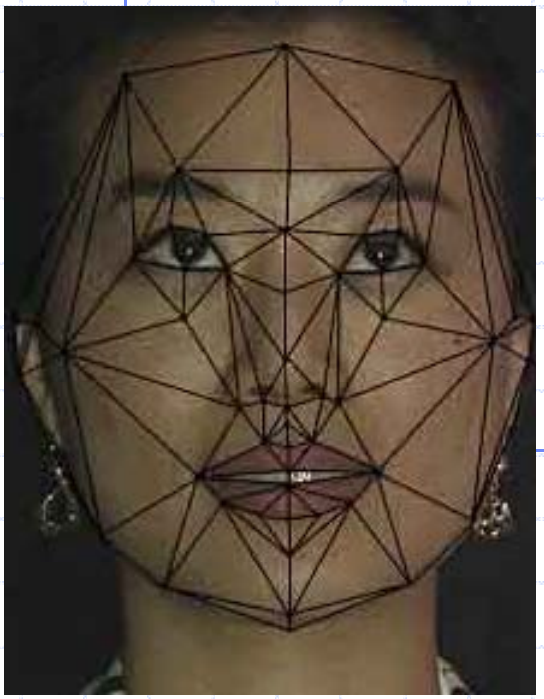
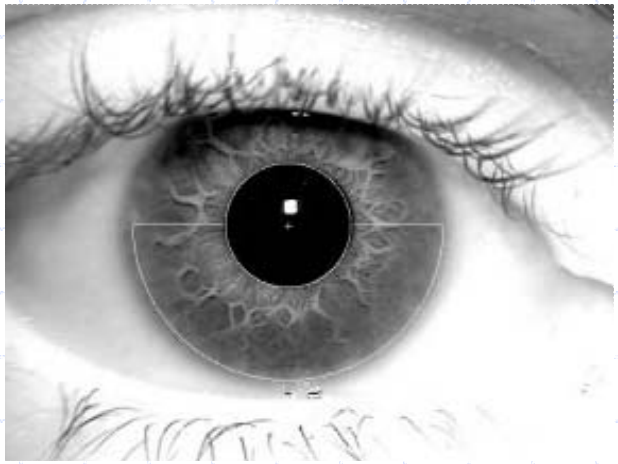
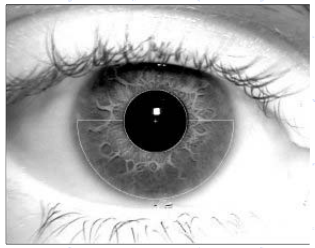
Face detection – part 2



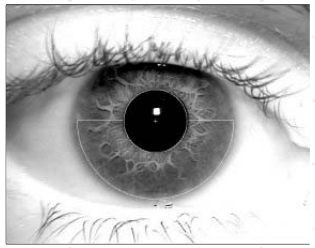


Face Recognition & Biometric Systems

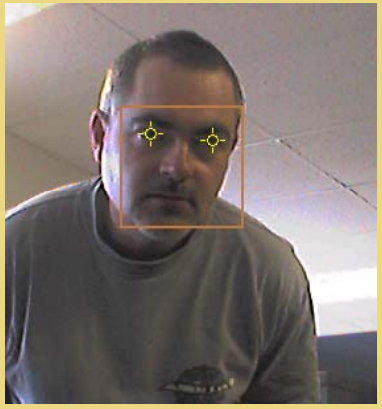


Plan of the lecture

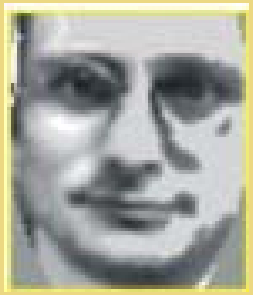
- Detection – main issues
- Hough transform
  - ellipse detection
- Face detection based on ellipses
- Verification
- Precision improvement



