Recognition:
A machine learning approach

Slides adapted from Fei-Fei Li, Rob Fergus, Antonio Torralba, Kristen Grauman, and Derek Hoiem

The machine learning framework

- Apply a prediction function to a feature representation of the image to get the desired output:

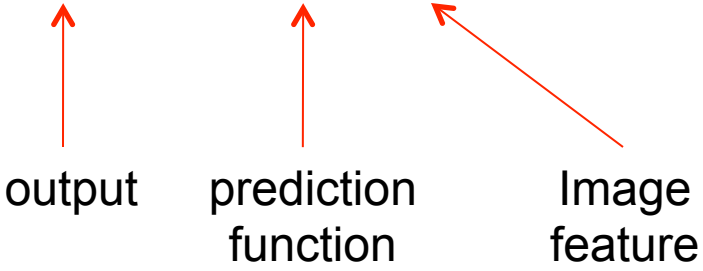
f() = “apple”

f() = “tomato”

f() = “cow”

The machine learning framework

$$y = f(\mathbf{x})$$



- **Training:** given a *training set* of labeled examples $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$, estimate the prediction function f by minimizing the prediction error on the training set
- **Testing:** apply f to a never before seen *test example* $\mathbf{x}$ and output the predicted value $y = f(\mathbf{x})$

Steps

Training

Training Images

Training Labels

Image Features

Training

Learned model

Testing

Test Image

Image Features

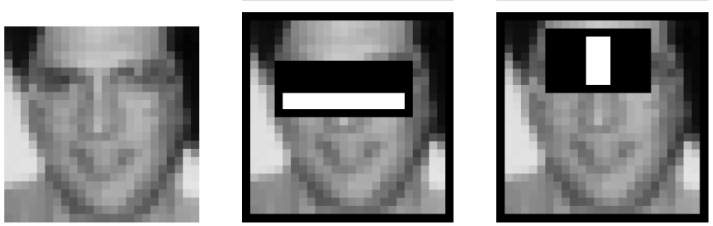
Learned model

Prediction

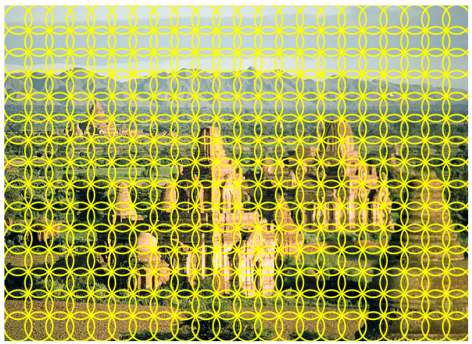
Slide credit: D. Hoiem

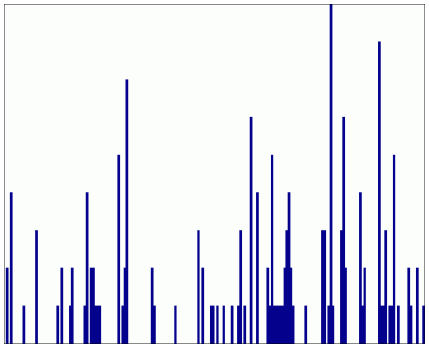
Features (examples)

- Raw pixels (and simple functions of raw pixels)

