Homework #1

Deep Learning for Computer Vision

NTU, Fall 2020

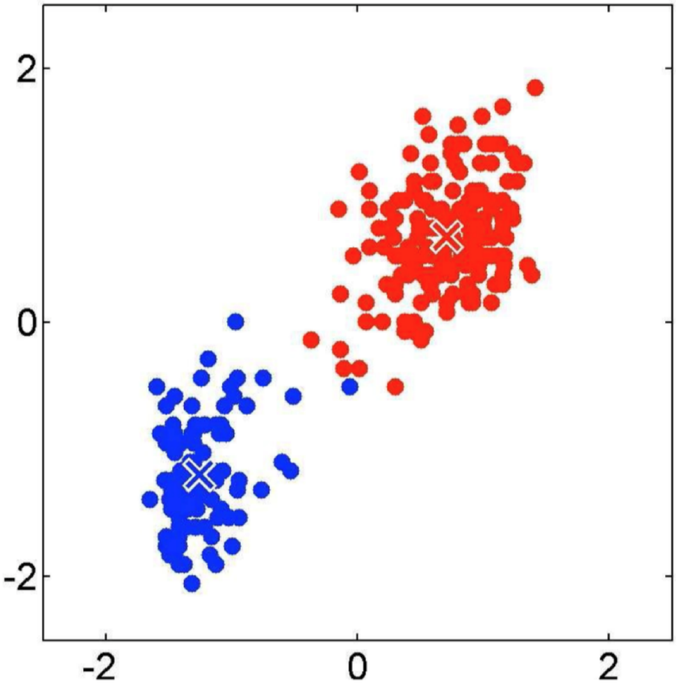
109/9/29

109/10/13 (Tue.) 02:00 AM due

Problem 1: K-Means Clustering

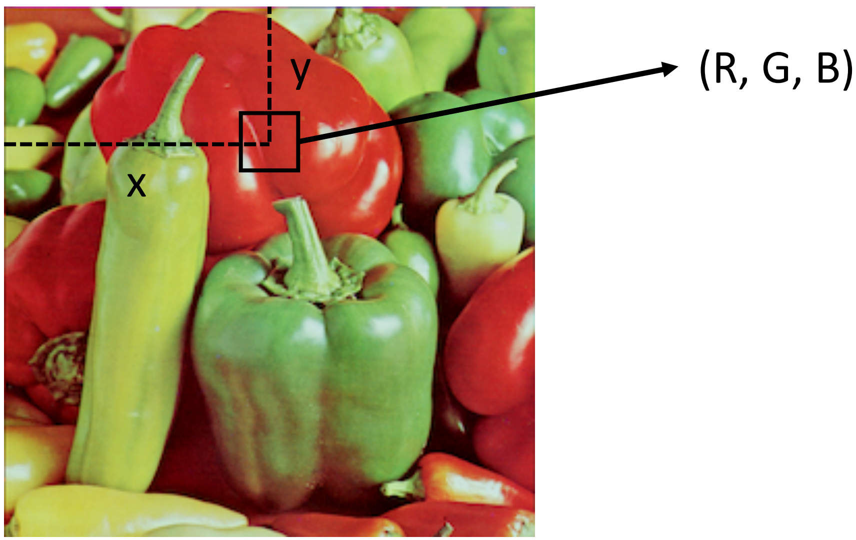
- Perform K-means clustering as taught in the lectures

- Example: K = 2



Problem 1: K-Means Clustering

- Perform K-means clustering on each pixel's color
- Perform K-means clustering on each pixel's color and location



Problem 1: K-Means Clustering

- Example: K-means clustering on each pixel's color with different number of clusters
  - For each clustering group, replace all pixels' RGB values with that of the cluster center

