Non-parametric classification of facial features

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MAS622J Pattern Recognition and Analysis

Aim

- What to classify?
  - Gender (male / female)
  - Expression (serious / smiling / funny)
  - Accessory (glasses / bandana / hat)
  - Age (child / teen / adult / senior)
  - Race (white / hispanic / asian / black)
  - Other features (moustache / beard)
- With what feature?
  - Non-parametric facial images
    - Prior face detection assumed

Related approaches: References

- M. Turk and A. Pentland, “Eigenfaces for recognition,” *J. Cogn. Neurosci.,* 3(1): 71-86, 1991.
- W. S. Yambor, “Analysis of PCA-based and Fisher discriminant-based image recognition algorithms,” Master's thesis, Dept. of Comp. Sci., Colorado State Univ., July 2000.
- H. A. Rowely, S. Baluja, and T. Kanade, “Neural network based face detection,” *IEEE Trans. Pattern Anal. Machine Intell.,* 20(1):23-38, Jan. 1998.

Related approaches: Face detection

Neural network for multi-resolution images

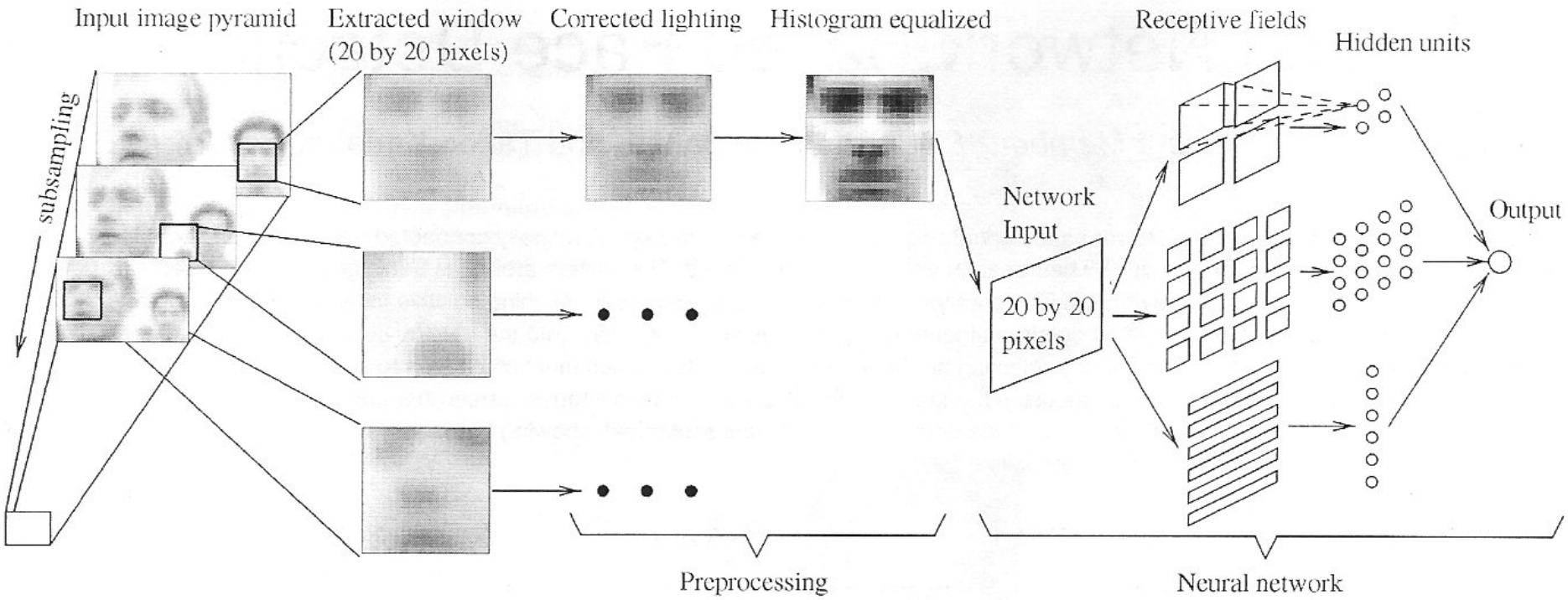


Fig. 1. The basic algorithm used for face detection.