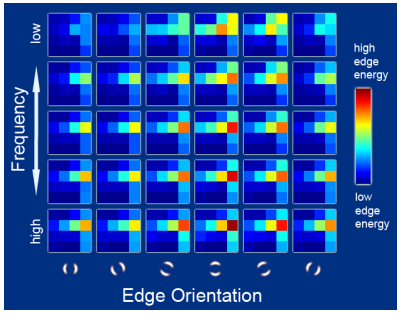


- Histograms, bags of features

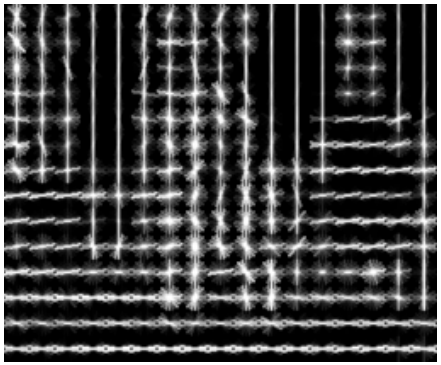




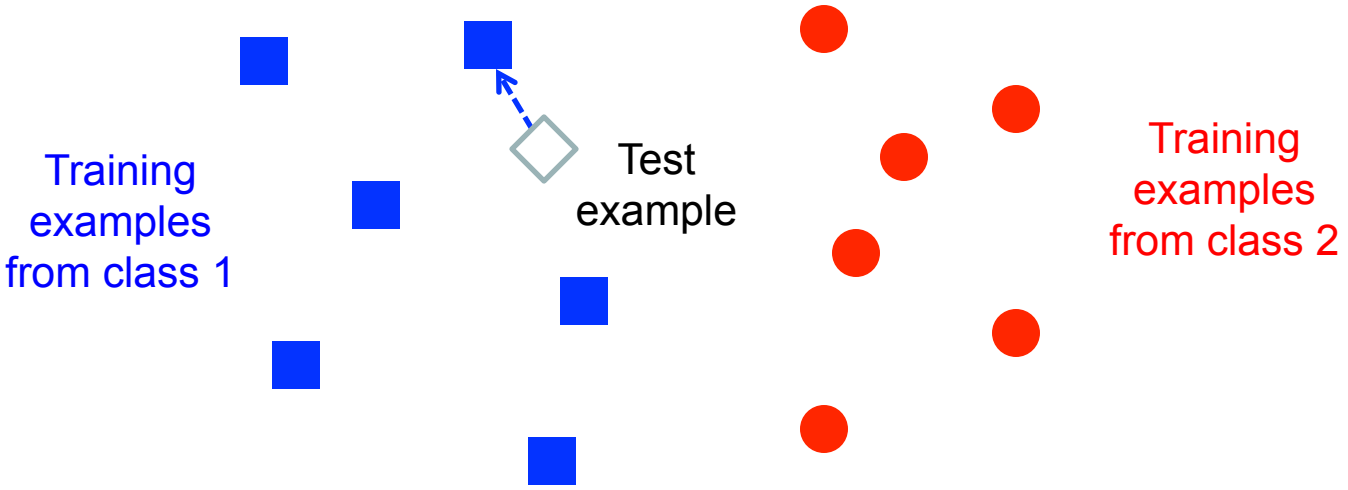
- GIST descriptors



- Histograms of oriented gradients (HOG)



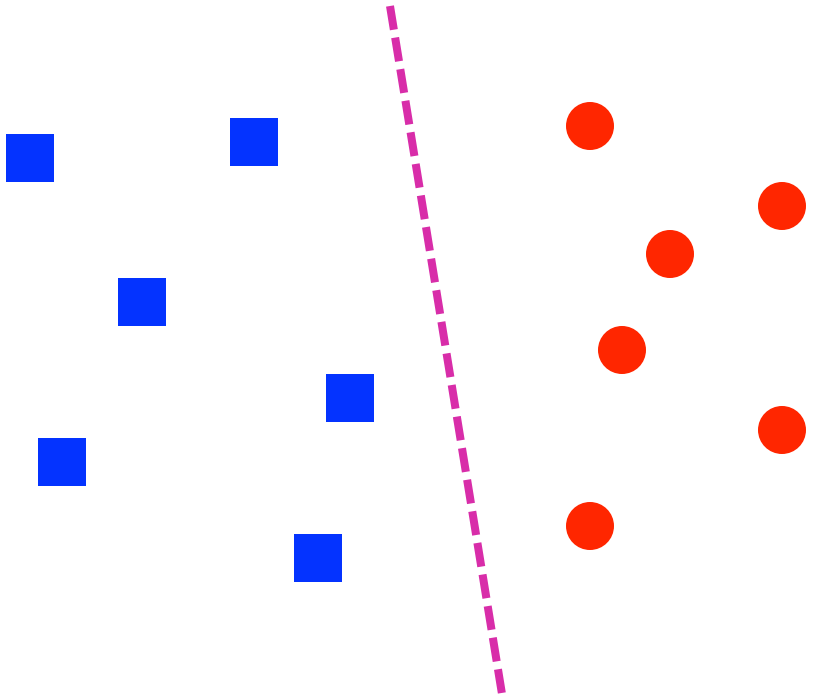
Classifiers: Nearest neighbor



f(**x**) = label of the training example nearest to **x**

- All we need is a distance function for our inputs
- No training required!