K = 2

K = 4

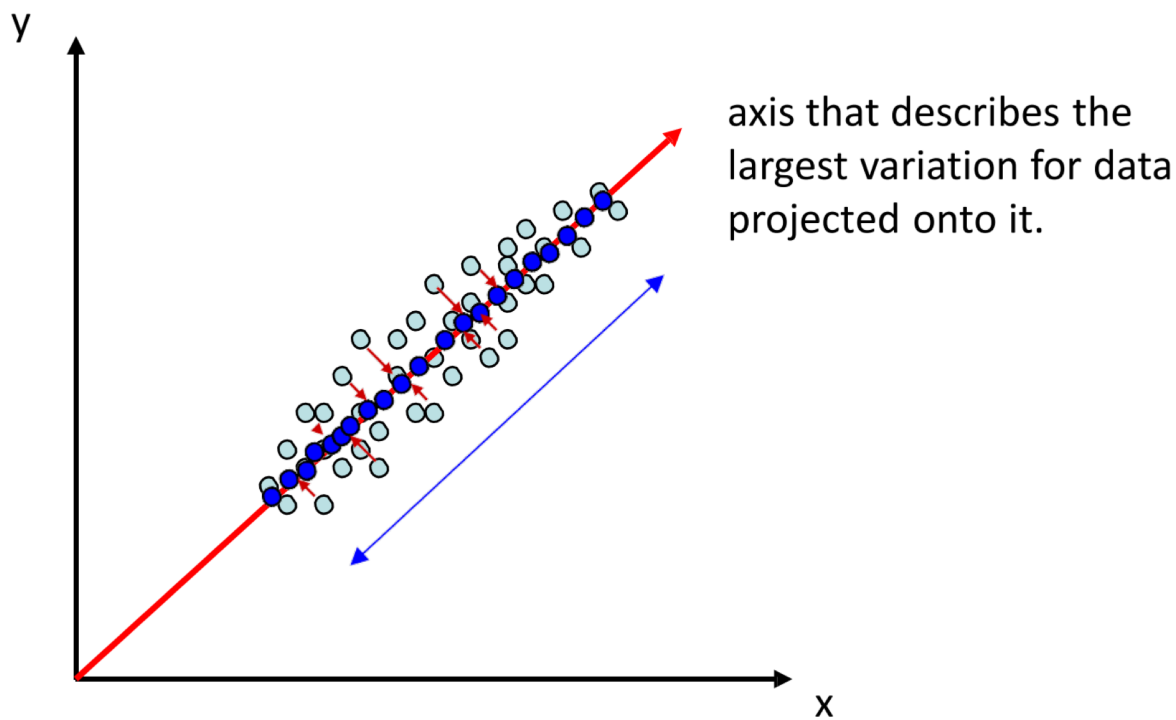
K = 8

K = 16

K = 32

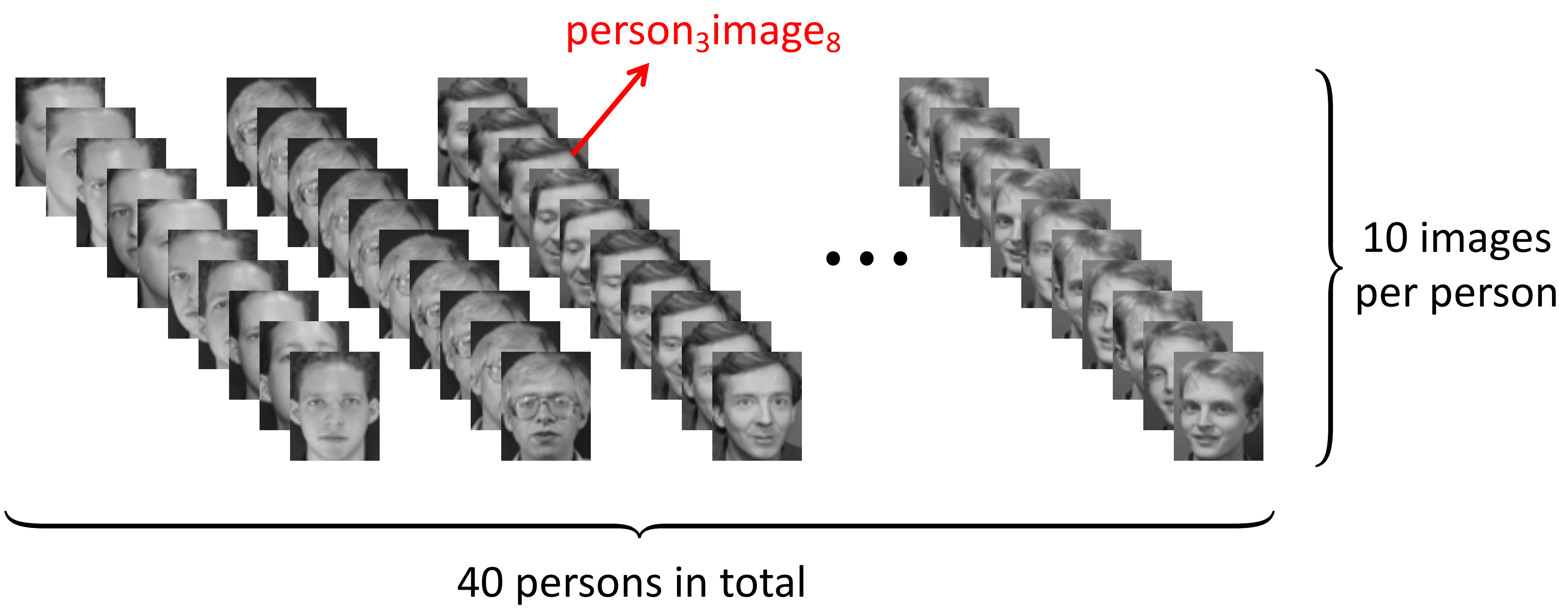
Problem 2: Principle Component Analysis

- Perform PCA as taught in the lectures



