

# Wrap-up



# Course announcements

- Homework 7 is due on Sunday 6<sup>th</sup>.
  - Any questions about homework 7?
  - How many of you have looked at/started/finished the homework?
- Everyone gets an extra free late day!
  - You can use it either on homework 7, or retroactively for some old homework to remove the late submission penalty.

# Class evaluation\*s\* – please take them!

- CMU's Faculty Course Evaluations (FCE): <https://cmu.smartevals.com/>
- 16-385 end-of-semester survey:  
[https://docs.google.com/forms/d/e/1FAIpQLSfcIxl17cqIRrZ4uQI-8-d6KMlh2-Q\\_bRZNtBaFzA1o5XLT1A/viewform](https://docs.google.com/forms/d/e/1FAIpQLSfcIxl17cqIRrZ4uQI-8-d6KMlh2-Q_bRZNtBaFzA1o5XLT1A/viewform)
- Please take both, super helpful for developing future offerings of the class.
- Thanks in advance!

# Course overview

- |                           |   |  |
|---------------------------|---|--|
| 1. Image processing.      | ← | Lectures 1 – 7<br>See also 18-793: Image and Video Processing  |
| 2. Geometry-based vision. | ← | Lectures 7 – 12<br>See also 16-822: Geometry-based Methods in Vision   |
| 3. Physics-based vision.  | ← | Lectures 13 – 16<br>See also 16-823: Physics-based Methods in Vision<br>See also 15-463: Computational Photography |
| 4. Semantic vision.       | ← | Lectures 17 – 21<br>See also 16-824: Vision Learning and Recognition   |
| 5. Dealing with motion.   | ← | Lectures 22 – 25<br>See also 16-831: RoboStats   |

# Image processing



Image filtering

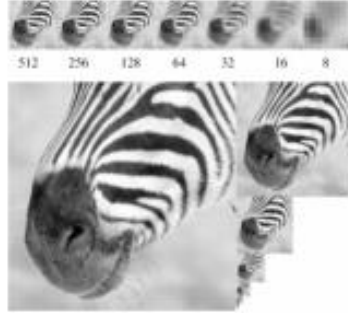


image pyramids



Fourier filtering

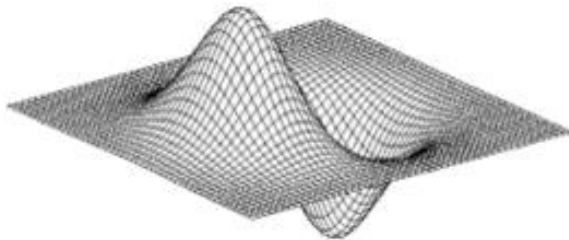
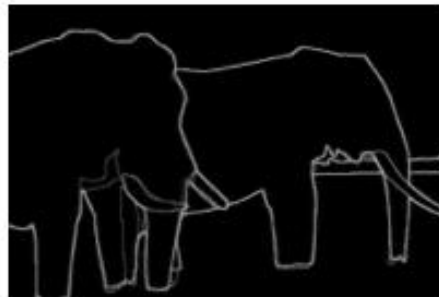
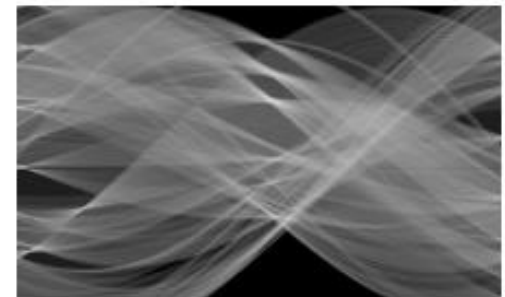


Image gradients



Boundaries



Hough Transform



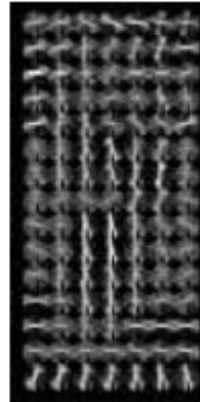
# Image features



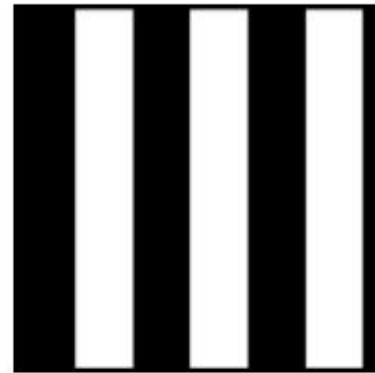
Corner detection    Multi-scale detection



