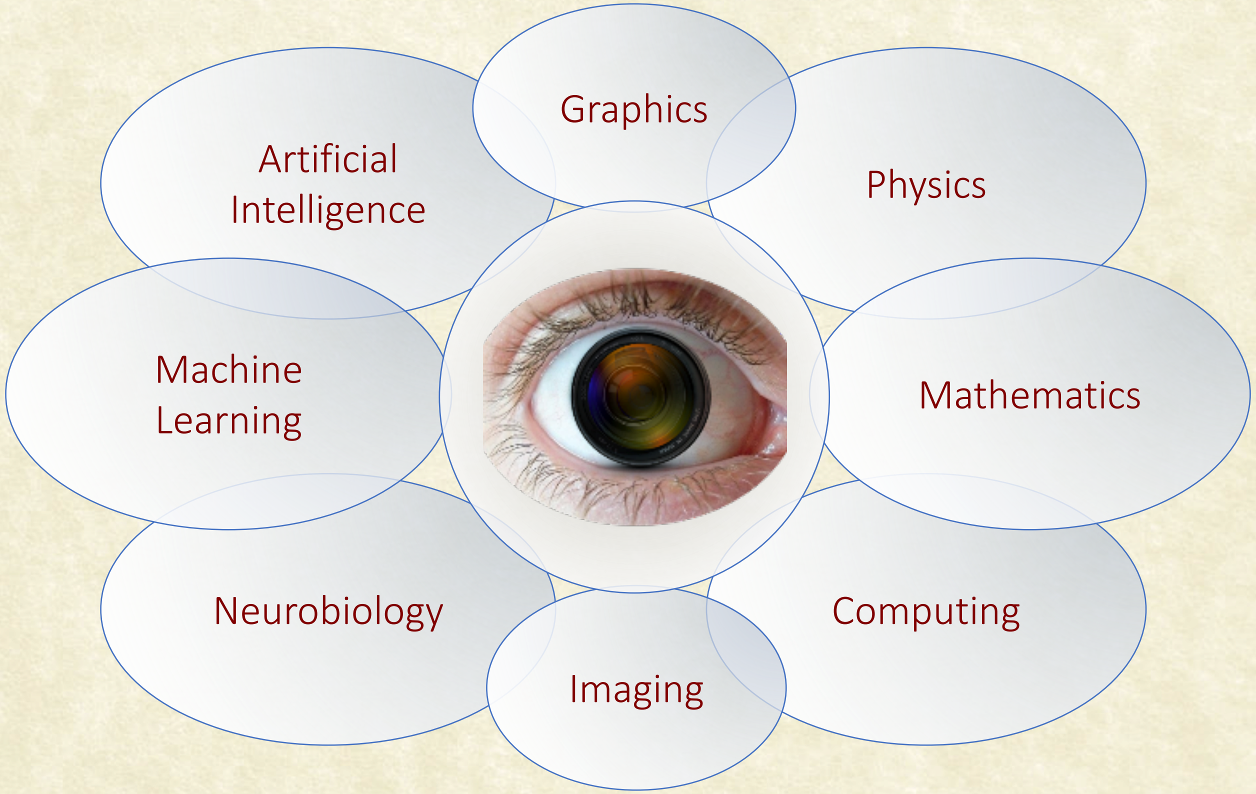
CS7.505: Computer Vision

Spring 2022: Introduction



Anoop M. Namboodiri

Biometrics and Secure ID Lab, CVIT,

IIIT Hyderabad

Course Outline, Topics

Computer Vision

Geometry
Pinhole Camera Model
Proj. Geometry, Camera Matrix
Camera Calibration
2-View Geometry, Homography
Fundamental Matrix
Stereo Corr., Depth Estimation
SFM and Bundle Adjustment
Image Rectification
Computational Imaging

Image Grouping
Segmentation as Labelling
Graphcut, Binary Segmentation
MRF for Segmentation
Multi-label MRFs
Image-to-Image Networks, Segm
Monocular Depth Estimation

Recognition
Feature Detection, Descriptors
Face Detection, Recognition
Pedestrian Detection (HoG,SVM)
Bag of Words, SURF, Others
Indexing and Retrieval
CNNs for Recognition
CNN Training, Transfer Learning
CNNs for Detection

What about Deep Learning?

- DL has become the primary driving force behind most recent success in CV. However, this is the first course on Computer Vision. So we will limit the amount of DL in this course.

- Computer vision has a strong mathematical and conceptual basis developed over 4 decades
  - Geometry
  - Optimization
  - Visual object representations
  - Optics, Lighting, Appearance models
- You need to know the basics to build on it

Pre-Requisites for the Course

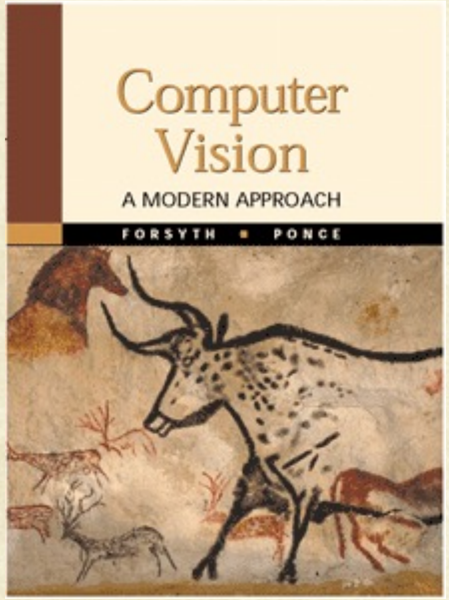
- Linear algebra and a good mathematical outlook
  - Vectors, matrices, eigenvalues, singular values
  - 2D/3D geometry
  - See course page for a more detailed list of topics
- Image/Signal processing
  - Filtering, edge detection, segmentation
  - Transforms, analysis
- Pattern Analysis, Algorithms, Programming
  - Features, classifiers
  - Training, testing, validation
  - Python/C++, OpenCV

Brush up these topics if you are not certain. A reading list of online material will be prepared for the preliminaries

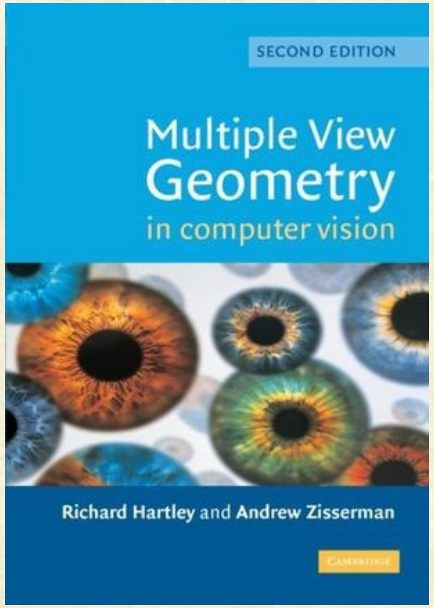
Reference Books

No single textbook

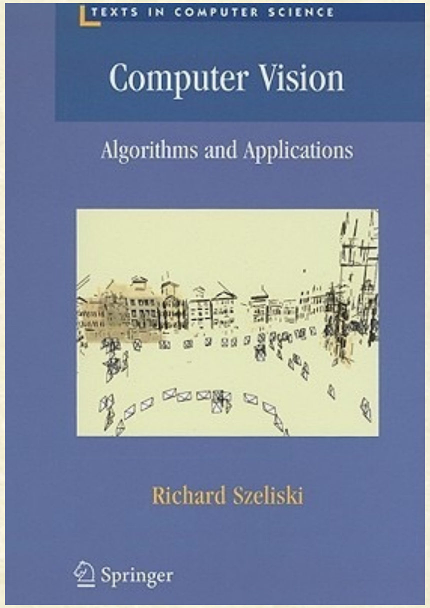
Forsyth & Ponce
Indian Edition



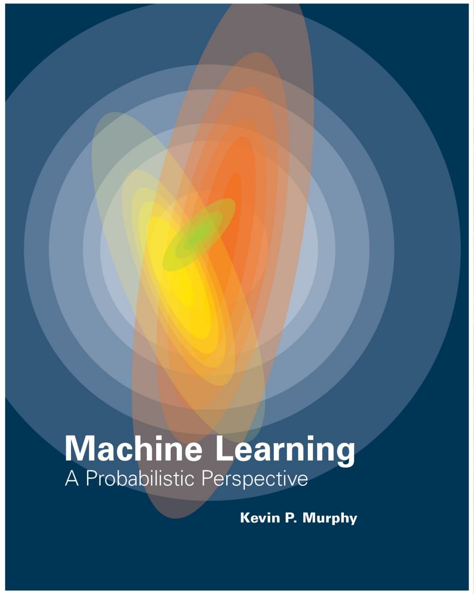
Hartley & Zisserman
Indian Edition



Rick Szeliski
PDF Online



Kevin P. Murphy
PDF Online



… and several papers and resources.

Administrivia

- Grade Distribution
  - Quizzes: Q1 + Q2 (~16%)
  - Exams: MidTerm + Final (~34%)
  - Homeworks/Assignments: (~25%)
  - Project: In groups of 3 (~25%)
- This is an advanced elective that you opted for
  - We expect you to work hard to learn well.
  - Class participation lifts the level of the class
  - We don’t want credit-seekers or resume-padders here
- Mode of Classes
  - The classes will be conducted in person as long as the pandemic allows us

Class Etiquettes

- Be in the class before 2pm
- Keep your cellphones switched off. Those messages can wait.
- Reduce noise in the class (online and offline)
  - Switch off your cameras, microphones
  - Put your hand up if you have a question
  - If online, you may also type your questions in the chat
- If you have a doubt, ask. Others are also likely to have the same doubt.
- A significant amount of learning comes from questions asked by participants. So please listen to the lecture and to other participant’s questions.

