



## Tratamiento de Señales

Version 2022-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

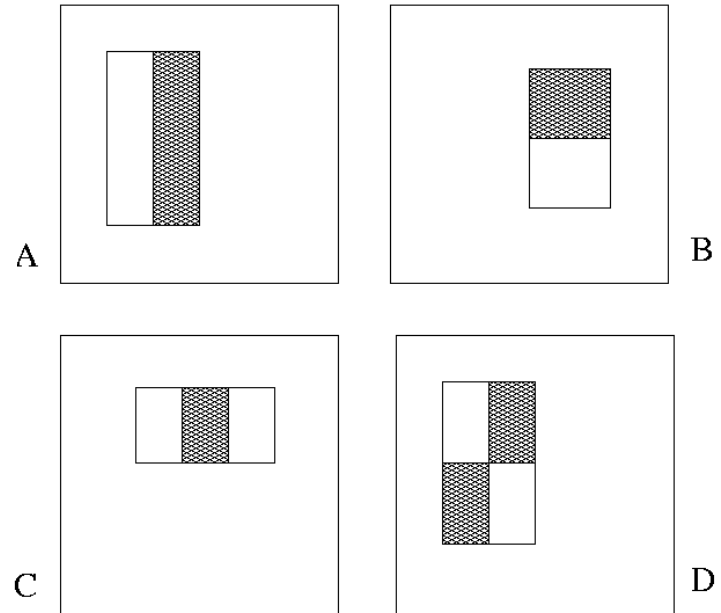
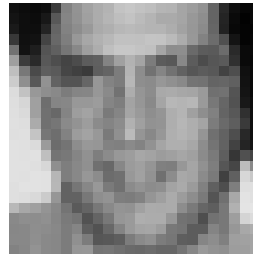
“Rectangle filters”

Similar to Haar wavelets

Papageorgiou, et al.

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

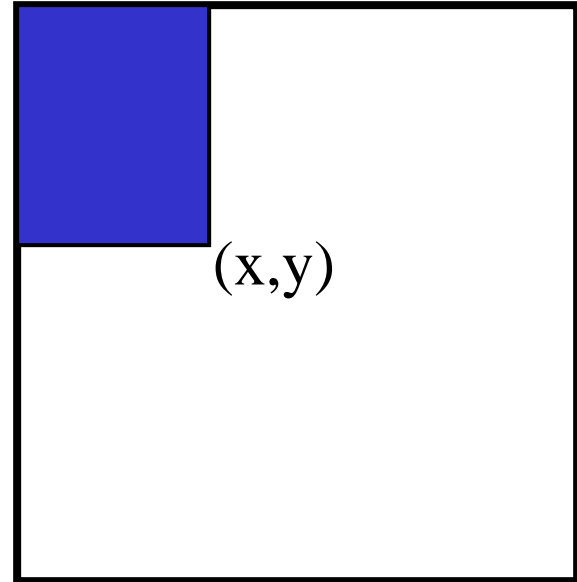
$$C(x) = \theta \left( \sum_t h_t(x) + b \right)$$



