Personal Authentication using Hand Geometry

Project Evaluation

Phase I

Biometrics – EEL851

BY

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Biometrics

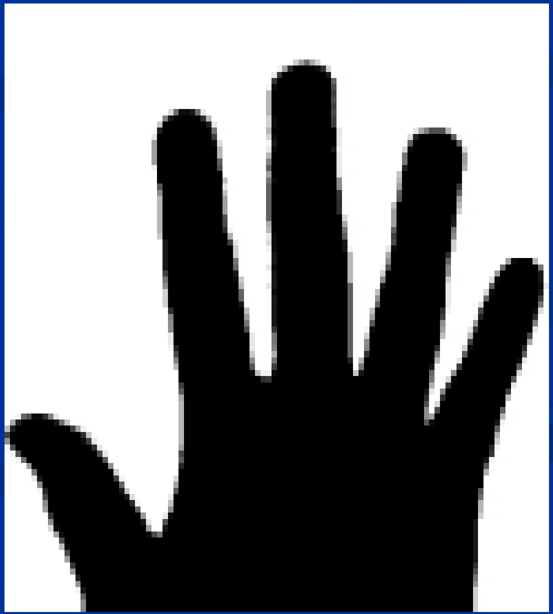
- Definition
  - Automatic recognition of individuals based on their physiological and/or behavioral characteristics
  - Based on “who she (he) is” rather than “what she (he) possess” or “what she (he) remembers”.
- Many Many Biometric Technologies!!!
  - Face, Iris, Fingerprint, Hand-Geometry, Palmprint, Signature, Gait, Voice, Retina, DNA, Ear, Hand Vein etc…

Y Hand Goemetry?

- Lack of clear fingerprints because of physical work.
- Iris and retina suffer from high cost.
- Face and voice systems has low performance.

Advantages

- Simple, easy to use .
- Medium cost
- Low computational cost.
- Low template size.
- Null user-rejection.



