CSE190, Winter 2011

From Faces to Hands to Faces

Biometrics
CSE 190
Lecture 13

Announcements

- Literature review due today
- No class on Thursday
- Grading issue on HW1.
- HW3 to be assigned, today we get the data.

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HW3 Hand Recognition Challenge

- Data: Your hand outlines
- Goal: Build two different classifiers
- Features: Manual
- Evaluation:
  1. Four-fold cross validation on training set
  2. Unlabeled test set
- Winner – 10 pts extra credit on HW.

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Hand outline acquisition

- The Hand Recognition Challenge
  You are the data
- You will be given 5 pieces of paper.
- You will be assigned an ID number
- On the upper right corner, write
  <Your ID> - 1 ...... <Your ID> - 5
- Flip over pages, so ID Is on back
- Trace your left hand on four pieces of paper.
- Now have your neighbor trace your left hand
  on the fifth pieces of paper.

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Hand Geometry as a Biometric

Video
Applications

- Commercially available since the 1970’s
- November 18, 2004 Port of Rotterdam Relies on Recognition Systems Biometric HandReaders for Transportation Worker Identity Credential
- October 27, 2004 Prestigious Wisconsin Private School Selects Recognition Systems Biometric HandReader to Secure Campus
- September 14, 2004 IR Recognition Systems HandReaders Verify Transportation Security Administration Employee Identities at San Francisco Airport
- August 31, 2004 Yeager Airport Uses Recognition Systems Biometric HandReaders to Secure Control Tower
- August 17, 2004 With IR Recognition Systems HandReader, German Fuel Terminal Verifies Driver Identities

Hand Geometry Based Verification

- Anthropologists suggest that humankind survived and evolved due to our large brains and opposing thumbs
- Versatile human hand allows us to grasp, throw, and make tools
- Today, the human hand has another use, a media to verify identity
- A U.S. patent was issued to Robert P. Miller in 1971 for a device that measures hand characteristics and records unique features for comparison and ID verification; highly mechanical device sold under the name Identimation
- Sidlausks received patent for an electronic device in 1988 and established RSI in 1986.

Why Hand Geometry?

- It is non-intrusive and simple to use
- Inexpensive acquisition procedure
- Only simple shape/geometric features are used
- Robust to environmental changes
- Has demonstrated excellent performance in verification tasks

Hand Geometry Based Verification

- Each human hand is unique
- Finger length, width, thickness, curvatures & relative locations of these features can distinguish people and confirm identity
- Scanners record no surface details, ignoring fingerprints, lines, scars and color
- Only the silhouette of the hand is recorded
- Orthographic scanning—two distinct images, one from the top and one from the side

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Hand Image Acquisition

Feedback offered by the GUI

Captured Image

Enrollment

- Scanner prompts the user to place his hand on the scanner platen three consecutive times
- Pins on the platen position the enrollee’s fingers to assure accurate image capture
- System “averages” the three templates and stores a single template
- Template is stored as 9 bytes; small enough to be stored in the magnetic stripe of a card; smart card can also receive updated template after verification
- To verify, user inputs his PIN number and places his hand on the platen

Privacy Issues

Template cannot be “reverse engineered” to identify users. Consequently, hand geometry based authentication protects privacy of the users better than other biometrics, say, fingerprints

Verification Accuracy

Sandia Labs evaluation results for IDID System for authenticating identity based on hand geometry. EER = 0.1% based on 2-try false reject rate. One-try FAR is 0.2%

Feature Extraction

Feature Values

Measurement axes

Ideal grayscale profile along an axis

Observed grayscale profile along axis F3

Feature Extraction

G(x) is the grayscale profile along the x-axis, 0 <= x < Len. Goal is to compute P_s and P_e from this profile.

- Slide a window across the profile starting from the leftmost pixel.
- The window is moved to its right one pixel at a time.
- Compute the following parameters for each window position W:

  Maxval(i) = \max_j G(j)

  Minval(i) = \min_j G(j)

  Maxindex(i) = \arg \max_j G(j)

  Minindex(i) = \arg \min_j G(j)

- Compute P_s and P_e as follows:

  P_e = Maxindex(i)
  \forall k, 0 < k < \text{Len}.

  P_s = \text{Maxindex}(k) \land (\text{Maxindex}(k) > \text{Maxindex}(k-1)) \land (\text{Minindex}(k) > \text{Minindex}(k-1)).

