Face Recognition Committee Machine: Methodology, Experiments and A System Application

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Outline

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  - Committee Members
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Outline

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Introduction: Face Recognition

- Definition
  - A recognition process that analyzes facial characteristics
- Two modes of recognition
  - Identification: “Who is this”
  - Verification: “Is this person who she/he claim to be?”

Face Recognition Applications

- Security
  - Access control system
  - Law enforcement
- Multimedia database
  - Video indexing
  - Human search engine

Problems & Objectives

- Current problems of existing algorithms
  - No objective comparison
  - Accuracy not satisfactory
  - Cannot handle all kinds of variations
- Objectives
  - Provide thorough and objectively comparison
  - Propose a framework to integrate different algorithms for better performance
  - Implement a real-time face recognition system

Face Recognition Committee Machine (FRCM)

- Motivation
  - Achieve better accuracy by combining predictions of different experts
- Two structures of FRCM
  - Static structure (SFRCM)
  - Dynamic structure (DFRCM)

Static vs. Dynamic

- Static structure
  - Ignore input signals
  - Fixed weights
- Dynamic structure
  - Employ input signal to improve the classifiers
  - Variable weights

Committee Members

- Template matching approach
  - Eigenface
  - Fisherface
  - Elastic Graph Matching (EGM)
- Machine learning approach
  - Support Vector Machines (SVM)
  - Neural Networks (NN)

Review: Eigenface & Fisherface

- Feature space
  - Eigenface: Principal Component Analysis (PCA)
  - Fisherface: Fisher's Linear Discriminant (FLD)
- Training & Recognition
  - Project images on feature space
  - Compare Euclidean distance and choose the closest projection

Review: Elastic Graph Matching

- Based on dynamic link architecture
  - Extract facial feature by Gabor wavelet transform
  - Face is represented by a graph consists of nodes of jets
- Compare graphs by cost function
  - Edge similarity S_e and vertex similarity S_v
  - Cost function

