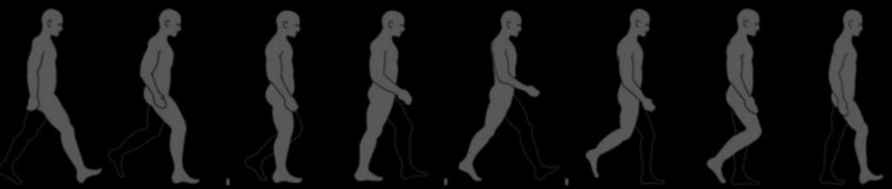
Biometric Authentication Systems

Chapter 10:

Face

Ngo Thanh Trung



Reviewing questions

1- Name the three most important parts of iris for recognition?

Reviewing questions

- 2- Iris or fingerprint has better recognition performance?

Reviewing questions

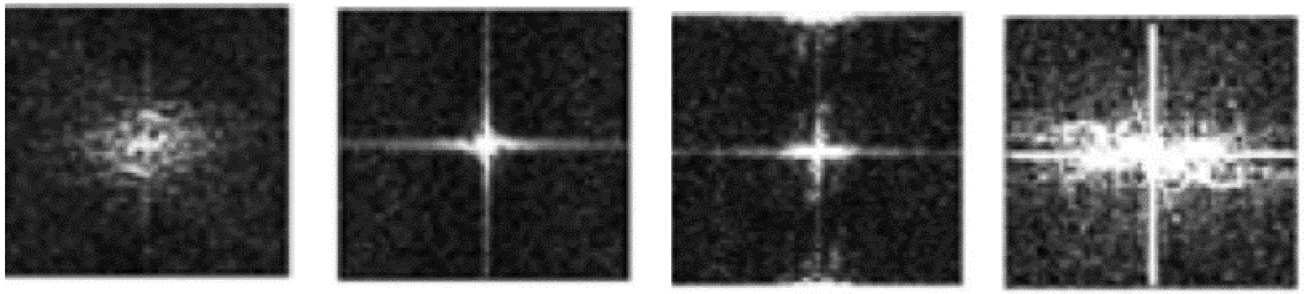
- 3- fingerprint or iris has better (farther) working distance?

Reviewing questions

- 4- what do not affect the performance of iris recognition?
  - light frequency
  - light color
  - motion blur
  - occlusion,
  - defocus,
  - nonuniform illumination,
  - low resolution sensor,
  - iris dilation,
  - off-angled imaging,
  - the presence of a printed contact lens
  - all of these factors

Reviewing questions

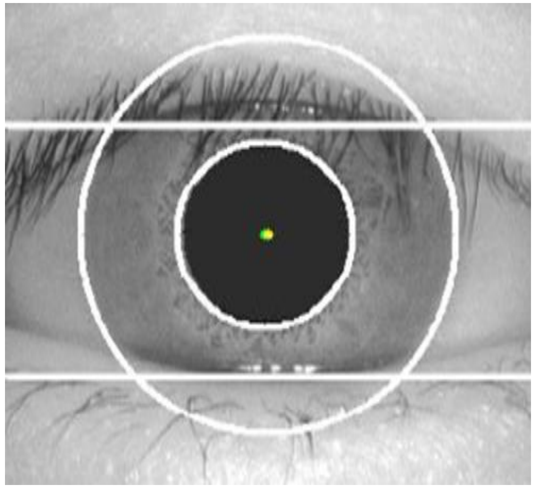
- 5- Below are the Fourier transform spectrums of iris image area, which one is of good iris image?



a b c d

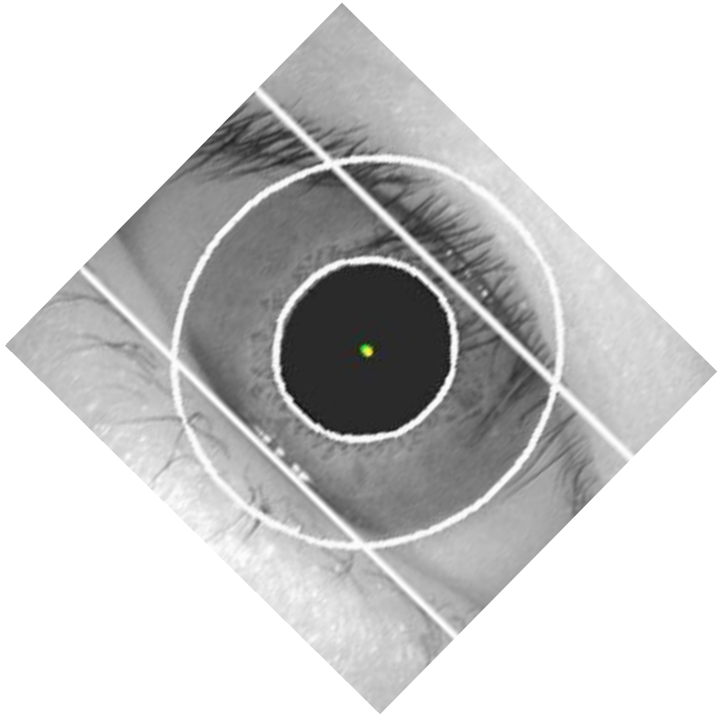
Reviewing questions

- 6- How to detect inner and outer circles of Iris area?



Reviewing questions

- 7- What to do with iris code when iris is rotated?

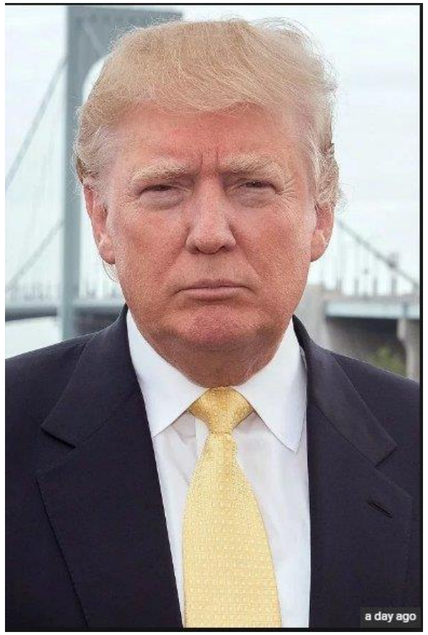


Outline

1. Introduction
2. Face feature
3. Design of face recognition system
4. Image Acquisition
5. Face Detection
6. Feature Extraction and Matching

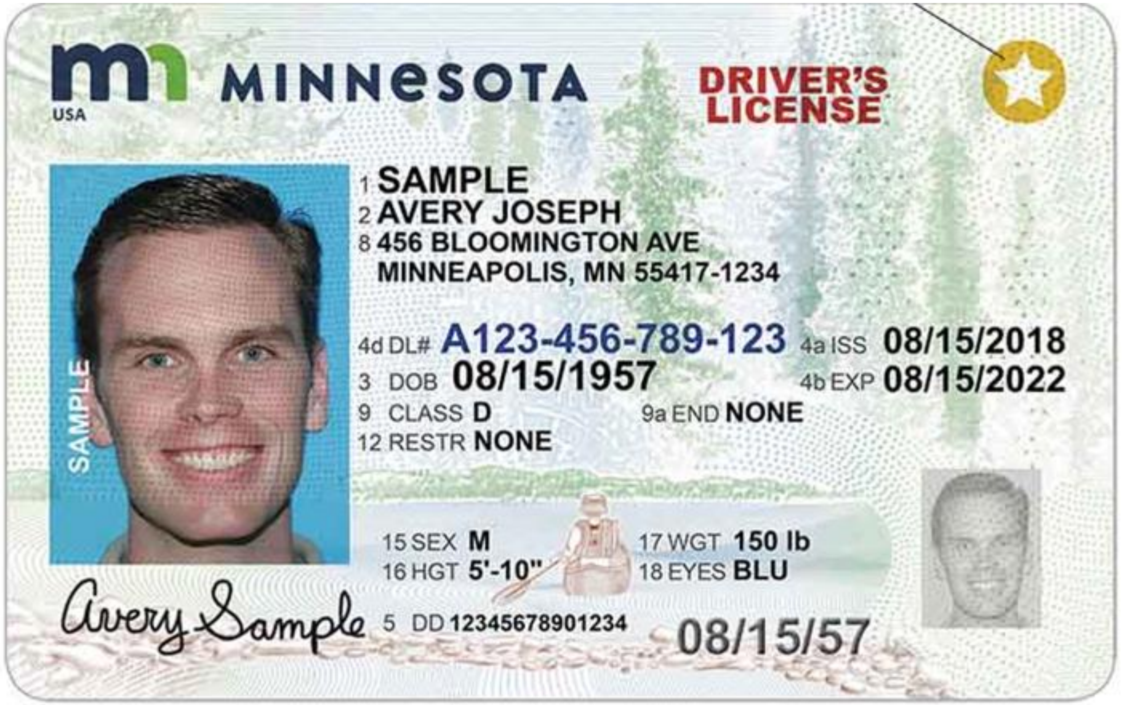
1- Introduction

- The face is the most visible part of the human body
- The most commonly used biometric trait by humans
- The human face is the most natural identifying characteristic, also conveying emotions, physical condition, gender, ethnicity, and age. We are very good at recognizing face.



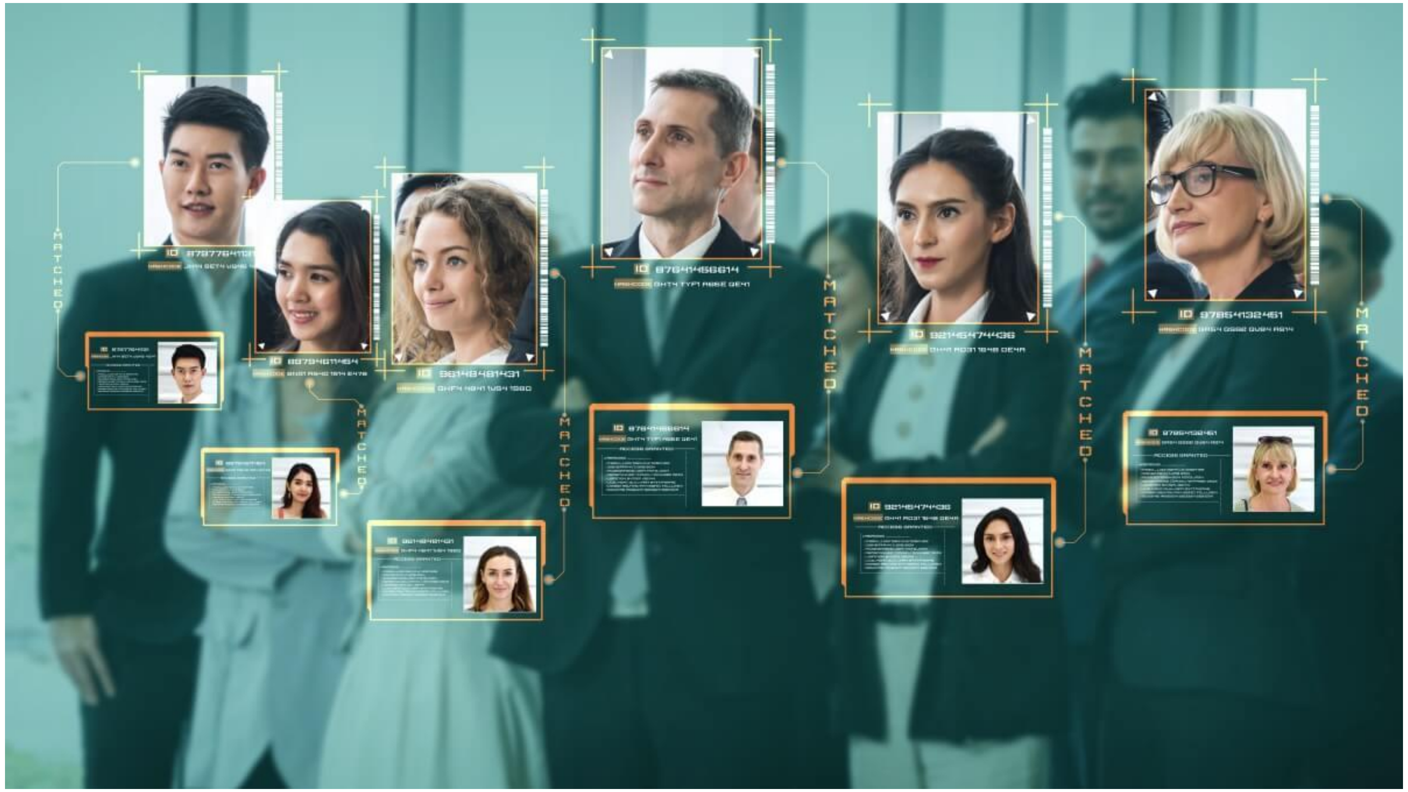
1- Introduction

- Face is an important biometric identifier in the law enforcement and human-computer interaction (HCI) communities



1- Introduction

- Recognizing persons based on their face images are classical object recognition problems in computer vision



1- Introduction

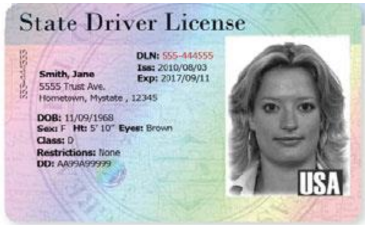
- Unlike iris, fingerprint twins seem to have very similar face
- But face can be captured from much longer distance than iris or fingerprint
- People are likely to share their face on internet rather than fingerprint or iris!



