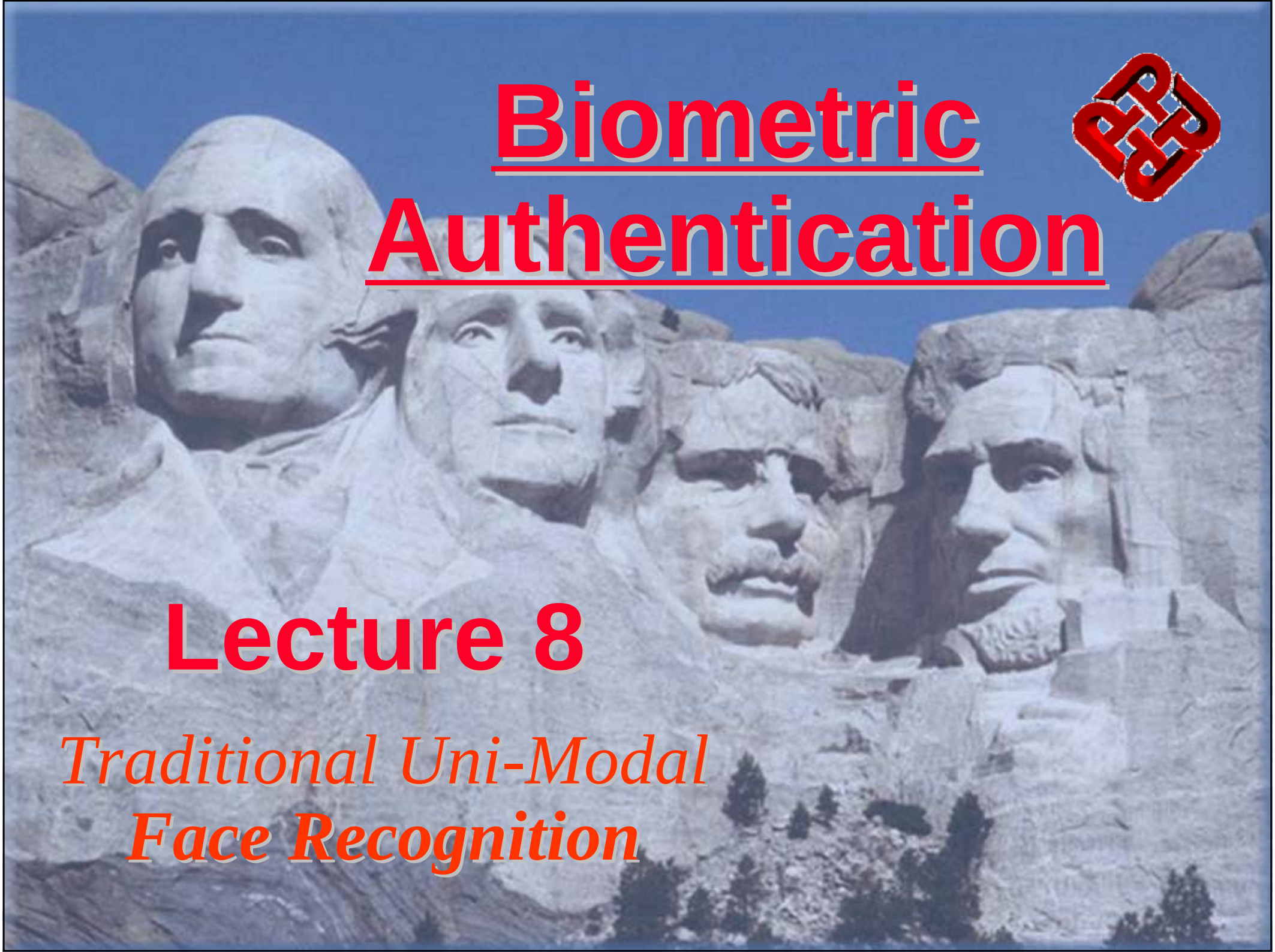


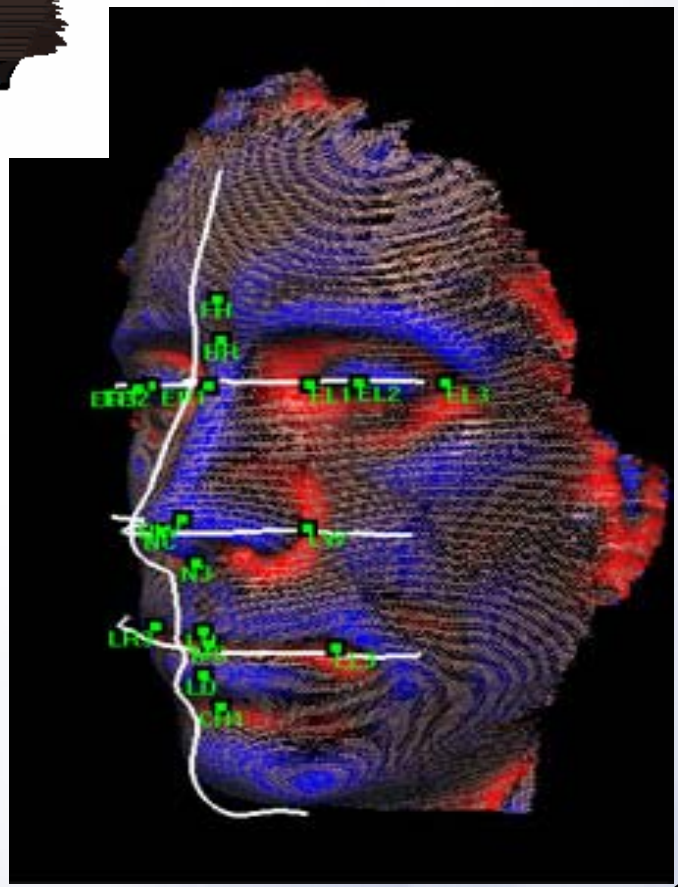
Biometric Authentication

Lecture 8

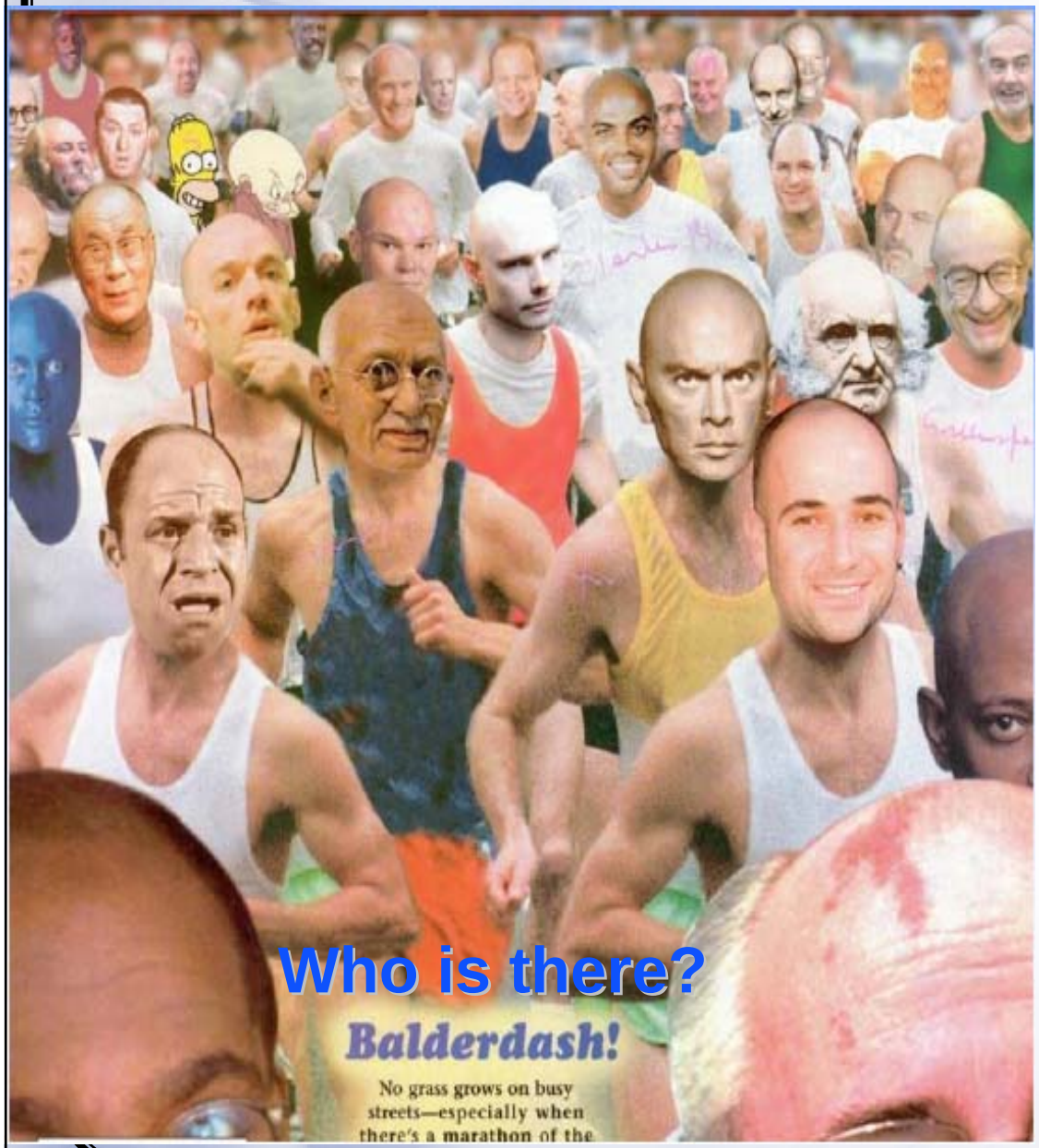
Traditional Uni-Modal
Face Recognition

OUTLINE

- Introduction
- System Overview
- Face Detection /Extraction
- Face Applications



Why Use Face?



