Detecting Faces in Images: A Survey

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Agenda

- Introduction
- Approaches
  - Knowledge-based
  - Feature invariant
  - Template matching
  - Appearnce-based
- Databases and Evaluation
- Discussion

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Introduction

- Domain
  - Face detection (not recognition)
  - Still images
- Objectives
  - Comprehensive survey of techniques
  - Discussion of performance measures
- Limitations
  - Methods are not directly comparable

Challenges

- Pose
- Structural components
- Facial expression
- Occlusion
- Image orientation
- Imaging conditions

General Tasks

- Face localization
- Facial feature detection
- Face recognition
- Face authentication
- Face tracking
- Facial expression recognition

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Survey of Techniques

- Knowledge Based
  - Top-down — Knowledge-based
  - Bottom-up — Feature invariant
- Template Based
  - Defined templates — Template matching
  - Learned templates — Appearance-based

Survey of Techniques

Approach	Loc.	Det.
Knowledge-based	X	
Feature Invariant	X	
Template Matching	X	X
Appearance-based		X

Knowledge-Based Top-Down Methods

Main Idea: Use knowledge about what constitutes a face faces to define rules

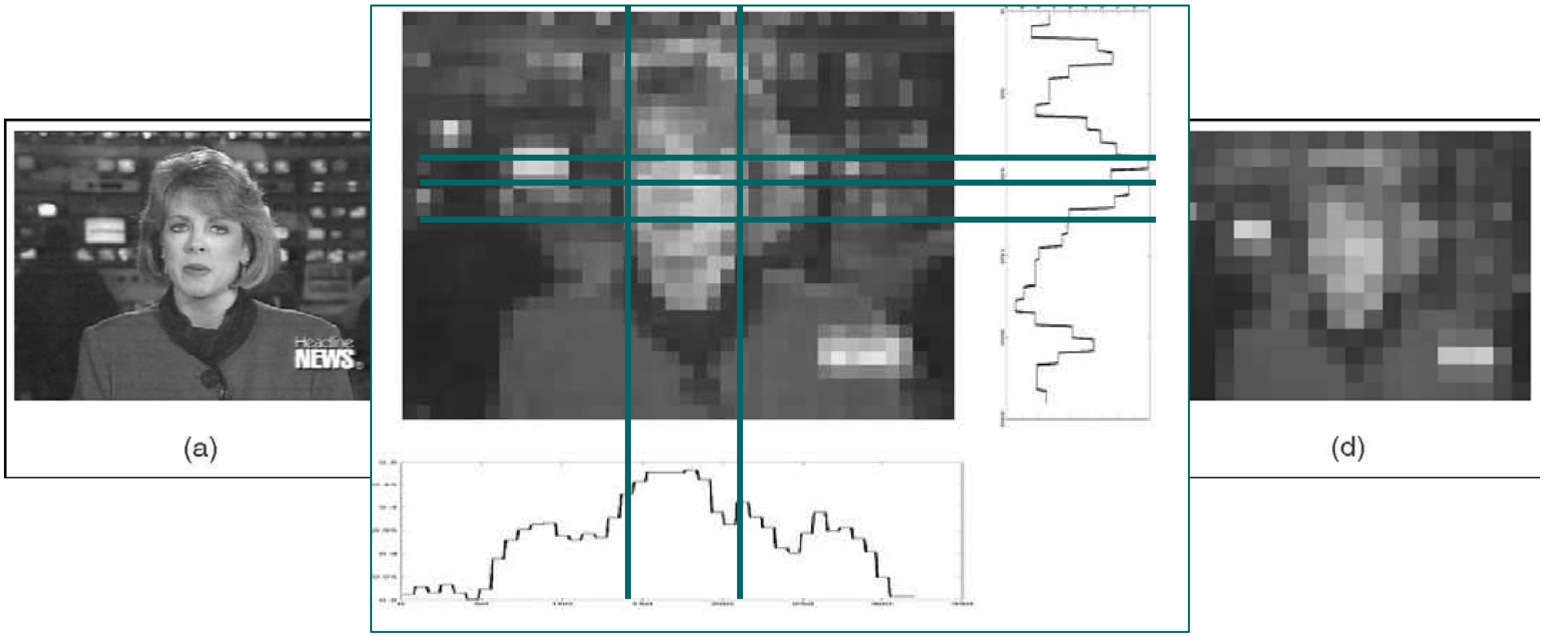
Strengths: Frontal faces in uncluttered scenes

