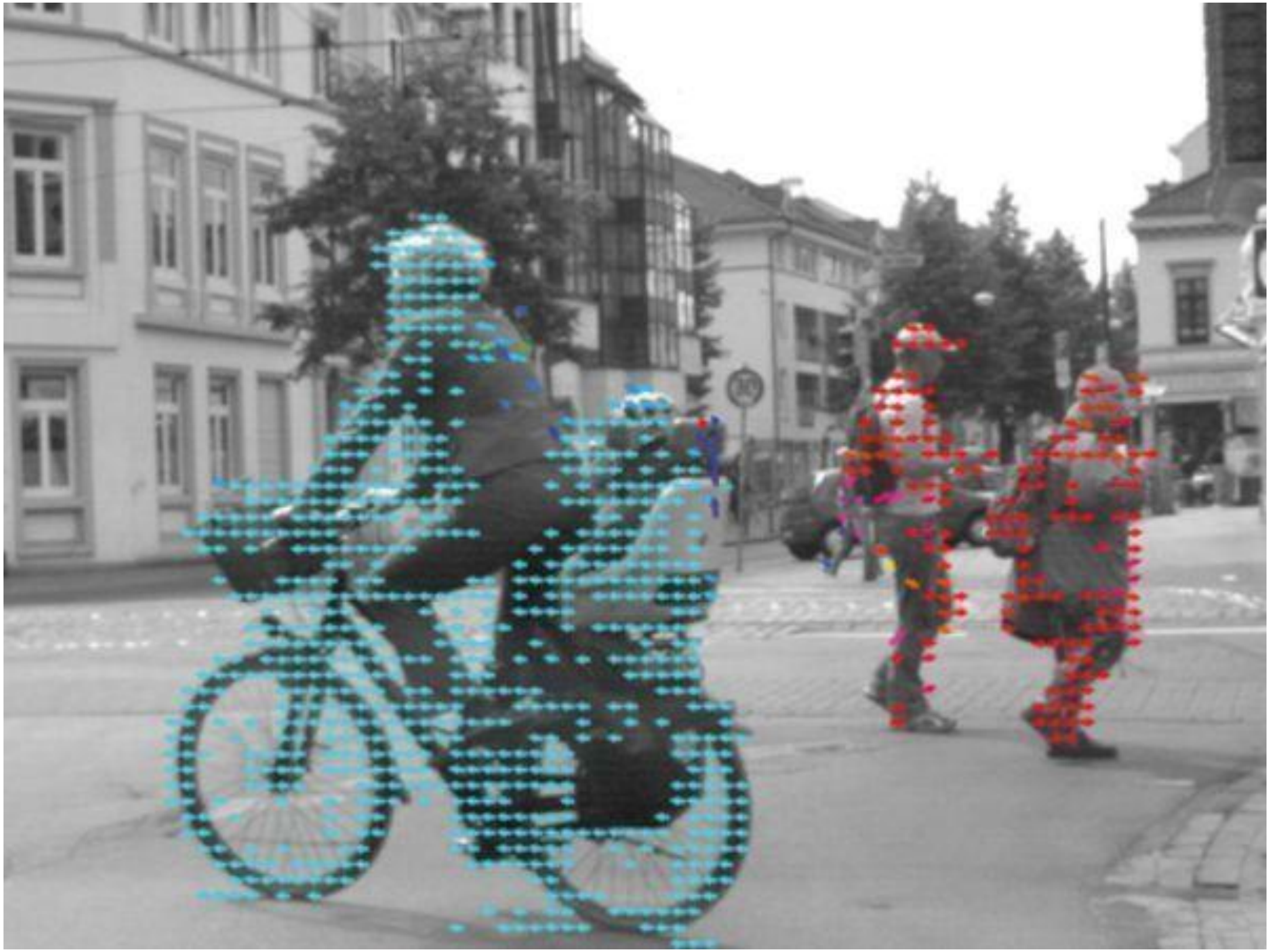
Segmentation

https://gts.ai/how-do-we-solve-the-challenges-faced-due-to-semantic-segmentation/