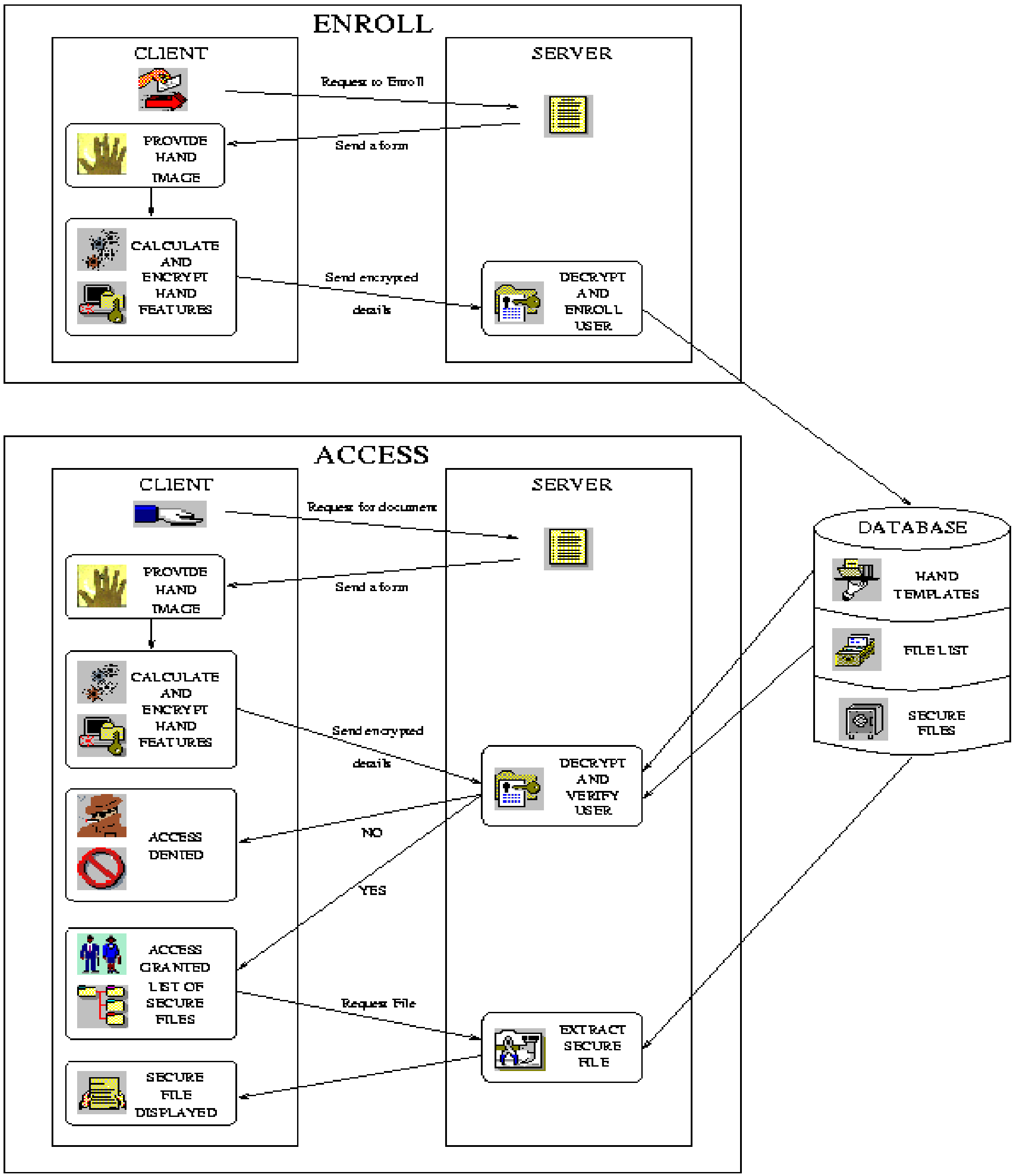
Coverage

- Applications and State-of-the-art.
- Image Acquisition Systems.
- Feature Selection .
- Feature Measurements.
- Matching Algorithms.
- Comparison.

Applications

- In Airport to permit frequent travelers to by-pass waiting lines (INSPASS project).
- Employers time/attendance procedures, recording staff movement.
- Verification at entrances of nuclear power plants
- RSI's integration with Olympic Village security system in 1996 Olympic Games.
- Revenues – 2.5% of biometric market about 97.4m by 1997.

Hand Geometry Based Web-Access



State-of-the-art

Approaches	Database	FAR	FRR
Hand silhouette contour as feature	53	2%	1.5%
Feature based	70	1%	3%
Employing hierarchical authentication scheme	22	2.22%	12%
Implicit polynomials	45	1%	1%
Grating pattern and quad-tree representation	100	0.48%	0.48%
Touch-free technique	15	0	2.8

Acquisition Systems

- Platform designed to guide the hand to fixed location.
- Six tops placed in determined positions
- Each of them equipped with pressure sensors
- When all are activated trigger the camera.

Commercial Systems

Handpunch50E

HP2000

Hand reader with MIFARE

	HP1000	HP2000	HP3000	HP4000
Transaction memory	5120 trans.	5120	5120	7680
User Capacity	50 -512	512	512-32512	530-3498
PRICE	$1595	$1800	$2295	$3320
Communications	RS-232, 50 foot cable	RS-232, 50 foot cable	RS-485, RS-232/ network	RS-485, RS-232/ network

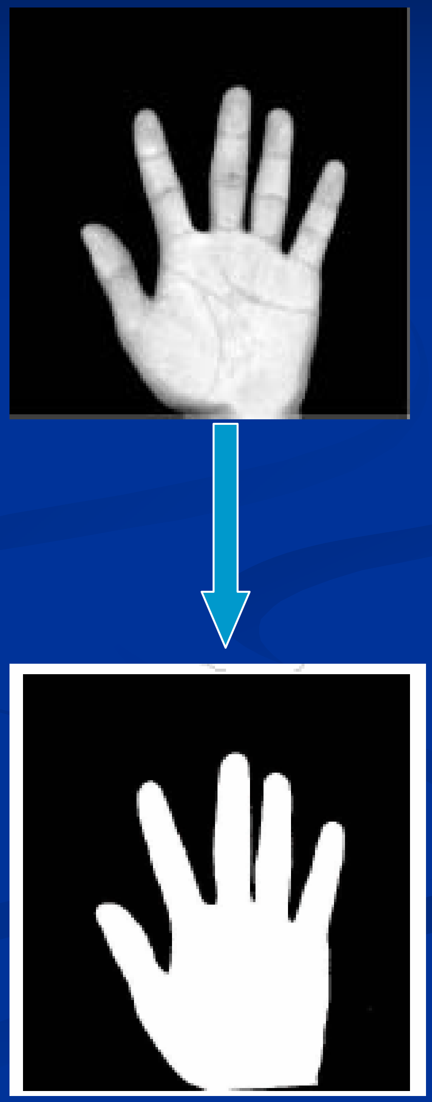
Size: 22.3cm wide, 29.6cm high, 21.7cm deep
Weight: 2.7kg
Template size: 9bytes
Memory Retention: 5yrs.

