Tutorial 7

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COMP435p
Biometrics Authentication

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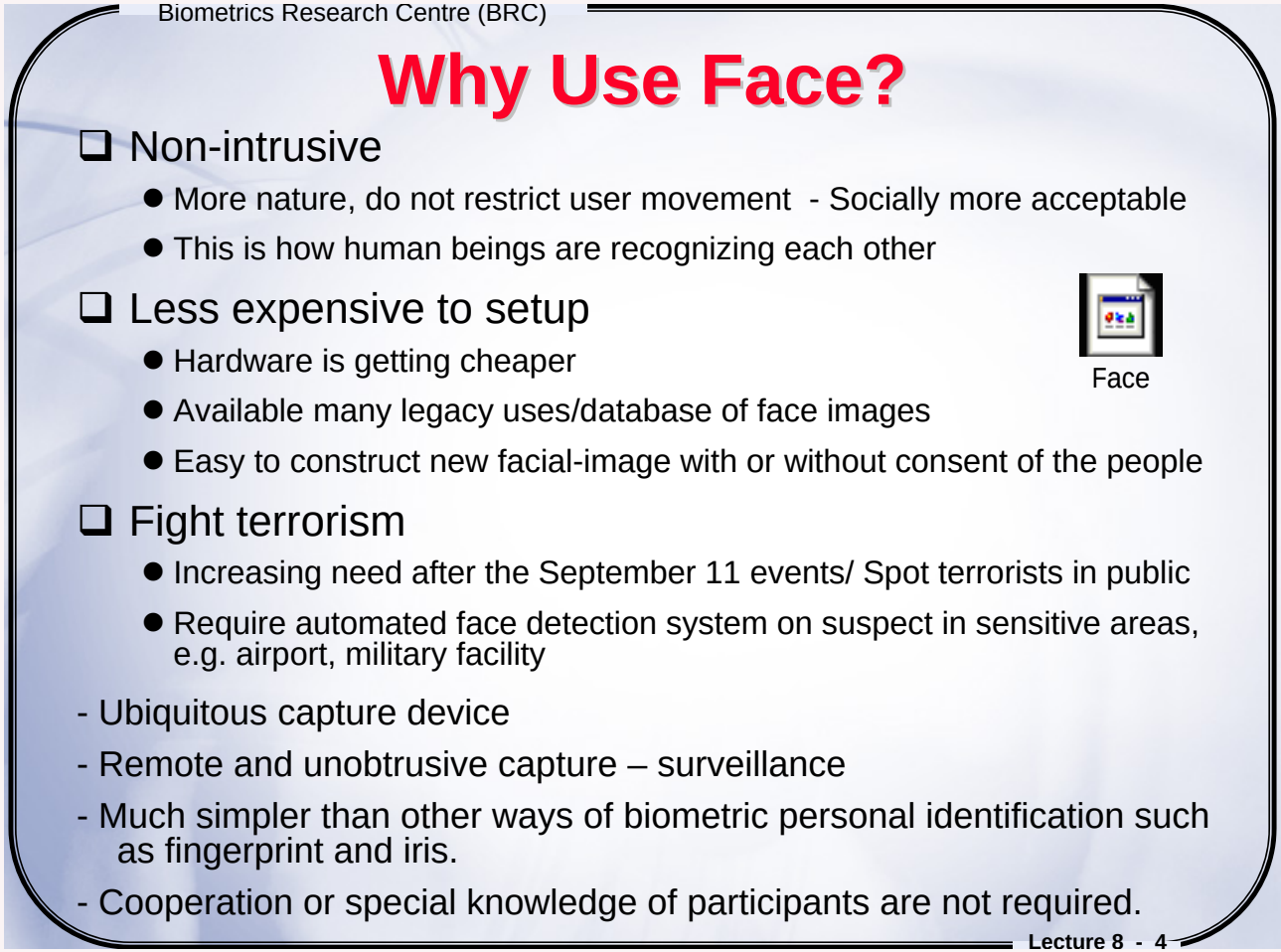
Understand why use face (P8:3-4) and face recognition system (P8:5-10).

Problem 1.1 Face recognition system

Problem 1.1 Face recognition system



Problem 1.1 Face recognition system

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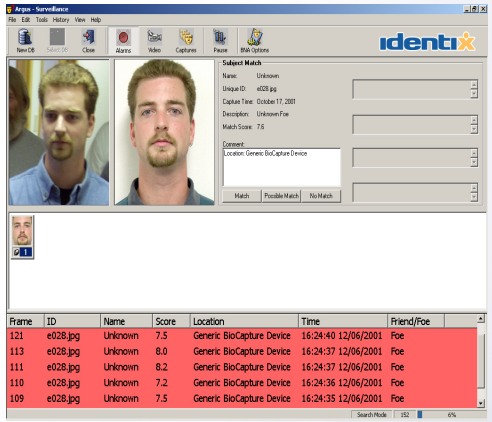
Face Recognition: Situation

- *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!)

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Problem 1.1 Face recognition system

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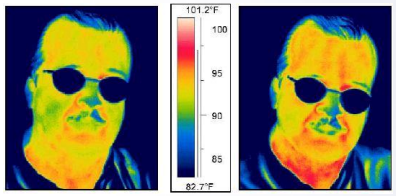
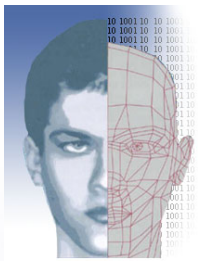
Face Recognition: Images

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



Facial thermogram




Video image

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Problem 1.1 Face recognition system

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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

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Problem 1.1 Face recognition system

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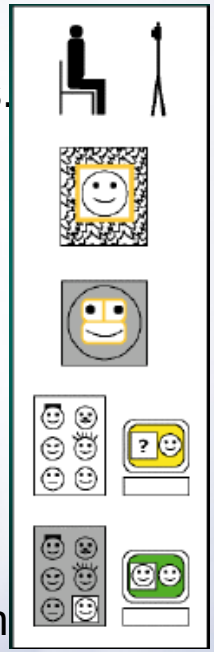
What Facial Features?

- 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



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Problem 1.1 Face recognition system

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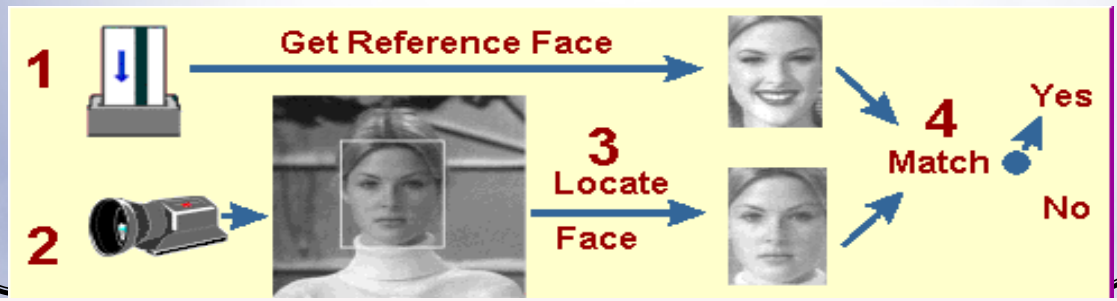
Face Recognition System

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



Problem 1.1 Face recognition system

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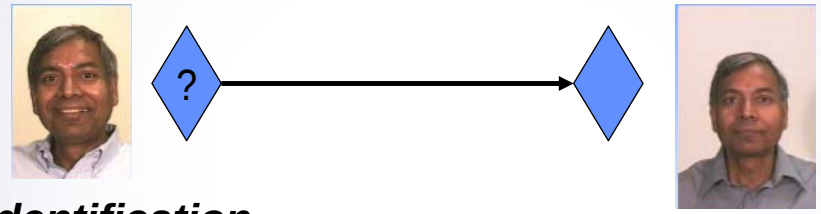
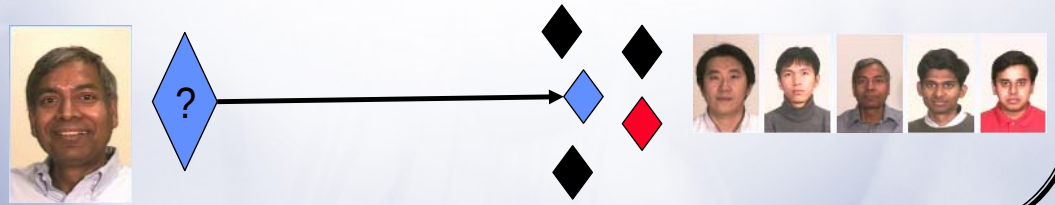
Face Recognition System

- ***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.



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Problem 1.1 Face recognition system

- Face
  - Unique: every one has a unique face
  - Passive: can be captured without user cooperation
  - Non-intrusive: nature, do not restrict user, more acceptable, human beings tradition
  - Less expensive: hardware is cheaper, many available database, easy to construct
  - Fight terrorism: Increasing need, Require automated face detection
  - 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.

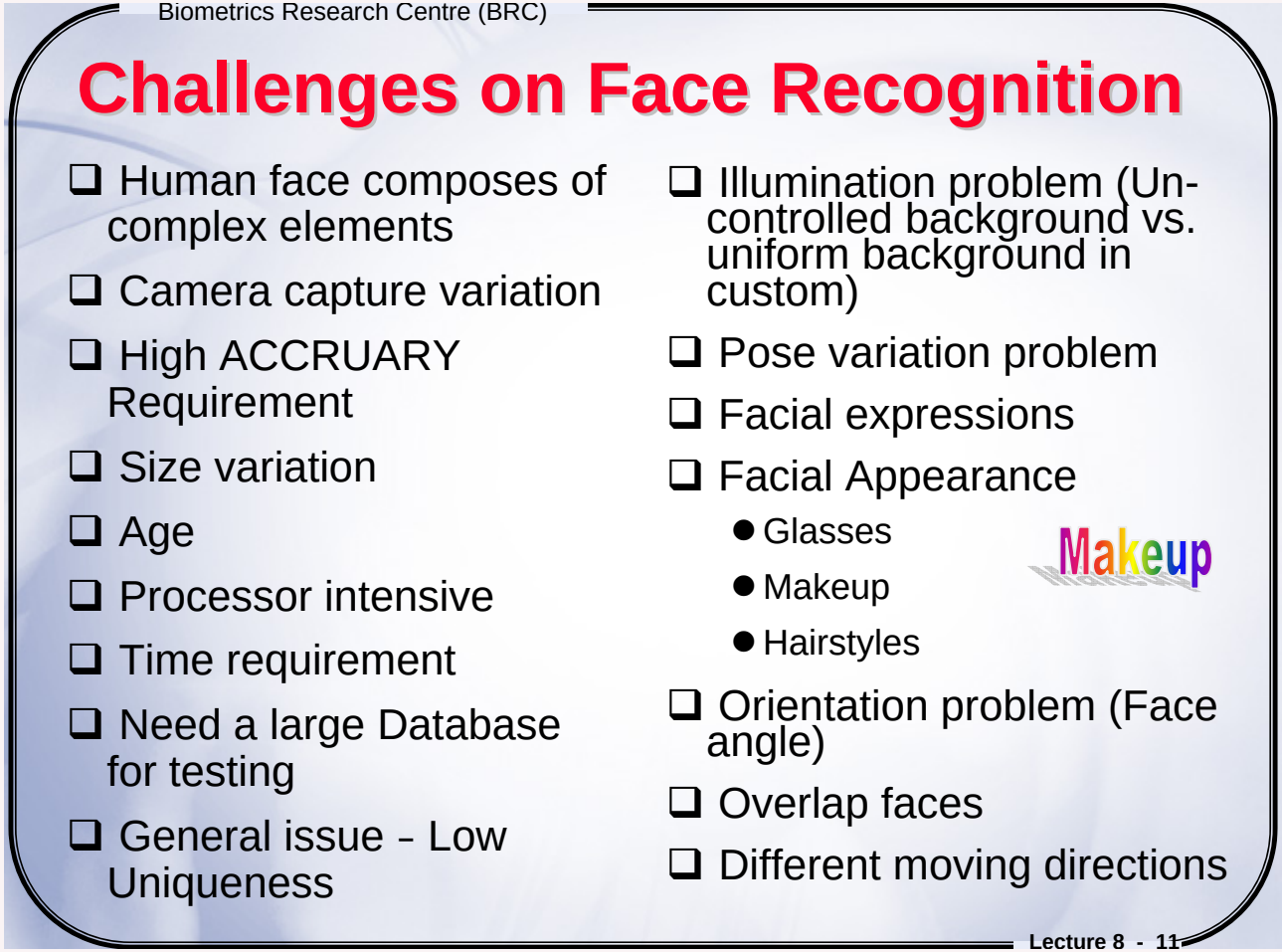
Problem 1.1 Face recognition system

- Face recognition system
  - Programming a computer to recognize a human face.
  - It analyzes facial characteristics
  - It requires a camera.
  - This technique has attracted considerable interest.
  - Uses distinctive features of the human face in order to verify or identify individuals
  - Accuracy . . . .
  - Still image or video sequence; color or grayscale; thermogram / near infrared / 3D.
  - Capturing a face image . . .
  - Facial Features: . . .
  - Face Recognition System Structure: Detection, location, and Matching with Reference . . .
  - Verification vs identification: . . .