Features



Optical Flow



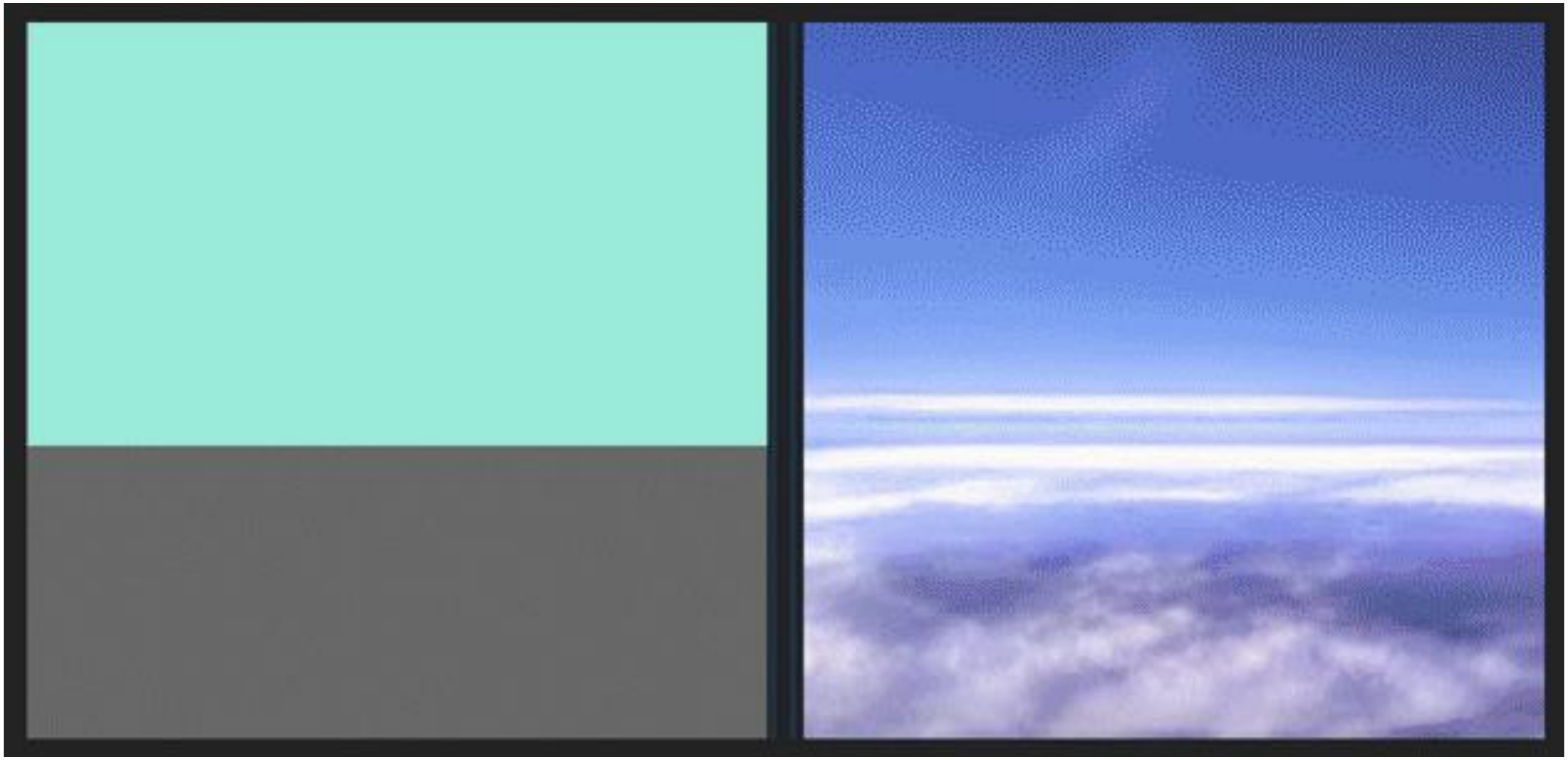
https://www.commonlounge.com/discussion/1c2eaa85265f47a3a0a8ff1ac5fbce51

3D Mapping (SLAM and SfM)

Computational Photography

https://ai.googleblog.com/2017/10/portrait-mode-on-pixel-2-and-pixel-2-xl.html

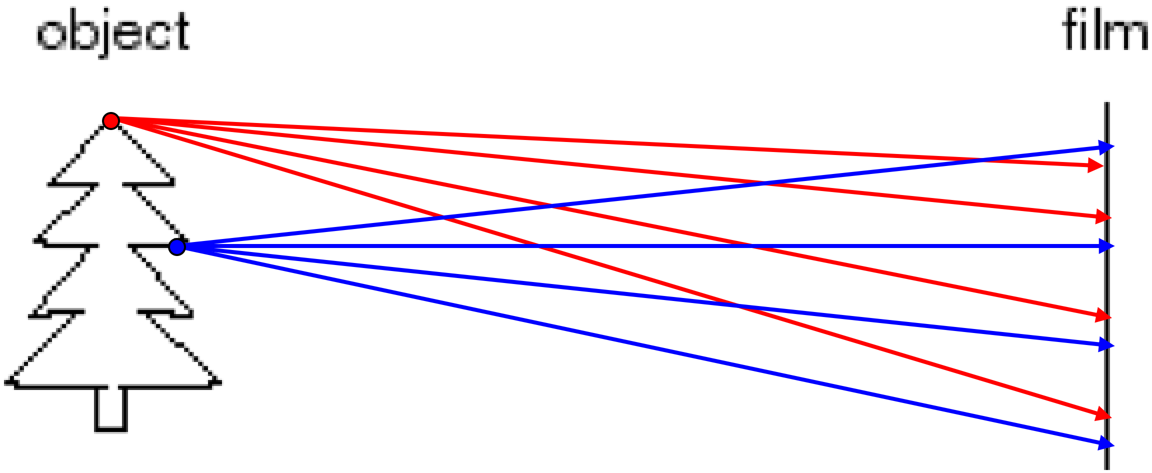
Generative Adversarial Networks (GANs)



GauGAN, NVidia https://arxiv.org/abs/1903.07291

Hololens

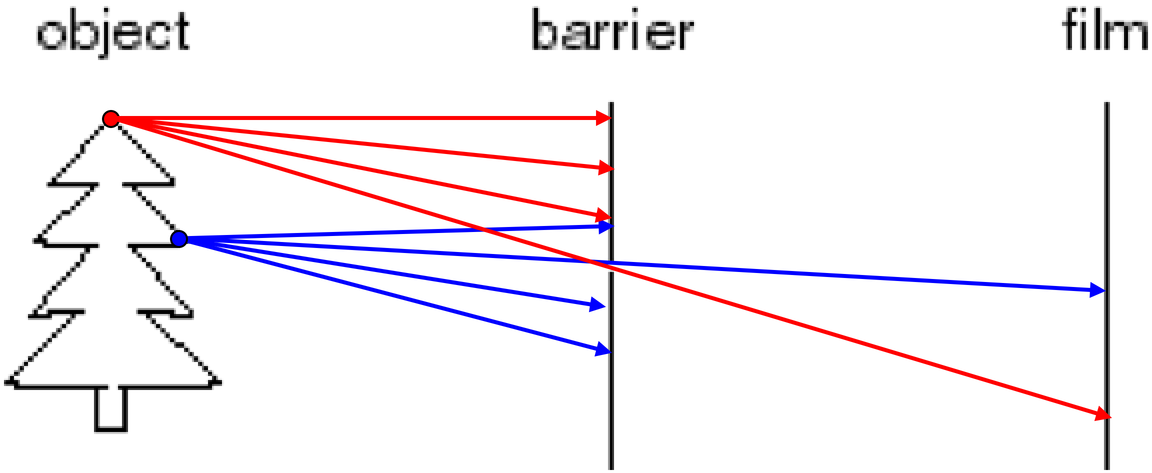
Image formation



Let’s design a camera

- Idea 1: put a piece of film in front of an object
- Do we get a reasonable image?

