



Tratamiento de Señales

Version 2024-I

Transformada de Haar

[Capítulo 4]

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The Viola/Jones Face Detector (2001)

- A widely used method for real-time object detection.
- Training is slow, but detection is very fast.

Classifier is Learned from Labeled Data

- Training Data
 - 5000 faces
 - All frontal
 - 300 million non faces
 - 9400 non-face images
 - Faces are normalized
 - Scale, translation
- Many variations
 - Across individuals
 - Illumination
 - Pose (rotation both in plane and out)



Key Properties of Face Detection

- Each image contains 10 - 50 thousand locs/scales
- Faces are rare 0 - 50 per image
 - 1000 times as many non-faces as faces
- Extremely small # of false positives: 10^{-6}

Boosted Face Detection: Image Features

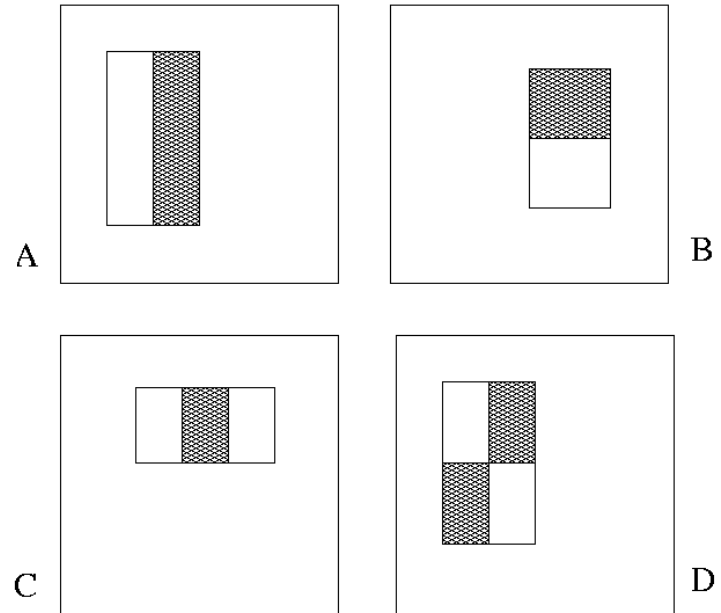
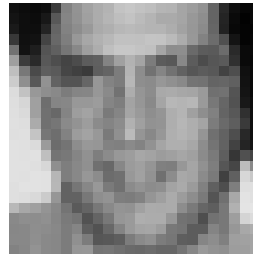
“Rectangle filters”

Similar to Haar wavelets

Papageorgiou, et al.

$$h_t(x_i) = \begin{cases} \alpha_t & \text{if } f_t(x_i) > \theta_t \\ \beta_t & \text{otherwise} \end{cases}$$

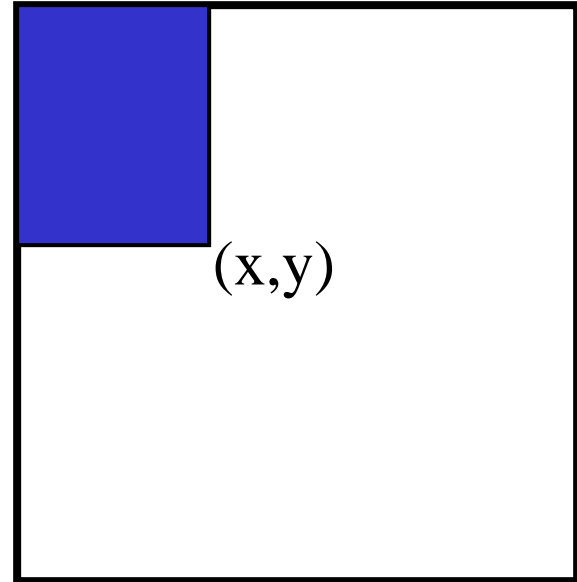
$$C(x) = \theta \left(\sum_t h_t(x) + b \right)$$



60,000 features to choose from

The Integral Image

- The *integral image* computes a value at each pixel (x,y) that is the sum of the pixel values above and to the left of (x,y) , inclusive.
- This can quickly be computed in one pass through the image