$$C_{total}(G^I, G^M) = \lambda S_e(G^I, G^M) - S_v(G^I, G^M)$$

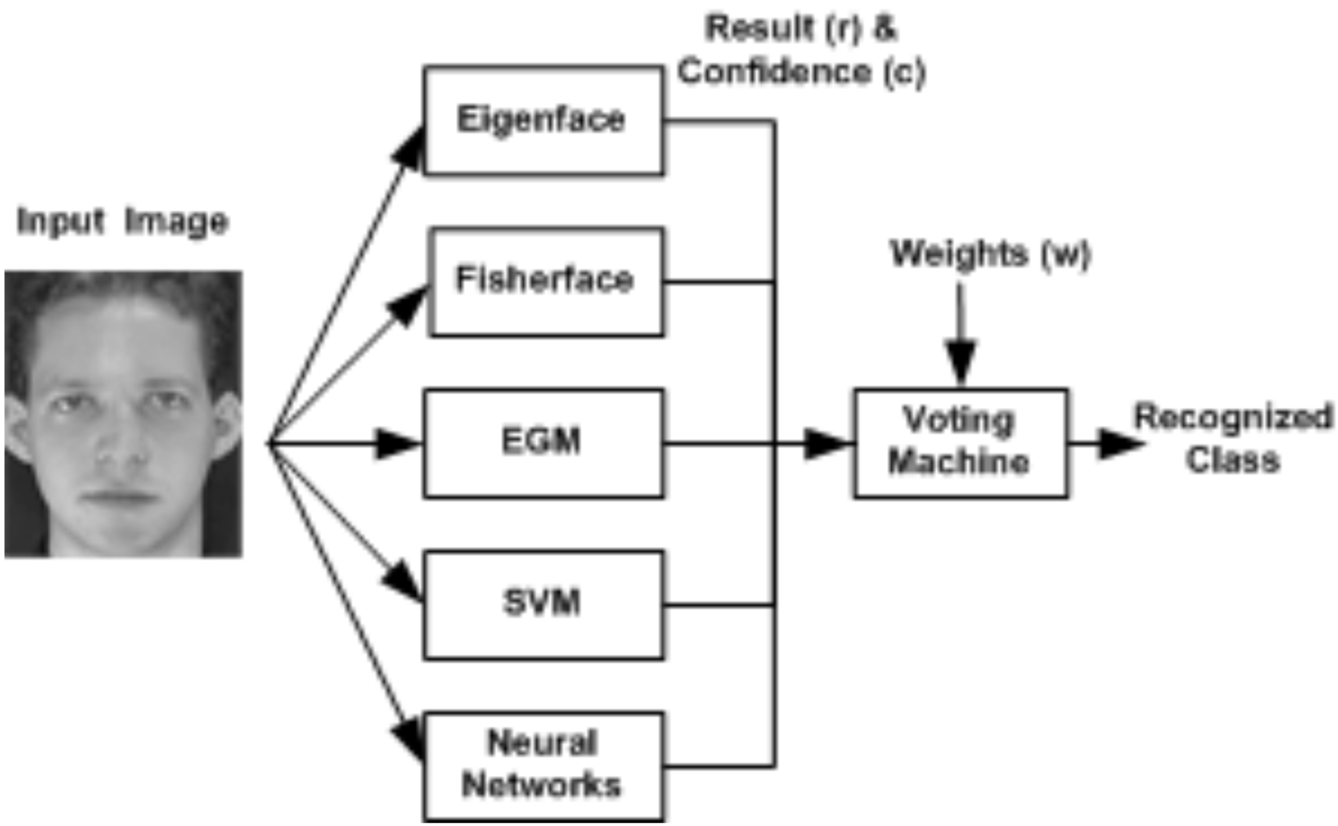
Review: SVM & Neural Networks

- SVM
  - Look for a separating hyperplane which separates the data with the largest margin
- Neural Networks
  - Adjust neuron weights to minimize prediction error between the target and output

Result, Confidence & Weight

- Result
  - Result of expert
- Confidence
  - Confidence of expert on its result
- Weight
  - Weight of expert's result in ensemble

SFRCM Architecture



Result & Confidence (1)

- Eigenface, Fisherface & EGM
  - Result:
    - Identification: $$r_i = \arg\max_j (v(j))$$
    - Verification: $$r_i = \begin{cases} 1 & \text{if } N_{threshold} \geq \frac{N_{total}}{2} \\ 0 & \text{otherwise} \end{cases}$$
  - Confidence:
    - Identification: $$c_i = \frac{v(r_i)}{K}$$
    - Verification: $$c_i = \frac{N_{threshold}}{N_{total}}$$

Result & Confidence (2)

- SVM
  - One-against-one approach
  - Result:
    - Identification: SVM result
    - Verification: direct matching
  - Confidence:

$$c_i = \frac{v(r_i)}{J - 1}$$

Result & Confidence (3)

- Neural network
  - A binary vector of size J for target representation
  - Result:
    - Identification: $r_i = \arg\max_j (o_j)$
    - Verification: $r_i = \begin{cases} 1 & \text{if } o_j \geq 0.5 \\ 0 & \text{otherwise} \end{cases}$
  - Confidence: output value o_j

$$\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Weight

- Derived from performance of expert:

$$p_i = \frac{n_i}{t_i}$$

- Amplify the difference of the performance:

$$w_i = \exp(\alpha p_i)$$

- Normalize in range [0, 1]:

$$\hat{w}_i = \frac{w_i}{\sum_{i=1}^{5} w_i}$$

Voting Machine

- Assemble result and confidence
- Score of expert's result:

$$s_j = \sum_{i=1}^{5} \hat{w}_i * c_i, \forall j \in r_i$$

- Ensemble result:

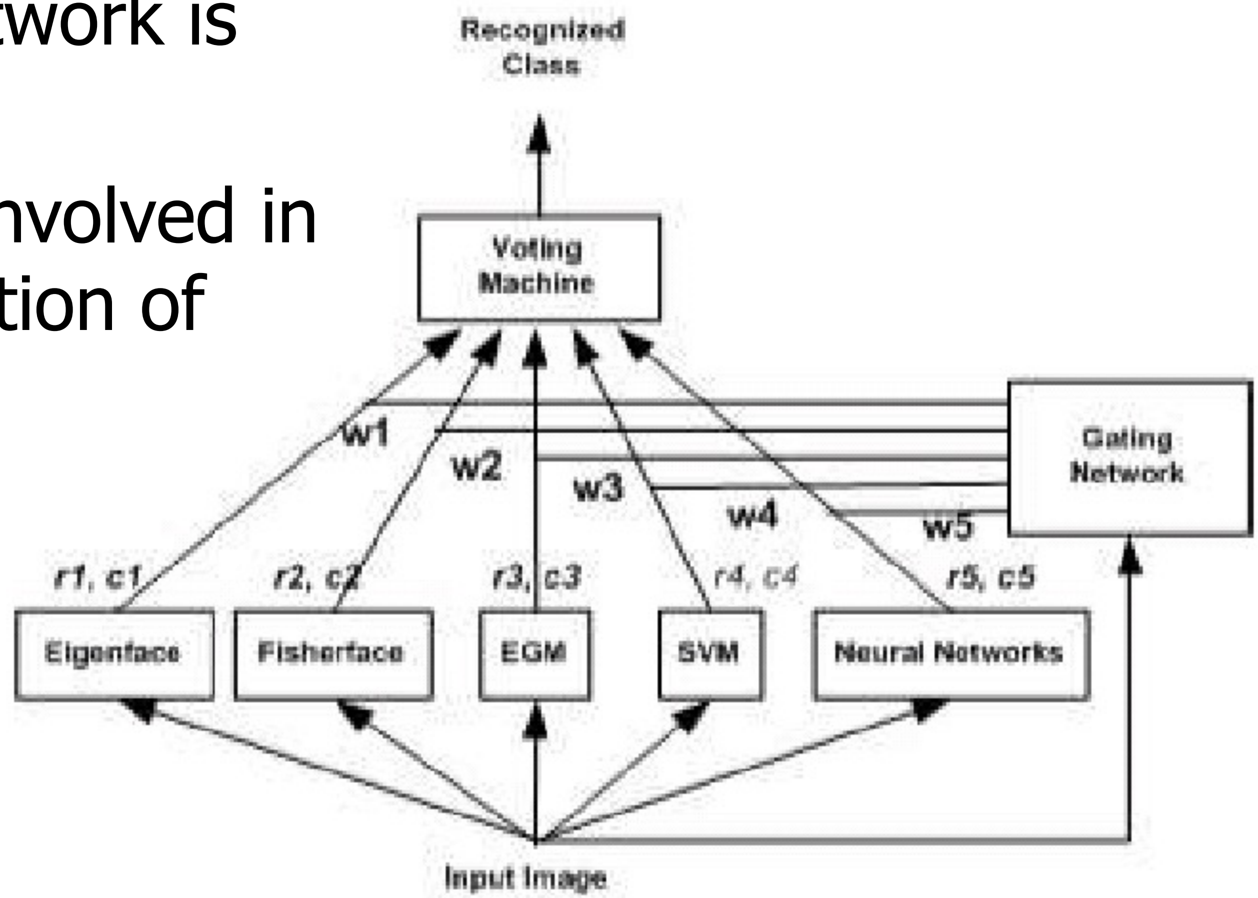
$$\hat{r} = \arg\max_j (s_j)$$

SFRCM Drawbacks

- Fixed weights under all situations
  - The weights of the experts are fixed no matter which images are given.
- No update mechanism
  - The weights cannot be updated once the system is trained

DFRCM Architecture

- Gating network is included
- Image is involved in determination of weight



Gating Network

- Keep the performance of experts on different face databases
- Determine the database of input image
- Give the corresponding weights of the experts for that database