- Every one has got a “fairly unique” face
- Can be captured without user cooperation (passive)

Why Use Face?

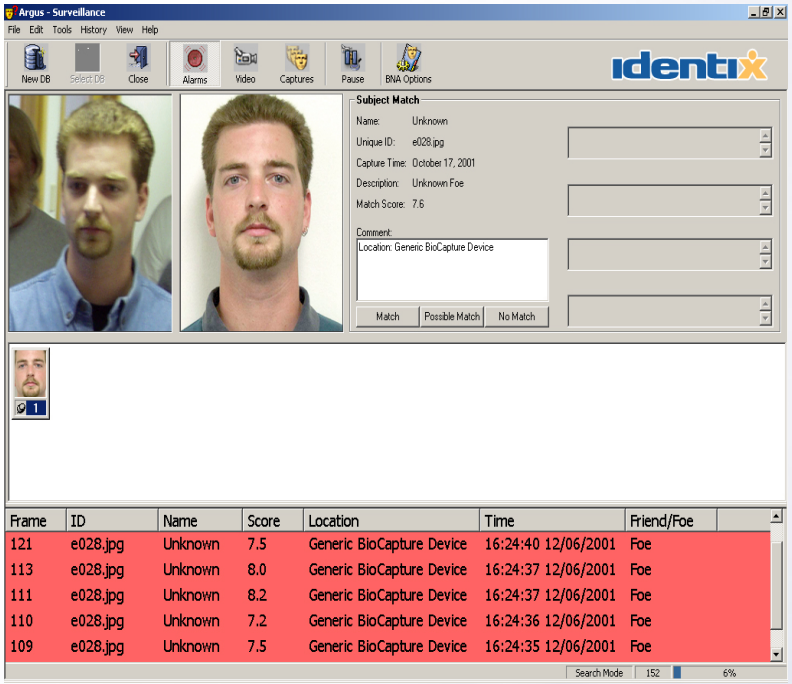
- Non-intrusive
  - More nature, do not restrict user movement - Socially more acceptable
  - This is how human beings are recognizing each other
- Less expensive to setup
  - Hardware is getting cheaper
  - Available many legacy uses/database of face images
  - Easy to construct new facial-image with or without consent of the people
- Fight terrorism
  - Increasing need after the September 11 events/ Spot terrorists in public
  - Require automated face detection system on suspect in sensitive areas, e.g. airport, military facility

Face

- Ubiquitous capture device
- Remote and unobtrusive capture – surveillance
- Much simpler than other ways of biometric personal identification such as fingerprint and iris.
- Cooperation or special knowledge of participants are not required.

Face Recognition: Situation

- *Face recognition* is the science of programming a computer to recognize a human face. Human beings have a biological mechanism to recognize known persons by a small number of certain nodes and size ratios.
- It analyzes facial characteristics.
- It requires a digital (web) camera (of low quality is enough).
- This technique has attracted considerable interest.
- Uses distinctive features of the human face in order to verify or identify individuals

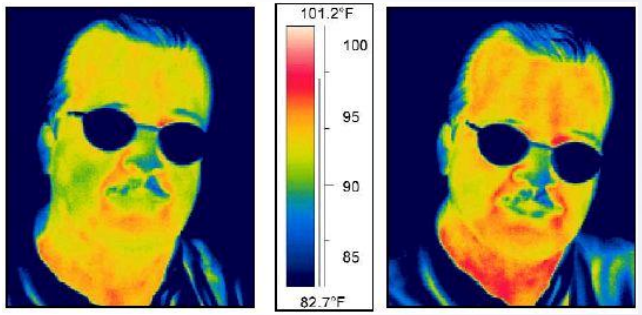


- Accuracy: the best performance had a 90% verification rate at a FAR of 1%. (However, when the face is captured at outdoor, for the same 1% FAR, the verification rate is dropped to 50% only!)

Face Recognition: Images

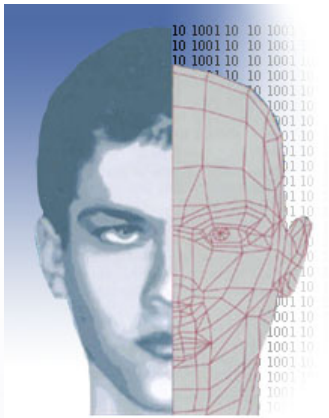
- Face Recognition is the identification or verification of a person solely from the facial appearance

- Uses an image or series of images either from a camera or photograph to recognize a person.



Facial thermogram

- Typically a face from a photographic technique
  - Still Image
  - Video sequence
  - Color or Black and White
  - Facial thermogram/Near Infrared
  - 3D image



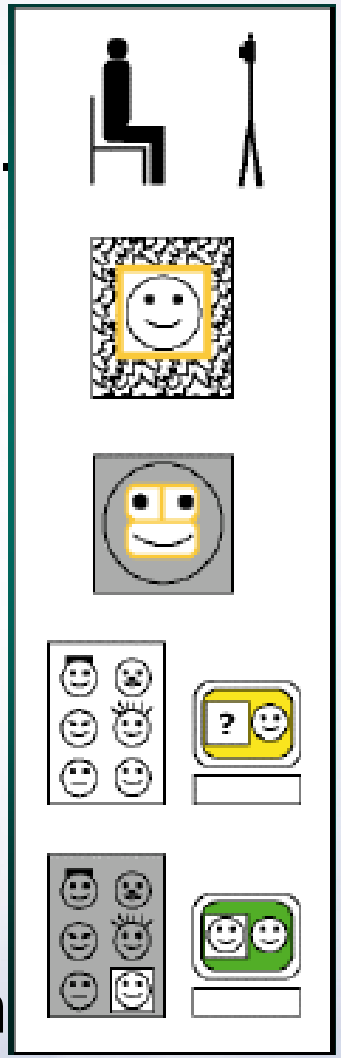
Video image

How to Capture Images?

- User faces the camera, standing about two feet from it.
- The system will locate the user's face and perform matches against the claimed identity or the facial database.
- It is possible that the user may need to move and reattempt the verification based on his facial position.
- To prevent a fake face or mold from faking out the system, many systems now require the user to smile, blink, or otherwise move in a way that is human before verifying

What Facial Features?

- Facial recognition analyzes the **characteristics** of a person's face images input through a digital video camera.
- Measure the **overall facial structure**, including distances between eyes, nose, mouth & jaw edges.
- These measurements are retained in a database and used as a comparison when a user stands before the camera.
- This biometric has been widely, and perhaps wildly, touted as a fantastic system for recognizing potential threats (whether terrorist, scam artist, or known criminal) but so far has been unproven in high-level usage.
- It is currently used in verification only systems with a good deal of success



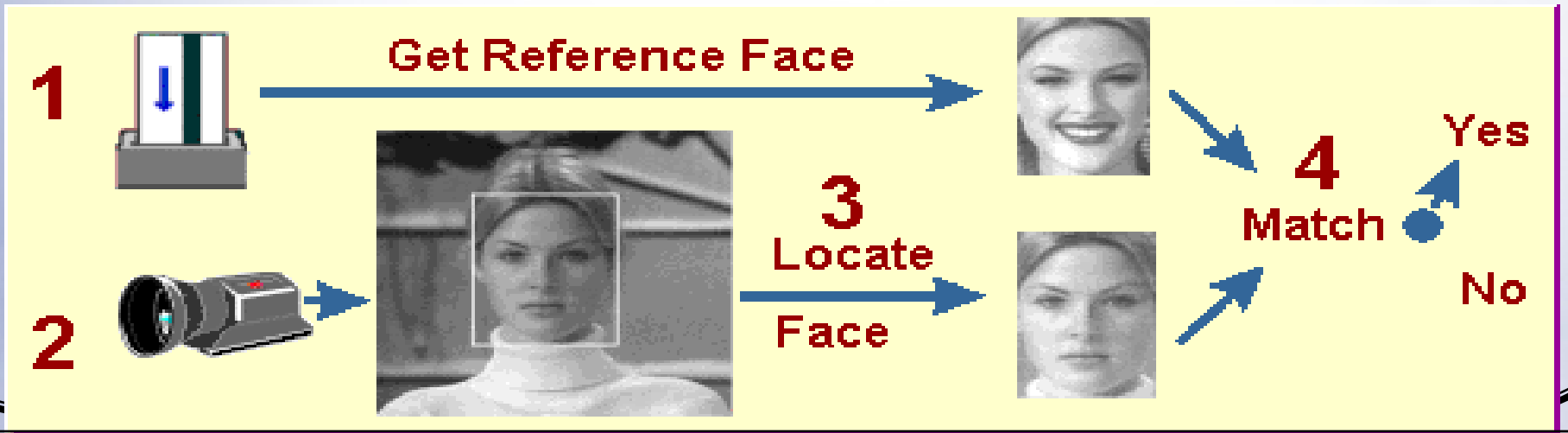
Face Recognition System

Face detection / location

1. Detect whether the input images or image sequences include faces
2. If they do include faces, figure out the position of the faces
3. Segment each face from background

