Face Detection using the Viola-Jones Method

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Viola-Jones Face Detection Algorithm

Overview :

- Viola Jones technique overview
- Features
- Integral Images
- Feature Extraction
- Weak Classifiers
- Boosting and classifier evaluation
- Cascade of boosted classifiers
- Example Results

P. Viola and M. Jones, “Robust Real-Time Face Detection,” Int’l J. Computer Vision, vol. 57, no. 2, pp. 137-154, 2004.

Viola Jones Technique Overview

State-of-the-art face detector

Three major contributions/phases of the algorithm :

- Feature extraction
- Classification using boosting
- Multi-scale detection algorithm

Feature extraction and feature evaluation.

- Rectangular features are used, with a new image representation their calculation is very fast.

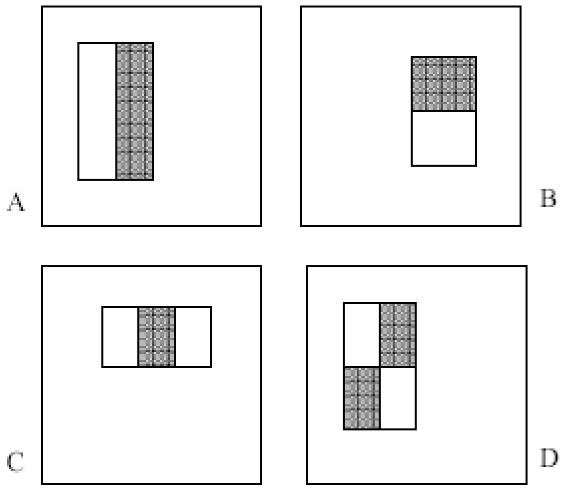
Classifier training and feature selection using a slight variation of a method called AdaBoost.

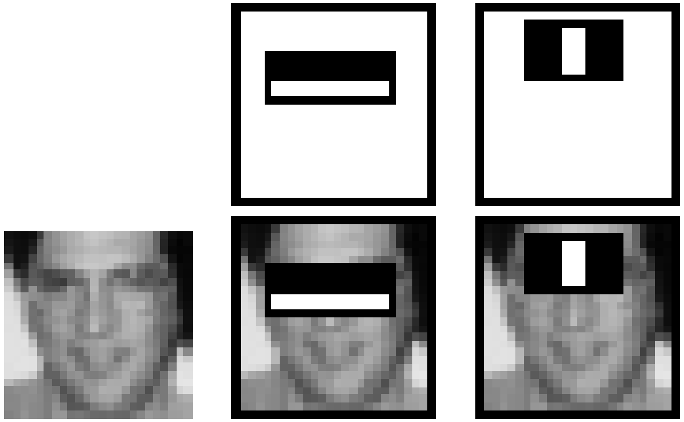
A combination of simple classifiers is very effective

Features

Four basic types.

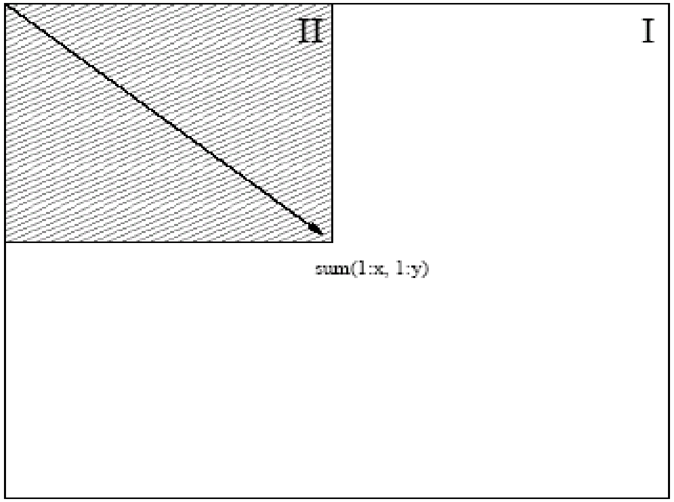
- They are easy to calculate.
- The white areas are subtracted from the black ones.
- A special representation of the sample called the **integral image** makes feature extraction faster.





Integral images

Summed area tables



A representation that means any rectangle's values can be calculated in four accesses of the integral image.