Problem 1.2 Problems of face recognition

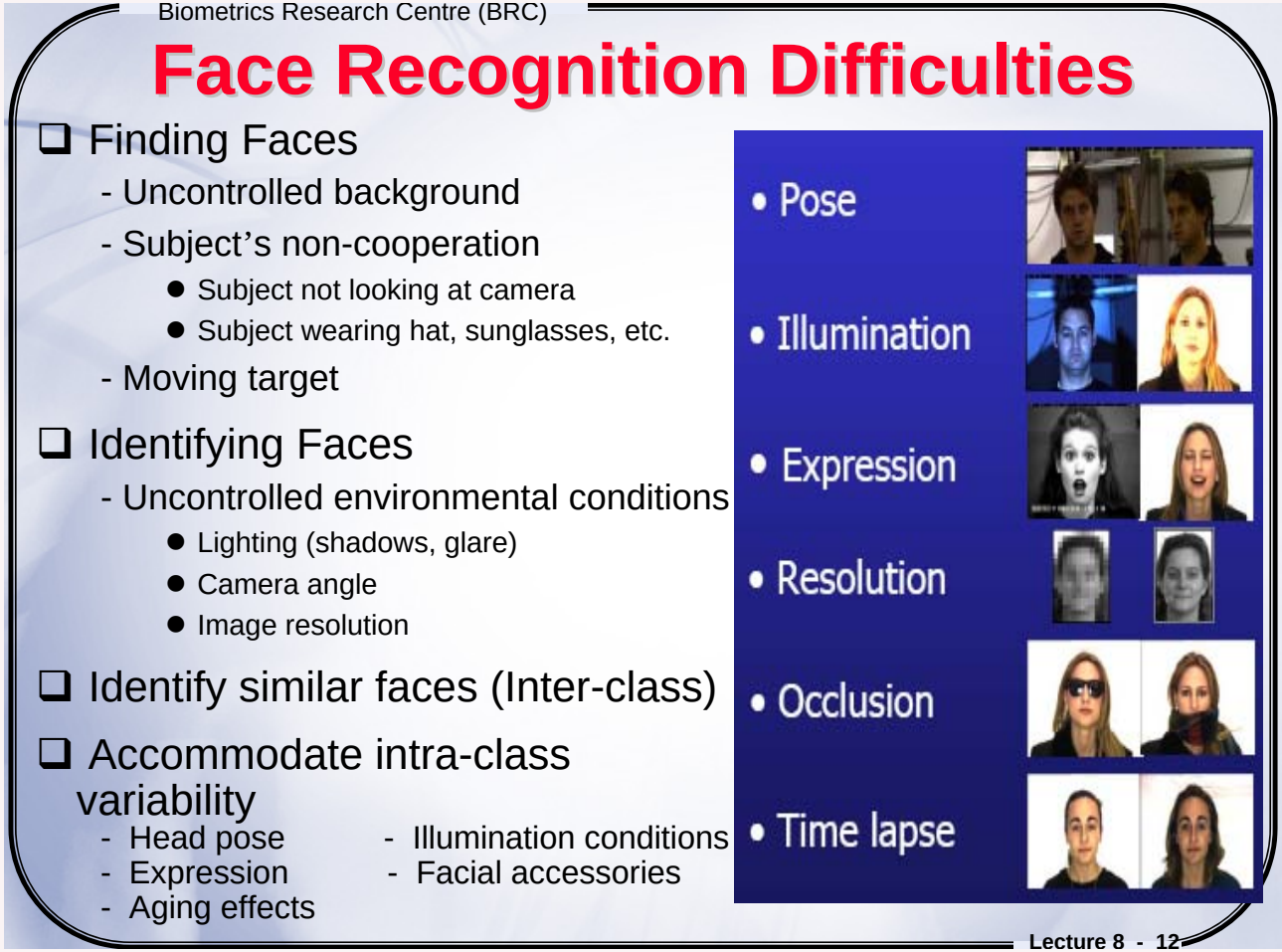
Please point out some problems of face recognition. Can you give their solutions? (P8:11-16)

Problem 1.2 Problems of face recognition



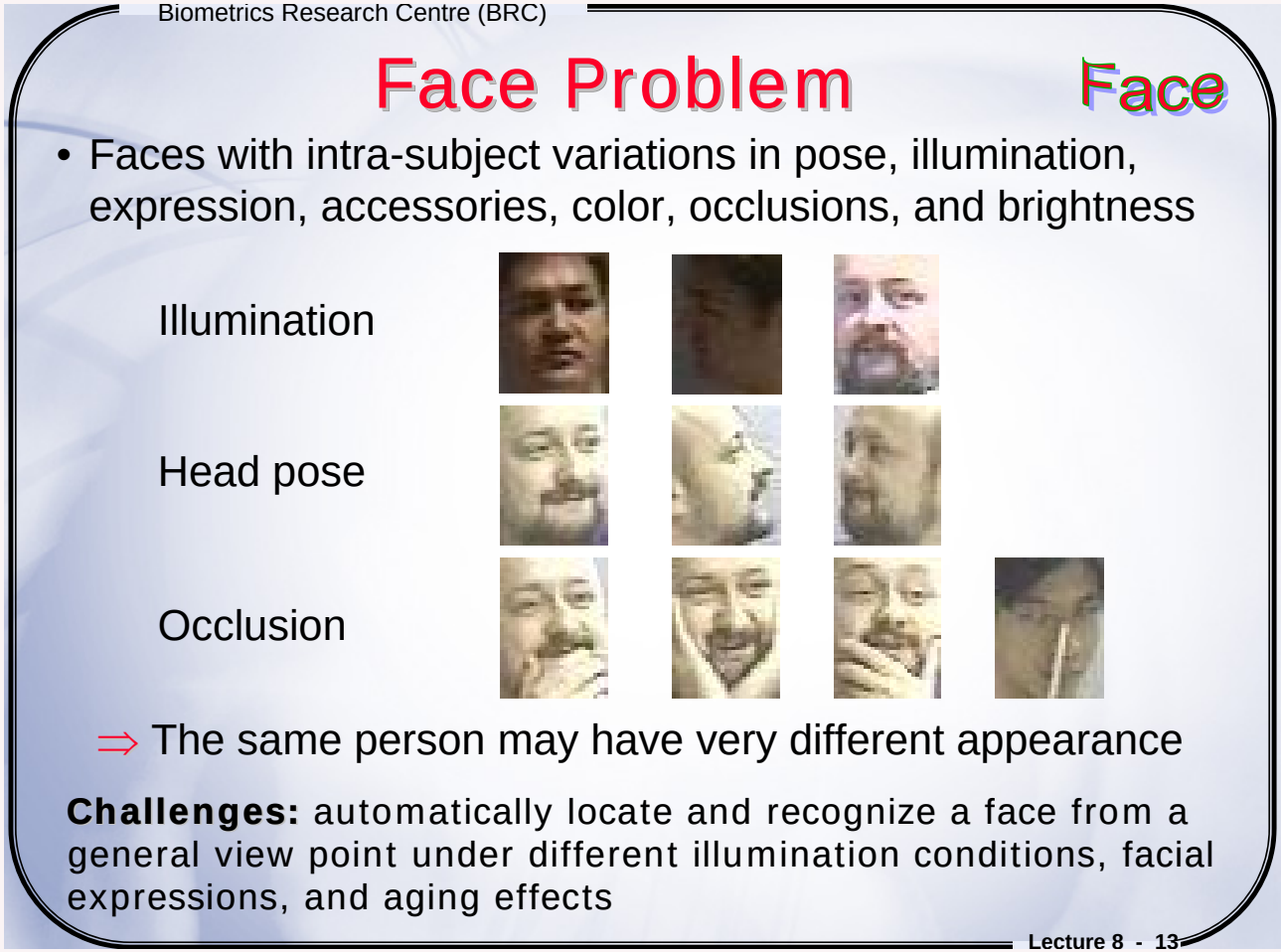
Above are the typical problems

Problem 1.2 Problems of face recognition



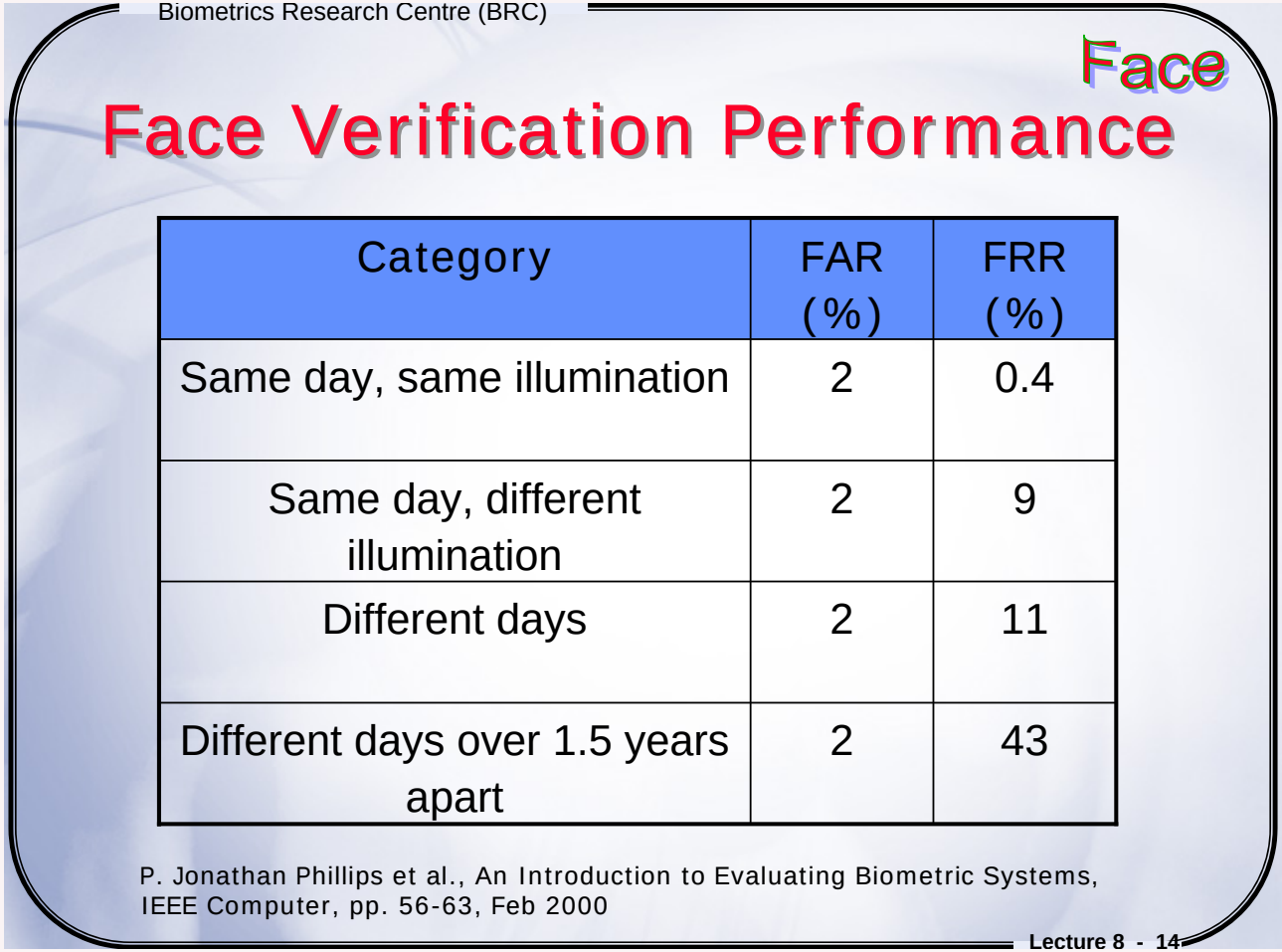
Data flow sequence.