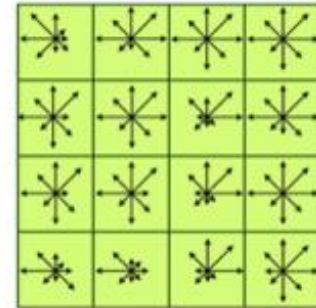
Haar-like



HOG



SURF



SIFT

# 2D alignment

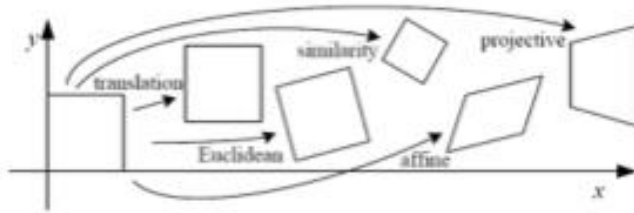


Figure 1: Basic set of 2D planar transformations

2D Transforms



DLT



RANSAC

# H

Homography

# Camera and multi-view geometry

$$x = PX$$

camera matrix

$P$

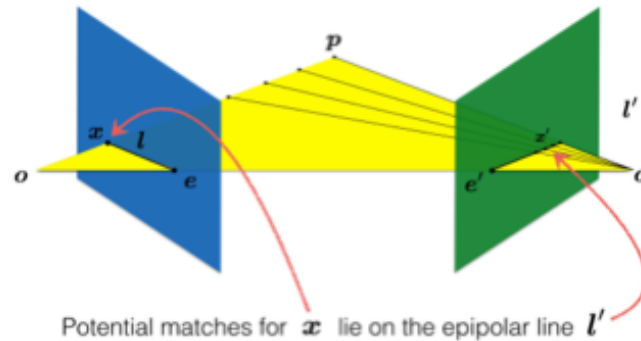
pose estimation

$X$

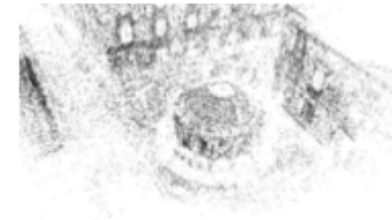
triangulation

$F$

fundamental matrix



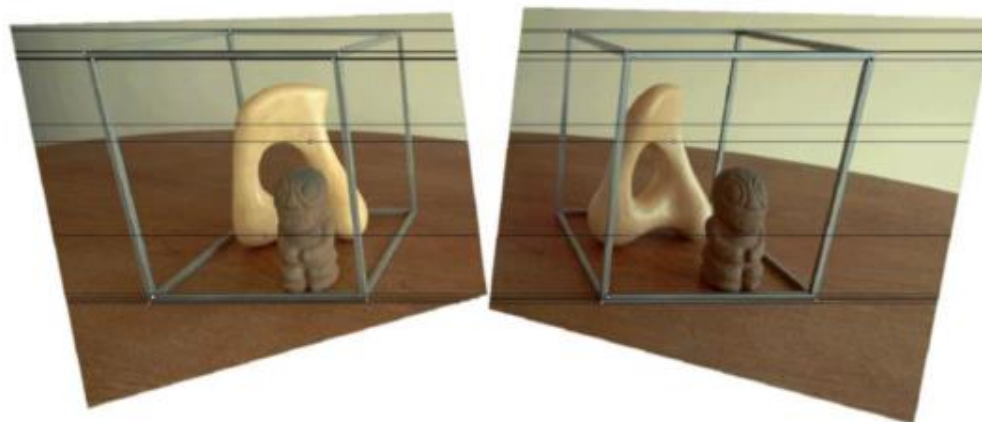
epipolar geometry