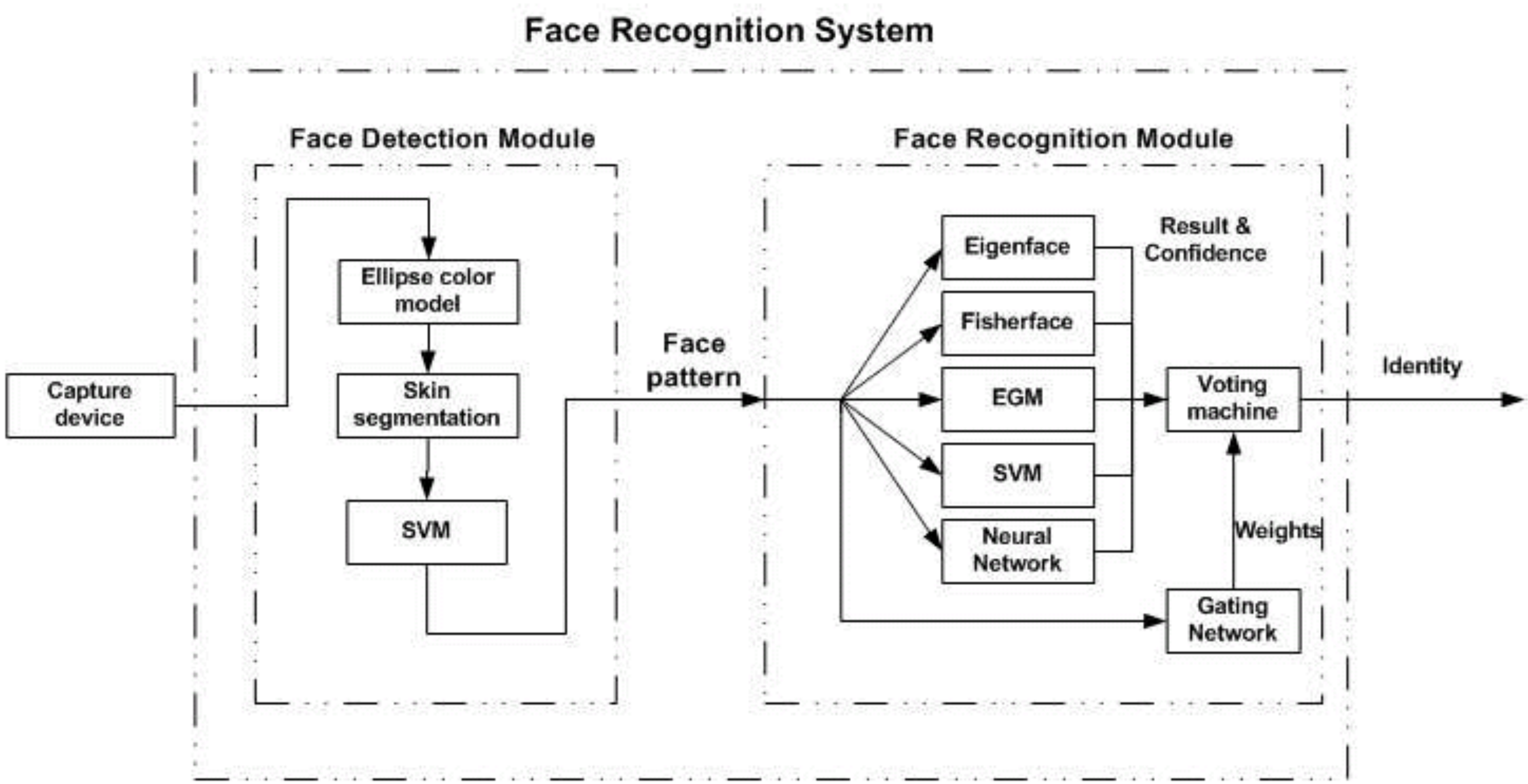
Feedback Mechanism

1. Initialize $n_{i,j}$ and $t_{i,j}$ to 0
2. Train each expert i on different database j
3. While TESTING
   a) Determine j for each test image
   b) Recognize the image in each expert i
   c) If $t_{i,j}$!= 0 then Calculate $p_{i,j}$
   d) Else Set $p_{i,j} = 0$
   e) Calculate $w_{i,j}$
   f) Determine ensemble result
   g) If FEEDBACK then Update $n_{i,j}$ and $t_{i,j}$
4. End while