Preprocessing

- Databases of images collected under various subjects – age, sexes, profession etc. over periodic intervals of time.
- Images are transformed into binary images using the following formula

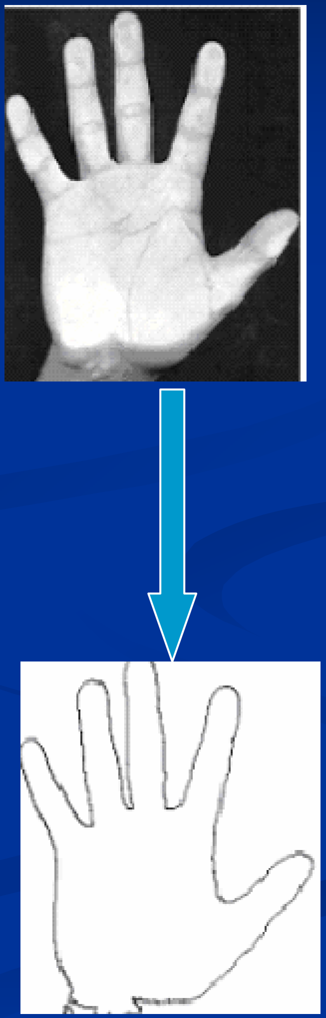
$$I_{BW} = \langle\langle I_R + I_G \rangle - I_B \rangle$$

where $\langle\ \rangle$ is a contrast stretching function.



Preprocessing

- Increased contrast allows better segmentation of the hand from the background.
- Spurious pixels can be removed using thresholding.
- Image resized and rotated – to address small deviations of hand position.
- Edge detection algorithms (e.g. Sobel) applied to extract contour of the hand.



NEXT…

- Measurements
- Minimize the variation
- Feature selection and feature vector size

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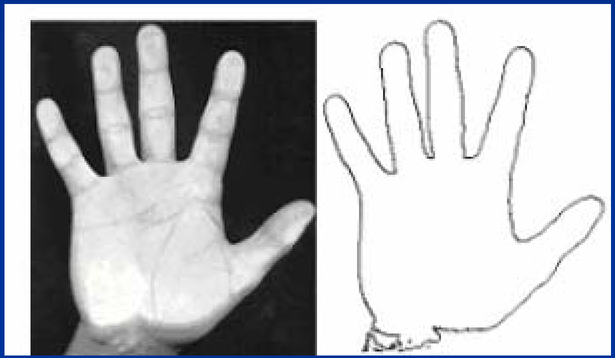
Measurements

- After preprocessing, the resulting image is a contour.
- This simplifies the measurement algorithm.



Original Image and the desired contour

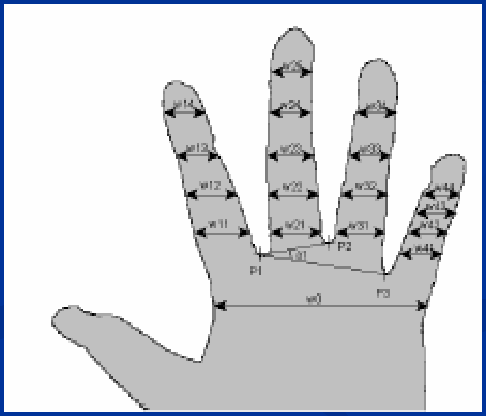
Measurements

Five categories:

- Width
- Angle
- Height
- Length
- Deviation

Measurements

- **Widths :--** of the four fingers, palm and the distance among the three interfinger points
- **Angles :** between the interfinger points and the horizontal