Weaknesses:

Translating knowledge into rules

Enumeration of cases

Knowledge-Based Top-Down Methods



Bottom-Up Feature-Based Methods

Main Idea: Describe relationships between invariant features using statistical models

Strengths: Improved invariance for different poses and lighting conditions

Weaknesses: Corruption of individual due to illumination, noise, or occlusion

Bottom-Up Feature-Based Methods

- Facial Features
- Texture
- Skin Color
- Multiple Features

Template Matching

Main Idea: Find correlation values with a standard face pattern for face contour, eyes, nose, and mouth

Strengths: Simple to implement

Weaknesses: Cannot deal with variation in scale, pose, and shape

Alternatives: Multiresolution, multiscale, subtemplates, and deformable templates

Appearance-Based Methods

Main Idea: Use statistical analysis and machine learning techniques to learn "template" characteristics

Strengths: Most successful approach

Weaknesses: Relatively complex to implement, high-dimensionality requires many training examples

Overview of Techniques

- Eigenfaces
- Distribution-Based Methods
- Neural Networks (ANN)
- Support Vector Machines (SVM)
- Sparse Network of Winnows (SNoW)
- Naïve Bayes Classifier
- Hidden Markov Models (HMM)
- Information Theoretic Approaches
- Inductive Learning

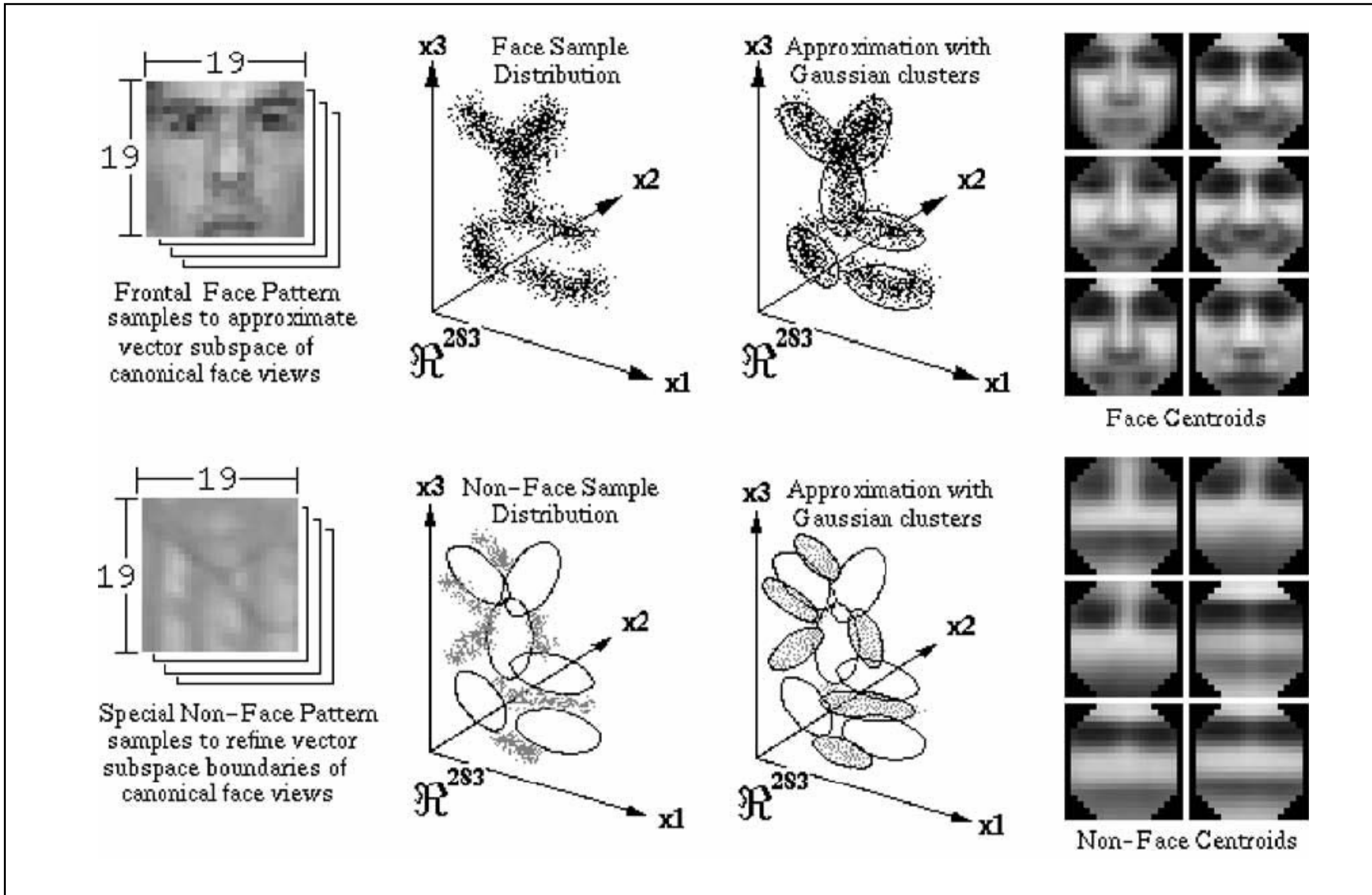
Eigenfaces

- Pedro?
- **Main Idea:** Calculate distance between an instance and exemplary data in a reduced dimensional space
  - Build a face map

Distribution-Based Methods

- Fit a distribution model to examples
- Project example into reduced dimensional space
- Build classifier to decide face/non-face

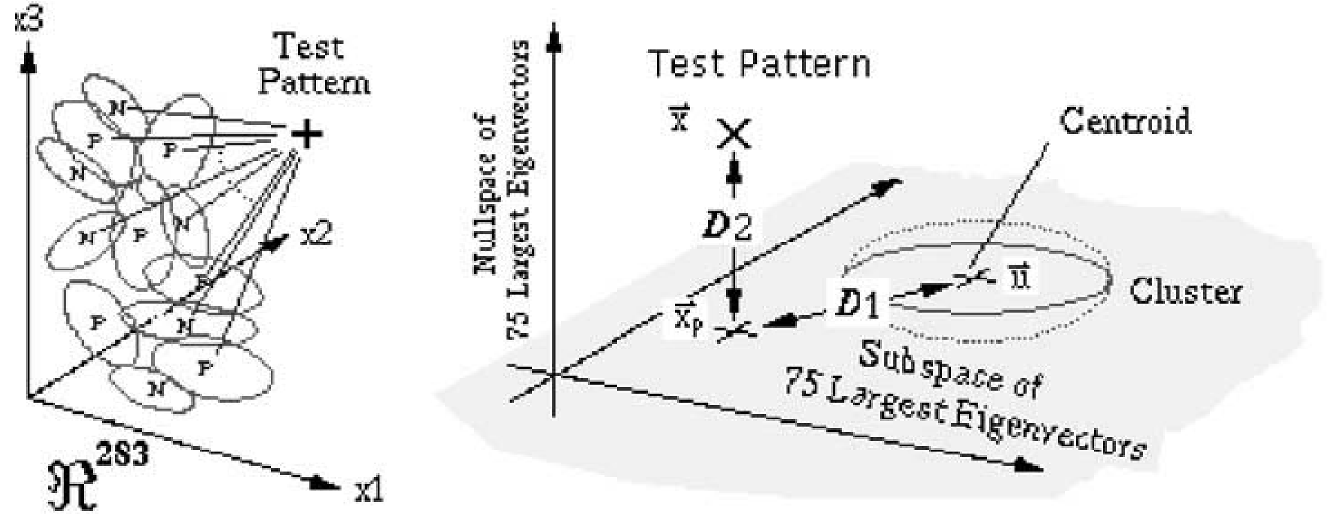
Sung and Poggio



Eigenfaces
Distribution
ANN
SVM
SNoW
Baysian
HMM
Info. Theory
Inductive

Knowledge-based | Feature Invariant | Template Matching | **Appearance-based**

Sung and Poggio



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Knowledge-based Feature Invariant Template Matching **Appearance-based**