Problem 1.2 Problems of face recognition



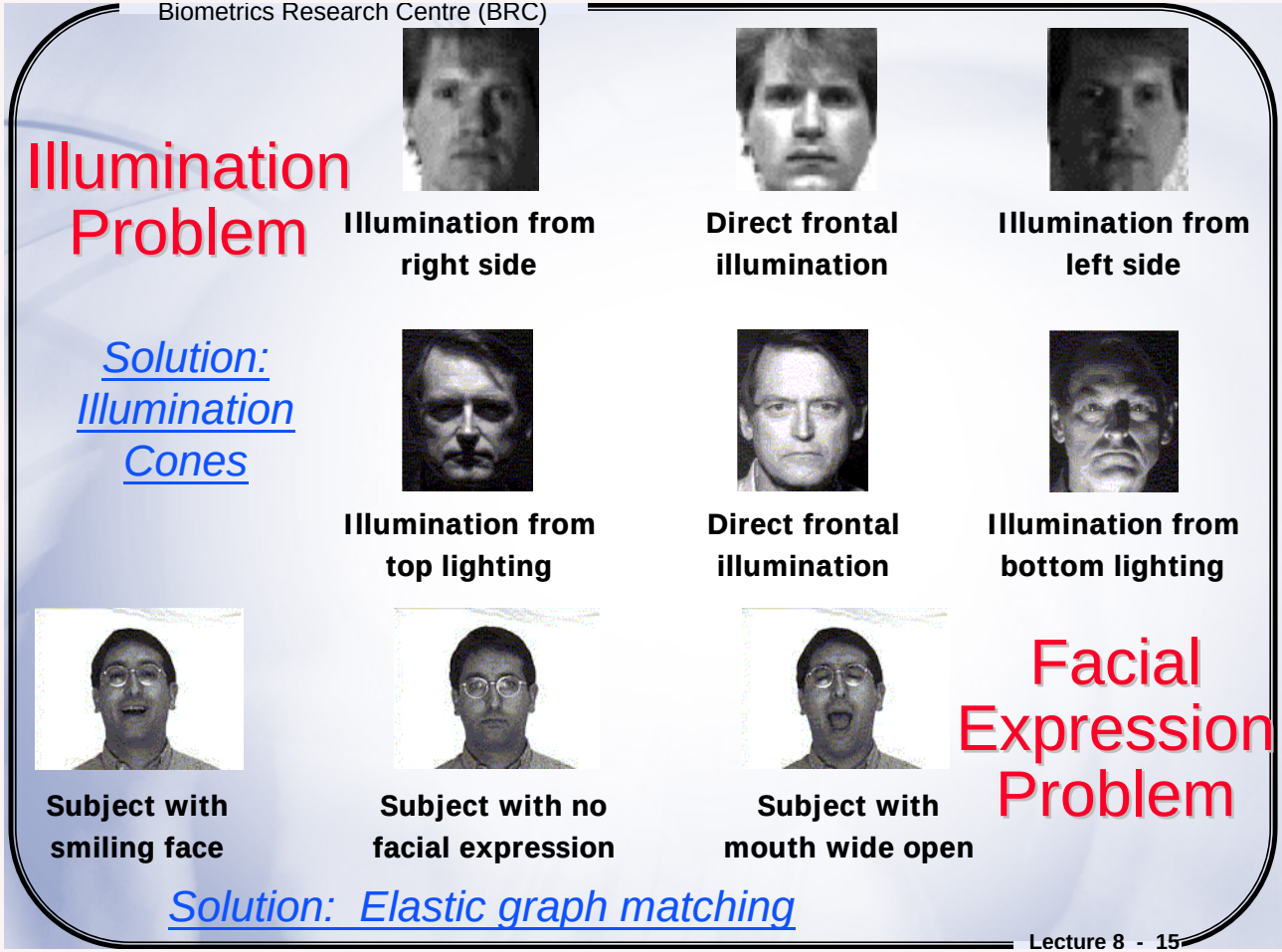
Intra-class problems.

Problem 1.2 Problems of face recognition



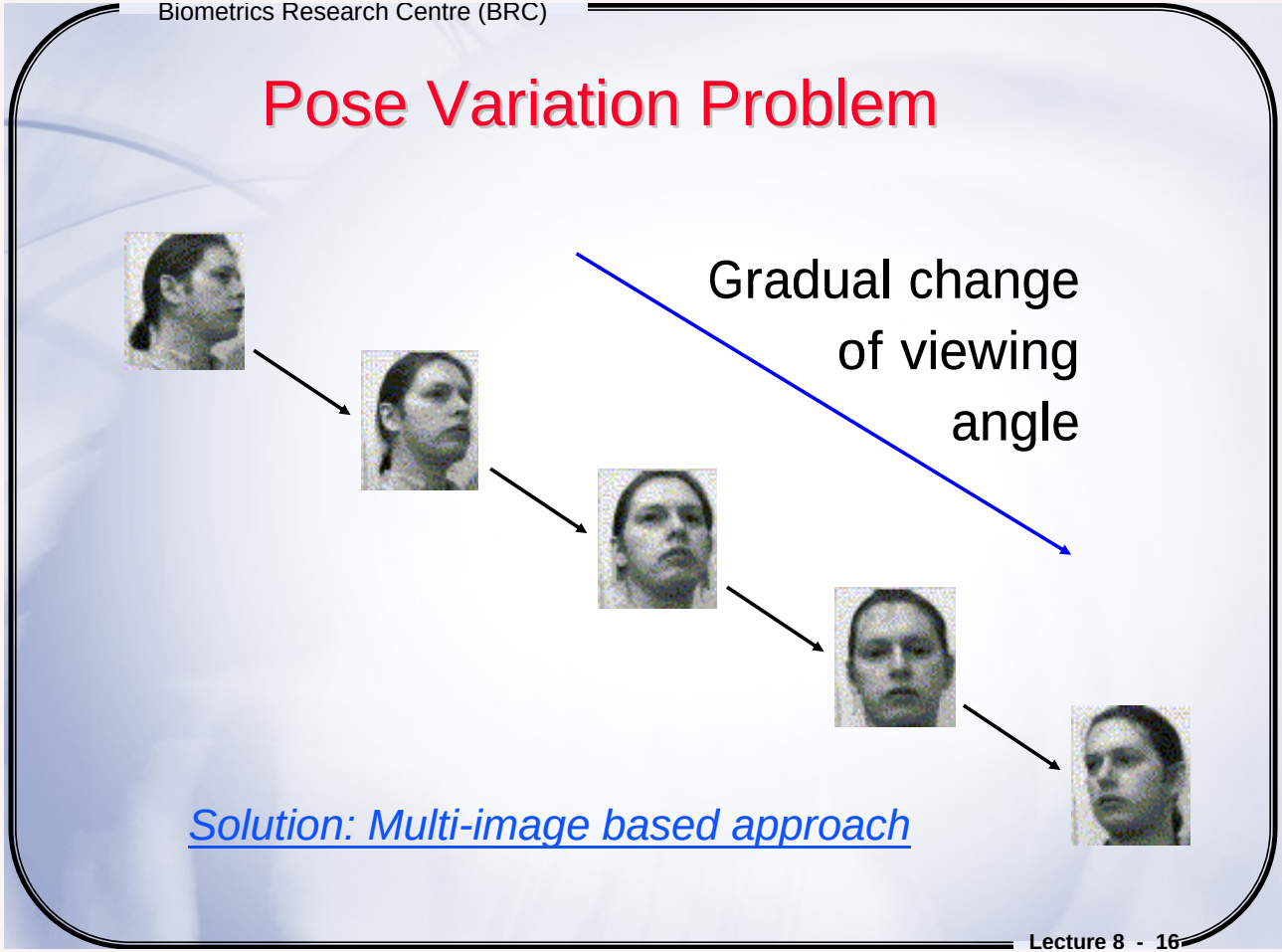
Performances

Problem 1.2 Problems of face recognition



Illumination

Problem 1.2 Problems of face recognition



Pose

Problem 1.3 Three steps of face recognition

What are the general 3 steps of face recognition? (P8:17)

Problem 1.3 Three steps of face recognition

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General Three Steps

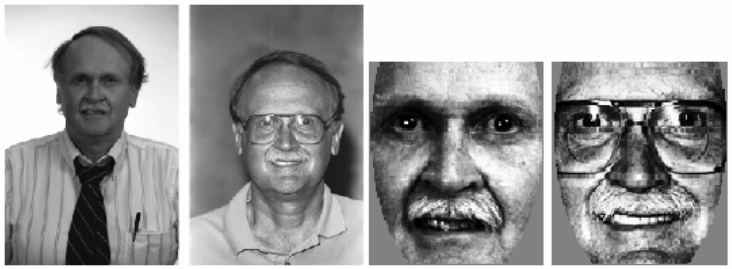
❑ Face Detection

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

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Problem 1.4 Face detection and location

There are two kinds of the methods in face detection and location, which are statistics-based and knowledge-based method. What difference between them? (P8:18-22)

Problem 1.4 Face detection and location

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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

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Problem 1.4 Face detection and location

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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”

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Problem 1.4 Face detection and location

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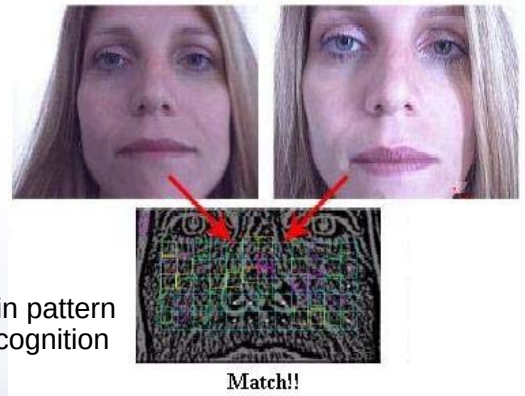
Statistics-based Method 2: NN Method

- 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



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Problem 1.4 Face detection and location

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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

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Problem 1.4 Face detection and location

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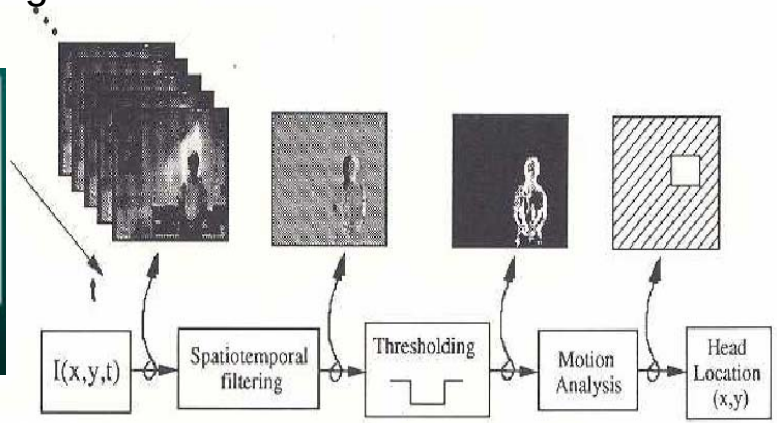
Knowledge-based Method 6: Movement Information

- 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

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Problem 1.4 Face detection and location

- Statistics-based method
  1. Subspace method
  2. NN method

     The information is learned by statistics data. The learning process can be implemented by programs, which is an automatic process. And the performance can be enhanced by using a larger database.
- Knowledge-based method
  1. Distribution ruler of gray-value-based
  2. Contour ruler
  3. Color information
  4. Movement Information
  5. Symmetry Information

     The grammar is provided by human experts. The performance of these methods greately depends on the knowledge of human experts.