1- Introduction

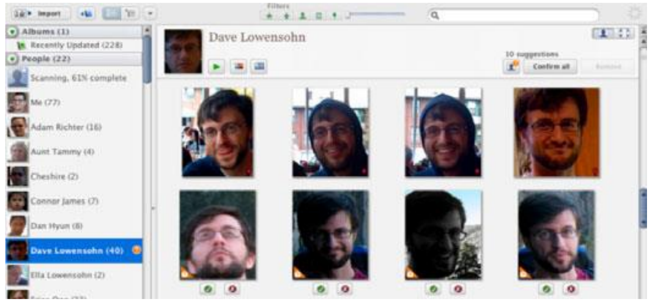
- Face has wide range of applications in:
  - law enforcement,
  - civilian identification,
  - surveillance systems, and
  - entertainment/amusement systems

Australia’s SmartGate system that facilitates faster immigration



Id card

Kinect gaming system with face recognition

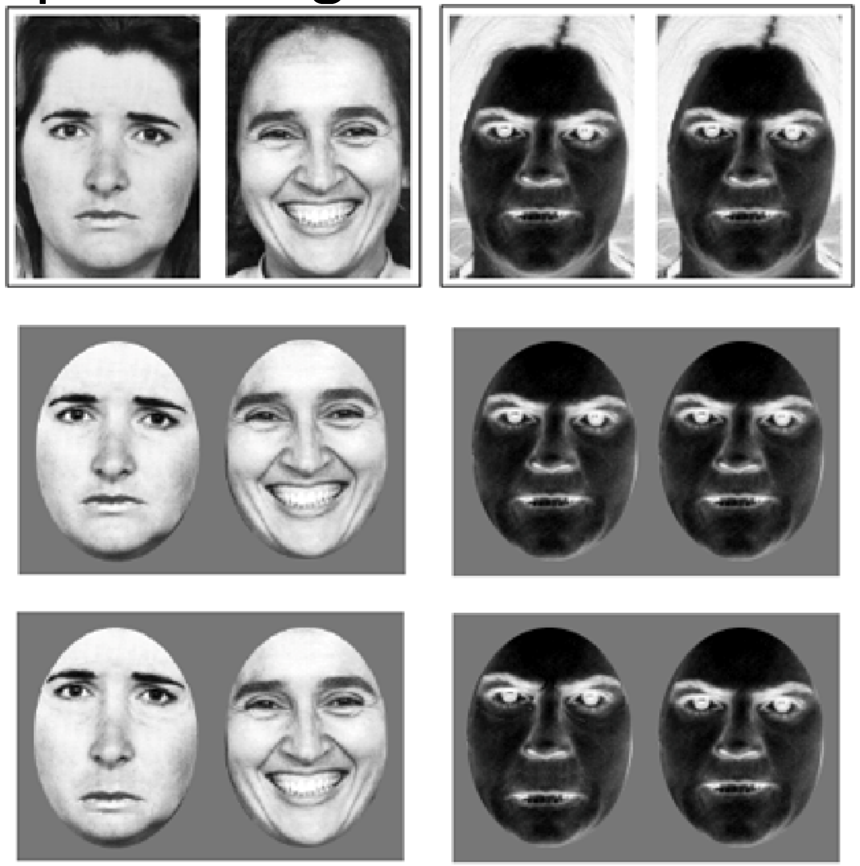


Face tagging in Google Picasa

1 Introduction

Psychology of face recognition

- Research in the fields of psychology and neuro-cognition indicates that certain parts of the brain are geared toward perceiving the face.
- How about face image in untraditional way?



Why face recognition?

Advantages:

- Most natural for humans
- Highly acceptable and non-intrusive
- Highly applicable:
  - Static identity verification
  - Uncontrolled face detection and Identification from video

Disadvantages:

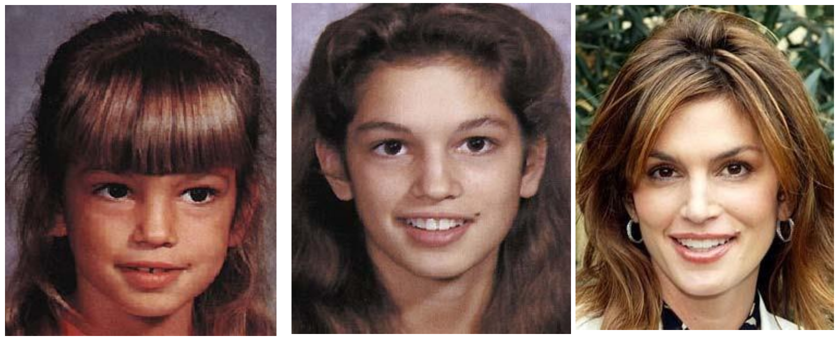
- Medium to Low performances
- Not unique (twins)
- Aging and time effects

Difficulties of face recognition

- Intra-class variation

Variations of illumination, appearance

Appearance changes

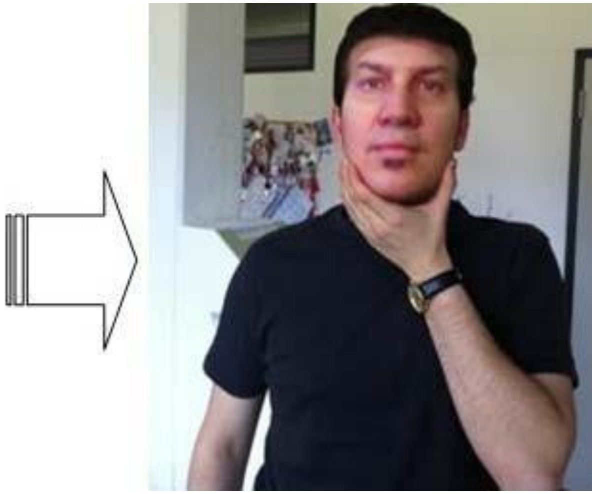


Aging

Make-up

Face surgery

Face spoofing



An ill-posed problem

Do they look at all similar… ?

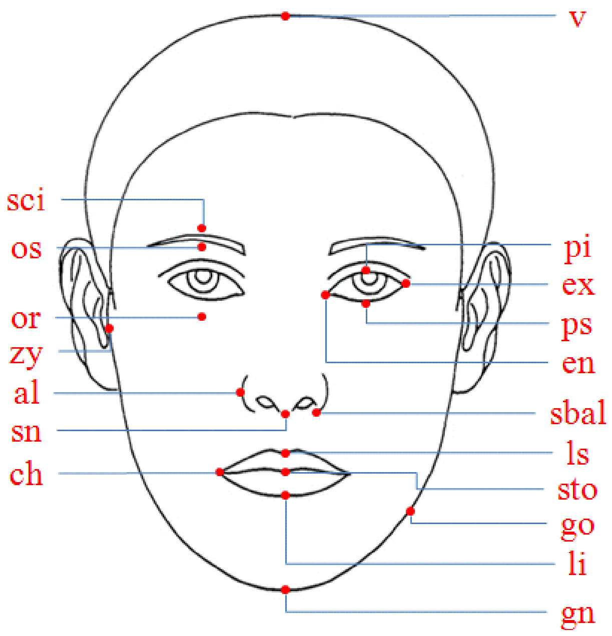
Difficulties of face recognition

- Inter-class similarity

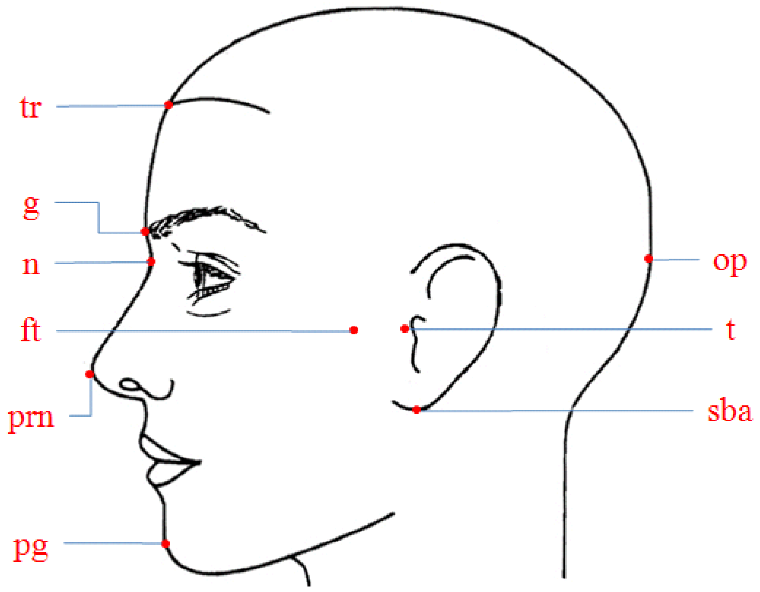
Twins **Father and son**

2- Face features

- Face is composed of the forehead, eyebrows, eyes, nose, mouth, cheeks, and chin
- Anthropometric facial landmarks are used to characterize identity, ethnicity, gender, or age.