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

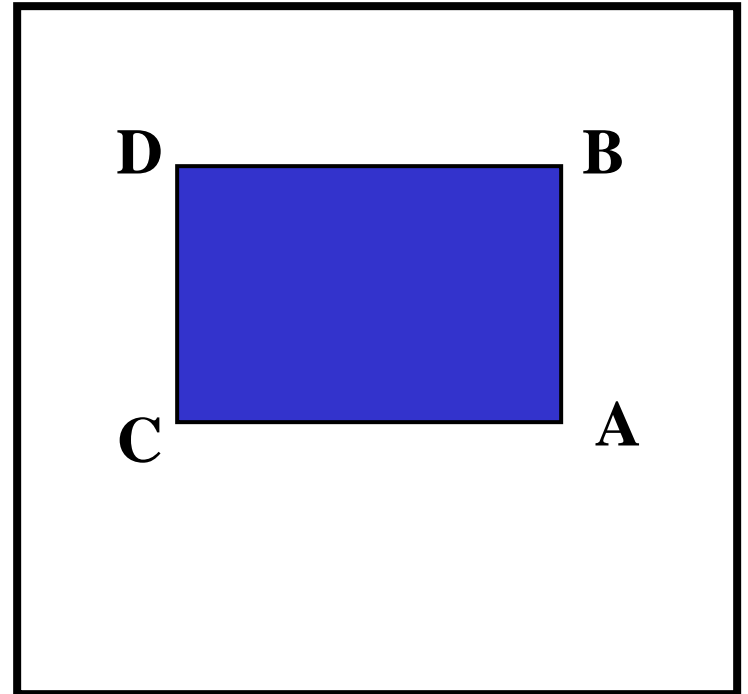


# *Computing Sum within a Rectangle*

- 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

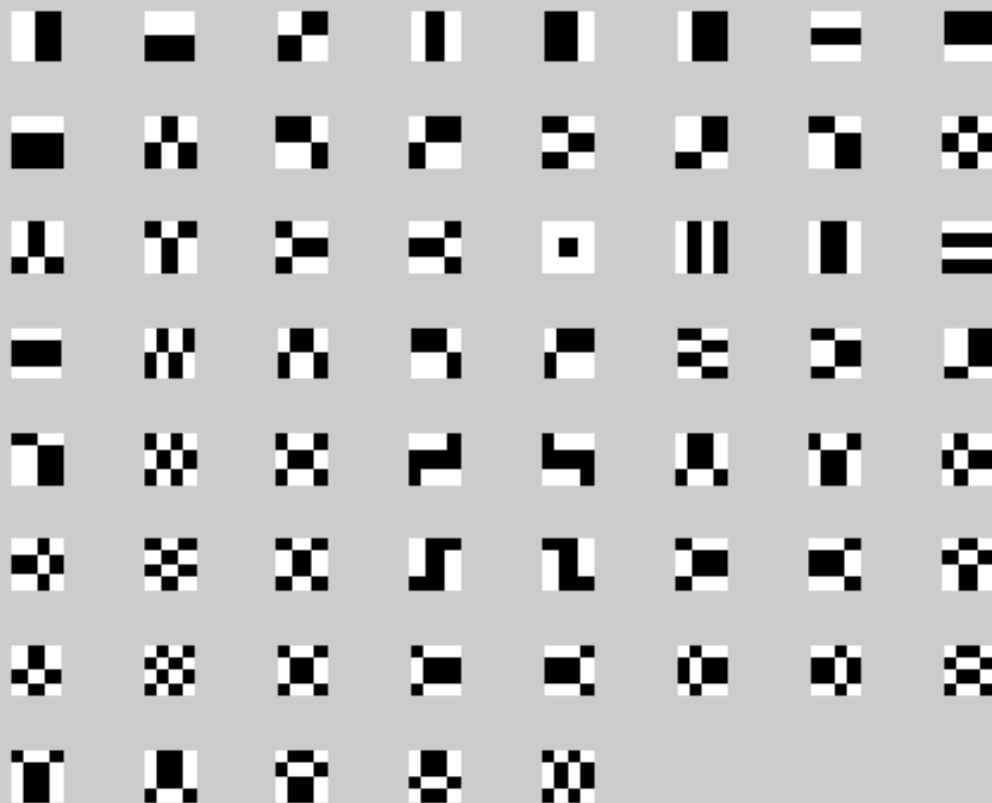


# *Feature Selection*

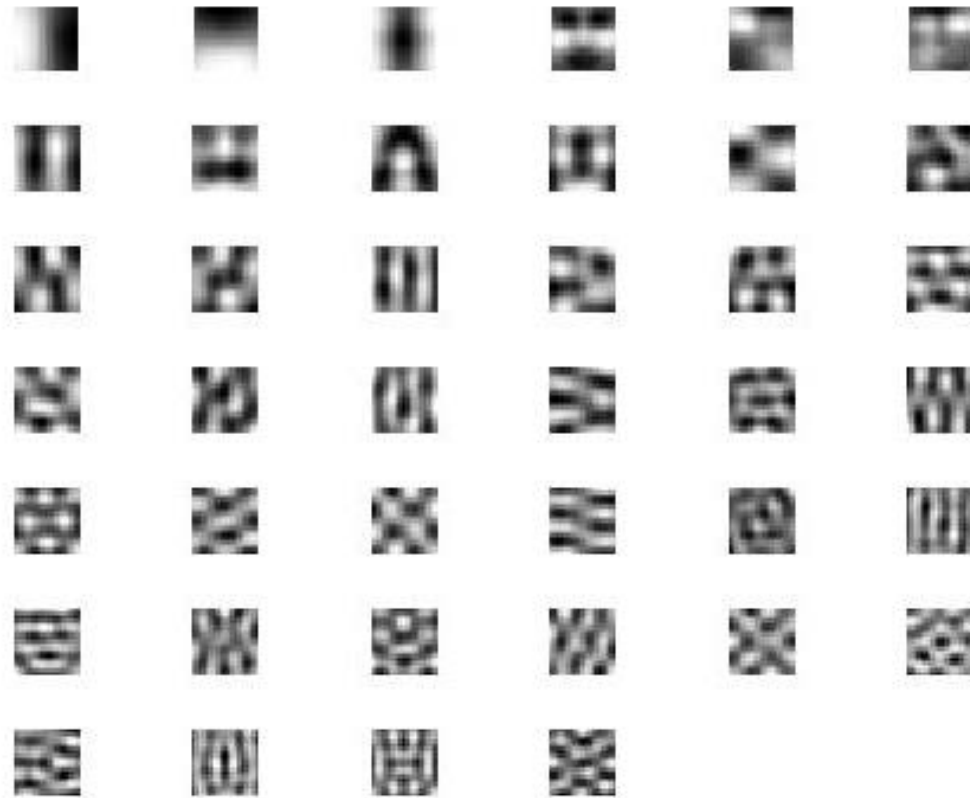
- For each round of boosting:
  - Evaluate each rectangle filter on each example