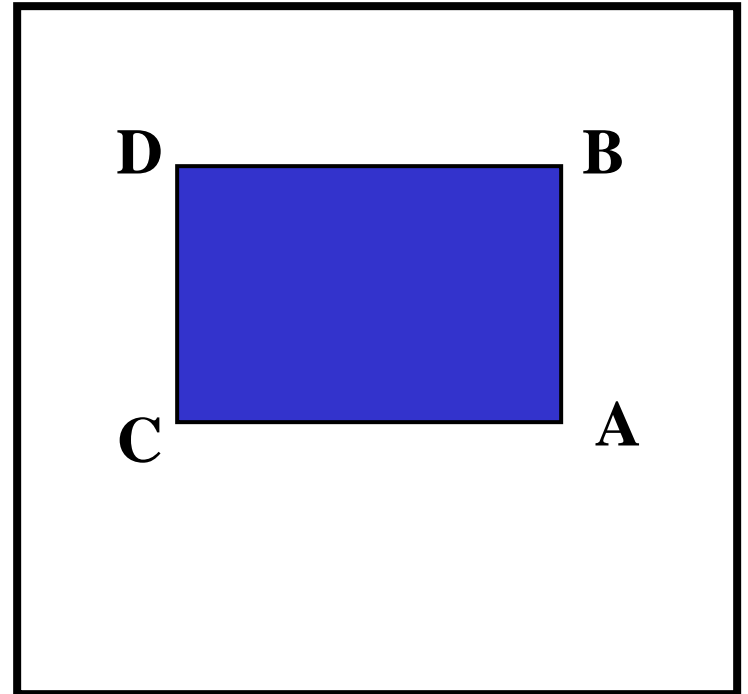


Computing Sum within a Rectangle

- Let A,B,C,D be the values of the integral image at the corners of a rectangle
- Then the sum of original image values within the rectangle can be computed:

$$\text{sum} = A - B - C + D$$

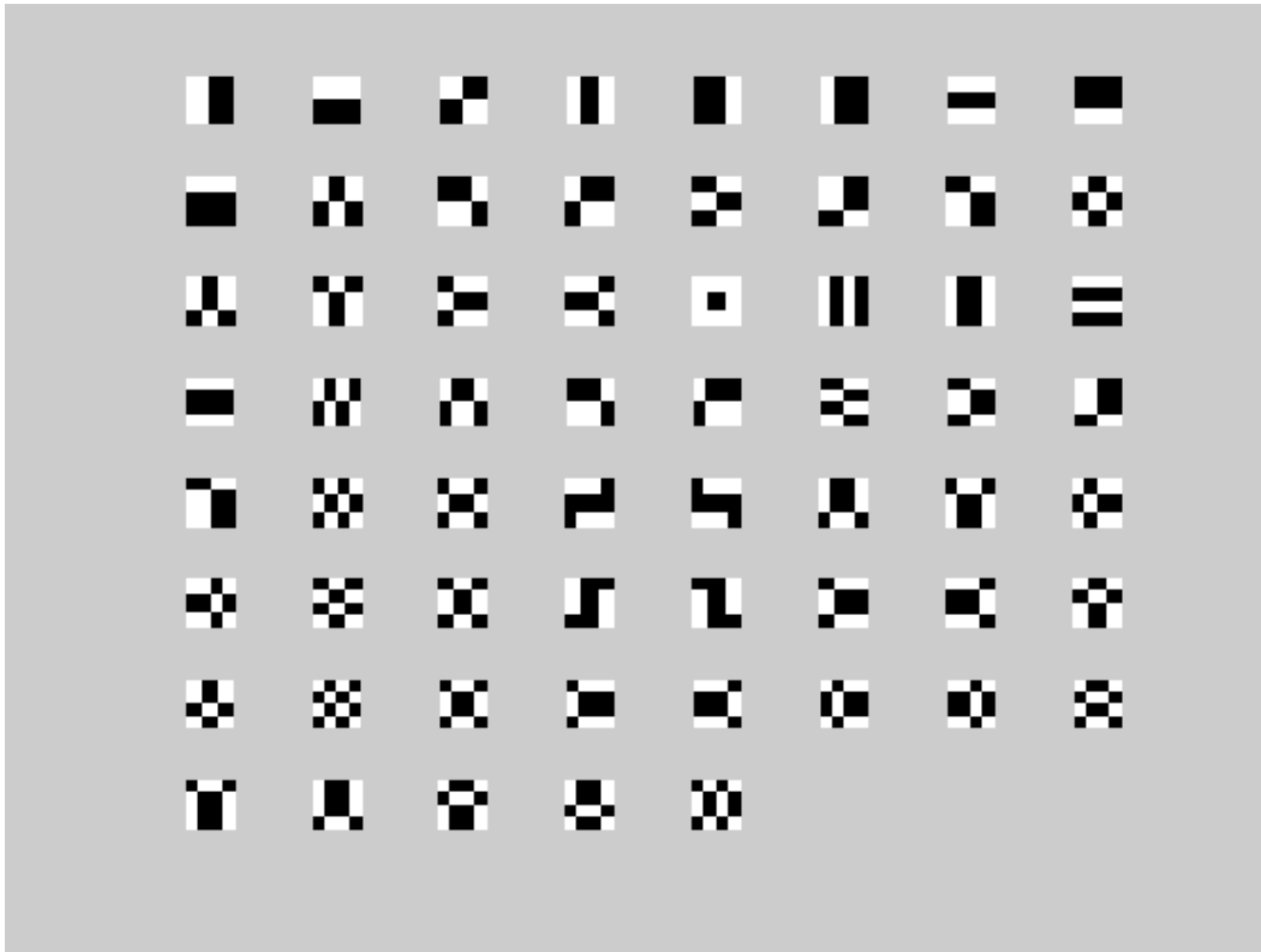
- Only 3 additions are required for any size of rectangle!
 - This is now used in many areas of computer vision