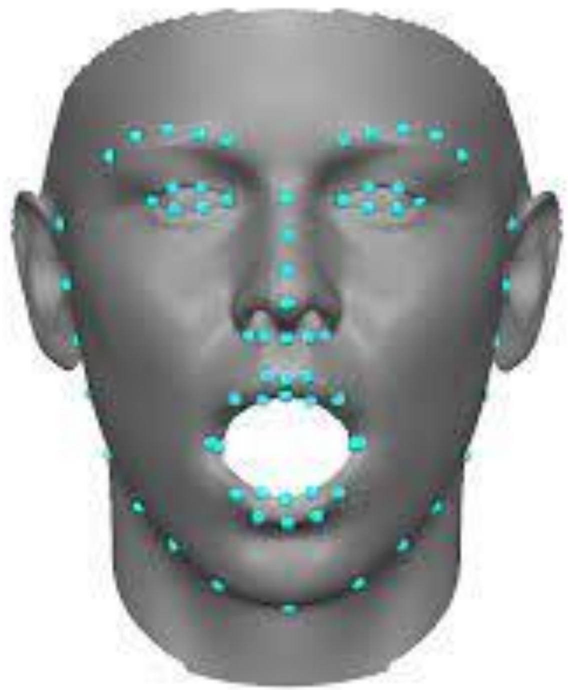
(a) Frontal

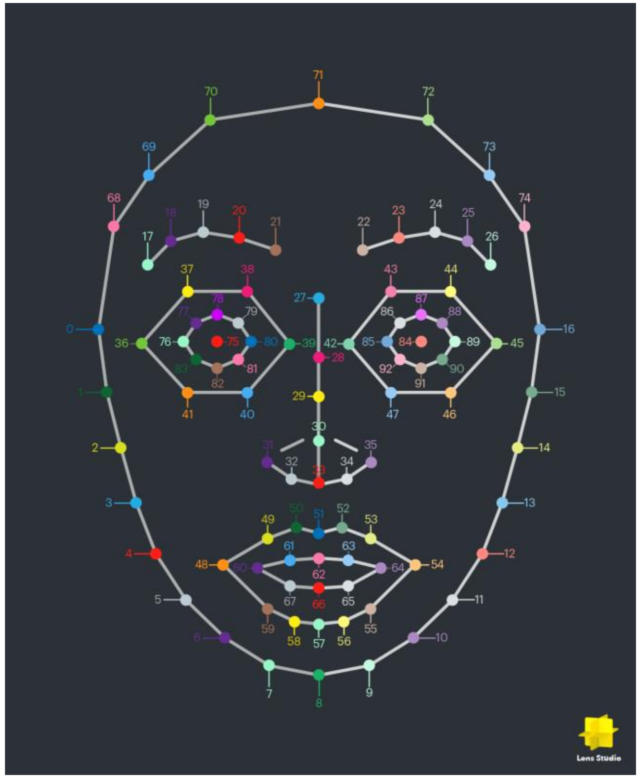


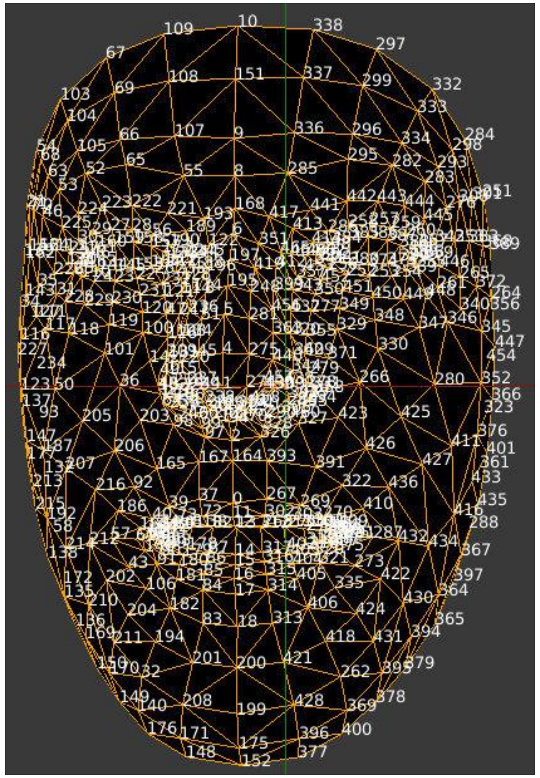
(b) Profile

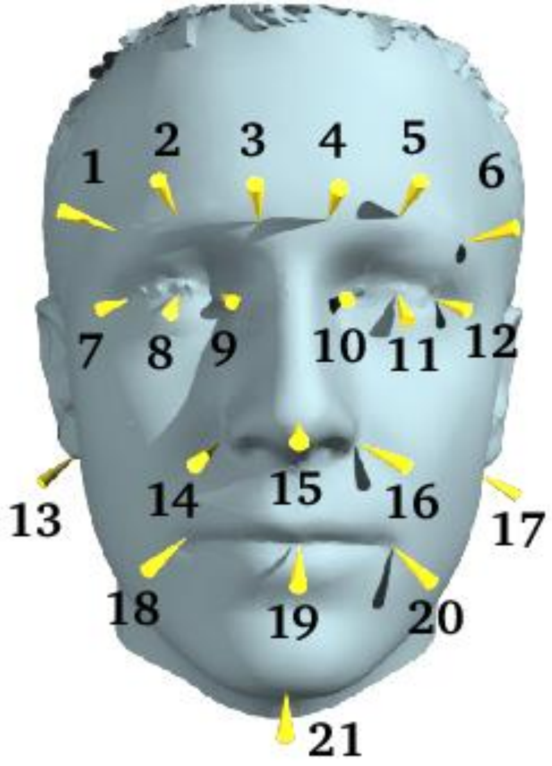
Some anthropometric facial landmarks

Different landmarking

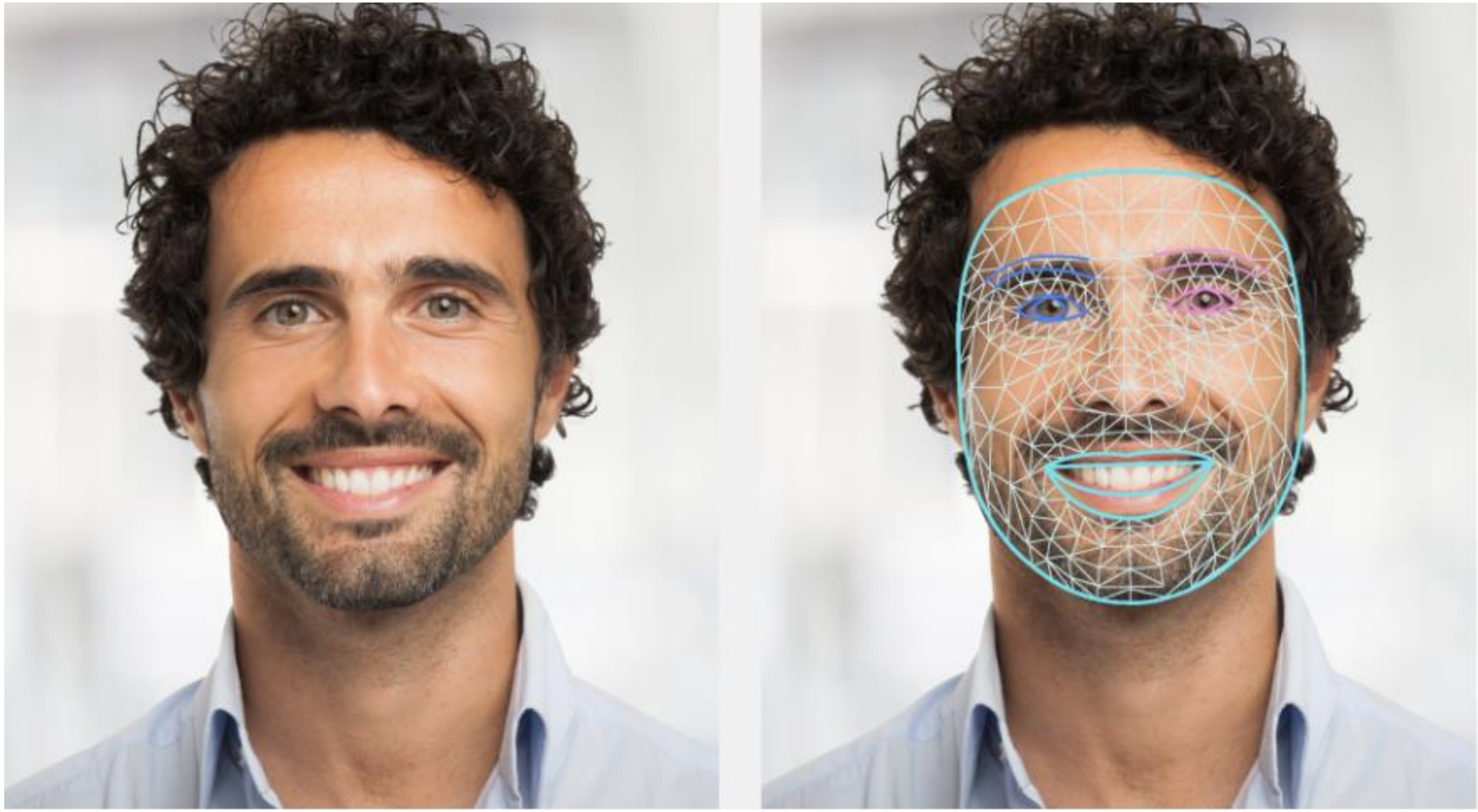








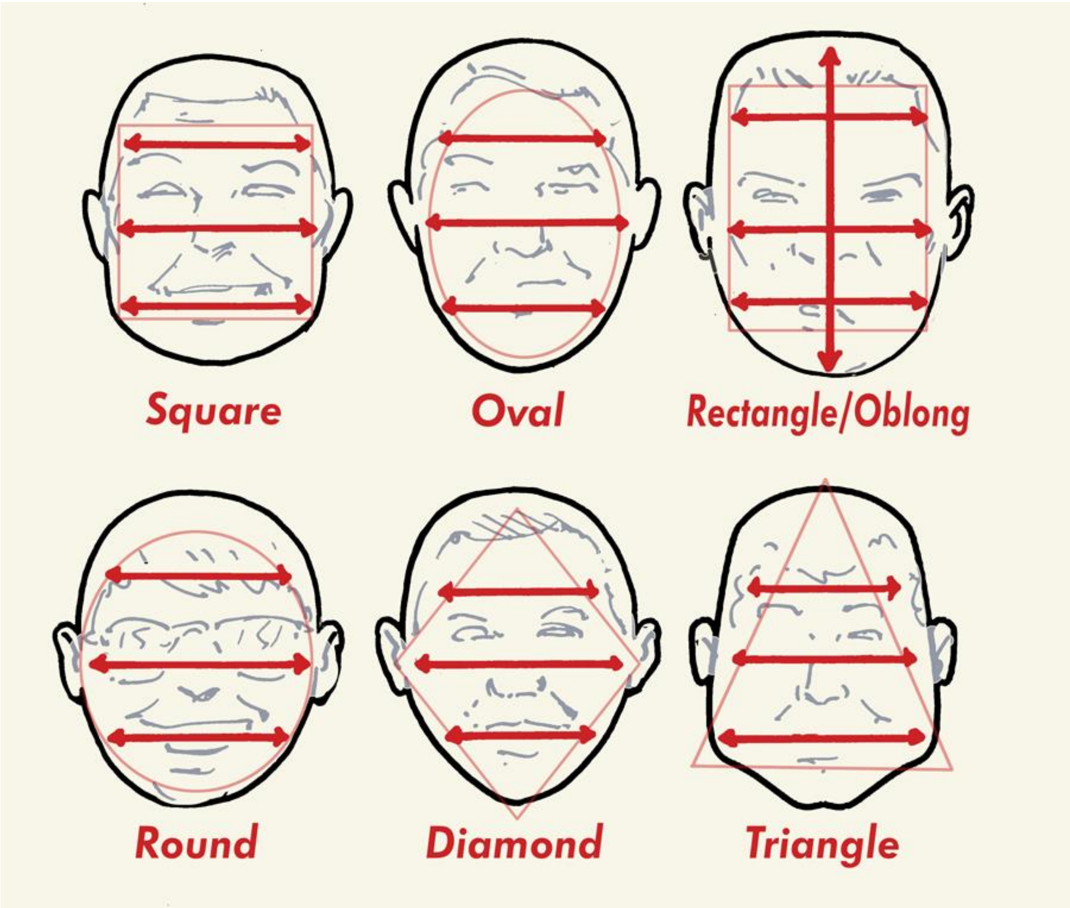
Tool



- MediaPipe tool: https://developers.google.com/mediapipe/solutions/vision/face_landmarker

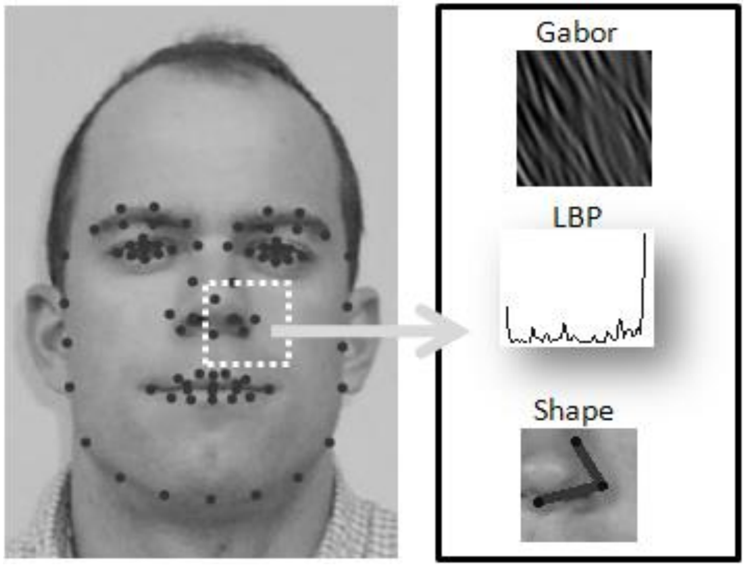
2- Face features

- **Level 1:**
  - Gross facial characteristics that are easily observable: such as general geometry of the face and global skin color



2- Face features

- Level 2:
  - localized face information such as the structure of the face components (e.g., eyes), the relationship between facial components and the precise shape of the face



2- Face features

- Level 3:
  - consist of unstructured, micro level features on the face, which includes
    - scars,
    - freckles,
    - skin discoloration,
    - and moles


moles

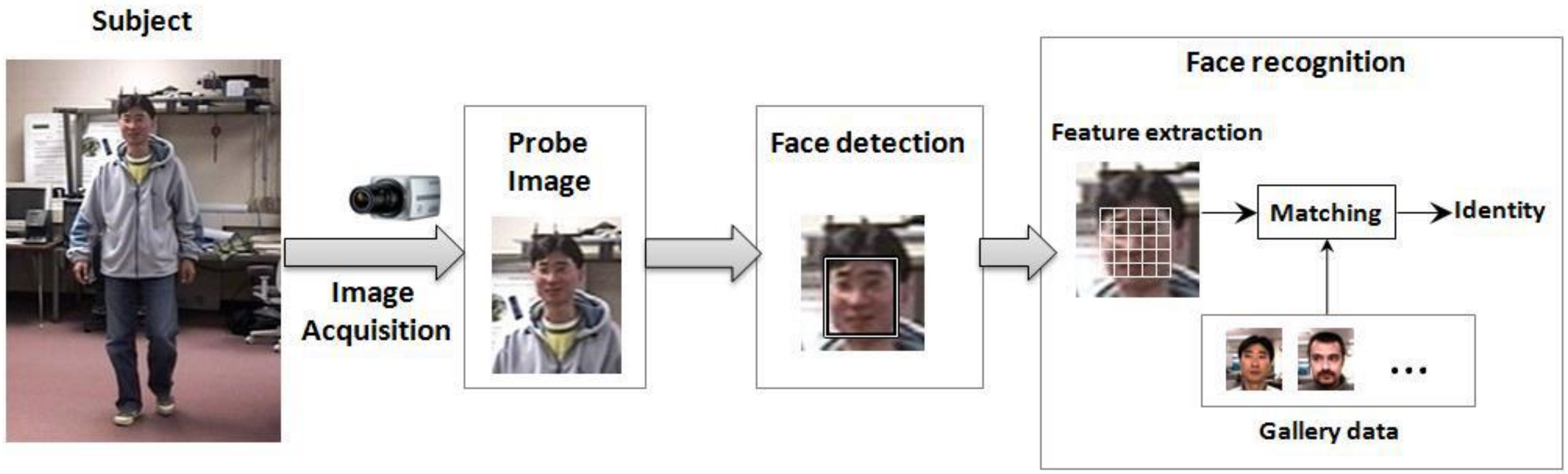

freckles


scars


skin discoloration

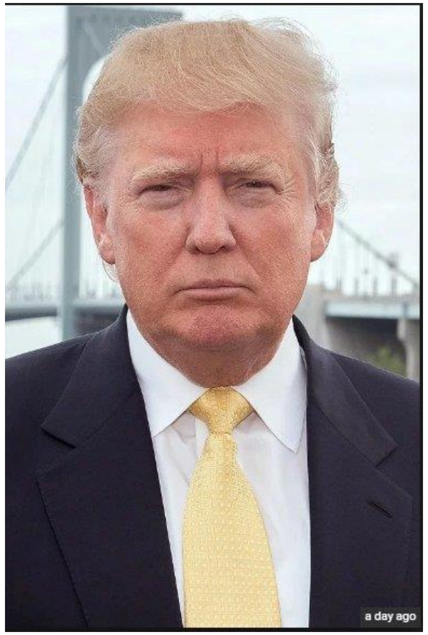
3- Design of a face recognition system

- Three main components
  - Image acquisition
  - Face detection
  - Face matching

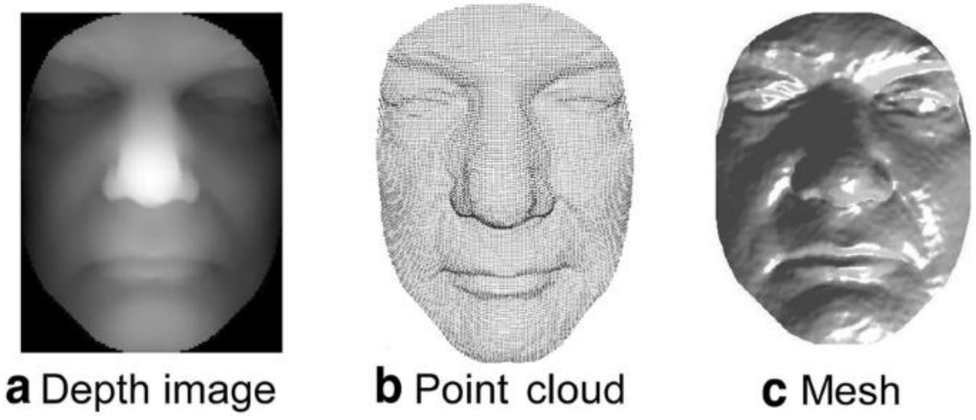


4- Image Acquisition

- Data in face recognition can be
  - 2D image
  - 3D range or depth images



2D image



3D data

4.1 2D Sensors

- Frontal view of a face contains more details than a profile view and multi-camera configurations for pose variation problem
- 2D face images are also greatly affected by variations in illumination and spatial resolution

Multiple 2D cameras capturing face images at three different viewpoints

Sony EVI-D70 Pan-Tilt-Zoom camera

Sony long range infrared camera.