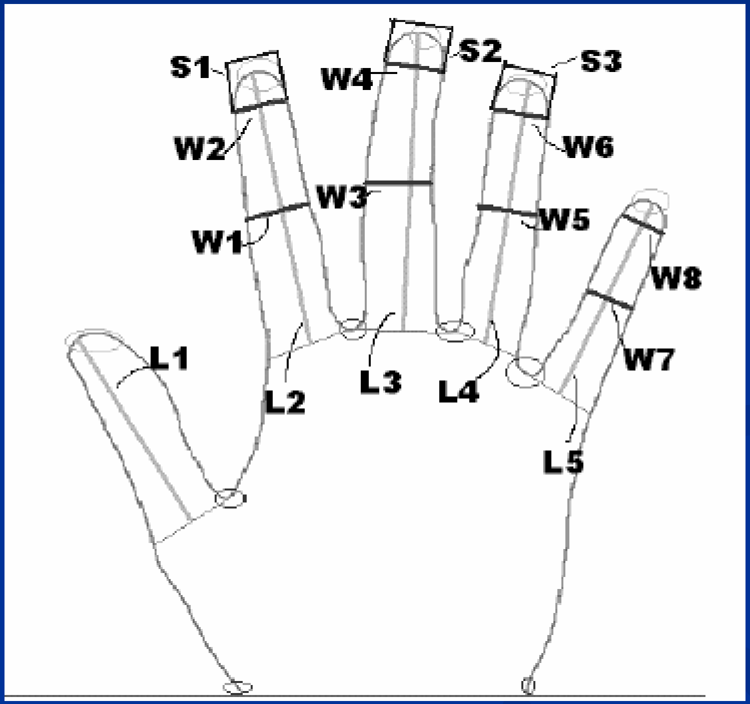
Location of measurement points for feature extraction

Measurements

- **Lengths:--** Li,

  where,

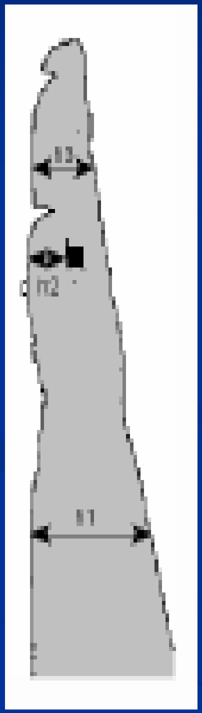
  i=1, 2, 3, 4, 5.



features: finger length Li (i=1,…,5)

Measurements

- **Heights :--** the middle finger, the little finger and the palm



Location of measurement points for feature extraction

Measurements

- **Deviation :--**

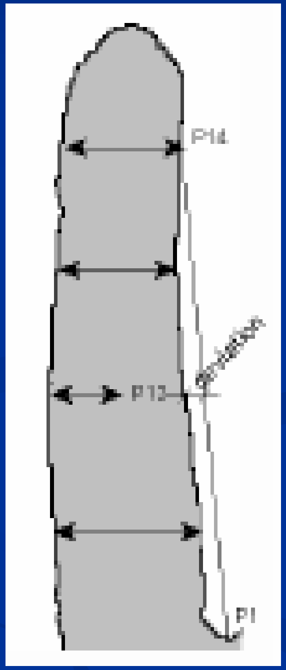
$$p_{12}^{X} - \left(\frac{p_{14}^{X} - p_{1}^{X}}{p_{14}^{Y} - p_{1}^{Y}} \right) \left(p_{12}^{Y} - p_{1}^{Y} \right),$$

where,

$p_{12}^{X}, p_{12}^{Y} =$ X and Y coordinates of the middle point of the finger.

$p_{14}^{X}, p_{14}^{Y} =$ X and Y coordinates of the last height.

$p_{1}^{X}, p_{1}^{Y} =$ X and Y coordinates of the interfinger point.



Deviation measurement

Minimize the variation

- All distances are taken relative to a determine measure.
- The vertical coordinates, are determined by the interfinger points and the tops.

Feature selection and feature vector size

- 31 features have been extracted.
- A statistical analysis has been performed.
- This is analyzed by a ratio F.
- The higher this ratio.

Feature selection and feature vector size

$$F_j = \frac{\text{interclass variability}}{\text{intraclass variability}} = \frac{\left(V \cdot \frac{1}{N}\sum_{i=1}^{N} \overline{f}_j^{\,i}\right)}{\frac{1}{N}\sum_{i=1}^{N} V\left(f_j^{\,i}\right)},$$

where,

F_j is the ratio for the j^{th} features.

V is the standard deviation function.

N is the number of classes.

$\overline{f}_j^{\,i}$ is the mean of the j^{th} features of the i^{th} class.

$f_j^{\,i}$ is the j^{th} feature of the i^{th} class.

Finally…

Matching Algorithms and their comparison

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Matching

Matching Algorithms

- Euclidean Distance.
- Hamming Distance.
- Gaussian Mixture Models.