Face recognition process



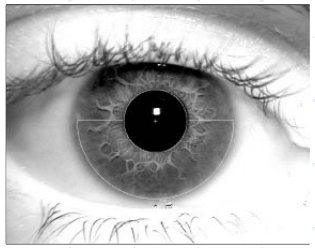
Detection



Normalisation

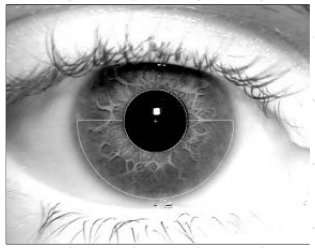
Feature extraction

Feature vectors comparison



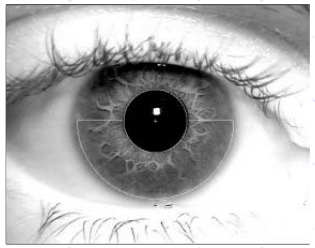
Detection – main issues

- Aim: find a face in the image
  - independent on image size
  - independent on face size
  - for greyscale & colour images
  - fast (real-time) and effective
  - independent on head rotation angle
- Face location
  - defined by centres of eyes



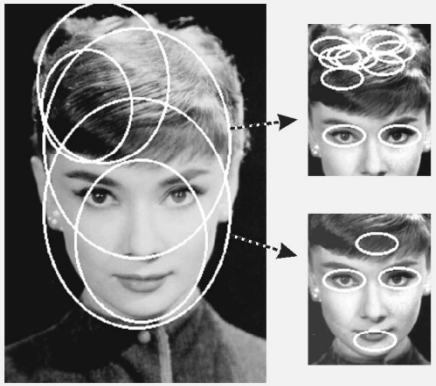
Geometrical method

- Selection of candidates
  - Maio & Maltoni algorithm
  - Head ellipses detection
  - Eye sockets detection
- Verification of the candidates
  - Support Vector Machines (SVM)
- Detection precision improvement
  - Verification maximisation
  - Iris detection

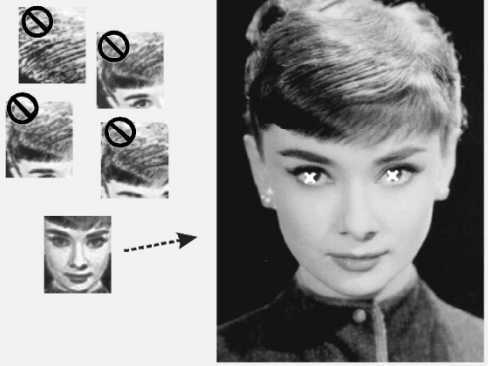


Geometrical method

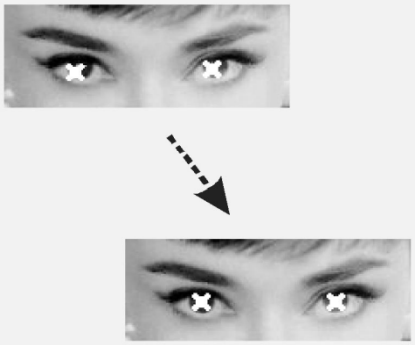
Selection of eye candidates

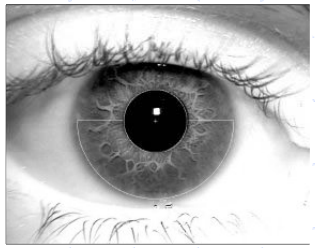


Verification of candidates



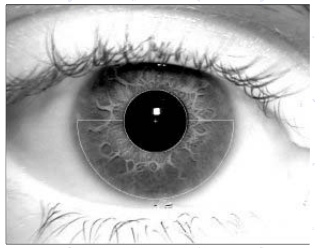
Precision improvement





Ellipse detection

- Generalised Hough Transform – GHT
- Directional image
  - set of segments
- Single segment – possible ellipse centres
- Results summarised
  - most probable ellipse centres