Problem 2: Principle Component Analysis

- Perform PCA as taught in the lectures
- Dataset



Problem 2: Principle Component Analysis

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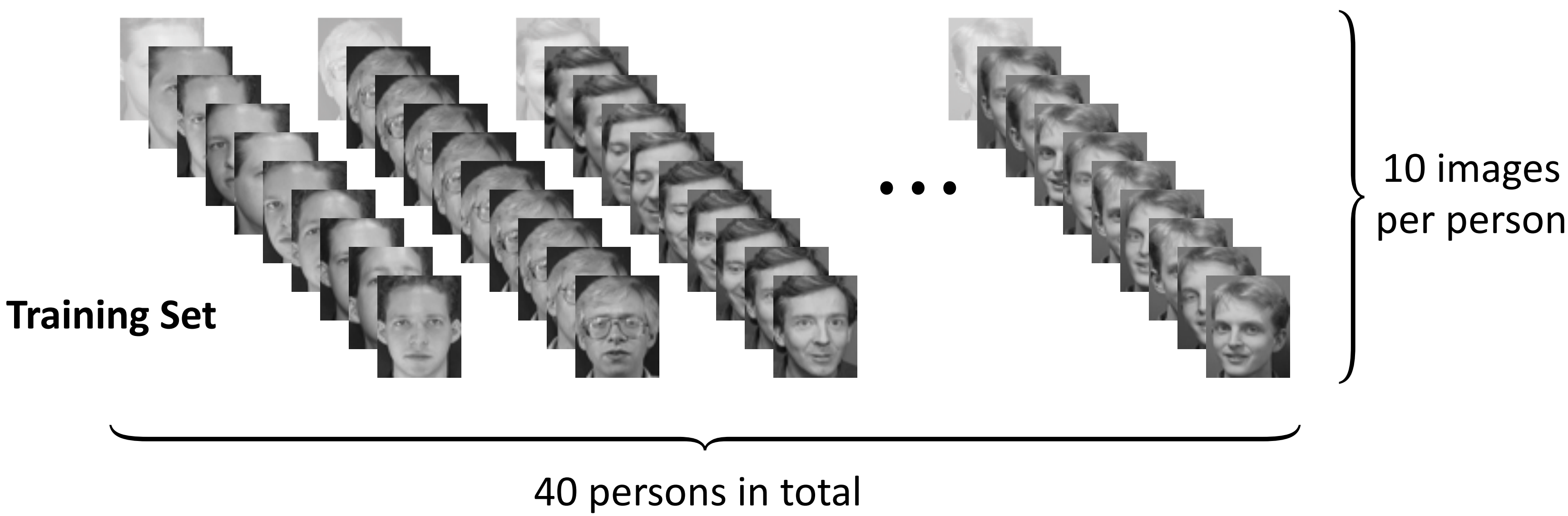

