Low-Rank Matrix Recovery with Structural Incoherence for Robust Face Recognition

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Motivation and Contribution

- Real-World Face Recognition (FR)
  - (1) BOTH training and test data might be corrupted.
  - (2) NO prior knowledge on the type of corruption. (e.g., sunglasses, masks, etc.)
- Our Proposed Method
  - (1) Low-Rank Matrix Decomposition (LR)
    -> Extract ***representative*** features for each class.
  - (2) Structural Incoherence (SI)
    -> Introduce ***discriminating*** features for classification.

SRC for Face Recgonition?

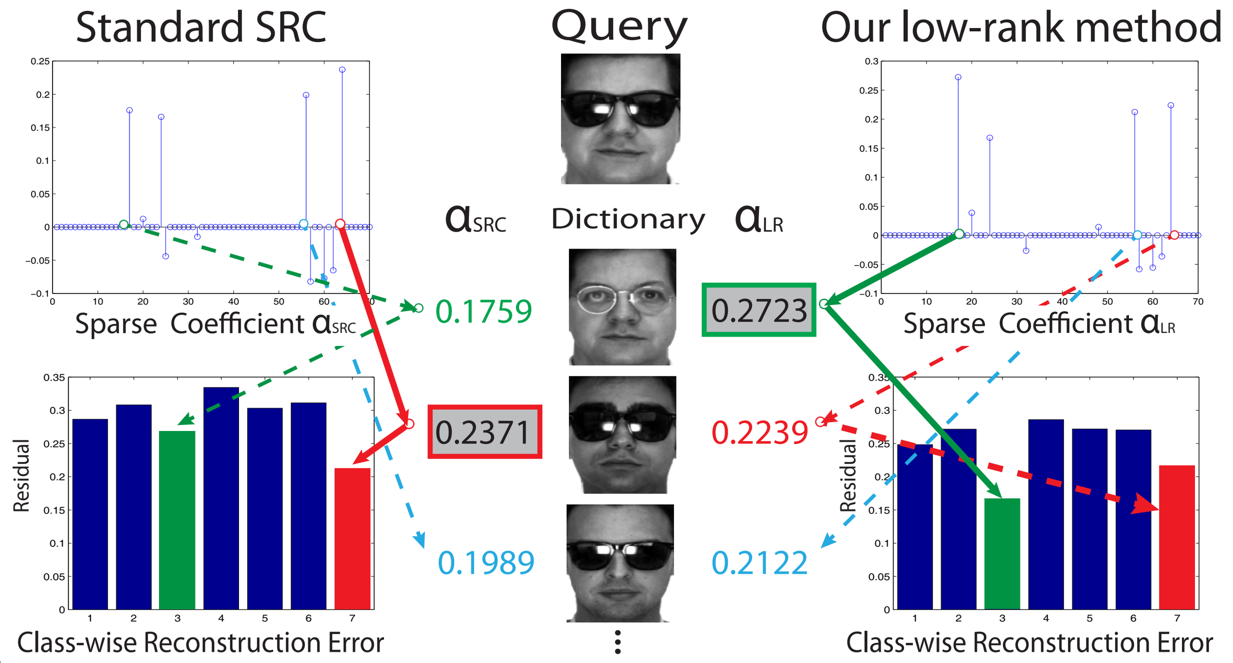
- SRC (Sparse Representation-based Classification)
  - (1) Sparse representation of input data:

$$\min_{\alpha} \|y - \mathbf{D}\alpha\|_2^2 + \lambda_{SRC}\|\alpha\|_1$$

  - (2) Classification via class-wise reconstruction error :

$$j^* = \arg\min_j \|y - \mathbf{D}_j\alpha_j\|_2^2$$

  - (3) SRC tends to recognize the test input as the class with the most similar training images.
- SRC for Real-World FR?
  - (1) SRC requires ***unoccluded*** training images for face recognition.
  - (2) It would fail if both training and test data have similiar types of corruption.