Fast Computation of Pixel Sums

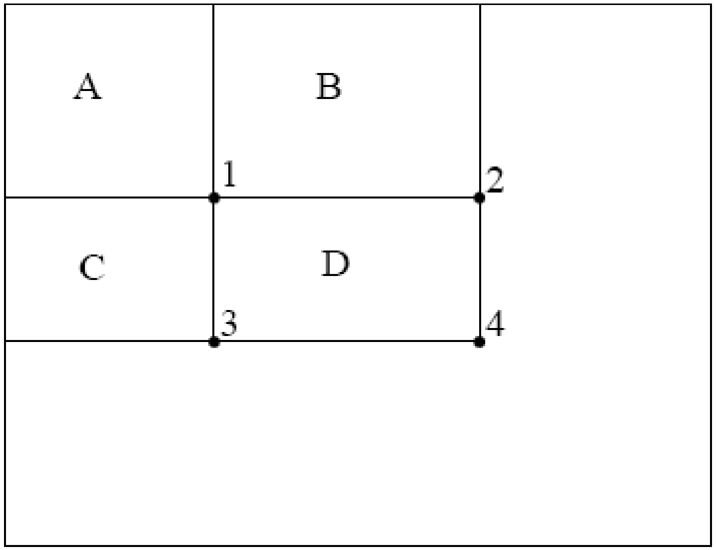
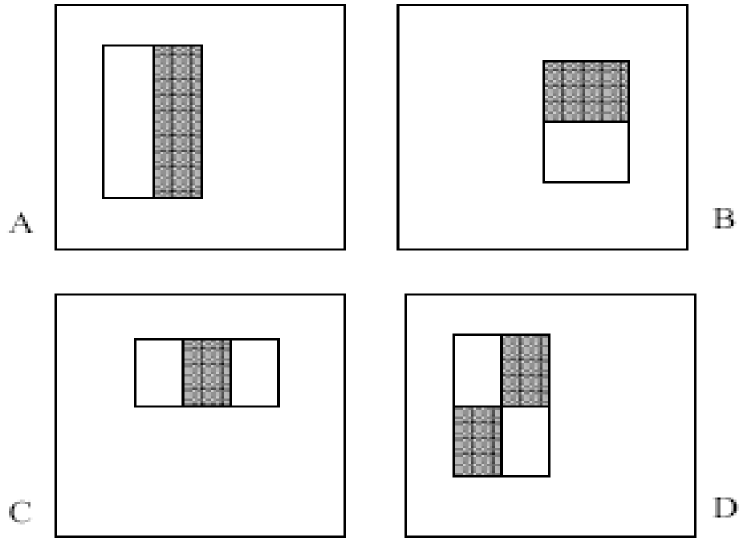


Figure 3: The sum of the pixels within rectangle D can be computed with four array references. The value of the integral image at location 1 is the sum of the pixels in rectangle A. The value at location 2 is $A + B$, at location 3 is $A + C$, and at location 4 is $A + B + C + D$. The sum within D can be computed as $4 + 1 - (2 + 3)$.

Feature Extraction

Features are extracted from 24x24 subwindows of a sample image.

- Each of the four feature types are scaled and shifted across all possible combinations
  - In a 24 pixel by 24 pixel sub window there are ~160,000 possible features to be calculated.



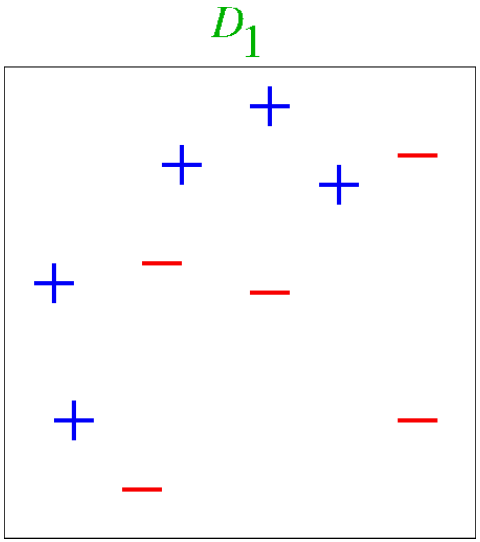
Learning with many features

We have 160,000 features – how can we learn a classifier with only a few hundred training examples without overfitting?