Sung and Poggio

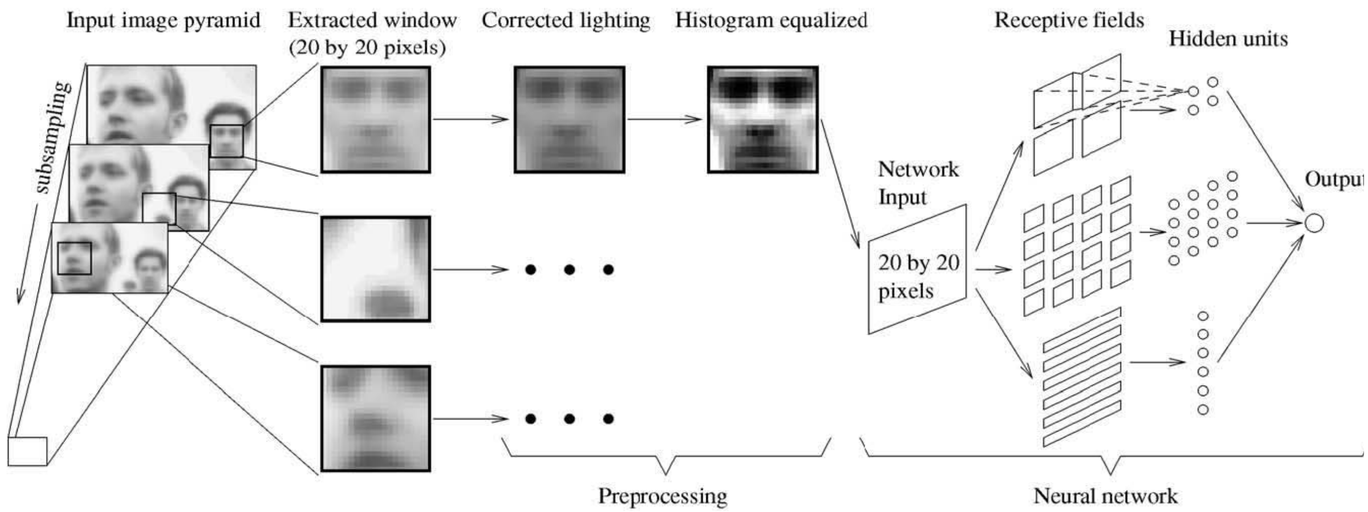
- Mahalanobis
  - PCA for each cluster
- Representative sample of non-face images?
  - Bootstrap approach

Yang, Ahuja, Kriegman

- Method 1:
  - Factor Analysis
    - Instead of PCA
    - Does not define a mixture model
  - Estimate mixture model using EM
- Method 2:
  - Fisher's Linear Discriminant
  - Class decomposistion using Kohonen's Self Organizing Maps
  - ML decision rule to detect faces

Neural Networks

- Two class pattern recognition
- Advantage: capture complex class conditional desnsity
- Drawback: Requires extensively tuning



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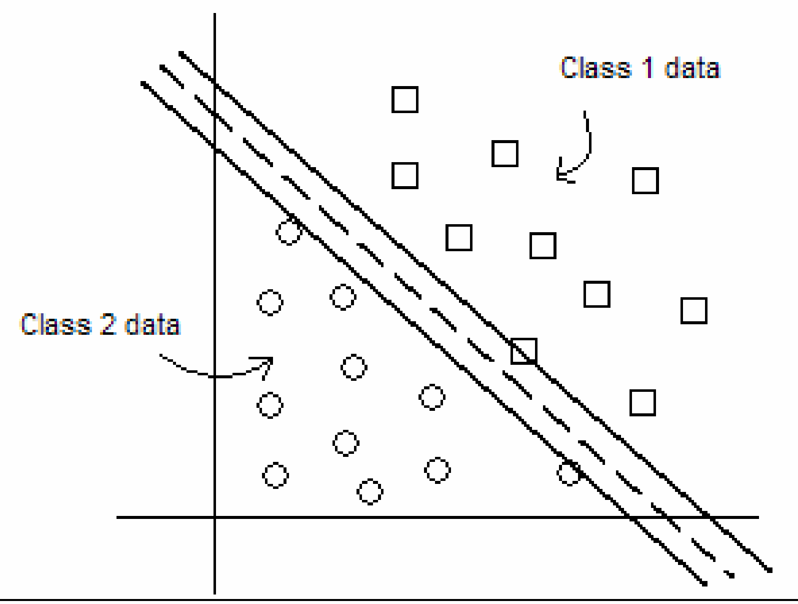
Support Vector Machines