Face Recognition by Low-Rank Matrix Recovery

- Robust PCA (Low-Rank Matrix Recovery)

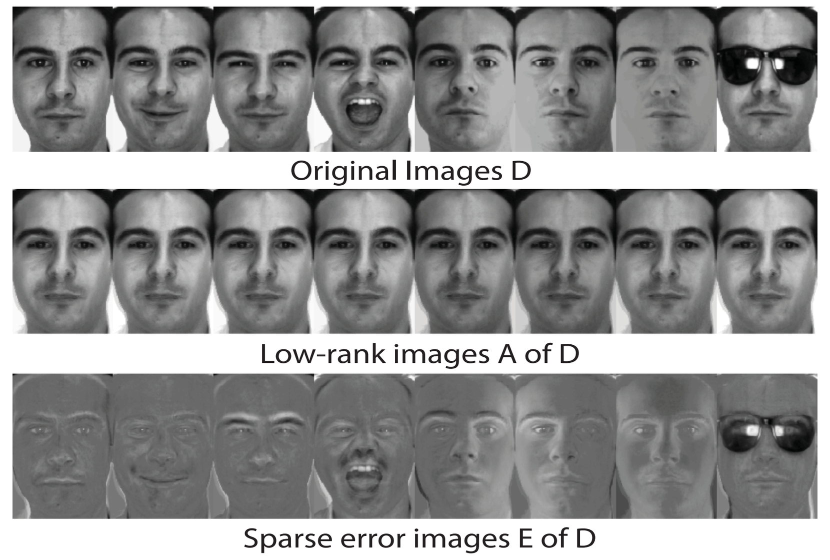
Decompose original data (D) into a LR matrix (A) and a sparse error matrix (E), so that A has a better representive ability than D does.

$$\min_{\mathbf{A},\mathbf{E}} \|\mathbf{A}\|_* + \lambda\|\mathbf{E}\|_1 \quad s.t.\ \mathbf{D} = \mathbf{A} + \mathbf{E}$$

- LR for Face Recognition
  - (1) Derive A by perfroming LR for each of the N subjects.

$$\min_{\mathbf{A}_i,\mathbf{E}_i} \sum_{i=1}^{N} \{\|\mathbf{A}_i\|_* + \lambda\|\mathbf{E}_i\|_1\} \quad s.t.\ \mathbf{D}_i = \mathbf{A}_i + \mathbf{E}_i$$

  - (2) Perform subspace learning (e.g., PCA) on A instead of D.
  - (3) Project training and test data onto the subspace of (2) and apply SRC for classification.



LR Matrix Decomposition with Structural Incoherence

- We advocate the structural incoherence between the low-rank matrices of different classes.
  - (1) We formulate LR matrix recovery with regulization on SI.

$$\min_{\mathbf{A}_i,\mathbf{E}_i} \sum_{i=1}^{N} \{\|\mathbf{A}_i\|_* + \lambda\|\mathbf{E}_i\|_1\} + \eta \sum_{j\neq i} \|\mathbf{A}_j^T\mathbf{A}_i\|_F^2 \quad s.t.\ \mathbf{D}_i = \mathbf{A}_i + \mathbf{E}_i$$

  - (2) For each class, we solve the following relaxed version. (approximated by Cauchy-Schwarz inequality).

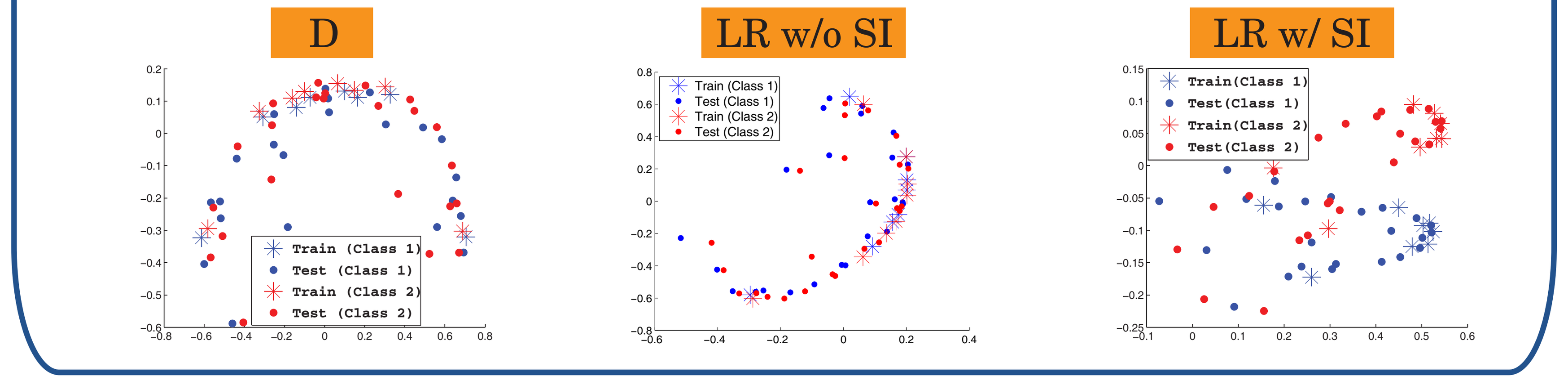
$$\min_{\mathbf{A}_i,\mathbf{E}_i} \|\mathbf{A}_i\|_* + \lambda\|\mathbf{E}_i\|_1 + \eta'\|\mathbf{A}_i\|_F^2 \ s.t.\ \mathbf{D}_i = \mathbf{A}_i + \mathbf{E}_i \quad \text{where} \quad \eta' = \eta\sum_{j\neq i}\|\mathbf{A}_j\|_F^2$$