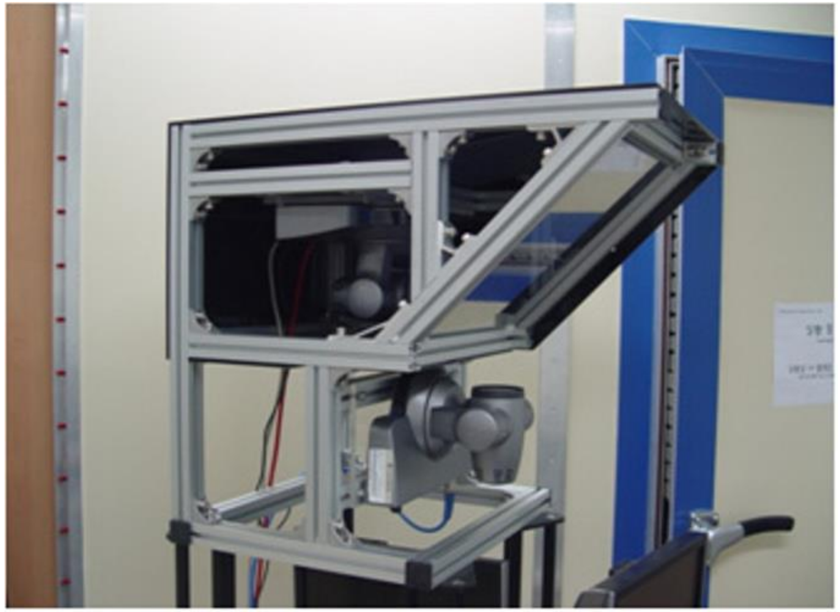
4.1 2D Sensors

- Multispectral imaging to avoid illumination interference.
- Light with wavelength> 950 is invisible to human eyes

Face images captured in the visible and near-infrared spectra at different wavelengths

4.1 2D Sensors

- Typical face acquisition systems have a short operating distance limited to approximately 1-2 meters
- For longer distance, PTZ camera can be used



Pan-Tilt-Zoom camera

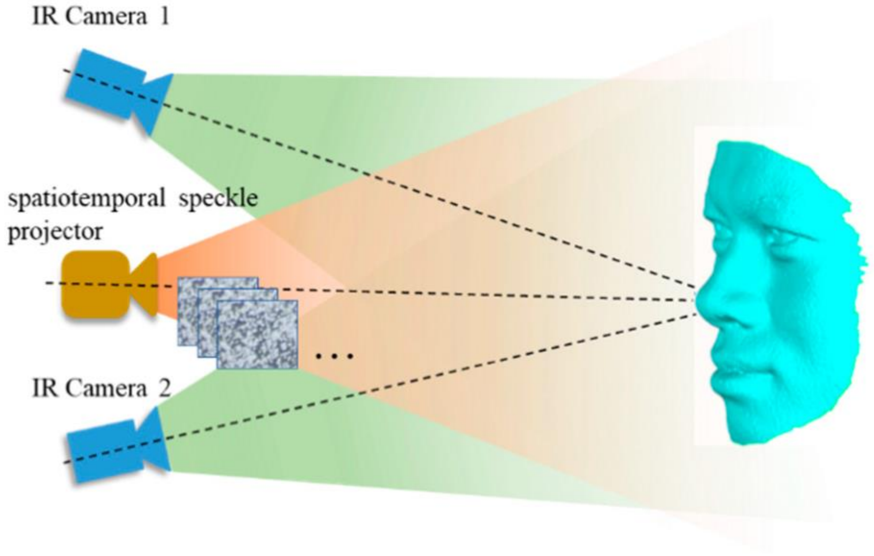
zoom-out

zoom-in

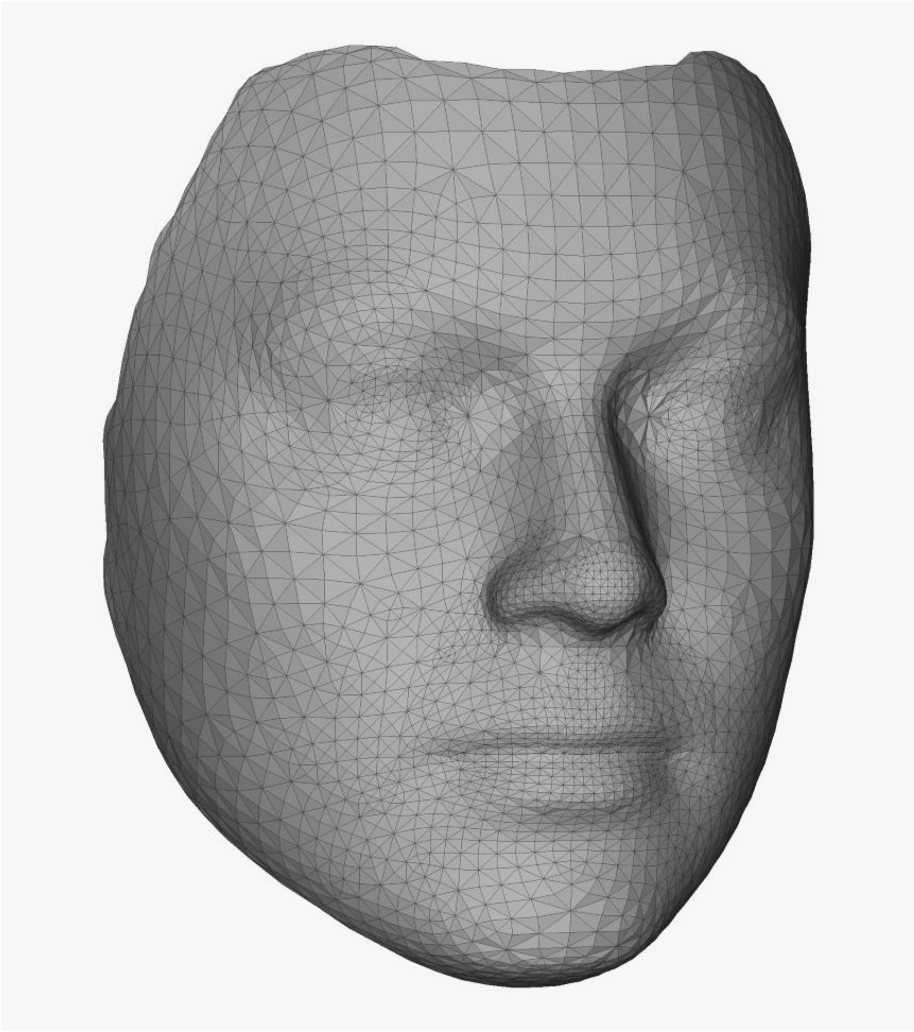
4.2 3D Sensors

- Two types of 3D face capture systems:
  - Laser scanning
  - Stereographic reconstruction
- 3D face format is usually represented as a polygonal mesh structure

Laser scanning



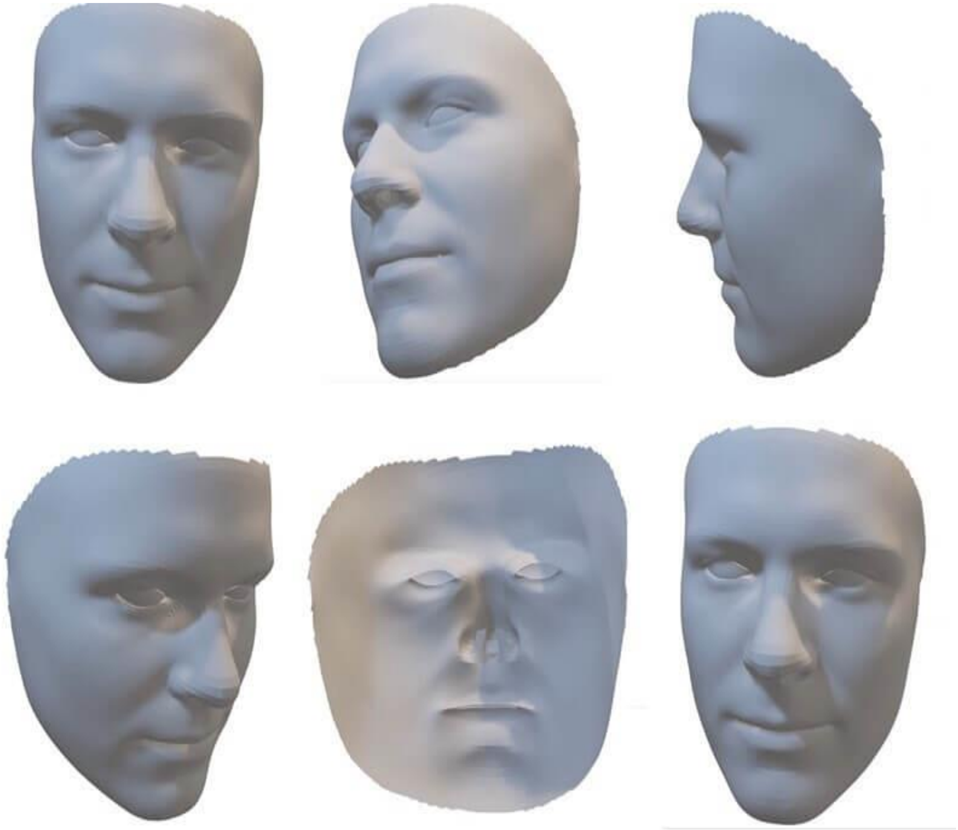
Stereographic reconstruction



3D face mesh

4.2 3D Sensors

- Advantages of 3D face representation:
  - Illumination invariant
  - Pose invariant
- Disadvantage
  - not invariant to changes in expression, aging, and occlusion
  - longer acquisition time

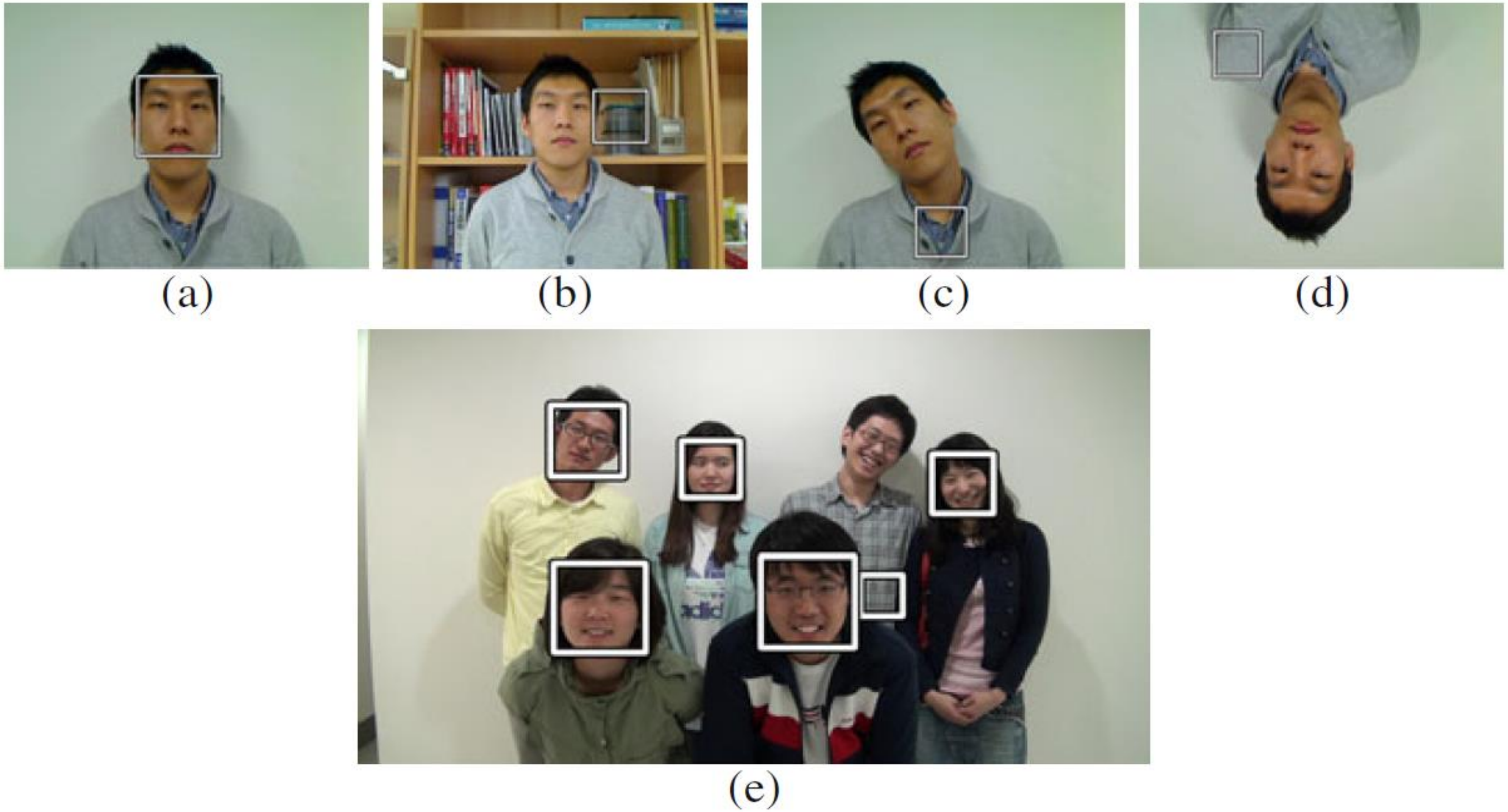


pose adjustment of
3D face

4.3 Video camera

- Continuously capture face images ➔ enabling the selection of a good quality face image
- Advantages of video camera over still camera
  - Multiple frames of the same subject:
    - Variety of poses
  - Temporal information pertaining to an individual’s face
    - Facial motion