  - Sort examples by filter values
  - Select best threshold for each filter (min  $Z$ )
  - Select best filter/threshold (= Feature)
  - Reweight examples
- $M$  filters,  $T$  thresholds,  $N$  examples,  $L$  learning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



# *Haar Basis*



# *Haar \* Faces*

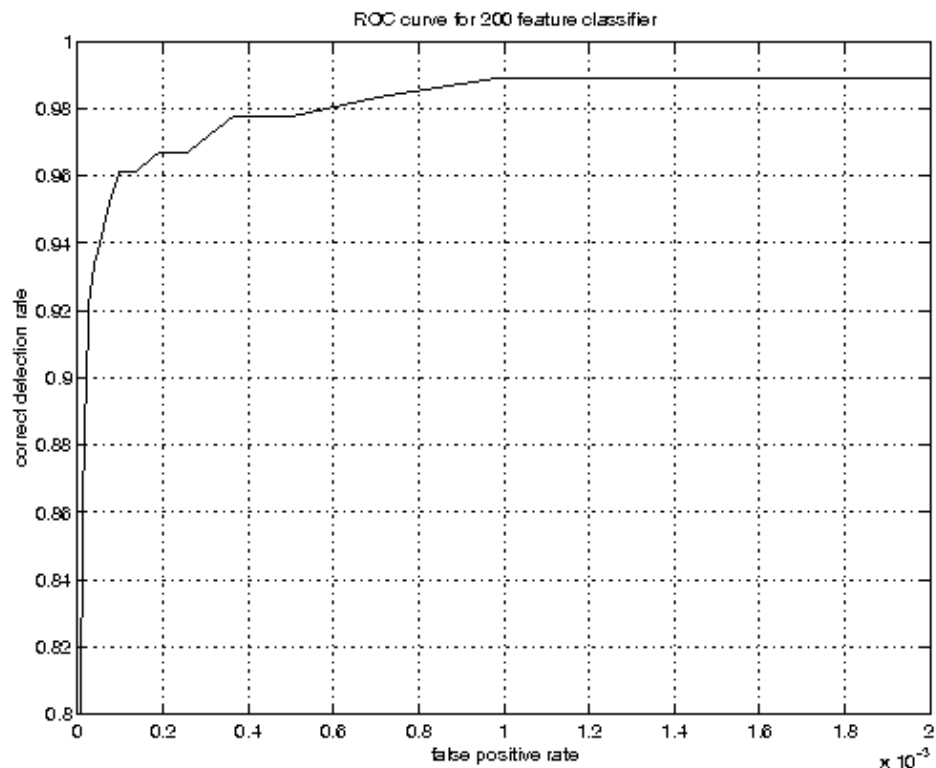
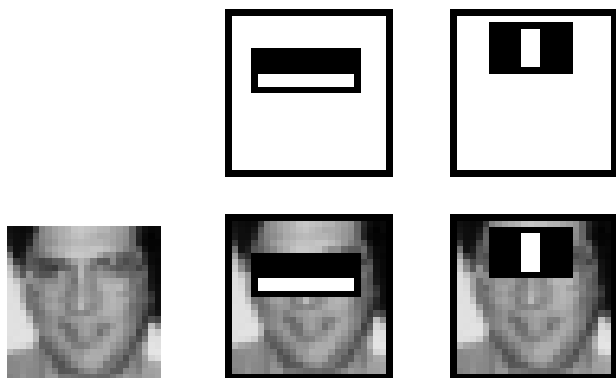