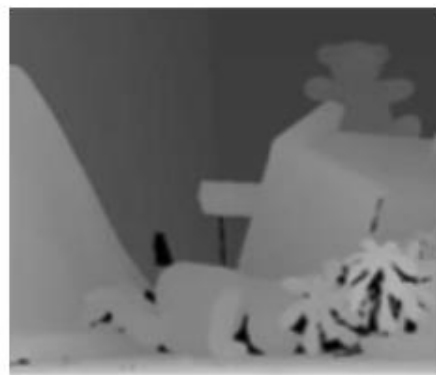
Reconstruction



# Stereo



Stereo Rectification

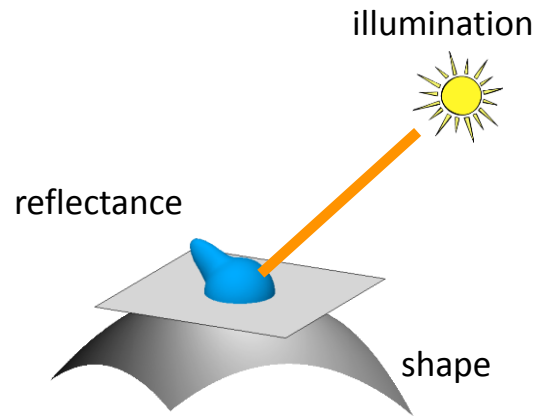


Block matching

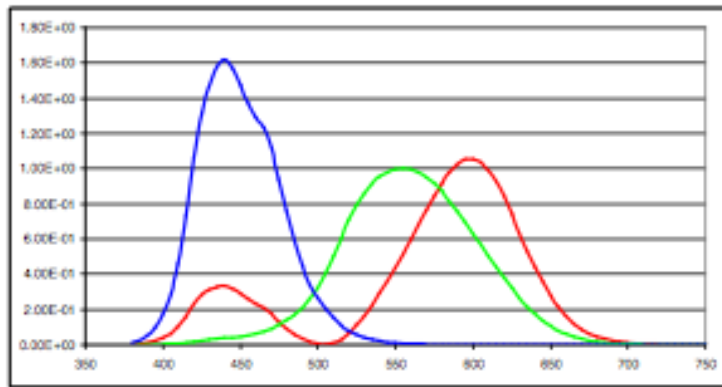


Energy minimization

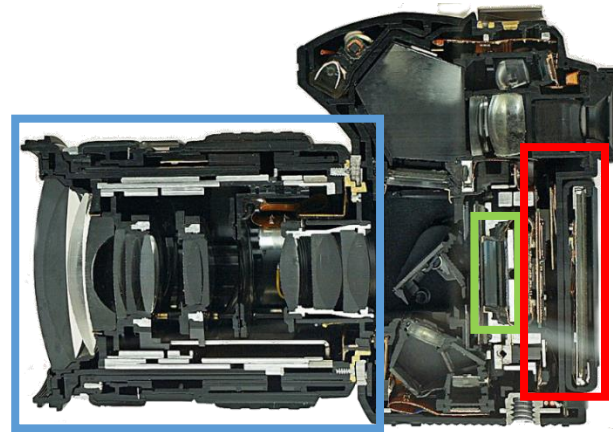
# Image formation and physics



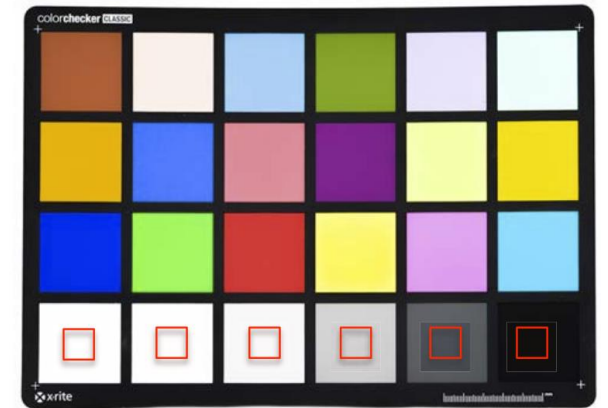
## Radiometry and image formation



## Color and color processing



## Image processing pipeline

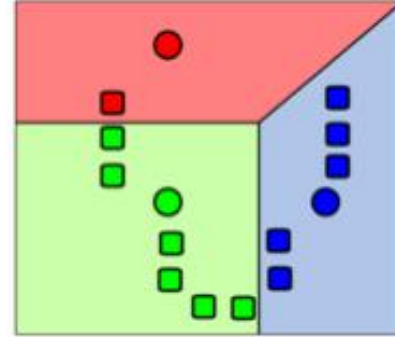


## Radiometric and color calibration

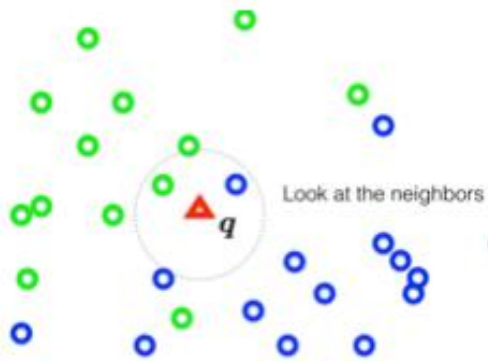