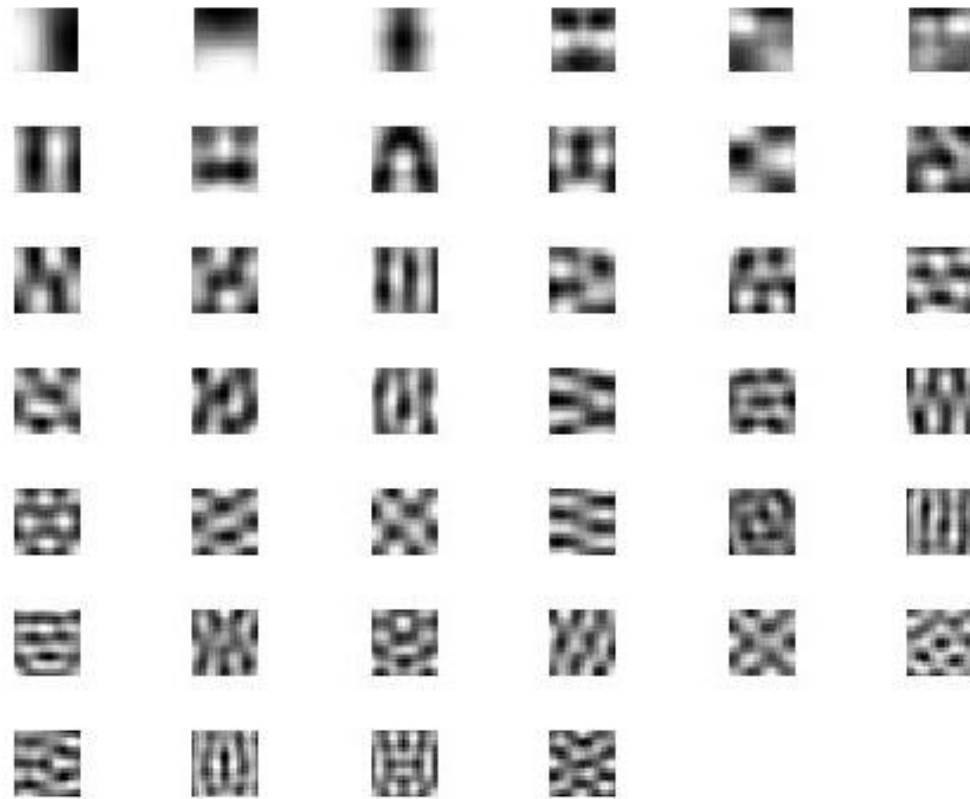
Feature Selection

- For each round of boosting:
 - Evaluate each rectangle filter on each example
 - Sort examples by filter values
 - Select best threshold for each filter (min Z)
 - Select best filter/threshold (= Feature)
 - Reweight examples
- M filters, T thresholds, N examples, L learning time
 - $O(MT L(MTN))$ Naïve Wrapper Method
 - $O(MN)$ *Adaboost* feature selector