Problem 2: Principle Component Analysis

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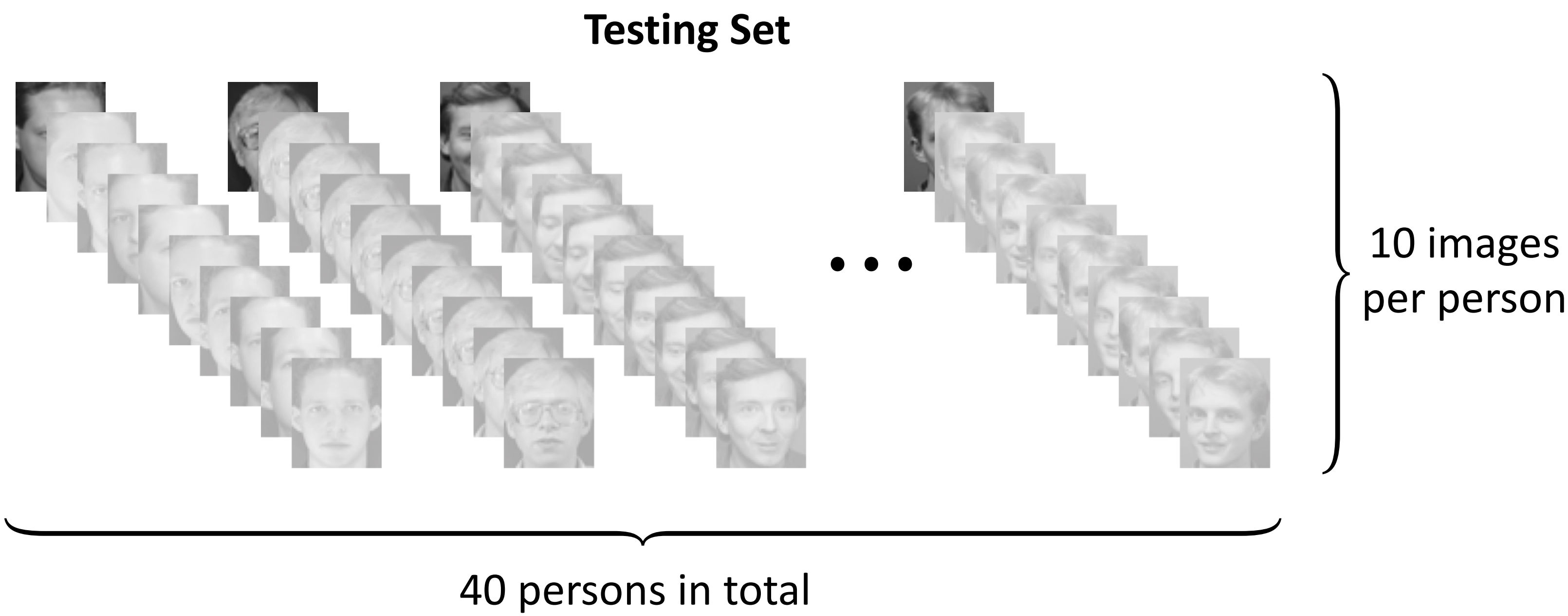
- Dataset

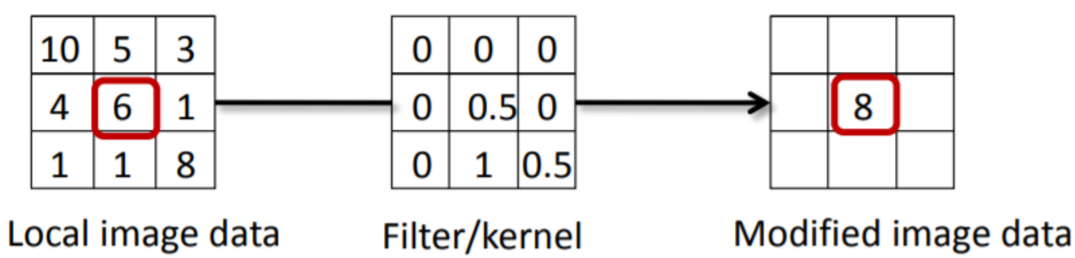


Problem 2: Principle Component Analysis

- Plot the mean face and eigenfaces
- Project face images onto the eigenspace
- Plot the reconstructed image
- Compute mean squared error
- Apply k-nearest neighbors for classification