Implementation: Face Recognition System

- Real-time face recognition system
- Implementation of FRCM
- Face processing
  - Face tracking
  - Face detection
  - Face recognition

System Architecture



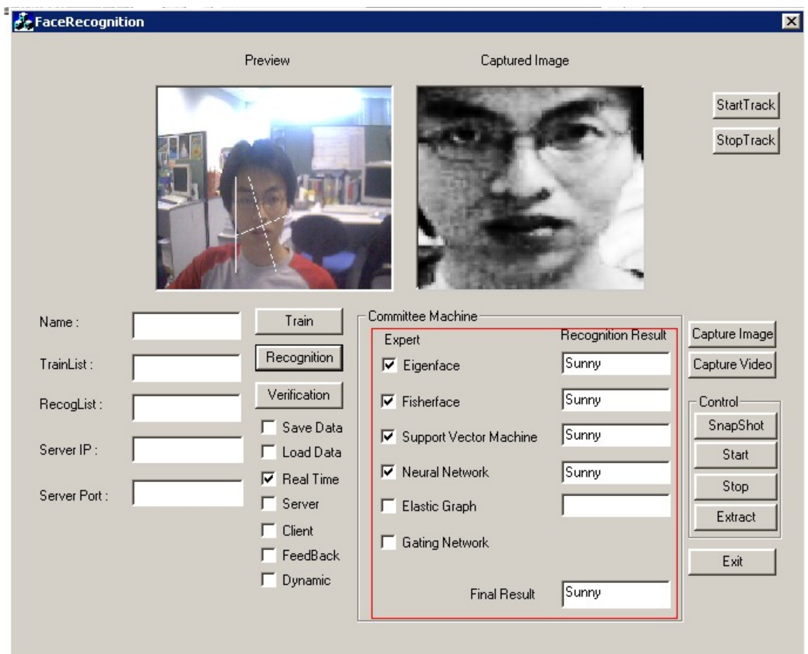
Face Recognition Process

- Enrollment
  - Collect face images to train the experts

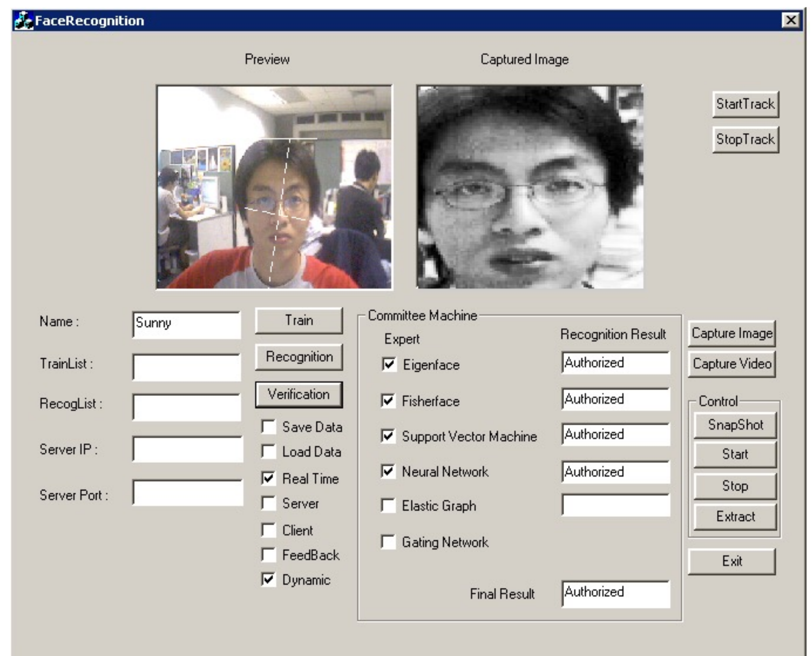
- Recognition
  - Identification
  - Verification