Features extraction and Face recognition

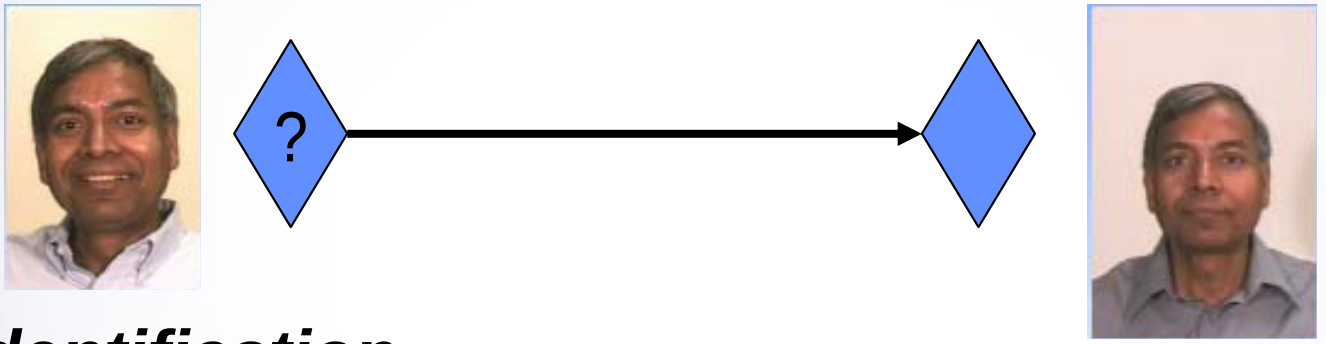
1. Look for face features which distinguish individuals
2. Judge whether the people in image is the given person or in the database



Face Recognition System

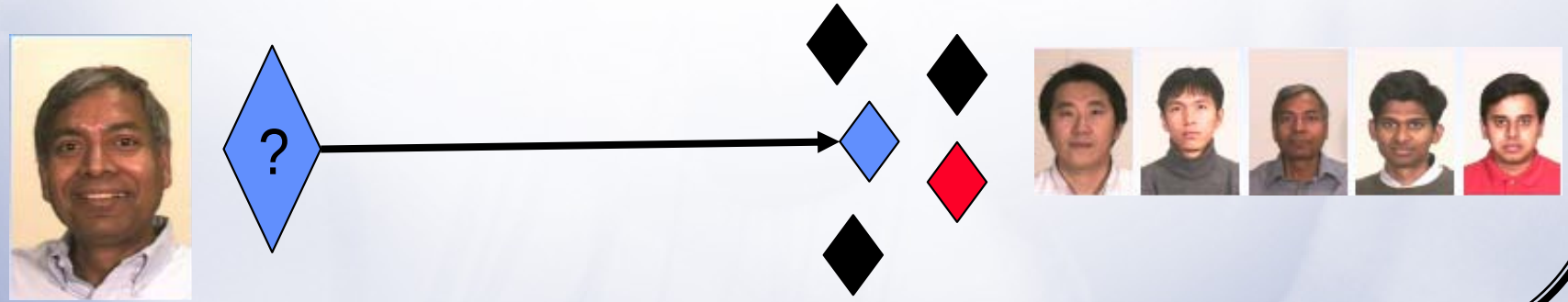
❑ *Face Verification*

- (1:1 matching)–“Are you the same person you say you are?”
  Given a face image that might not belong to the database, verify whether it is from the person it is claimed to be in the database.



❑ *Face Identification*

- (1:N matching)–“Who are you?”
  Given a face image that belongs to a person in a database, tell whose image it is.



Challenges on Face Recognition

- Human face composes of complex elements
- Camera capture variation
- High ACCRUARY Requirement
- Size variation
- Age
- Processor intensive
- Time requirement
- Need a large Database for testing
- General issue – Low Uniqueness
- Illumination problem (Un-controlled background vs. uniform background in custom)
- Pose variation problem
- Facial expressions
- Facial Appearance
  - Glasses
  - Makeup
  - Hairstyles

- Orientation problem (Face angle)
- Overlap faces
- Different moving directions

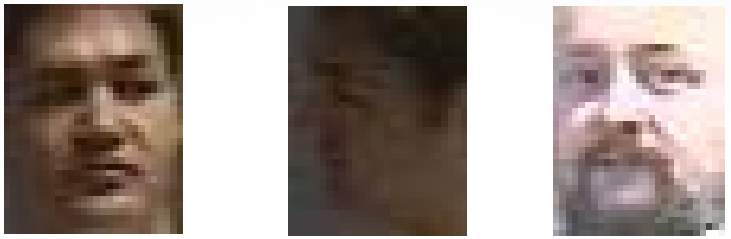
Face Recognition Difficulties

- Finding Faces
  - Uncontrolled background
  - Subject's non-cooperation
    - Subject not looking at camera
    - Subject wearing hat, sunglasses, etc.
  - Moving target
- Identifying Faces
  - Uncontrolled environmental conditions
    - Lighting (shadows, glare)
    - Camera angle
    - Image resolution
- Identify similar faces (Inter-class)
- Accommodate intra-class variability
  - Head pose
  - Expression
  - Aging effects
  - Illumination conditions
  - Facial accessories

Face Problem

- Faces with intra-subject variations in pose, illumination, expression, accessories, color, occlusions, and brightness

Illumination



Head pose

Occlusion

⇒ The same person may have very different appearance

Challenges: automatically locate and recognize a face from a general view point under different illumination conditions, facial expressions, and aging effects

Face Verification Performance

Category	FAR (%)	FRR (%)
Same day, same illumination	2	0.4
Same day, different illumination	2	9
Different days	2	11
Different days over 1.5 years apart	2	43