  - (3) Iteratively solve (2) via Augmented Lagrange Multipliers.

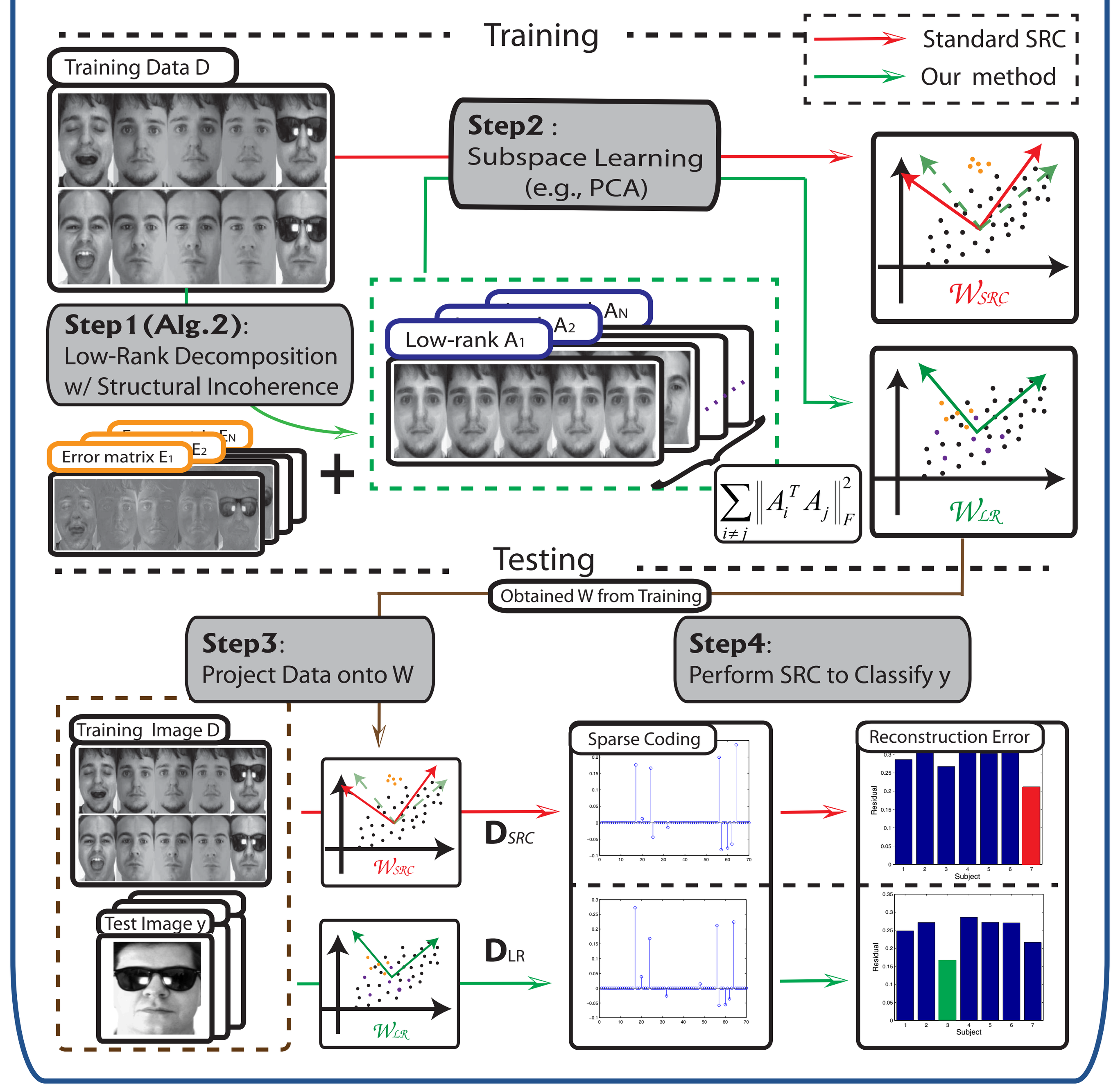
$$L(\mathbf{A}_i,\mathbf{E}_i,\mathbf{Y}_i,\mu,\eta') = \|\mathbf{A}_i\|_* + \lambda\|\mathbf{E}_i\|_1 + \eta'\|\mathbf{A}_i\|_F^2 + \langle \mathbf{Y}_i, \mathbf{D}_i - \mathbf{A}_i - \mathbf{E}_i\rangle + \frac{\mu}{2}\|\mathbf{D}_i - \mathbf{A}_i - \mathbf{E}_i\|_F^2$$

