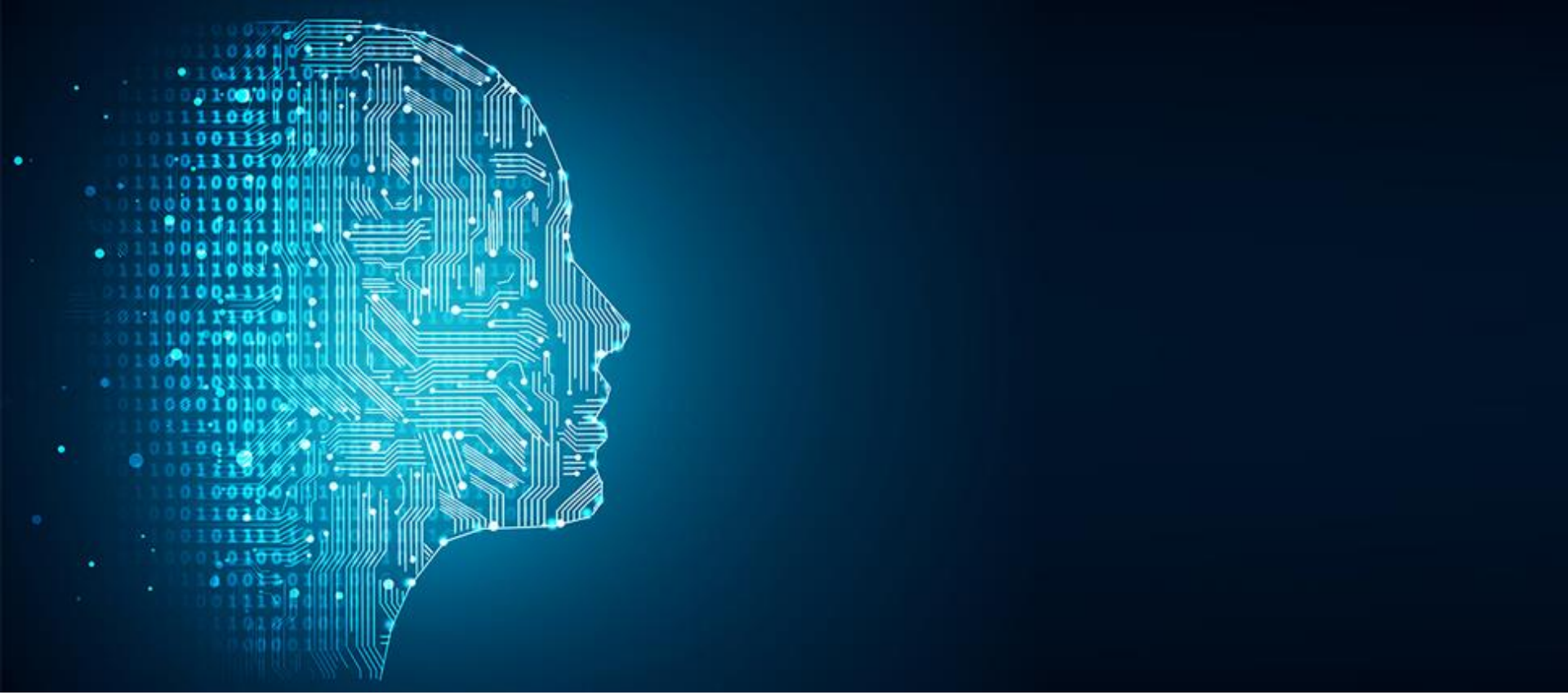


COMP SCI 1400
AI Technologies

Computer Vision Intro

Dr. Kamal Mammadov

What is CV

Supervised Learning

x

f

"Cat"

y

x_1:  y_1:"Cat"

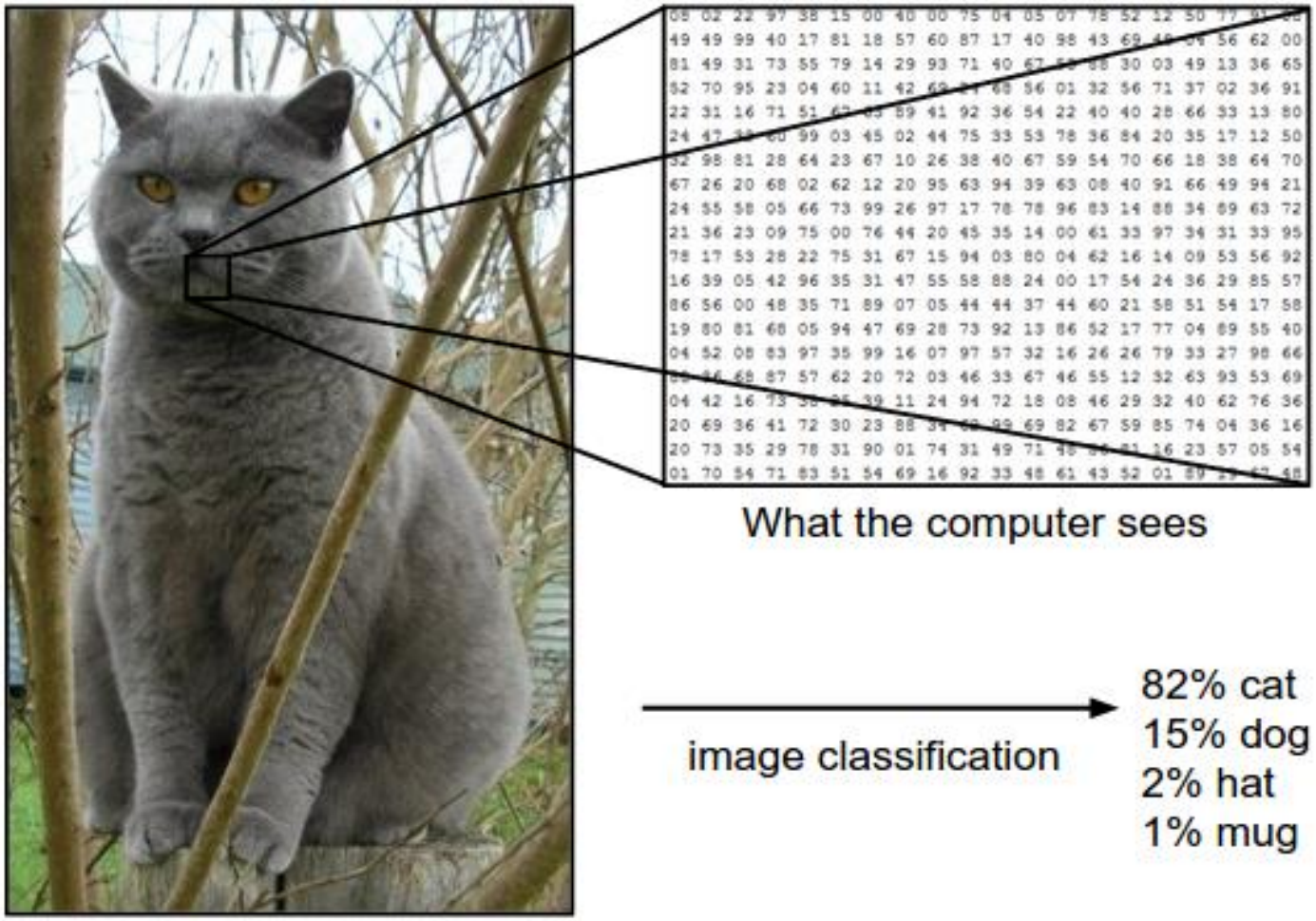
x_2:  y_2:"Cat"

x_3:  y_3:"Dog"

x_4:  y_4:"Dog"