P. Jonathan Phillips et al., An Introduction to Evaluating Biometric Systems, IEEE Computer, pp. 56-63, Feb 2000

Illumination Problem

Illumination from right side

Direct frontal illumination

Illumination from left side

Solution: Illumination Cones

Illumination from top lighting

Direct frontal illumination

Illumination from bottom lighting

Subject with smiling face

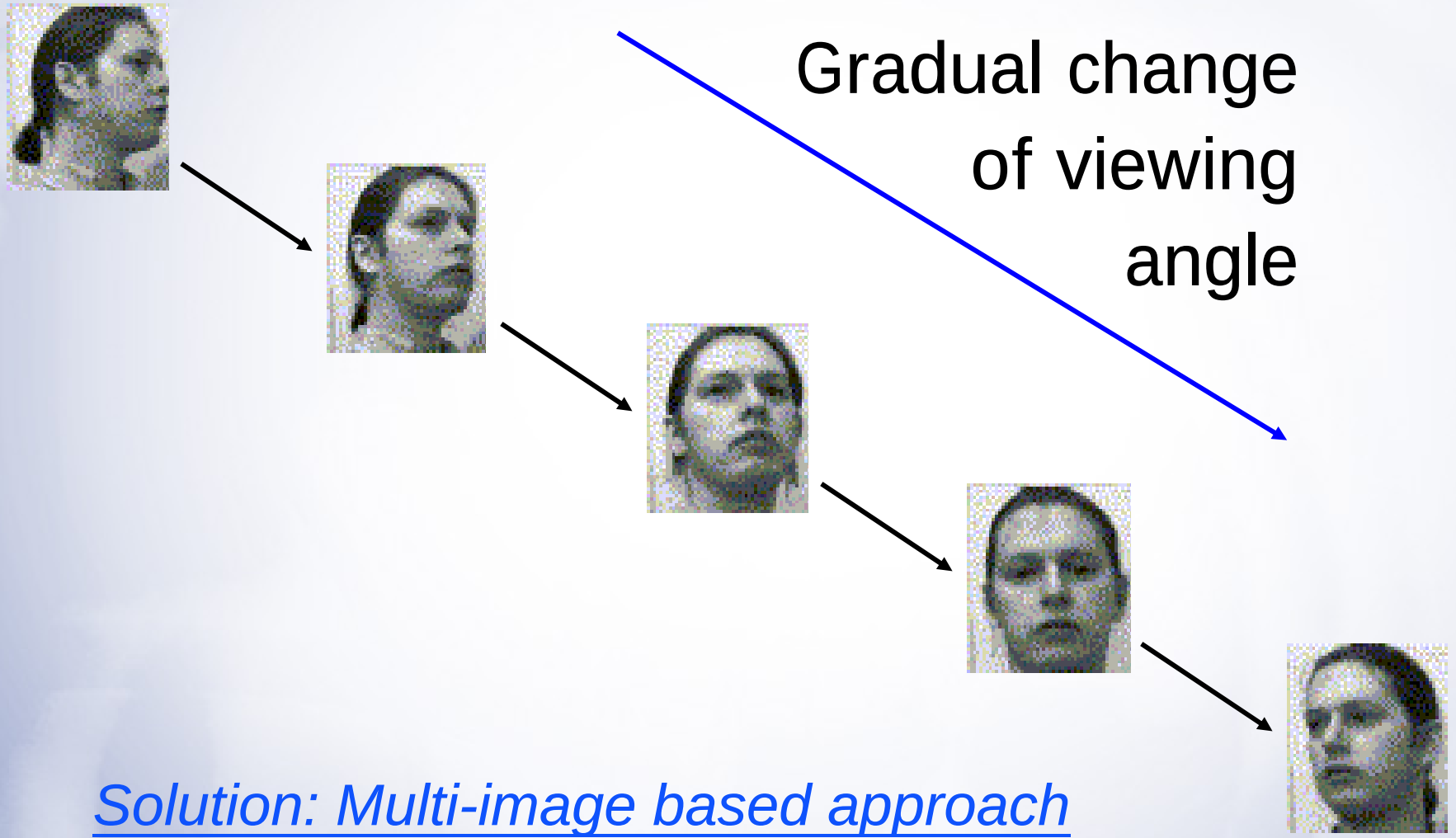
Subject with no facial expression

Subject with mouth wide open

Facial Expression Problem

Solution: Elastic graph matching

Pose Variation Problem



Solution: Multi-image based approach

General Three Steps

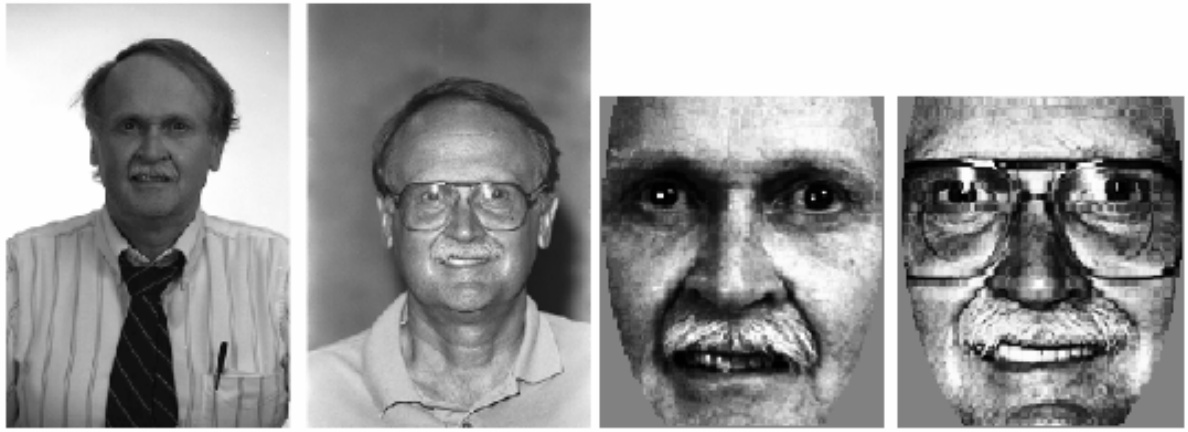
❑ Face Detection

In General

- ❑ Locate face in a given image
- ❑ Separate it from the scene

Different Approaches

- ❑ Motion detecting and head tracking
- ❑ "Face Space" distance



❑ Face Normalization - Adjustment

- – Expression
- – Scale
- – Rotation
- – Head tilt
- – Lighting
- – Eye location

❑ Face Identification

- Features extraction and Face recognition

Face Detection & Location

Statistics-based method

Method 1: Subspace method

Method 2: NN method
(classification into face & non-face classes)

Knowledge-based method

Method 3: Distribution ruler of gray-value-based
(e.g. gray values of eyes' a rea)

Method 4: Contour ruler

Method 5: Color information

Method 6: Movement Information

Method 7: Symmetry Information

Statistics-based Method 1: Subspace Method

- Find the subspace of face images which shows common features of faces, which is a good representation of face
- This can be done by using Karhunen-Loeve (K-L) transformation, which is an image-gray-value-based method, and the image gray values have to be normalized first.
- Each face image is considered as a higher dimensional vector
- Calculate the covariance matrix of the specimen images
- Find out the eigenvalues ($\lambda_1, \lambda_2, \ldots, \lambda_d$) and corresponding eigenvectors ($\varphi_1, \varphi_2, \ldots, \varphi_d$) of the covariance matrix
- Face images can be represented by fewer base vectors, the “eigenfaces”

Statistics-based Method 2: NN Method

- Two-class classification problem: Face class/ non-face class
- Need to train the NN with face & non-face image specimens
- Limitation is often combined with other methods
- Problem: many kinds of non-face images which are not collected. Slow - lots of specimens or input nodes

Knowledge-based Method 3: Distribution Ruler of Gray-Value-Based

- Detect faces using the nearly universal distribution rulers of gray values of faces under normal light condition
- Extract skin pattern

Knowledge-based Method 4: Contour Ruler

- Detect & extract face contour with edge detection algorithms
- Contour is an important feature of face
- Face contour is modeled as ellipse
- Two straight lines (cheek) and two arcs of ellipse
- Use snake techniques to get the face contour

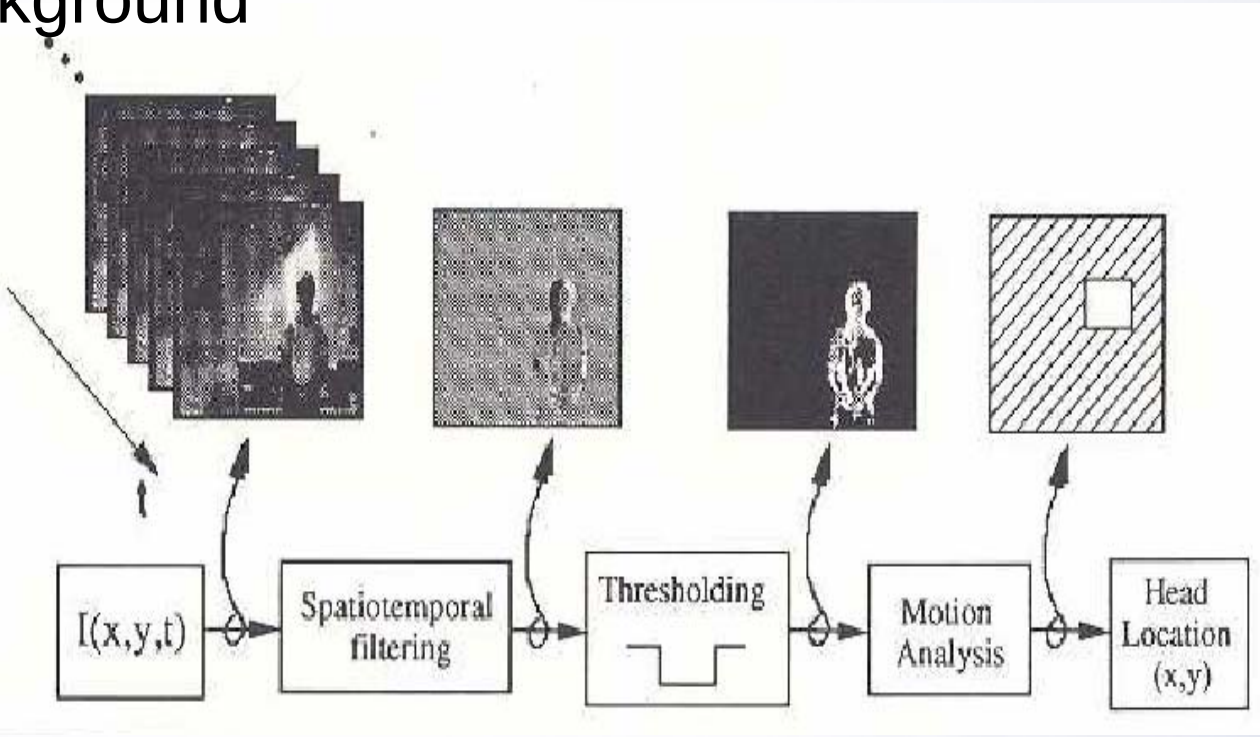
Knowledge-based Method 5: Color Information

- Detect faces with the use of color information of face, as usually color of faces are different from that of background color in an image

- The skin colors are usually different to background color
- the face colors in the same race is similar
- the pixels in face areas are clustered in a small area

Knowledge-based Method 6: Movement Information

- Sequence of images showing people moving relative to the background as input of the system (e.g. video surveillance system). So, movement information can be used to segment the face from the background



Knowledge-based Method 7: Symmetry Information

- Face is symmetrical in general and symmetrical objects in a face can be used

Face Normalization

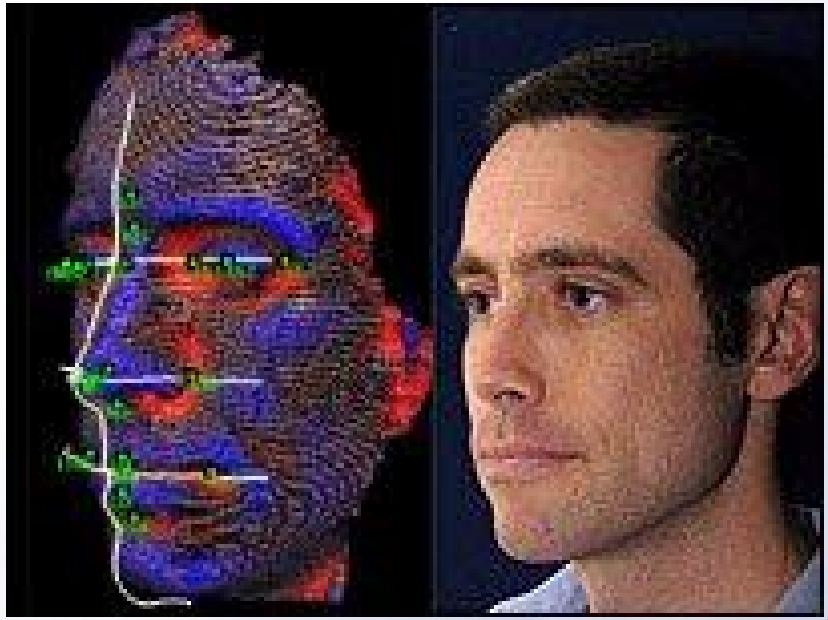
1. Image is rotated to align the eyes (eye coordinates must be known).
2. The image is scaled to make the distance between the eyes constant. The image is also cropped to a smaller size that is nearly just the face.
3. A mask is applied that zeros out pixels not in an oval that contains the typical face. The oval is generated analytically.
4. Histogram equalization is used to smooth the distribution of gray values for the non-masked pixels.
5. The image is normalized so the non-masked pixels have mean zero and standard deviation one.