- Visualization (Extended YaleB)

Projected face data in the subspace spanned by the first two eigenvectors.



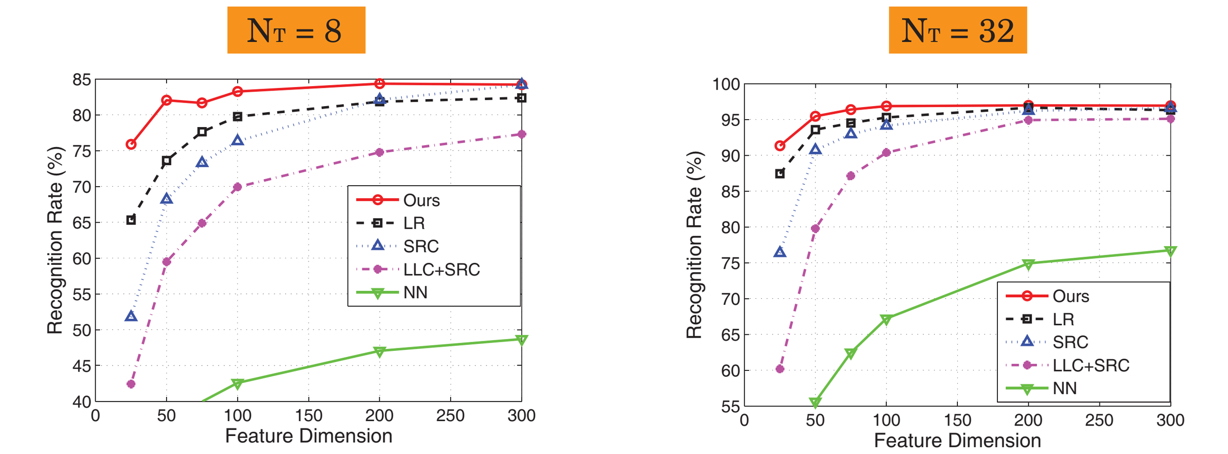
System Overview and Comparison



Extended YaleB Database (Illumination)

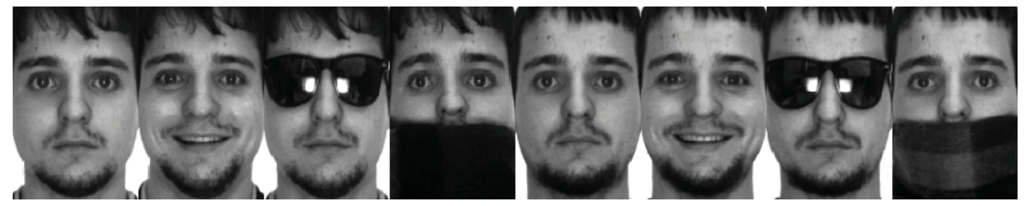
- * 38 subjects, 59-64 images each

- * Randomly select N_T images for training.
- * Compare to NN, SRC, LLC-SRC and LR w/o SI.