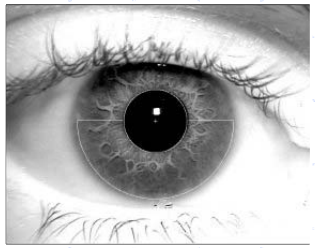
Directional image

1. Median and gaussian filtering
2. Gradients calculation
   - For every pixel in 3x3 neighbourhood

$$g(m,n)=\begin{bmatrix} a+b+2I_{m,n+1}-2I_{m,n-1} \\ a-b-2I_{m-1,n}-2I_{m+1,n} \end{bmatrix} \quad \begin{aligned} a &= I_{m-1,n+1}-I_{m-1,n-1} \\ b &= I_{m+1,n+1}-I_{m+1,n-1} \end{aligned}$$

3. Tangent ($\mathbf{u}$) calculated for a group of gradients $\{\mathbf{g}_i\}$
   - 3x3 gradients, neighbourhood 5x5, error minimisation

$$\delta(\mathbf{u})=\sum_k \left(\mathbf{g}_k \cdot \mathbf{u}\right)^2$$



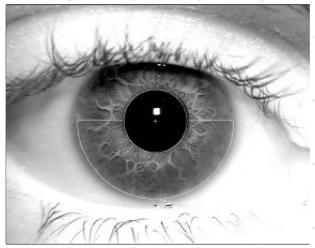
Directional image

4. Segment: direction, intensity, error

$$E = \delta_{\min}(\mathbf{u}) / \sum_k (\mathbf{g}_k)^2$$

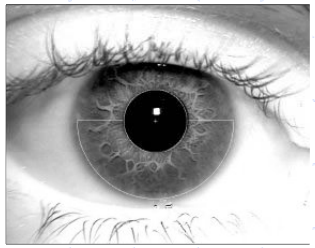
   - Error thresholding E_{th} = 0.25

5. Canny edge detector in the intensity image
   - Similar segments eliminated



General Hough Transform

- Aimed at detecting objects of parametrized shape
  - Shape, e.g. ellipse, segment defined by parameters
- Image transformed to a parameter space
  - Number of dimensions = number of parameters
  - Accumulator – image in the parameter space
- Local maxima in the accumulator
  - Probable values of the parameters
  - Parameters define the object

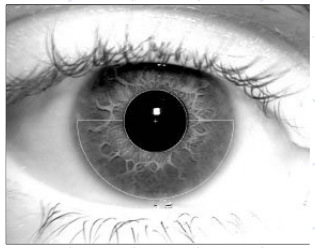


General Hough Transform

- Search for objects:
  - shape defined
  - directional image
- Ellipse case:
  - a, b – length of ellipse semi-axes
  - ρ_r, ρ_e – reduction and expansion coefficients

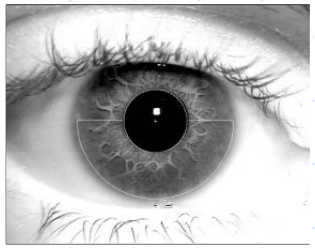
$$a_{\min} = \rho_r \cdot a \qquad a_{\max} = \rho_e \cdot a$$

$$b_{\min} = \rho_r \cdot b \qquad b_{\max} = \rho_e \cdot b$$



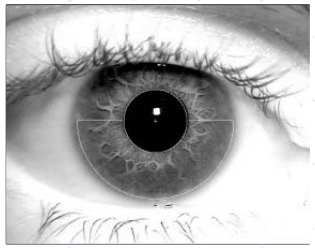
General Hough Transform

- Assumption:
  - every segment may be a part of an ellipse
  - ellipses of defined shape and size
  - segment - two possible centres of an ellipse
- Tolerance accepted:
  - two sets of possible ellipse centres
  - weights assigned to the points