Classifiers: Linear



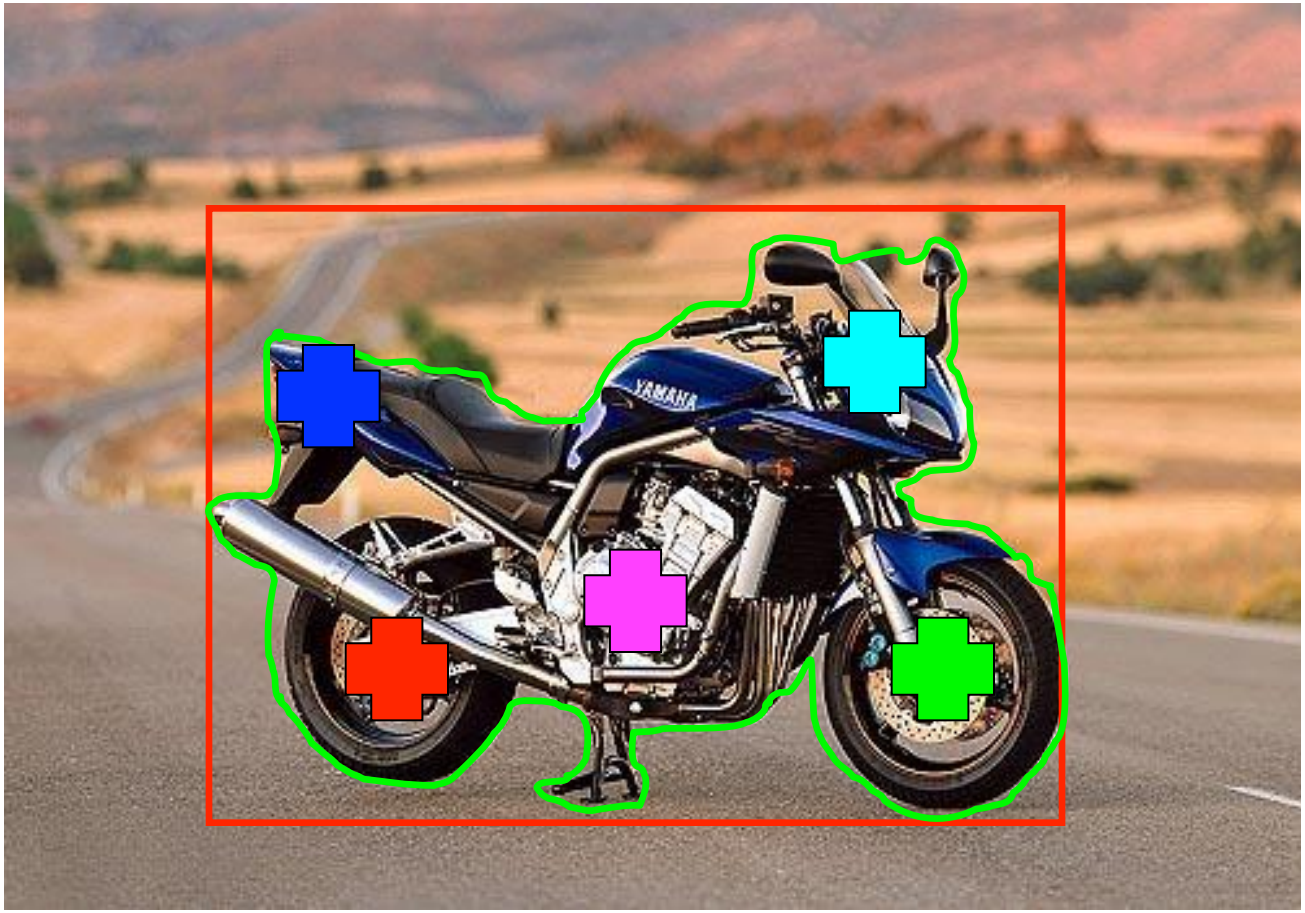
- Find a *linear function* to separate the classes:

$$f(\mathbf{x}) = \text{sgn}(\mathbf{w} \cdot \mathbf{x} + b)$$

Recognition task and supervision

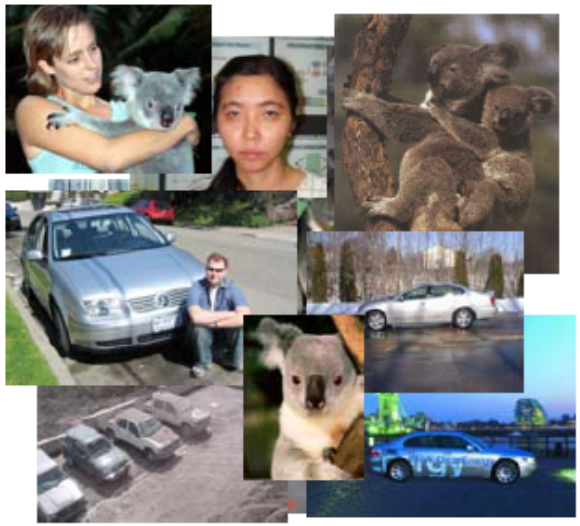
- Images in the training set must be annotated with the "correct answer" that the model is expected to produce

Contains a motorbike

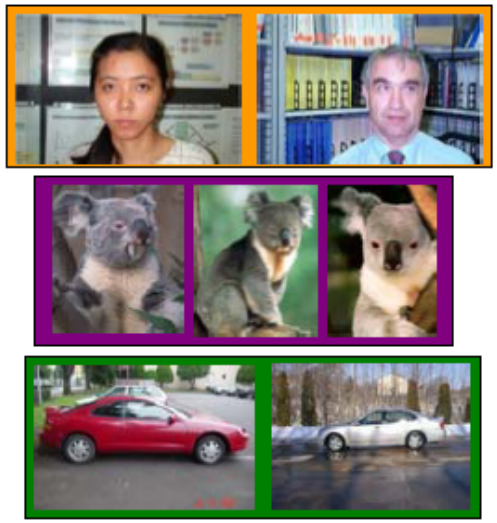


Spectrum of supervision

Less — More



Unsupervised



"Weakly" supervised

Fully supervised

Definition depends on task

Generalization

Training set (labels known)

Test set (labels unknown)

- How well does a learned model *generalize* from the data it was trained on to a new test set?

