Recognition by finding patterns

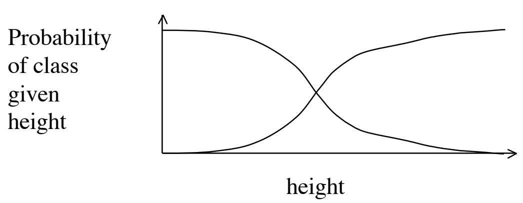
- Template matching with correlation (linear filters) is a simple example of recognition by pattern matching
- Some objects behave like quite simple templates
  - Frontal faces

Recognition by finding patterns

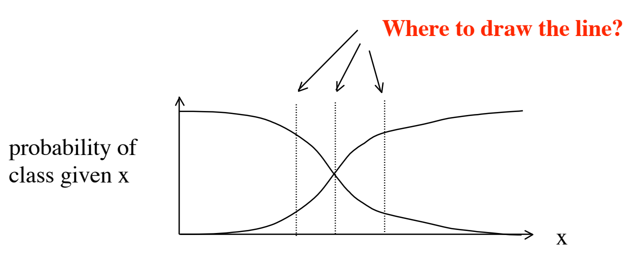
- Example strategy:
  - Find image windows
  - Correct for lighting
  - Pass them to a statistical test (a classifier) that accepts faces and rejects non-faces
- Important high level point:
  - Need to understand relationship between **modeling statistics** and deciding between options (classification AND risk analysis).

Basic ideas in classification

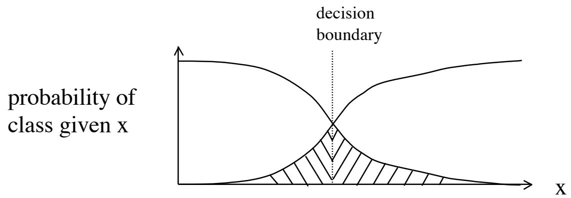
- Concrete example
  - "guess" male / female from height
- Probabilistic approach
  - Consider P(female|height)



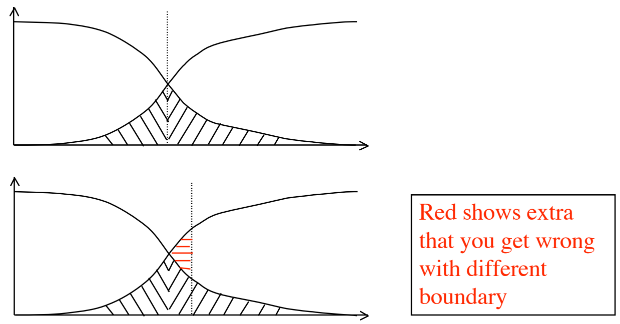
Basic ideas in classification



Basic ideas in classification



Area of intersection under curves gives expected value of making a mistake



Basic ideas in classification

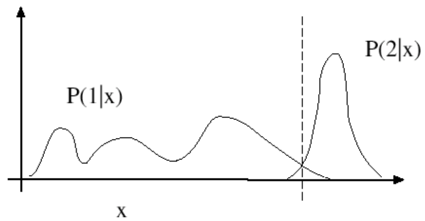
- Concrete example
  - "guess" male / female from height
- Probabilistic approach
  - Consider P(female|height)
- Now consider "risk"
  - Suppose you want to give vaccine based on height for a disease that only males get.
  - There is great benefit to males who may be exposed
  - Vaccines have risk as well as benefit
  - Thus there is also some risk to giving females a vaccine they do not need
- This changes the boundary.

Details ommitted in 2010

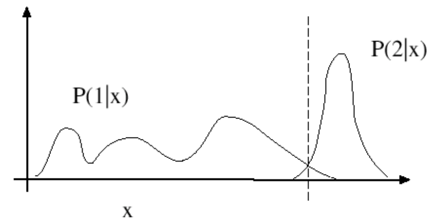
Building classifiers

- Standard scenario
  - Have training data
  - Want to classify new data
- One approach
  - Estimate the probability distributions (we have being thinking about them all along, e.g. P(1|x))
  - Issue: parameter estimates that are "good" may not give optimal classifiers

Finding a decision boundary is not the same as modeling a conditional density.



Finding a decision boundary is not the same as modeling a conditional density.



Important point: P(l|x) can be inaccurate, but the system can work well, as long as the boundary is correct.