# *Example Classifier for Face Detection*

A classifier with 200 rectangle features was learned using AdaBoost

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

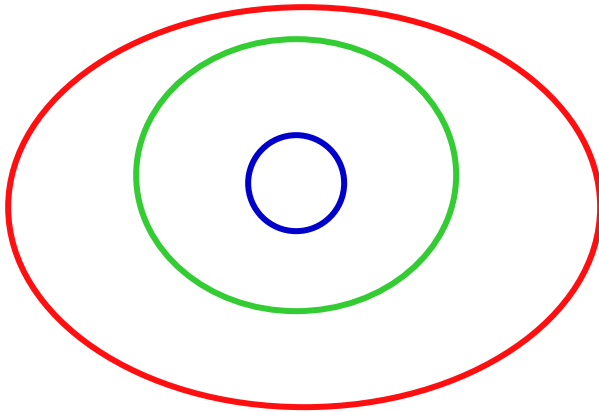
Not quite competitive...



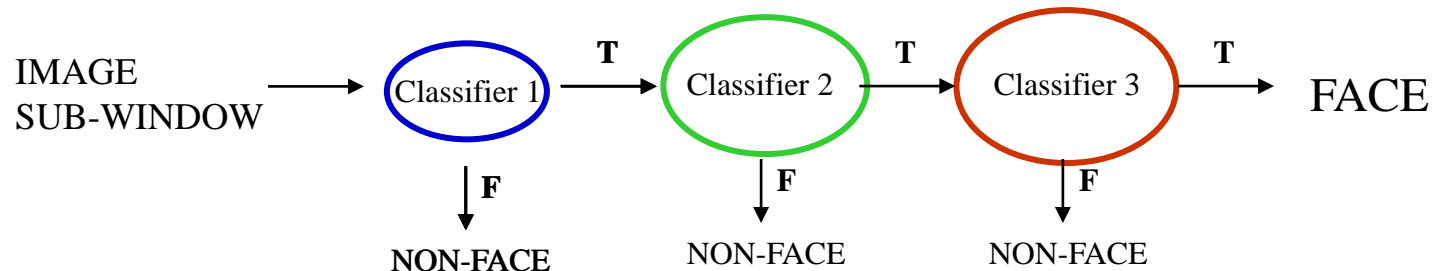
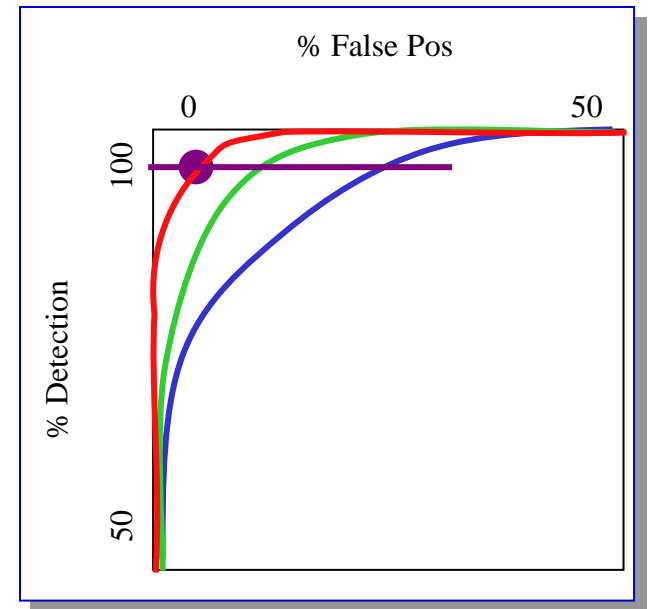
ROC curve for 200 feature classifier