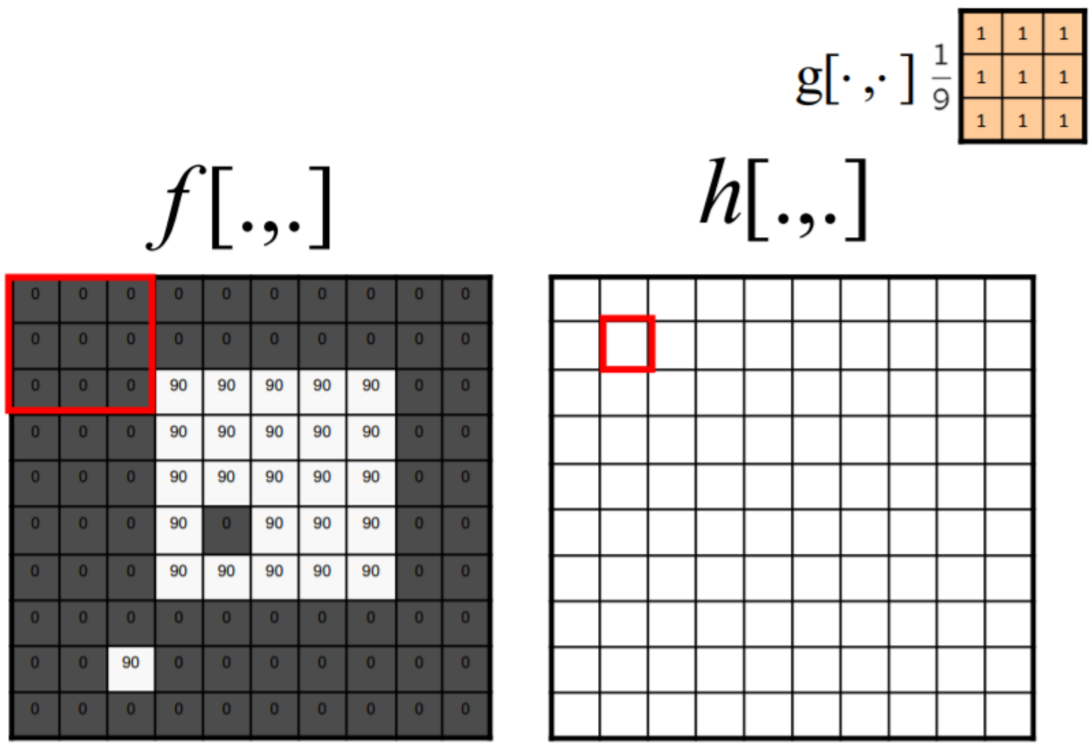
Problem 3: Image Filtering

- What's Image Filtering?
  - Image Filtering
    - For each pixel of interest, compute the function of local neighborhood and output the new value.
    - Generally (while not always true), same function applied to each position
  - Linear filtering
    - function is a weighted sum/difference of pixel values (all the filtering methods we use in this homework are linear filtering)