5 Face detection



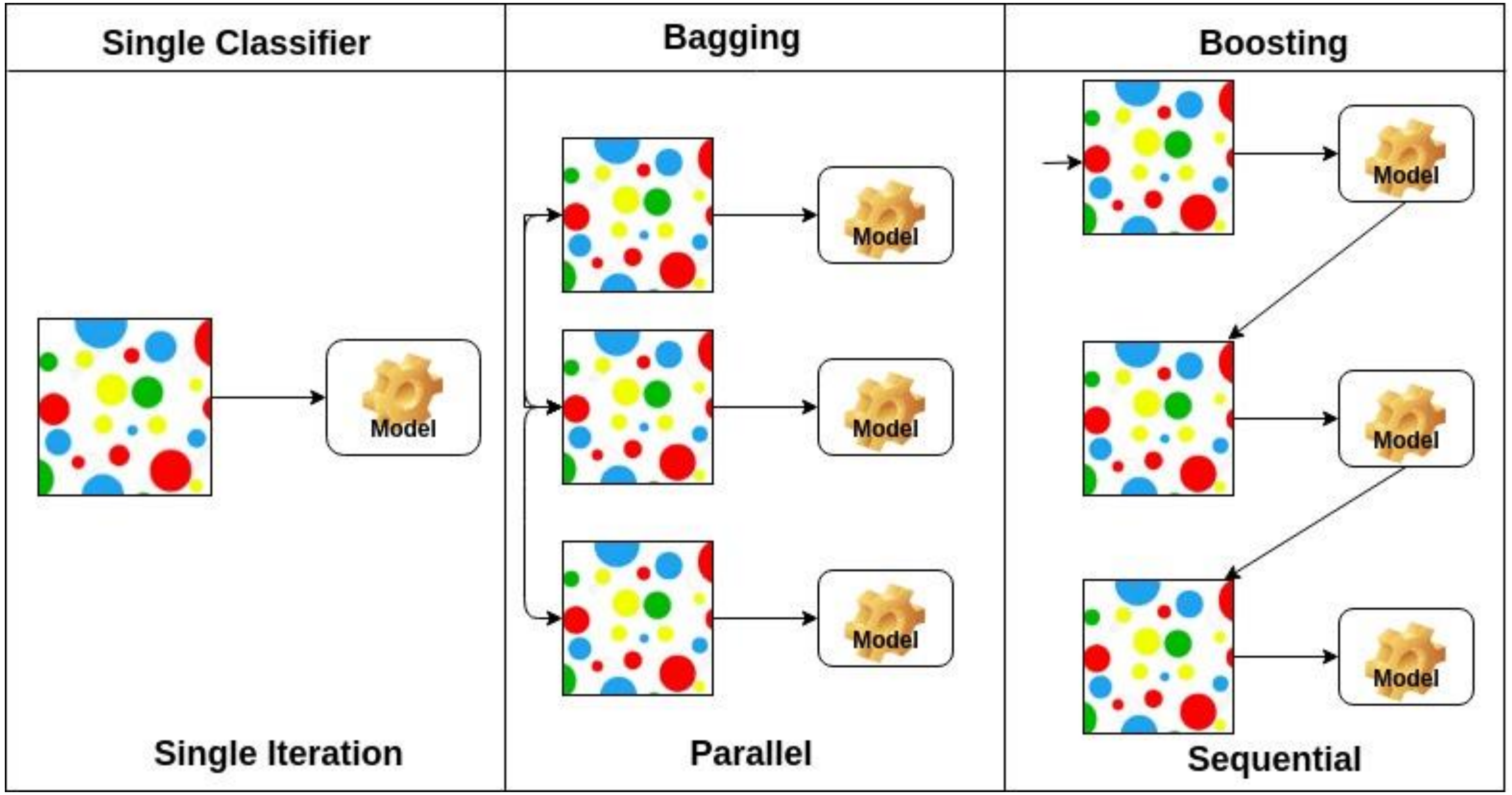
(a) simple background, (b) cluttered background, (c) tilted face, (d) inverted face, and (e) multiple faces. Figures (b) through (e) have both false negatives (faces that are not detected)

Face detection methods

- Viola-Jones algorithm
- Template matching
- Appearance-based by Machine learning including CNN
- …

Viola-Jones algorithm

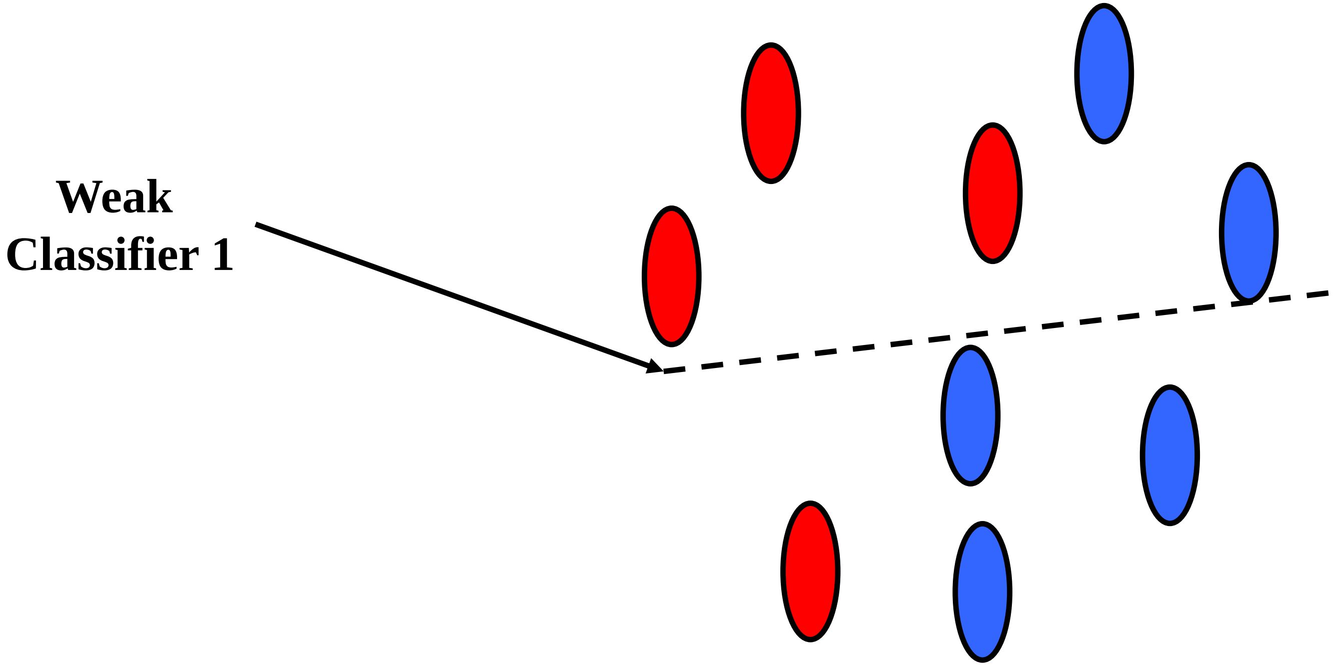
- Uses boosting technique
  - An ensemble of weak learners to improve the accuracy and performance