Dataset

- Raw image data
  - 128×128 grey-scale face image
- Dimensionality reduced using PCA
  - 1 mean face, 99 eigenfaces (computed using 100 face image samples)
- Database size
  - 1,997 labeled training data (faceR)
  - 1,996 labeled test data (faceS)

Dataset

- Dataset composition (gender & expression)

	gender		expression		
	male	female	serious	smiling	funny
Eigenface generating data	61 /100	39 /100	45 /100	51 /100	4 /100
Training data (faceR)	1,150 /1,997	847 /1,997	917 /1,997	1,043 /1,997	37 /1,997
Testing data (faceS)	1,277 /1,996	719 /1,996	1,097 /1,996	836 /1,996	63 /1,996

Dataset

- Dataset composition (glasses & bandana)

	glasses		bandana	
	on	off	on	off
Eigenface generating data	4 /100	96 /100	0 /100	101 /100
Training data (faceR)	59 /1,997	1,938 /1,997	13 /1,997	1,984 /1,997
Testing data (faceS)	8 /1,996	1,988 /1,996	8 /1,996	1,988 /1,996

Objective of this project

- To practice meaningful classification problem
  - k-NN, neural network, linear discriminant, (*+bagging*)
  - *Multi-linear analysis*
- To enlighten inherent limitation of PCA approach
  - Error analysis: classification error vs. image distortion induced by PCA

Eigenface representation

e_j Eigenfaces

Y_k Sample faces used to generate a set of eigenfaces

$$Y_k \simeq \sum_{j=1}^{d} \alpha_{kj} e_j$$

X An arbitrary face

$\hat{X}$ Approximation of X using eigenfaces

$$\hat{X} = \sum_{k=1}^{d} \beta_k e_k \simeq \sum_{k=1}^{d} \gamma_k Y_k \quad \text{(Sensitive to } Y_k \text{)}$$

Approximation error may be measured in terms of MSE or PSNR

- MSE $\frac{1}{n}\left\|X - \hat{X}\right\|^2$
- PSNR $10 \log \frac{255^2 n}{\left\|X - \hat{X}\right\|^2} \, (dB)$

Eigenface representation

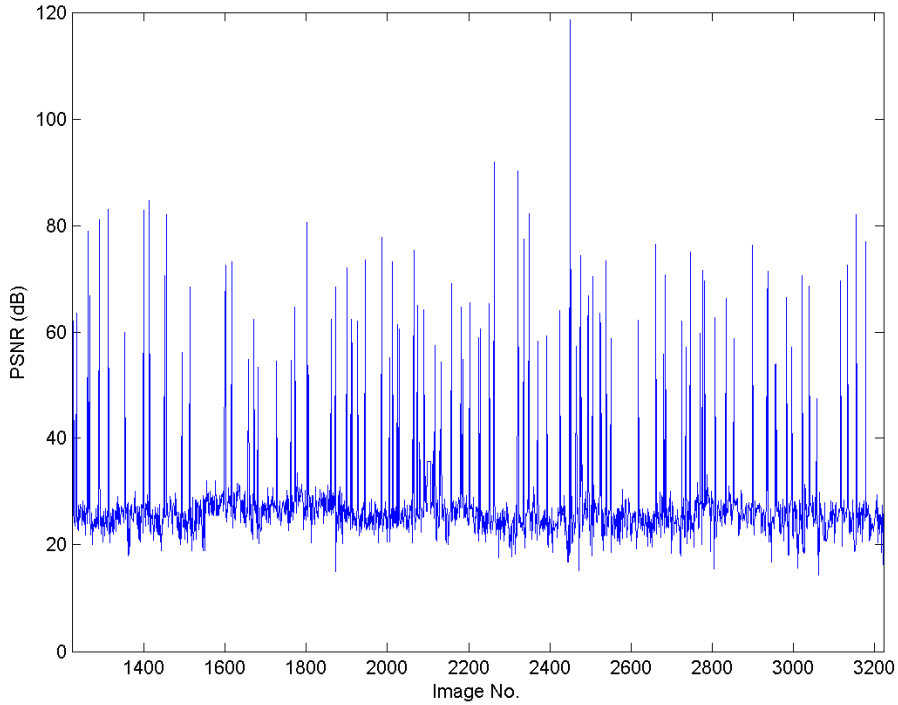
- How severely distorted? Bandana for example
  - Image id = 4241, PSNR = 14.47