# Object recognition



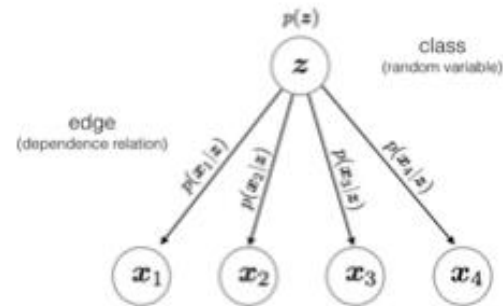
Bag-of-words



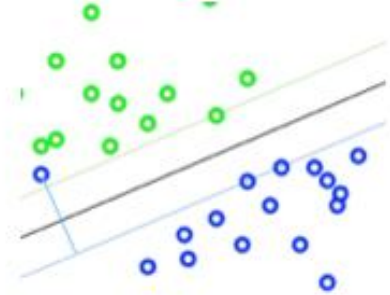
K-means



Nearest Neighbor

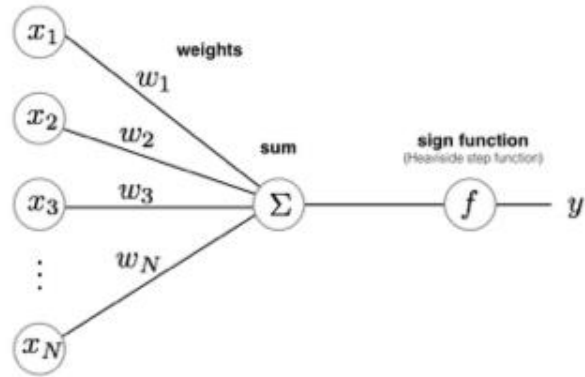


Naive Bayes

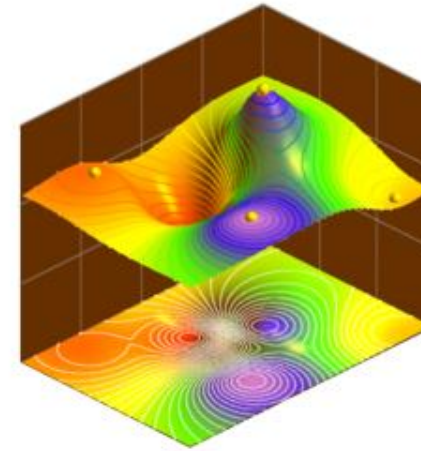


SVM

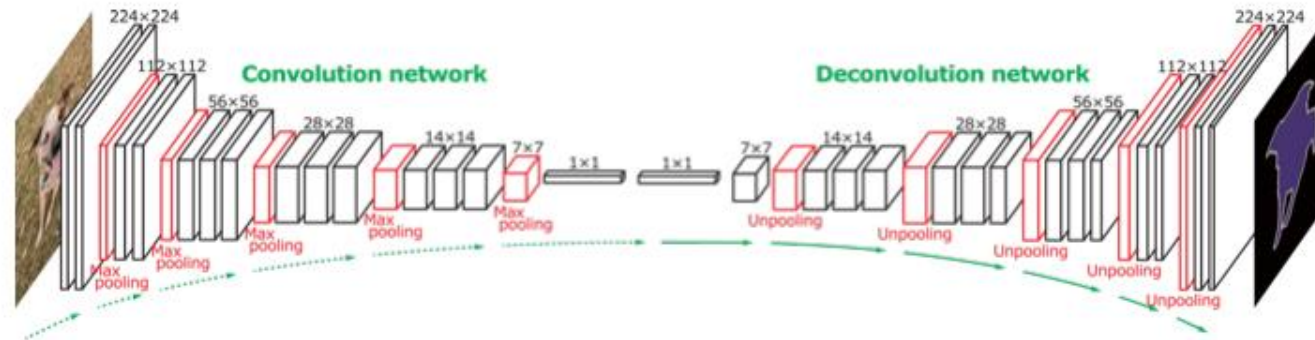
# Neural networks



Perceptron



Gradient Decent



Convolutional Neural Networks

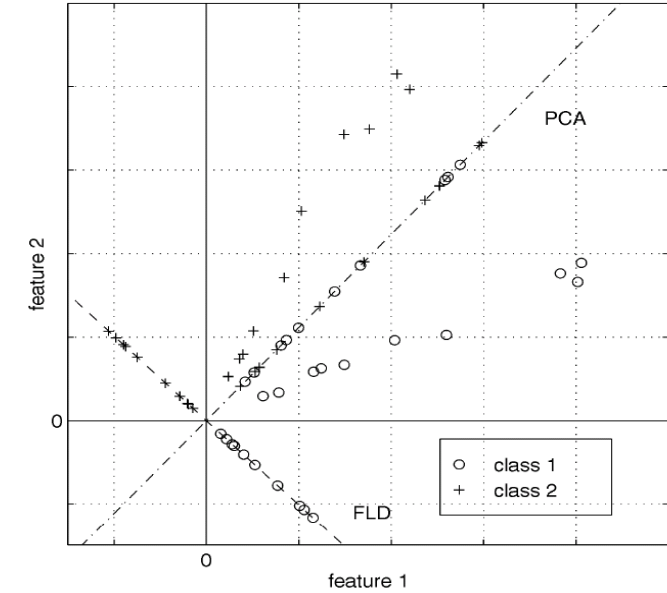
# Face detection and recognition



Eigenfaces



Viola-Jones detector