- Estimating hyperplane is expensive
- Evaluation is fast



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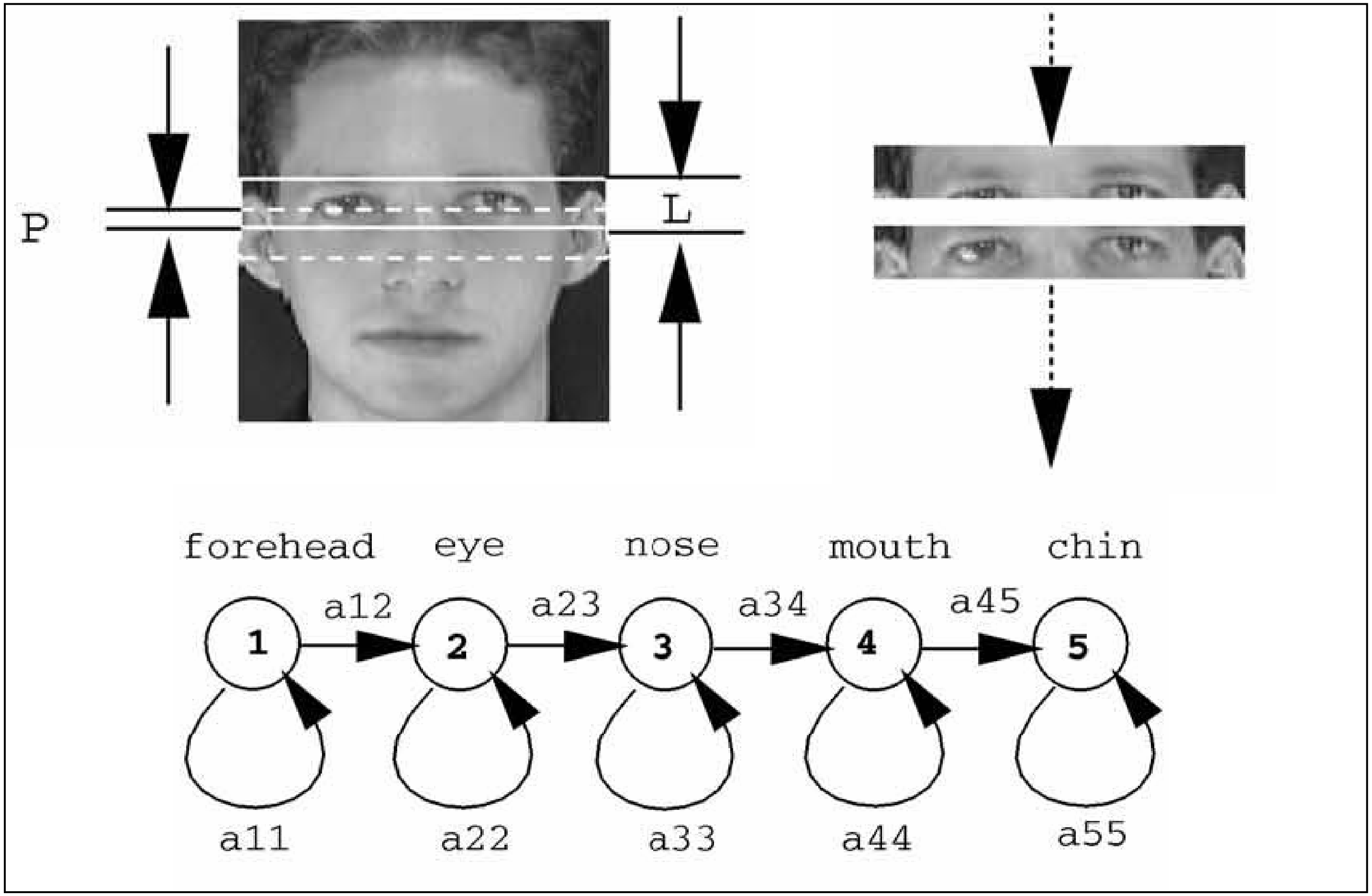
Sparse Network of Winnows