Problem 1.5 Face feature extraction

There are five methods of face feature extraction (P8:24-41). Please give their basic ideas.

Problem 1.5 Face feature extraction

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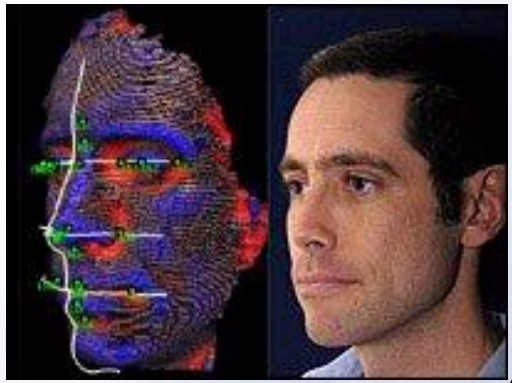
Feature Extraction & Face Recognition

- ***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

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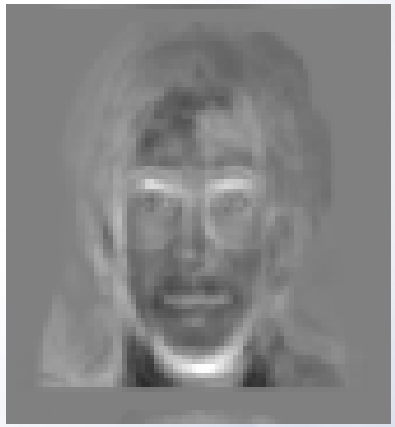
PCA, Geometry Features, Deformation Models, Neural Networks, Identify Surface

Problem 1.5 Face feature extraction

Biometrics Research Centre (BRC)

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



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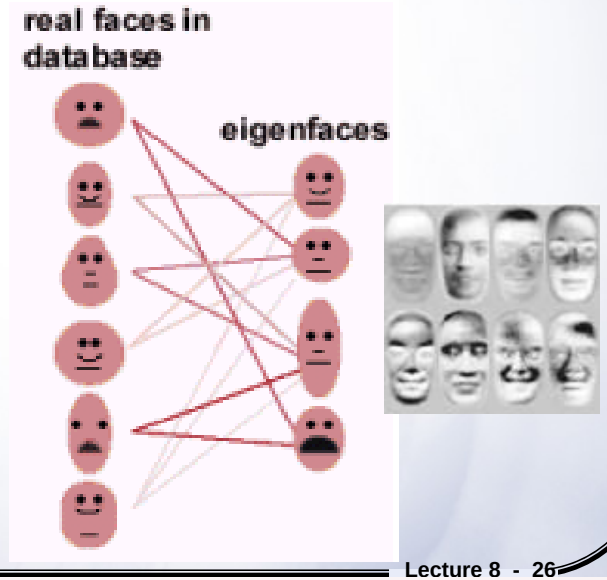
Problem 1.5 Face feature extraction

Biometrics Research Centre (BRC)

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



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Problem 1.5 Face feature extraction

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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.

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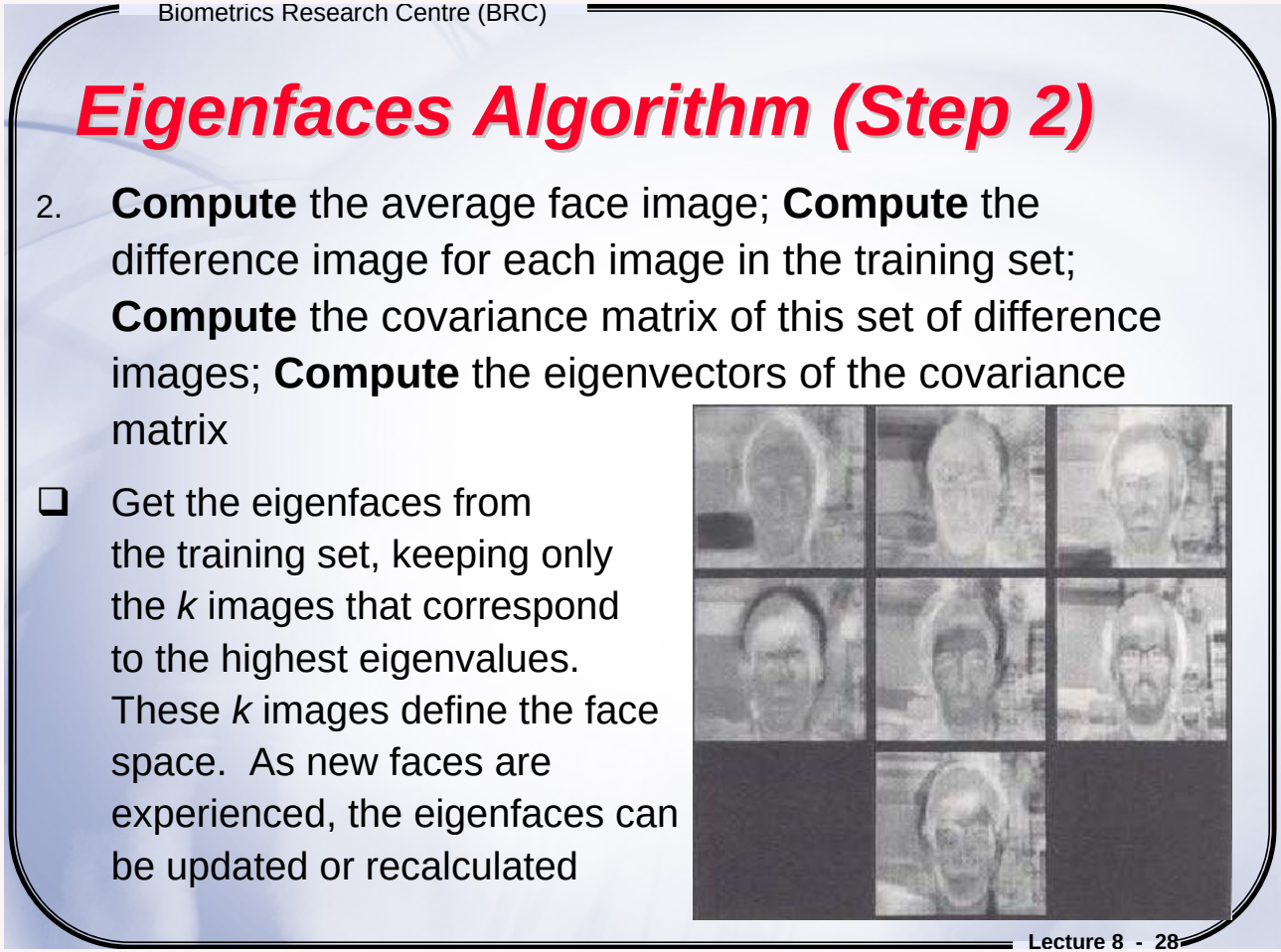
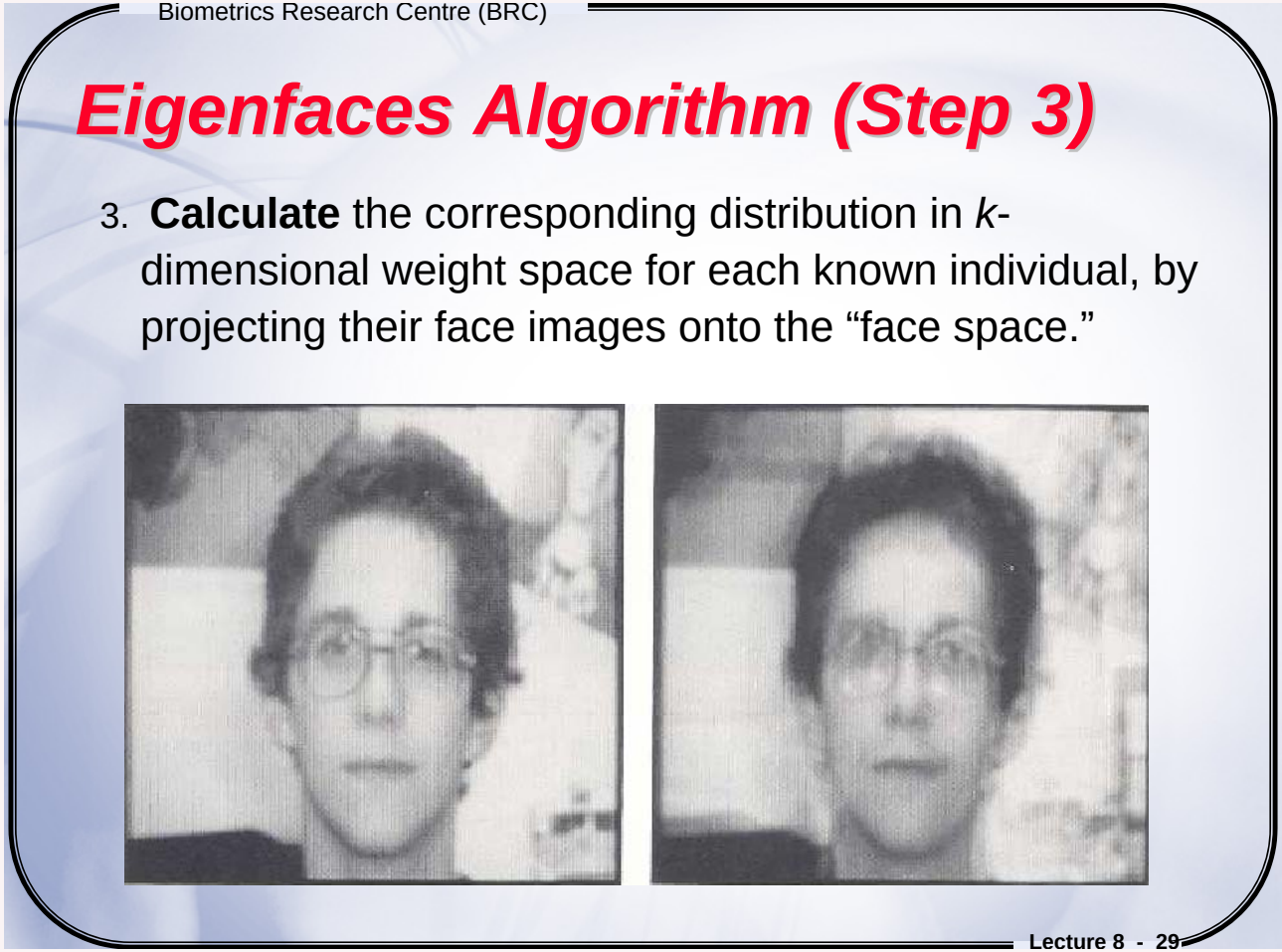
Problem 1.5 Face feature extraction