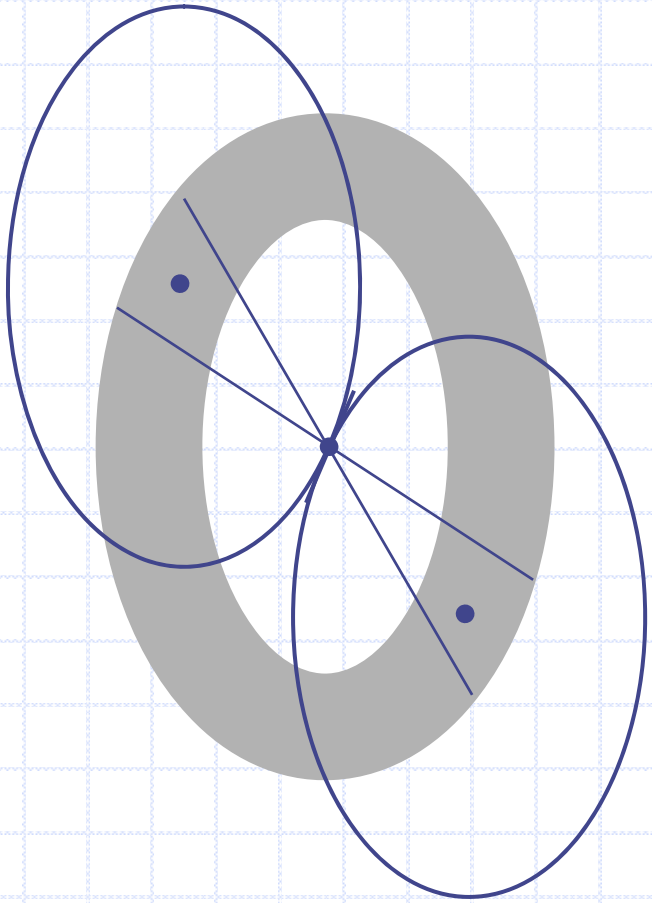


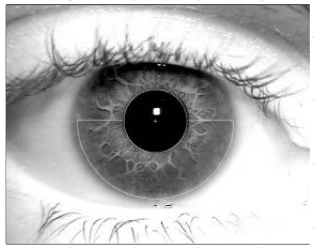
General Hough Transform

- Accumulator:
  - matrix of image size or smaller
  - contains zeros at the beginning
  - modified by each segment (sum possible centres)
  - image intensity: threshold or influence
  - final value in each accumulator point proportional to the probability that an ellipse centre is located there



GHT - example

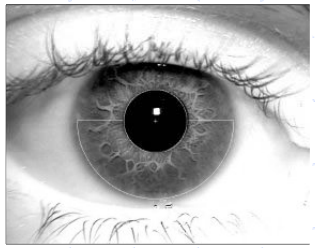




GHT – performance

- Ellipse estimation for each segment (very time-consuming)
  - application of templates (discrete direction)

- Time depends on relative ellipse size
  - image scaling
- GHT – constant size of ellipse
  - pyramid – scale image instead of ellipse

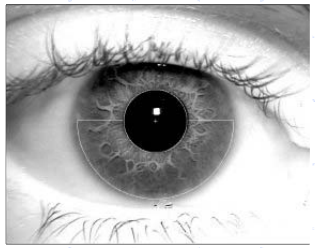


GHT – summary

- Controllable speed
- Easy to control and modify
  - directional image generation method
  - angle and size tolerance
- Any shape can be detected