Problem 3: Image Filtering

- Example: Image Filtering with a Box Filter

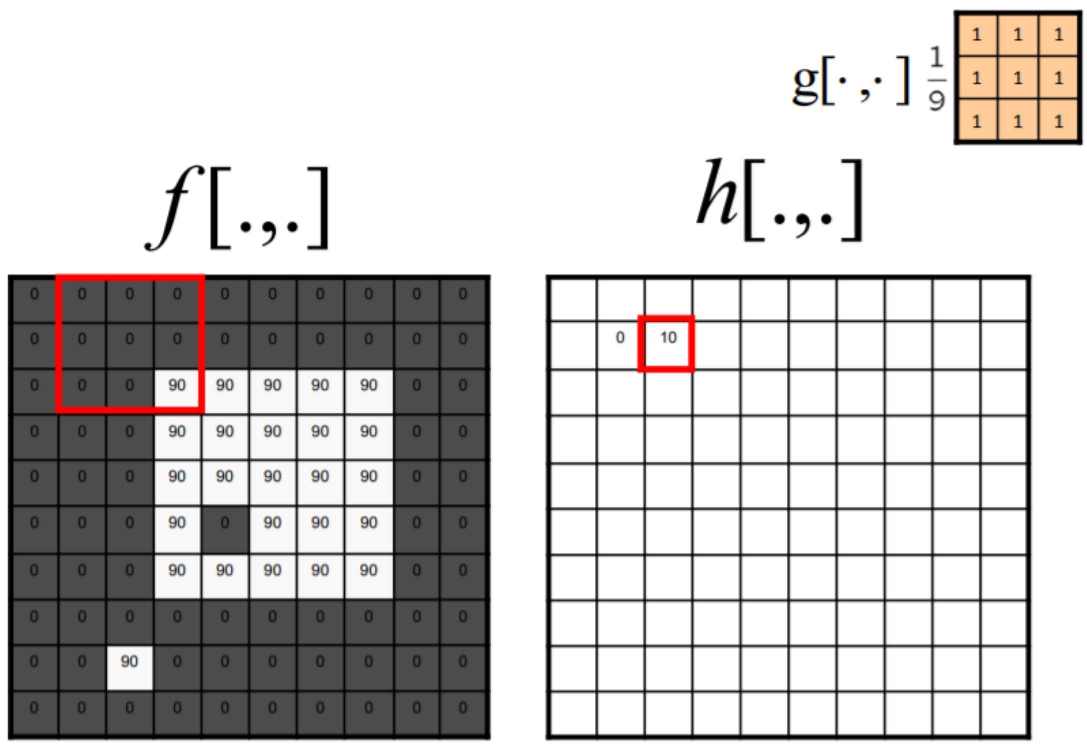


$$h[m,n] = \sum_{k,l} g[k,l]\, f[m+k, n+l]$$

Slide credit: S. Seitz

Problem 3: Image Filtering

- Example: Image Filtering with a Box Filter



$$h[m,n]=\sum_{k,l} g[k,l]\, f[m+k,n+l]$$

Slide credit: S. Seitz

Problem 3: Image Filtering

- Example: Image Filtering with a Box Filter

$$g[\cdot,\cdot]\ \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

$$f[.,.] = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 90 & 90 & 90 & 90 & 90 & 0 & 0 \\
0 & 0 & 0 & 90 & 90 & 90 & 90 & 90 & 0 & 0 \\
0 & 0 & 0 & 90 & 90 & 90 & 90 & 90 & 0 & 0 \\
0 & 0 & 0 & 90 & 0 & 90 & 90 & 90 & 0 & 0 \\
0 & 0 & 0 & 90 & 90 & 90 & 90 & 90 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 90 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

$h[.,.]$

	0	10	20						

$$h[m,n] = \sum_{k,l} g[k,l]\, f[m+k, n+l]$$

Slide credit: S. Seitz

Problem 3: Image Filtering

- Example: Image Filtering with a Box Filter

$$g[\cdot,\cdot] \quad \frac{1}{9}\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix}$$

$f[.,.]$

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$h[.,.]$

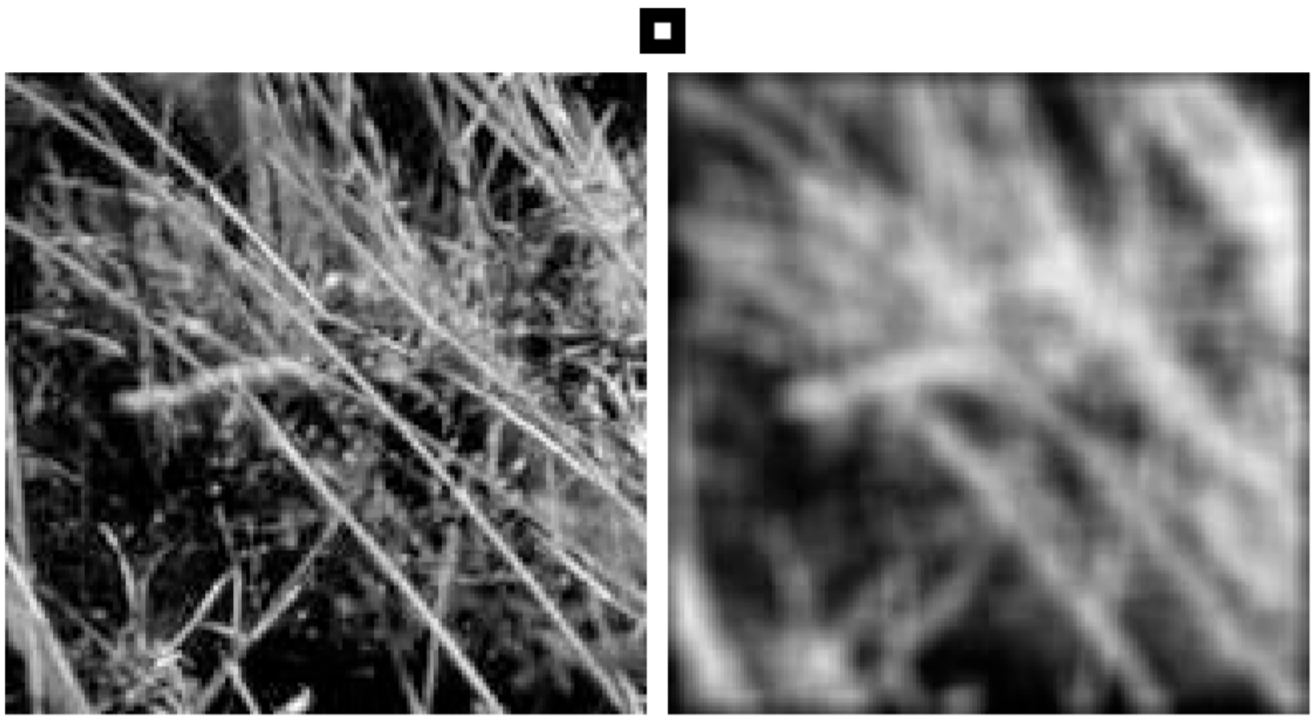
	0	10	20	30	30	30	20	10	
	0	20	40	60	60	60	40	20	
	0	30	60	90	90	90	60	30	
	0	30	50	80	80	90	60	30	
	0	30	50	80	80	90	60	30	
	0	20	30	50	50	60	40	20	
	10	20	30	30	30	30	20	10	
	10	10	10	0	0	0	0	0	