2 different ensemble methods of weak learners

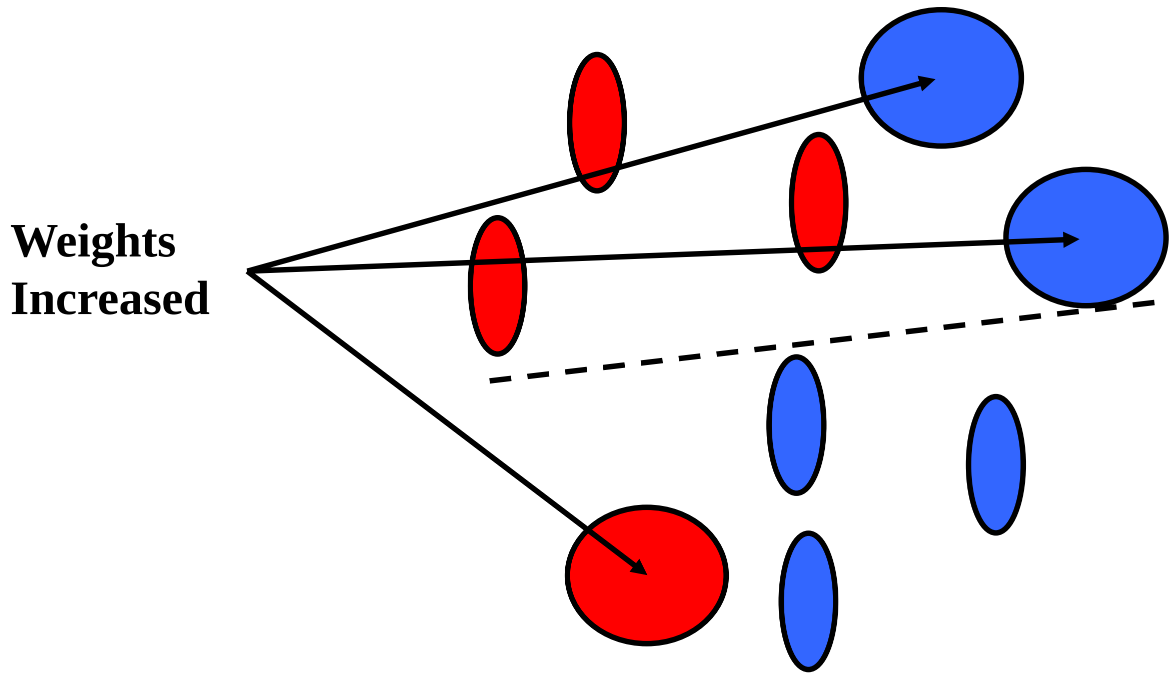
Eg:
Random forest vs. Adaboost

Boosting intuition

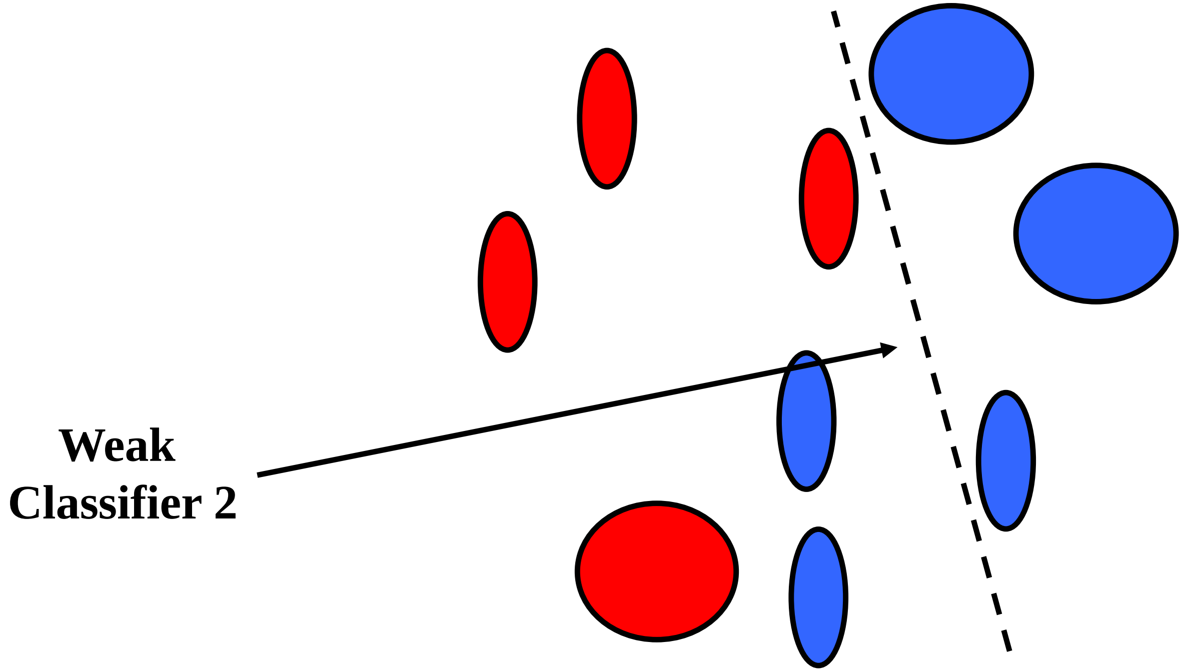


Slide credit: Paul Viola

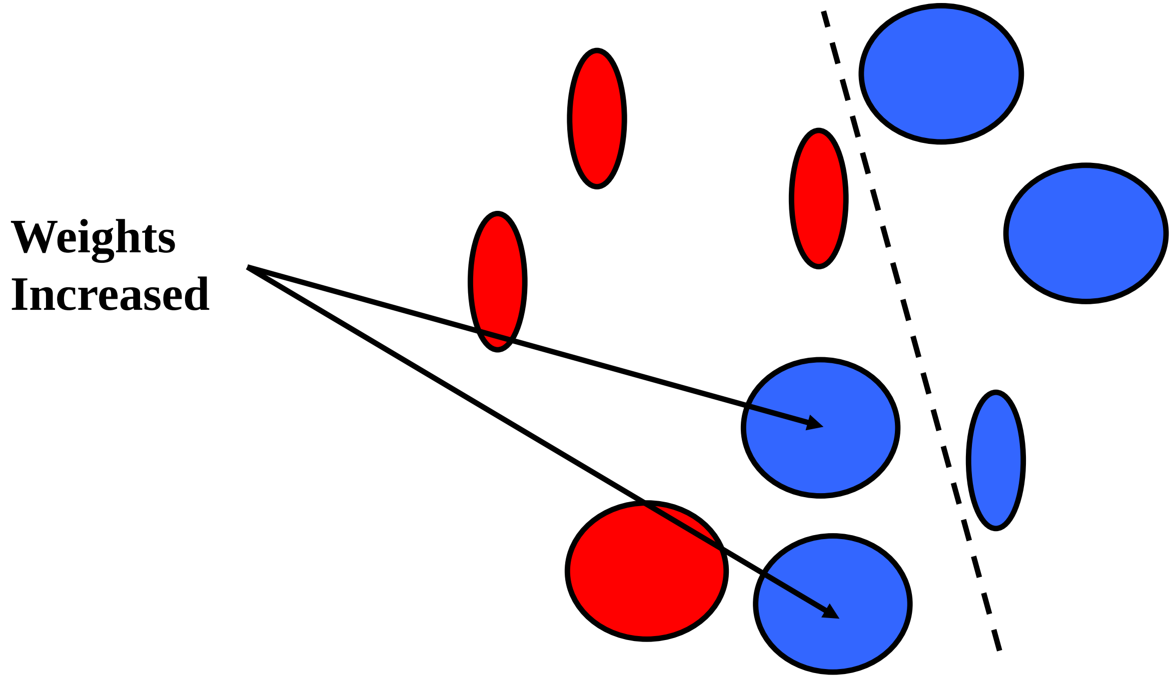
Boosting illustration



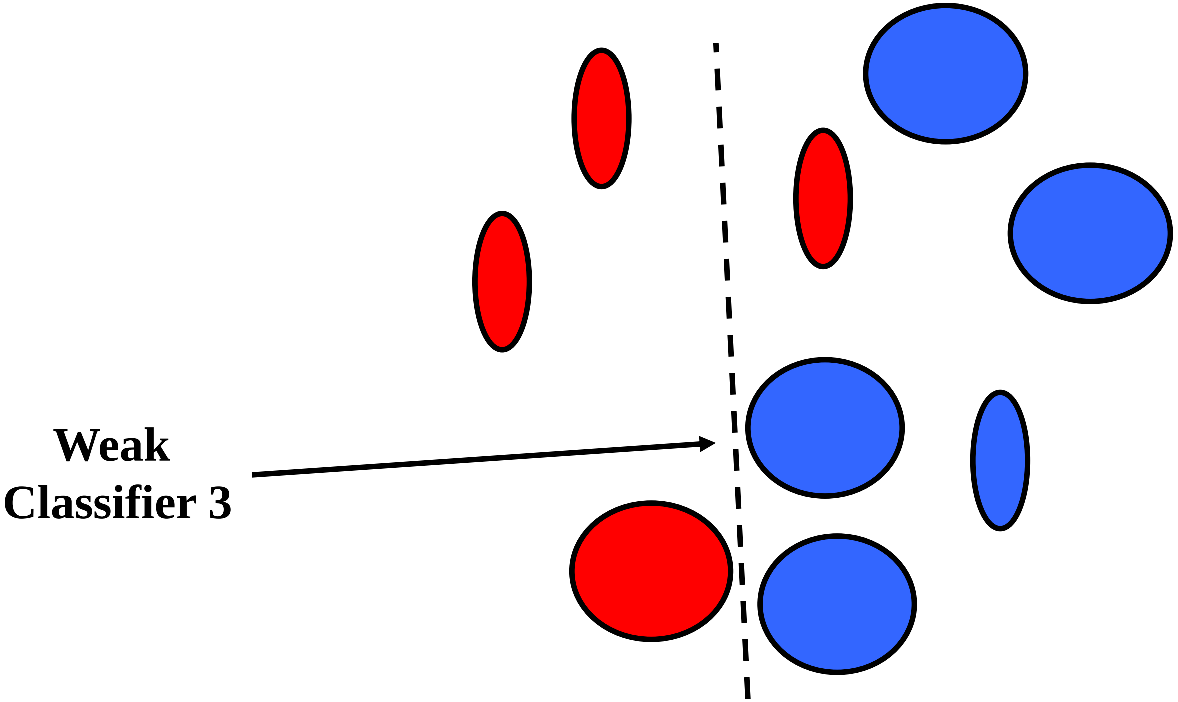
Boosting illustration



Boosting illustration

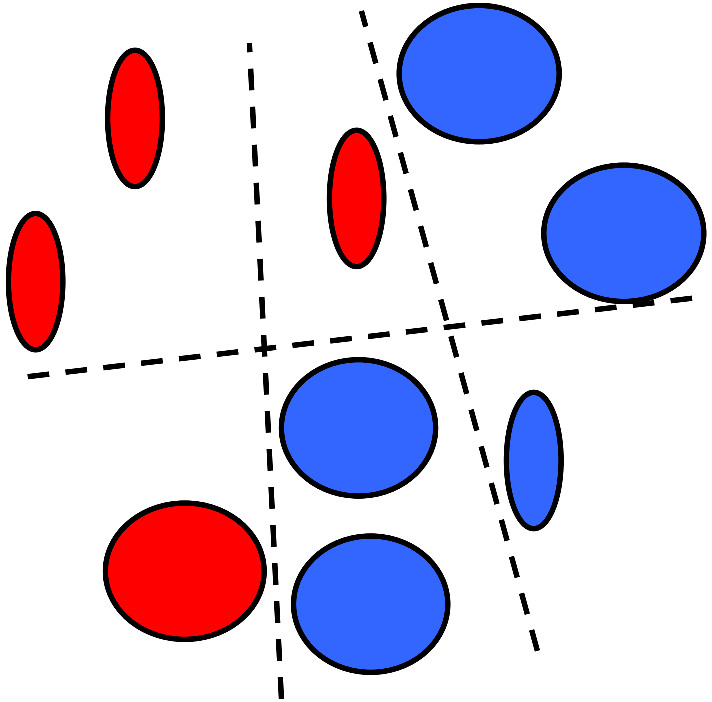


Boosting illustration



Boosting illustration

Final classifier is
a combination of weak
classifiers

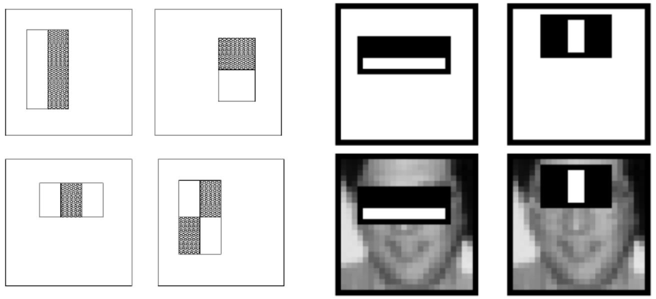


Viola-Jones face detector

Main idea:

- Represent **local texture with efficiently computable “rectangular” features** within window of interest
- Select discriminative features to be weak classifiers
- Use boosted combination of them as final classifier
- Form a cascade of such classifiers, rejecting clear negatives quickly

Viola-Jones detector: features

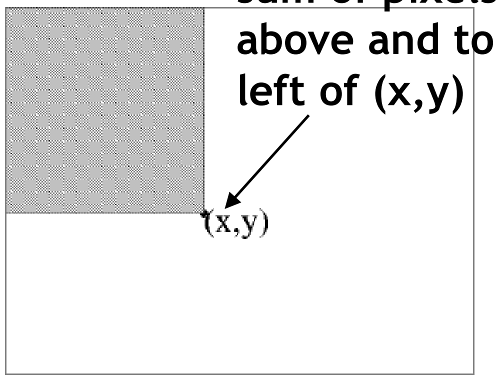


- **"Rectangular" filters**

  Feature output is difference between adjacent regions

- Efficiently computable with **integral image**: any sum can be computed in constant time.

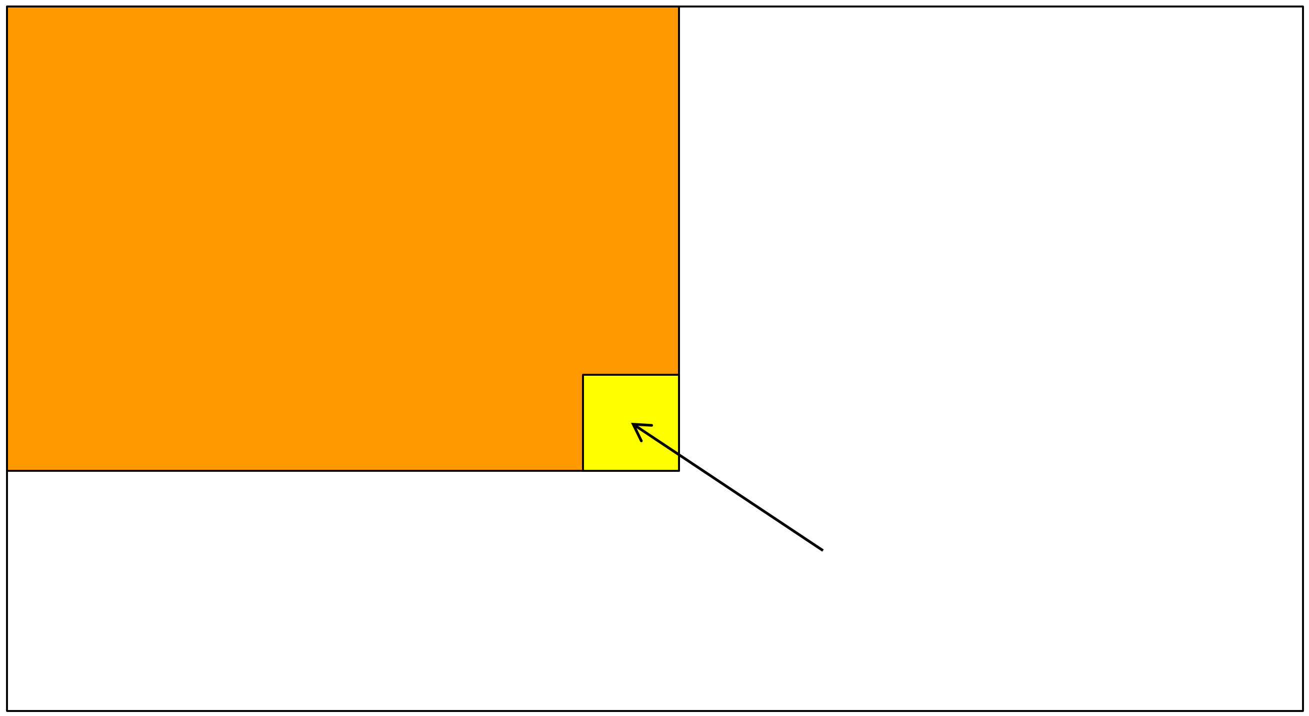
Value at (x,y) is sum of pixels above and to the left of (x,y)



Integral image

Slide: Kristen Grauman

Computing the integral image



Lana Lazebnik

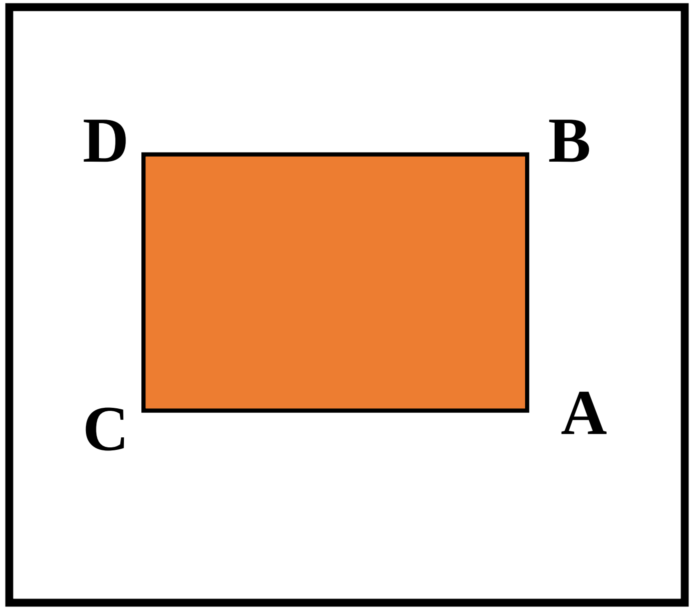
Computing sum within a rectangle

- 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 as:

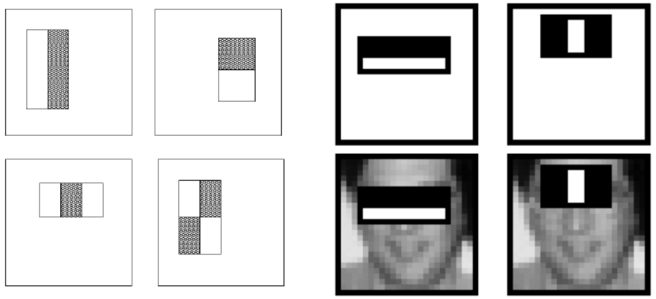
  sum = A – B – C + D

- Only 3 additions are required for any size of rectangle!



Lana Lazebnik

Viola-Jones detector: features

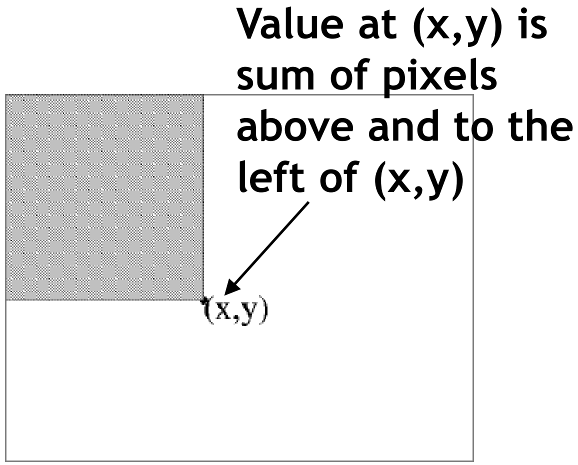


- **“Rectangular” filters**

  Feature output is difference between adjacent regions

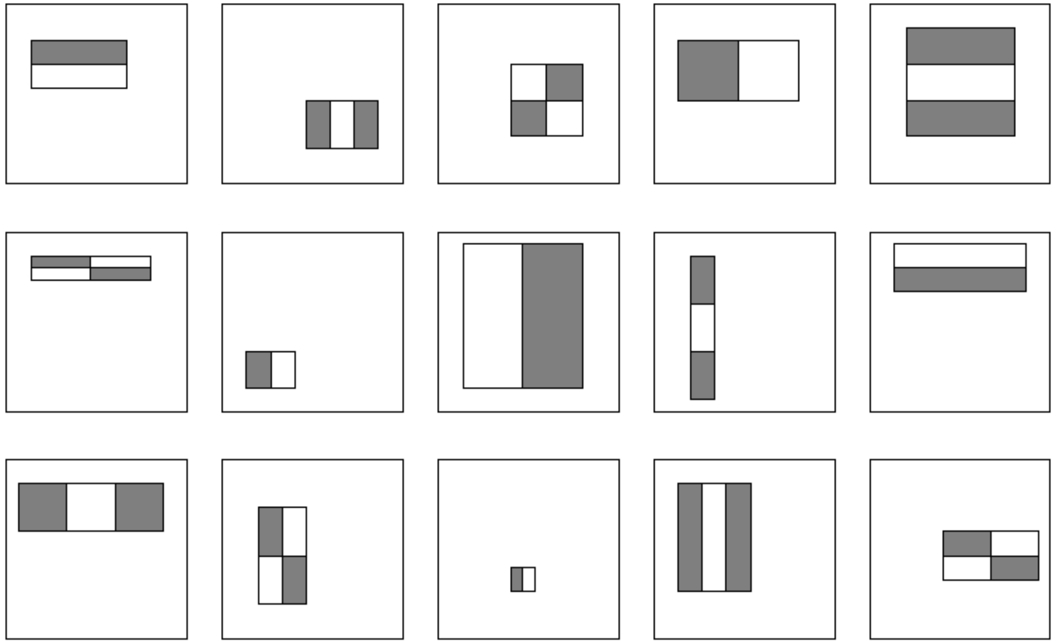
- Efficiently computable with integral image: any sum can be computed in constant time