Euclidean Distance

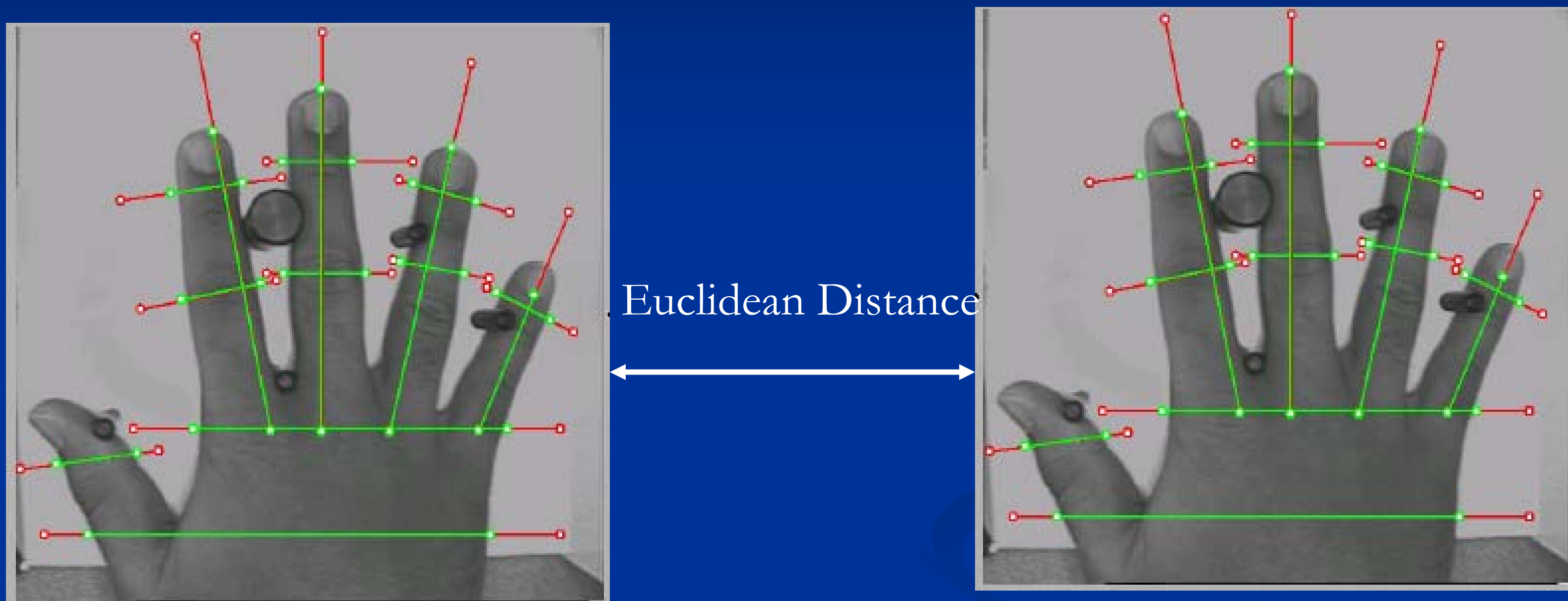
- Template Feature vector $(T_1,T_2,\ldots\ldots\ldots,T_{25})$
- Input Feature vector $(X_1,X_2\ldots\ldots\ldots.,X_{25})$
- Matching Score :Euclidean Distance

$$D = \sqrt{\sum_{i=1}^{L} (X_i - T_i)^2}$$

  T_i- i^{th} Component of Template feature Vector.
  X_i- i^{th} Component of Input feature Vector.
  L - Dimension of Feature vector.

- Compare this Matching Score with predefined Threshold value.
- Template vector dimension must same as Input vector.
- Set of Images of same user are taken and mean of these feature vectors is the Template.

Euclidean Distance



- Advantages
  - Easy to calculate.
  - Fast.
- Disadvantages
  - no invariance against any transformation.
  - sensitive to lighting changes.

Hamming Distance

- Number of Components differ in value rather than difference between components of the feature vectors.
- From set of Input Images of same user, measure mean and standard deviation and store these as template.
- Number of components of feature vector outside these values is Hamming Distance.

Hamming Distance

- Matching Score: Hamming Distance

$$d(X_i, T_i^m) = \#\{i \varepsilon \{1, \ldots.., L\} / |X_i - T_i^m| > T_i^v\}$$

d – Hamming Distance.

L – Dimension of the feature vectors.

Xi - ith Component of the sample vector.