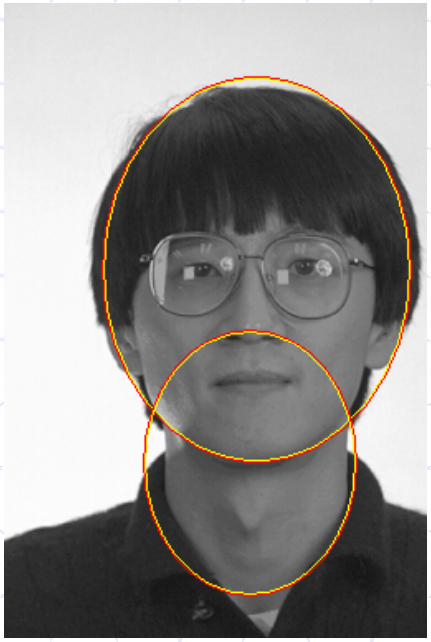


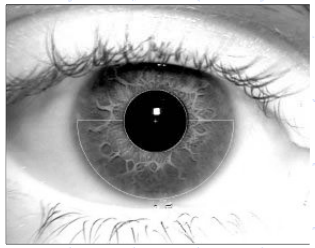




Head detection

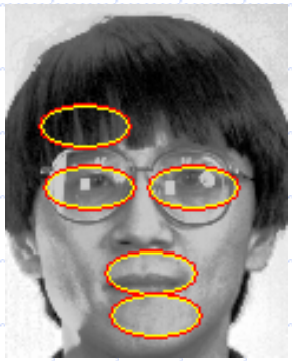
- „Vertically-oriented” ellipses
  - potential faces
  - low acceptance threshold
  - many non-faces

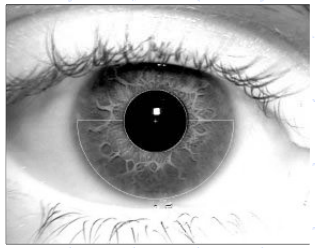




Eye detection

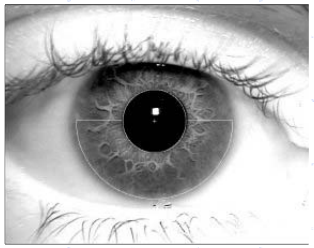
- Aim: find eye sockets candidates
- Searching restricted to the vertical ellipses area
- Low acceptance threshold
- Large number of false detected „eyes”