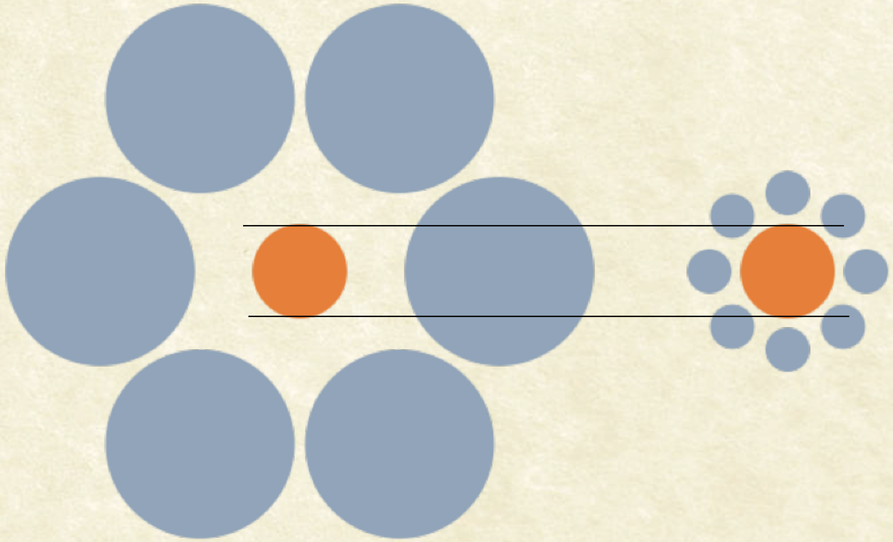
What is Computer Vision?

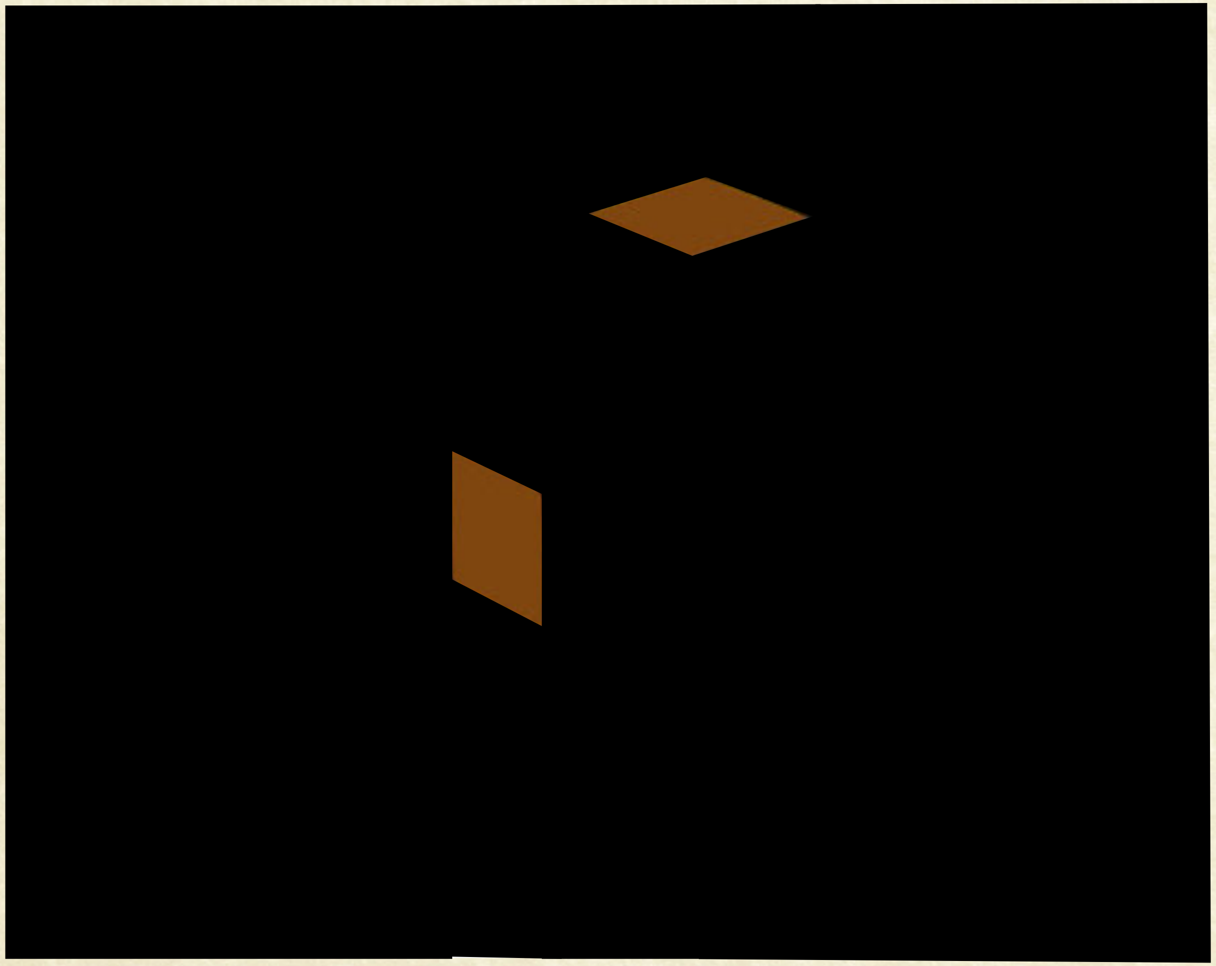
- Understanding of visual inputs (images/videos) by computers.
- Making sense out of them. Describing them.
- Does computer vision mimic the human vision?
  - Certainly in many of its goals
  - Why? Human vision is among the best!
  - Sophisticated and efficient but not understood well
- Should computers process visual inputs like humans?

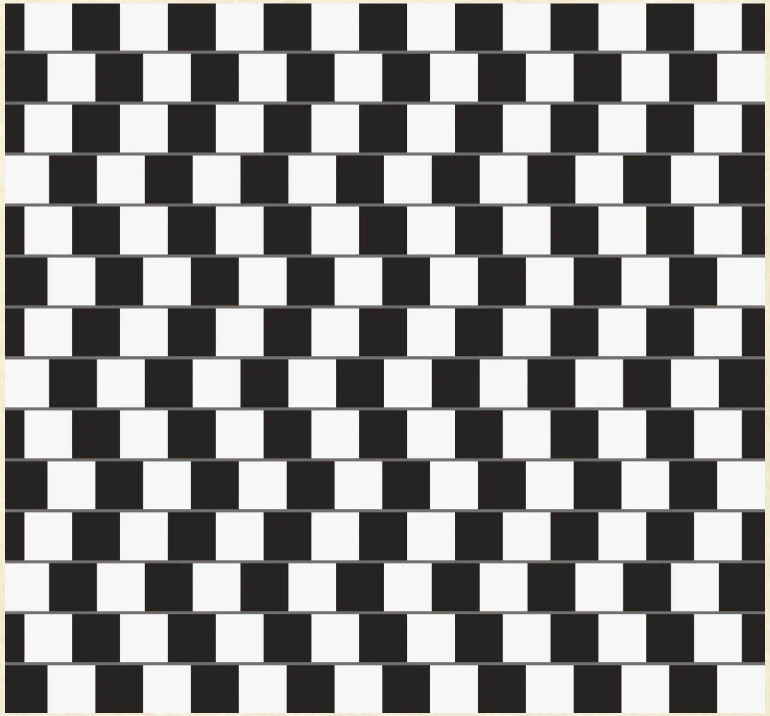
Not necessarily!

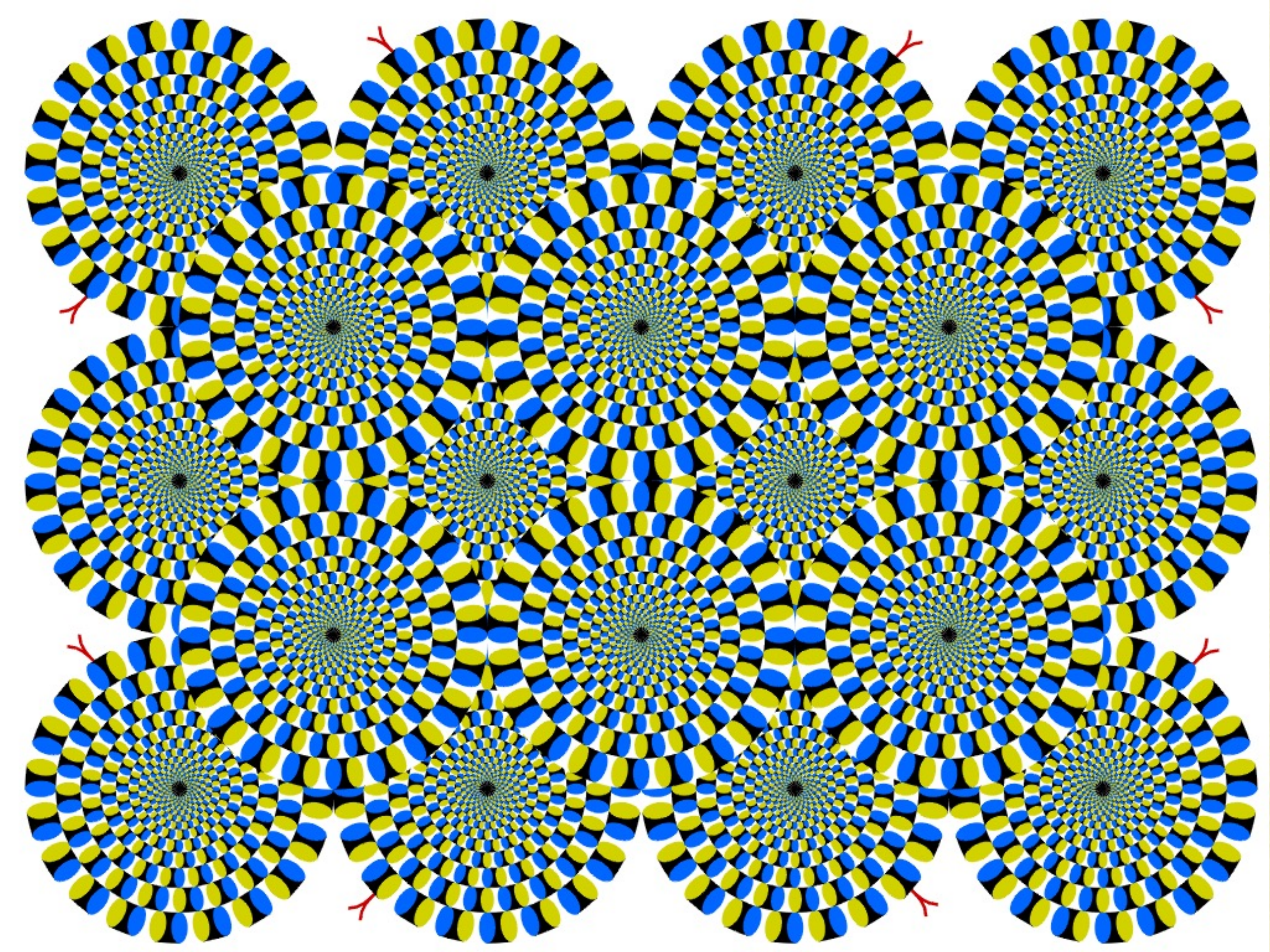
  - Human visual system need not limit computer vision
  - We draw inspiration from it as often as is convenient

