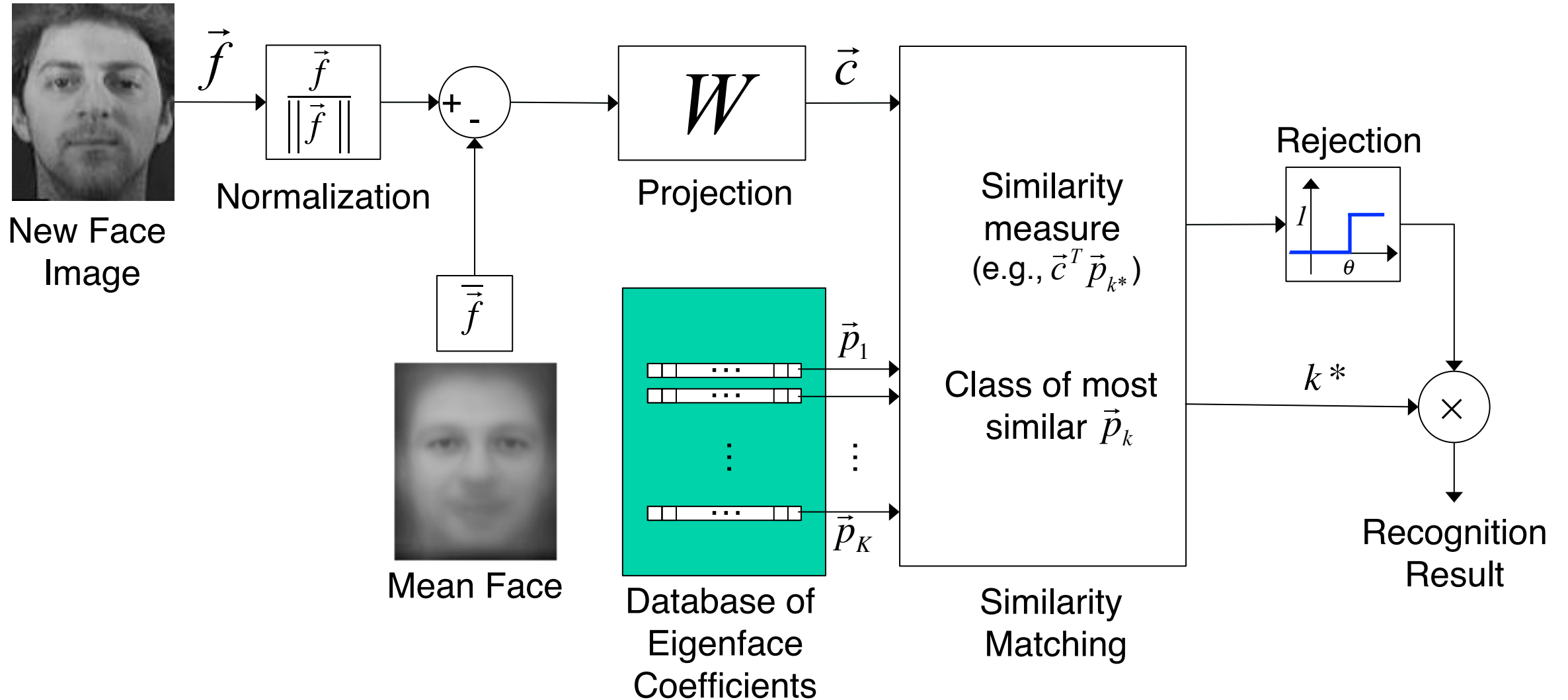


Eigenimages for recognition

- To recognize complex patterns (e.g., faces), large portions of an image have to be considered
- High dimensionality of “image space” means high computational burden for many recognition techniques
 - Example: nearest-neighbor search requires pairwise comparison with every image in a database
- Transform $\vec{c} = W\vec{f}$ can reduce dimensionality from N to J by representing the image by J coefficients
- Idea: tailor a KLT to a specific set of training images representative of the recognition task to preserve the salient features

Eigenimages for recognition



Computing eigenimages from a training set

■ How to obtain $N \times N$ covariance matrix?

- Use training set $\vec{\Gamma}_1, \vec{\Gamma}_2, \dots, \vec{\Gamma}_L$ (each column vector represents one image)
- Let $\vec{\mu}$ be the mean image of all samples
- Define training set matrix $S = (\vec{\Gamma}_1 - \vec{\mu}, \vec{\Gamma}_2 - \vec{\mu}, \vec{\Gamma}_3 - \vec{\mu}, \dots, \vec{\Gamma}_L - \vec{\mu})$,

$$\text{and calculate scatter matrix } R = \sum_{l=1}^L (\vec{\Gamma}_l - \vec{\mu})(\vec{\Gamma}_l - \vec{\mu})^H = SS^H$$

Problem 1: Training set size should be $L \gg N$

If $L < N$, scatter matrix R is rank-deficient

Problem 2: Finding eigenvectors of an $N \times N$ matrix.

- ## ■ Can we find a small set of the most important eigenimages from a small training set $L \ll N$?