Haar Basis



*Haar * Faces*

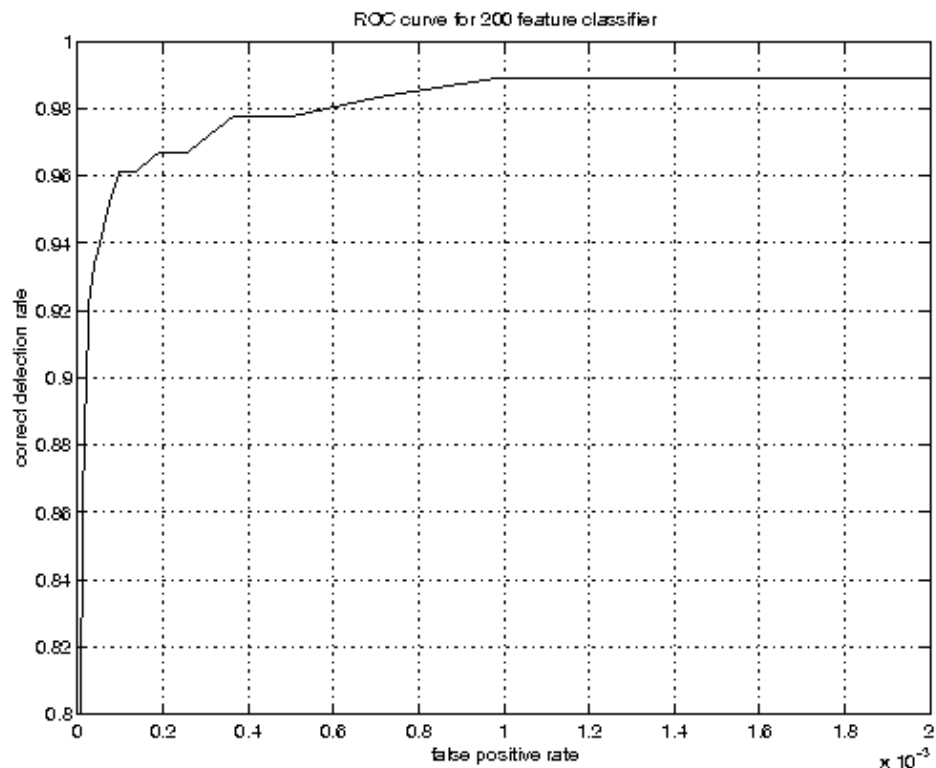
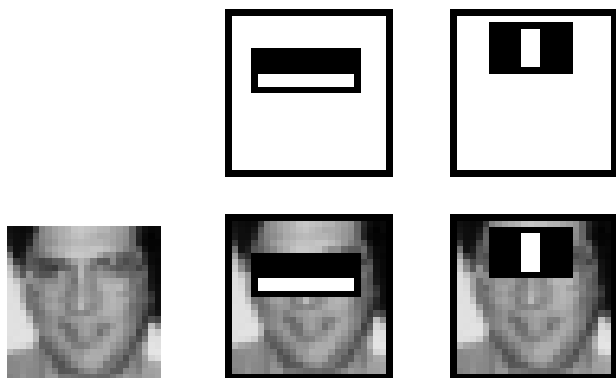


Example Classifier for Face Detection

A classifier with 200 rectangle features was learned using AdaBoost

95% correct detection on test set with 1 in 14084 false positives.

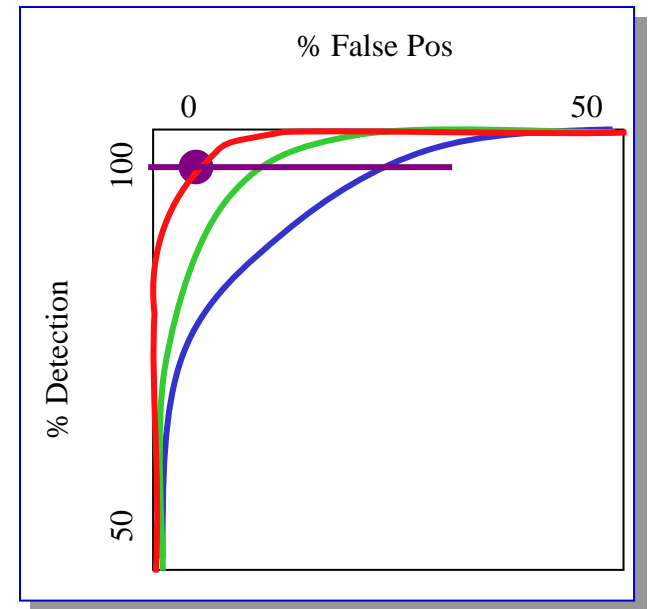
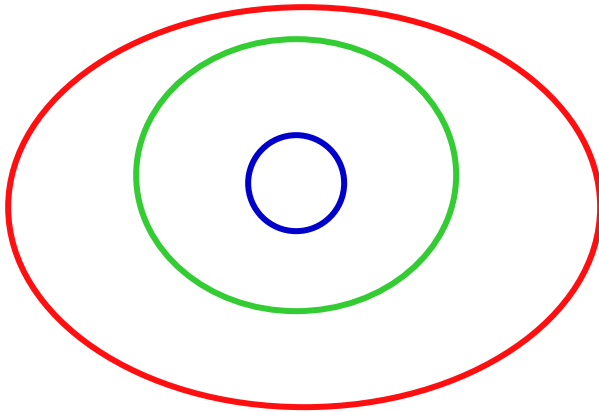
Not quite competitive...