# *Building Fast Classifiers*

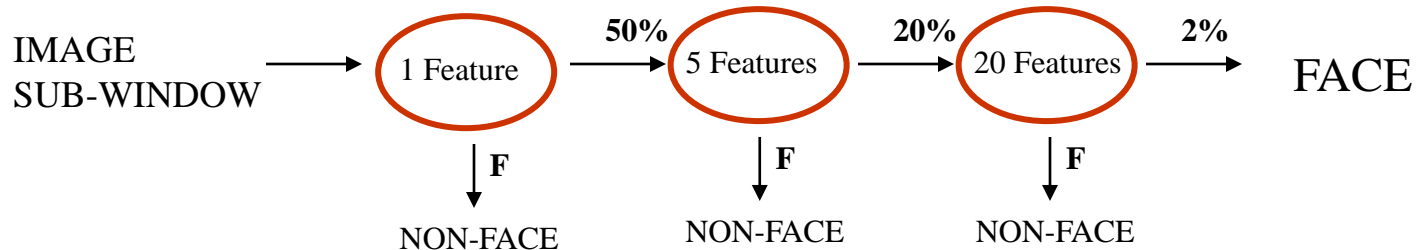
- Given a nested set of classifier hypothesis classes



- Computational Risk Minimization

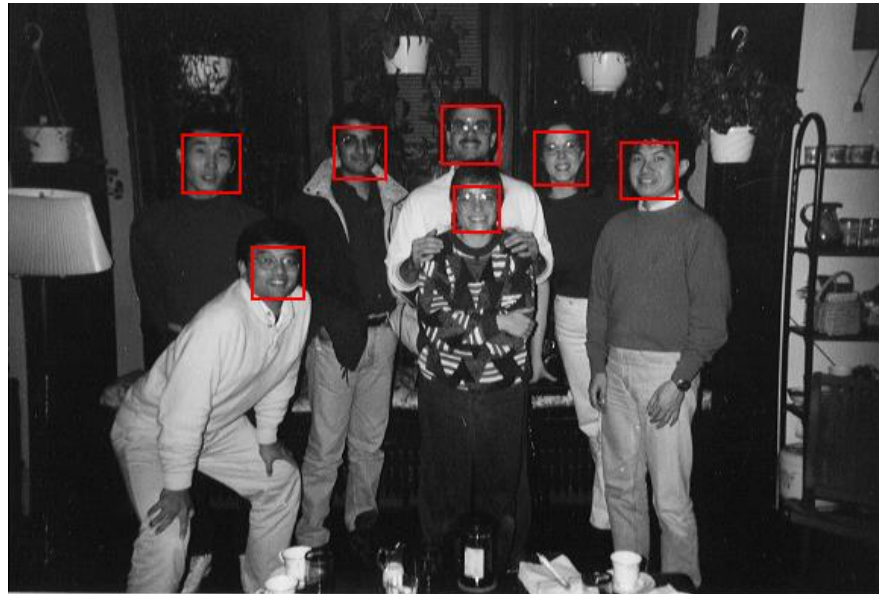
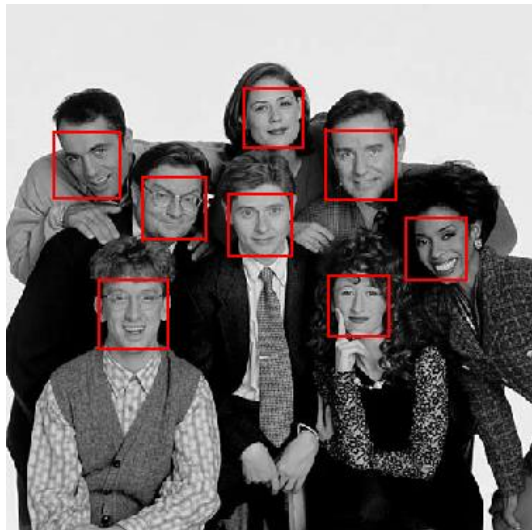