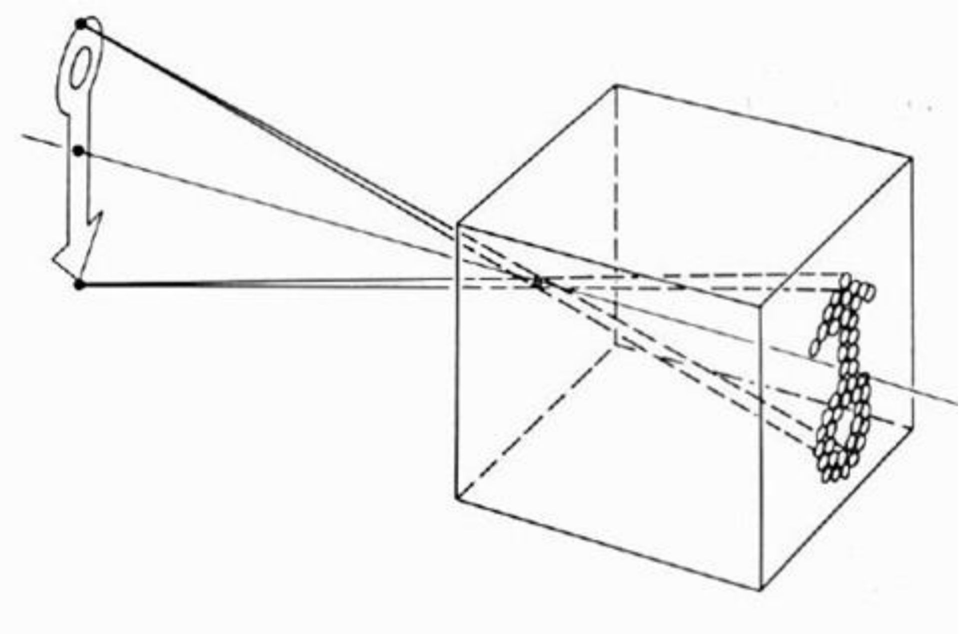
Pinhole camera



Add a barrier to block off most of the rays

- This reduces blurring
- The opening known as the aperture
- How does this transform the image?

Pinhole Camera (*Camera Obscura*)



Pinhole cameras everywhere

Sun “shadows” during a solar eclipse

by Henrik von Wendt http://www.flickr.com/photos/hvw/2724969199/

Pinhole cameras everywhere

Sun “shadows” during a solar eclipse
http://www.flickr.com/photos/73860948@N08/6678331997/