  Avoid scaling images → scale features directly for same cost



Integral image

Viola-Jones detector: features



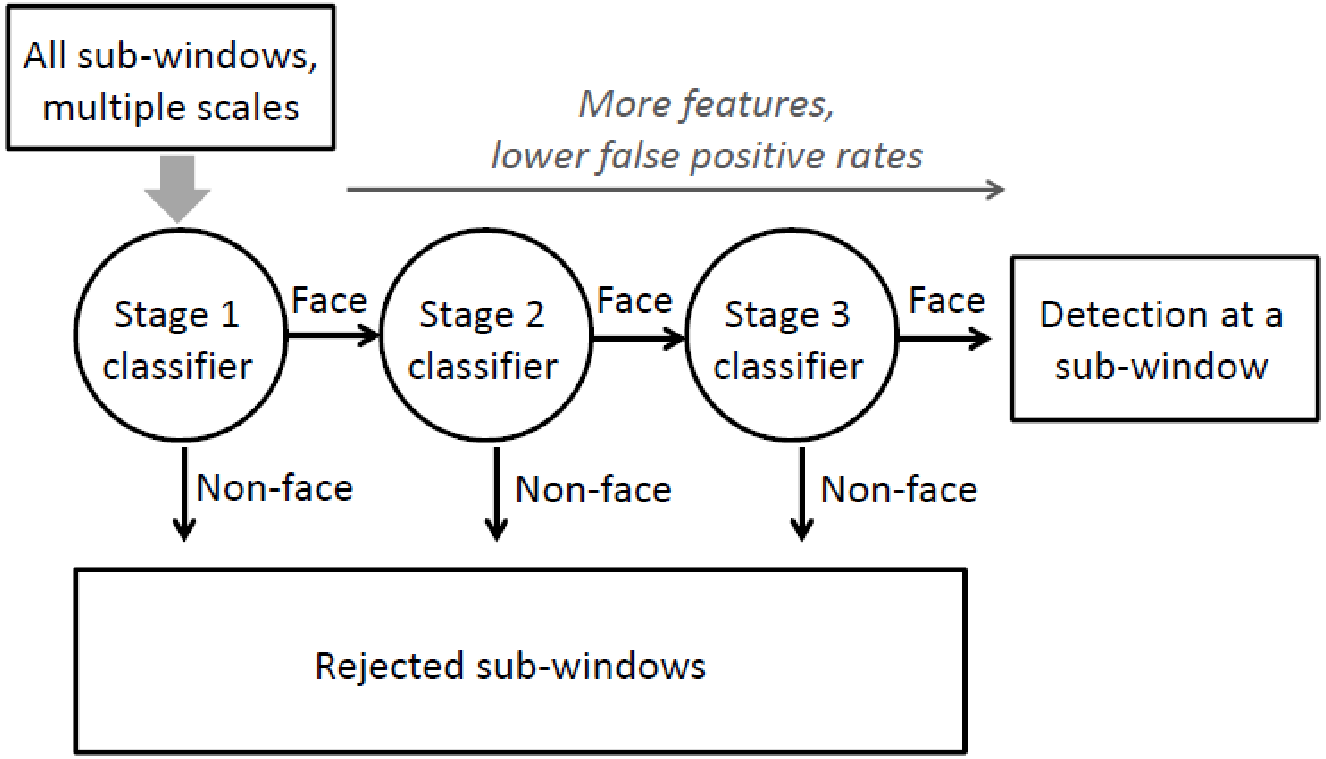
Considering all possible filter parameters: position, scale, and type:

180,000+ possible features associated with each 24 x 24 window

Which subset of these features should we use to determine if a window has a face?

Use AdaBoost both to select the informative features and to form the classifier

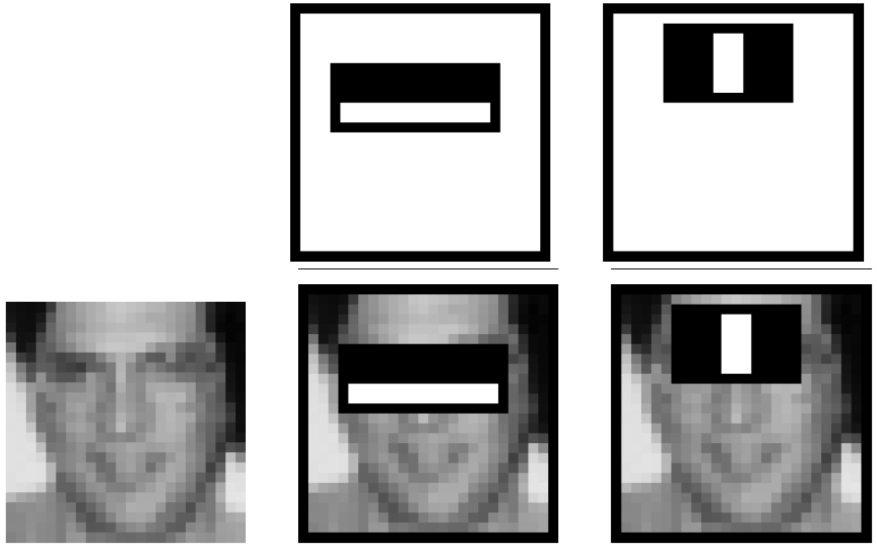
Cascading classifiers for face detection



- Form a *cascade* with low false negative rates early on
- Apply less accurate but faster classifiers first **to immediately discard** windows that **clearly appear to be negative**

Slide: Kristen Grauman

Viola-Jones Face Detector: Results



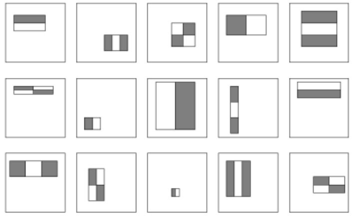
First two features selected

Viola-Jones detector: summary

Faces

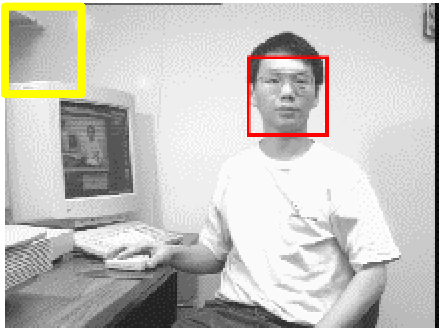
Non-faces

Train cascade of classifiers with AdaBoost



Selected features, thresholds, and weights

Apply to each subwindow



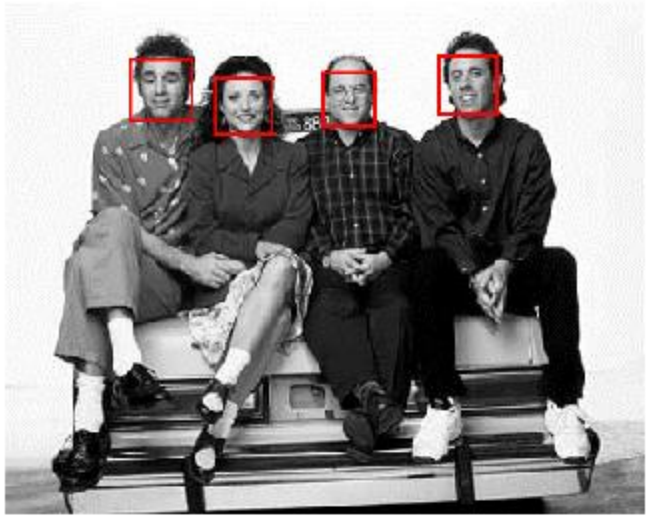
New image

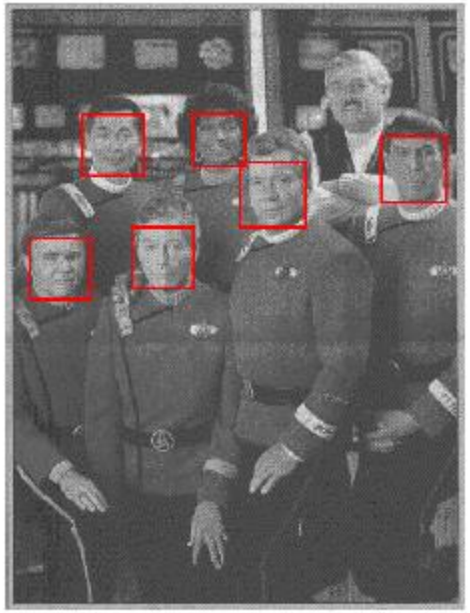
- Train with 5K positives, 350M negatives
- Real-time detector using 38 layer cascade
- 6061 features in all layers

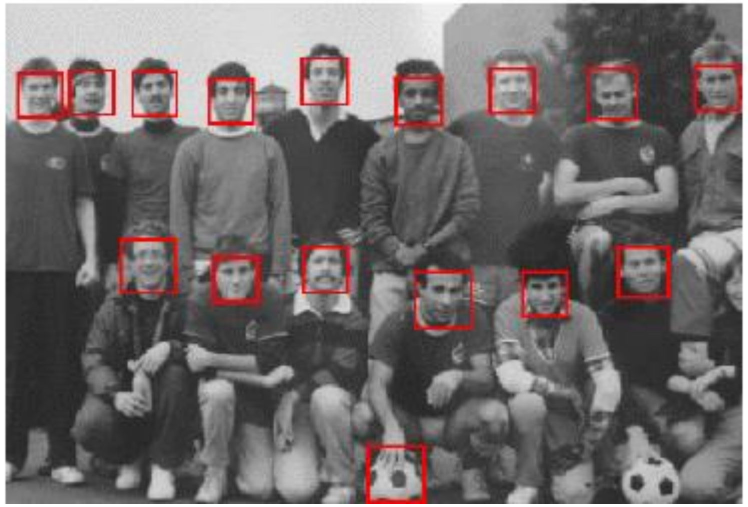
[Implementation available in OpenCV]

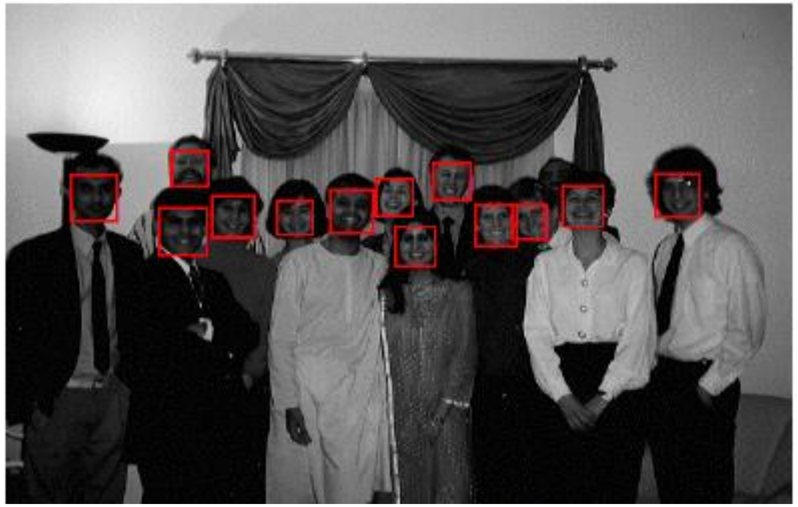
Slide: Kristen Grauman

Viola-Jones Face Detector: Results









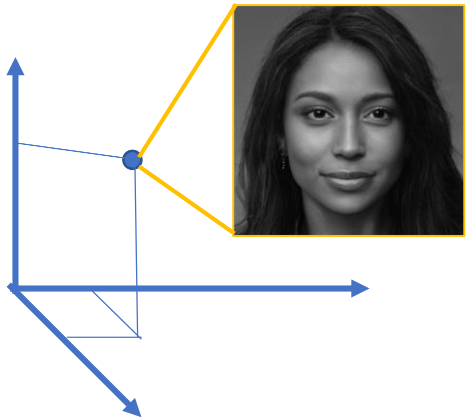
6-Feature Extraction and Matching

- There are three main approaches to match the detected face images:
  - Appearance-based techniques
  - Model-based techniques
  - Texture-based approaches

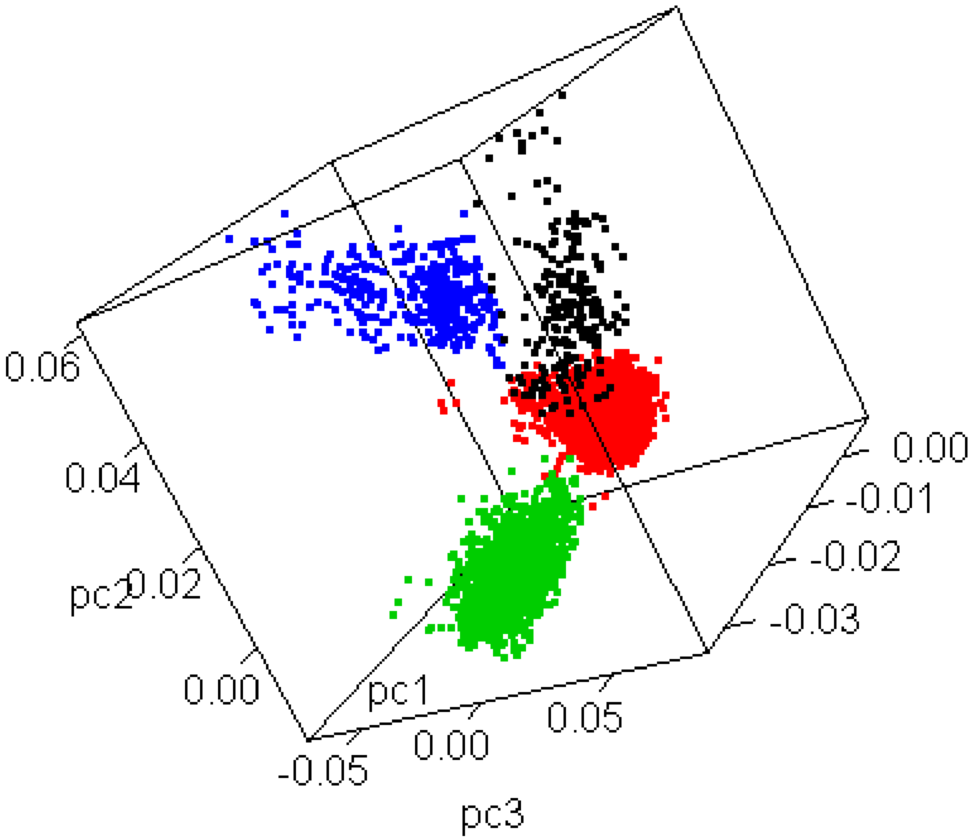
Principle Component Analysis - PCA

How to present each FACE by a much **lower dimensions**???

