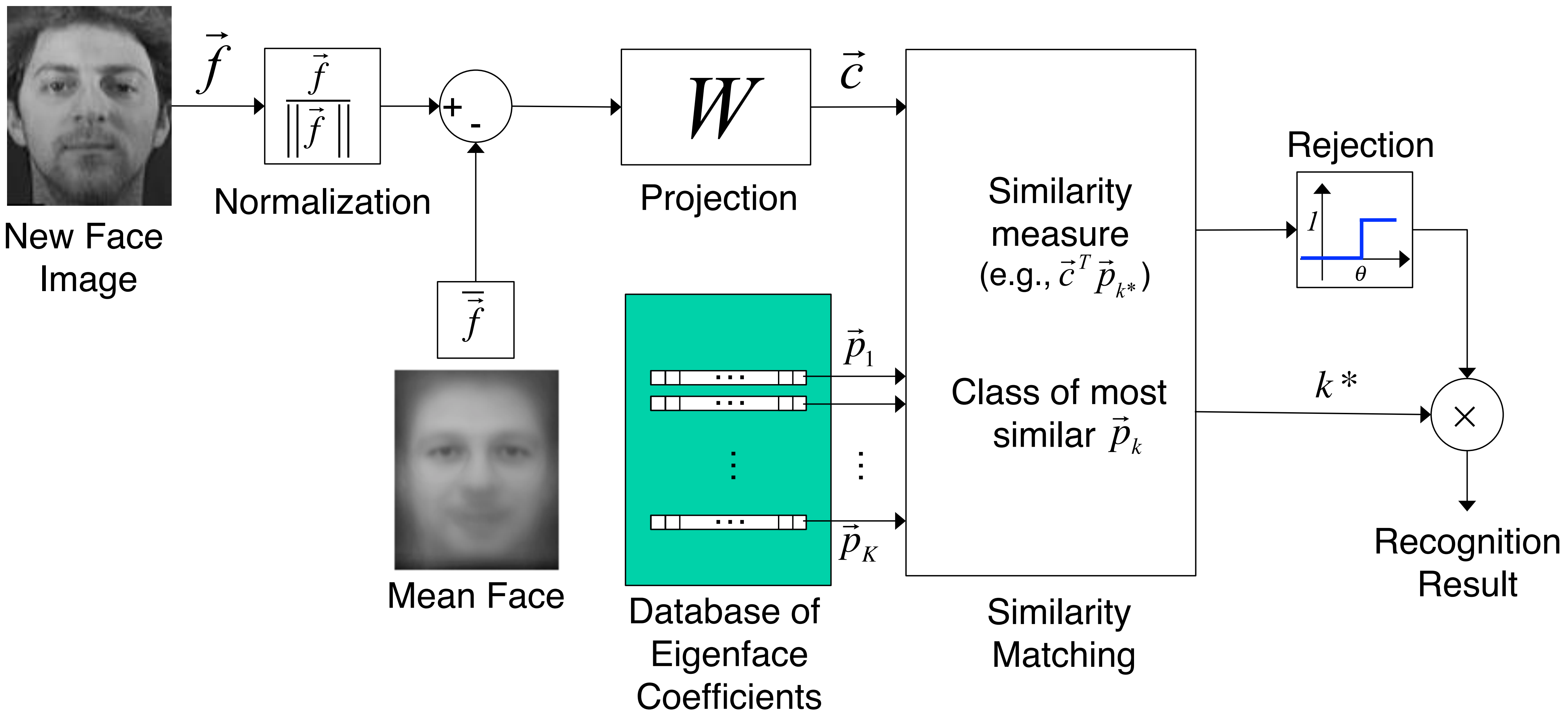
Eigenimages for recognition

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

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

  Problem 1: Training set size should be $L >> N$

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

  Problem 2: Finding eigenvectors of an NxN matrix.

- Can we find a small set of the most important eigenimages from a small training set $L << N$?