Labelled Data

Digital images



Three Categories of Tasks in CV

Computer Vision: Stages

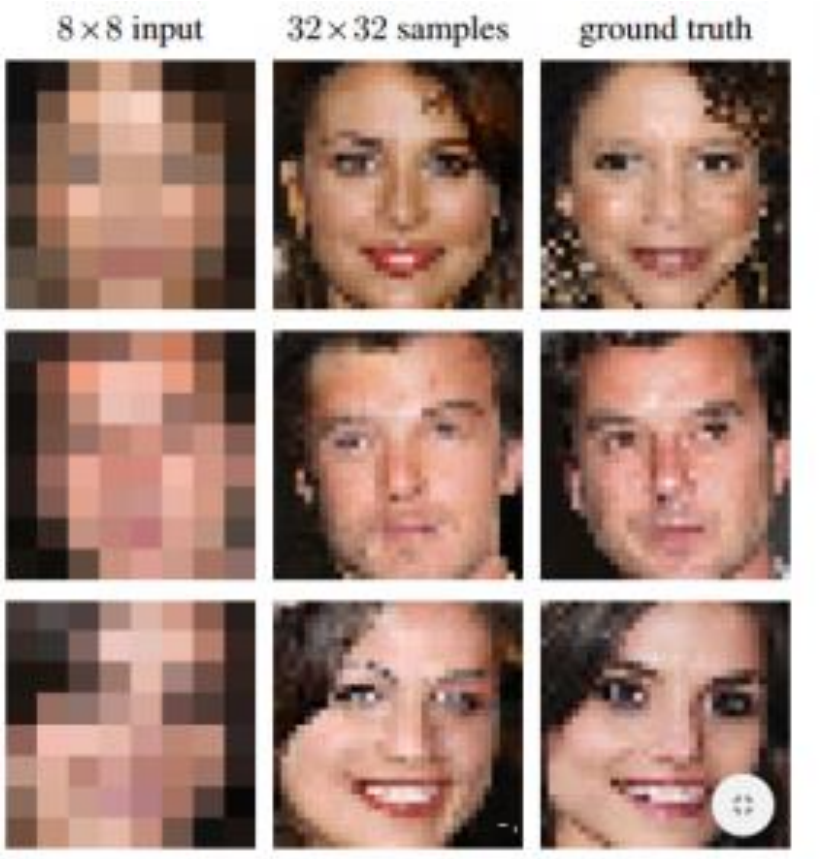
- Image formation
- Low-level
  - Single image processing
  - Multiple views
- Mid-level
  - Estimation, segmentation (main topic of Image Analysis and Foundations of Image Analysis and will only be covered briefly here)
- High-level
  - Recognition
  - Classification

The IT University of Copenhagen

https://slideplayer.com/slide/5146536/

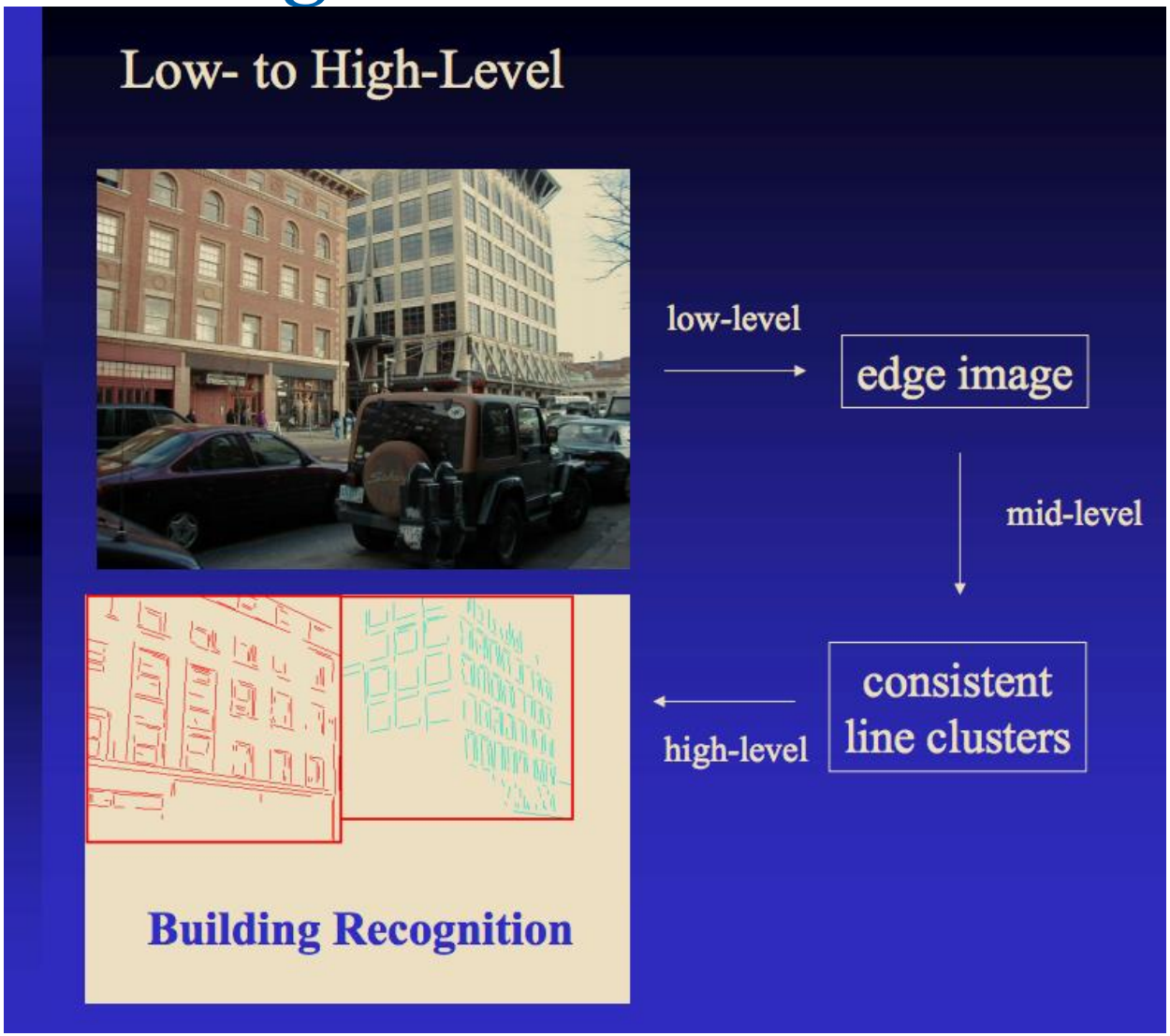
Low level CV --- Denoising

Low level CV --- Super-Resolution



Low level CV --- Dehaze

Three Categories of Tasks in CV



https://courses.cs.washington.edu/courses/cse576/06sp/notes/Basics1.pdf

History of CV

Data --- images

Top row, left to right:
Image by Roger H Goun is licensed under CC BY 2.0
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Image is CC0 1.0 public domain
Image is CC0 1.0 public domain

Middle row, left to right
Image by BGPHP Conference is licensed under CC BY 2.0; changes made
Image is CC0 1.0 public domain
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Image is CC0 1.0 public domain

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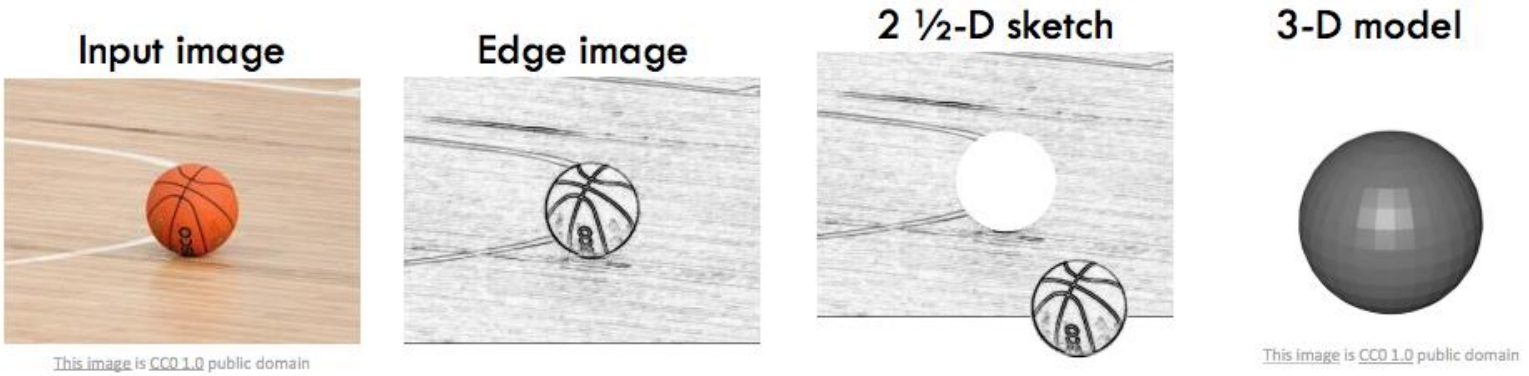
Emerging of Computer Vision