- Linear Algebra
- Statistics



Principle Component Analysis - PCA

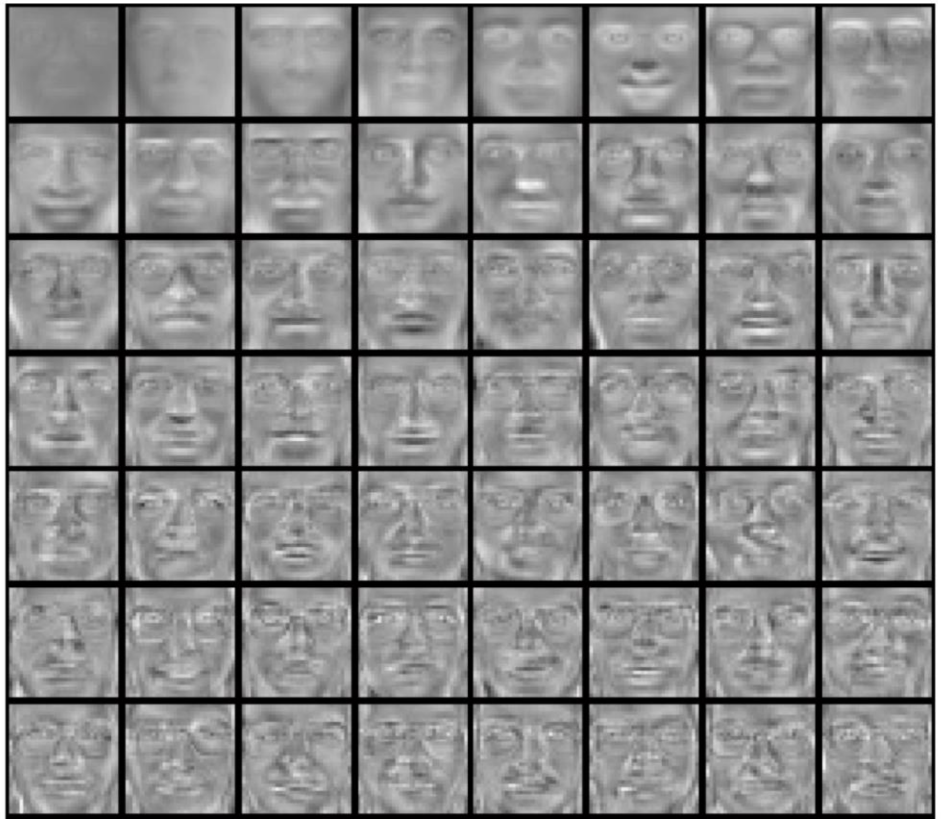


- Each subject has single cluster (same color)

Eigenfaces example

Mean: μ

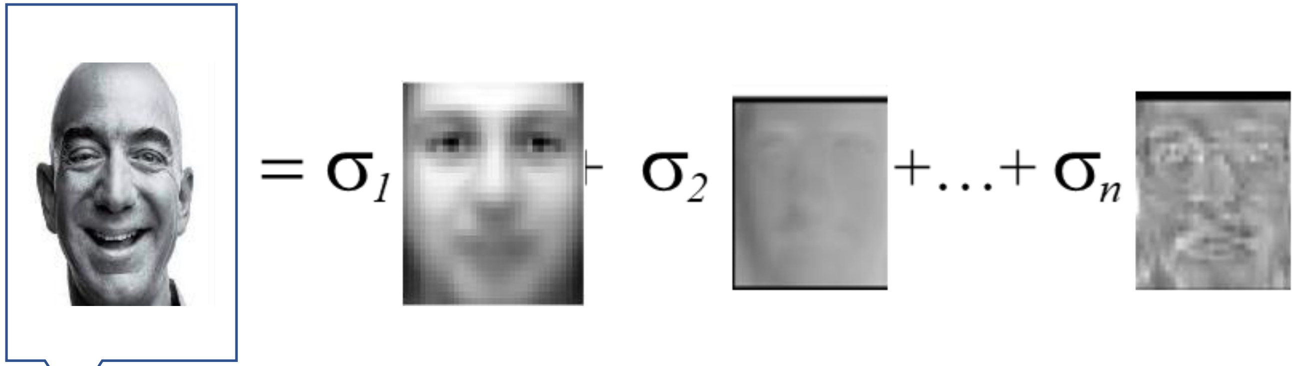
Top eigenvectors: $u_1, \ldots u_k$



Slide by Jana Kosecka

Face representation

- A face is a linear combination of mean and eigenfaces

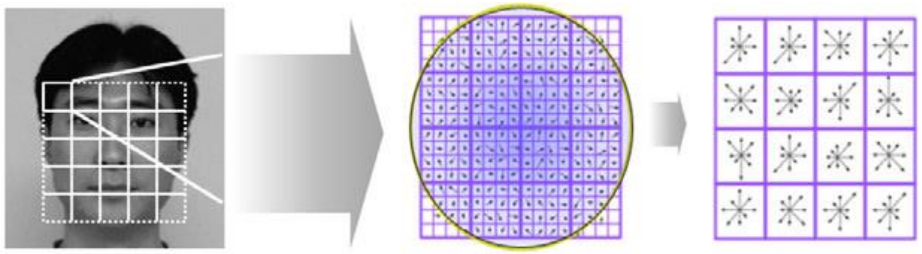


New face $= (\sigma_1, \sigma_2, \ldots, \sigma_n)$

- This feature is used for recognition

Texture-based face recognition

- Use some feature on face such as
  - SIFT
  - LBP

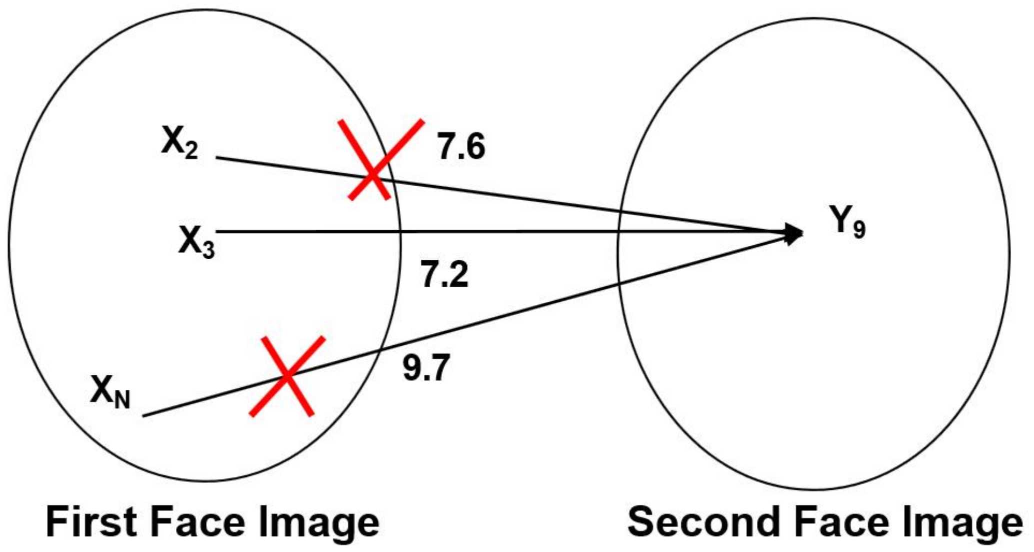


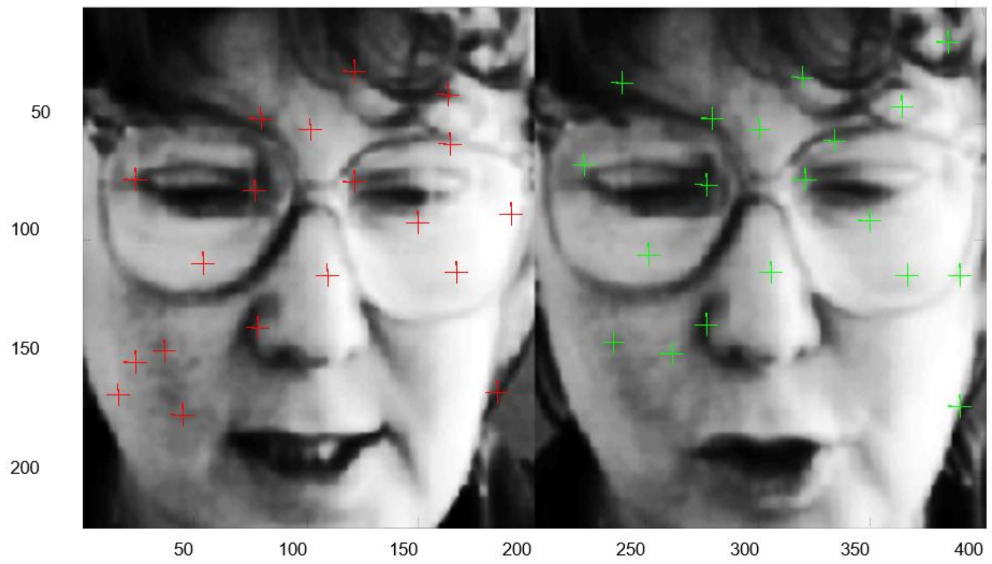
SIFT descriptor for
face description

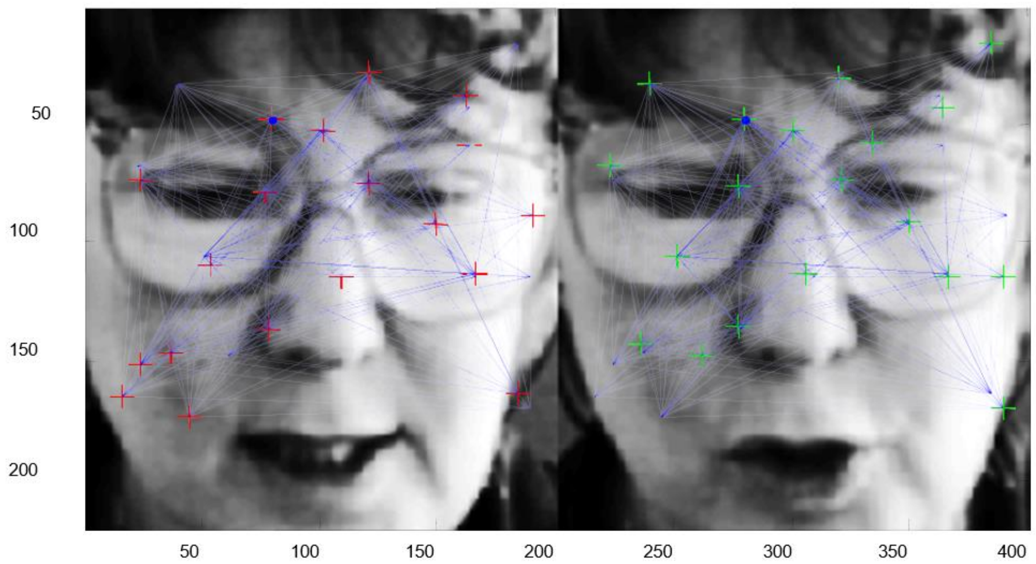
Image and different
LBP features

Texture-based face recognition

SIFT feature is used for matching



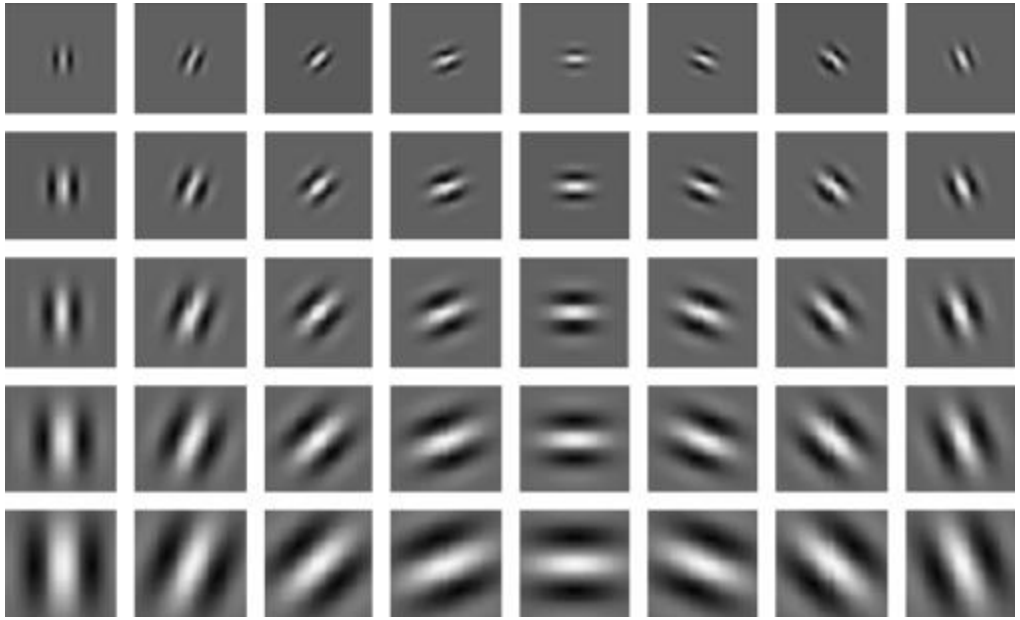




Model-based face recognition

Elastic Bunch Graph Matching

- Labeled image graph based on face landmarks
- Each node of the graph is labeled with a set of Gabor coefficients



Gabor filters of five scales and eight directions

Thank you for listening !