System Snapshots

Identification



Verification



Problems of FRCM on mobile device

- Memory limitation
  - Little memory for mobile devices
  - Requirement for recognition

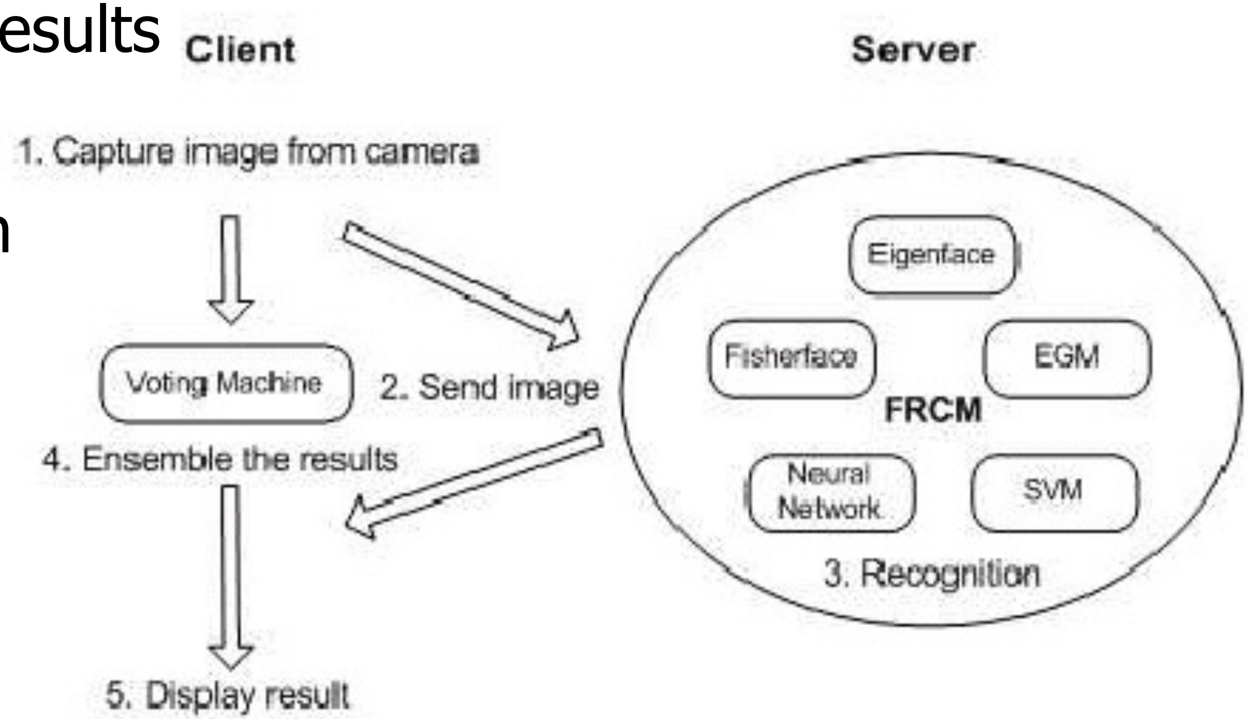
Algorithm	ORL(40)	Yale(15)	AR(130)	HRL(5)
Eigenface	5.0MB	5.0MB	5.5MB	15.0MB
Fisherface	4.0MB	1.5MB	13.5MB	0.5MB
EGM	1.5MB	0.5MB	4.5MB	1.0MB
SVM	38.0MB	14.0MB	122.0MB	14.0MB
Neural Networks	32.0KB	13.0KB	106.0KB	6.0K

- CPU power limitation
  - Time and storage overhead of FRCM

$$T_{FRCM} = \sum_{i=1}^{n} T_i$$

Distributed Architecture

- Client
  - Capture image
  - Ensemble results
- Server
  - Recognition



Distributed System: Evaluation

- Implementation
  - Desktop (1400MHz), notebook (300MHz)
  - S: Startup, R: Recognition