Input Image	Primal Sketch	2 ½-D Sketch	3-D Model Representation
Perceived intensities	Zero crossings, blobs, edges, bars, ends, virtual lines, groups, curves boundaries	Local surface orientation and discontinuities in depth and in surface orientation	3-D models hierarchically organized in terms of surface and volumetric primitives

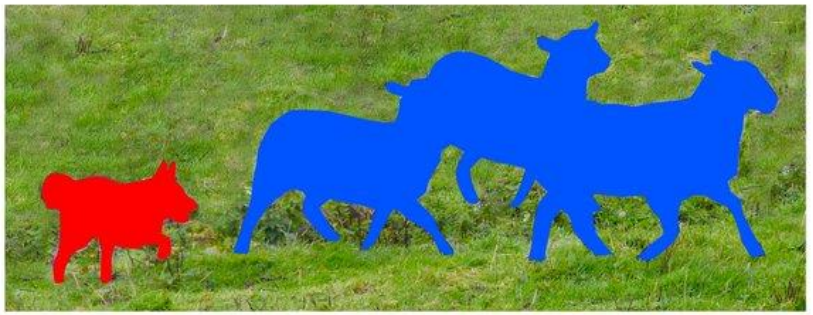
Stages of Visual Representation, David Marr, 1970s

Canny Edge Detector

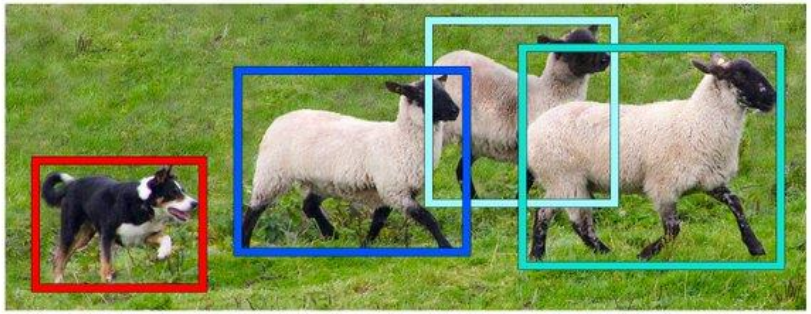
By John F. Canny in 1986

Computer Vision tasks

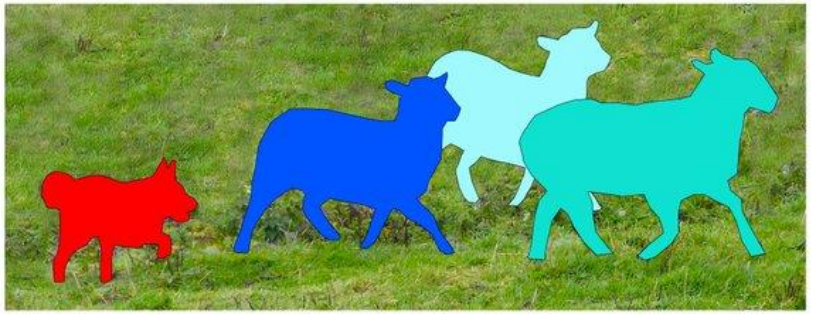
Image Recognition



Semantic Segmentation



Object Detection



Instance Segmentation

History of Computer Vision

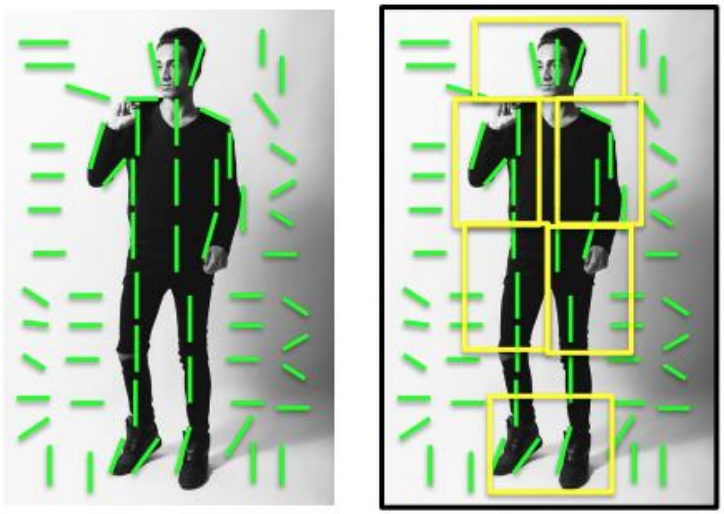
Image is public domain

Image is public domain

"SIFT" & Object Recognition, David Lowe, 1999

History of Computer Vision

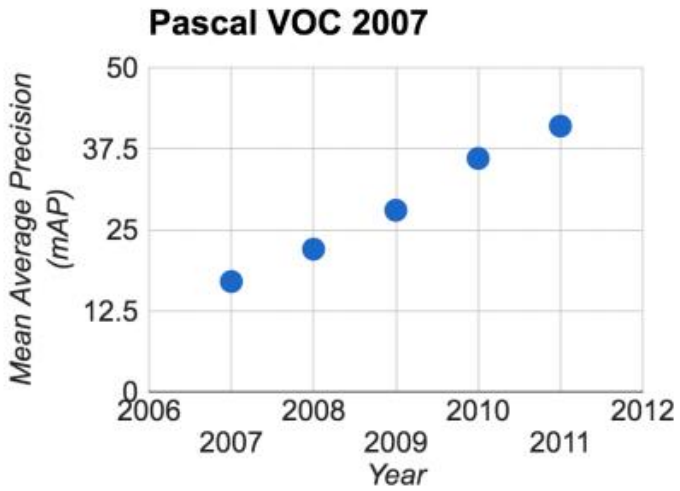
Histogram of Gradients (HoG)
Dalal & Triggs, 2005



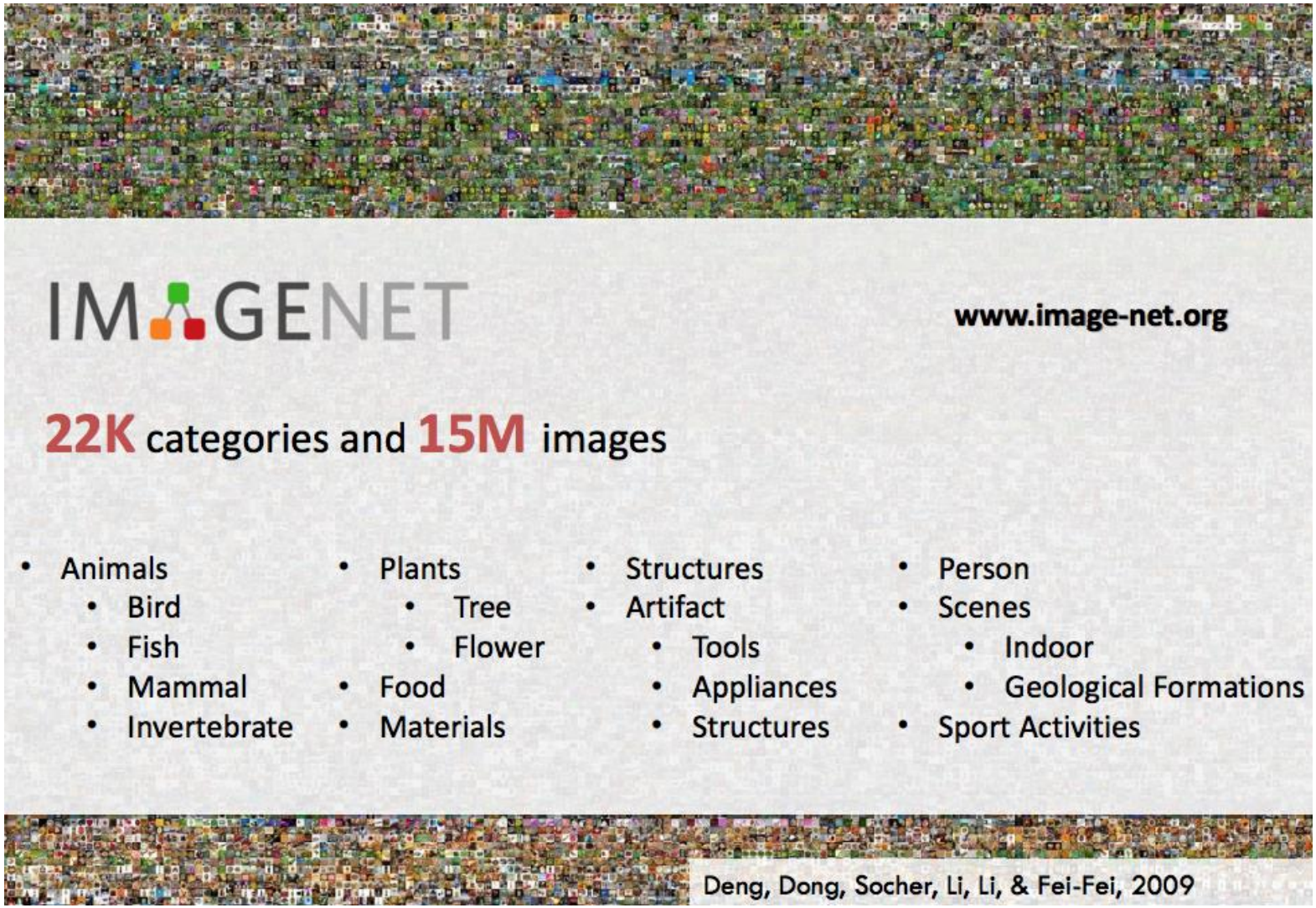
Deformable Part Model
Felzenswalb, McAllester, Ramanan, 2009