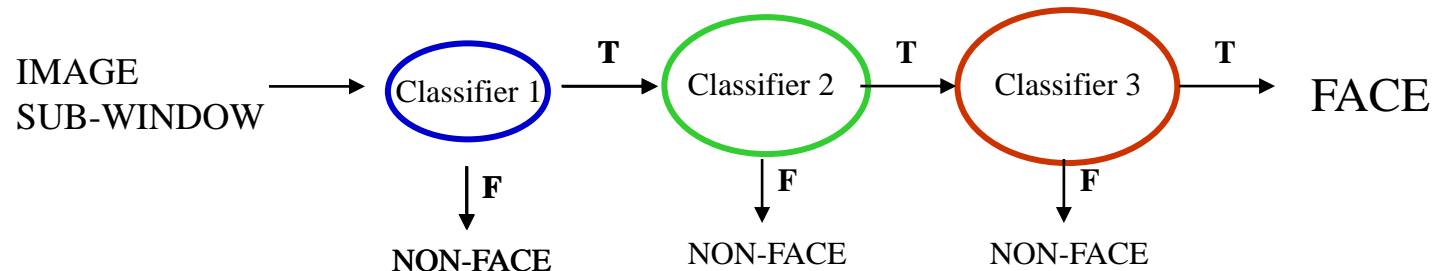
ROC curve for 200 feature classifier

Building Fast Classifiers

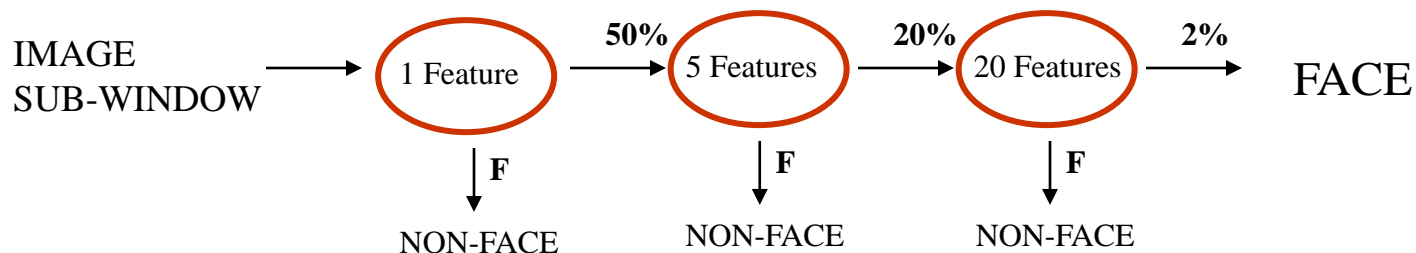
- Given a nested set of classifier hypothesis classes