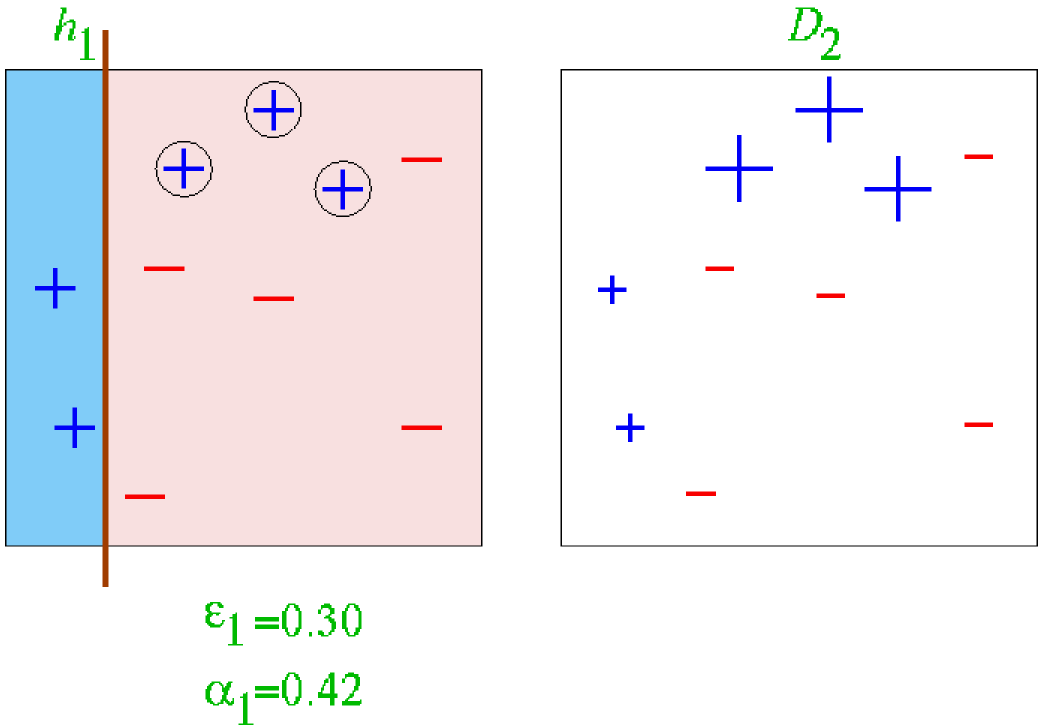
Idea:

- Learn a single simple classifier
- Classify the data
- Look at where it makes errors
- Reweight the data so that the inputs where we made errors get higher weight in the learning process
- Now learn a 2nd simple classifier on the weighted data
- Combine the 1st and 2nd classifier and weight the data according to where they make errors
- Learn a 3rd classifier on the weighted data
- … and so on until we learn T simple classifiers
- Final classifier is the combination of all T classifiers
- This procedure is called “Boosting” – works very well in practice.