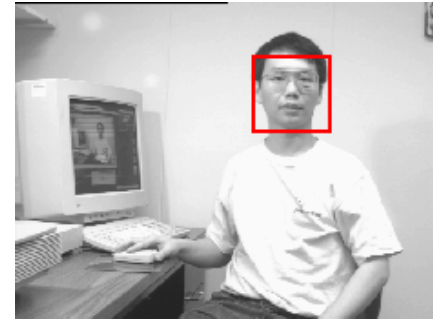
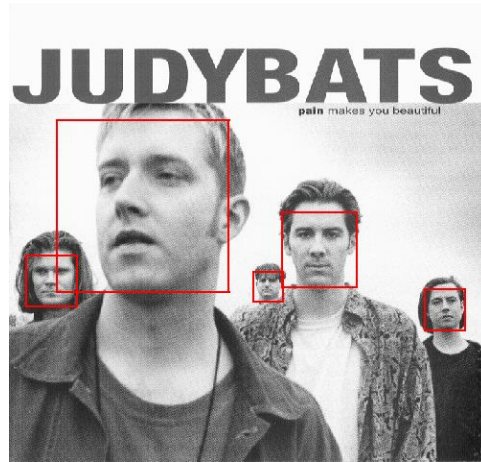


# *Cascaded Classifier*



- 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)

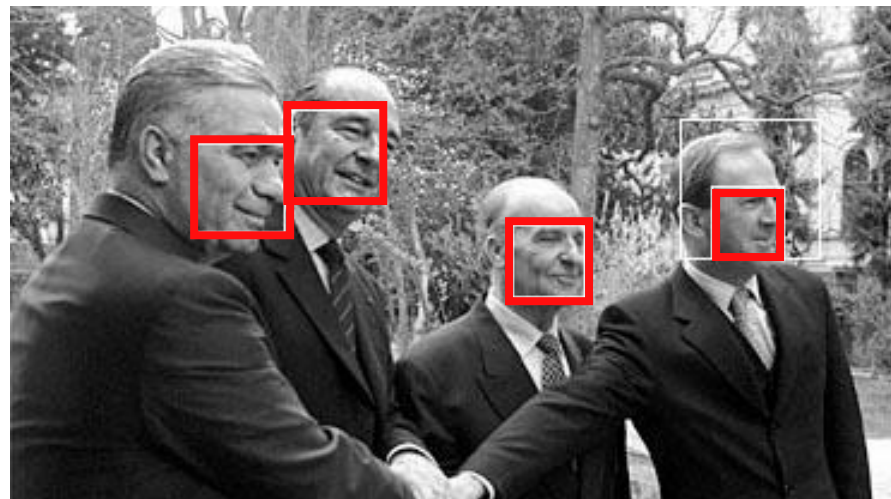
# *Output of Face Detector on Test Images*