Fisherfaces



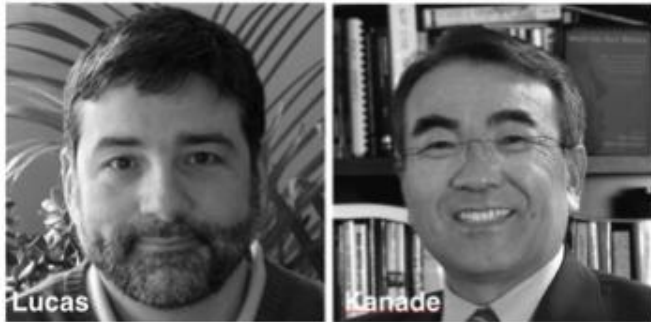
# Optical flow and alignment

$$\begin{bmatrix} I_x(\mathbf{p}_1) & I_y(\mathbf{p}_1) \\ I_x(\mathbf{p}_2) & I_y(\mathbf{p}_2) \\ \vdots & \vdots \\ I_x(\mathbf{p}_{25}) & I_y(\mathbf{p}_{25}) \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} = - \begin{bmatrix} I_t(\mathbf{p}_1) \\ I_t(\mathbf{p}_2) \\ \vdots \\ I_t(\mathbf{p}_{25}) \end{bmatrix}$$

Constant Flow

$$\min_{\mathbf{u}, \mathbf{v}} \sum_{ij} \left\{ E_d(i, j) + \lambda E_s(i, j) \right\}$$