Feature Extraction & Face Recognition

- ***Detection*** – Two-class classification (face vs. non-face)
- ***Recognition*** – Multi-class classification (one person vs. all the others)

Main methods of feature extraction:

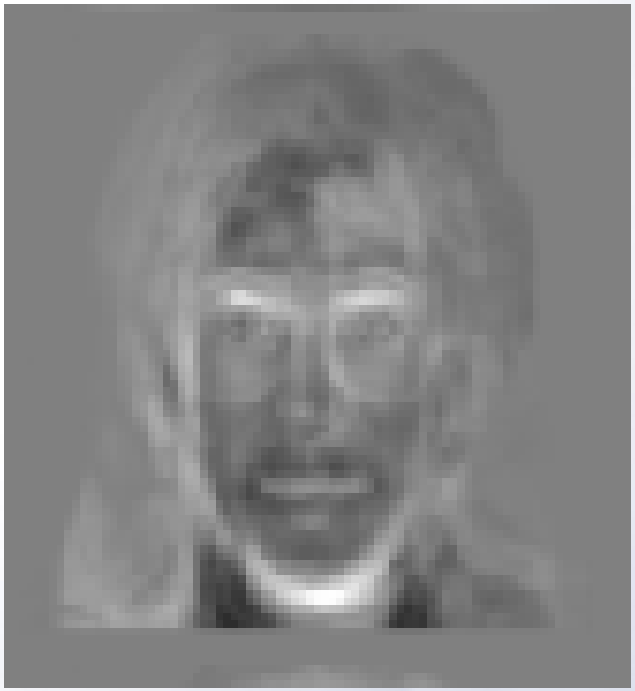
- Principal Component Analysis (PCA) i.e. Eigenfaces
- Geometry-feature-based method (e.g. position between eyes, nose, mouth & chin)
- Deformation models
- Neural networks method
- Identify surface



Facial geometry recognition

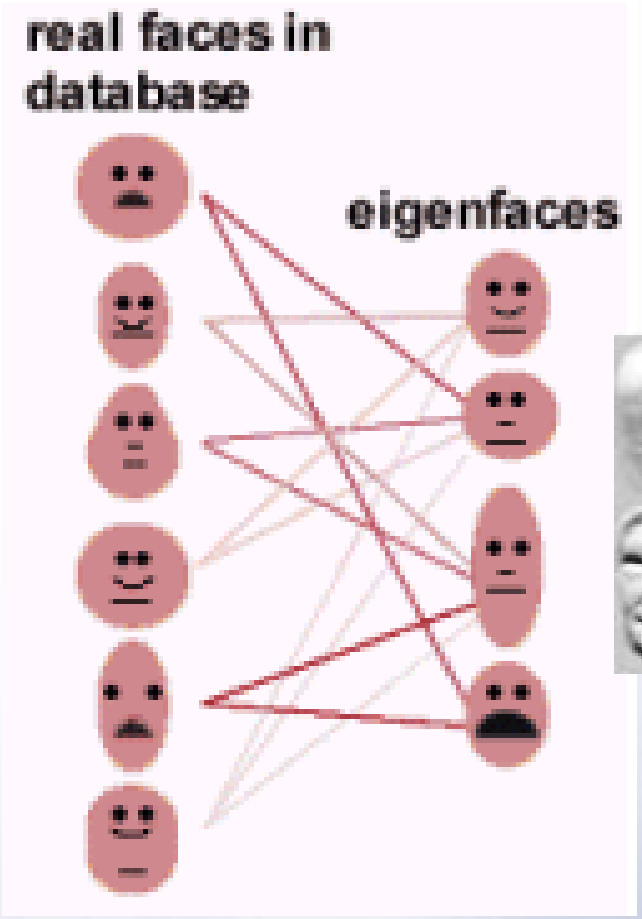
Feature Extraction 1: Eigenface (PCA)

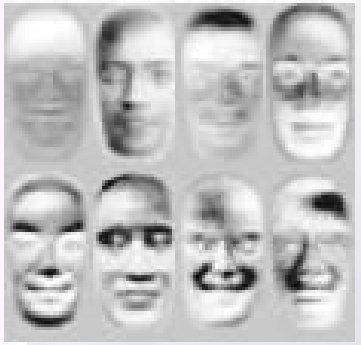
- Principal components are gained by training step, each image in a training set is projected to eigenface subspace
- Also called Principal Component Analysis (PCA), patented at MIT, currently used by Viisage's face recognition software
- Roughly translated as "one's own face"
- Take advantage redundancy existing in the training set and represent it in a more compact and meaningful way
- Variations of eigenface are frequently used as basis of other face recognition methods



What about Eigenfaces?

- Training set: global grayscale face images
- Find the principal component of the distribution of faces, i.e. Select *k* eigenvectors that have the largest eigenvalues to represent the most significant variation within the image set, which are called eigenfaces
- These *k* eigenfaces span a *k*-dimensional subspace, called the “face space”
- Each image in the training set can be represented as a linear combination of eigenvectors





Eigenfaces Algorithm (Step 1)

Eigenfaces

Initialization

1. Acquire and align an initial set of face images (the training set) - Rotate, scale and translate such that the eyes are located at the same coordinates.

Eigenfaces Algorithm (Step 2)

2. **Compute** the average face image; **Compute** the difference image for each image in the training set; **Compute** the covariance matrix of this set of difference images; **Compute** the eigenvectors of the covariance matrix

- Get the eigenfaces from the training set, keeping only the *k* images that correspond to the highest eigenvalues. These *k* images define the face space. As new faces are experienced, the eigenfaces can be updated or recalculated

Eigenfaces Algorithm (Step 3)

3. **Calculate** the corresponding distribution in *k*-dimensional weight space for each known individual, by projecting their face images onto the “face space.”

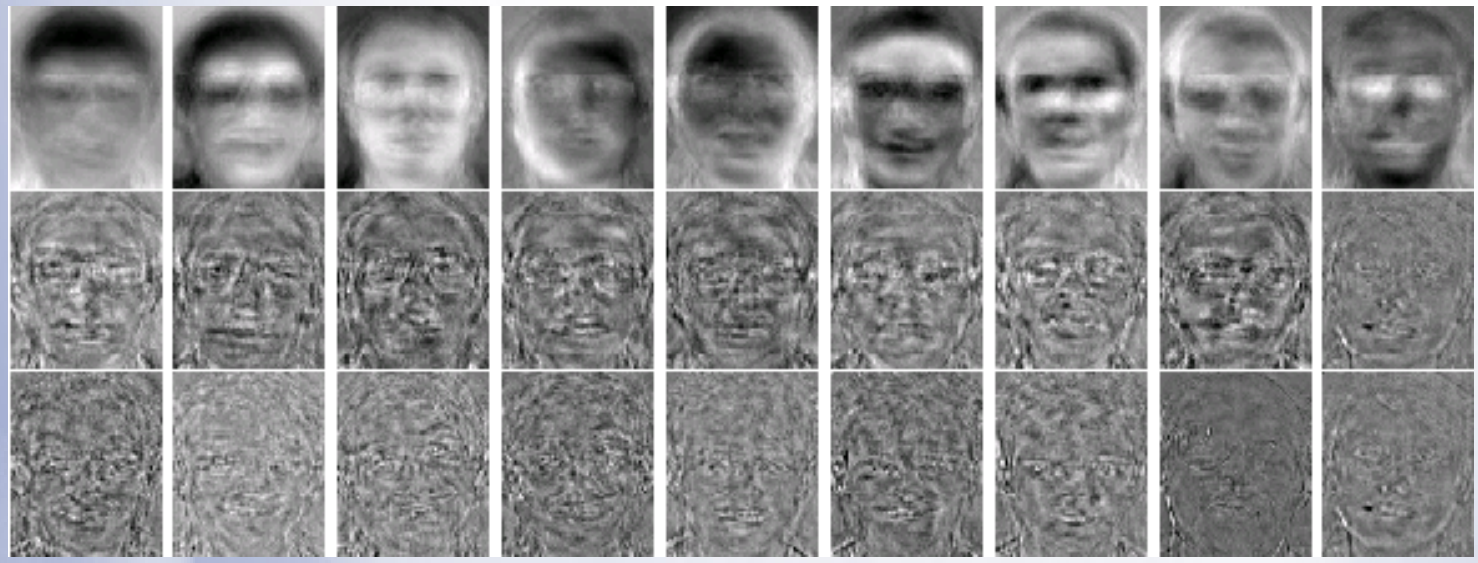
Eigenfaces Recognition Algorithm

1. **Calculate** a set of weights based on the input image and the *M* eigenfaces by projecting the input image onto each of the eigenfaces.
2. **Determine** if the image is a face at all by checking to see if the image is sufficiently close to “face space.”
3. If it is a face, classify the weight pattern as either a known person or as unknown.
4. (Optional) Update the eigenfaces and/or weight patterns.

- Each training image can be represented by a *k* dimensional vector
- For 1-to-many identification, project the concerned image to the face space and get a *k* dimensional vector, the ‘live’ template
- A distance measure is used to compare the similarity between the ‘live’ template and the training vectors

Eigenfaces: Sample

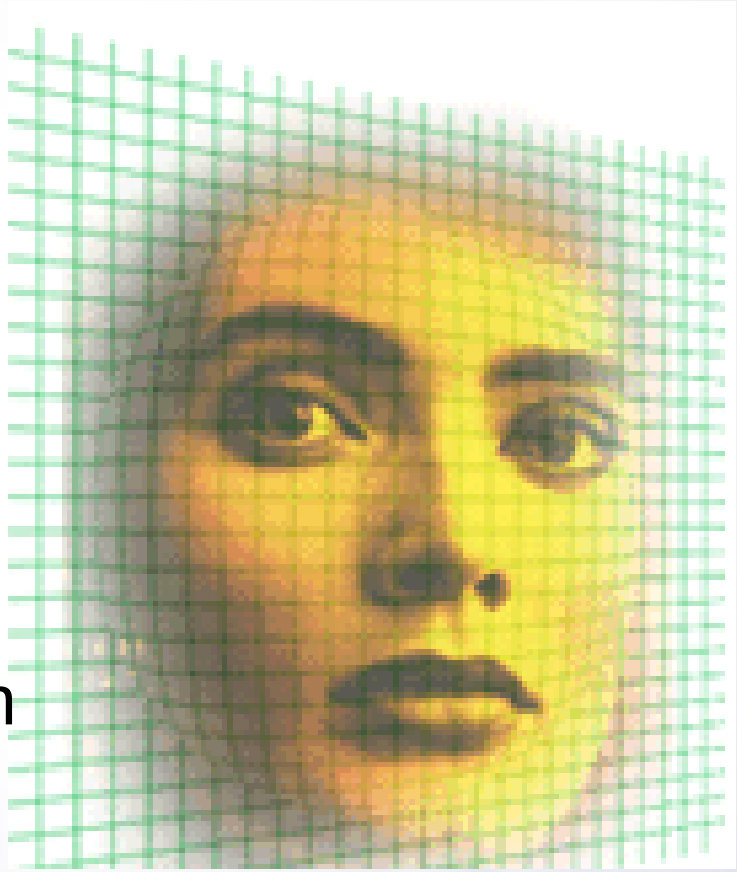
Training Images



Eigenfaces

Face Recognition Developer (Viisage Technology)