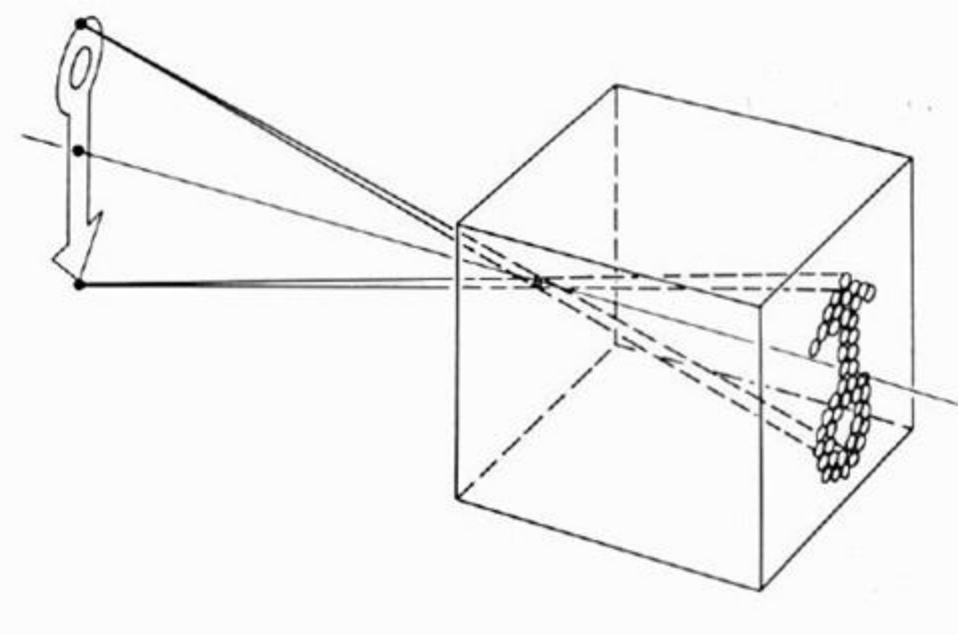
Pinhole cameras everywhere

Tree shadow during a solar eclipse

photo credit: Nils van der Burg

http://www.physicstogo.org/index.cfm

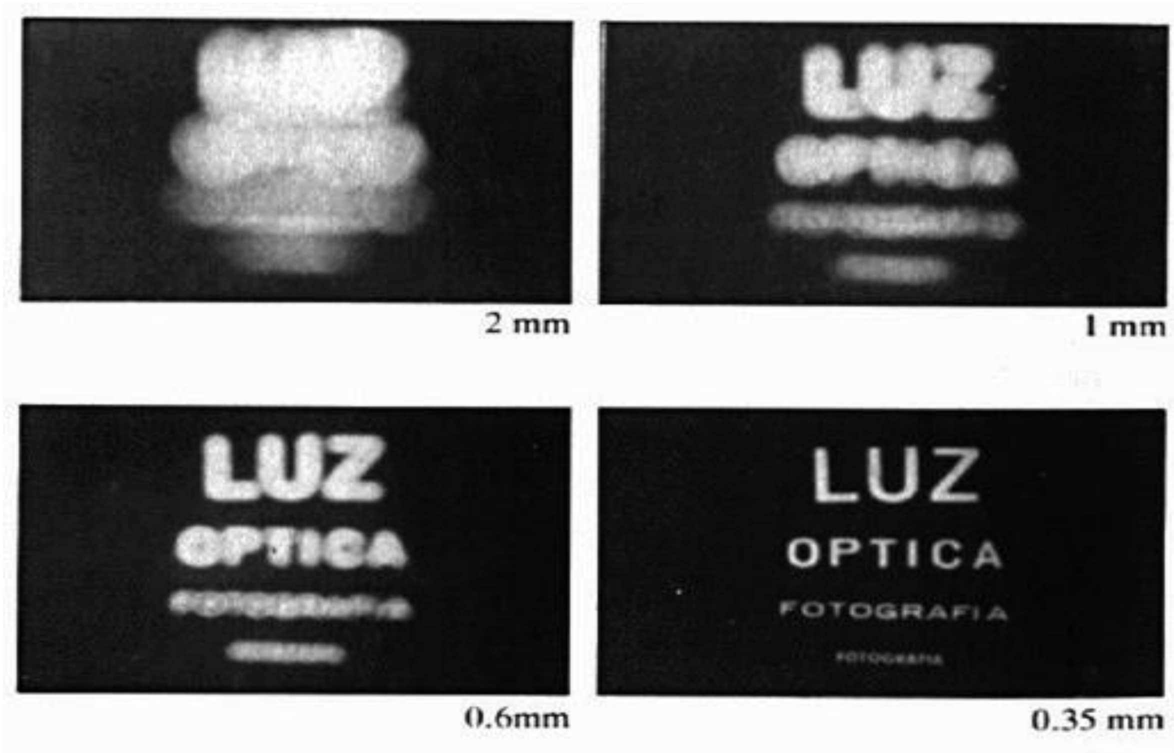
Camera Obscura



The first camera

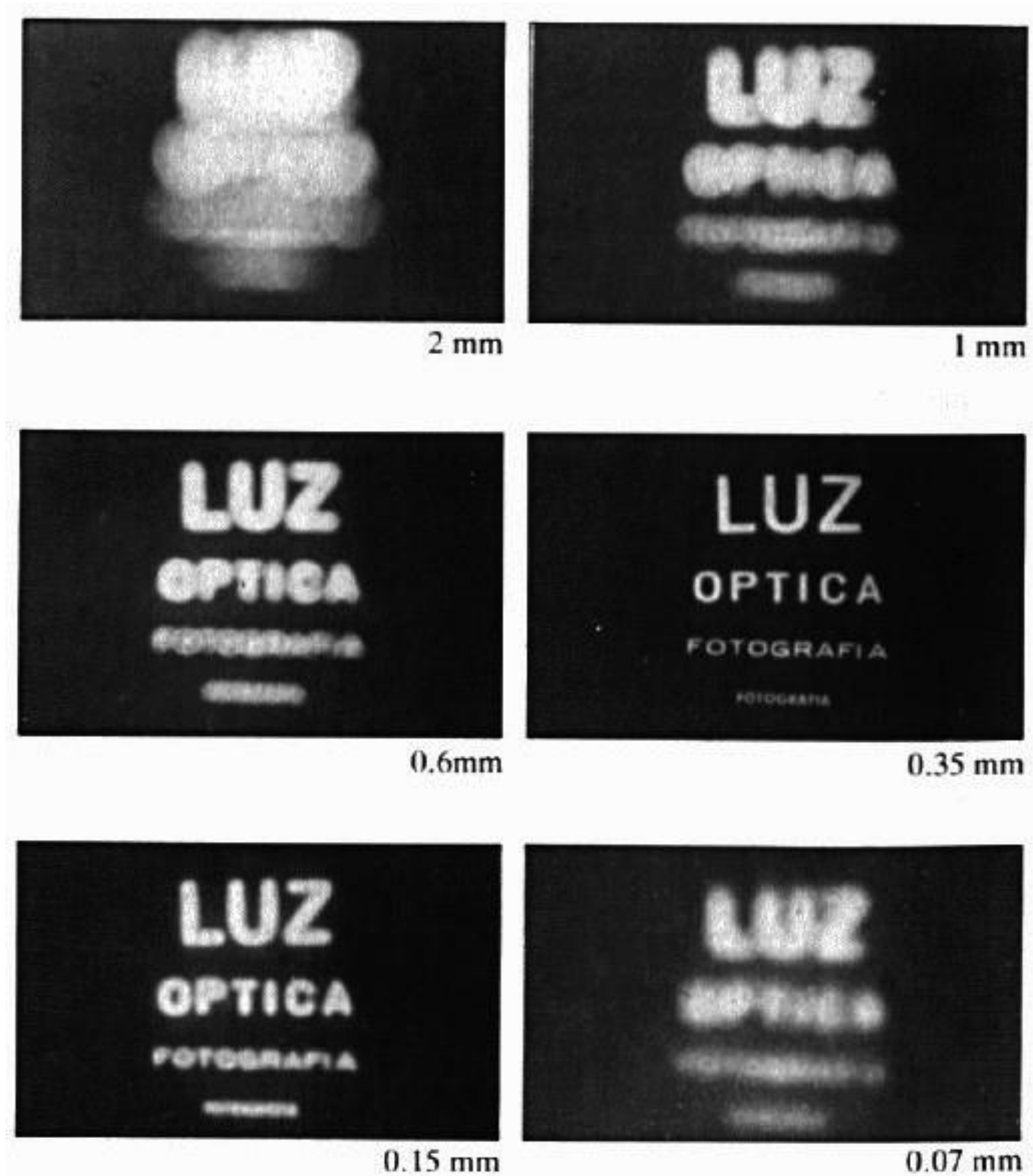
- How does the aperture size affect the image?

