CSE185
Introduction to Computer Vision
Lab 11: Eigenfaces

Instructor: Prof. Ming-Hsuan Yang

TA: Taihong Xiao & Tiantian Wang

Eigenfaces

- Eigenfaces are a set of representative faces from a given dataset

AT&T Face dataset: http://www.cl.cam.ac.uk/research/dtg/attarchive/facedatabase.html

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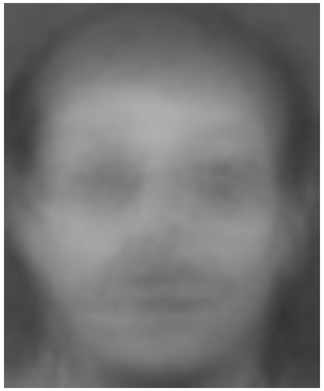
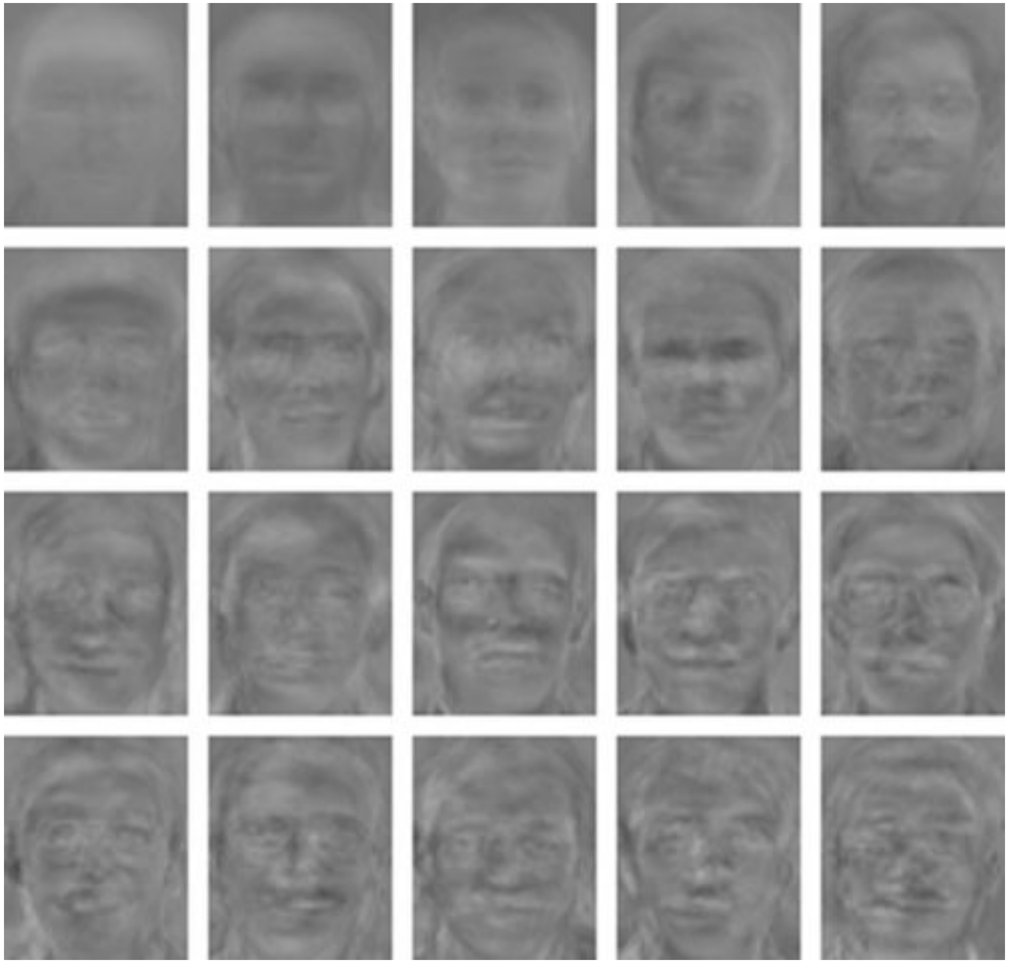