Classification results other than bandana may be affected by bandana

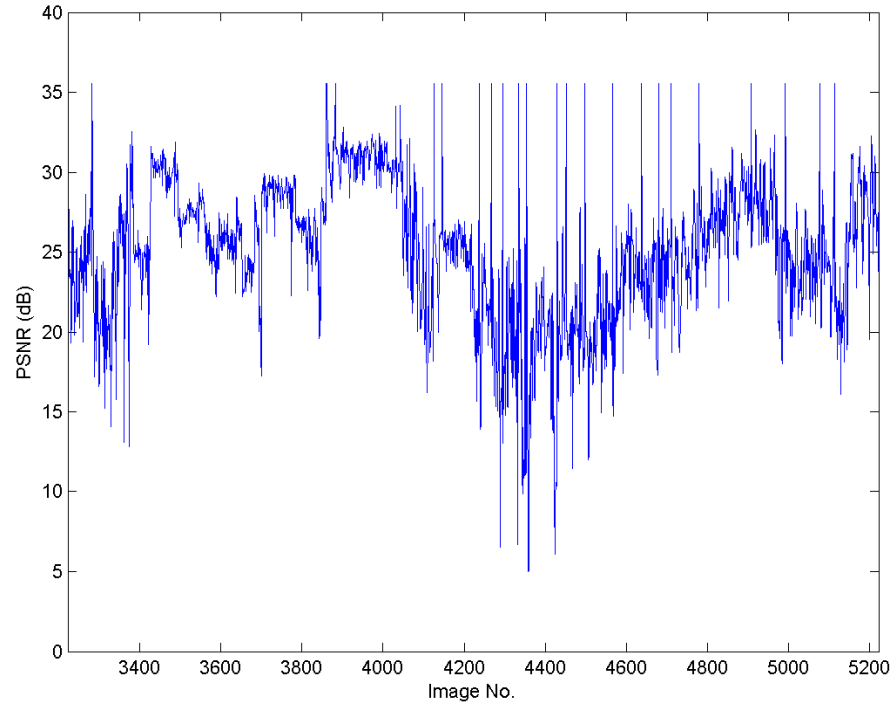
Eigenface representation

- PSNR for eigenface representation

faceR



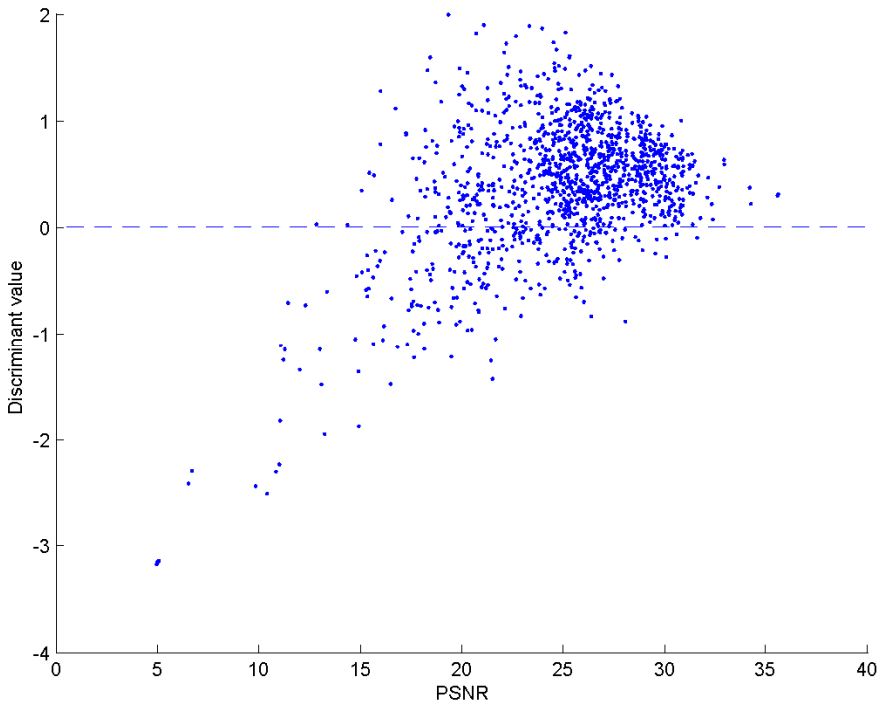
faceS



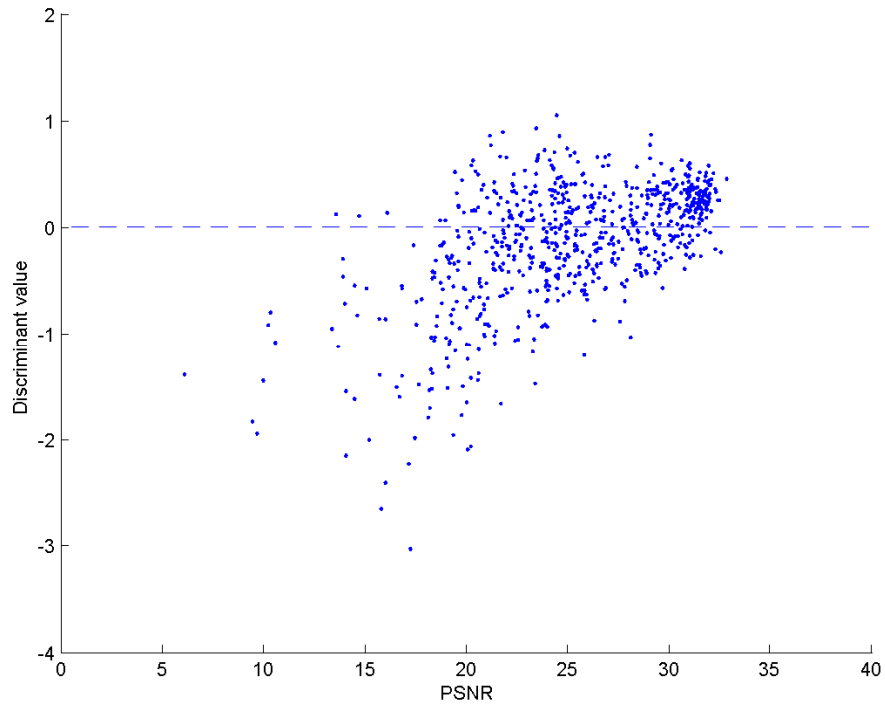
Classification error vs. PSNR

- Example : Linear Discriminant for gender

Class 1



Class 2



Classification practice

- Classification schemes
  - k-NN method
  - Linear discriminant
  - Neural networks
  - Random guess
    - Scheme 1: choose the class whose prior probability is maximum
    - Scheme 2: choose classes randomly according to their prior probabilities

Classification result: gender

k–NN $(k = 1)$

	detect	miss
male	823	454
female	402	317

Linear discriminant

	detect	miss
male	1,026	251
female	375	344

NN–1 $(n_H = 3)$

	detect	miss
male	1,008	269
female	378	341

NN–2 $(n_H = 2 + 2)$

	detect	miss
male	763	514
female	544	175

Classification result: gender

Random guess 1

	detect	miss
male	1,277	0
female	0	719

Random guess 2

	detect	miss
male	753	542
female	305	414

Classification result: expression

k–NN $(k = 27)$

	detect	miss
serious	586	511
smiling	468	368
funny	0	63

Linear discriminant

	detect	miss
serious	936	161
smiling	623	213
funny	0	63

NN–1 $(n_H = 6)$

	detect	miss
serious	932	165
smiling	617	219
funny	0	63

NN–2 $(n_H = 3 + 3)$

	detect	miss