Shrinking the aperture

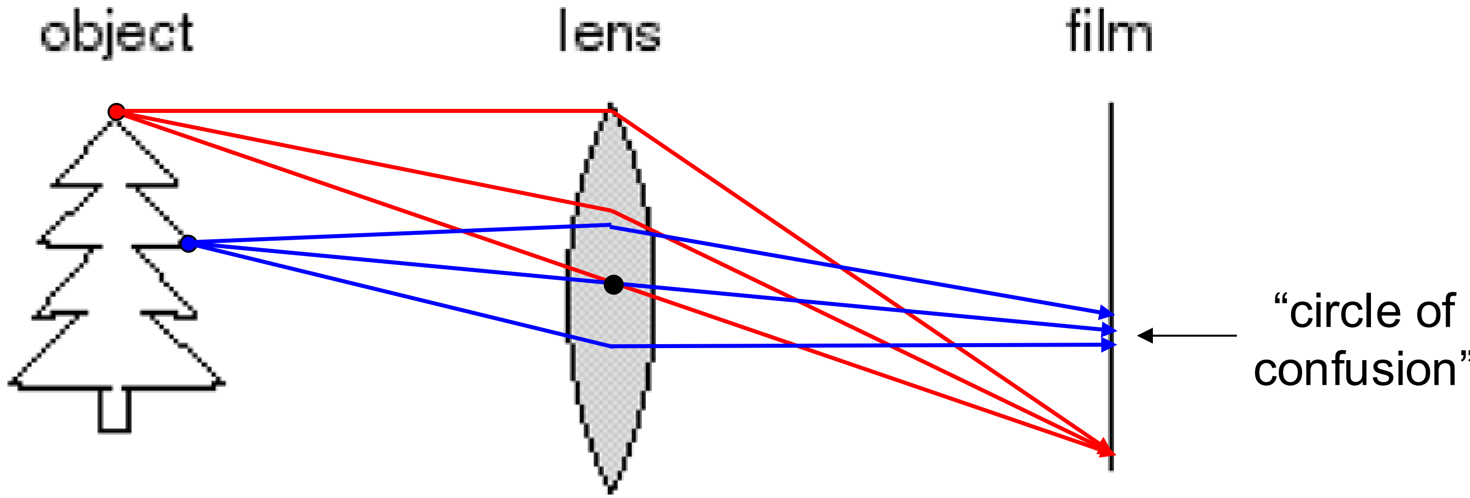


Why not make the aperture as small as possible?

Shrinking the aperture



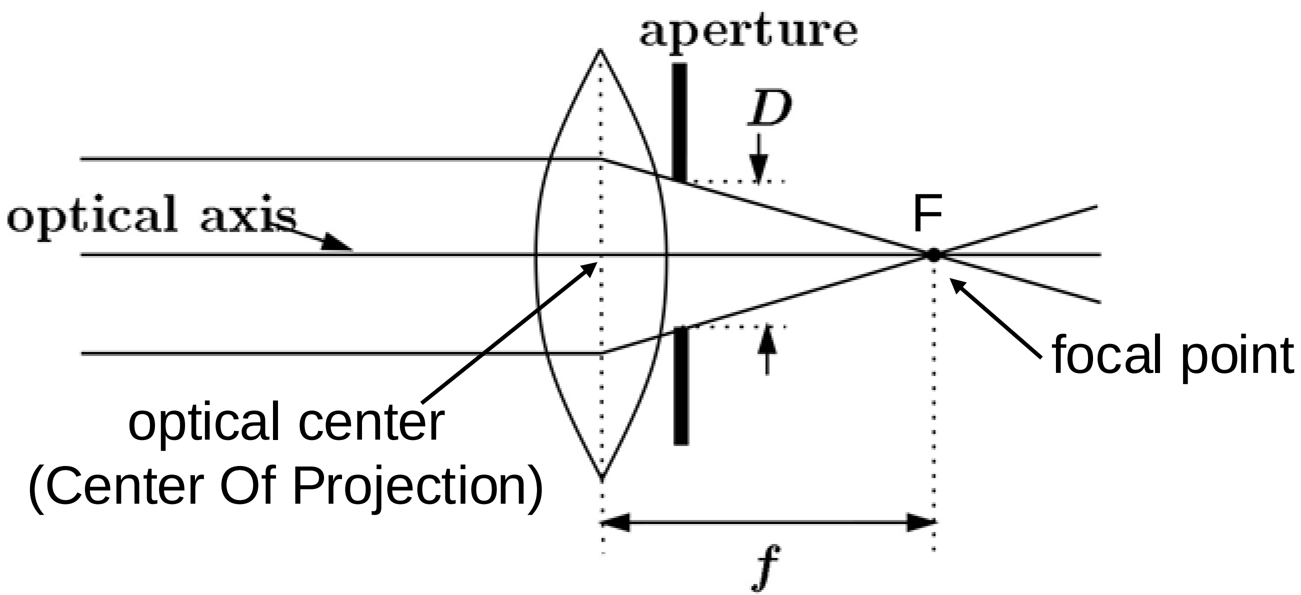
Adding a lens



A lens focuses light onto the film

- There is a specific distance at which objects are "in focus"
  - other points project to a "circle of confusion" in the image
- Changing the shape of the lens changes this distance