mean face

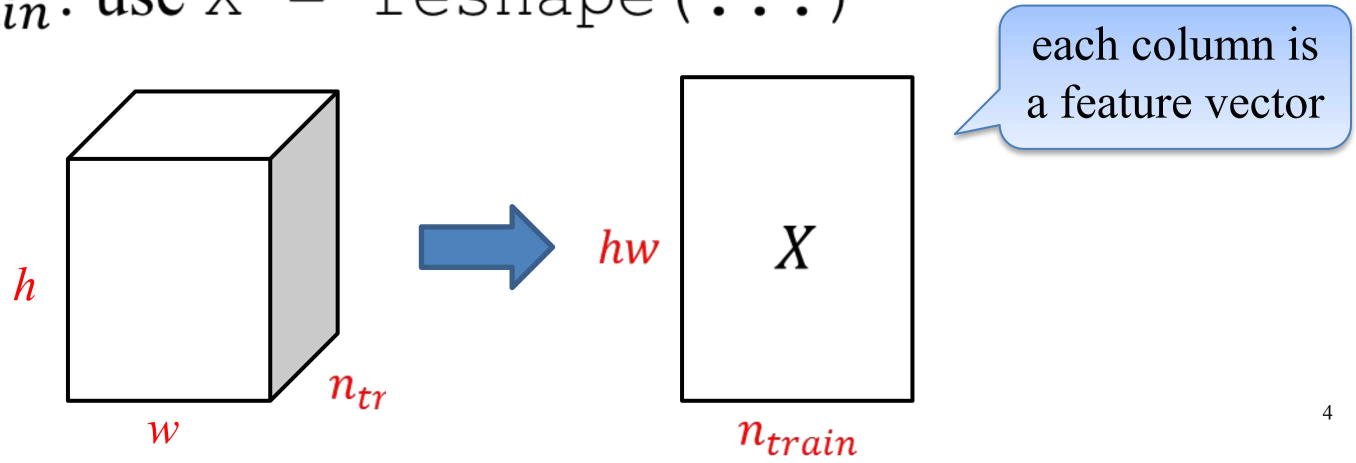


eigenfaces

Step 1: reshape training data

- Use `load('att_face.mat')` to load the mat file to your workspace:
  - `face_training` (56×46×40): training images
  - `face_testing` (56×46×160): testing images
  - `id_training` (40×1): the id/label of training images
  - `id_testing` (160×1): the id/label of testing images

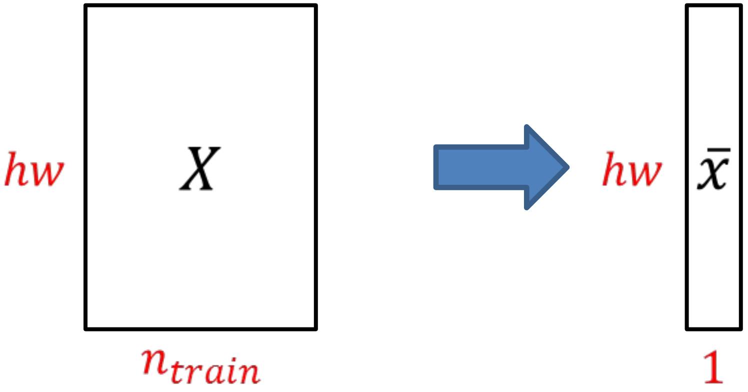
- Reshape `face_training` from $h \times w \times n_{train}$ to $(hw) \times n_{train}$: use `X = reshape(...)`



each column is a feature vector

Step 2: Mean Face

- Compute a mean face from X
  - $\bar{x}$ is a $hw \times 1$ vector



- Plot mean face by reshaping it back to $h \times w$

mean face

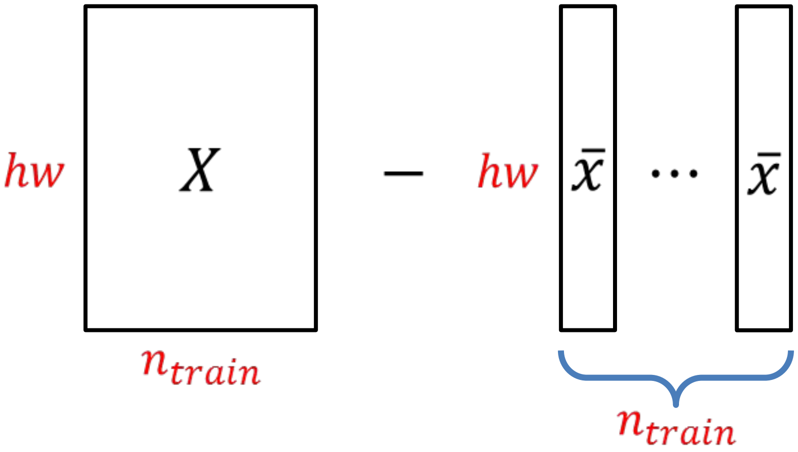
Step 3 : Covariance Matrix

- Covariance matrix:

$$C = \sum_i (x_i - \bar{x})(x_i - \bar{x})^T$$

x_i is a column of X

- 3 methods to subtract $\bar{x}$ from each column of X
  - use for loop
  - `Y = X - repmat(x_bar, 1, n_train);`
  - `Y = bsxfun(@minus, X, x_bar);`