History of Computer Vision

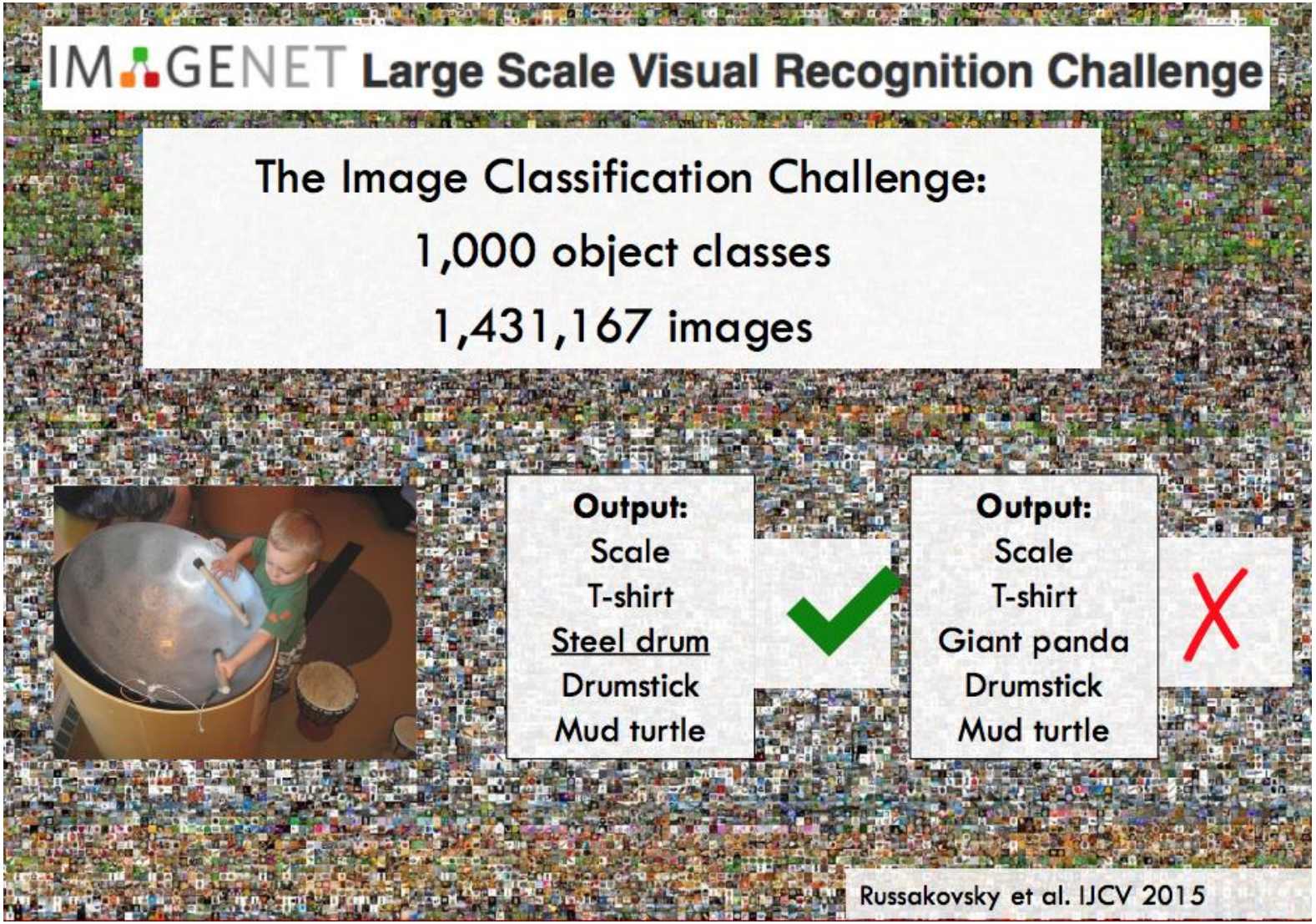
PASCAL Visual Object Challenge
(20 object categories)
[Everingham et al. 2006-2012]