Human perception is not perfect...









Three "Urges" on seeing a Picture*

- Given an image, you want to do:

Segmentation

Group proximate and similar parts into meaningful regions

Recognition

Recollect previously seen objects from memory

Reconstruction

Measure quantitative aspects: Number, Size, Distance, etc.

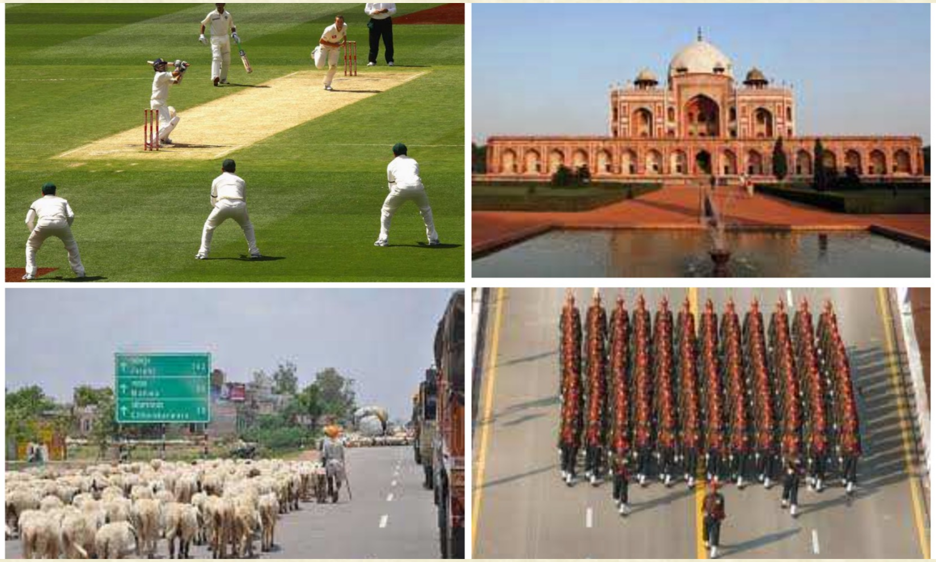
**Jitendra Malik; Mysore Park, Dec. 2011*

The Three Rs of Computer Vision

Reorganization (Segm.)

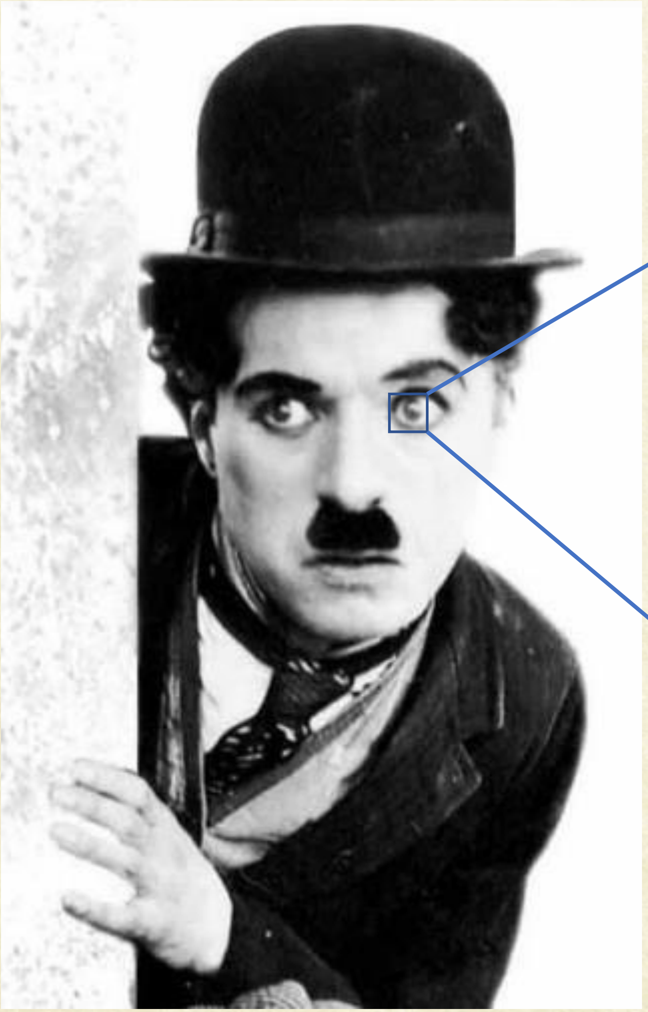
Group semantically similar pixels

Recognition
Connecting what we see to our memory



Reconstruction
Measure/recreate a 3D model of what we see in the world

Why is it Difficult?

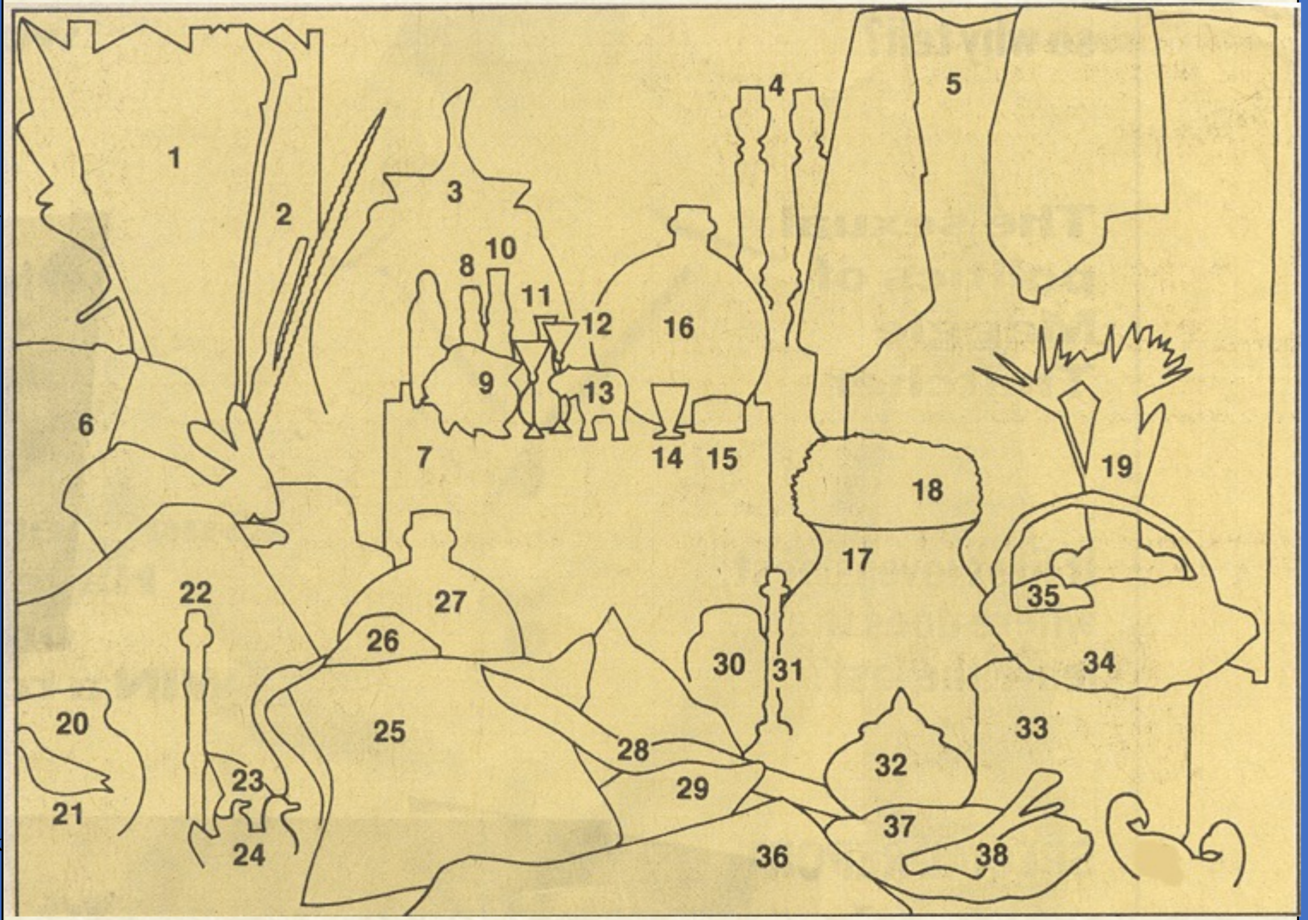


90	126	180	120	102	131	126	91
82	140	143	182	180	142	138	81
81	141	148	195	188	147	140	80
75	144	150	210	198	149	141	73
71	144	151	241	214	150	143	70
88	142	147	236	205	146	141	85
106	139	142	225	197	141	138	101
128	135	139	184	180	138	132	121