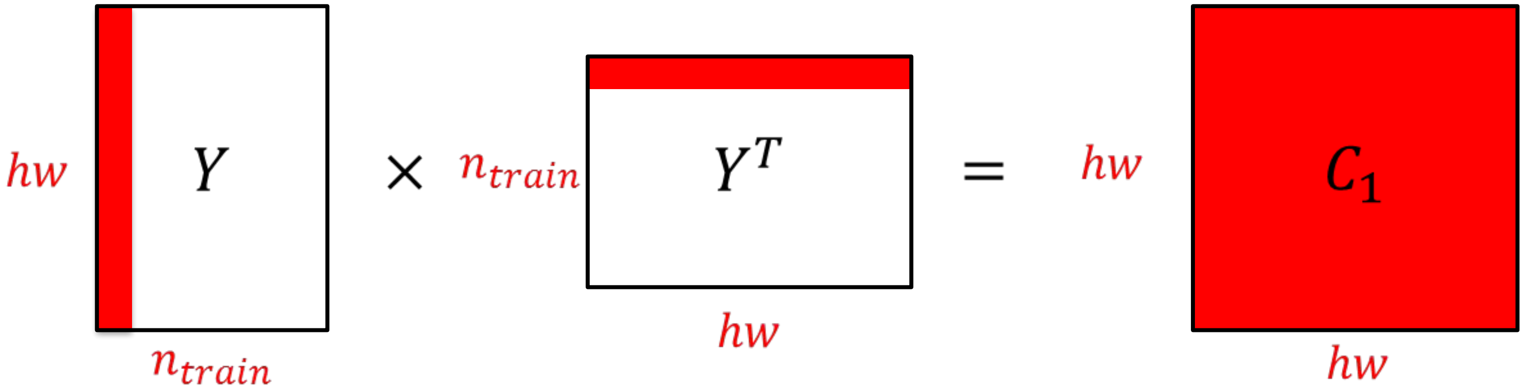


Step 3 : Covariance Matrix

- Covariance matrix, let $y_i = x_i - \bar{x}$:

$$C_{\mathrm{i}} = y_i y_i^T, \; C = \sum_i C_i$$

- Use for loop to compute and accumulate C_{i}:



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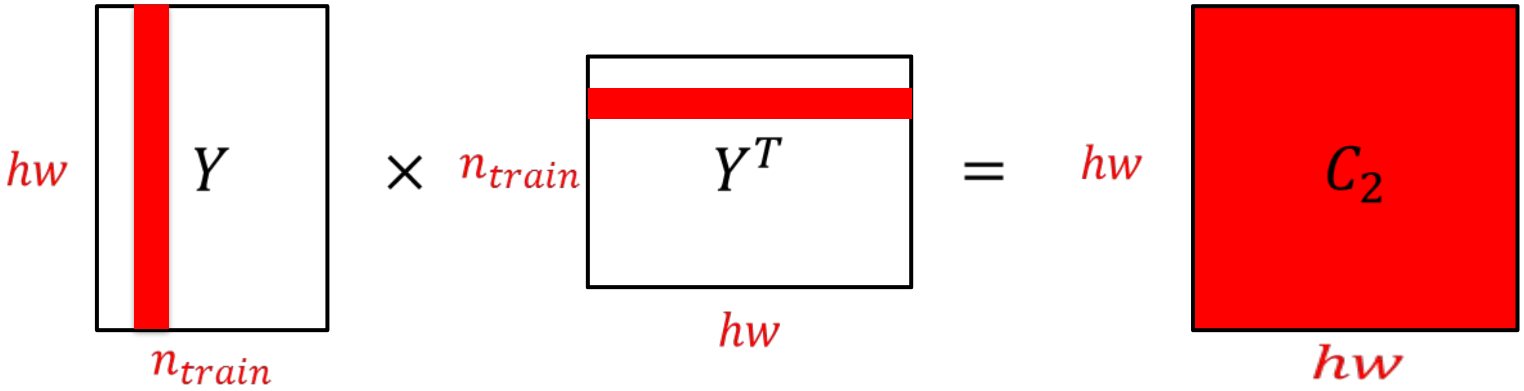