- Detect images with:
  - Different features and expressions
  - Different poses
  - Different lighting conditions
- Primitive and multiscale features
- Tailored for domains where
  - Number of features is large
  - Features unknown *a priori*

Naïve Bayes Classifier

- Estimate joint probability of local appearance
  - c.f. bottom-up methods
- Emphasize local appearance
  - Some patterns are more unique
- Detects some ratated and profile faces

Hidden Markov Model



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Hidden Markov Model

- Alternatives
  - Karhunen Loeve Traform coefficients as input to HMM
  - Use HMM to learn face to non-face transition

Information Theoretic Approaches

- Markov Random Fields (MRF)
  - Model context-dependent entities
- Kullback relative inforamtion
  - Maximize information-based discriminant between the two classes

Inductive Learning

- C4.5 Algorithm
  - Builds a decision tree
  - 8x8 pixel window
    - Represented as 30 value vector
    - Entropy, mean, std dev. of pixel value
- Find-S
  - Gaussian clusters to aproximate distribution of face patterns
  - Find-S to learn thresholding

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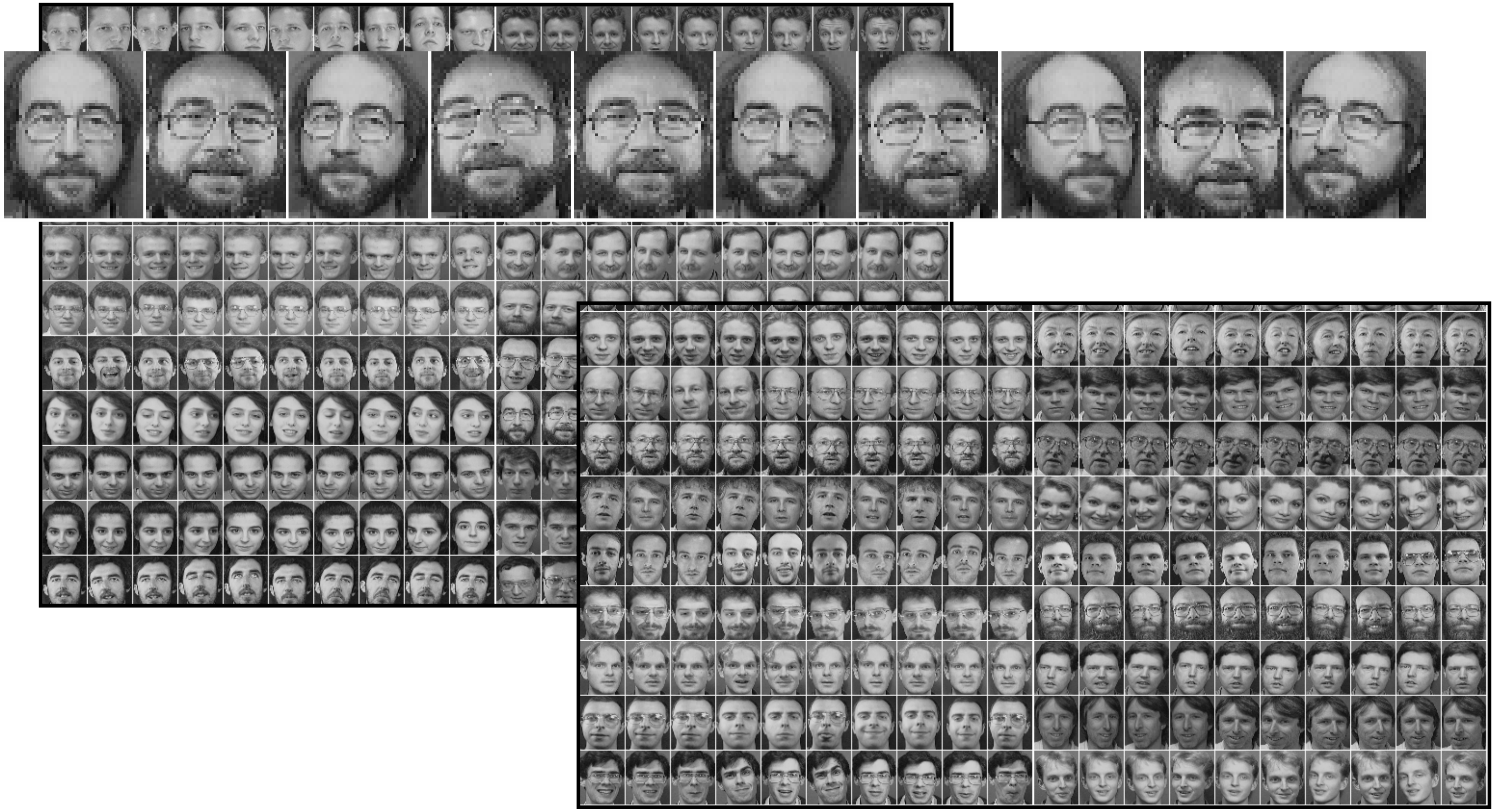
AT&T Cambridge Laboratories Face Database