Machine for Testing	Time (S+R)	Time (R)
PIV 1400 MHz(Desktop)	13s	1s
PII 300 MHz (Notebook)	93s	2s
PII 300 MHz Client + PIV 1400 MHz Server	16s	2s

- Distinct servers:

$$T_{FRCM} = T_{cs} + \max_i T_i + T_{sc}$$

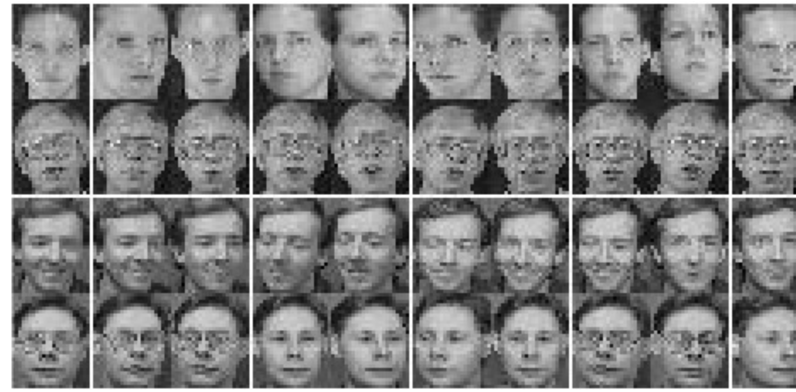
Experimental Results

- Databases used:
  - ORL from AT&T Laboratories
  - Yale from Yale University
  - AR from Computer Vision Center at U.A.B
  - HRL from Harvard Robotics Laboratory
- Cross validation testing

Preprocessing

1. Apply median filter to reduce noise in background
2. Apply Sobel filter for edge detection
3. Covert to a binary image
4. Apply horizontal and vertical projection
5. Find face boundary
6. Obtain the center of the face region.
7. Crop the face region and resize it

ORL Result

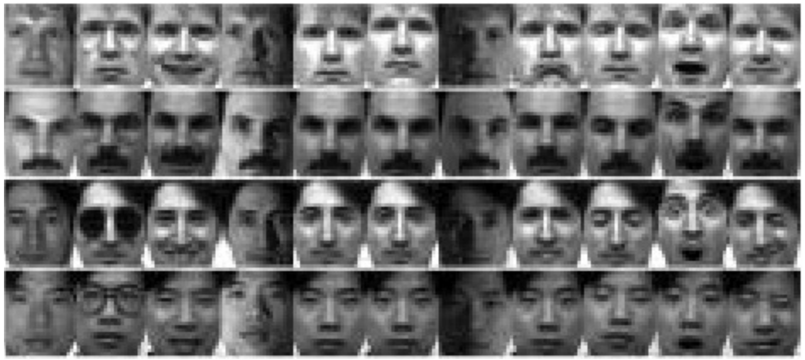


- ORL Face database
  - 400 images
  - 40 people
  - Variations
    - Position
    - Rotation
    - Scale
    - Expression

S	Eigen	Fisher	EGM	SVM	NN	DFRCM	SFRCM
1	82.5%	90.0%	90.0%	92.5%	**97.5%**	**92.5%**	**92.5%**
2	85.0%	**100.0%**	92.5%	**100.0%**	97.5%	**100.0%**	**100.0%**
3	87.5%	**100.0%**	72.5.0%	**100.0%**	92.5%	**100.0%**	**100.0%**
4	75.0%	92.5%	85.0%	**95.0%**	87.5%	**100.0%**	**95.0%**
5	72.5%	**97.5%**	80.0%	90.0%	87.5%	**90.0%**	**97.5%**
6	82.5%	90.0%	82.5%	**97.5%**	87.5%	**95.0%**	**92.5%**
7	80.0%	**92.5%**	75.0%	**92.5%**	90.0%	**97.5%**	**92.5%**
8	77.5%	87.5%	77.5%	**95.0%**	87.5%	**95.0%**	**90.0%**
9	75.0%	90.0%	77.5%	**97.5%**	92.5%	**100.0%**	**97.5%**
10	85.0%	**97.5%**	82.5%	95.0%	95.0%	**95.0%**	**97.5%**
Average	80.3%	93.8%	81.5%	**95.5%**	91.5%	**96.5%**	**95.5%**