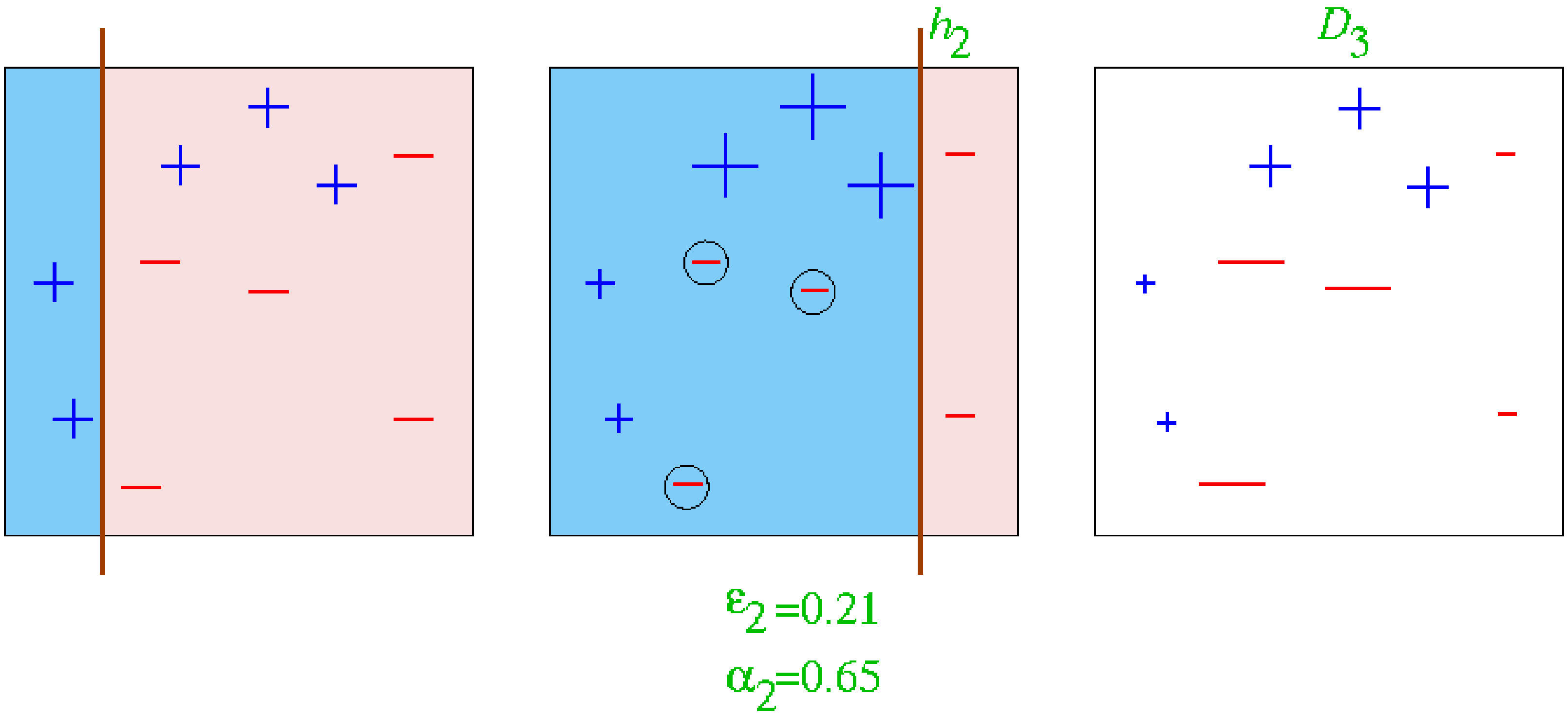
Boosting Example



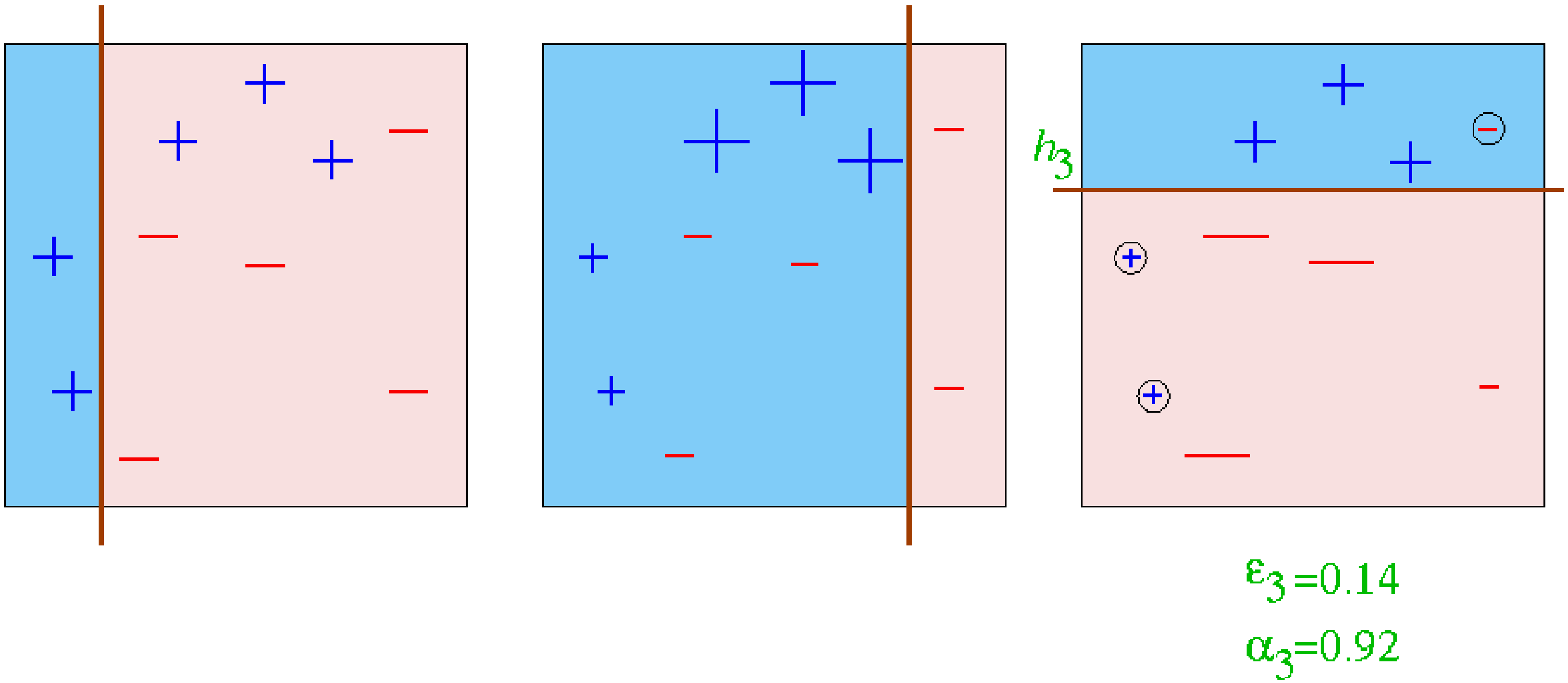
First classifier



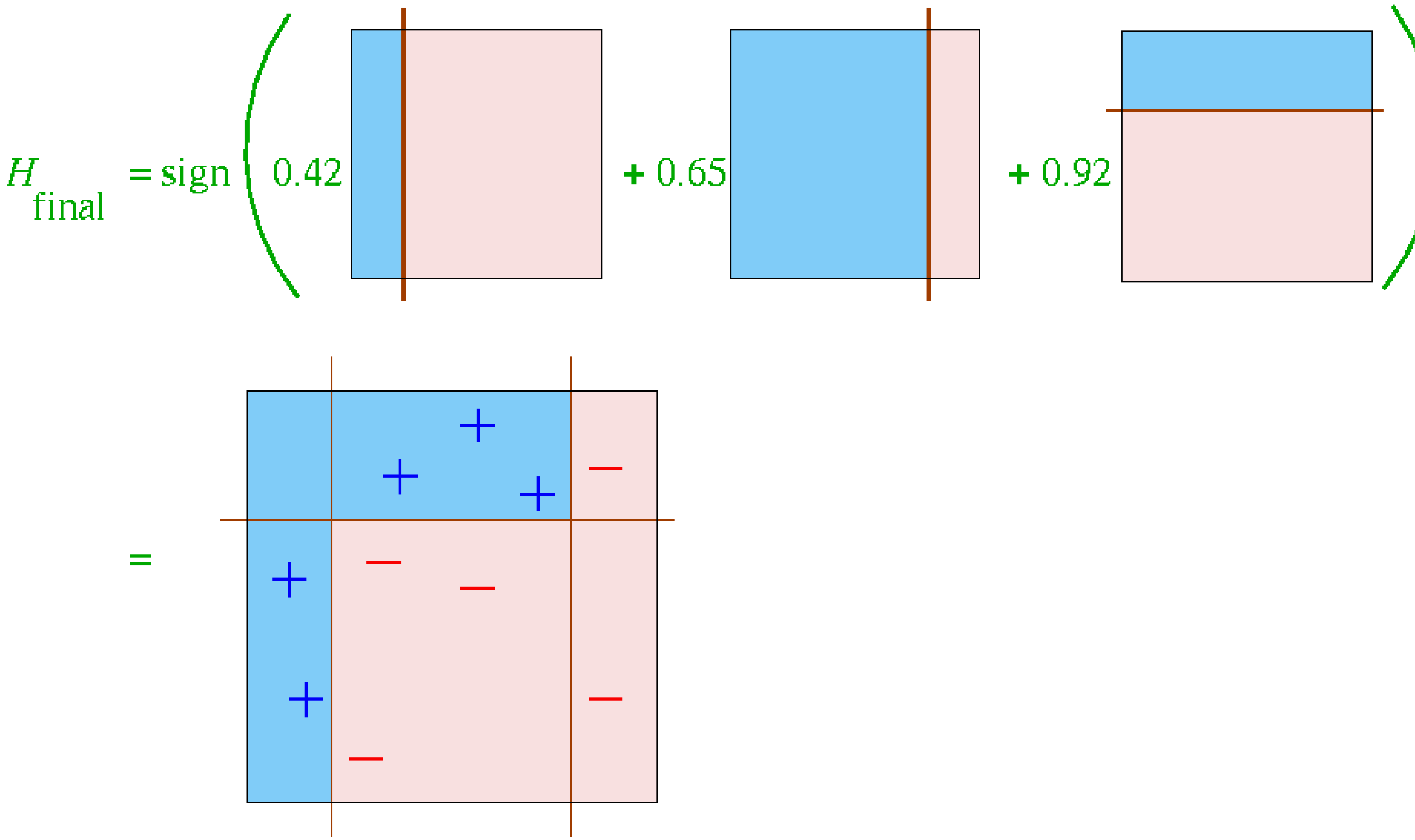
First 2 classifiers



First 3 classifiers



Final Classifier learned by Boosting



Stump weak classifiers

- Equivalent to comparing the feature to a threshold
- Learning = finding the best threshold for a single feature
- Can be trained by gradient descent (or direct search)

Boosting with Single Feature Perceptrons

Viola-Jones version of Boosting:

- "simple" (weak) classifier = single-feature perceptron
- With K features (e.g., K = 160,000) we have 160,000 different single-feature perceptrons

- At each stage of boosting, given reweighted data from previous stage:
  - Train all K (160,000) single-feature perceptrons
  - Select the single best classifier at this stage
  - Combine it with the other previously selected classifiers
  - Reweight the data
  - Learn all K classifiers again, select the best, combine, reweight
  - Repeat until you have T classifiers selected

- Hugely computationally intensive
  - Learning K perceptrons T times
  - E.g., K = 160,000 and T = 1000

How is classifier combining done?