- Computational Risk Minimization

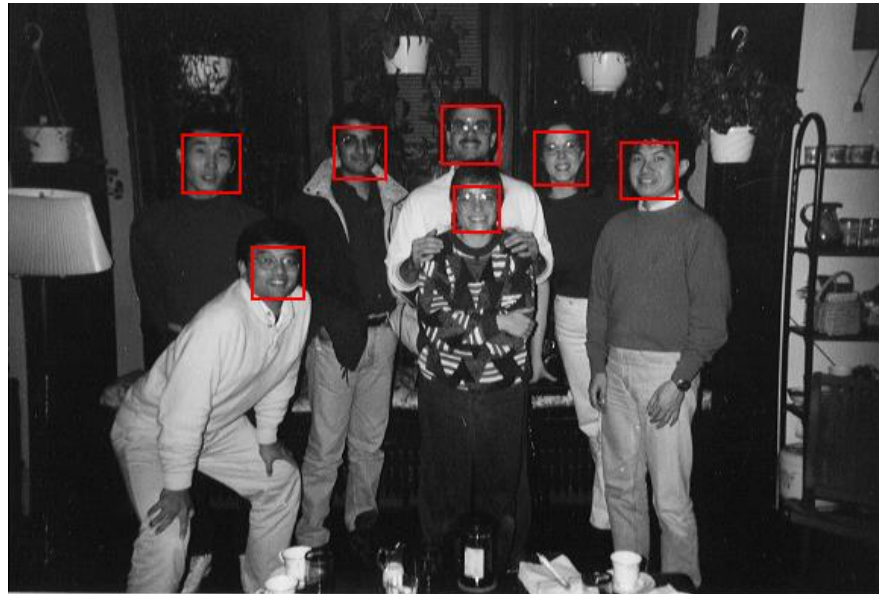
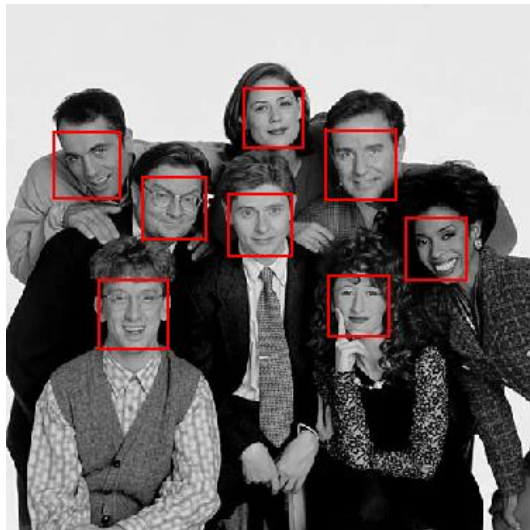
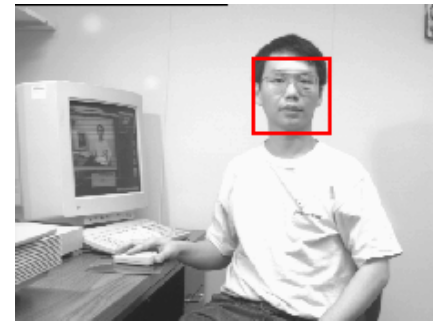
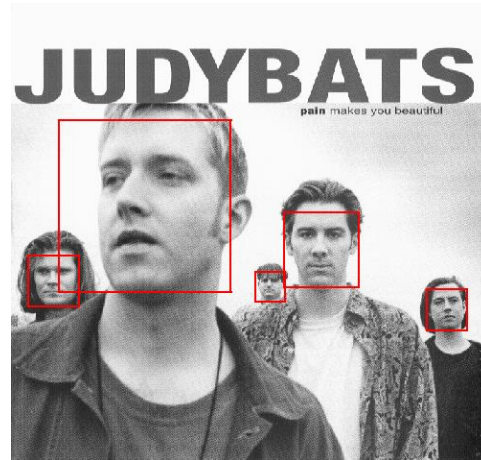


Cascaded Classifier



- A 1 feature classifier achieves 100% detection rate and about 50% false positive rate.
- A 5 feature classifier achieves 100% detection rate and 40% false positive rate (20% cumulative)
 - using data from previous stage.
- A 20 feature classifier achieve 100% detection rate with 10% false positive rate (2% cumulative)