Diagnosing generalization ability

- **Training error:** how well does the model perform at prediction on the data on which it was trained?
- **Test error:** how well does it perform on a never before seen test set?
- Training and test error are both *high*: **underfitting**
  - Model does an equally poor job on the training and the test set
  - Either the training procedure is ineffective or the model is too "simple" to represent the data
- Training error is *low* but test error is *high*: **overfitting**
  - Model has fit irrelevant characteristics (noise) in the training data
  - Model is too complex or amount of training data is insufficient

Underfitting and overfitting

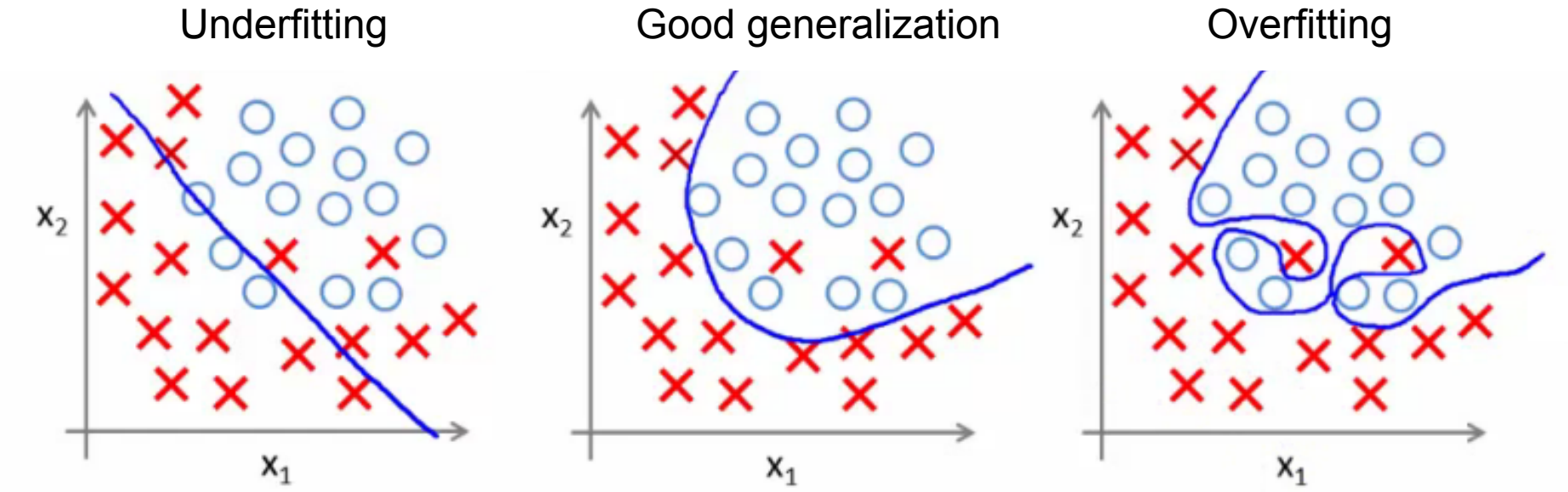
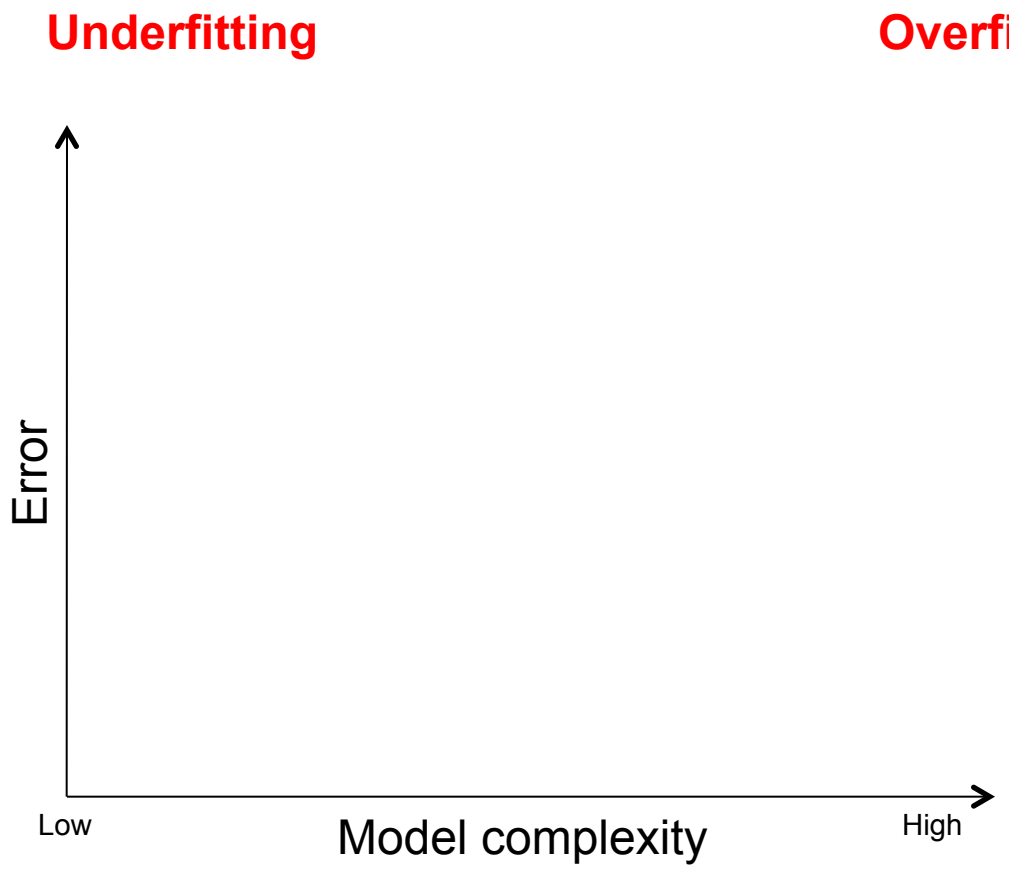