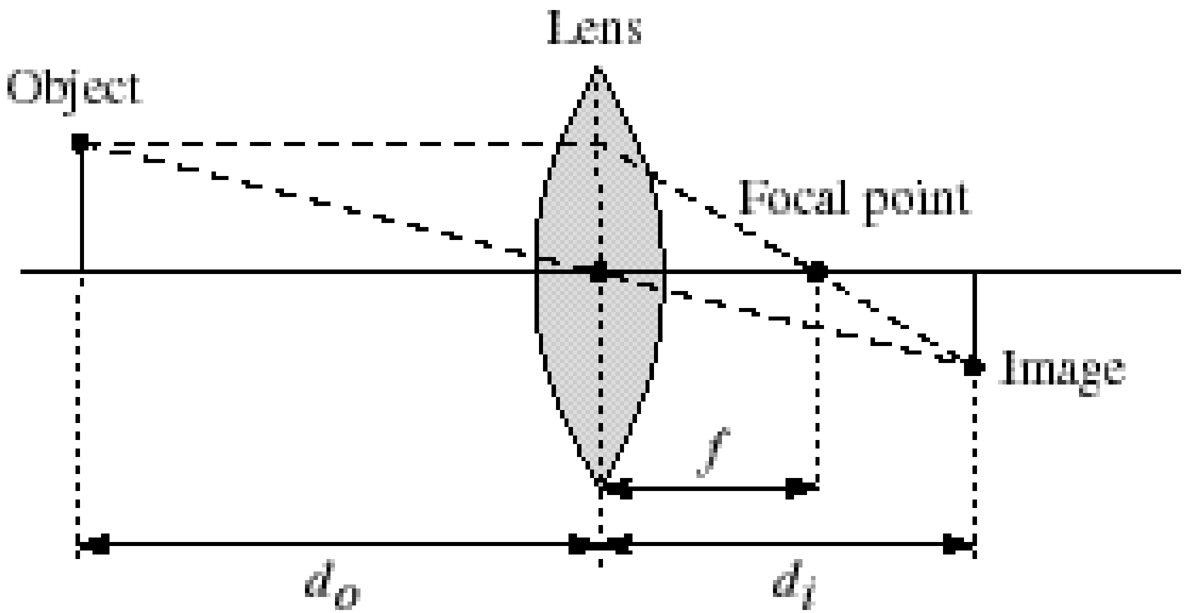
Lenses



A lens focuses parallel rays onto a single focal point

- focal point at a distance f beyond the plane of the lens
  - f is a function of the shape and index of refraction of the lens
- Aperture of diameter D restricts the range of rays
  - aperture may be on either side of the lens
- Lenses are typically spherical (easier to produce)

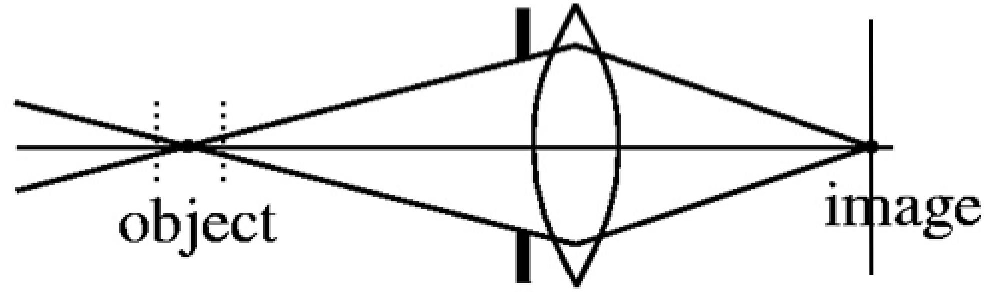
Thin lenses



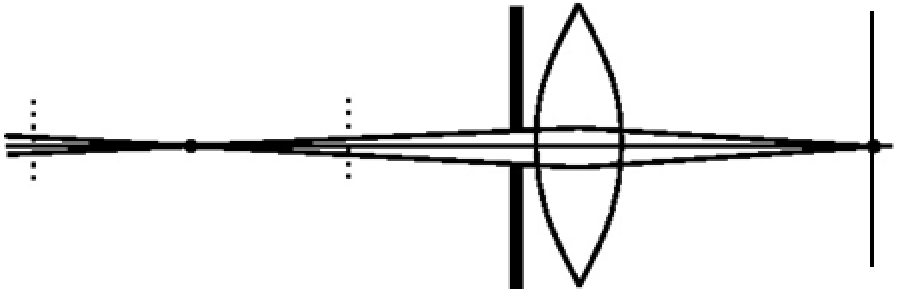
Thin lens equation: $$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

- Any object point satisfying this equation is in focus
- What is the shape of the focus region?
- How can we change the focus region?
- Thin lens applet: http://www.phy.ntnu.edu.tw/java/Lens/lens_e.html (by Fu-Kwun Hwang)