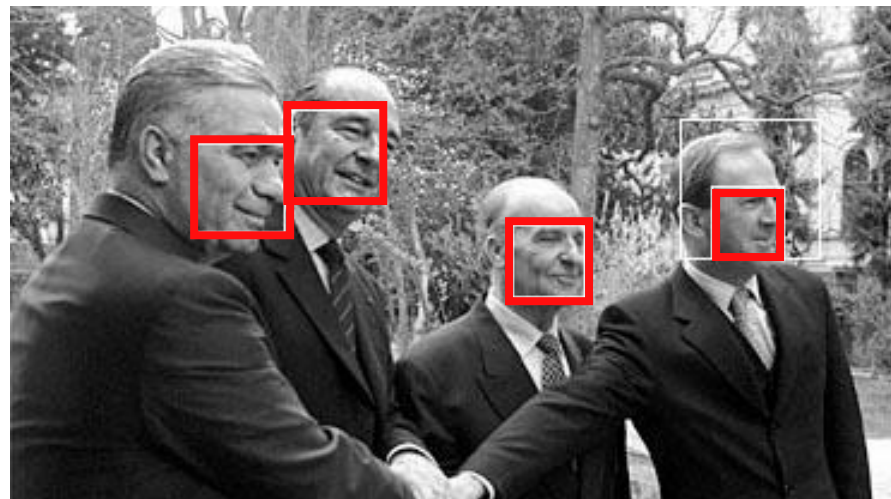
Output of Face Detector on Test Images



Solving other “Face” Tasks

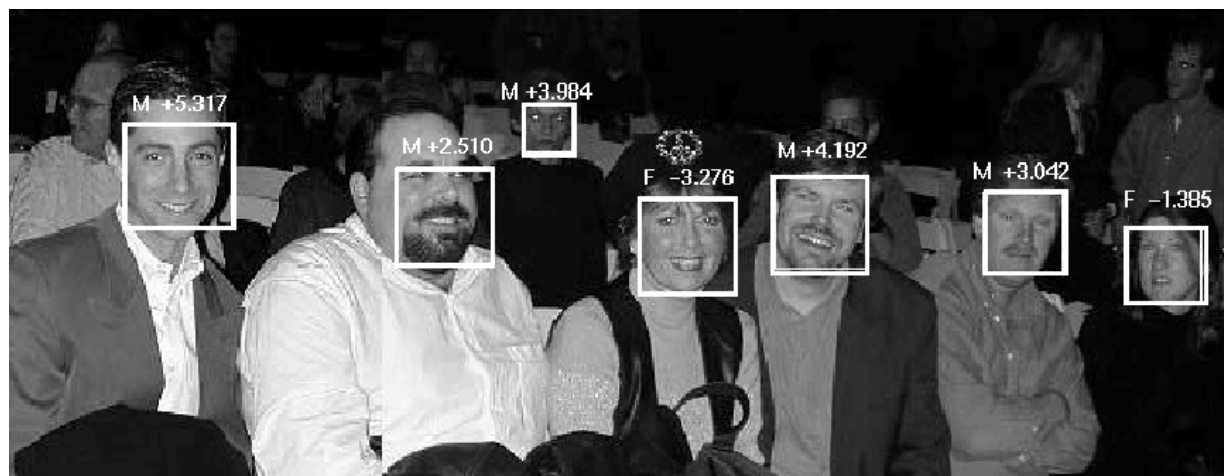


Facial Feature Localization



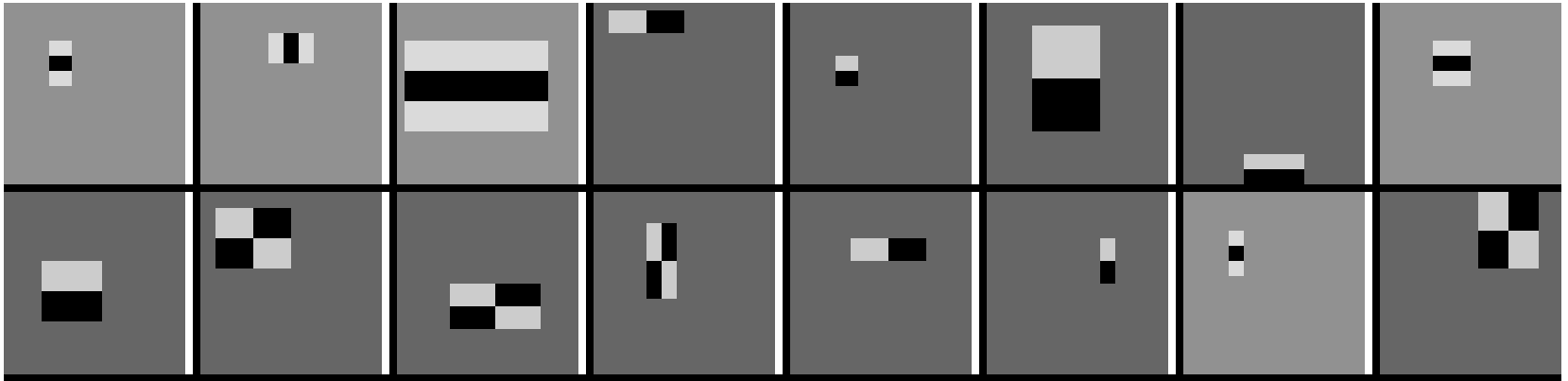
Profile Detection

Demographic Analysis

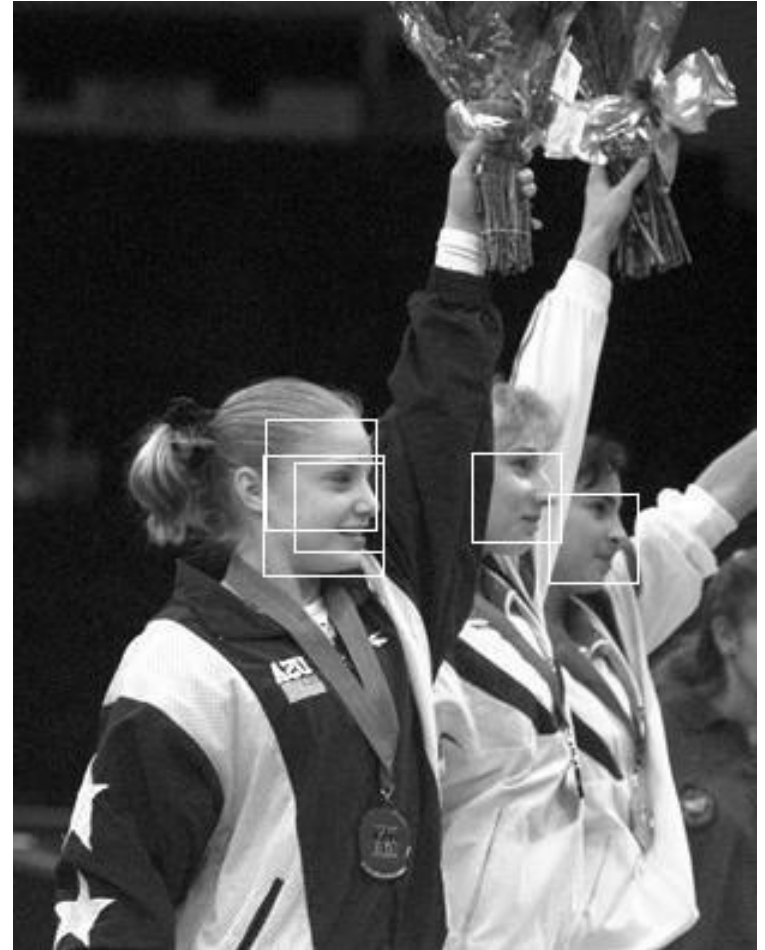


Feature Localization Features

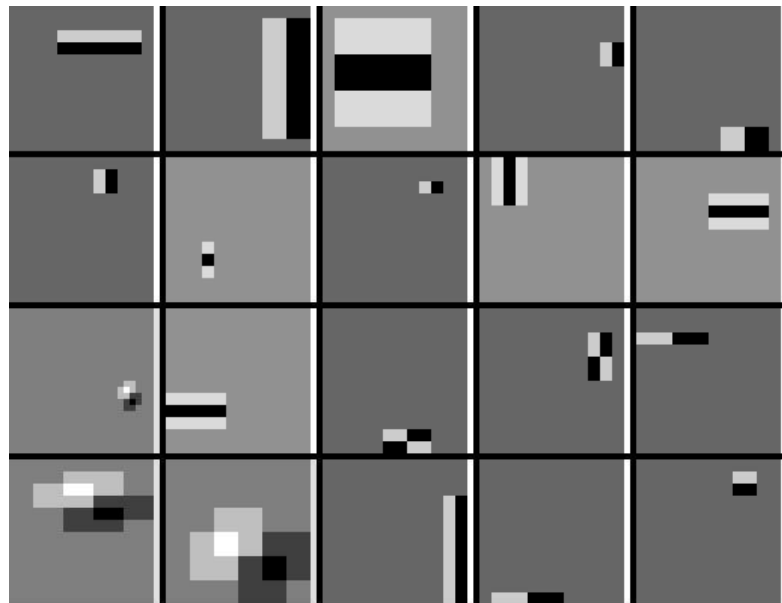
- Learned features reflect the task



Profile Detection



Profile Features



Review: Colour

- Spectrum of illuminant and surface
- Human colour perception (trichromacy)
- Metameric lights, Grassman's laws
- RGB and CIE colour spaces
- Uniform colour spaces
- Detection of specularities
- Colour constancy

Review: Invariant features

- Scale invariance, using image pyramid
- Orientation selection
- Local region descriptor (vector formation)
- Matching with nearest and 2nd nearest neighbours
- Object recognition
- Panorama stitching

Review: Classifiers

- Bayes risk, loss functions
- Histogram-based classifiers
- Kernel density estimation
- Nearest-neighbor classifiers
- Neural networks

Viola/Jones face detector

- Integral image
- Cascaded classifier