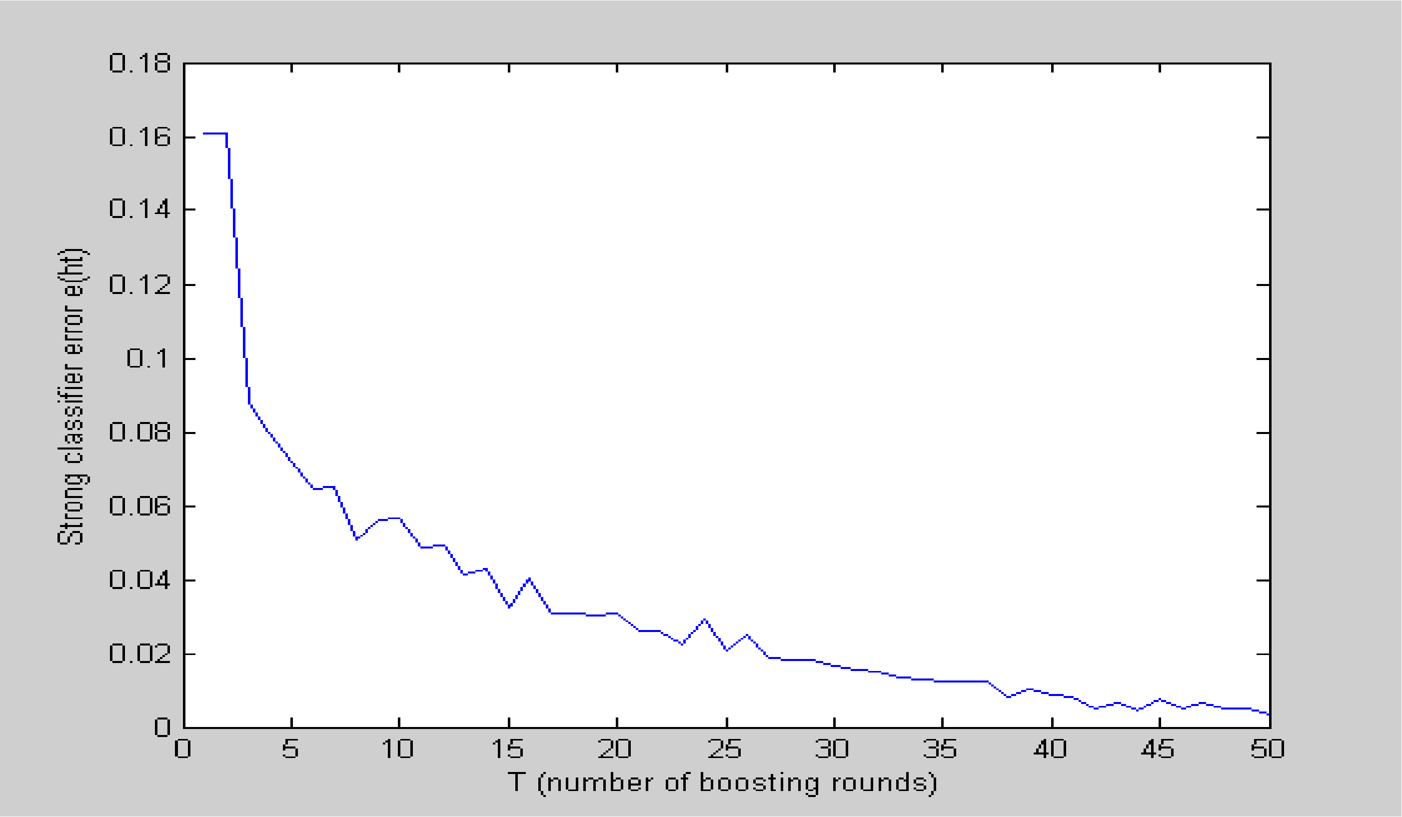
At each stage we select the best classifier on the current iteration and combine it with the set of classifiers learned so far

How are the classifiers combined?

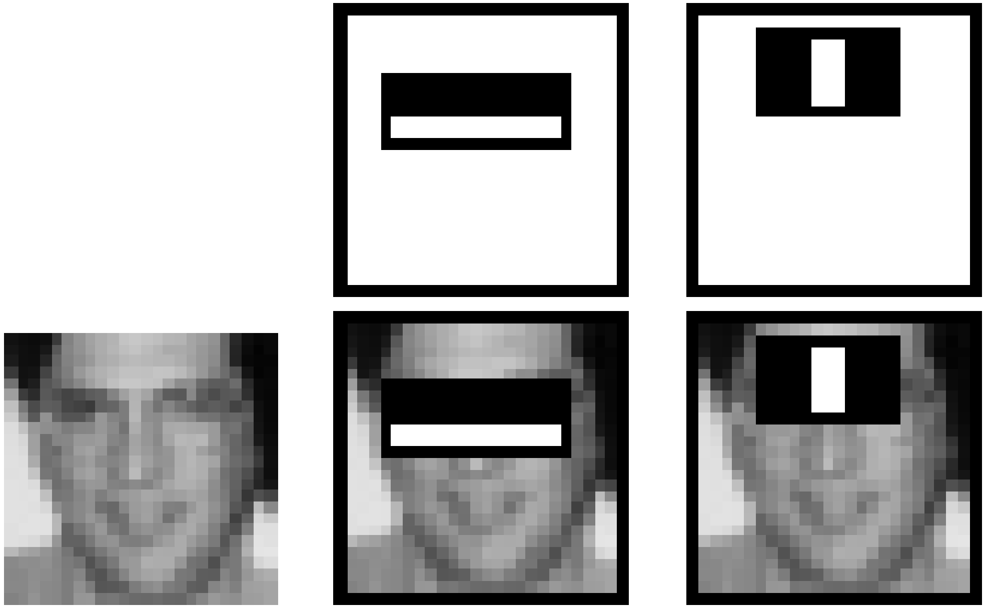
- Take the weight*feature for each classifier, sum these up, and compare to a threshold (very simple)
- Boosting algorithm automatically provides the appropriate weight for each classifier and the threshold
- This version of boosting is known as the AdaBoost algorithm

Y. Freund and R.E. Schapire, "A decision-theoretic generalization of on-line learning and an application to boosting". Journal of Computer and System Sciences 55. 1997. doi:10.1006/jcss.1997.1504.