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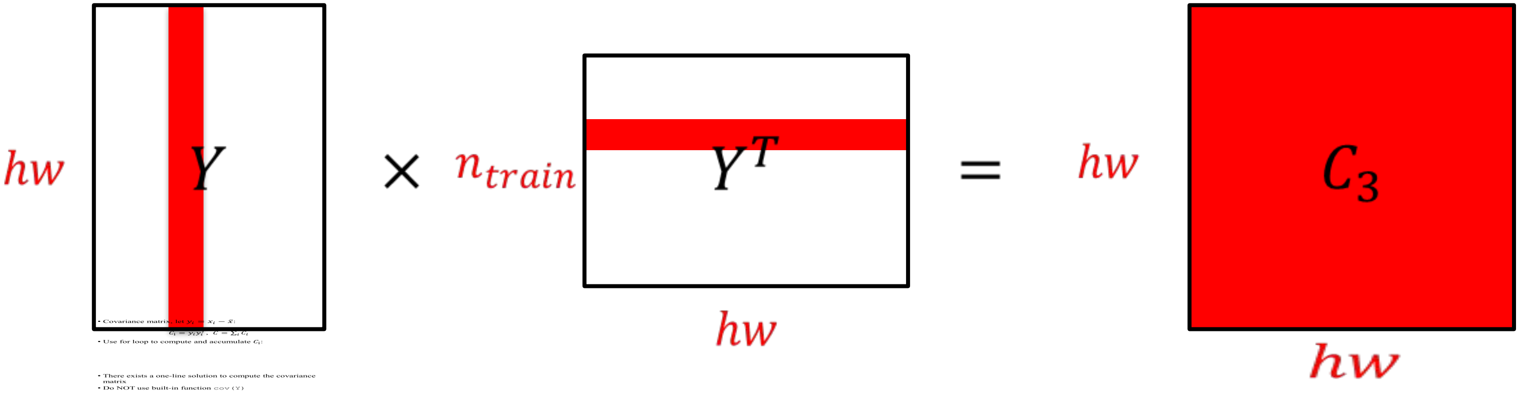

• Covariance matrix, let $y_i = x_i - \bar{x}$:
$C_{\mathrm{i}} = y_i y_i^T,\ C = \sum_i C_i$
• Use for loop to compute and accumulate C_{i}:
• There exists a one-line solution to compute the covariance matrix
• Do NOT use built-in function `cov(Y)`

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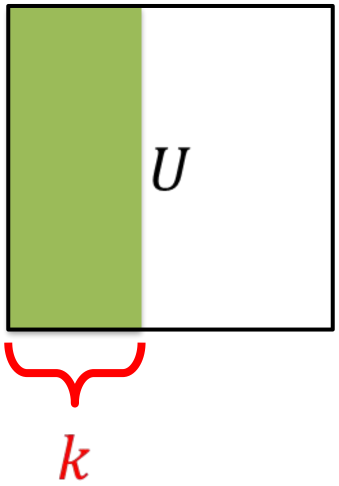
- Do NOT use built-in function `cov(Y)`