Building classifiers

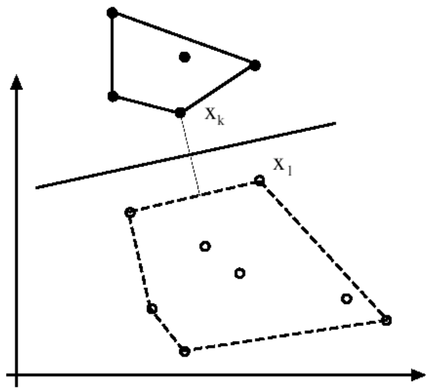
- Standard scenario
  - Have training data
  - Want to classify new data
- One approach
  - Estimate the probability distributions (we have being thinking about them all along, e.g. P(1|x))
  - Issue: parameter estimates that are "good" may not give optimal classifiers
- Another approach
  - Directly go for the boundary

We will start with this one

Support vector machines

- The generic, standard way to do this is with a SVM
- The basic "plug-in classifier" (black box)
- Typically now used for many tasks where before the method of choice was neural networks.
- Very convenient software is now available to do this.
- We will cover the approach briefly

Support vector machines



Support vector machines

- If we have a *separating* hyperplane, then if you are on one side $\mathbf{w} \bullet \mathbf{x_i} + b \geq +1$
- If you are on the other side $\mathbf{w} \bullet \mathbf{x_i} + b \leq -1$
- Let y_i be +1 for one class, -1 for the other.

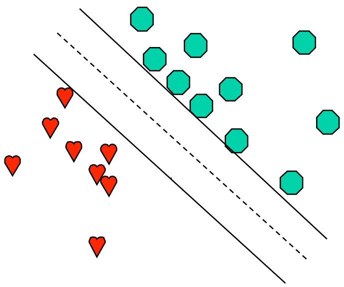
Support vector machines

- Linearly separable data means that we can chose

$$y_i \left(\boldsymbol{w} \cdot \boldsymbol{x}_i + b \right) \geq 1$$

- Consider the best pair of parallel planes that push against points on the two groups.

Support vector machines



Support vector machines

- Consider the best pair of parallel planes that push against points on the two groups.
- The sum of the minimum distances from each group to the other plane can be shown to be:

$$\frac{2}{|\mathbf{w}|}$$

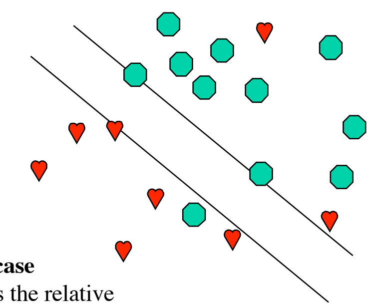
Support vector machines

- Solved by

$$\text{minimize} \quad (1/2)\boldsymbol{w} \cdot \boldsymbol{w}$$
$$\text{subject to} \quad y_i\,(\boldsymbol{w} \cdot \boldsymbol{x}_i + b) \geq 1$$

- (See book, section 22.5 for how to solve it)
- What if the data is not linearly separable
  - Find "best" plane (see book)
  - The boundary is determined by a few points (the support vectors)

Support vector machines

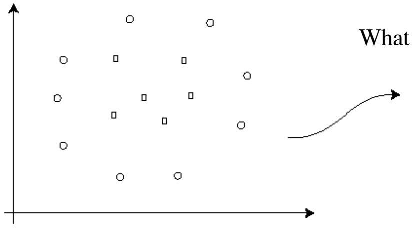


Non-separable case
Cost, C, specifies the relative desire to push the planes apart, verses the number of mistakes.

Support vector machines

- Now that we have the "best" plane, how do we classify?
  - Easy---we have a simple formula for determining which side of the plane we are on!
- Pseudo probabilities can be created from the distance to the plane
- This describes a binary classifier. For more than one class, there are two approaches
  - Multiple one against all
  - All against all, and a consensus measure

Support vector machines (kernel tricks)



What about this case?

Support vector machines (kernel tricks)

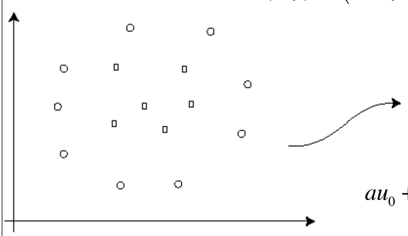
Key observation: The SVM is completely a function of dot products between the vectors.

This means that we can get a non-linear SVM by using a different form of the dot product, K(**x,y**).

This is equivalent to a linear classification in a much higher dimensional space.

Support vector machines (kernel tricks)

$$(x,y)\rightarrow\left(x^2,xy,y^2,x,y\right)=\left(u_0,u_1,u_2,u_3,u_4\right)$$



Space in which decision boundary is linear - a conic in the original space has the form

$$au_0+bu_1+cu_2+du_3+eu_4+f=0$$

Testing classifiers

- Standard method is to use Cross-Validation
- Test classification accuracy on data not used in training
- Test generalizability by using data that is progressively different than training data
  - new experiment
  - different camera
  - different researchers