Scene Interpretation

Segmentation and Labeling

1. Hand-carved Shesham wooden screen
2. Wooden flowers
3. Wicker basket
4. Pair of hand-carved Thai candlesticks
5. Indonesian rattan screen
6. Dhurry covered armchair
7. Hand-painted chest
8. Striped wooden Indian candlestick
9. Stone terracotta Thai
10. Moroccan ceramic candlestick
11. Blue Egyptian glass decanter
12. Bronze goblet-shaped candlesticks
13. Painted wooden Indian elephant
14. Blue Egyptian glass goblets
15. Indian brass filigree box
16. Painted Indian oil bottle
17. Large African water pot
18. Philippino twig basket
19. Philippino bamboo covered urn



20. African cooking pot
21. Decoy bird
22. Painted candlestick
23. Thai wooden swan
24. Carved wooden duck
25. Embroidered mirror cushion covers
26. Green hexagonal Indian box
27. Painted Indian oil bottle
28. Joint wooden snake
29. Black embroidered cushion
30. Moroccan ceramic jar
31. Painted wooden candlestick
32. Thai pot with lid
33. Octagonal Indian box
34. Shallow twig baskets
35. Mexican paper mache fake fruit and vegs
36. Nakshe Kantha Bengali wall-hanging
37. Wooden shell bowl
38. Wooden servers

Computer Vision

- Goal: Extract all possible information about a visual scene by computer processing

  What? When? Where? Who? How? Why? How many?

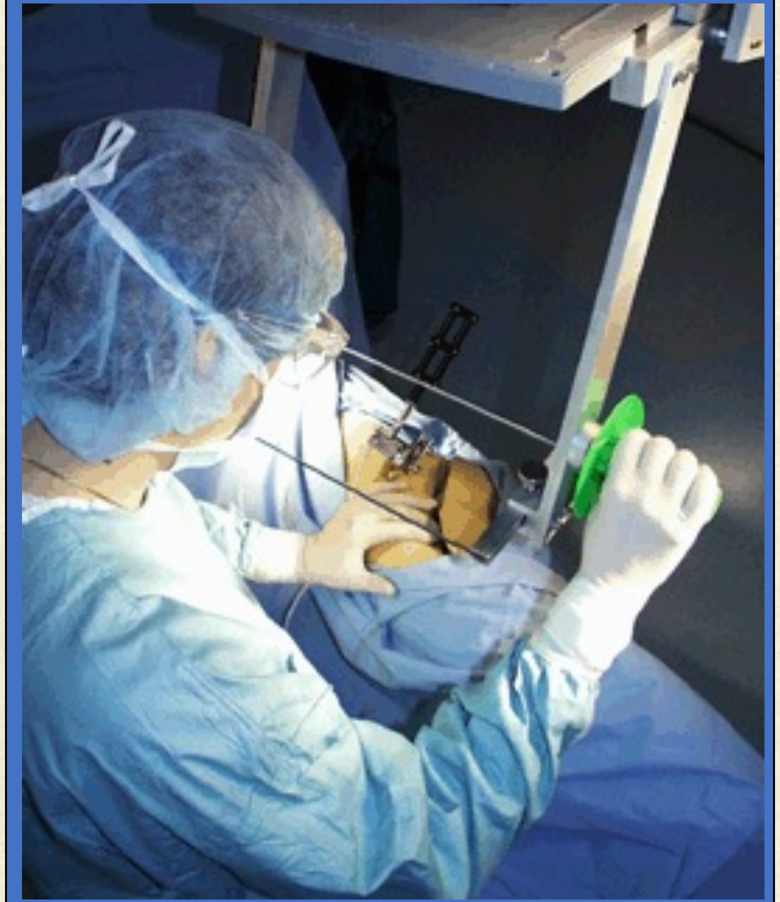
- Over 50% of the brain is devoted to vision for humans.
  – Must be important to us!

- Why is it difficult?

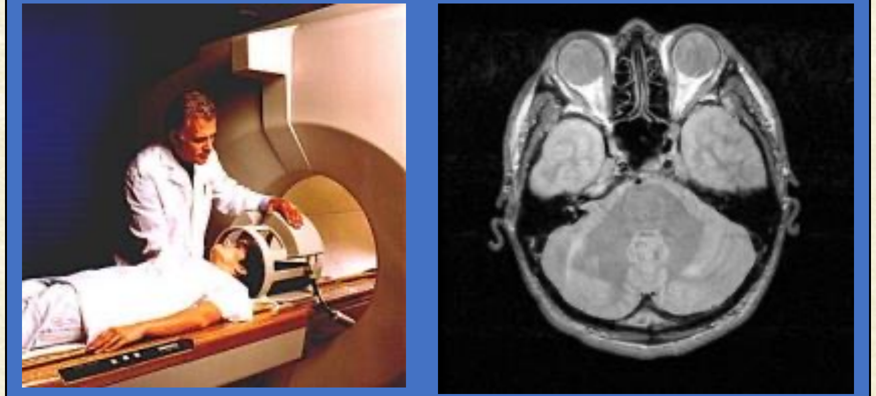
Chairs and Chairs

- Which are chairs?
- Large intra-class variations
- How do we describe a chair?
- Basic property: Sittability!
- We infer a lot from pictures. Can we instruct a computer to do the same?
- Do we understand how we infer?

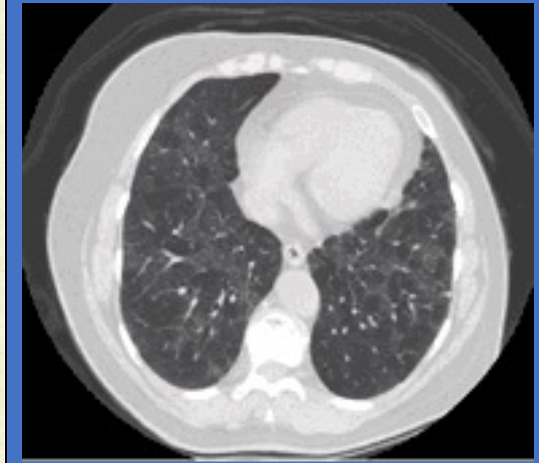
Applications: Medical



Computer Assisted Surgery



CT Scan



Segmentation

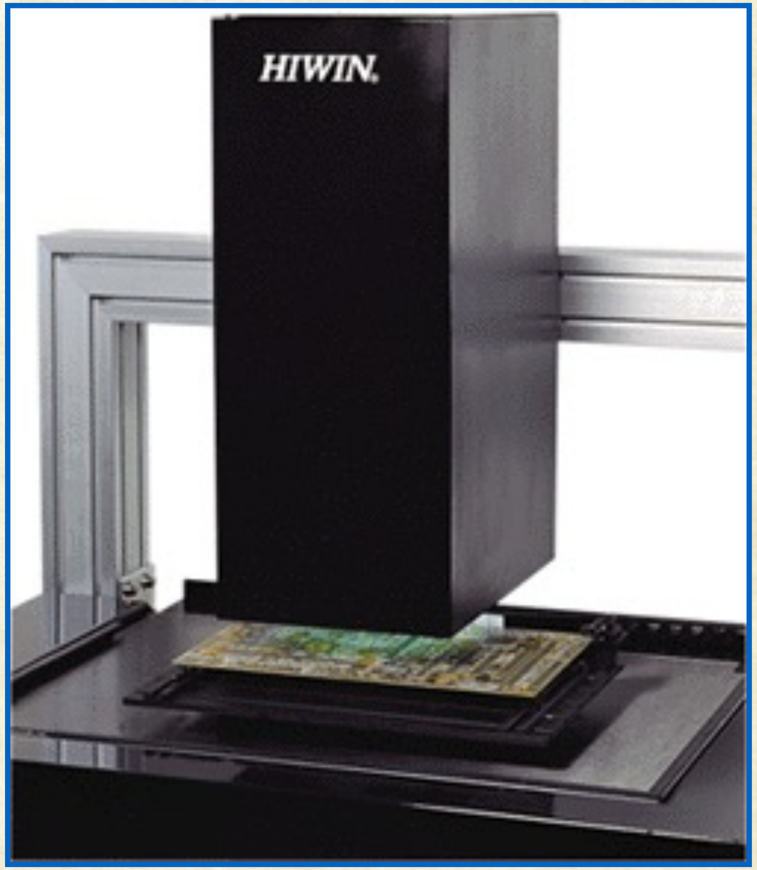
Applications: Space Imaging

Ikonos

Rio Negro (black) meets Amazon (blue)