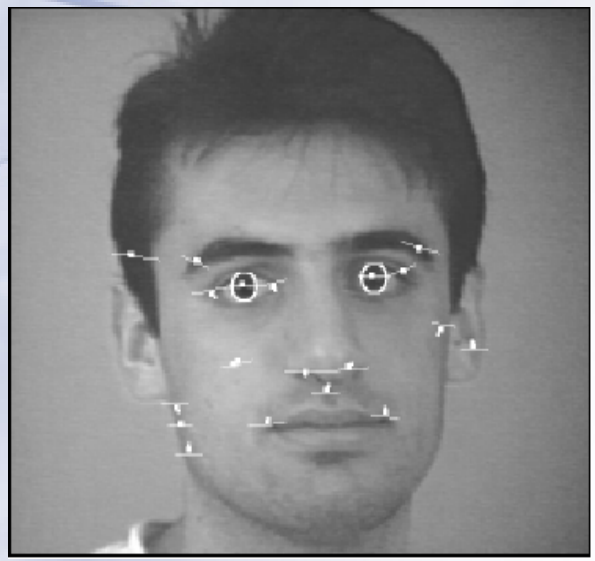
- 128 archetypes on record
- Differences/similarities with models on record use eigenface-based recognition algorithm
- Map characteristics of a person's face into a multi-dimensional face space
- Use in conjunction with identification cards (e.g. driver's licenses and similar government ID cards) in many States of US
- http://www.viisage.com/facialrecog.htm

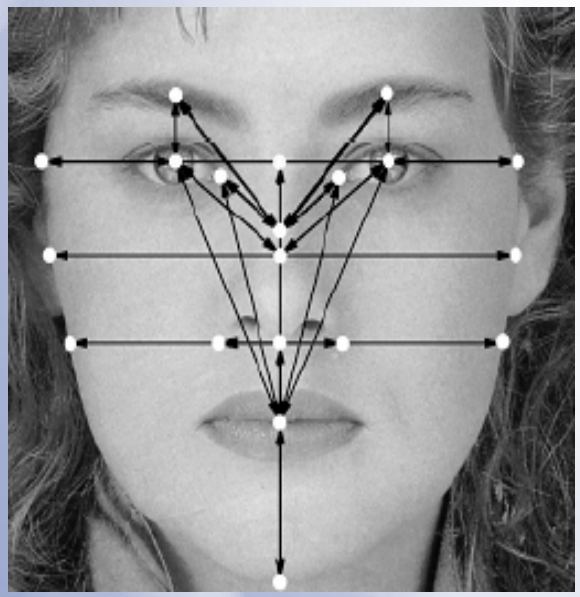


Feature Extraction 2: Geometry-Feature-Based Method

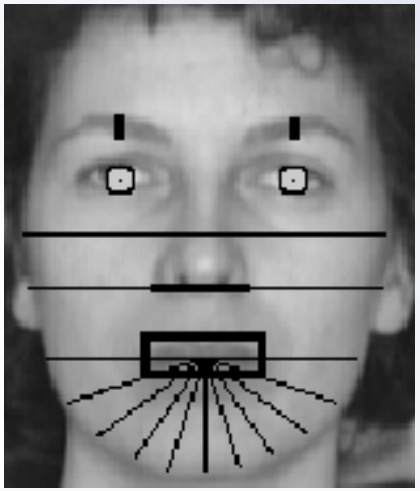
- Using **geometric information** of different parts of the face like eyes, nose, mouth, chin, cheekbones etc, as features of the face, for instance, distance between eyes, width of nose, etc.
- **Position relationship** between face parts, such as eyes, nose, mouth and chin, their shapes and sizes have strong contribution to classify faces
- Problem: geometry features can not be calculated accurately, which effects the recognition capacity directly

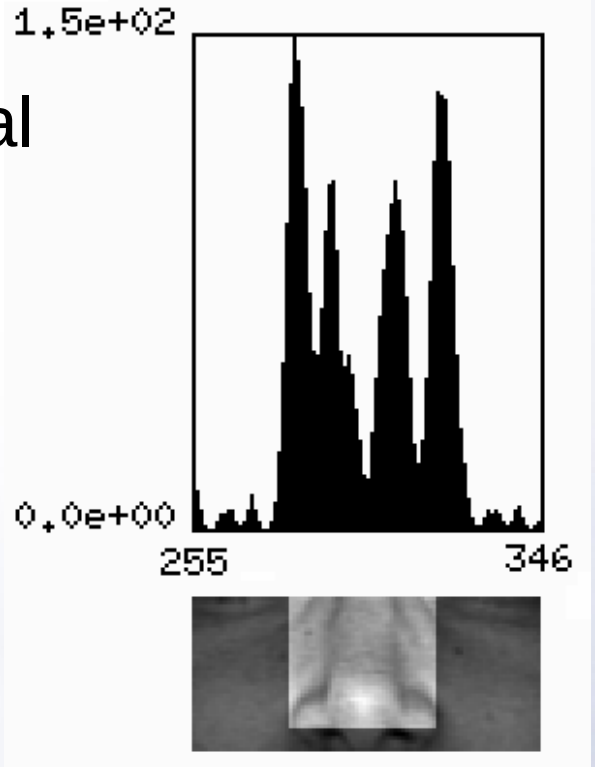
Local Features (Geometry)





- Uses vertical and horizontal integral projections of edge maps.
- The nose is found by searching for peaks in the vertical projection.
- 21 Geometrical features used.
- Recognition performed by nearest neighbour.





Face Recognition Developer
(Visionic's FaceIt)

- Represent facial images in terms of local statistically derived building blocks
- Identify 80 nodal points on a face
  - Distance between eyes
  - Width of nose
  - Depth of eye sockets
  - Cheekbones
  - Jaw line
  - Chin

- Use local feature analysis (geometric-feature based method)

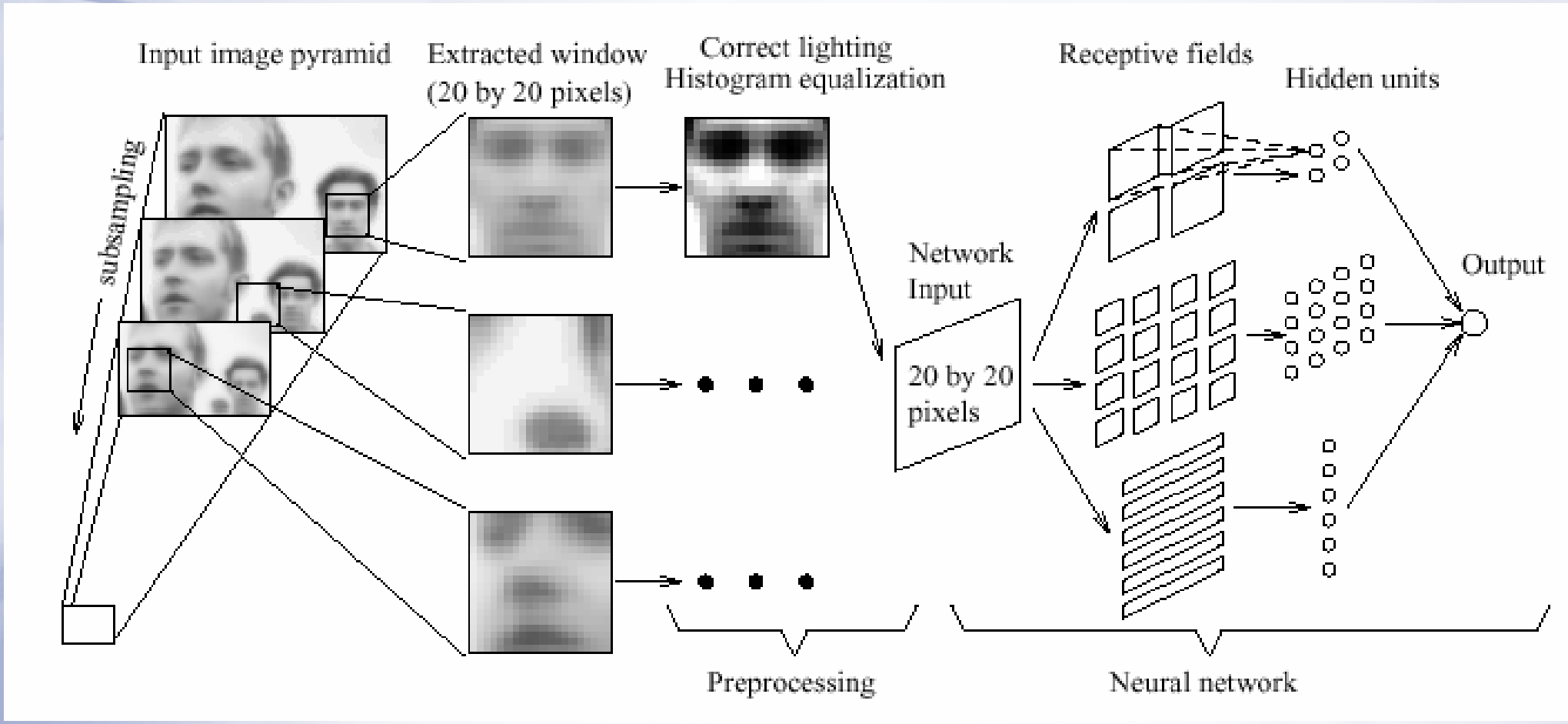
Visionic's FaceIt Software

- Nodal points are measured to generate a number, call a faceprint, 84 bytes in size
- Faceprint can be matched or compared with others
- Faceprint is resistant to changes in lighting, facial expression and is robust with respect to pose variations, up to 35 degrees
- Being incorporated into a Close Circuit Television anti-crime system in UK
- Visionics Corporation has merged with Identix Incorporated at 26 June, 2002
- http://www.identix.com/products/pro_security_bnp_argus.html