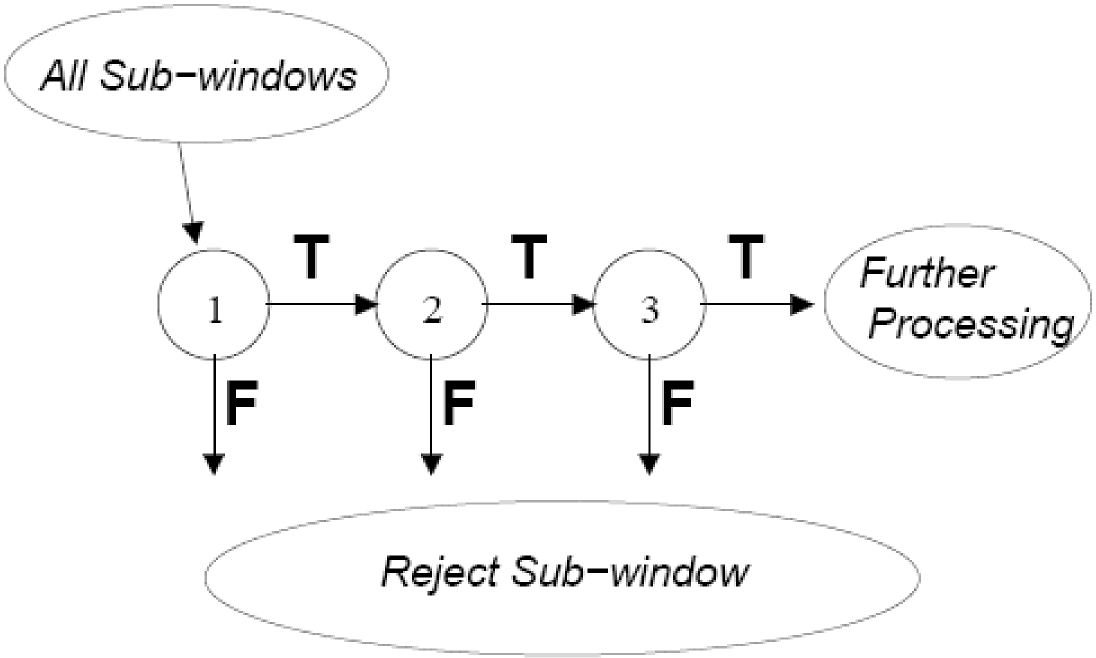
Reduction in Error as Boosting adds Classifiers



Useful Features Learned by Boosting



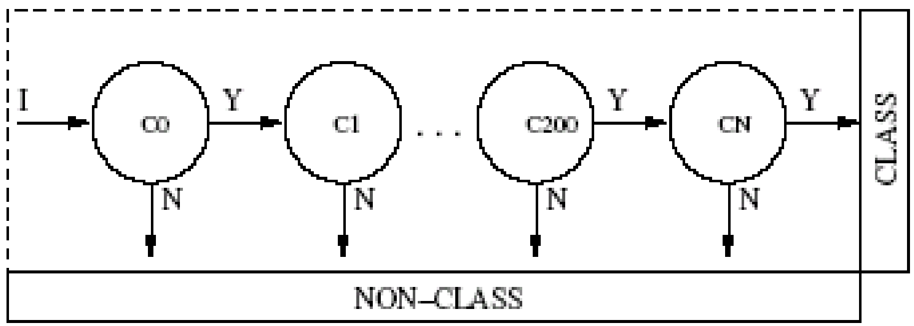
A Cascade of Classifiers



Cascade of Boosted Classifiers

Referred here as a degenerate decision tree.

- Very fast evaluation.
- Quick rejection of sub windows when testing.



Reduction of

- Each node is trained with the false positives of the prior.

AdaBoost can be used in conjunction with a simple bootstrapping process to drive detection error down.

- Viola and Jones present a method to do this, that iteratively builds boosted nodes, to a desired false positive rate.

