

Dual Subspace Nonnegative Matrix Factorization for Person-Invariant Facial Expression Recognition

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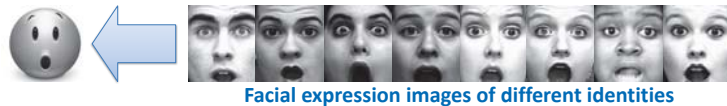
Introduction

✓ Problem of expression recognition:

- Environmental changes (e.g., pose, illumination)
- **Different appearance changes among different individual**

✓ Goal: To Extract **person-invariant expression features**

- Expression-related facial appearance changes



Dual Subspace Nonnegative Matrix Factorization (DSNMF)

✓ Nonnegative Matrix Factorization (NMF):

- Part-based facial representation
- More interpretable for facial image analysis



✓ Dual Subspace Decomposition:

- Decomposing expressive image into 2 parts:
 - Identity part
 - Expression part

$$\mathbf{x}_i \approx \underbrace{\mathbf{x}_i^I}_{\text{Identity-related information}} + \underbrace{\mathbf{x}_i^E}_{\text{Expression changes}} = \underbrace{\mathbf{W}_I \mathbf{h}_I + \mathbf{W}_E \mathbf{h}_E}_{\text{Nonnegative data Factorization}}$$

✓ Constraints:

For same identity, minimize: $\sum_{i \neq j} \|\mathbf{h}_i^I - \mathbf{h}_j^I\|^2 S_{ij}^I$

For same expression, minimize: $\sum_{i \neq j} \|\mathbf{h}_i^E - \mathbf{h}_j^E\|^2 S_{ij}^E$

$$S_{ij}^I = \begin{cases} \exp\left(-\frac{\|\mathbf{x}_i - \mathbf{x}_j\|_2^2}{\sigma^2}\right) & \dots E(\mathbf{x}_i) = E(\mathbf{x}_j) \\ 0 & \dots \text{otherwise} \end{cases}$$

$$S_{ij}^E = \begin{cases} \exp\left(-\frac{\|\mathbf{x}_i - \mathbf{x}_j\|_2^2}{\sigma^2}\right) & \dots P(\mathbf{x}_i) = P(\mathbf{x}_j) \\ 0 & \dots \text{otherwise} \end{cases}$$

✓ Objective function of DSNMF:

$$\min_{\mathbf{W}, \mathbf{H}} \|\mathbf{X} - \mathbf{W}\mathbf{H}\|_F^2 \quad \text{s.t.} \quad \mathbf{W}, \mathbf{H} \geq 0$$

Nonnegative Matrix Factorization

$$+ \min_{\mathbf{H}_I} \sum_{i \neq j} \|\mathbf{h}_i^I - \mathbf{h}_j^I\|^2 S_{ij}^I + \min_{\mathbf{H}_E} \sum_{i \neq j} \|\mathbf{h}_i^E - \mathbf{h}_j^E\|^2 S_{ij}^E$$

Dual Subspace Decomposition

$$\min_{\mathbf{W}, \mathbf{H}} \|\mathbf{X} - \mathbf{W}\mathbf{H}\|_F^2 + \lambda_1 \text{Tr}(\mathbf{H}_I \mathbf{L}^I \mathbf{H}_I^T) + \lambda_2 \text{Tr}(\mathbf{H}_E \mathbf{L}^E \mathbf{H}_E^T)$$

Identity-related Expression-related

✓ Goal:

- Decompose the whole dataset into 2 subspaces:

$$\mathbf{X} \approx \underbrace{\mathbf{W}_I}_{\text{Basis } W} \underbrace{\mathbf{H}_I}_{\text{Coefficient } H} + \underbrace{\mathbf{W}_E}_{\text{Basis } W} \underbrace{\mathbf{H}_E}_{\text{Coefficient } H}$$

s.t. $\mathbf{W}, \mathbf{H} \geq 0$

✓ For a test image \mathbf{x}_{test} :

$$\min_{\mathbf{h}^{test}} \|\mathbf{x}_{test} - \mathbf{W}\mathbf{h}^{test}\|_F^2 \quad \text{s.t.} \quad \mathbf{h}^{test} \geq 0$$

$\mathbf{h}^{test} = \begin{bmatrix} \mathbf{h}_I^{test} \\ \mathbf{h}_E^{test} \end{bmatrix}$

- For face recognition
- For expression recognition

Experimental Results

✓ 6 expressions: Angry, Disgust, Fear, Happy, Sad, Surprise

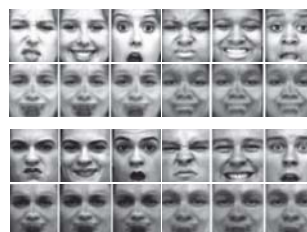
✓ Dataset:

- CK+: 309 sequences, 106 subjects
- JAFFE: 183 images, 10 subjects
- TFEID: 229 images, 40 subjects

✓ Leave one person out strategy

✓ Nearest-neighbor classifier

	PCA	NMF	GSNMF	PNGE	SR-Diff	DSNMF
CK+	67.96	72.82	71.84	51.78	80.91	90.92
JAFFE	44.26	41.53	43.17	42.62	45.90	53.01
TFEID	81.22	79.91	76.42	63.76	73.99	89.52



Reconstructed only by identity bases



Reconstructed only by expression bases