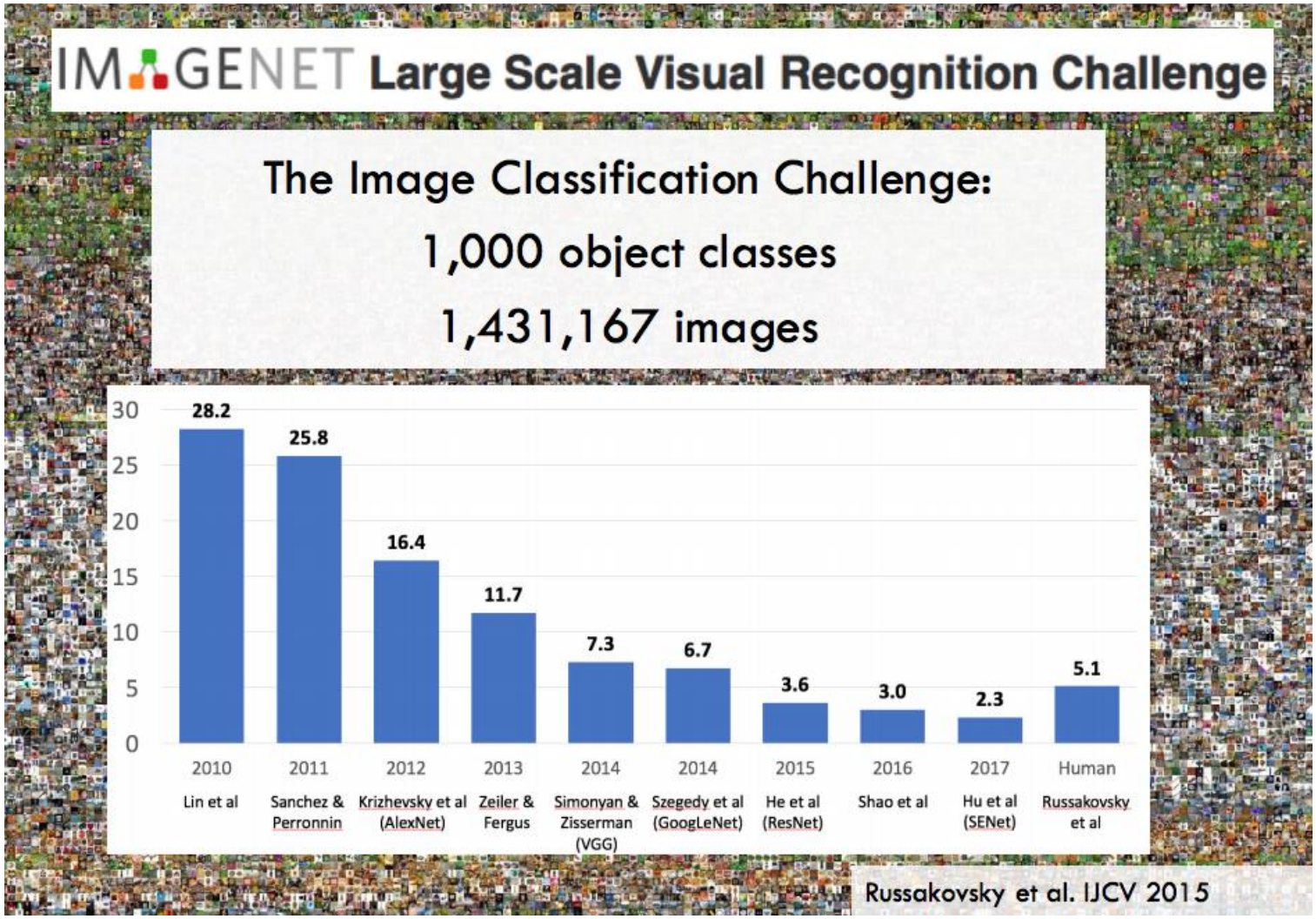
History of Computer Vision



History of Computer Vision

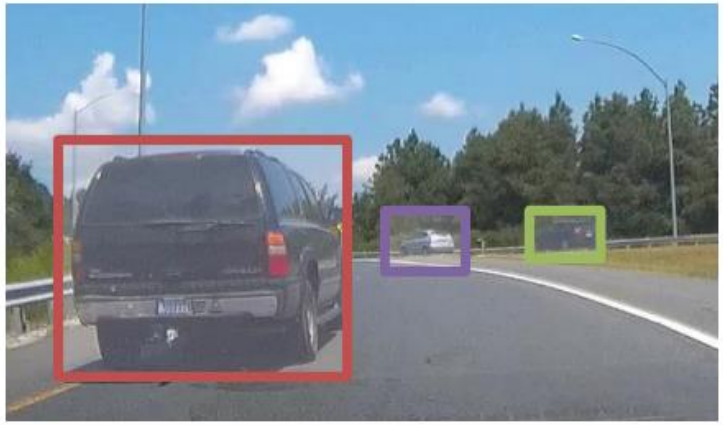


History of Computer Vision

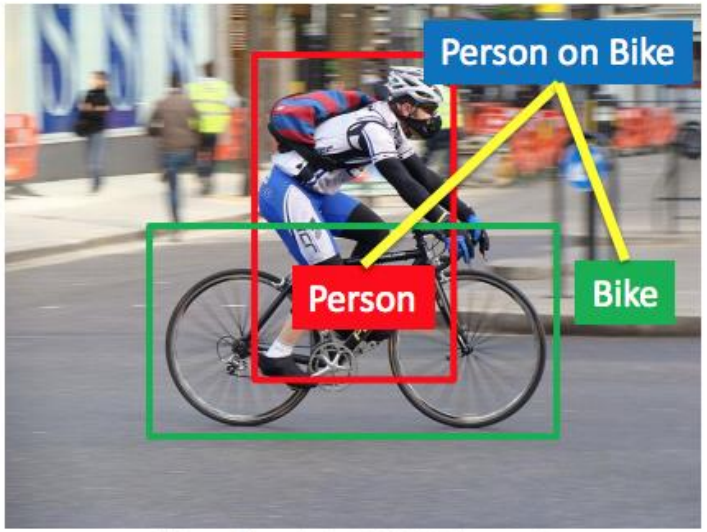


CV Tasks

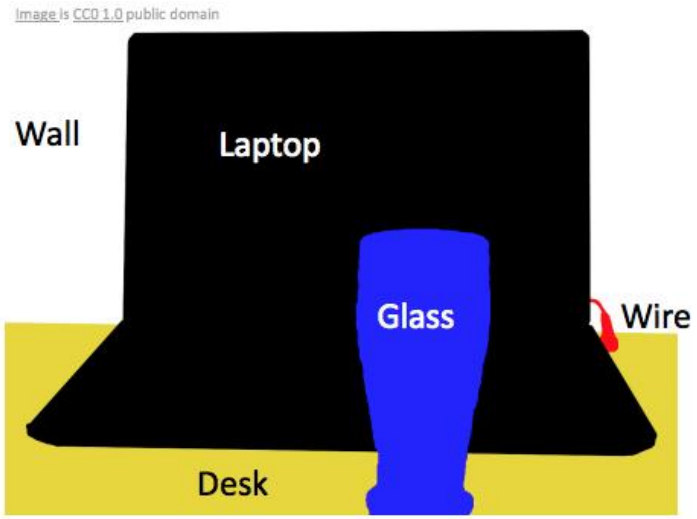
Computer Vision tasks

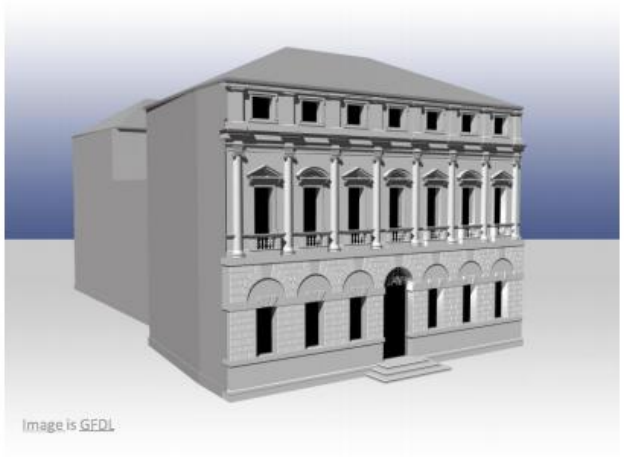


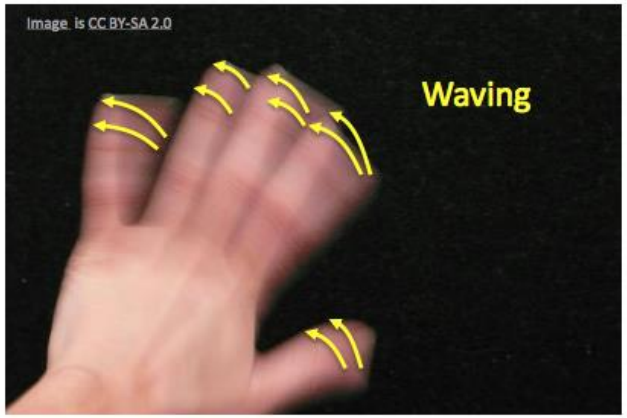
- Object detection
- Action classification
- Image captioning
- ...