  \forall \text{Maxindex}(k) \land (\text{Maxindex}(k) > \text{Maxindex}(k-1)) \land (\text{Minindex}(k) > \text{Minindex}(k-1)).

  \forall 0 < k < \text{Len}.
Matching

- Template feature vector: \((x_1, x_2, \ldots, x_{14})\)
- Input feature vector: \((y_1, y_2, \ldots, y_{14})\)
- Matching score: Euclidean distance \(\sum_{i=1}^{14} (x_i - y_i)^2\)

System Performance

Test database consists of 400 hand images of 55 users.

Alignment-based Verification

- Peg removal - a mask containing the known positions of the five pegs is used to replace the pegs with a color that closely matches the background
- Contour extraction - an adaptive thresholding is applied to each image and a contour following algorithm is used to compute the shape of the hand
- Finger extraction and alignment - the five pairs of corresponding fingers are aligned separately with respect to the rigid transformations group
- Pairwise distance computation - each alignment in Step 3 produces a set of point correspondences. The Mean Alignment Error (MAE) between the two hand shapes is defined as the average distance between the corresponding points
- Verification - the pair of hand shapes are said to belong to the same hand if their MAE is smaller than a threshold \(T\)

Hand Shape Alignment

- Scans of two different hands
- Scans of the same hand

Shape distance distributions for genuine (red) and imposter (blue) classes

System Performance

- Based on 353 images of 53 persons
- Genuine distribution: 3021 pairs, Imposter distribution: 2809 pairs
- By learning a shape template for each user, the system performance is 96.5% GAR at 1.5% FAR
Limitations of Hand Geometry

- Hand geometry is not unique to an individual; hence application in large-scale identification is limited
- Information not invariant over the lifespan of an individual, especially during childhood
- An individual’s jewelry or limitations in dexterity (e.g., arthritis) may pose challenges in extracting correct features
- Physical size of a hand geometry-based system is large; cannot be used in applications like laptop computers

Example: Face Detection

- Scan window over image.
- Classify window as either:
  - Face
  - Non-face

Image as a Feature Vector

- Consider an n-pixel image to be a point in an n-dimensional space, \( x \in \mathbb{R}^n \).
- Each pixel value is a coordinate of \( x \).

Nearest Neighbor Classifier

\[ \{ R_j \} \text{ are set of training images.} \]

\[ ID = \arg \min_{j} \| R_j - I \| \]

Eigenface (Turk, Pentland, 91) -1

- Use Principle Component Analysis (PCA) to determine the most discriminating features between images of faces.
An idea:
Represent the set of images as a linear subspace

What is a linear subspace?
Let $F$ be a vector space and let $W$ be a subset of $F$. Then $W$ is a subspace iff:
1. The zero vector, 0, is in $W$.
2. If $u$ and $v$ are elements of $W$, then any linear combination of $u$ and $v$ is an element of $W$, $au + bv \in W$.
3. If $u$ is an element of $W$ and $c$ is a scalar, then the scalar product $cu \in W$.

A $k$-dimensional subspace is spanned by $k$ linearly independent vectors. It is spanned by a $k$-dimensional orthogonal basis.

Eigenfaces: linear projection

• An $m$-pixel image $x \in \mathbb{R}^d$ can be projected to a low-dimensional feature space $y \in \mathbb{R}^k$ by $y = Wx$.

• Recognition is performed using nearest neighbor in $\mathbb{R}^k$.

• How do we choose a good $W$?

Example: Projecting from $\mathbb{R}^3$ to $\mathbb{R}^2$.

How do you construct Eigenspace?

Assume we have a set of $n$ feature vectors $x_i (i = 1, \ldots, n)$ in $\mathbb{R}^d$. Write

$$
\mu = \frac{1}{n} \sum_{i} x_i
$$

$$
\Sigma = \frac{1}{n-1} \sum_{i}(x_i - \mu)(x_i - \mu)^T
$$

The unit eigenvectors of $\Sigma$ — which we write as $v_1, v_2, \ldots, v_k$, where the order is given by the size of the eigenvalue and $v_1$ has the largest eigenvalue — give a set of features with the following properties:
• They are independent.
• Projection onto the basis $\{v_1, \ldots, v_k\}$ gives the $k$-dimensional set of linear features that preserves the most variance.

Algorithm 22.5: Principal components analysis identifies a collection of linear features that are independent, and capture as much variance as possible from a dataset.

Some details: Use Singular value decomposition, “trick” described in text to compute basis when $n \ll d$.