Applications: Automated Inspection

Manual PCB Inspection



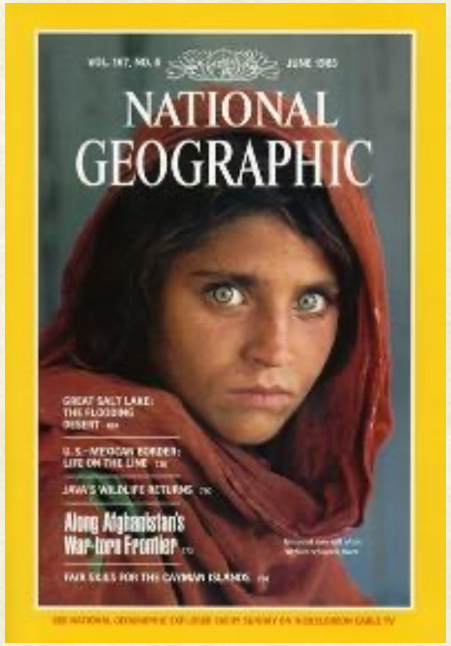
Automated PCB Inspection

Applications: Biometrics

Travel

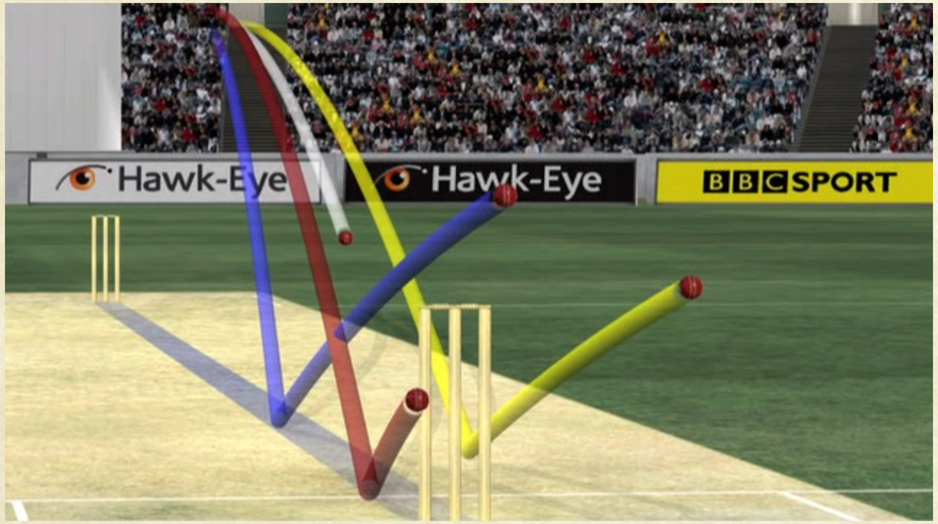
Disney Land

Computer Access



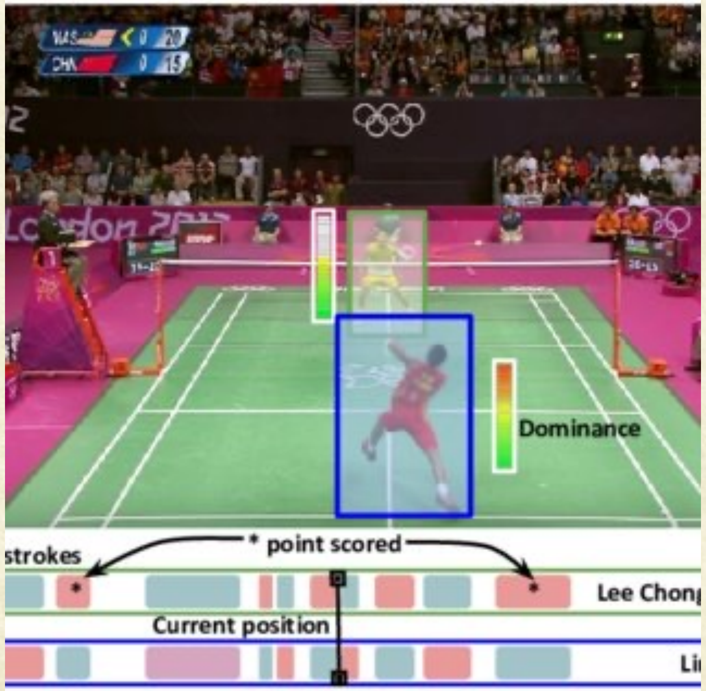
Applications: Broadcasting

Field Understanding: Virtual Line



Ball Tracking: Hawk Eye

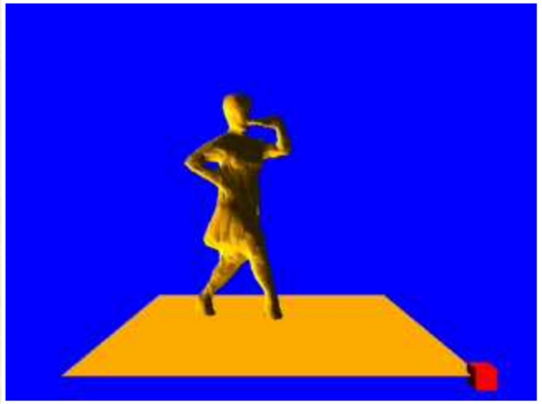
Chroma Keying: Replacing Backgrounds



Player Tracking: CVIT, IIITH

3D Shape and Motion Recovery

- Structure light scanner, laser range finder
- Multi-camera stereo, structure recovery
- Reverse Engineering
- Virtualized/Augmented reality



Applications: Others

- Surveillance
- Automated Assembly
- Mail Sorting
- Face detection (photography)
- Robot Navigation
- Content-Based Image Retrieval
- Entertainment
- And many more… with your help…

Why Automated Vision?

1. High reliability
2. High repeatability
3. More objective evaluation
4. Lower cost
5. Higher speed
6. Ability to operate in hazardous environments

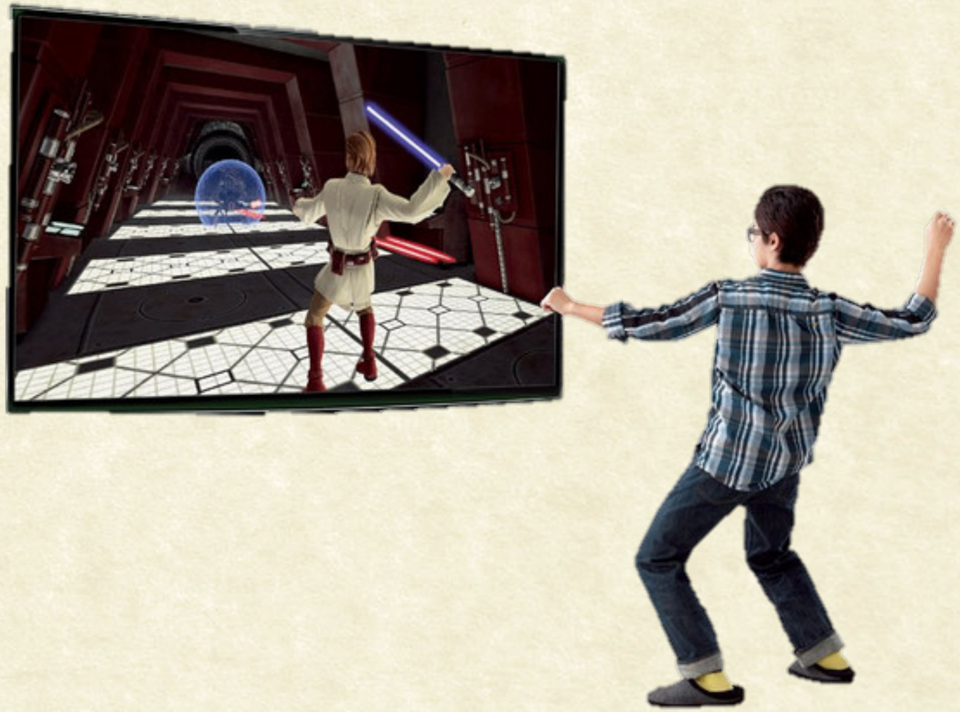
General purpose machine vision system do not exist.

Recent: Structure from Motion

- Approximate 3D structure from an unstructured collection of images! [PhotoTourism, SIGGRAPH2006]
- PhotoSynth
- Autodesk 123D: Your pictures to model
- And many more to follow soon