Feature Extraction 3: Deformation Models

- This model considered distortion characteristics of faces, e.g. the face image may vary in terms of sizes, angles, and vary when the person smile
- Recognize distortion invariant object by expressing them in **a sparse graph** whose vertices can be marked with multi-resolution description of local energy spectrum, and whose edges show topological relation between vertices, and edges have distance property
- A face in normal condition can be expressed by **a uniform image**
- Face recognition is transformed as a graphic matching problem

Feature Extraction 4: Neural Networks

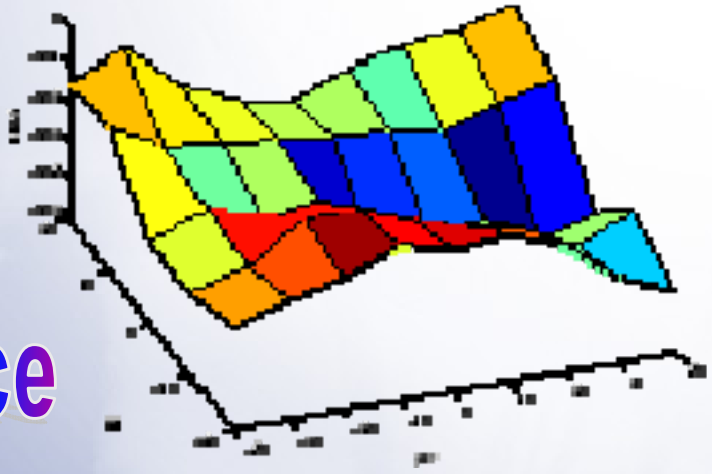


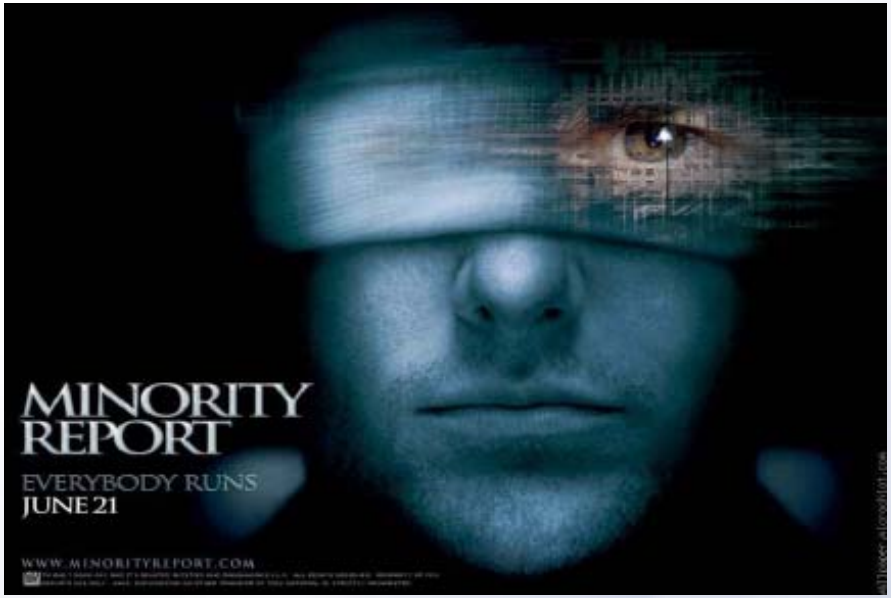
- Large training set of faces and small set of non-faces
- Training set of non-faces automatically built up:
  - Set of images with no faces
  - Every ‘face’ detected is added to the non-face training set.

ANN

Feature Extraction 5: Identity Surface

- Construct the identity surface for each face
- Track the trajectory of unknown face
- Compute the Euclidean distance between unknown and identity surface





Face Recognition Developer (Cognitec's FaceVACS)

- Technology used is believed to be neutral nets
- Take user's face image with a video camera (or even a standard webcam)
- Extract feature using its image processing algorithm and compare it with user's reference set stored in database
- http://www.cognitec-systems.de/products-entry.htm

Face Recognition Developer (ZN-Face)

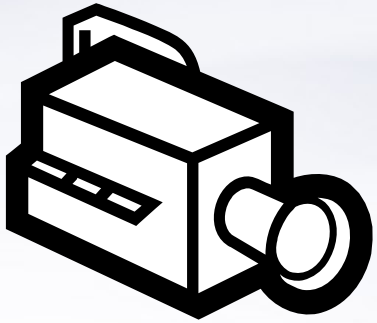
- Use an extension of the Elastic Graph Matching Algorithm
- Can perform image acquisition, face localization and identification in 3.5 seconds
- Allows robust identification of persons previously stored
- Reliable rejection of unknown persons
- Use in areas - air traffic, identity documents, forensic investigation, ID systems, access control and video surveillance
- http://www.zn-ag.com/content.en/face.htm

Current Applications

- Applications range from **static**, mug-shot verification to a **dynamic**, uncontrolled face identification and tracking in a cluttered background

Industry/Sector	Application	Where
Casinos/Gaming	Security, search for repeated cheat	Foxwoods, Trump Casino
Police/Corrections	Digitalize mug shot, scan for criminals	Tampa, London
Military	Monitor movements	Israel
Immigration	Rapid progression through customs	U.S./Mexico Border
Airport	Passenger surveillance against hotlist	Keflavik Intl. Airport, Iceland