Problem 1.5 Face feature extraction



Problem 1.5 Face feature extraction

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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

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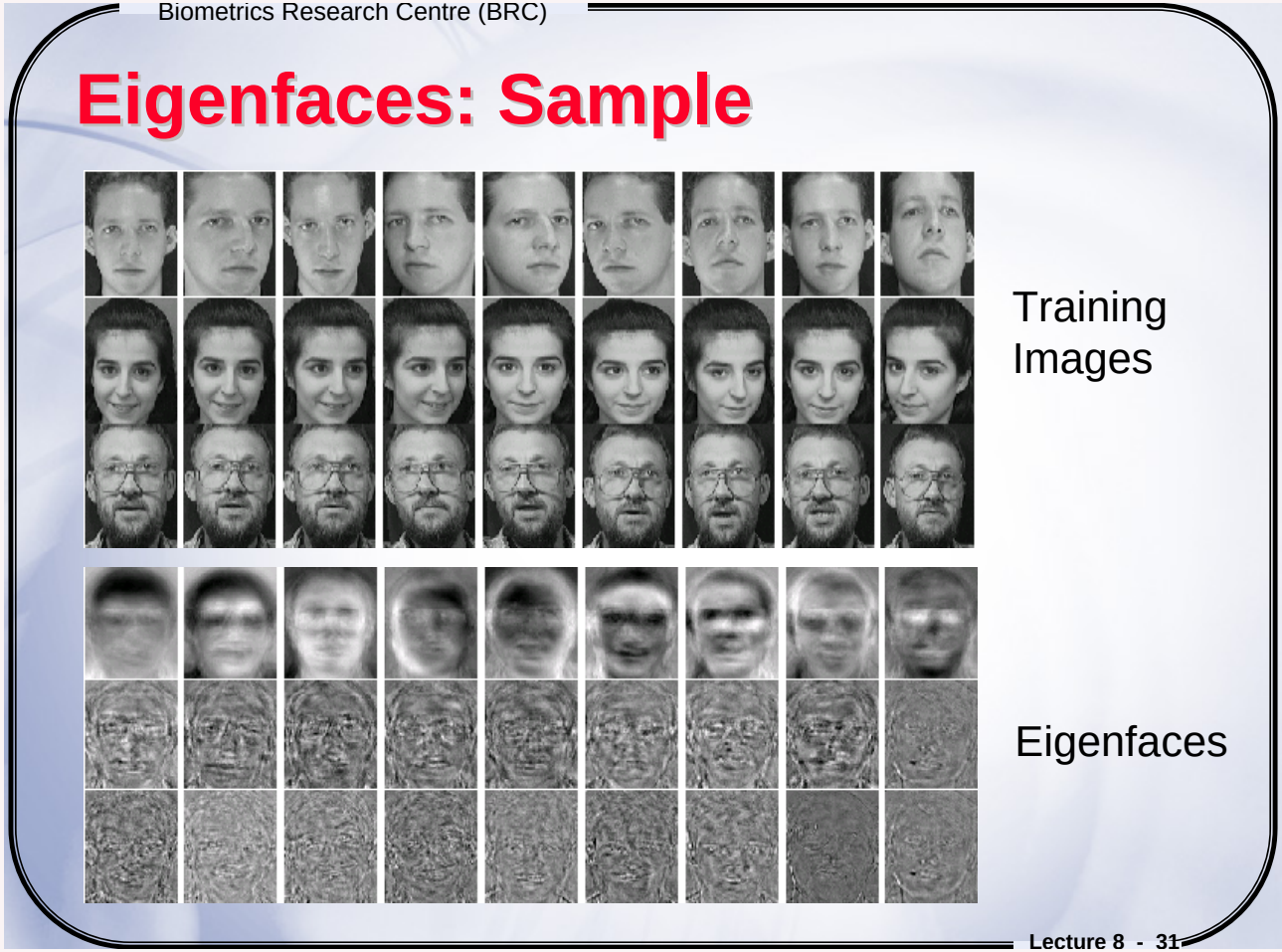
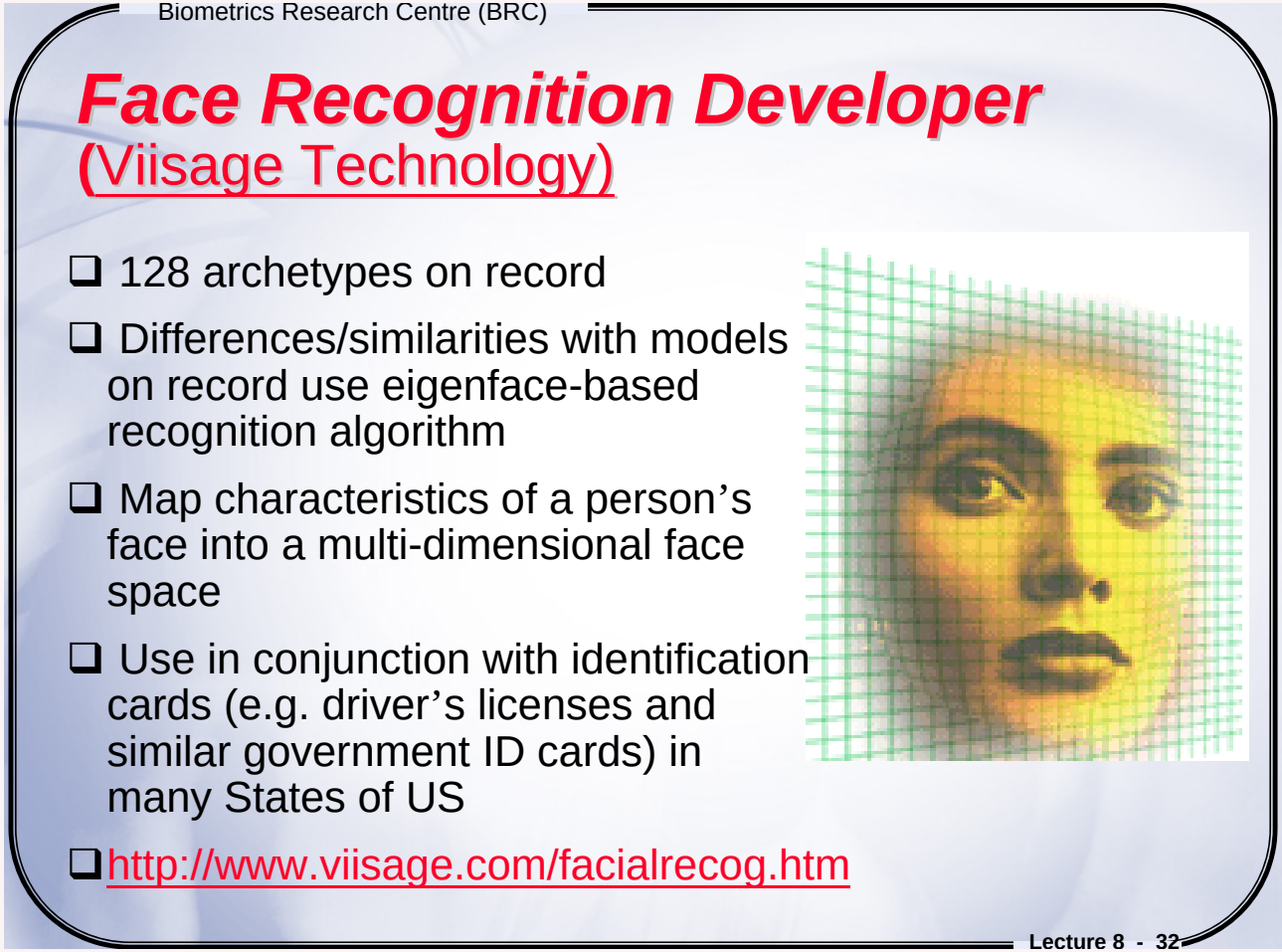
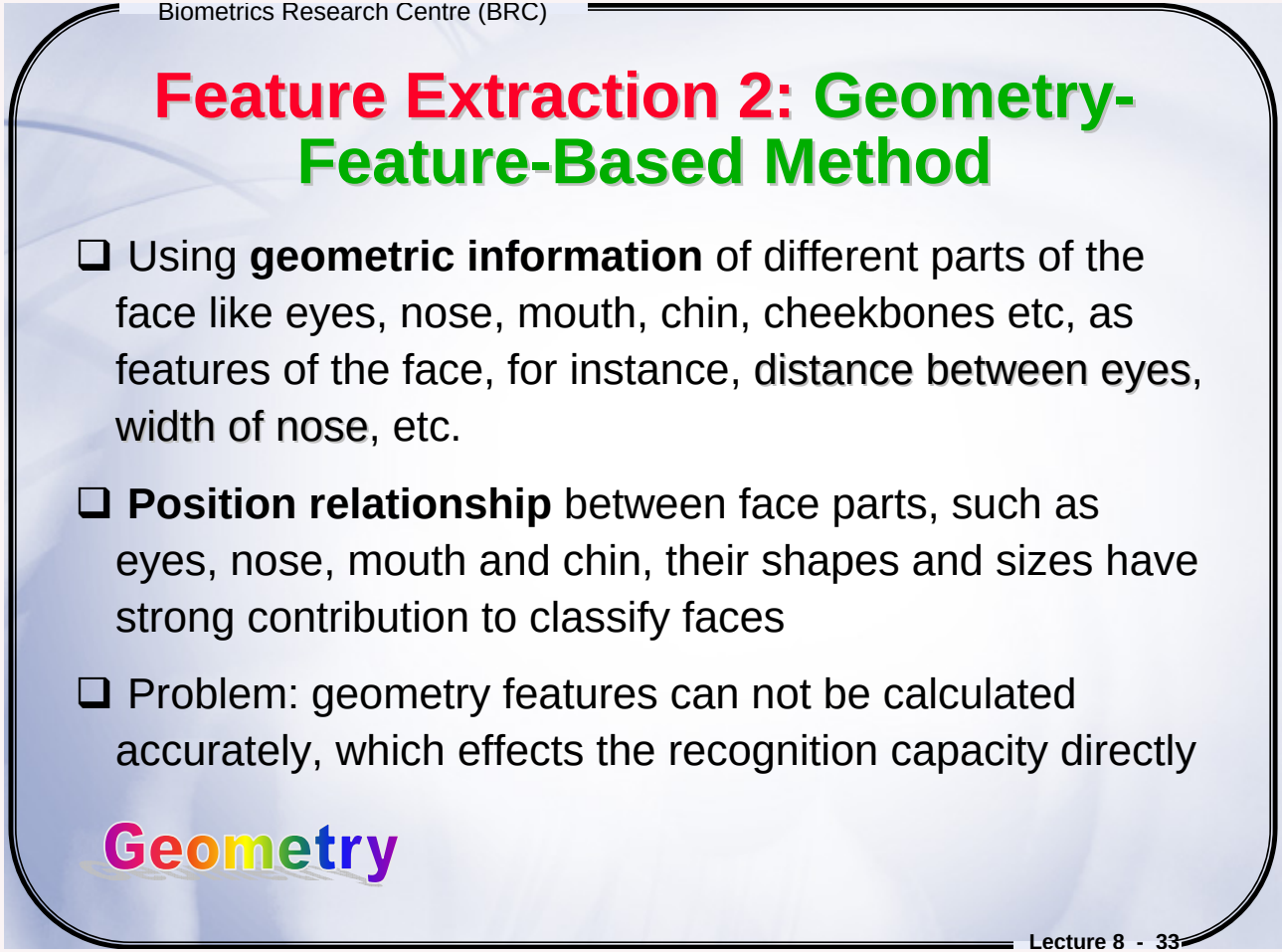
Problem 1.5 Face feature extraction