Step 4: Singular Value Decomposition

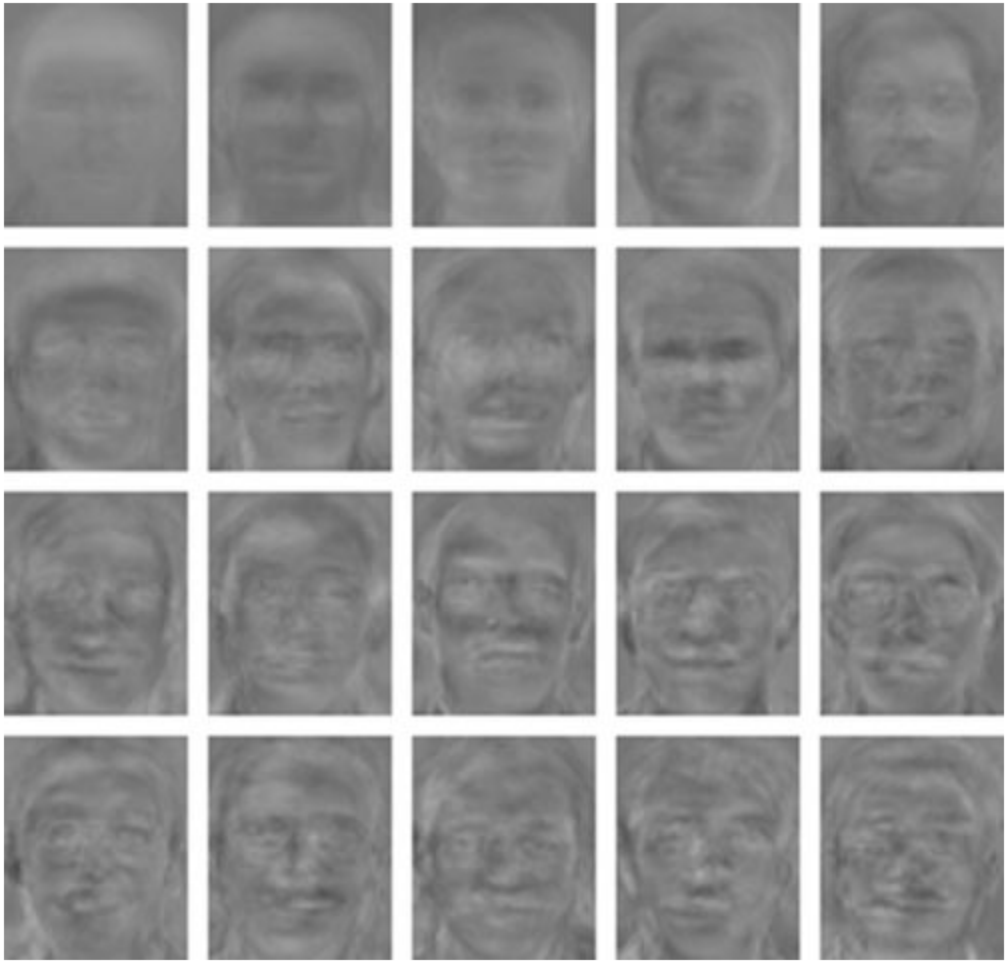
- Apply SVD to the covariance matrix:
  - `[U, S, D] = svd(C);`
  - columns in U are the eigen-vectors/eigenfaces

- Select the first *k* columns of U as our eigenfaces



Visualize Eigenfaces

- Reshape the column of U to $h \times w$, and add 0.5 or $\bar{x}$ before imshow



eigenfaces

Represent Face in the Face Space

- Represent each face image as coefficients of the eigenfaces

$$coef_i = (x - \bar{x}) \cdot u_i$$

inner product

- Encode each face image as the coefficients

```
x = face_training(:, :, 1);
x = x(:);
% subtract mean
x = ?
% inner product with U
coef = ?
```

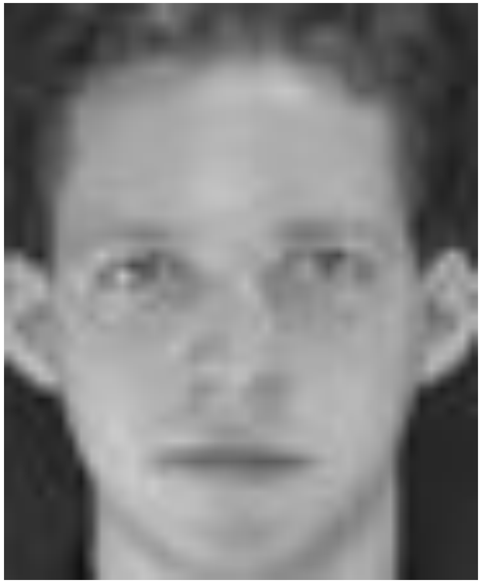
x, $\bar{x}$, and u_i are $hw \times 1$ vectors