Horn-Schunck



Lucas-Kanade  
(Forward additive)



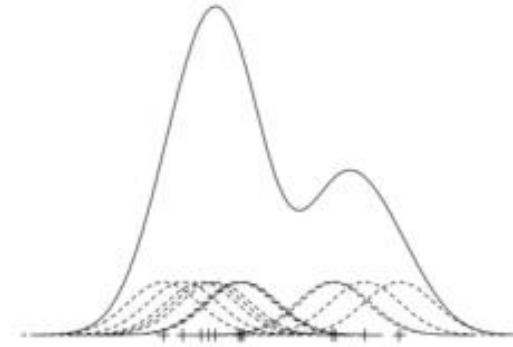
Baker-Matthews  
(Inverse Compositional)



# Tracking in videos



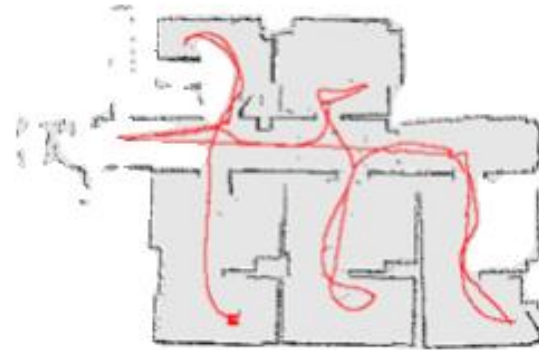
KLT



Mean shift

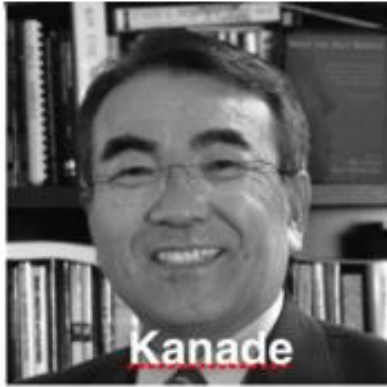


Kalman Filtering

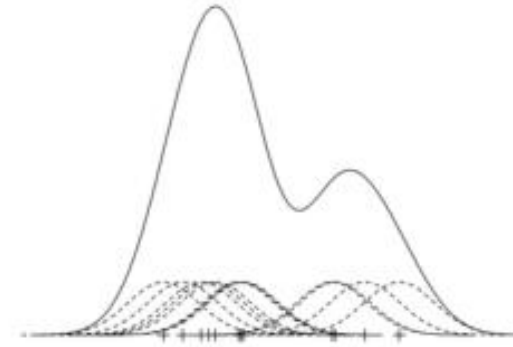


SLAM

# Segmentation



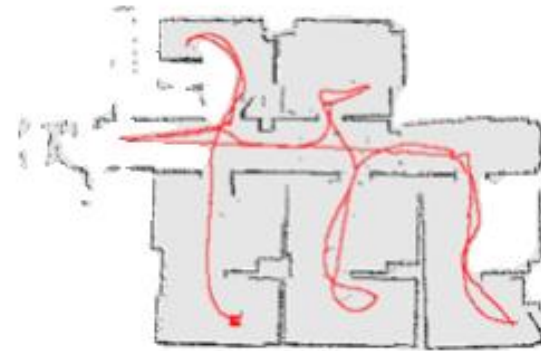
KLT



Mean shift



Kalman Filtering



SLAM

# Things you should know how to do

1. Detect lines (circles, shapes) in an image.
2. Perform automatic image warping and basic AR.
3. Reconstruct 3D scene structure from two images.
4. Do photometric stereo and render simple images.
5. Recognize objects using a bag-of-words model.
6. Recognize objects using deep CNNs.
7. Track objects in video.

Questions?

Do you plan on taking any other vision courses?

Which part of the class did you like the most?



Which part of the class did you like the least?

Any topics you wanted to learn more about?

Any topics you wanted to learn less about?

Would the class work better if we did learning first?

Which was your favorite homework?

Which was your least favorite homework?



How does homework difficulty compare to other classes?

Would it be better if homeworks were in Python?