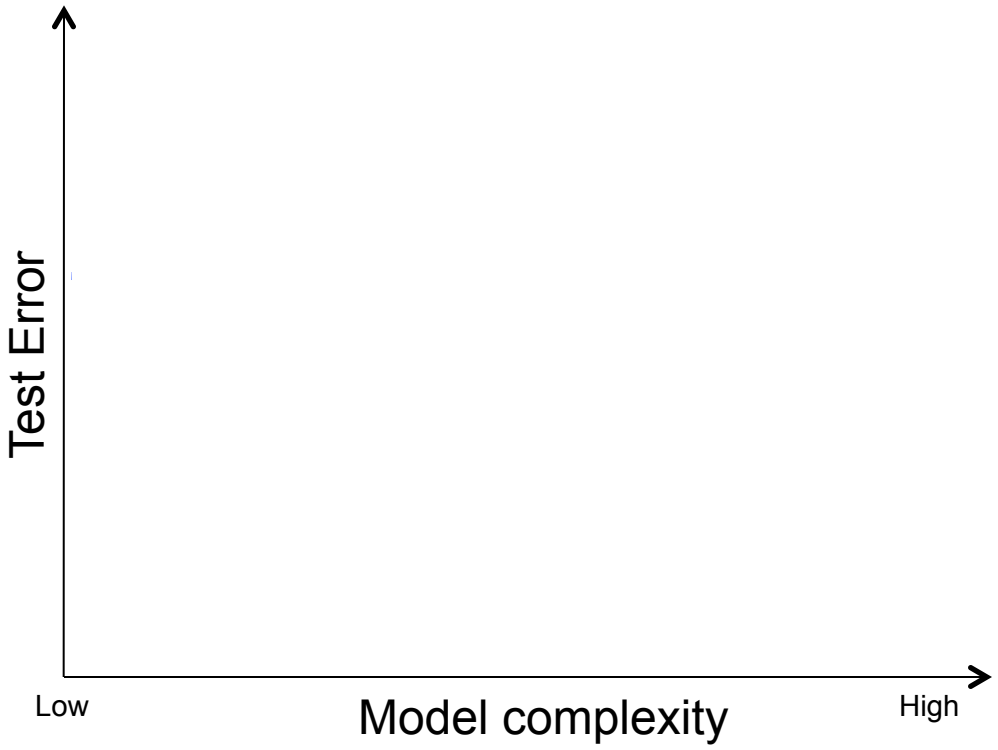
Figure source

Effect of model complexity



Slide credit: D. Hoiem

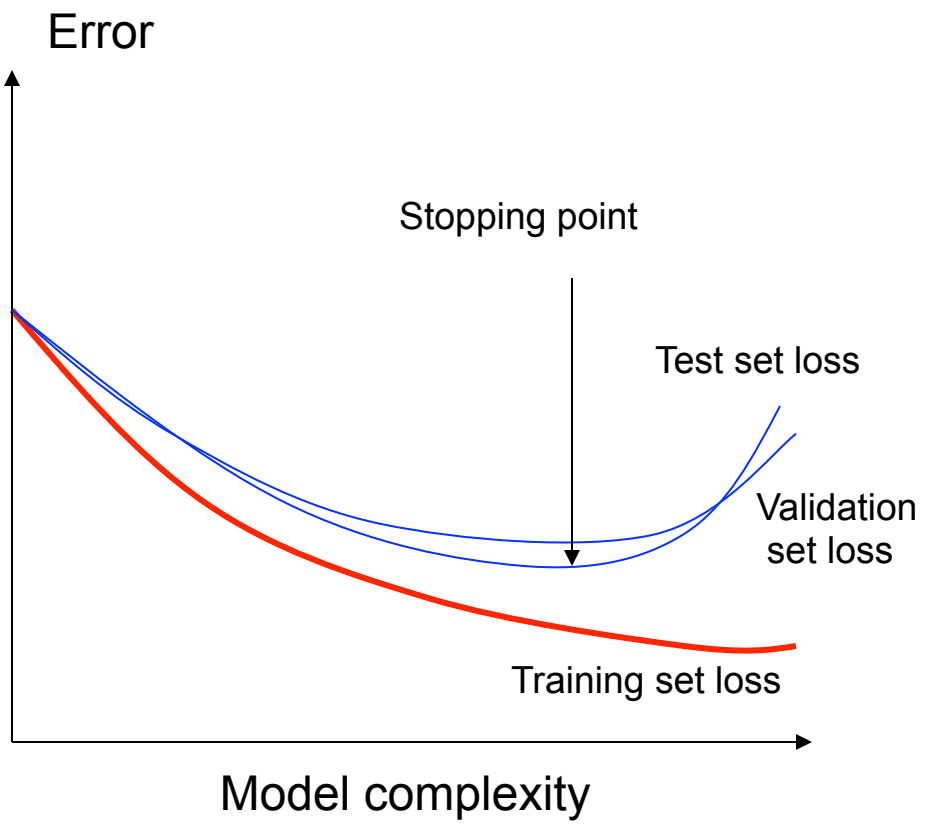
Effect of training set size



Slide credit: D. Hoiem

Validation

- Split the dataset into **training**, **validation**, and **test** sets
- Use training set to **optimize model parameters**
- Use validation test to **choose the best model**
- Use test set only to **evaluate performance**



Datasets

- **Circa 2001:** five categories, hundreds of images per category
- **Circa 2004:** 101 categories
- **Today:** up to thousands of categories, millions of images