Application - Video Surveillance

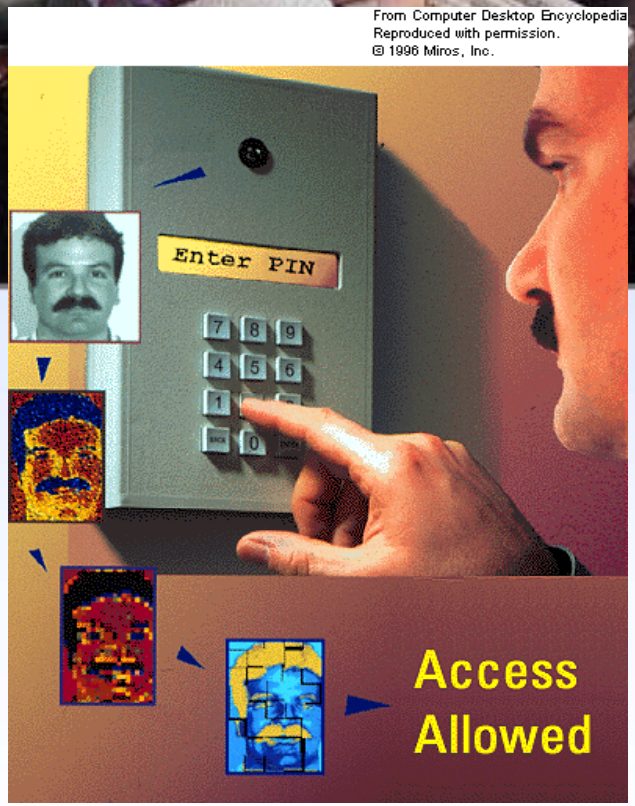


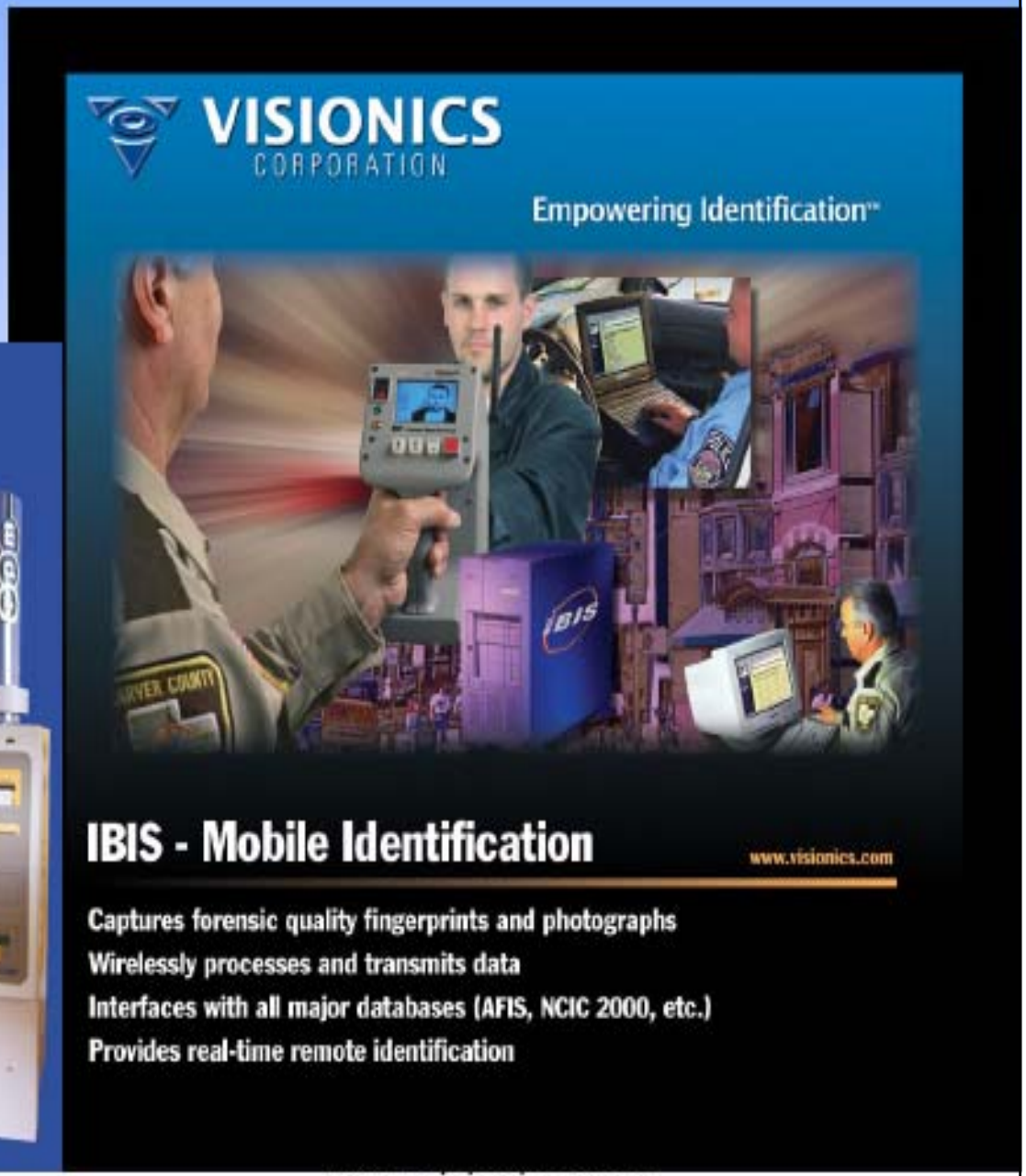
Face Scan at Airports

The St. Petersburg-Clearwater Airport installed facial recognition systems at two security checkpoints in January. Six-foot tall towers (above) house cameras that snap pictures of passengers as they pass through magnetometers. The passengers' faces instantly are compared to a database of images of wanted criminals. Sheriff Everett Rice (above left) was one of the first people to pass through the new security system.

www.facesnap.de

Application - Access Control





Access Control

Application – Smart Card / Casino Client

Smart Card

Typical casino client would have a number of facial databases:

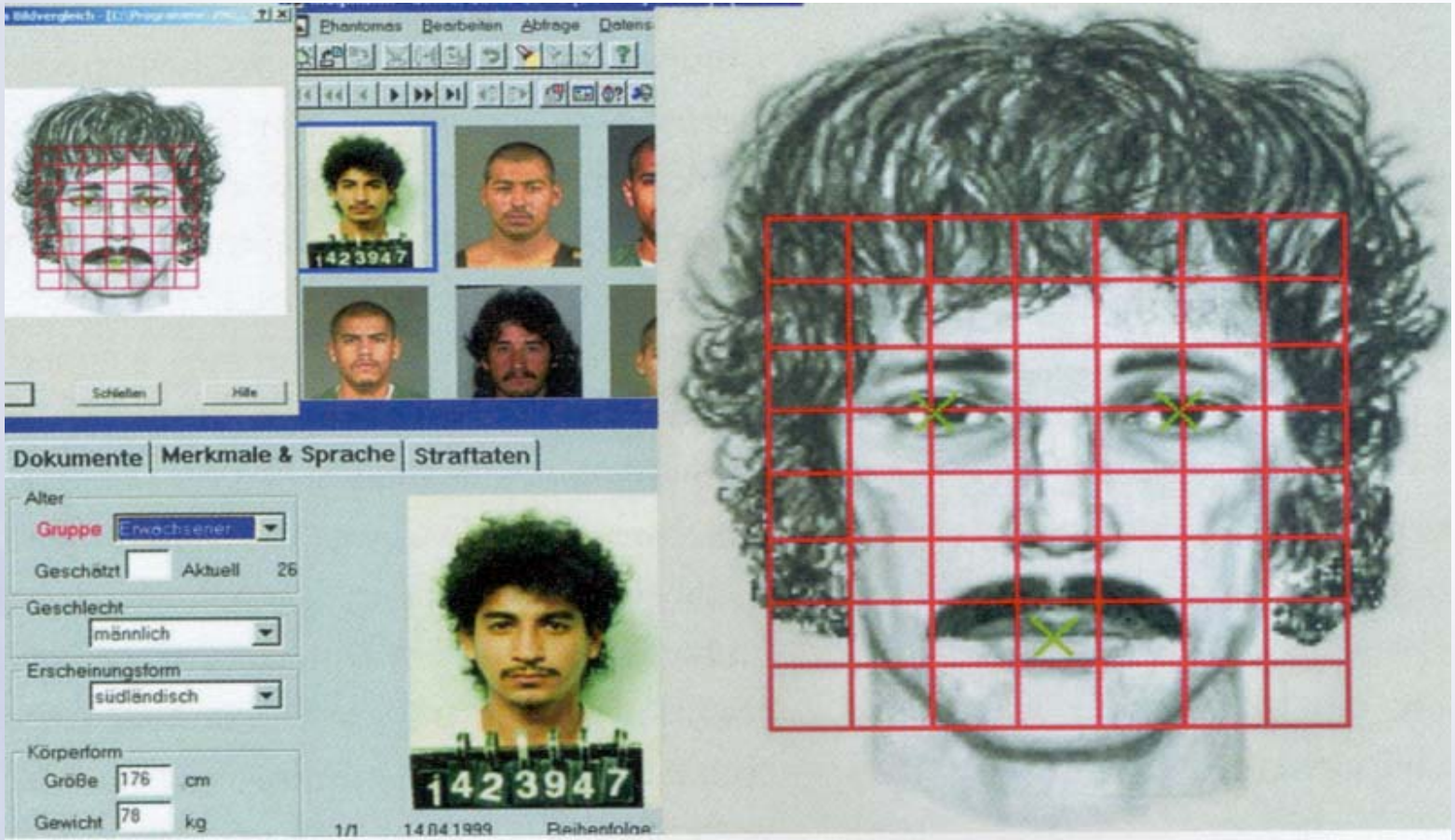
- 1 – Banned clients (Gamblers Anonymous);
- 2 – Common criminals (Police Database).
- 3 – Known card sharks (From other casinos).

Compare To
White, Male, banned clients, DB

Capture multiple images

Face Recognition Systems

- One of the world's leading face recognition systems: -- Phantomas for access control at airport in Berlin and by police forces throughout Europe.



"Phantomas" can automatically compare 10,000 faces per second.

Application – Protect Public Security

- The Tampa Police Department (Florida) use FRS to spot criminals in busy street
- The images are captured from cameras positioned in different areas of downtown
- The operator keep watching on the CCTV monitor
- Snapshots of faces are compared to a database of criminal mugshots.

Application – Eliminate Vote Fraud

- It can ensure that people register to vote only one time
- An image database is dynamically built for every voter
- For every incoming voter, the system will grab an image and match it against the image database
- Successfully in the parliamentary elections in Uganda (Africa)

Face – Strengths/Weaknesses

- Cheap hardware components and easy to be added to the existing computer systems.
- Can search against static images such as driver's license photographs
- Can be used to search for the suspect to protect public safety by mounting a camera on the place to be monitored.
- It is the only biometric able to operate without user cooperation

- Changes in both acquisition environment and physiological characteristics reduce matching accuracy, i.e. outdoor instead of indoor
- Has potential for abuse due to non-cooperative enrollment and identification capabilities
- Accuracy is not satisfied and cannot handle identical twins.

Future Of Face Recognition

- Accuracy
  - More Research, e.g. 3D Model /Heterogeneous Security Solution
  - Neural Nets to improve accuracy and predictions
- Fusion: - Sensor fusion: using camera + thermal scans
  - Fusion: face + other (i.e. voice) recognition
- Wearable computing will make face recognition ubiquitous - Very large potential market
  - Replace monetary exchange - credit cards and money
  - Utilize for security access to buildings and computers/ augment normal access to automobiles and homes
  - Work with ATM's to authenticate bank users by matching face prints with bank cards

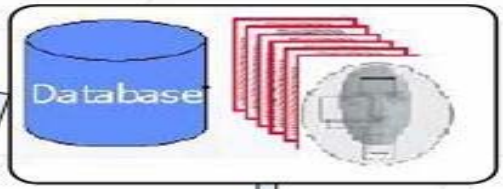
THE PROCESS OF BIOMETRICS 3D FACE RECOGNITION

Special near Infra Red light pattern projected onto face

Standard video camera captures distorted IR pattern

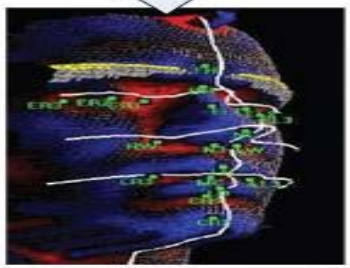
The scene on scanning process

Image processing



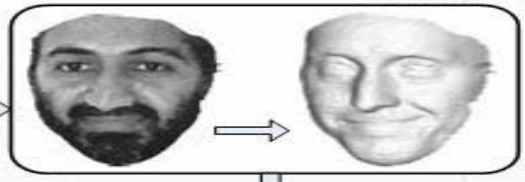
Enrollment

Get the template from the database



Feature Extraction

Identification



Output

Decision Theory

Questions?

- What problems can you find in the current face recognition? Can you give their solutions?
- Geometry feature is important in face recognition. Please try to list all useful features you can.
- There are two kinds of the methods in face detection and location, which are statistics-based and knowledge-based method. What difference between them?


END