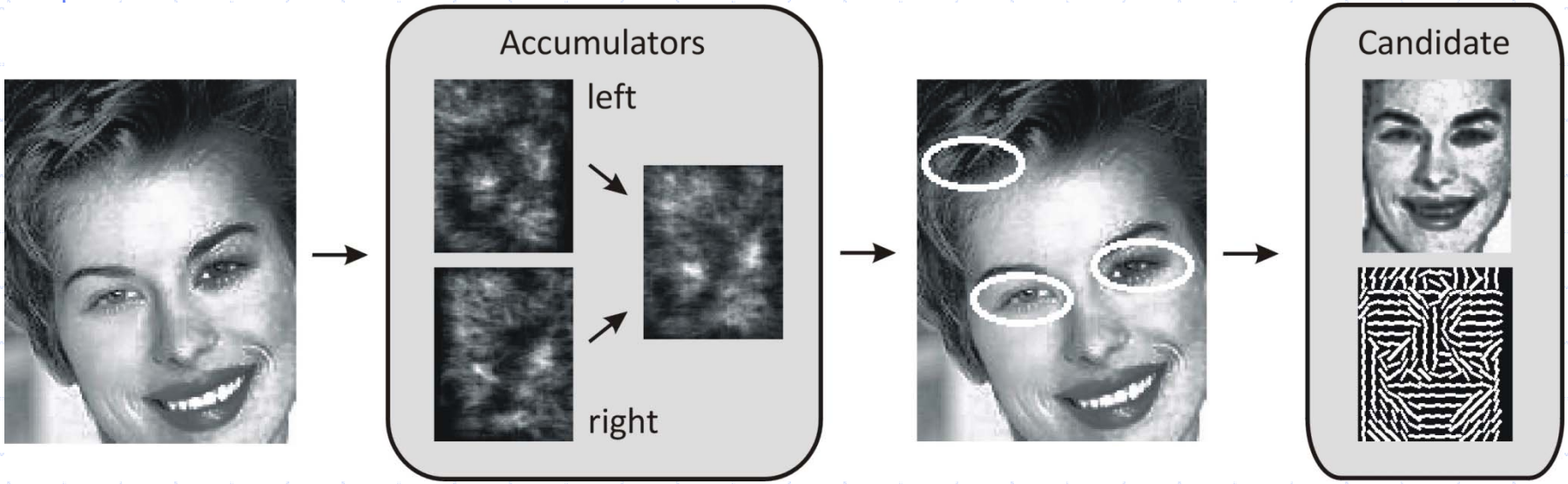


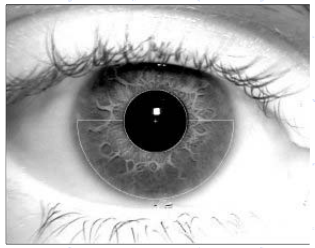
Eye detection

- Verification of each ellipse
  - Is it really an eye?
- Heuristic rules
  - Eyes should be at the same level
  - Distance shouldn't be too small nor too large within the main ellipse
- Outcome:
  - Location of eyes (the best pair chosen)
  - Face candidate

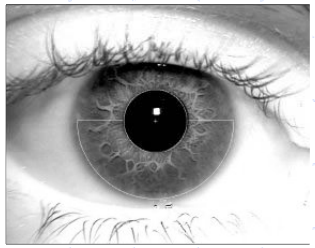


Eye detection



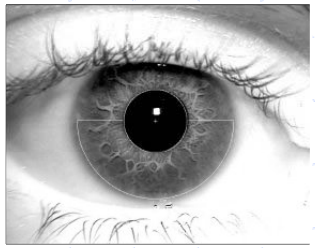


Ellipse detection examples



Verification

- List of candidates delivered by:
  - ellipse detection
  - color-based detection
- Candidate:
  - equal size, face in a set position
  - image normalisation