$$h[m,n] = \sum_{k,l} g[k,l]\, f[m+k, n+l]$$

Slide credit: S. Seitz

Problem 3: Image Filtering

- Smoothing with a Box Filter



Slide credit: S. Seitz

Problem 3: Image Filtering

- Rewrite the formulation of box filtering.

$$G[i,j] = \underbrace{\frac{1}{(2k+1)^2}}_{\substack{\textit{Attribute uniform weight} \\ \textit{to each pixel}}} \underbrace{\sum_{u=-k}^{k} \sum_{v=-k}^{k} F[i+u, j+v]}$$

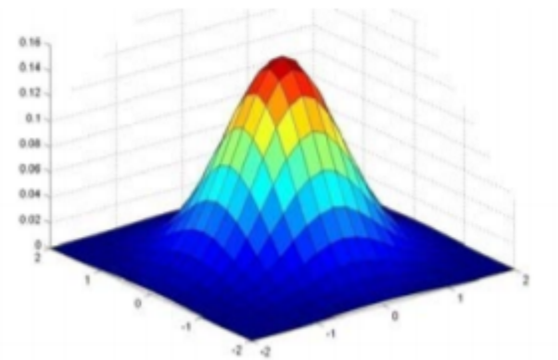
- Now generalize to allow different weights depending on neighboring pixel's relative position:

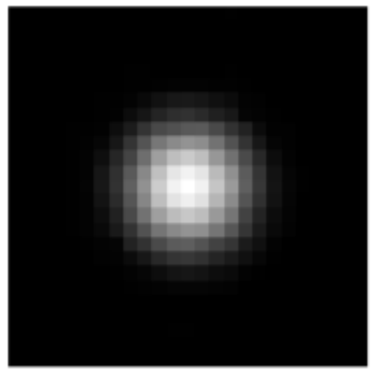
$$G[i,j] = \sum_{u=-k}^{k} \sum_{v=-k}^{k} \underbrace{H[u,v]} F[i+u, j+v]$$

Slide credit: S. Seitz

Problem 3: Image Filtering

- Gaussian Filter





0.003	0.013	0.022	0.013	0.003
0.013	0.059	0.097	0.059	0.013
0.022	0.097	0.159	0.097	0.022
0.013	0.059	0.097	0.059	0.013
0.003	0.013	0.022	0.013	0.003