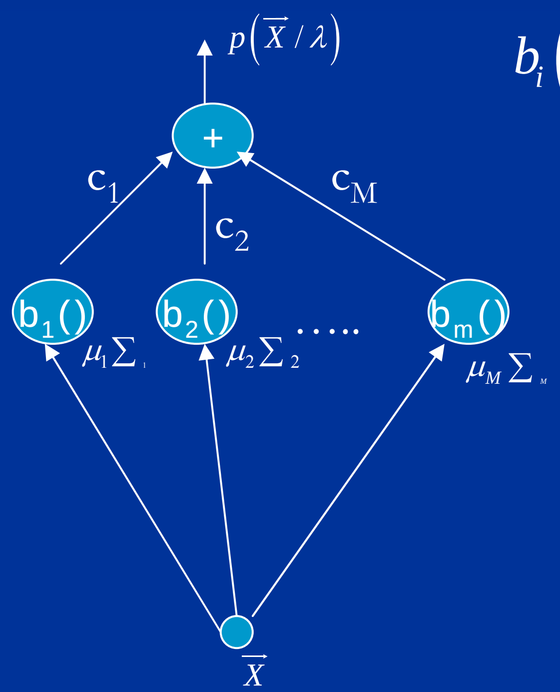
T_i^m- Mean of ith Component.

T_i^v – Standard Deviation of ith Component.

- Advantages: Easy to calculate.
- Disadvantages: Template Size becomes high.

Gaussian Mixture Model

- Based on modeling the patterns with a determined number of Gaussian Distributions.



GMM Architecture

$$b_i\left(\vec{X}\right)=\frac{1}{\left(2\pi\right)^{L/2}|\sum_i|^{L/2}}\exp\left\{-\frac{1}{2}\left(\vec{X}-\vec{\mu}_i\right)^T\sum_i^{-1}\left(\vec{X}-\vec{\mu}_i\right)\right\}$$

C_i–Weight of each of the Gaussian models.

μ_i–Mean value of each model.

S_i–Covariance matrix of each model.

M–Number of models.

L–Dimension of feature vector.

Probability density: $p\left(\vec{X}/\lambda\right)=\sum_{i=1}^{M} c_i b_i(\vec{X}_i)$

Gaussian Mixture Model

- GMMs should is initialized and trained to become operative.
- c_i initialized to 1/M.
- s_i unit matrix.
- μ_i random sample vector of that user.

- Expectation:

$$p\left(i / \overrightarrow{X_l}, \lambda \right) = \frac{c_i b_i \left(\overrightarrow{X_l} \right)}{\sum_{k=1}^{M} c_k b_k \left(\overrightarrow{X_l} \right)}, 1 \le i \le M, 1 \le l \le L$$

$$\hat{c}_i = \frac{1}{L} \sum_{i=1}^{L} p\left(i / \overrightarrow{X_i}, \lambda \right)$$

Gaussian Mixture Model

Maximization:

$$\hat{\vec{u}}_i = \frac{\sum_{l=1}^{L} p\left(i / \vec{X}_l, \lambda\right) . \vec{X}_l}{\sum_{i=1}^{L} p\left(i / \vec{X}_l, \lambda\right)}$$

$$\hat{s}_i^{\,2} = \frac{\sum_{l=1}^{L} p\left(i / \vec{X}_l, \lambda\right) . (\vec{X}_l - \hat{\vec{u}}_i) . (\vec{X}_l - \hat{\vec{u}}_i)^T}{\sum_{l=1}^{L} p\left(i / \vec{X}_l, \lambda\right)}$$

Gaussian Mixture Model

- Template of the user is final value of c_i, μ_i, s_i and M.
- Advantages:
  - High recognition rate, false Acceptance rate (FAR) and false Rejection rate (FRR).
  - Efficient for larger Database.
- Disadvantages:
  - Large Template size.

Comparison

- Data base is composed of 10 Images each from 20 people.
- Great acceptance of the System.
- Enrollment:
  - Final Images gives best results.
  - No variation problem in Euclidean distance Method.
- Preprocessing Algorithms were robust to allow colored skin.
- In Classification and Verification:

  Two main Analyses
  - Classification with changes in feature vector Dimension.
  - Classification with changes in enrollment set size.

Classification

- Comparison in Classification

No.enrollment vectors(25 features)		Euclidean	Hamming	GMMs
	3	86%	75%	88%
	4	85%	82%	93%
	5	86%	87%	96%
Feature vector dimension(5 enrollment vectors)	25	86%	87%	96%
	21	84%	86%	97%
	15	86%	88%	96%
	9	77%	75%	91%

Verification

- Three Main Results:
  - GMM give best results.
  - Same Equal Error rate for different feature vector sizes.
  - Variation in FAR and FRR
    - more acute with 9 features.
    - smoother with 21 or 25 features.

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