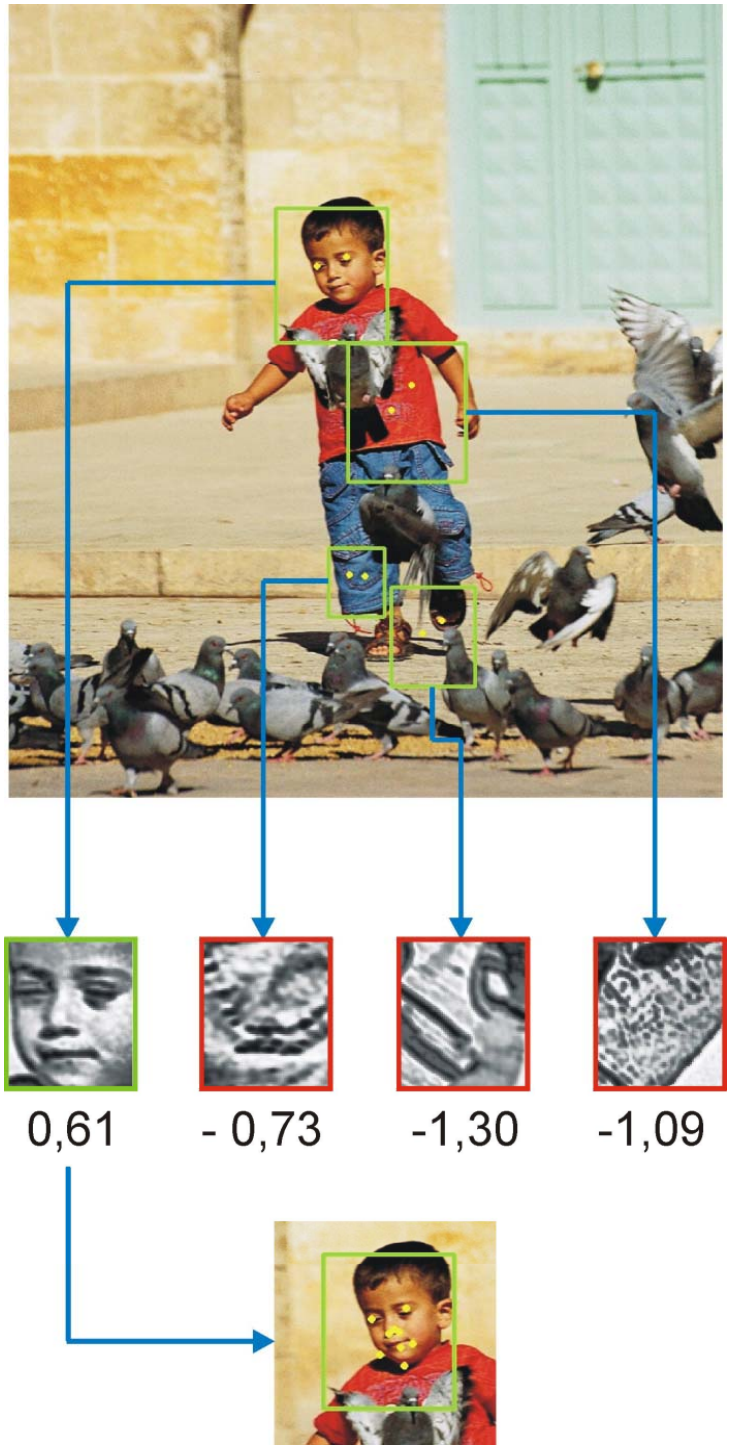
Verification

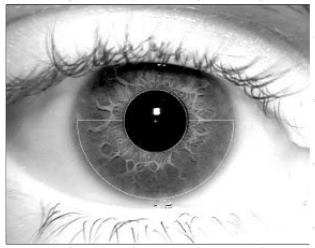
- Classifiers:
  - SVM, ANN
- How does it work?
  - training
  - classification
- Classification result
  - acceptance threshold
  - false rejection vs. false acceptance trade off

Selection of candidates

Verification of candidates

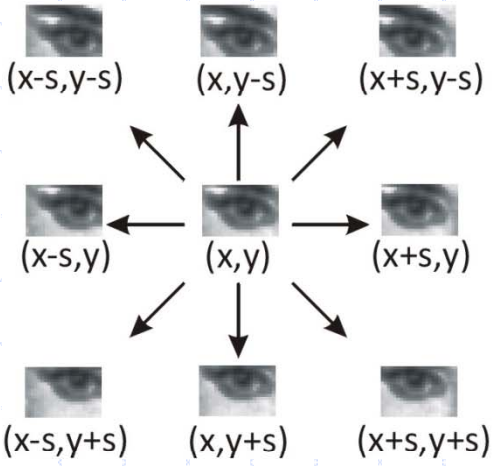
Facial features detection

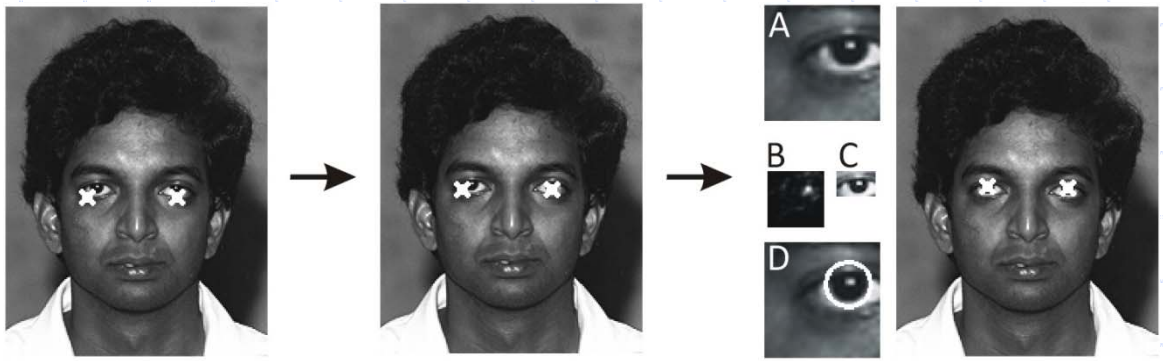




Precision improvement

- Verification-based correction
  - SVM trained for eye images
- Iris detection
  - Based on ellipse (circle) detection