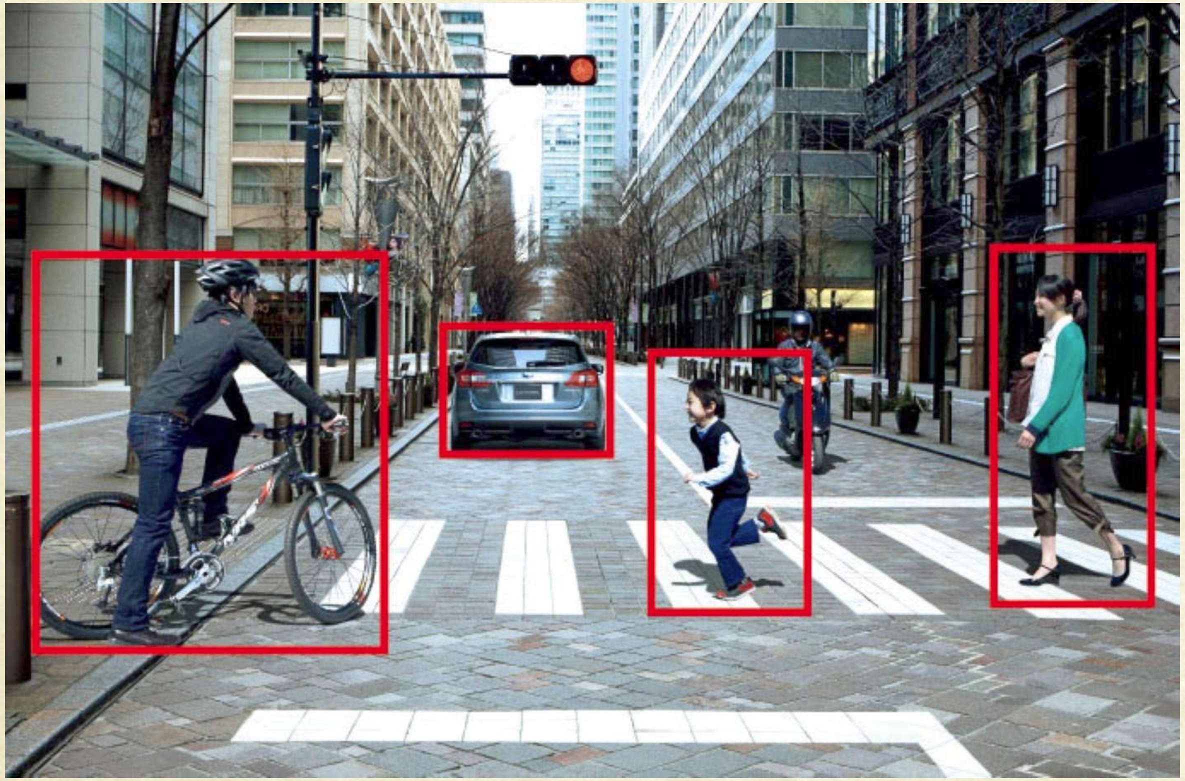
Recent: Natural Gaming

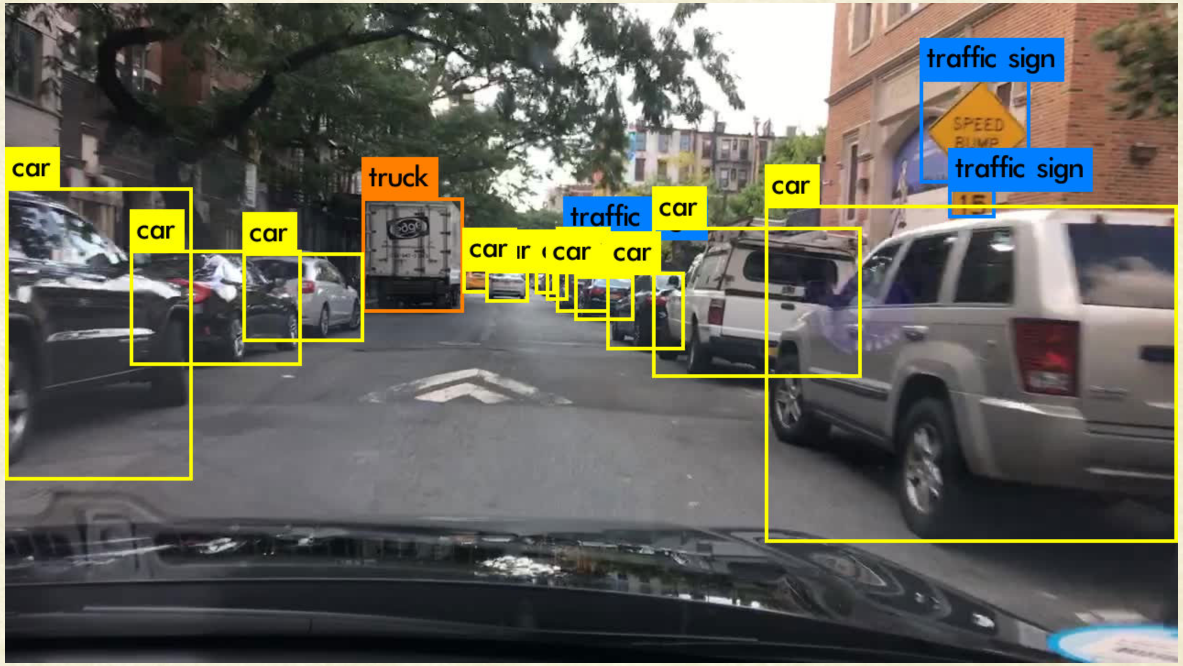
Microsoft Kinect



- You are the controller. Interact naturally with the game.
  - Fastest Selling Electronic Device Ever: 80 lakh units in 60 days!!
- Finding great use in Computer Vision, Robotics, etc.

Recent: Automotive Safety





Can help avoid accidents greatly!

The Real Problem

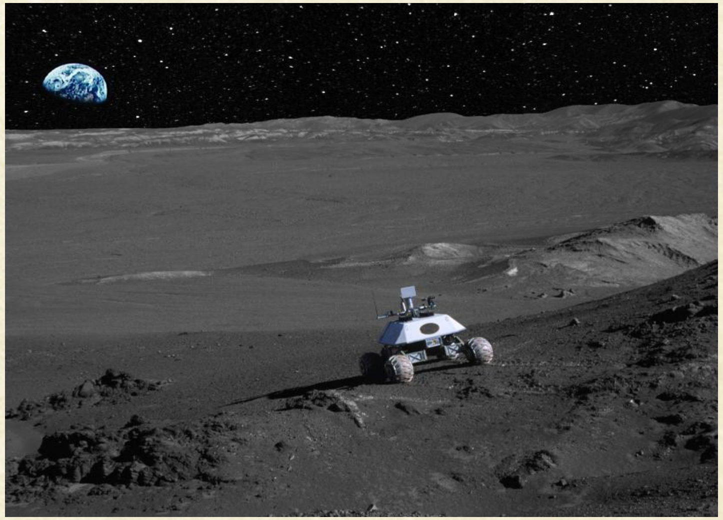





Develop something similar for Indian roads!

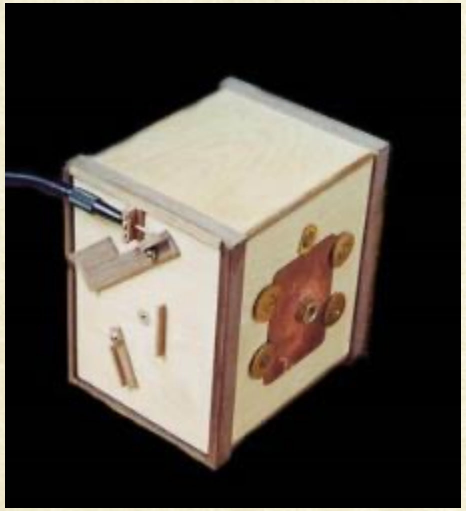
What More is Possible?

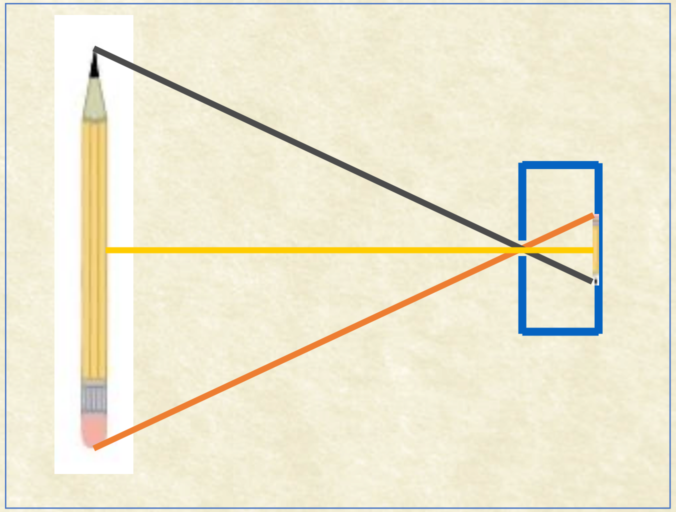
- Much much more .....
- The journey has just begun for computer vision.
- Large amount of data, high computing power, machine learning algorithms continue to transform computer vision.
- Big things are yet to come.



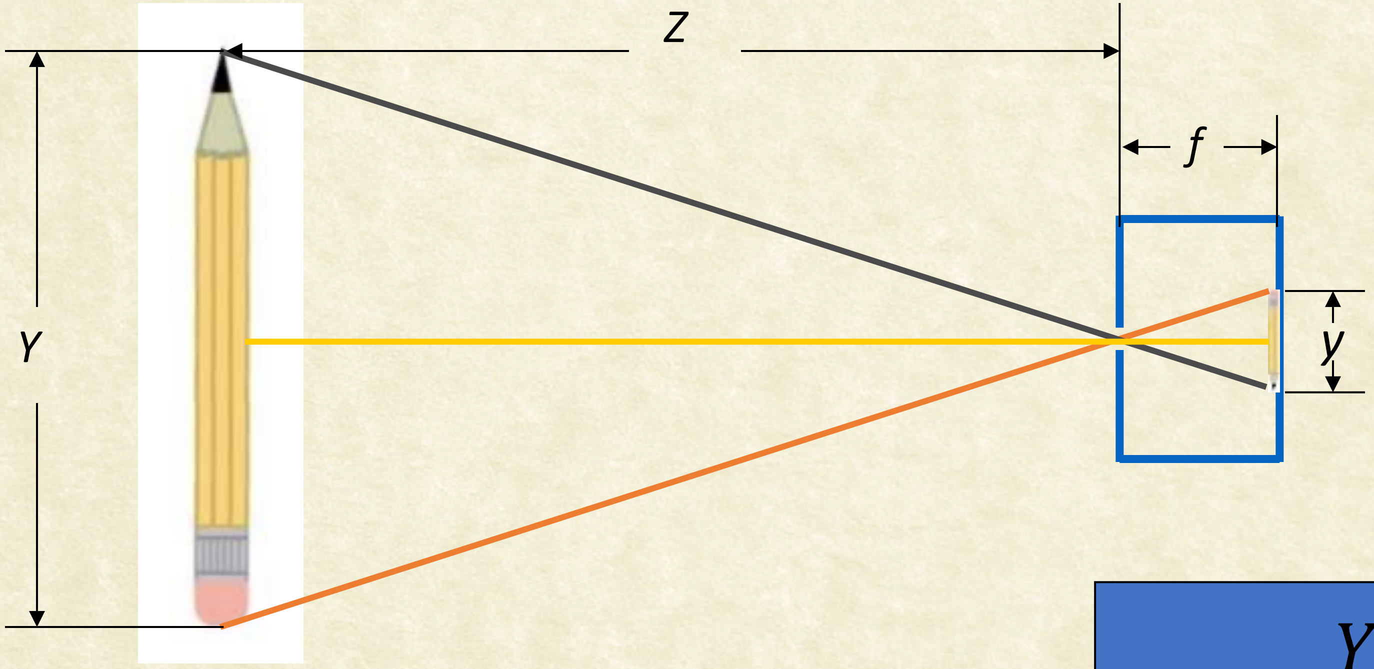
Questions?