Face Image Databases

Data Set	Location	Description
MIT Database [163]	ftp://whitechapel.media.mit.edu/pub/images/	Faces of 16 people, 27 of each person under various illumination conditions, scale and head orientation.
FERET Database [115]	http://www.nist.gov/humanid/feret	A large collection of male and female faces. Each image contains a single person with certain expression.
UMIST Database [56]	http://images.ee.umist.ac.uk/danny/database.html	564 images of 20 subjects. Each subject covers a range of poses from profile to frontal views.
University of Bern Database	ftp://iamftp.unibe.ch/pub/Images/FaceImages/	300 frontal face images of 30 people (10 images per person) and 150 profile face images (5 images per person).
Yale Database [7]	http://cvc.yale.edu	Face images with expressions, glasses under different illumination conditions.
AT&T (Olivetti) Database [136]	http://www.uk.research.att.com	40 subjects, 10 images per subject.
Harvard Database [57]	ftp://ftp.hrl.harvard.edu/pub/faces/	Cropped, masked face images under a wide range of lighting conditions.
M2VTS Database [116]	http://poseidon.csd.auth.gr/M2VTS/index.html	A multimodal database containing various image sequences.
Purdue AR Database [96]	http://rvl1.ecn.purdue.edu/~aleix/aleix_face_DB.html	3,276 face images with different facial expressions and occlusions under different illuminations.

Features of Databases

- Designed for single study
- Small
- Highly constrained
- Oriented to face recognition

Benchmark Test Sets

Benchmark Test Sets

Data Set	Location	Description
MIT Test Set [154]	http://www.cs.cmu.edu/~har	Two sets of high and low resolution gray scale images with multiple faces in complex background.
CMU Test Set [128]	http://www.cs.cmu.edu/~har	130 gray scale images with a total of 507 frontal faces.
CMU Profile Face Test Set [141]	ftp://eyes.ius.cs.cmu.edu/usr20/ftp/testing_face_images.tar.gz	208 gray scale images with faces in profile views.
Kodak Data Set [94]	Eastman Kodak Corporation	Faces of multiple size, pose and under varying illumination in color images. Designed for face detection and recognition.

Performance Evaluation

Method	Test Set 1		Test Set 2	
	Detection Rate	False Detections	Detection Rate	False Detections
Distribution based [154]	N/A	N/A	81.9%	13
Neural network [128]	92.5%	862	90.3%	42
Naive Bayes classifier [140]	93.0%	88	91.2%	12
Kullback relative information [24]	98.0%	12758	N/A	N/A
Support vector machine [107]	N/A	N/A	74.2%	20
Mixture of factor analyzers [175]	92.3%	82	89.4%	3
Fisher linear discriminant [175]	93.6%	74	91.5%	1
SNoW with primitive features [176]	94.2%	84	93.6%	3
SNoW with multi-scale features [176]	94.8%	78	94.1%	3
Inductive learning [38]	90%	N/A	N/A	N/A

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