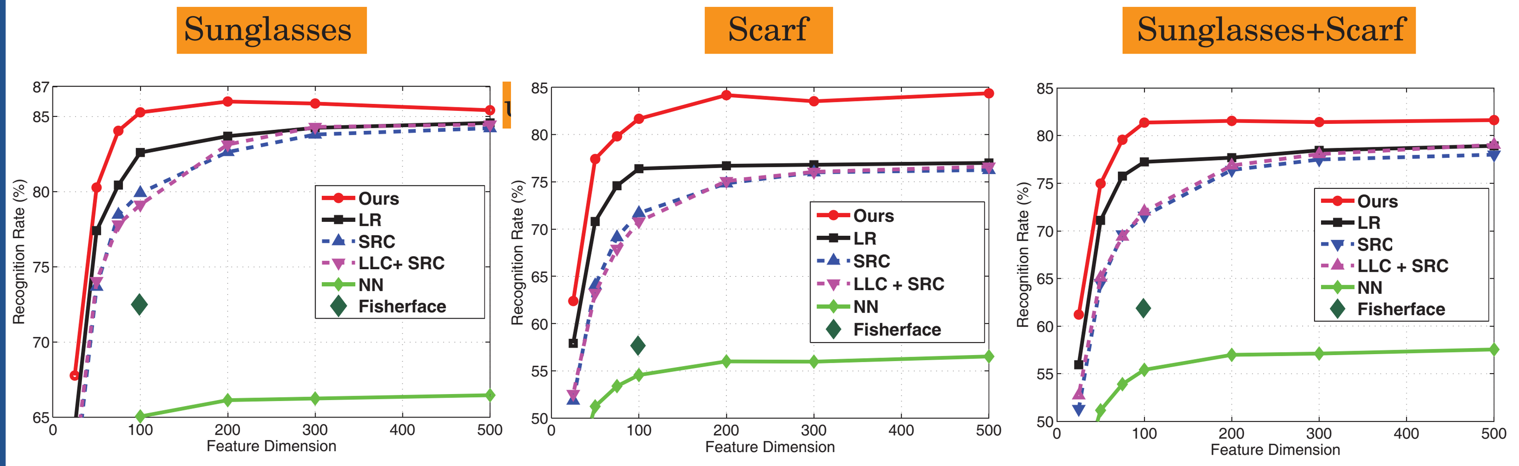


AR Database (Illumination/Expression/Occlusion/Disguise)

- * Image of 100 sujects (50 men + 50 women) taken in 2 seperate sessions.
- * Each session contains 7 neutral (illumination and expression), 3 sunglasses and 3 scaf images.



- * Training: images from session 1
  - (1) Sunglasses : 7 neutral + 1 sunglasses
  - (2) Scarf : 7 neutral + 1 scarf
  - (3) Sunglasses+Scarf : 7 neutral + 1 sunglasses + 1 scarf
- * Testing: the remaining images of session 1 and 2.
- * Compare to NN, Fisherface, SRC, LLC-SRC and LR w/o SI.



Methods	Dimension = 500			Dimension = 100			Dimension = 50		
	Sunglasses	Scarf	Sunglasses +Scarf	Sunglasses	Scarf	Sunglasses +Scarf	Sunglasses	Scarf	Sunglasses +Scarf
Fisherfaces*	−−	−−	−−	72.50	57.67	61.80	−−	−−	−−
NN	66.47	56.53	57.55	65.06	54.56	55.41	60.89	51.25	51.15
LLC+SRC	84.47	76.61	79.03	79.14	70.08	72.04	74.06	63.25	65.10
SRC	84.22	76.25	78.00	79.92	71.70	71.59	73.68	64.05	64.51
LR	84.58	77.00	78.92	82.61	76.39	77.23	77.41	70.81	71.10
Ours	**85.42**	**84.36**	**81.62**	**85.27**	**81.67**	**81.37**	**80.27**	**77.41**	**74.96**

* The dimension of Fisherfaces is fixed at N - 1 = 100 - 1 = 99, wher N is the number of subjects.

Conclusions

- We present a low-rank matrix recovery algorithm with structural incoherence for robust face recognition.
- The proposed SI introduces additional discriminating ability for improved recognition.
- Experiments confirm the effectiveness and robustness of our approach under a variety of variations/corruptions.

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