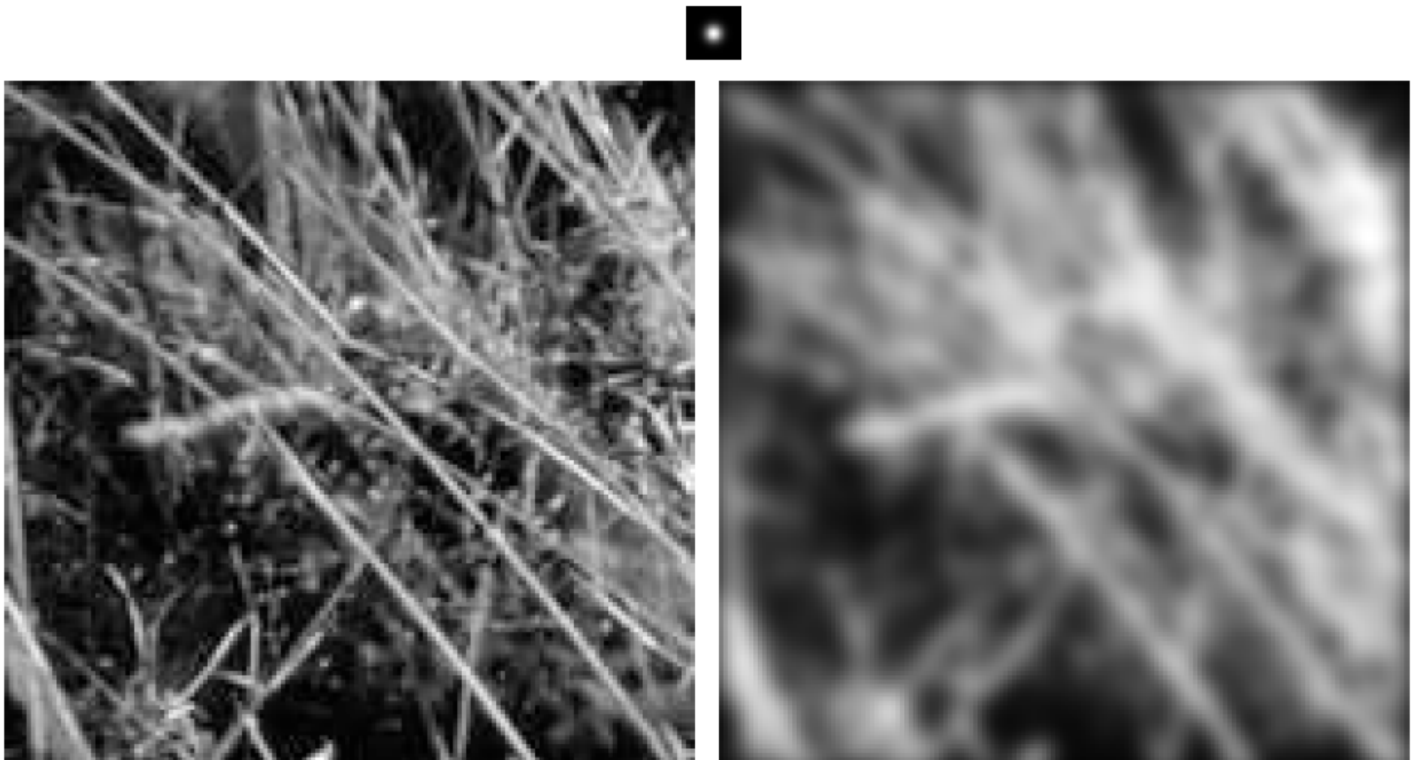
5 x 5, σ = 1

$$G_\sigma = \frac{1}{2\pi\sigma^2} e^{-\frac{(x^2+y^2)}{2\sigma^2}}$$

Slide credit: S. Seitz

Problem 3: Image Filtering

- Smoothing with a Gaussian Filter



Slide credit: S. Seitz

Problem 3: Image Filtering

- Convolution

$$G[i,j] = \sum_{u=-k}^{k} \sum_{v=-k}^{k} H[u,v]F[i-u, j-v]$$

$$G = H \star F$$

Notation for convolution operator

Slide credit: S. Seitz

Problem 3: Image Filtering

- Implement a simple 2D Gaussian filter
- Apply edge detection using derivatives of pixel values
- Plot the detected vertical and horizontal edges
- Plot the gradient magnitude image

Remarks

- You are allowed to use **any** programming language you desire, including all related packages/functions.
- In your report, provide detailed explanations or discussions about your answer.
- If unsure about your answer, write down how you obtained it as detailed as possible.