Yale Result

- Yale Face Database
  - 165 images
  - 15 people
  - Variations
    - Expression
    - Lighting



S	Eigen	Fisher	EGM	SVM	NN	DFRCM	SFRCM
1: centerlight	40.0%	73.3%	**100.0%**	93.3%	60.0%	**93.3%**	**86.7%**
2: glasses	73.3%	**93.3%**	80.0%	86.7%	86.7%	**86.7%**	**93.3%**
3: happy	73.3%	86.7%	**93.3%**	86.7%	**93.3%**	**86.7%**	**93.3%**
4: leftlight	26.7%	40.0%	**66.7%**	26.7%	40.0%	**46.7%**	**40.0%**
5: noglasses	93.3%	**100.0%**	**100.0%**	**100.0%**	93.3%	**100.0%**	**100.0%**
6: normal	86.7%	**93.3%**	80.0%	86.7%	**93.3%**	**93.3%**	**93.3%**
7: rightlight	26.7%	40.0%	**93.3%**	20.0%	26.7%	**53.3%**	**46.7%**
8: sad	66.7%	**93.3%**	**93.3%**	**93.3%**	86.7%	**93.3%**	**93.3%**
9: sleepy	80.0%	**93.3%**	86.7%	**100.0%**	**93.3%**	**100.0%**	**93.3%**
10: surprised	**73.3%**	53.3%	26.7%	66.7%	46.7%	**60.0%**	**53.3%**
11: wink	93.3%	86.7%	86.7%	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Average	66.7%	77.6%	**82.4%**	78.2%	74.5%	**83.0%**	**81.2%**
Nolighting	75.6%	85.9%	83.0%	**90.4%**	83.7%	**90.4%**	**89.6%**

AR Result

- AR Face Database
  - 1300 images
  - 130 people
  - Variations
    - Expression
    - Lighting
    - Occlusions

Performance	Eigen	Fisher	EGM	SVM	NN	DFRCM	SFRCM
Validation	38.1%	86.2%	35.4%	55.4%	59.2%		
Testing	28.7%	**89.2%**	58.7%	59.7%	76.4%	**89.2%**	**86.4%**

HRL Result

- HRL Face Database
  - 345 images
  - 5 people
  - Variation
    - Lighting

Performance	Eigen	Fisher	EGM	SVM	NN	DFRCM	SFRCM
Validation	79.2%	81.3%	87.5%	75.0%	83.3%		
Testing	80.4%	89.7%	86.6%	82.5%	**90.7%**	**94.8%**	**90.7%**

Average Running Time & Results

Average running time

Database (no.)	Eigen	Fisher	EGM	SVM	NN	FRCM	FRCM/Image
ORL (40)	2.1	1.5	16.3	6	1.4	27.3	0.68
Yale (15)	0.9	0.2	6.5	0.6	0.3	8.5	0.57
AR (390)	21	48	123	118	56	366	0.94
HRL (97)	20	1	54	3	1	79	0.81

Average experimental results

Database	Eigen	Fisher	EGM	SVM	NN	DFRCM	SFRCM
ORL	80.3%	93.8%	81.5%	**95.5%**	91.5%	**96.5%**	**95.5%**
Yale	66.7%	77.6%	**82.4%**	78.2%	74.5%	**83.0%**	**81.2%**
AR	28.7%	**89.2%**	58.7%	59.7%	76.4%	**89.2%**	**86.4%**
HRL	80.4%	89.7%	86.6%	82.5%	**90.7%**	**94.8%**	**90.7%**
Average	64.0%	**87.6%**	77.3%	79.0%	83.3%	**90.9%**	**88.5%**

Conclusion

- Make a thorough comparison of five face recognition algorithms
- Propose FRCM to integrate different face recognition algorithms
- Implement a face recognition system for real-time application
- Propose a distributed architecture for mobile device

Question & Answer Section

Thanks