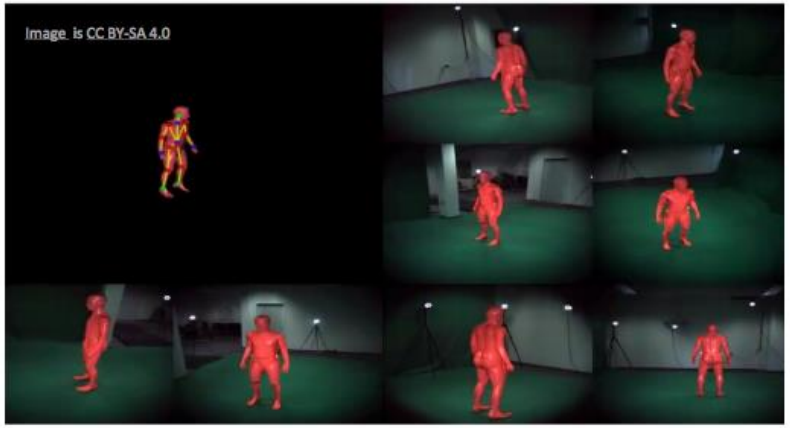


Computer Vision tasks

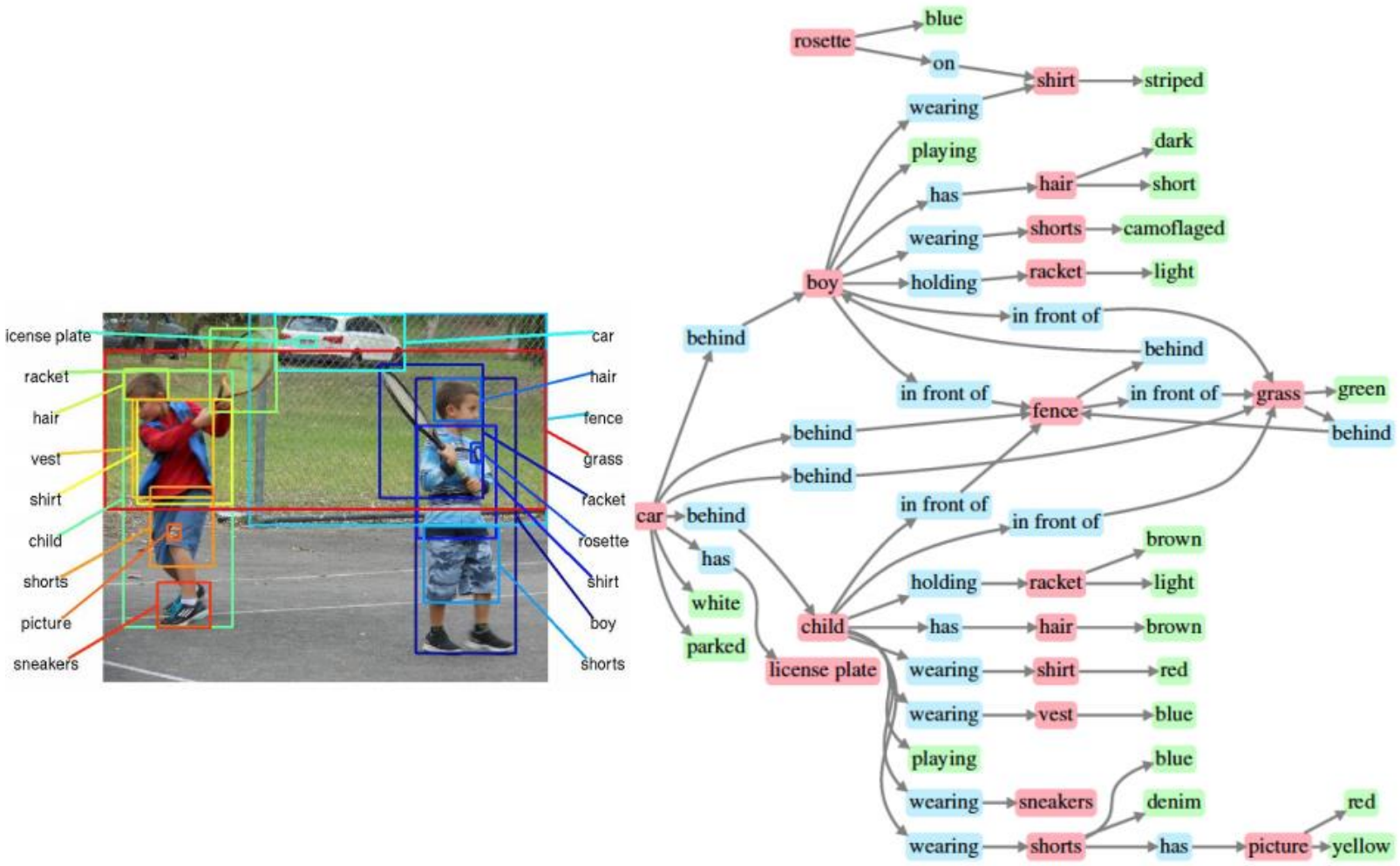








Computer Vision tasks



Johnson *et al.*, "Image Retrieval using Scene Graphs", CVPR 2015

Deep Dream

Style Transfer

Image Classification with KNN

- **Problems**

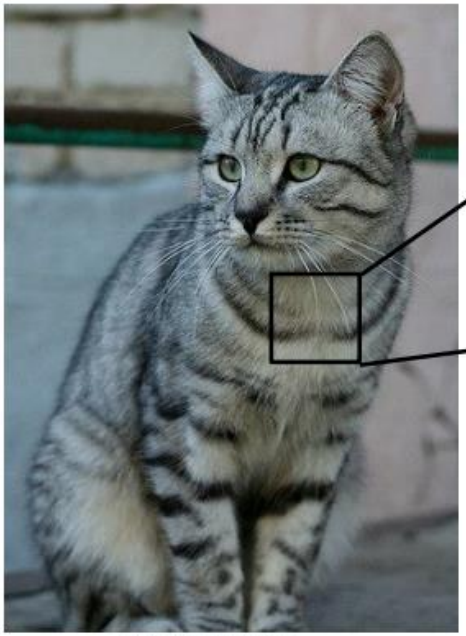
Image Classification: A core task in Computer Vision