coef is a $k \times 1$ vector

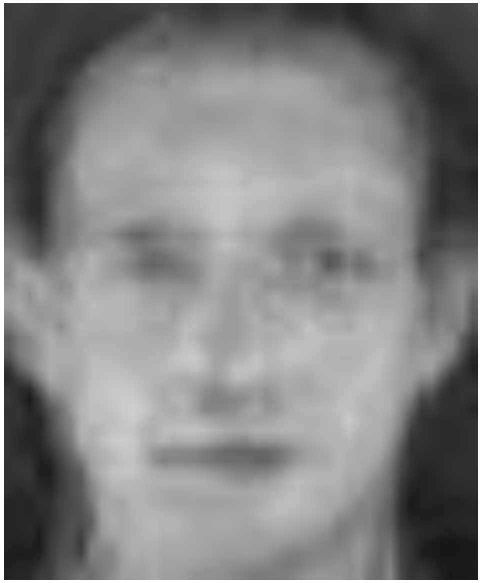
Reconstruct Image from the Face Space

- Given a coefficient vector $coef$ and mean face $\bar{x}$, we can reconstruct a face image by:

$$x_{rec} = \bar{x} + coef_1 u_1 + coef_2 u_2 + \cdots + coef_k u_k$$



input image



reconstruct image
k = 10

Reconstruct Image from the Face Space

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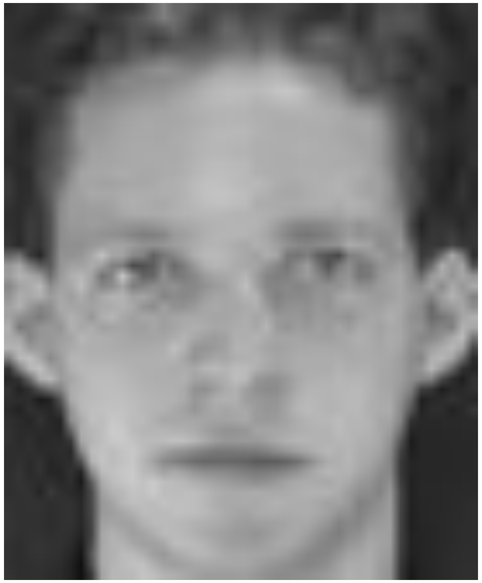

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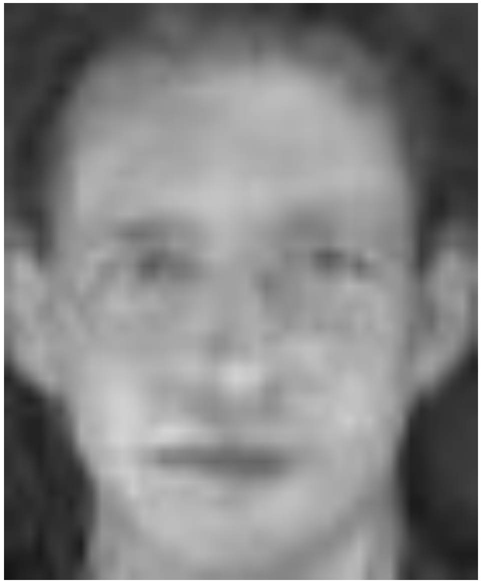

reconstruct image
k = 20

Reconstruct Image from the Face Space

- Given a coefficient vector $coef$ and mean face $\bar{x}$, we can reconstruct a face image by:

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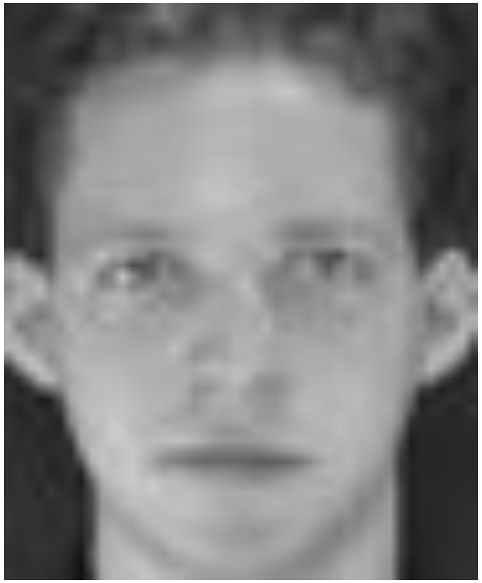

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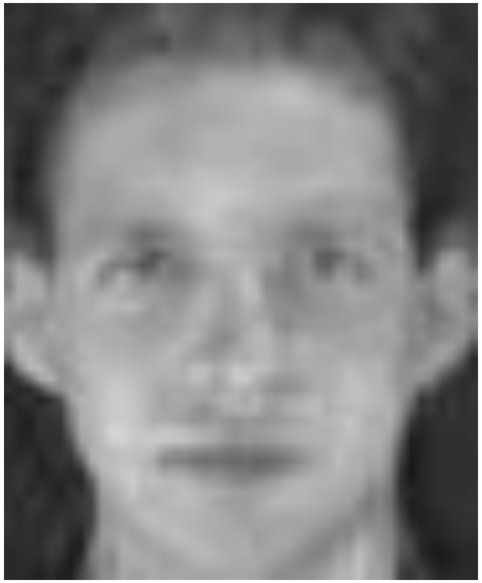