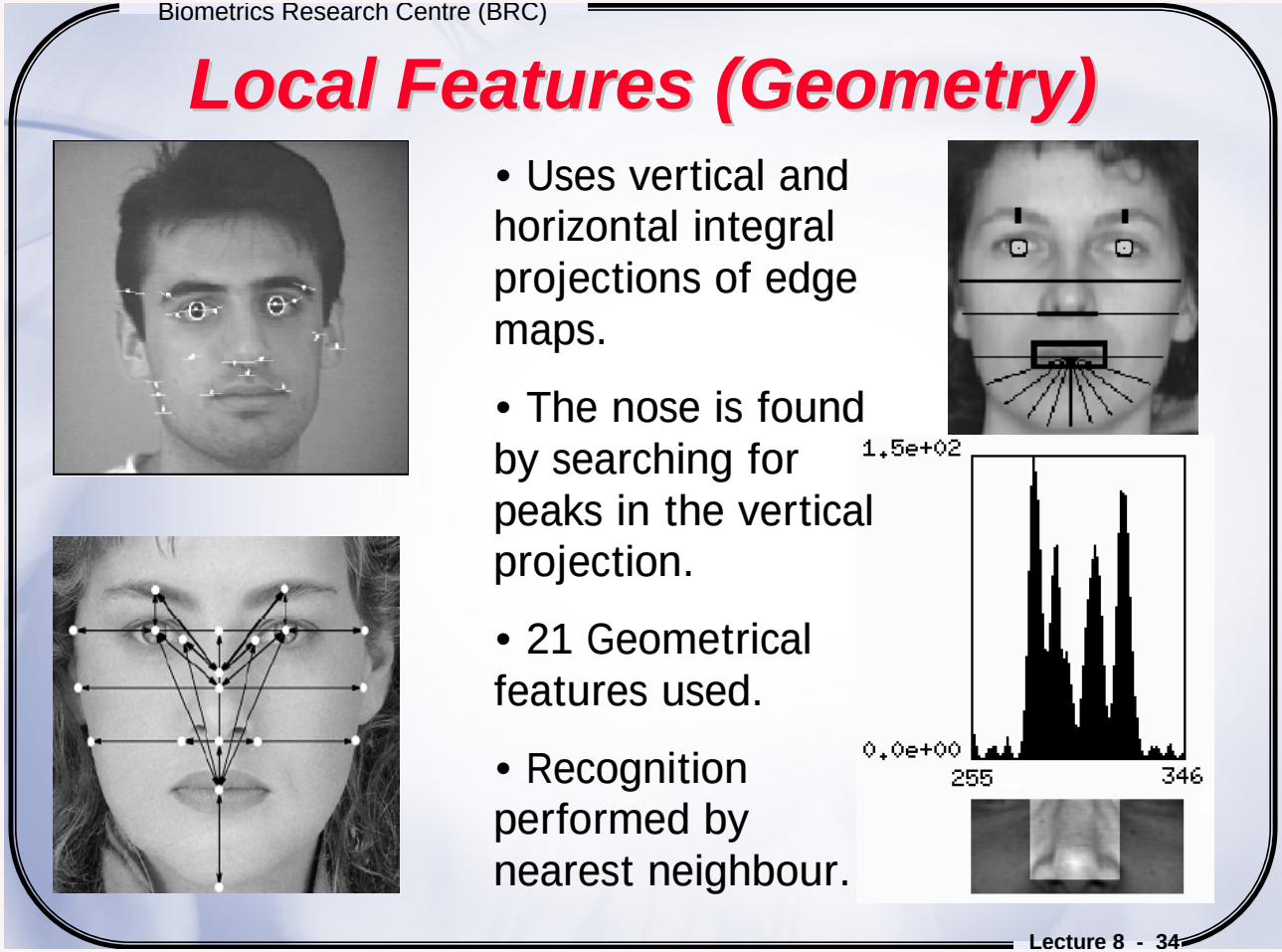
Problem 1.5 Face feature extraction



Problem 1.5 Face feature extraction



Problem 1.5 Face feature extraction



Problem 1.5 Face feature extraction

Biometrics Research Centre (BRC)

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)

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Problem 1.5 Face feature extraction

Biometrics Research Centre (BRC)

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

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Problem 1.5 Face feature extraction

Biometrics Research Centre (BRC)

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

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Problem 1.5 Face feature extraction

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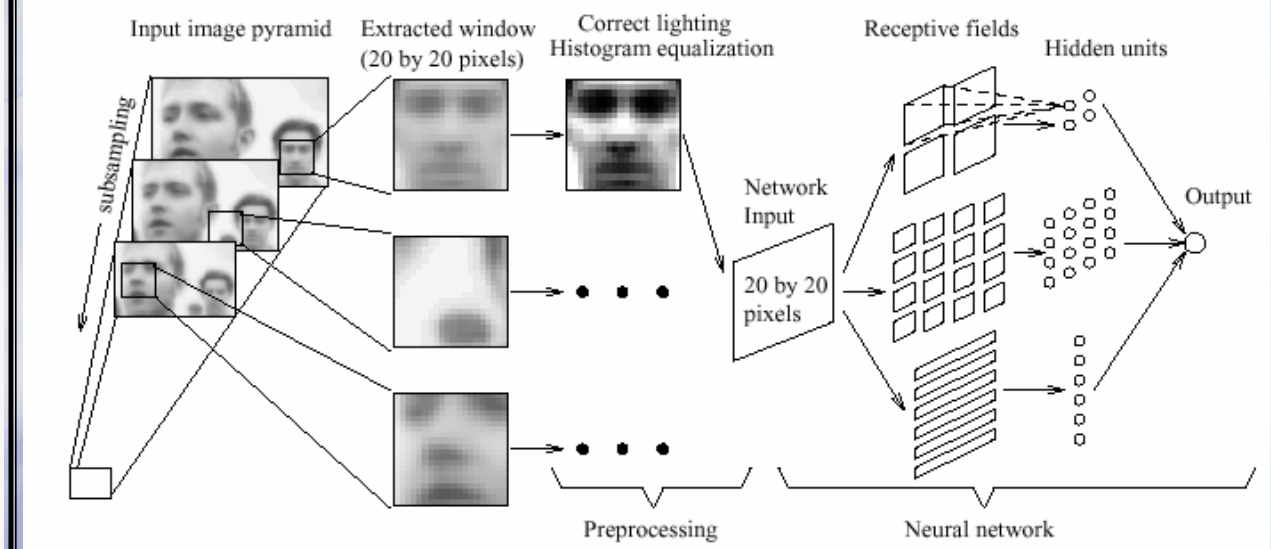
Feature Extraction 4: Neural Networks



- 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

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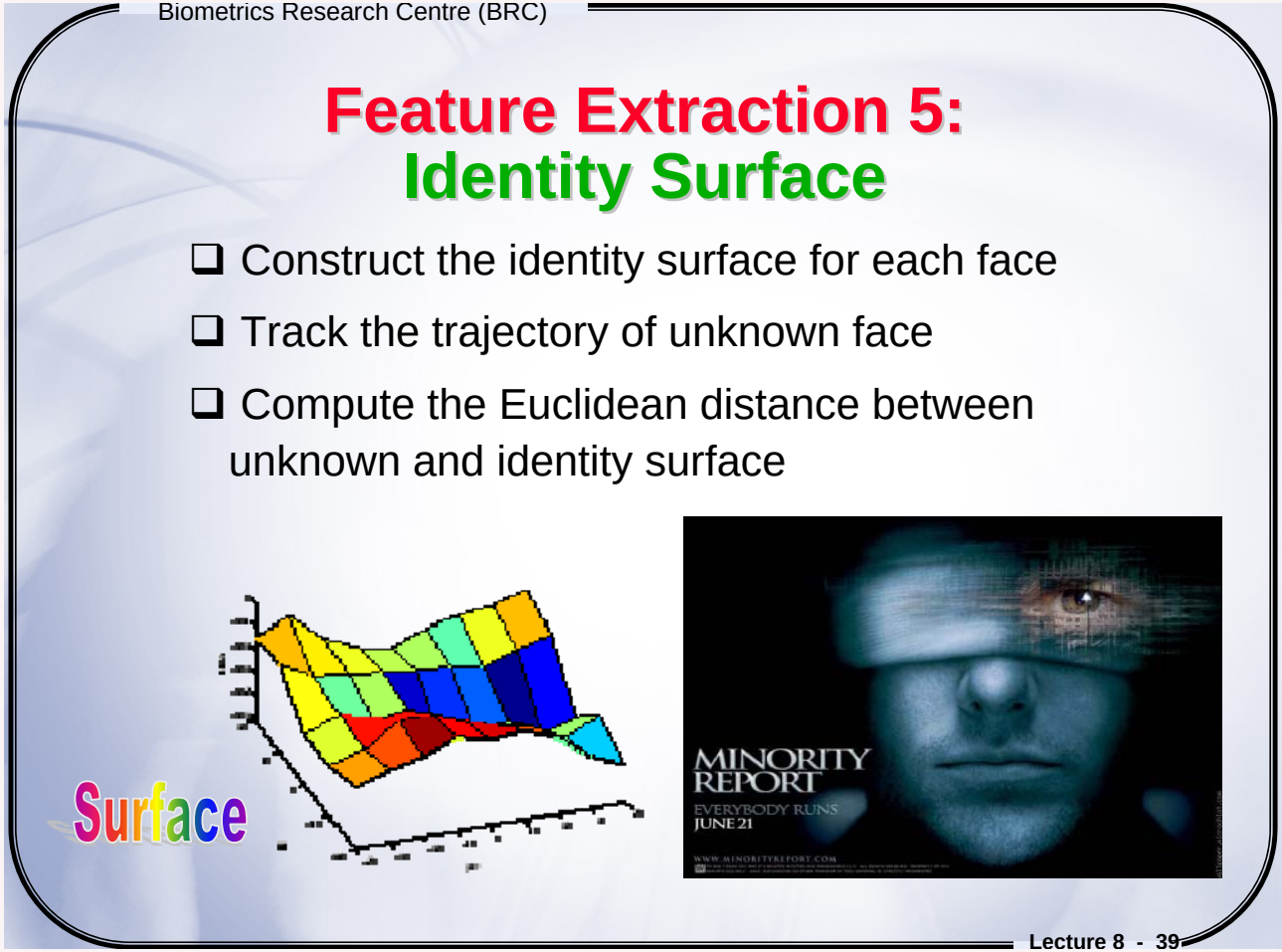
Problem 1.5 Face feature extraction



Problem 1.5 Face feature extraction

Biometrics Research Centre (BRC)

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

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Problem 1.5 Face feature extraction

Biometrics Research Centre (BRC)

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

Problem 1.6 Advantages and disadvantages

What are the advantages and disadvantages of face recognition? (P8:48)

Problem 1.6 Advantages and disadvantages

Biometrics Research Centre (BRC)

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.