M1 Geometry: Imaging and Camera Model



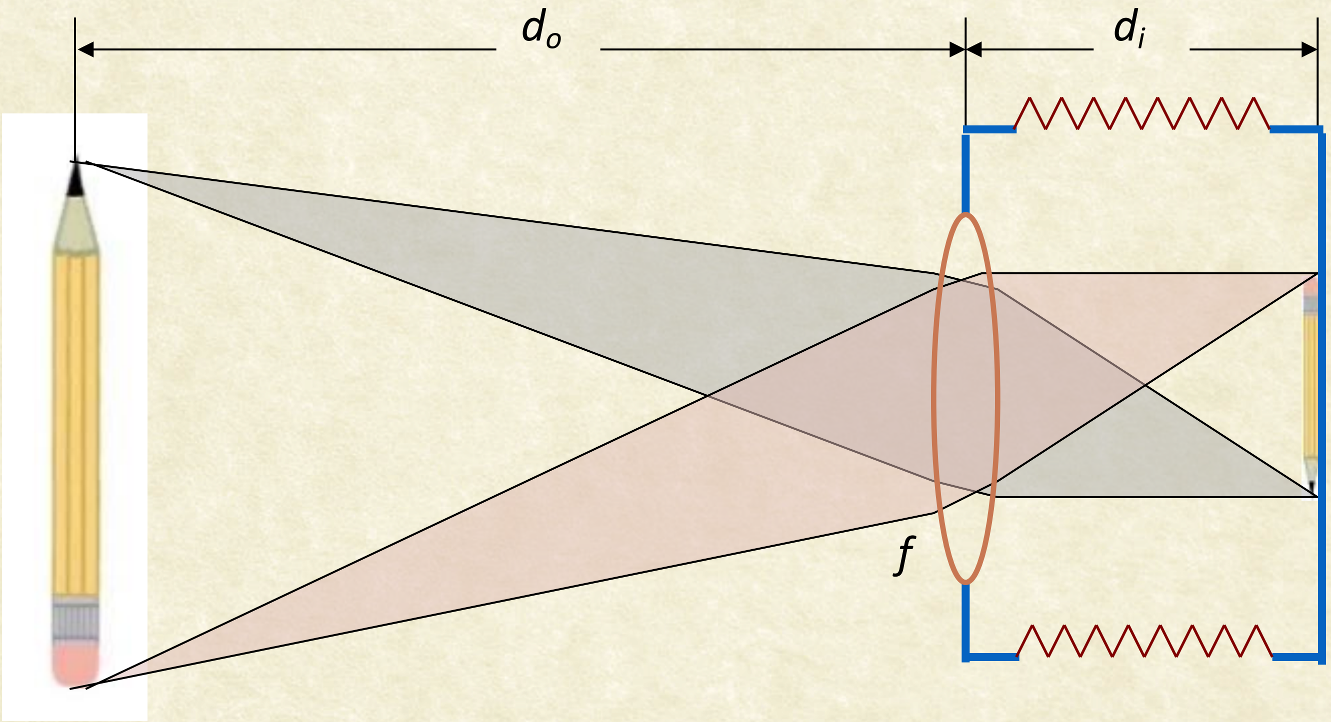


The Pinhole Camera



$$y = f\frac{Y}{Z}$$

Camera with Lens

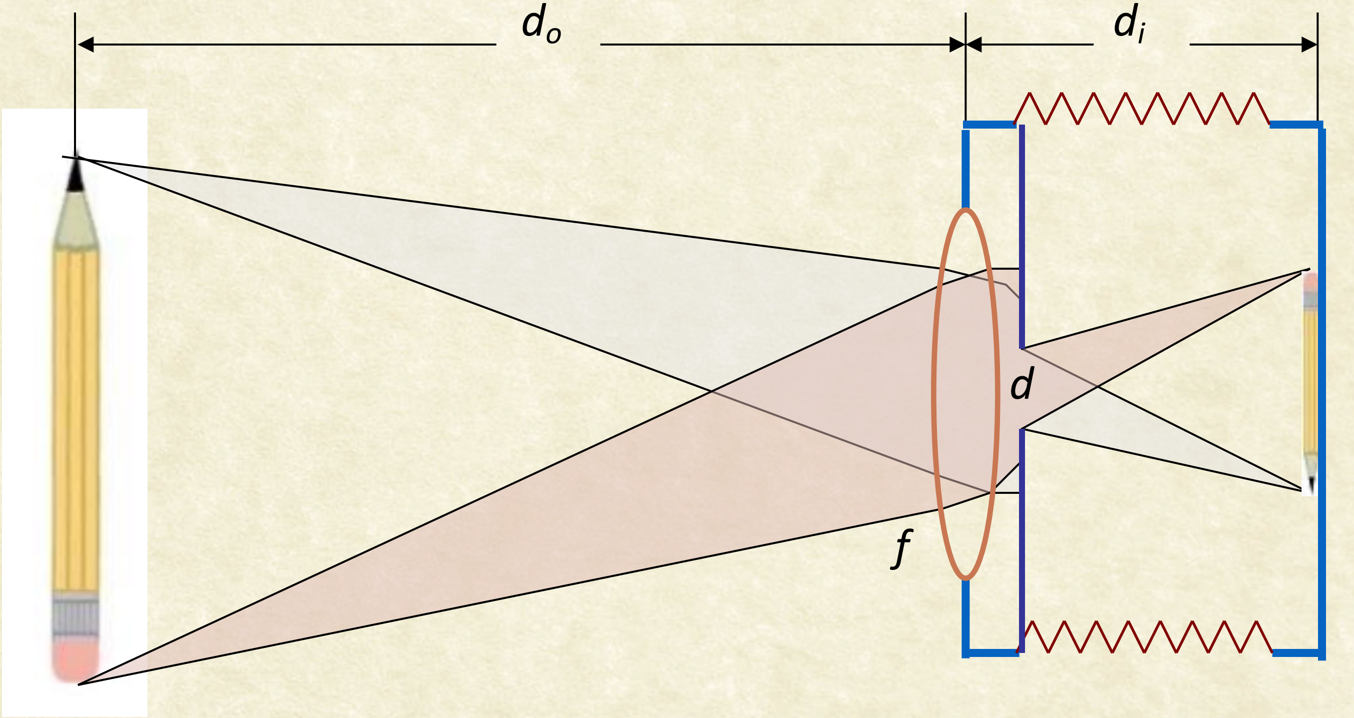


Thin lens equation: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$$d_i = f\,\frac{d_o}{(d_o - f)}$$