Detection in Real Images

Basic classifier operates on 24 x 24 subwindows

Scaling:

- Scale the detector (rather than the images)
- Features can easily be evaluated at any scale
- Scale by factors of 1.25

Location:

- Move detector around the image (e.g., 1 pixel increments)

Final Detections

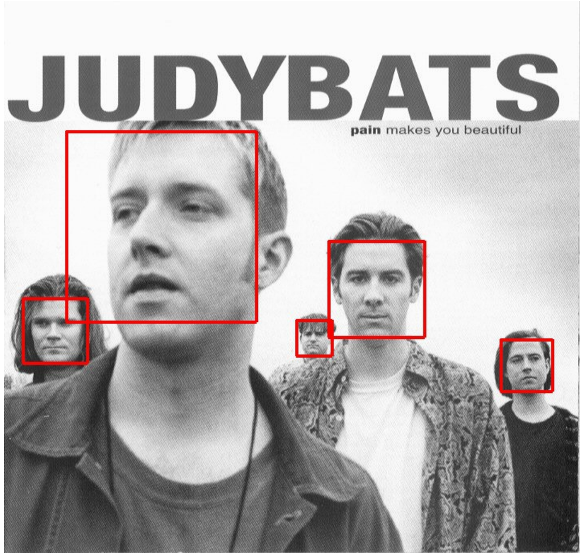
- A real face may result in multiple nearby detections
- Postprocess detected subwindows to combine overlapping detections into a single detection

Training

In paper, 24x24 images of faces and non faces.

Sample results using the Viola-Jones Detector

Notice detection at multiple scales



More Detection Examples

Practical implementation

Details discussed in Viola-Jones paper

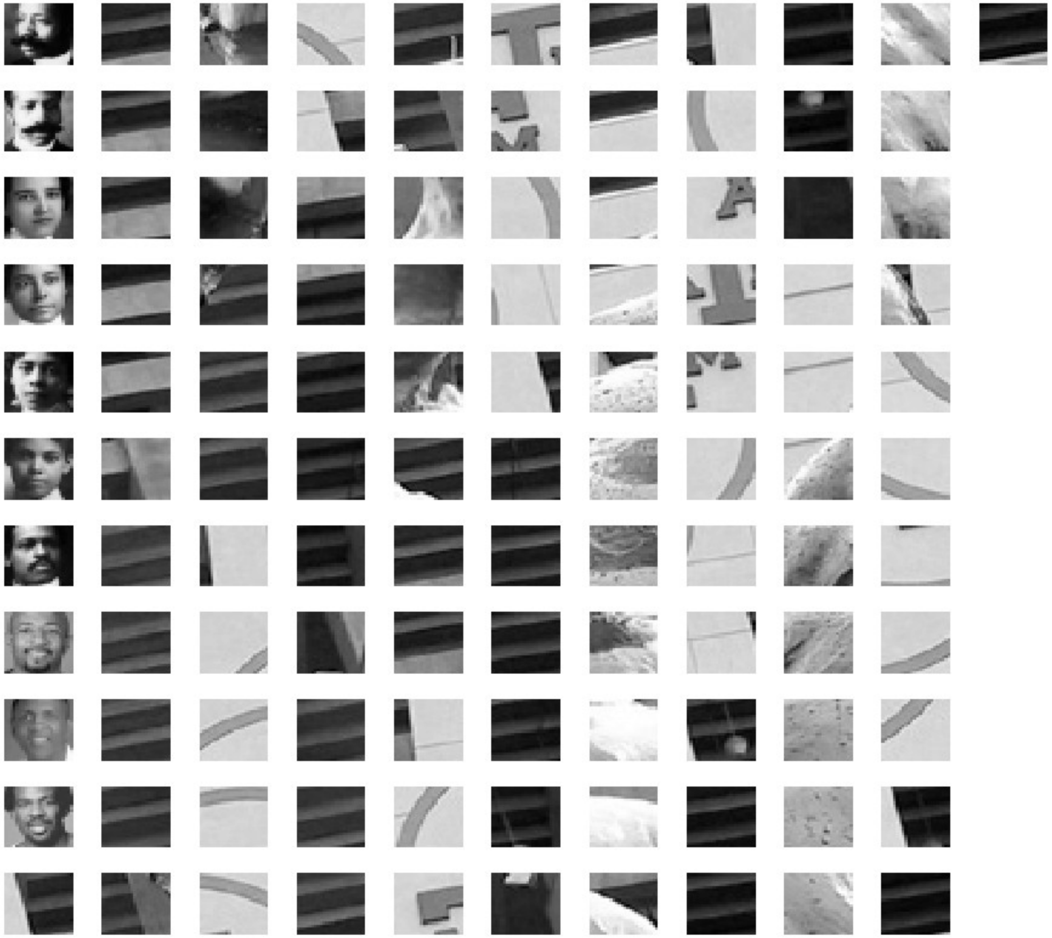
Training time = weeks (with 5k faces and 9.5k non-faces)

Final detector has 38 layers in the cascade, 6060 features

700 Mhz processor:

- Can process a 384 x 288 image in 0.067 seconds (in 2003 when paper was written)

Small set of 111 Training Images



Live demo

OpenCV implementation

facedetect.bat

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