# *Solving other “Face” Tasks*

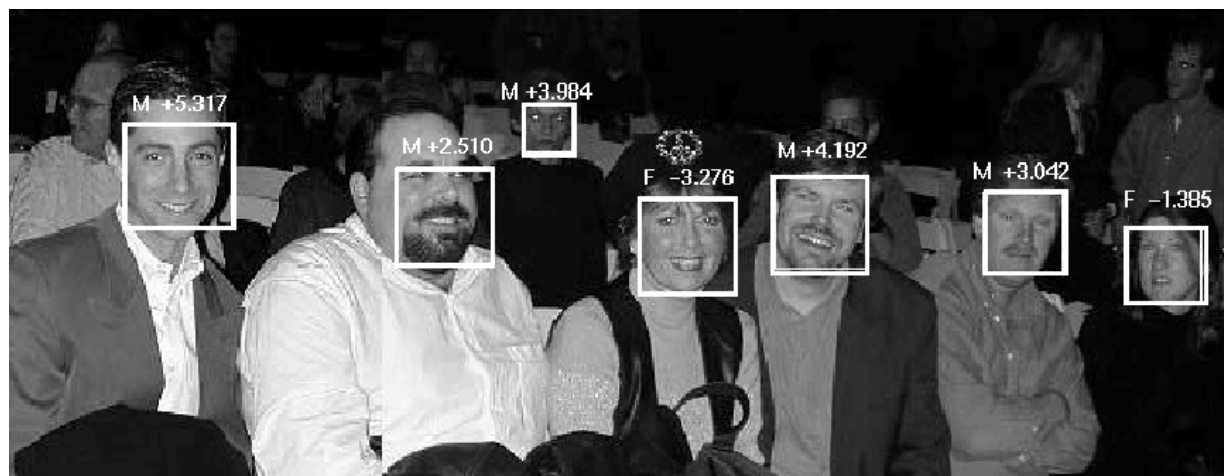


Facial Feature Localization



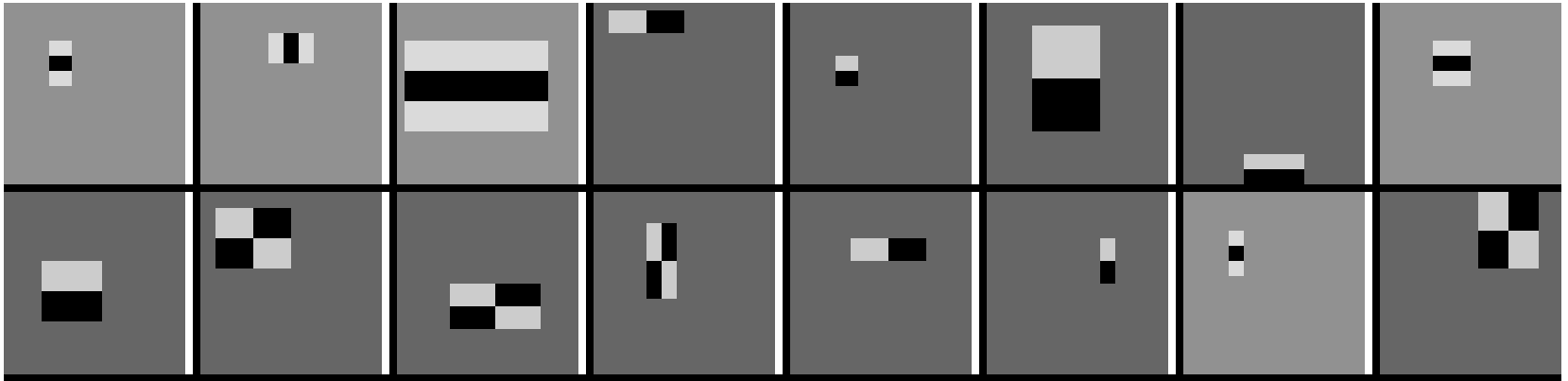
Profile Detection

Demographic Analysis



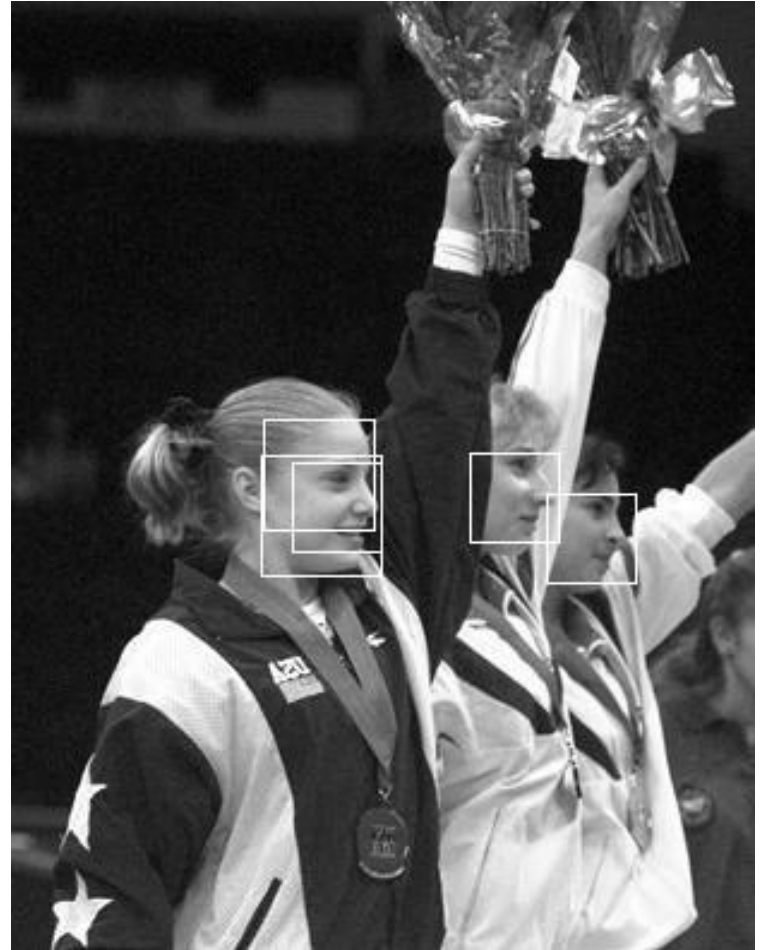