Depth of field



f / 5.6



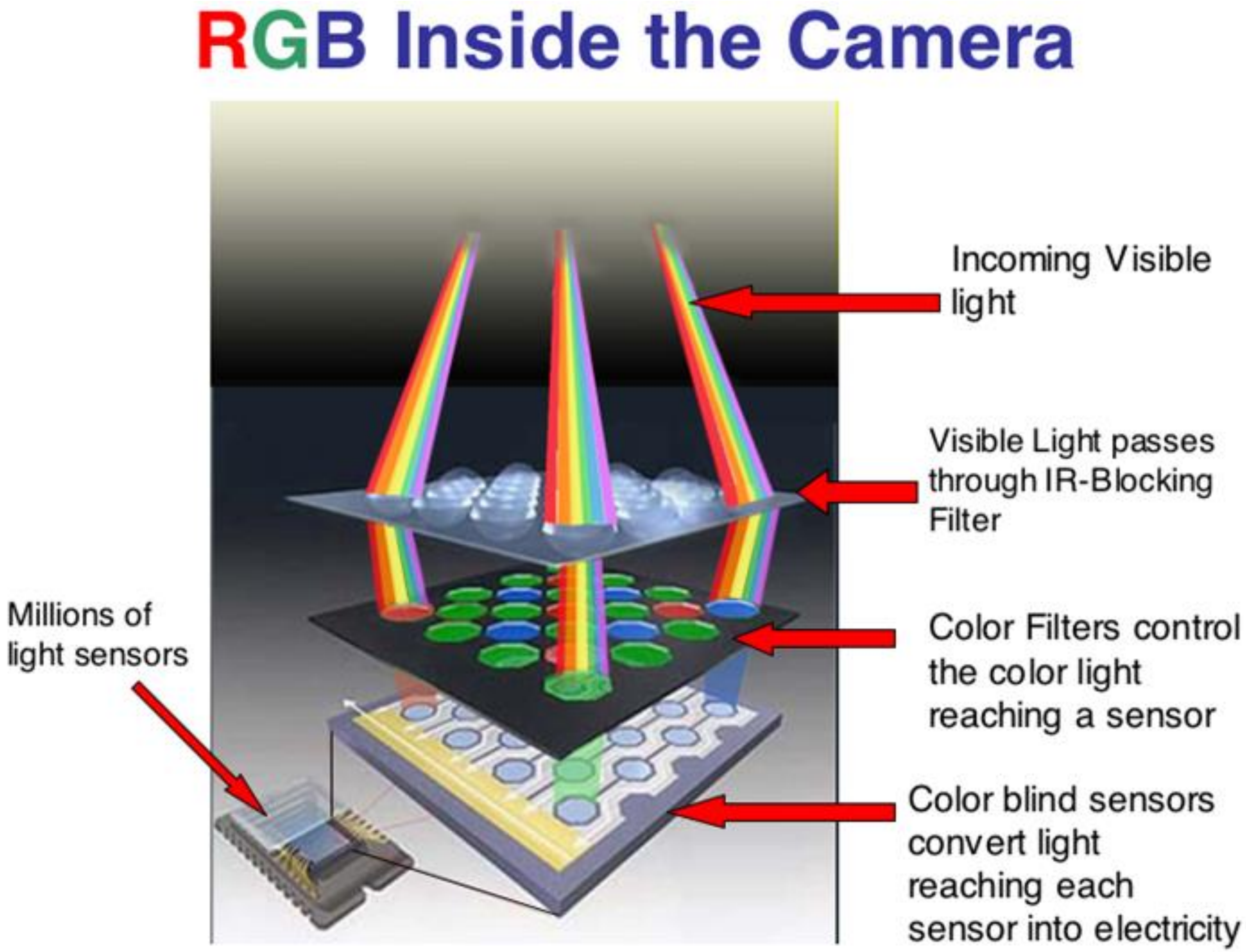
f / 32

Changing the aperture size affects depth of field

- A smaller aperture increases the range in which the object is approximately in focus

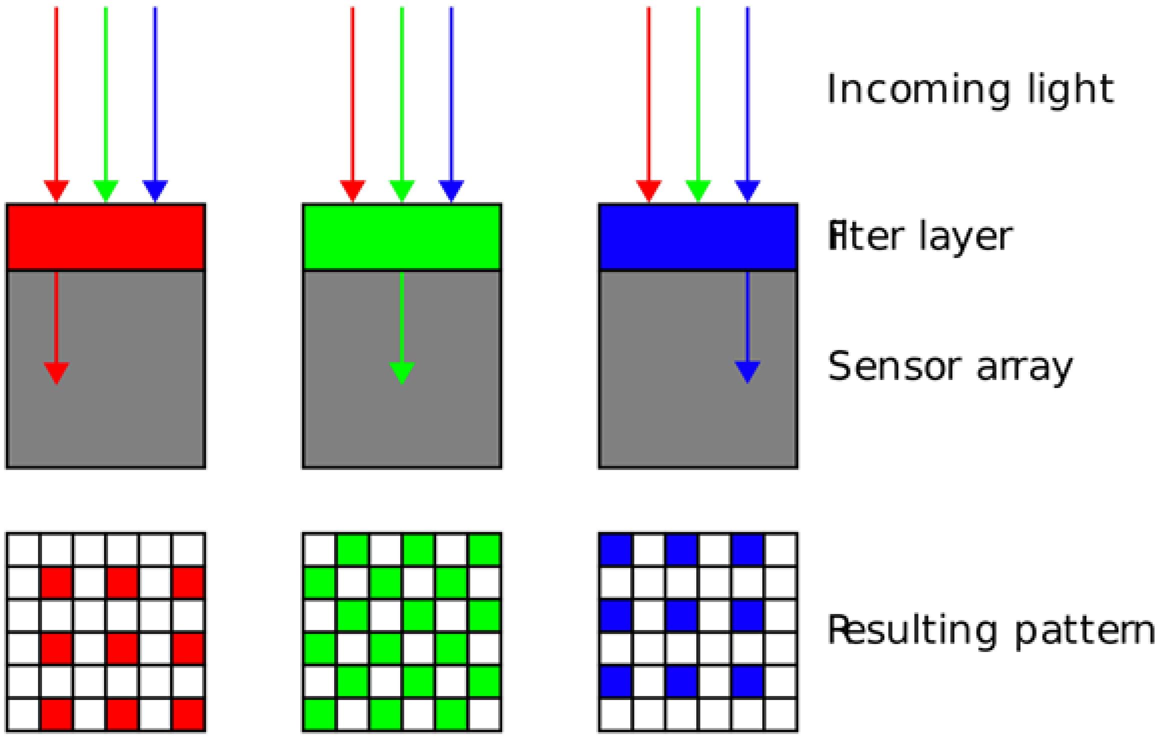
Flower images from Wikipedia http://en.wikipedia.org/wiki/Depth_of_field