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Outline

Problem 2: Eigenfaces algorithm

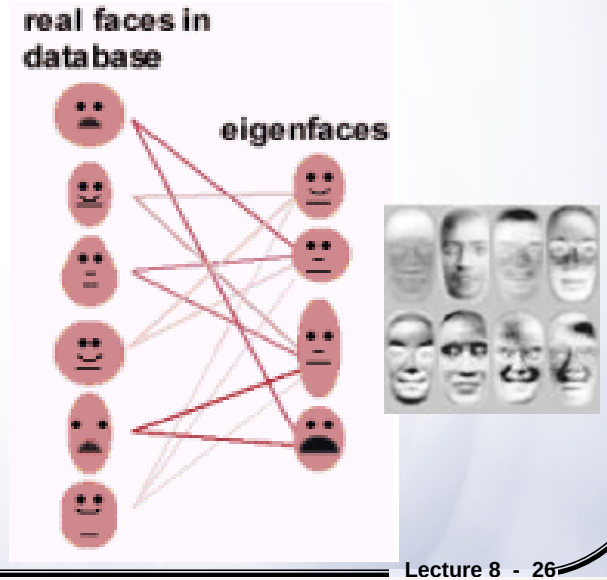
Understand the eigenfaces algorithm (P8:26-29) and eigenfaces recognition algorithm (P8:30-31).

Problem 2: Eigenfaces algorithm

Biometrics Research Centre (BRC)

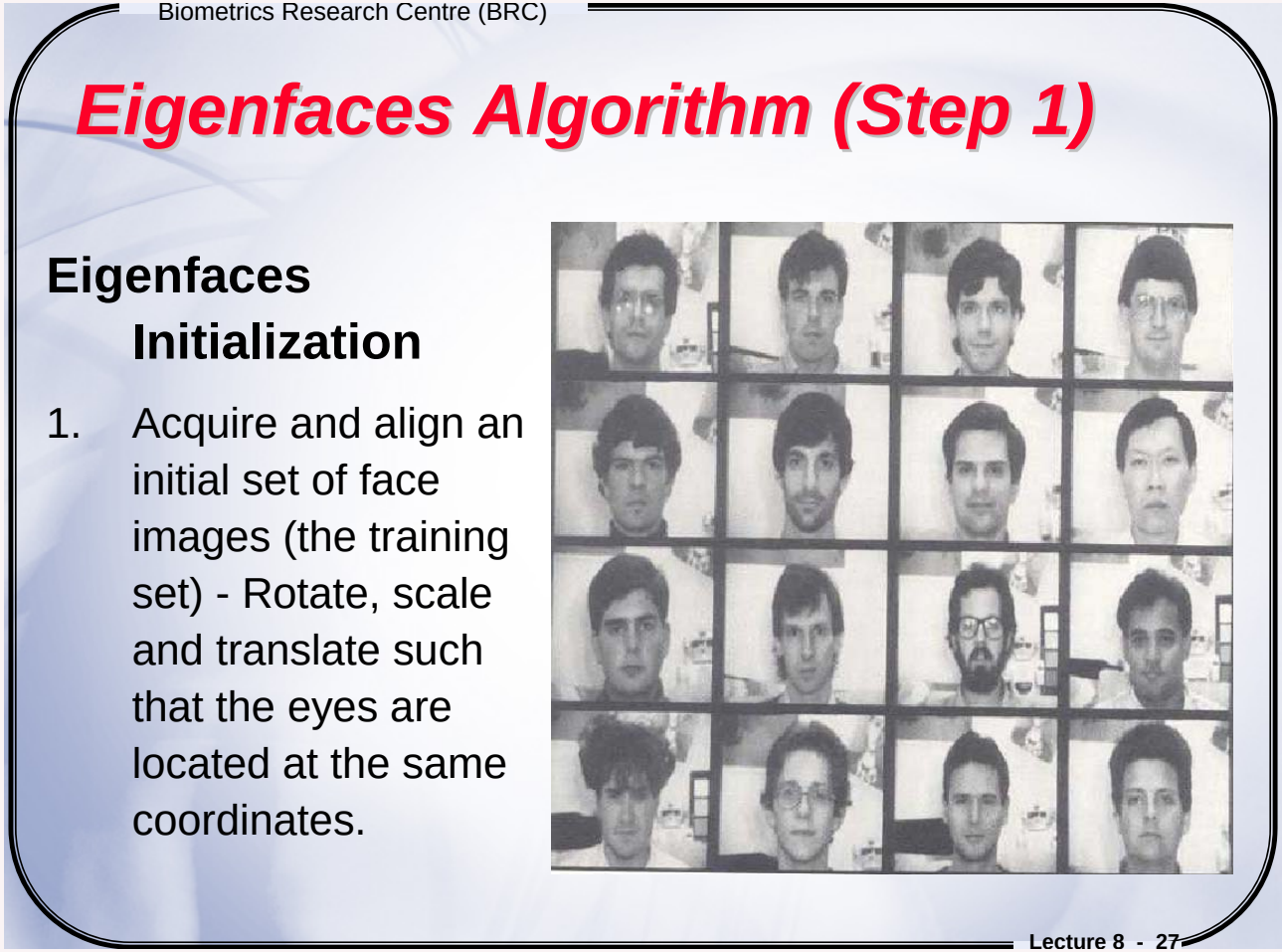
What about Eigenfaces?

- 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



Lecture 8 - 26

Problem 2: Eigenfaces algorithm



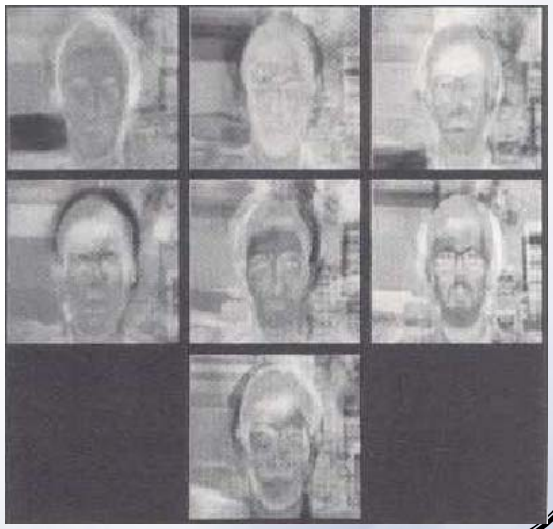
Problem 2: Eigenfaces algorithm

Biometrics Research Centre (BRC)

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



Lecture 8 - 28

Problem 2: Eigenfaces algorithm

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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.”

Lecture 8 - 29

Problem 2: Eigenfaces algorithm

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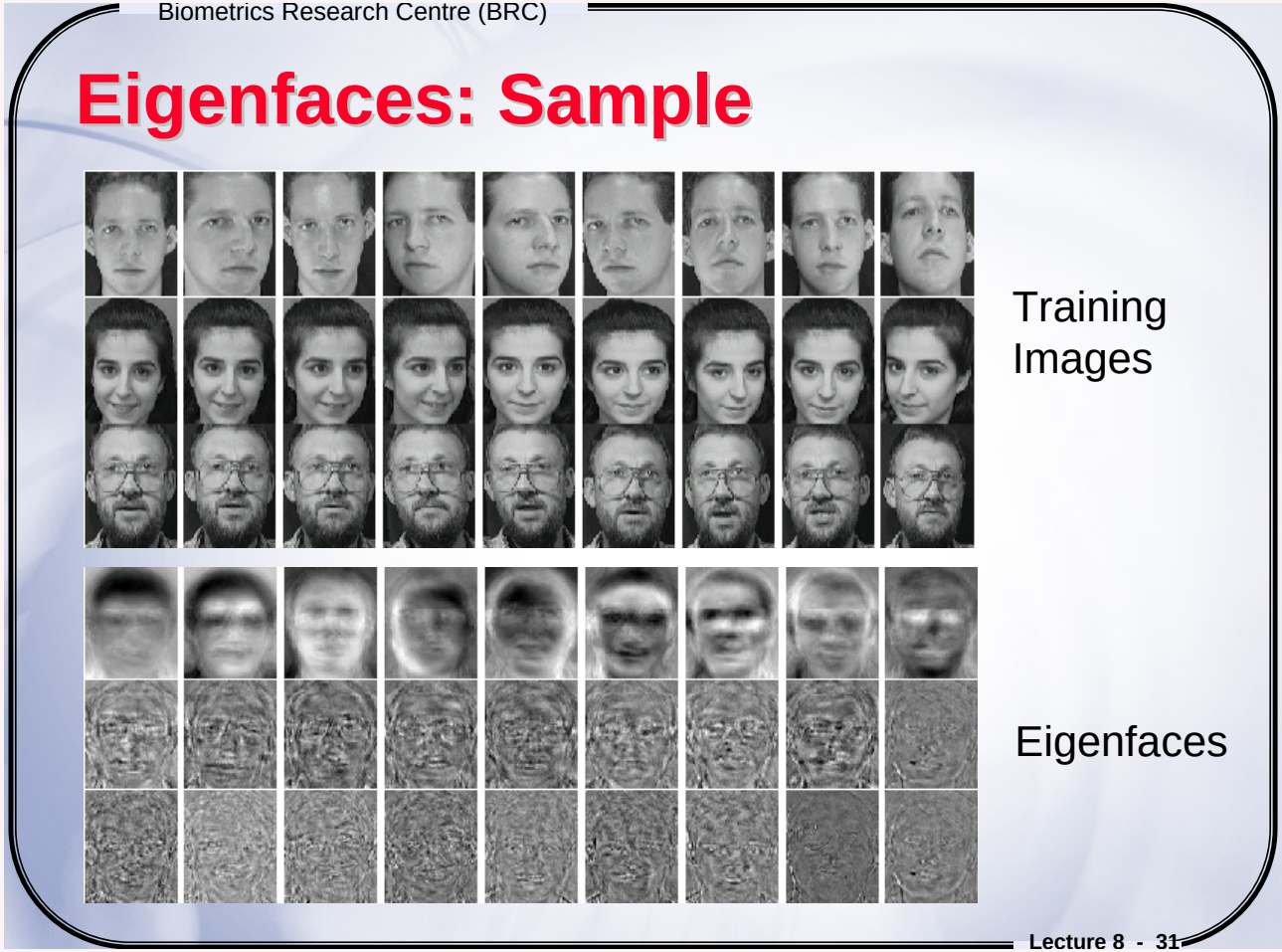
Eigenfaces Recognition Algorithm

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

Lecture 8 - 30

Problem 2: Eigenfaces algorithm



Problem 2: Eigenfaces algorithm

- Eigenfaces algorithm
  1. Initialization: Acquire and align an initial set of face images
  2. Compute: the average face image, the difference image for each image in the training set, the covariance matrix of this set of difference images, the eigenvectors of the covariance matrix
  3. Calculate: the corresponding distribution in k-dimensional weight space for each known individual by projecting their face images onto the “face space.”

Problem 2: Eigenfaces algorithm

- 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. Classify: If it is a face, classify the weight pattern as either a known person or as unknown.

Outline

Problem 3: Evaluation of the eigenfaces algorithm

Eigenfaces is PCA-based method which is introduced in Lecture 5. At the fifth step of PCA method (P5:23-24) the k most principal components are selected based on the ratio (γ_λ) of the eigenvalue sum of selected components to the total sum. Please decide the value of k when the threshold of γ_λ is 95%. In P8:31 there is a training set including 27 facial images to get eigenfaces. Can you give the value of k according to the training result (eigenfaces)?