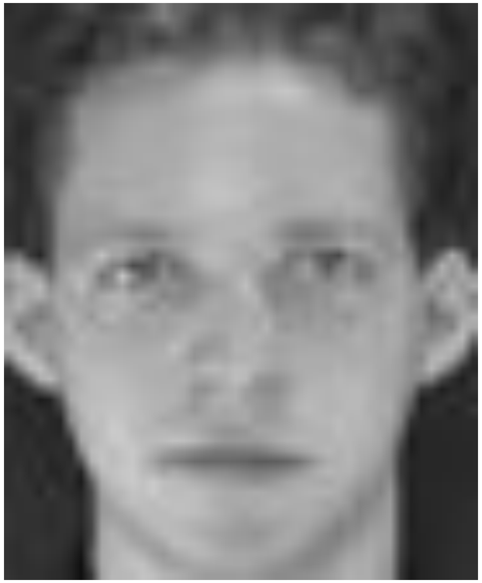
reconstruct image
k = 30

Reconstruct Image from the Face Space

- Given a coefficient vector $coef$ and mean face $\bar{x}$, we can reconstruct a face image by:

$$x_{rec} = \bar{x} + coef_1 u_1 + coef_2 u_2 + \cdots + coef_k u_k$$

input image



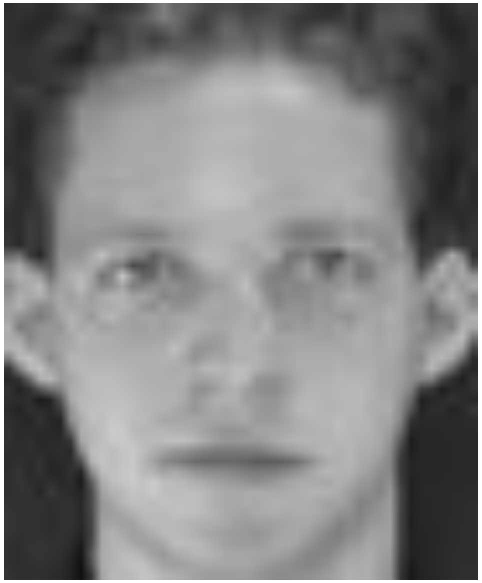
reconstruct image
k = 40

Reconstruct Image from the Face Space

- Given a coefficient vector $coef$ and mean face $\bar{x}$, we can reconstruct a face image by:

$$x_{rec} = \bar{x} + coef_1 u_1 + coef_2 u_2 + \cdots + coef_k u_k$$

input image



reconstruct image
k = 50

Face Recognition with Eigenfaces

- In lab06, we use Sobel features as feature vectors
- In this lab, we will use the coefficients of eigenfaces as feature vectors

```
coef_train = zeros(k, n_train);
% TODO: compute coef_train

id_predict = zeros(size(id_testing));
for i = 1:n_test
    img_test = face_testing(:, :, i);
    coef_test = ? % TODO: replace this line

    error = zeros(n_train, 1);
    for j = 1:n_train
        diff = coef_train(:, j) - coef_test;
        error(j) = sum( diff .^2 );
    end
```

Face Recognition with Eigenfaces

- Fill in the table with different *k*

```
%---------------------------------------%
%---------- Fill in this table ---------%
%---------------------------------------%
%   k   |  Accuracy |  Squared error
%---------------------------------------%
%  10   |        |
%---------------------------------------%
%  20   |        |
%---------------------------------------%
%  30   |        |
%---------------------------------------%
%  40   |        |
%---------------------------------------%
%  50   |        |
%---------------------------------------%
```

Assignment 11

- Run the lab11.m.
- Compute the accuracy and the squared error between the reconstructed faces and original ones.
- Fill in the table on Page 19.
- Write the table in one .pdf file and upload it.
- Compare the reconstruct images with input images. Upload the input and reconstruct images by using k=10, 20, 30, 40, 50.
- You have 2 weeks to finish this lab.