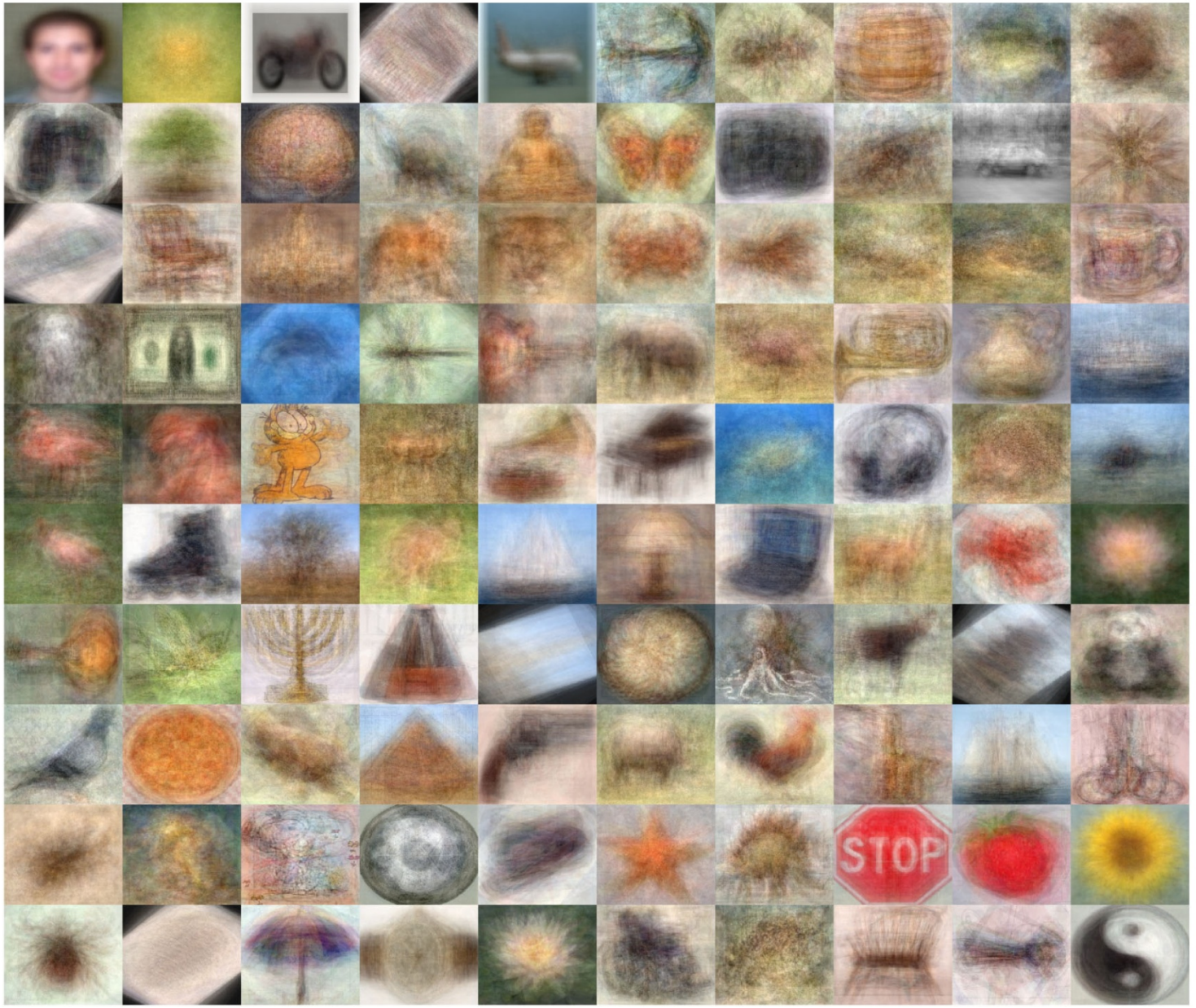
Caltech 101 & 256

http://www.vision.caltech.edu/Image_Datasets/Caltech101/
http://www.vision.caltech.edu/Image_Datasets/Caltech256/

Fei-Fei, Fergus, Perona, 2004

Griffin, Holub, Perona, 2007

Caltech-101: Intra-class variability

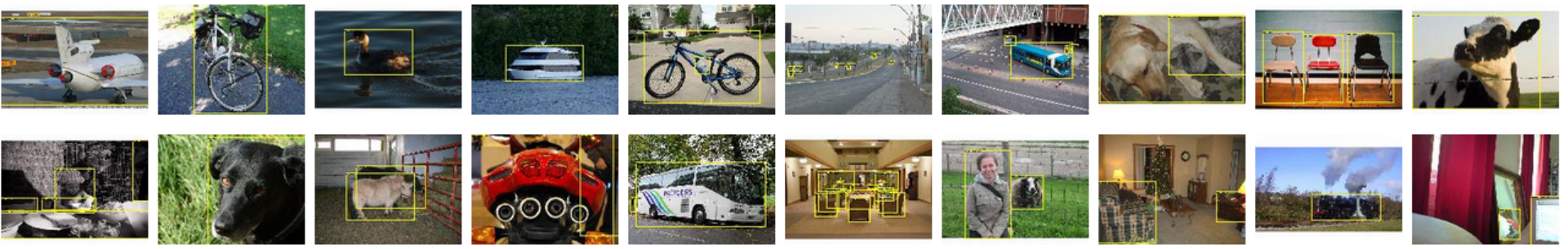


The PASCAL Visual Object Classes Challenge (2005-2012)