serious	963	134
smiling	593	243
funny	0	63

Classification result: glasses

k–NN $(k = 5)$

	detect	miss
on	0	8
off	1,988	0

Linear discriminant

	detect	miss
on	0	8
off	1,986	2

NN–1 $(n_H = 3)$

	detect	miss
on	2	6
off	1,962	16

NN–2 $(n_H = 2 + 2)$

	detect	miss
on	0	8
off	1,958	30

Classification result: bandana

k–NN $(k = 3)$

	detect	miss
on	0	8
off	1,988	0

Linear discriminant

	detect	miss
on	0	8
off	1,988	0

NN–1 $(n_H = 3)$

	detect	miss
on	0	8
off	1,988	0

NN–2 $(n_H = 2 + 2)$

	detect	miss
on	0	8
off	1,986	2

(Hasty) conclusion

- Samples from minority class (with very low prior probability) tend to be completely missed with any classifier
  - Bagging scheme may be helpful if each subset contains minority class samples
- Eigenface approaches
  - Good for recognition purpose
    - Known to be robust to noise, partial loss of data
  - Not as good for classification purpose
- In Fall 2004, Parzen window is reported to show nearly perfect classification performance (Tiwari)

Future works

- Until Friday
  - Bagging scheme will be implemented
  - Error analysis will be a little supplemented
- Direction of Further Study
  - Parzen window
  - Experiment with other classification criteria
  - Multi-linear analysis

- See webpage for more details
  - After Friday
- Comments and Questions
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