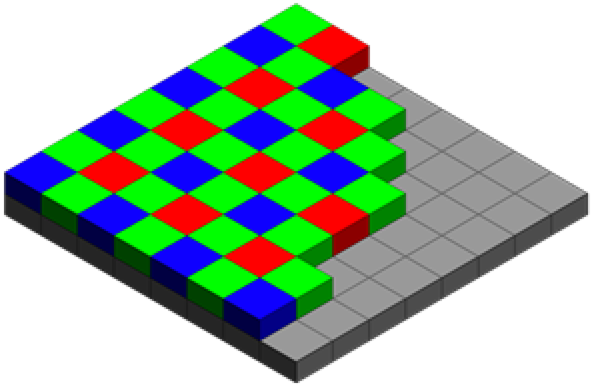
From light to pixels



https://sites.google.com/a/globalsystemsscience.org/digital-earth-watch/tools/digital-cameras-overview/what-happens-to-the-near-infared-entering-

Bayer filters



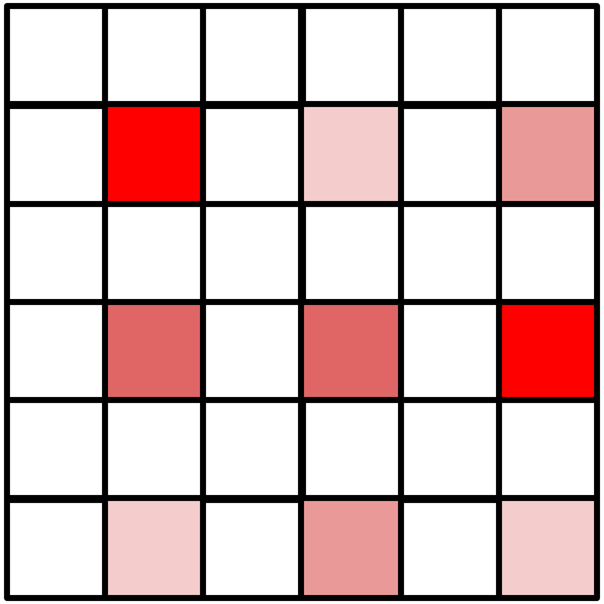


https://en.wikipedia.org/wiki/Bayer_filter

¼ of pixels see red light (e.g.)

- Q: how do you get red at every pixel?
- A: Need to interpolate -- called *debayering*

Debayering



	100		10		30
	50		50		100
	10		30		10

¼ of pixels see red light (e.g.)

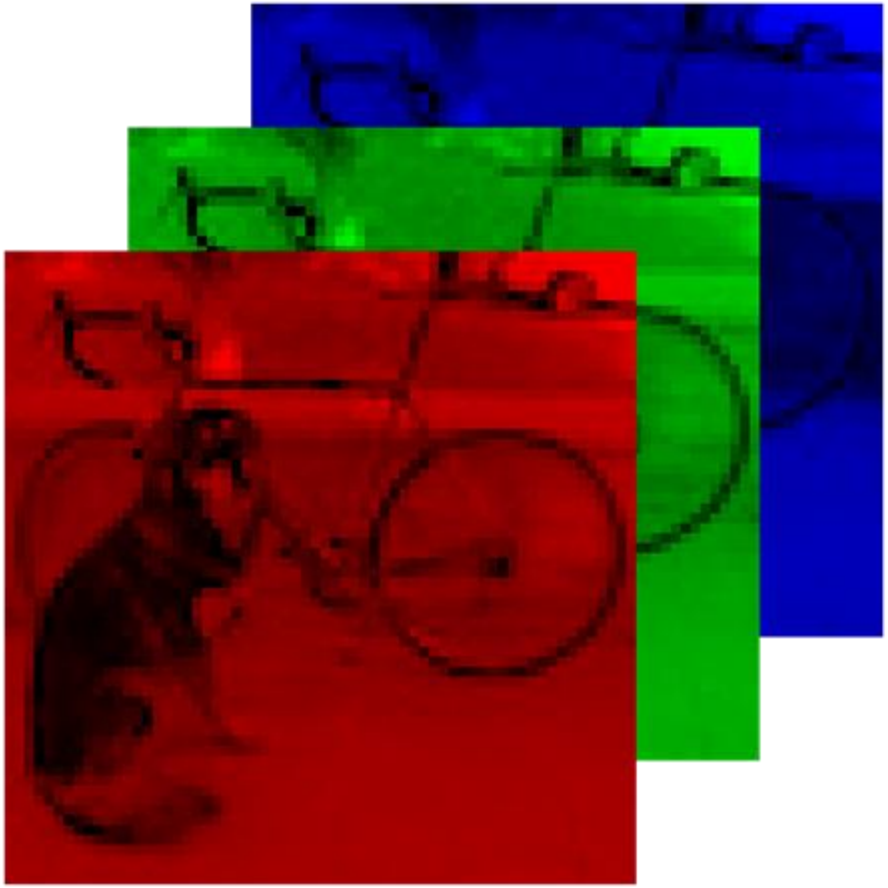
- Q: how do you get red at every pixel?
- A: Need to interpolate -- called *debayering*

RGB images (three channel)

what we see

What we get out of the

Images



From now on: what to do with these RGB images!