(assume given set of discrete labels)
{dog, cat, truck, plane, ...}

cat

- **Problems**

The Problem: Semantic Gap



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```
[[105 112 108 111 104  99 106  99  96 103 112 119 104  97  93  87]
 [ 91  98 102 106 104  79  98 103  99 105 123 136 110 105  94  85]
 [ 76  85  90 105 128 105  87  96  95  99 115 112 106 103  99  85]
 [ 99  81  81  93 120 131 127 100  95  98 102  99  96  93 101  94]
 [106  91  61  64  69  91  88  85 101 107 109  98  75  84  96  95]
 [114 108  85  55  55  69  64  54  64  87 112 129  98  74  84  91]
 [133 137 147 103  65  81  80  65  52  54  74  84 102  93  85  82]
 [128 137 144 140 109  95  86  70  62  65  63  63  60  73  86 101]
 [125 133 148 137 119 121 117  94  65  79  80  65  54  64  72  98]
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 [115 114 109 123 150 148 131 118 113 109 100  92  74  65  72  78]
 [ 89  93  90  97 108 147 131 118 113 114 113 109 106  95  77  80]
 [ 63  77  86  81  77  79 102 123 117 115 117 125 125 130 115  87]
 [ 62  65  82  89  78  71  80 101 124 126 119 101 107 114 131 119]
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 [122 121 102  80  82  86  94 117 145 148 153 102  58  78  92 107]
 [122 164 148 103  71  56  78  83  93 103 119 139 102  61  69  84]]
```
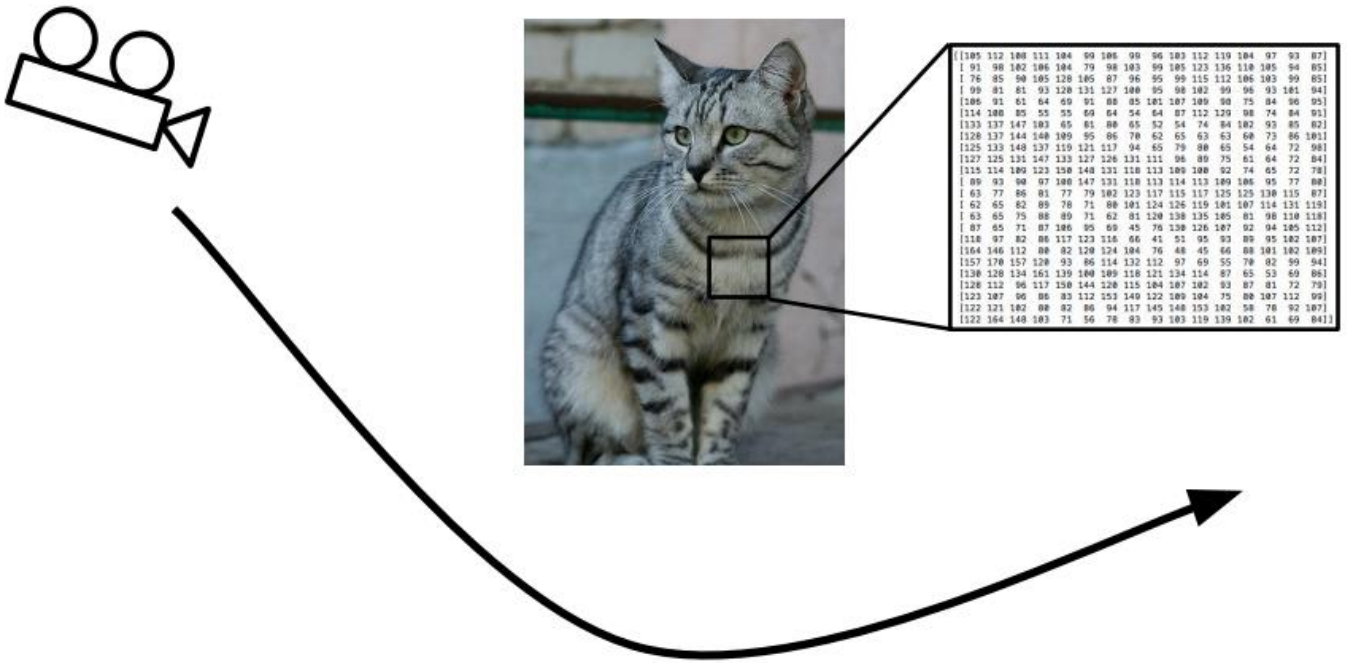

What the computer sees

An image is just a big grid of numbers between [0, 255]:

e.g. 800 x 600 x 3
(3 channels RGB)

Challenges: Viewpoint variation



Challenges: Background Clutter

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This image is CC0 1.0 public domain

Challenges: Illumination

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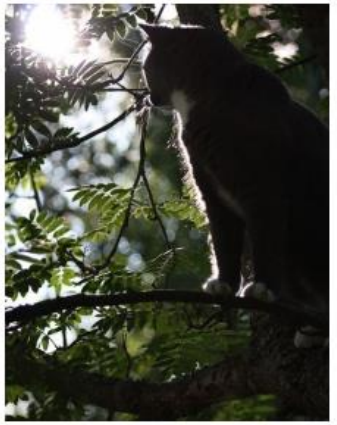
This image is CC0 1.0 public domain

This image is CC0 1.0 public domain



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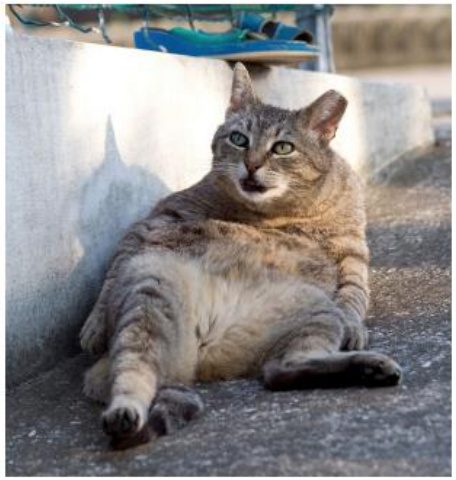
Challenges: Deformation



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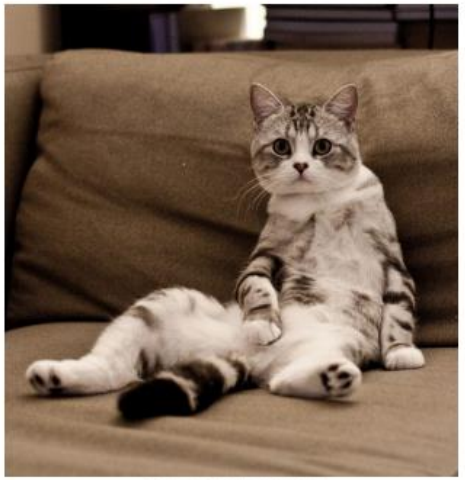

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Challenges: Occlusion

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Challenges: Intraclass variation

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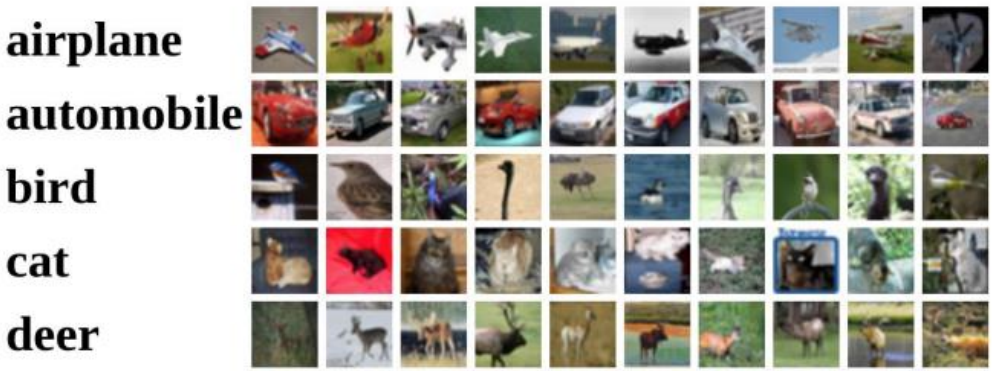
Machine Learning: Data-Driven Approach

1. Collect a dataset of images and labels
2. Use Machine Learning to train a classifier
3. Evaluate the classifier on new images

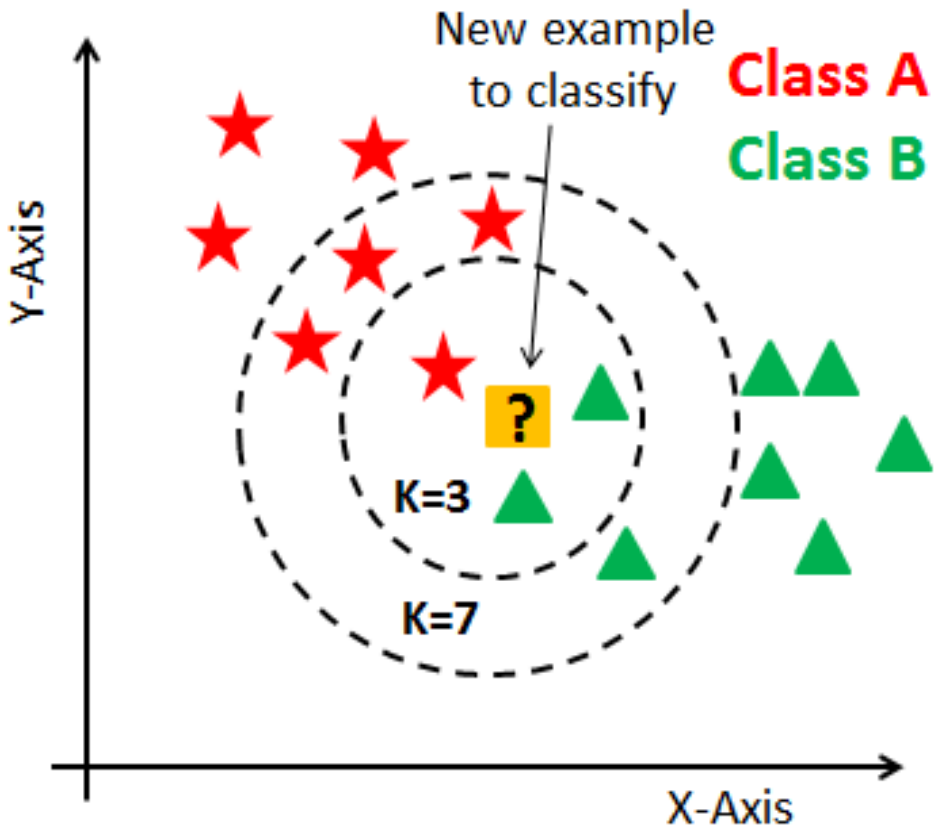
```
def train(images, labels):
  # Machine learning!
  return model
```