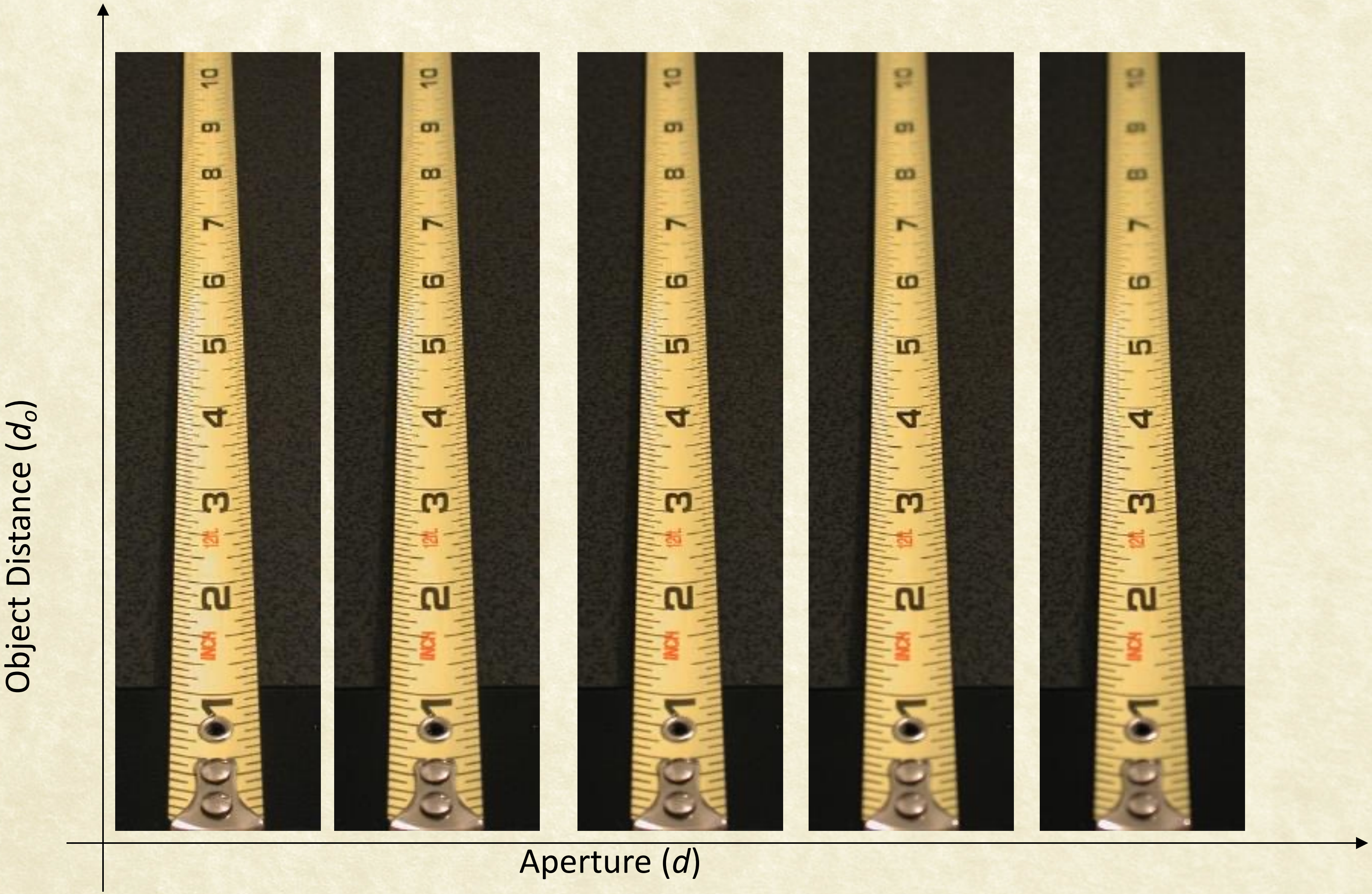
Focus and DOF

Aperture

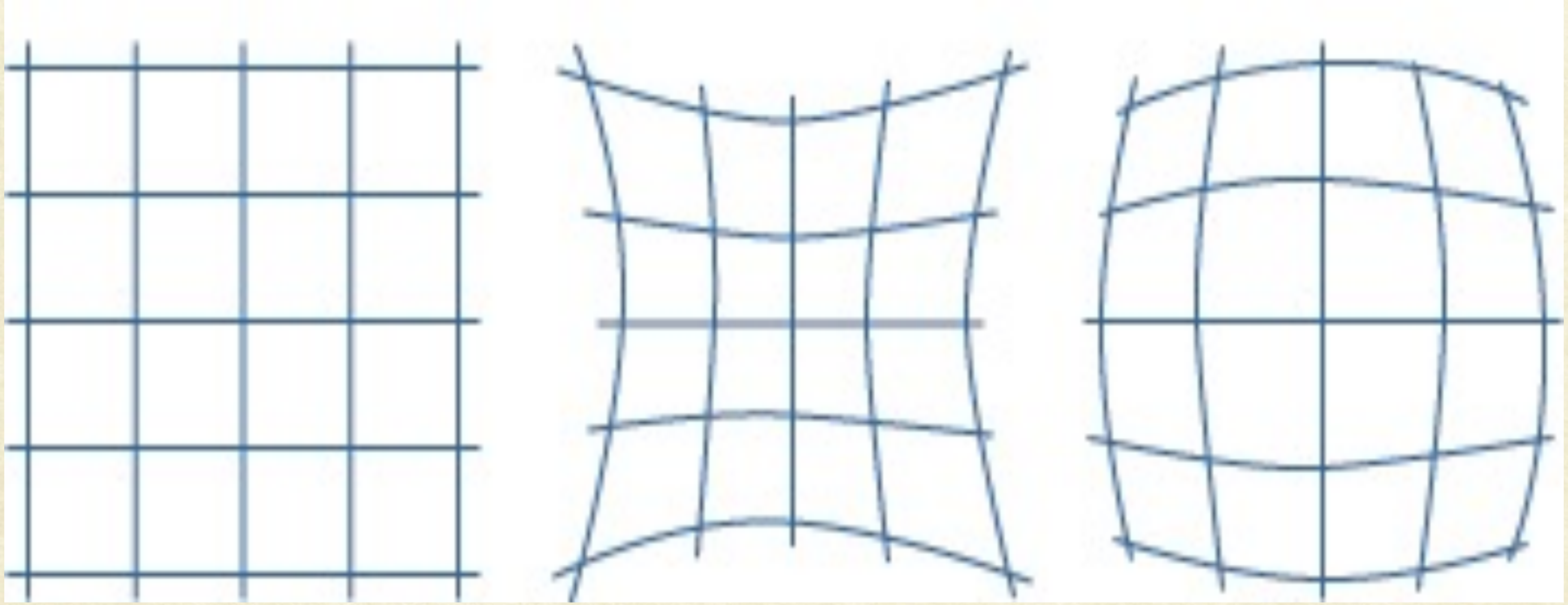


Focal Ratio = $f\,/\,d$

Aperture vs. DOF



Geometric Distortions



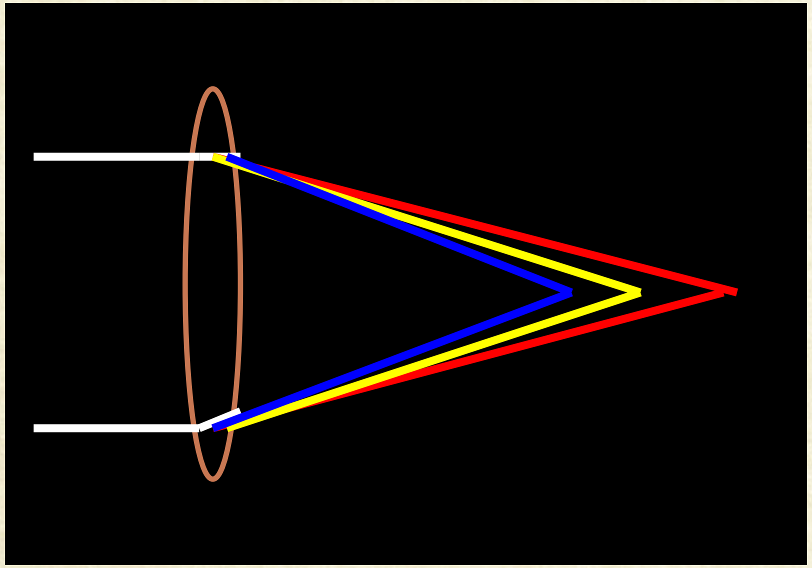
original pincushion barrel

Geometric Distortions

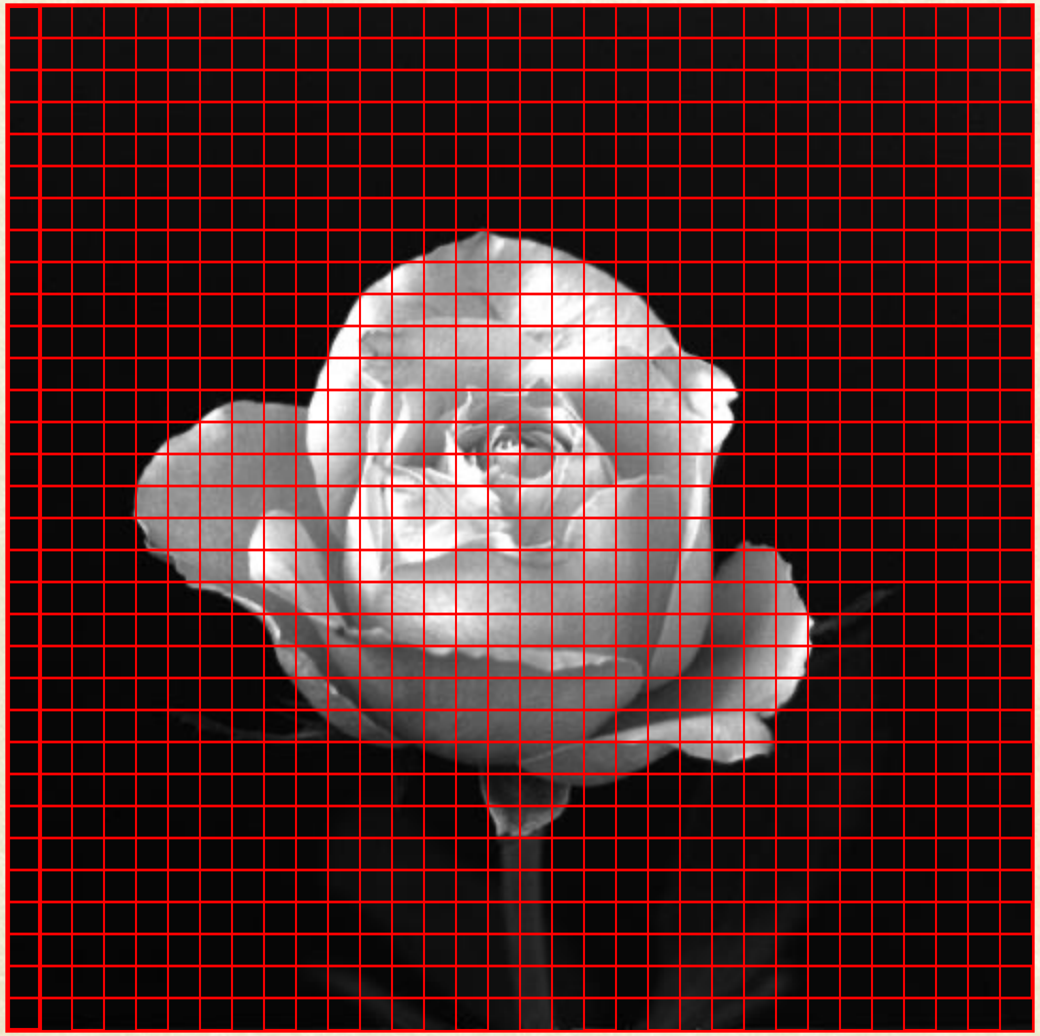
Lens Flare

Chromatic Aberration

Normal lenses diffract different wavelengths to different degree



Sampling an Image: Resolution



Resolution

- The number of samples in an image (number of sensor elements) is referred to as its resolution
- The resolution is typically represented as the product of number of samples in the horizontal and vertical directions in the image. e.g.: 32x32, 256x256, 640x480

<u>Common Resolutions:</u>

NTSC:	648 x 486
Typical Webcam:	1280 x 720
High-end SLR:	11,648 × 8,736 *
Hubbles Telescope:	1,600 x 1,600

Fujifilm GFX100

Camera Model: Objectives

- Mathematically model what a camera does
  - Also understand what the model means
- Getting the model for a real-world camera
  - Estimation from real world measurements
- Special imaging configurations with simpler properties
  - Simpler relationships
- General theory on fitting linear models under noisy observations
  - Techniques that work across problems

What does a Camera do?

- Form an image on the 2D image plane of the 3D world visible to it.
- Image is *behind* the lens; the scene is in front.
- 3D world is **projected** down to a 2D plane.
- Significant loss of information as one dimension is dropped.
- Mathematical depiction of this projection ...

Questions?