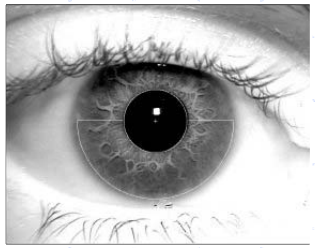




Eye socket detection

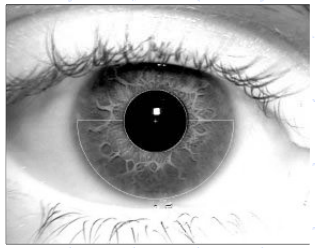
Verification correction

Iris detection



Face detection – applications

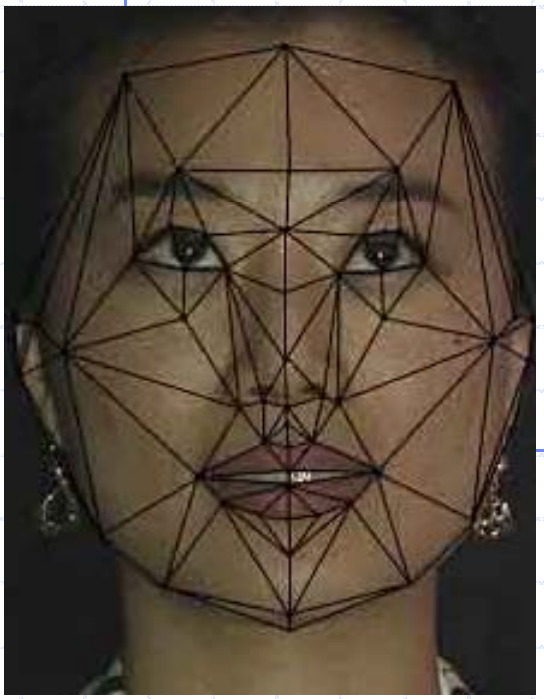
- Necessary step in automatic face recognition
- Face tracking applications
  - PTZ cameras
  - robotics
- Searching image databases
- Many other areas, e.g.:
  - smart image encoding (faces with higher quality)
  - eye direction (photography)

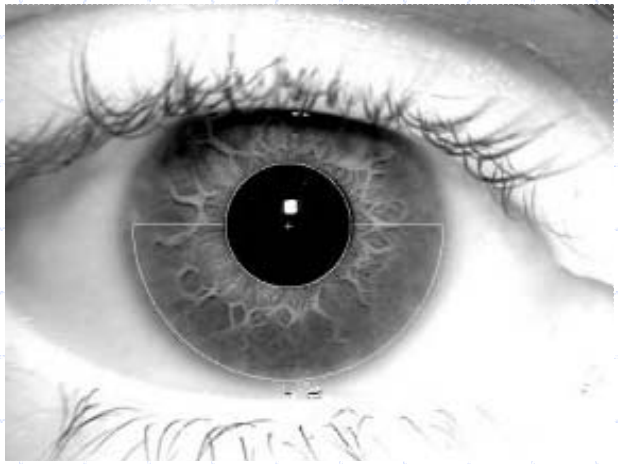


Summary

- Face detection
  - various methods
  - many applications
- Common face properties
  - colour (last week)
  - shape
- GHT – useful tool for shape detection

Thank you for your attention!





Face Recognition & Biometric Systems