```
def predict(model, test_images):
  # Use model to predict labels
  return test_labels
```

Example training set

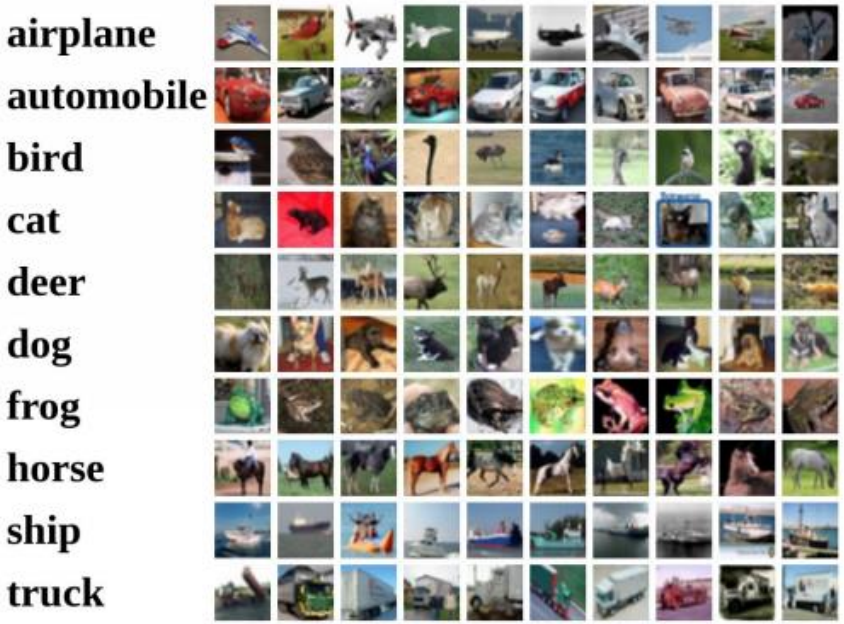


KNN



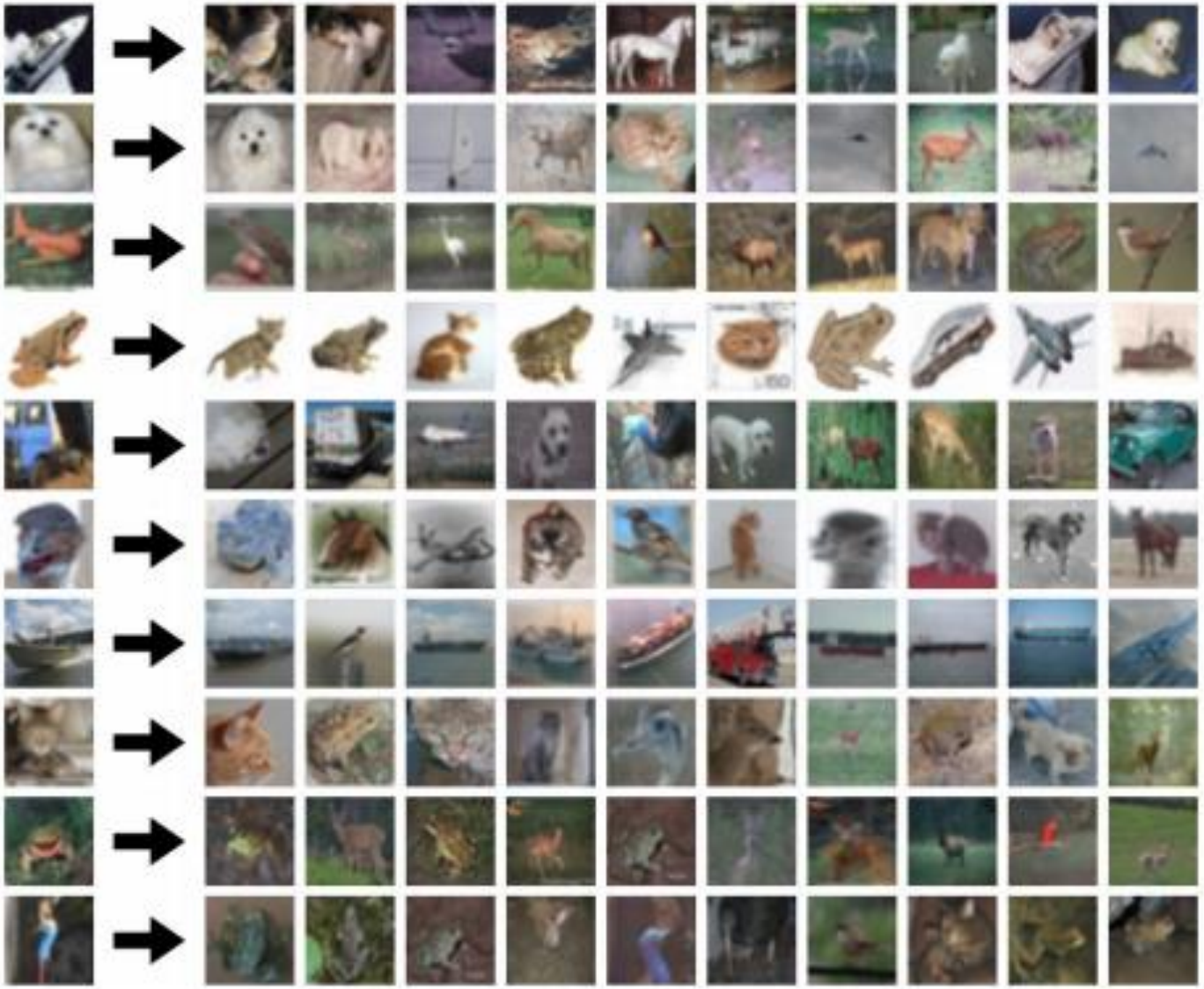
Example Dataset: **CIFAR10**

10 classes
50,000 training images
10,000 testing images



Alex Krizhevsky, "Learning Multiple Layers of Features from Tiny Images", Technical Report, 2009.

Test images and nearest neighbors



KNN classifier implementation

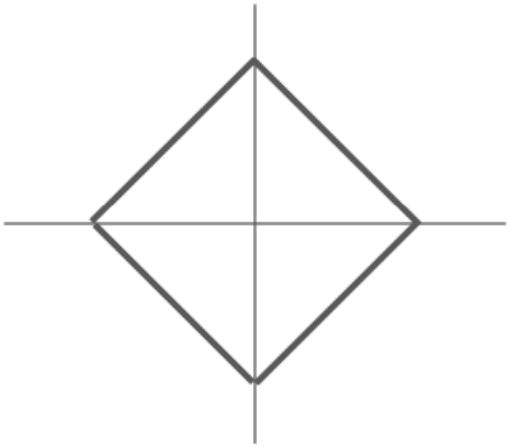
```python
import numpy as np

class NearestNeighbor:
  def __init__(self):
    pass

  def train(self, X, y):
    """ X is N x D where each row is an example. Y is 1-dimension of size N """
    # the nearest neighbor classifier simply remembers all the training data
    self.Xtr = X
    self.ytr = y

  def predict(self, X):
    """ X is N x D where each row is an example we wish to predict label for """
    num_test = X.shape[0]
    # lets make sure that the output type matches the input type
    Ypred = np.zeros(num_test, dtype = self.ytr.dtype)

    # loop over all test rows
    for i in xrange(num_test):
      # find the nearest training image to the i'th test image
      # using the L1 distance (sum of absolute value differences)
      distances = np.sum(np.abs(self.Xtr - X[i,:]), axis = 1)
      min_index = np.argmin(distances) # get the index with smallest distance
      Ypred[i] = self.ytr[min_index] # predict the label of the nearest example

    return Ypred
```

Nearest Neighbor classifier

K-Nearest Neighbors: Distance Metric

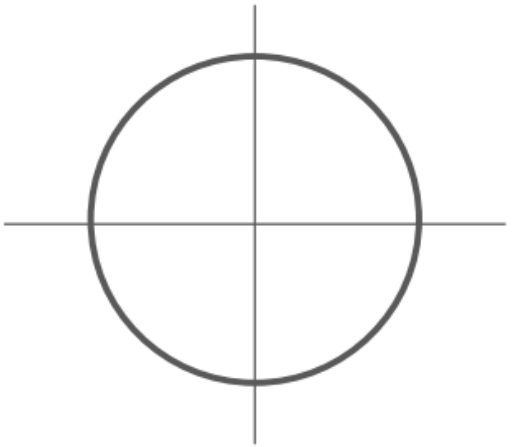
L1 (Manhattan) distance

$$d_1(I_1, I_2) = \sum_p |I_1^p - I_2^p|$$



L2 (Euclidean) distance

$$d_2(I_1, I_2) = \sqrt{\sum_p \left(I_1^p - I_2^p\right)^2}$$



k-Nearest Neighbor on images **never used.**

- Very slow at test time
- Distance metrics on pixels are not informative

(all 3 images have same L2 distance to the one on the left)

Reference

- Cs231n Stanford University Tutorial

  http://cs231n.stanford.edu/

  https://www.youtube.com/watch?v=vT1JzLTH4G4

- Canny edge detector

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