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 $L << N$)

- Compute the LxL 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

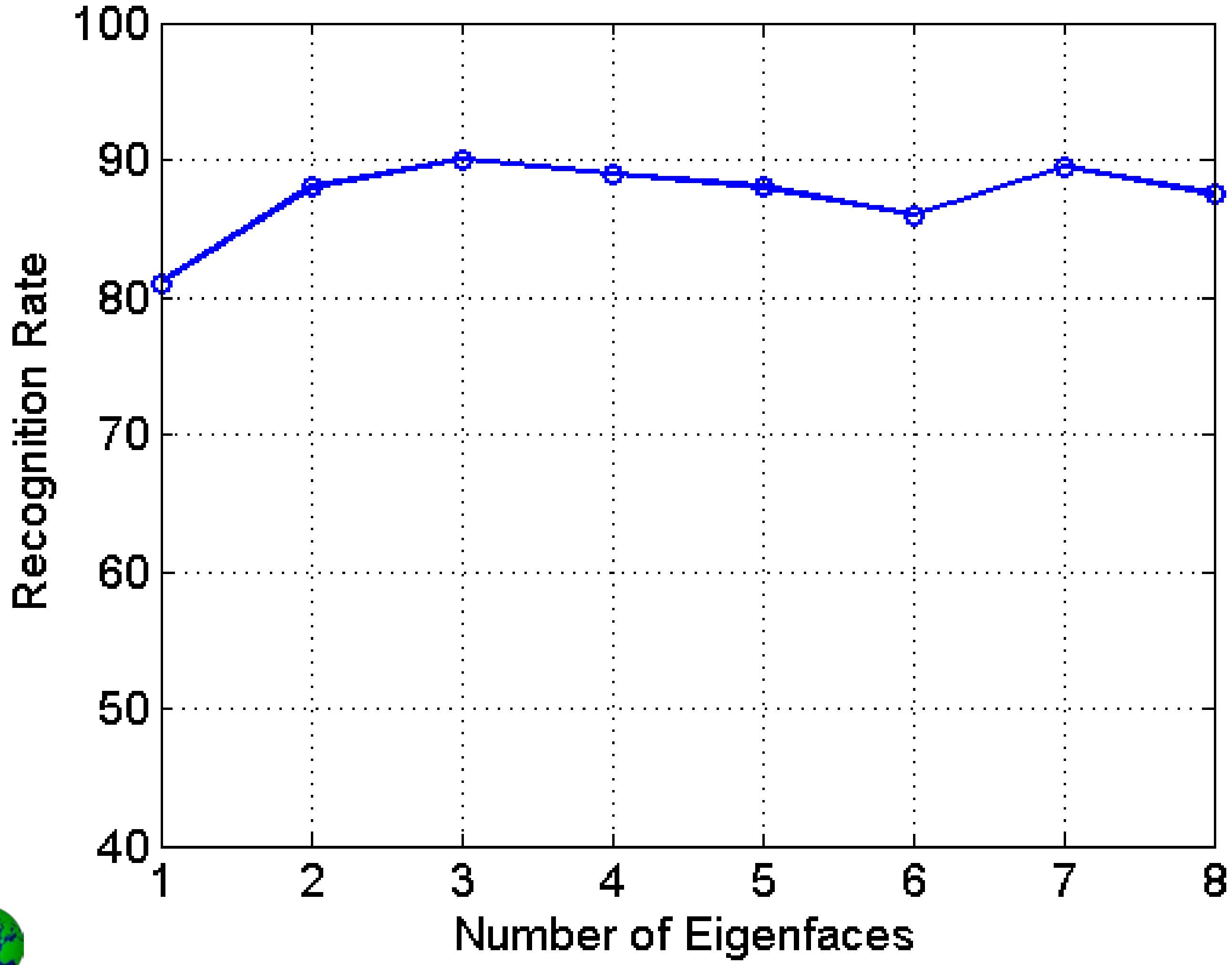

Eigenface 7


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