# *Feature Localization Features*

- Learned features reflect the task

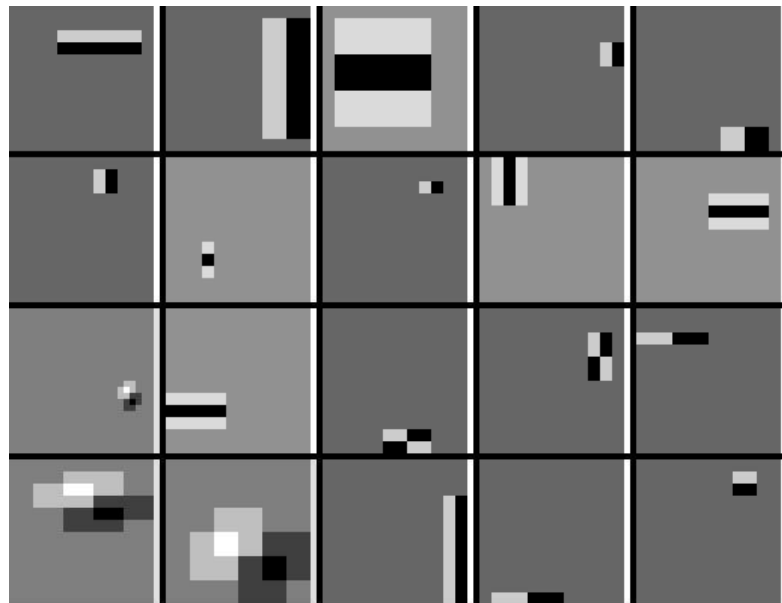




# *Profile Detection*



# *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 2<sup>nd</sup> 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