Problem 3: Evaluation of the eigenfaces algorithm

PCA Method (using image data)

Step 5: Select the most principal components or eigenvectors. From the following figure, we find that

$$\lambda_{10} = \lambda_{11} = \cdots = \lambda_{644} = 0 \quad ,$$

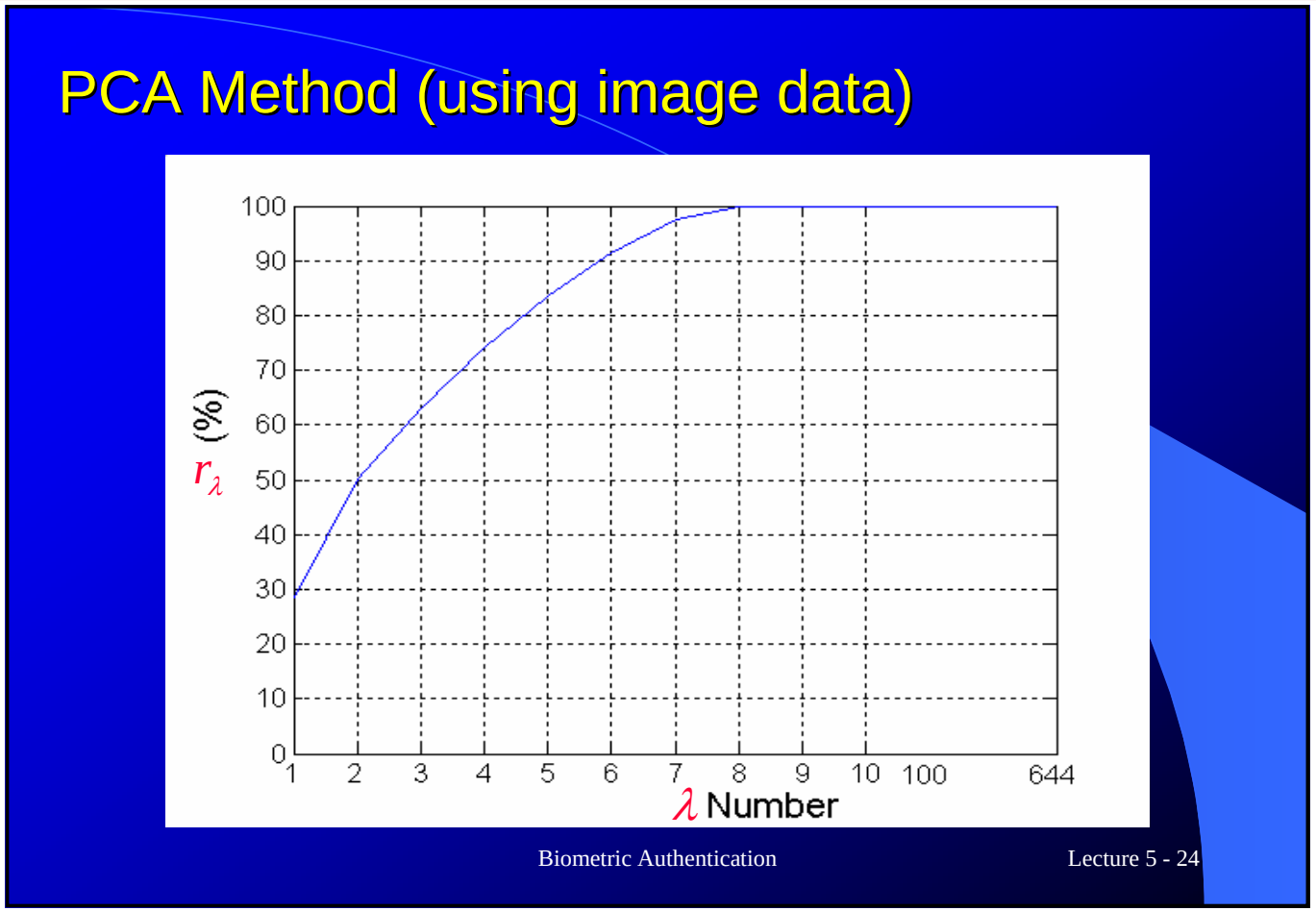
and

$$r_\lambda = \frac{\sum_{i=1}^{6} \lambda_i}{\sum_{j=1}^{644} \lambda_j} \times 100\ \% = 91.32\ \% > 90\ \% \quad ,$$

where r_λ is the ratio of the eigenvalue sum of selected components to the total sum (refer to the following figure).

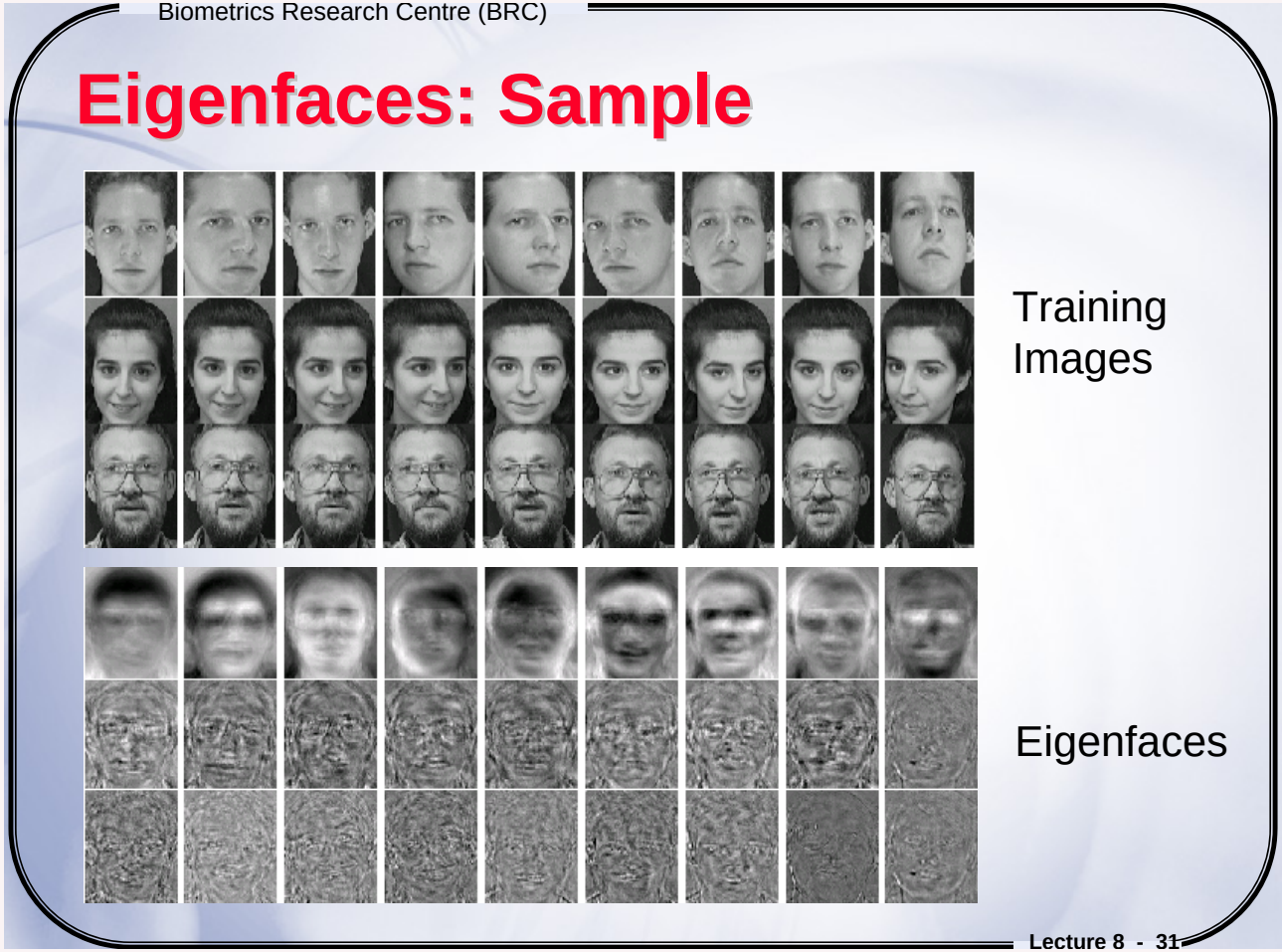
Biometric Authentication Lecture 5 - 23

Problem 3: Evaluation of the eigenfaces algorithm



The γ_λ of the first seven λ is over 95%.

Problem 3: Evaluation of the eigenfaces algorithm



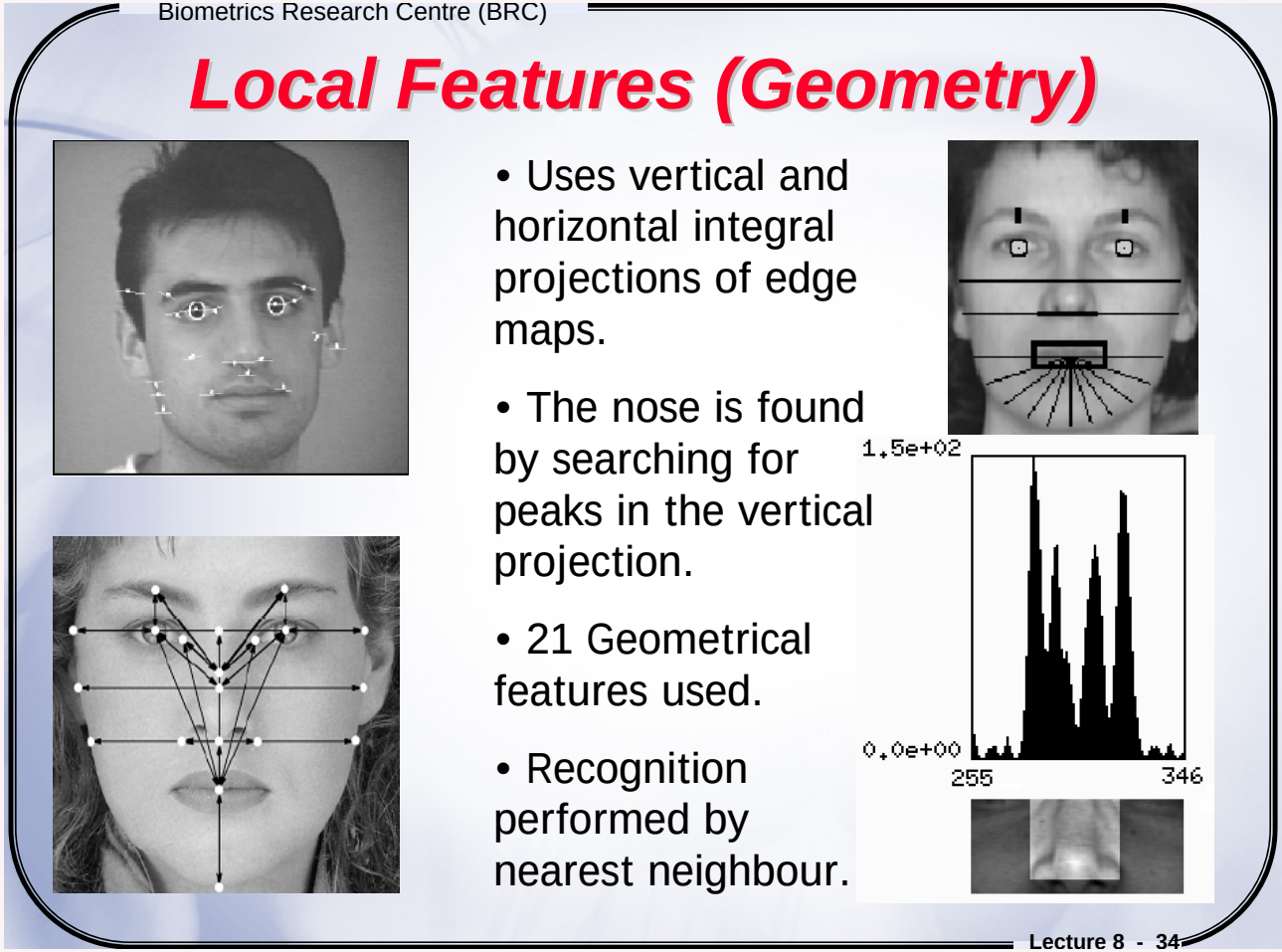
The first nine principal components are of the most information. □

Outline

Problem 4: Eigenfaces

P8:34 shows some examples of local features. Please try to define the geometry features based on the woman's face image (refer to P8:34) and give the number of features.

Problem 4: Eigenfaces



The proportions of different length of line segments can be defined as features. And twenty one geometrical features are used.

Q & A

Any questions?