http://pascallin.ecs.soton.ac.uk/challenges/VOC/

- **Challenge classes:**
  Person: person
  Animal: bird, cat, cow, dog, horse, sheep
  Vehicle: aeroplane, bicycle, boat, bus, car, motorbike, train
  Indoor: bottle, chair, dining table, potted plant, sofa, tv/monitor

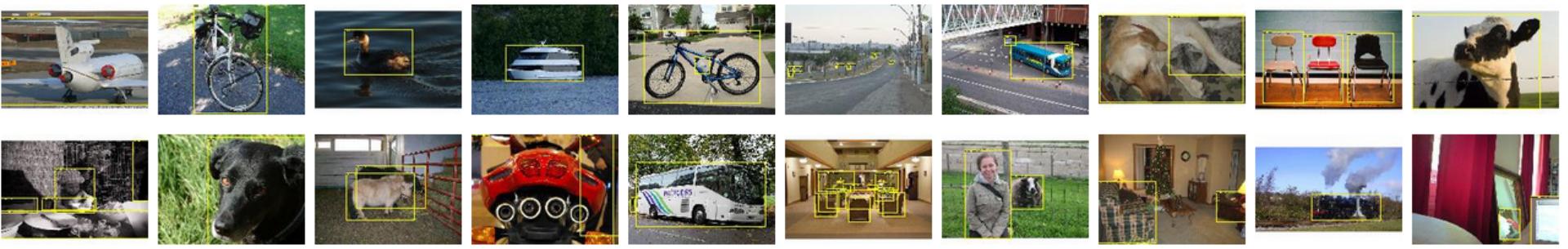
- **Dataset size (by 2012):**
  11.5K training/validation images, 27K bounding boxes, 7K segmentations