Sirovich and Kirby algorithm

- Instead of eigenvectors of SS^H , consider the eigenvectors of $S^H S$, i.e.,

$$S^H S \vec{v}_i = \lambda_i \vec{v}_i$$

- Premultiply both sides by S

$$SS^H S \vec{v}_i = \lambda_i S \vec{v}_i$$

- By inspection, we find that $S \vec{v}_i$ are eigenvectors of SS^H

Sirovich and Kirby Algorithm (for $L \ll N$)

- Compute the $L \times L$ matrix $S^H S$
- Compute L eigenvectors \vec{v}_i of $S^H S$
- Compute eigenimages corresponding to the $L_0 \leq L$ largest eigenvalues as a linear combination of training images $S \vec{v}_i$

L. Sirovich and M. Kirby, "Low-dimensional procedure for the characterization of human faces," *Journal of the Optical Society of America A*, 4(3), pp. 519-524, 1987.

Example: eigenfaces

- The first 8 eigenfaces obtained from a training set of 100 male and 100 female training images



Mean Face



Eigenface 1



Eigenface 2



Eigenface 3



Eigenface 4



Eigenface 5



Eigenface 6



Eigenface 7



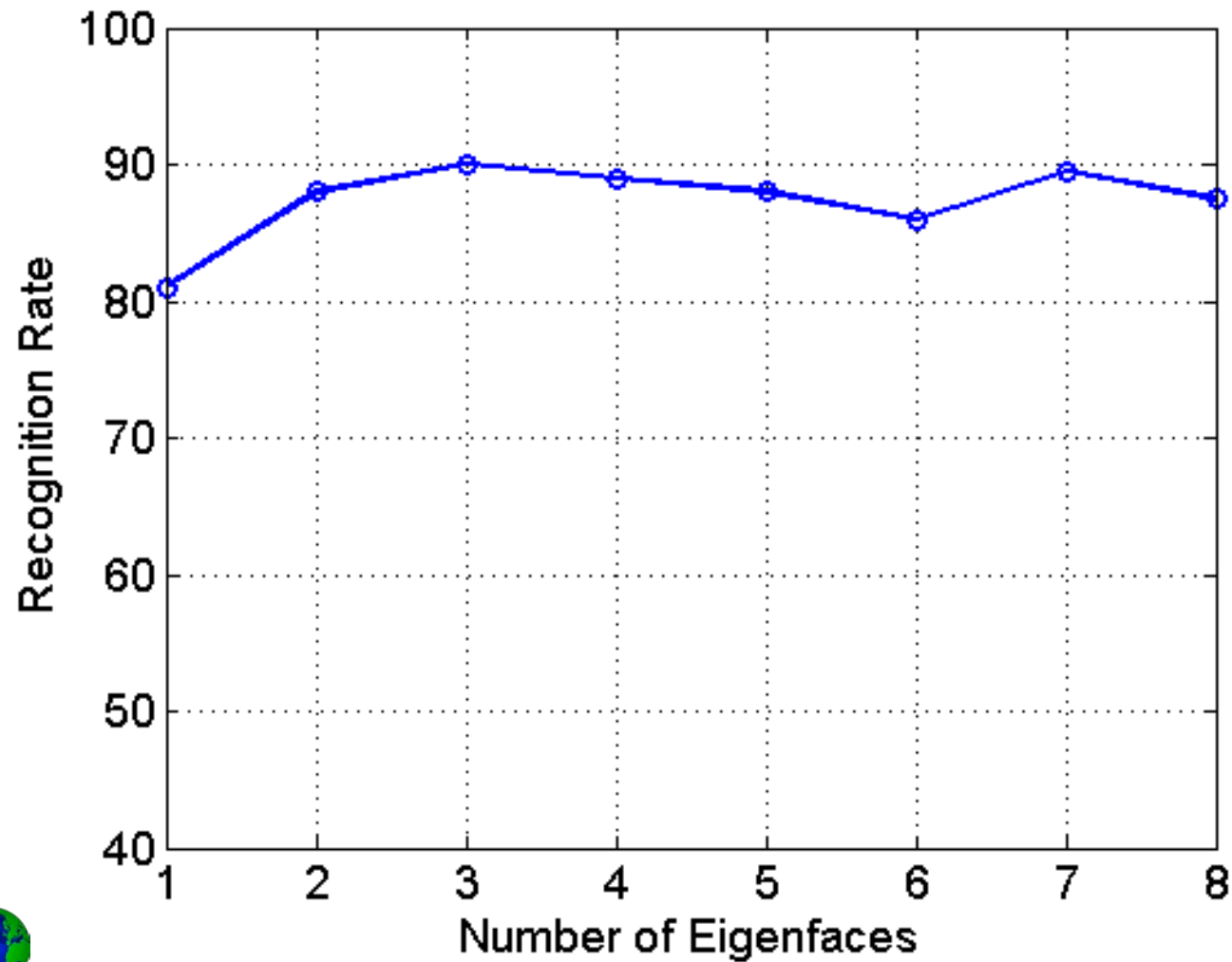
Eigenface 8

- Can be used to generate faces by adjusting 8 coefficients.
- Can be used for face recognition by nearest-neighbor search in 8-d „face space.“



Gender recognition using eigenfaces

Nearest neighbor search "face space"



Female face samples



Male face samples