PASCAL competitions

http://pascallin.ecs.soton.ac.uk/challenges/VOC/

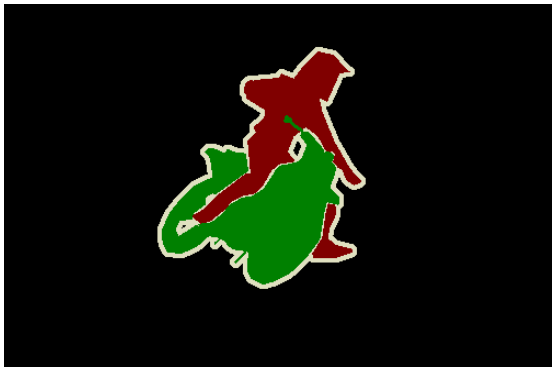
- **Classification:** For each of the twenty classes, predicting presence/absence of an example of that class in the test image
- **Detection:** Predicting the bounding box and label of each object from the twenty target classes in the test image



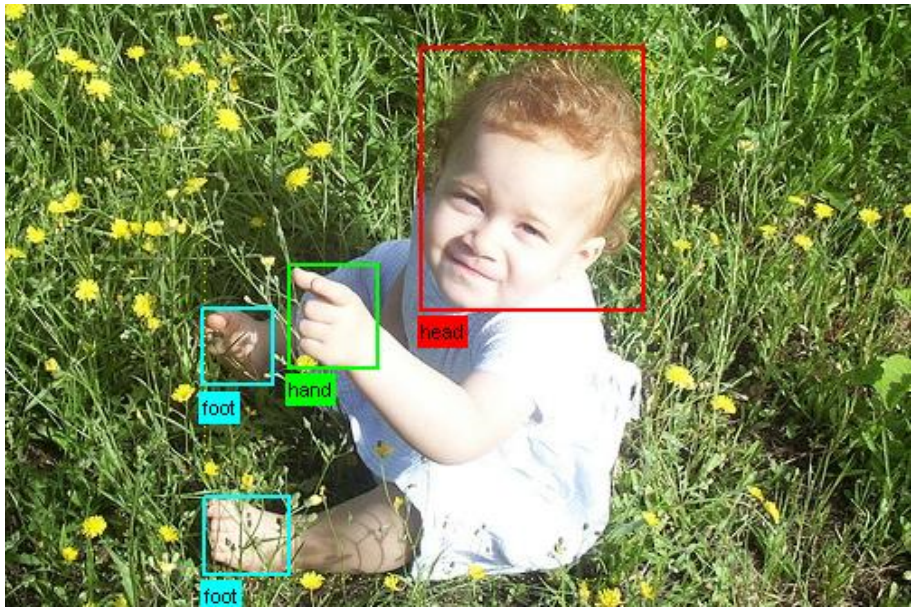
PASCAL competitions

http://pascallin.ecs.soton.ac.uk/challenges/VOC/

- **Segmentation:** Generating pixel-wise segmentations giving the class of the object visible at each pixel, or "background" otherwise



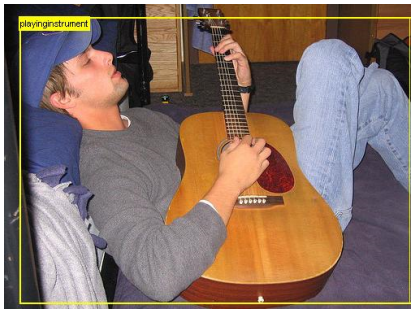
- **Person layout:** Predicting the bounding box and label of each part of a person (head, hands, feet)

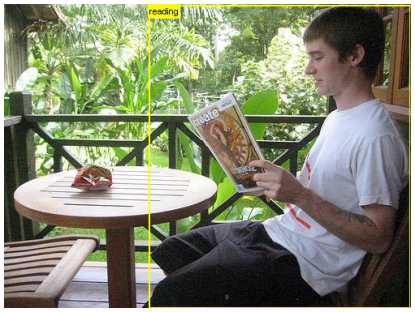


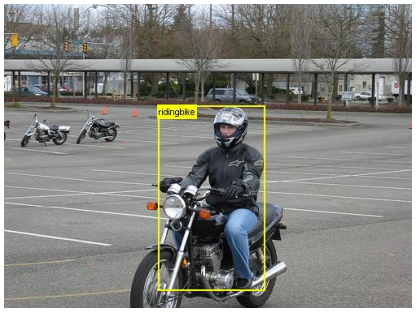
PASCAL competitions

http://pascallin.ecs.soton.ac.uk/challenges/VOC/

- Action classification (10 action classes)







LabelMe Dataset

http://labelme.csail.mit.edu/

Russell, Torralba, Murphy, Freeman, 2008

ImageNet

http://www.image-net.org/

IMAGENET

14,197,122 images, 21841 synsets indexed

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SEARCH

What do these images have in common? *Find out!*

The ImageNet Challenge 2013 is announced!