EE 4211 Computer Vision

Lecture 13: Summary and Presentation

Semester B, 2021-2022

Schedules

Week	Date	Topics
1	Jan. 11 (face to face)	Introduction/Imaging
2	Jan. 18 (online)	Image enhancement in spatial domain
3	Jan. 25 (online)	Image enhancement in frequency domain (HW1 out)
4	Feb. 8 (online)	Morphological processing
5	Feb. 15 (online)	Image restoration (HW1 due)
6	Feb. 22 (online)	Midterm (no tutorials this week)
7	Mar. 1 (online)	Edge detection (HW2 out)
8	Mar. 8 (online)	Image segmentation
9	Mar. 15 (online)	Face recognition with PCA, LDA (tutorial on segmentation) (HW2 due)
10	Mar. 22 (online)	Face recognition based on deep learning (Quiz on two code questions, 1 hour) Image segmentation based on deep learning
11	Mar. 29 (online)	Object detection with traditional methods Object detection based on deep learning (tutorial on detection)
12	Apr. 5	Events / Public Holidays
13	Apr. 12 (online)	Summary and Invited project presentation

Course Content

- First for the summary and the report information
- Then 6 group students will do presentation with the following sequence

55771909	CHAN Ka Yang	5 detection
56224506	LAU Shing Kuen	5 detection
55359060	LO Yuk Long	5 detection
55809965	WONG Ho Sum	5 detection
55691100	CHOW Wai Kit	13 Detection
55228060	KUK Man Ho	13 Detection
55691239	NG Chun Hei	13 Detection
56063675	NG King Hon	13 Detection
55956246	NANDI Mitsumi	3 Detection
55907774	PATRA Yuvraj	3 Detection
55877661	RAHMAN Alvi	3 Detection
55701944	CHAN Yiu Yu	10 Segmentation
56204372	CHENG Cheung Yu	10 Segmentation
56046680	LEUNG Chun Wai	10 Segmentation
55670096	RUAN Yuyan	10 Segmentation
55709099	LAI Daniel	8 Segmentation
55689686	TSO Tsz Shing	8 Segmentation
55678611	YANG Alva	8 Segmentation
55679306	CHAN Timothy Chit Yin	14 Segmentation
55701030	CHENG Kwan Ho	14 Segmentation
55684920	TSUI Wai Chiu	14 Segmentation

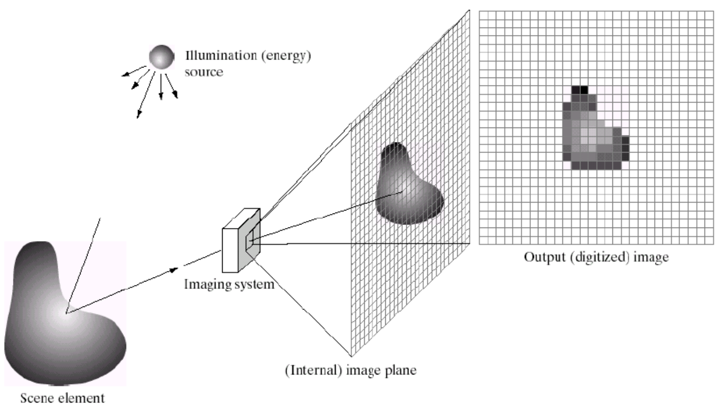
- 10 mins for presentation and ~5 mins for Q & A

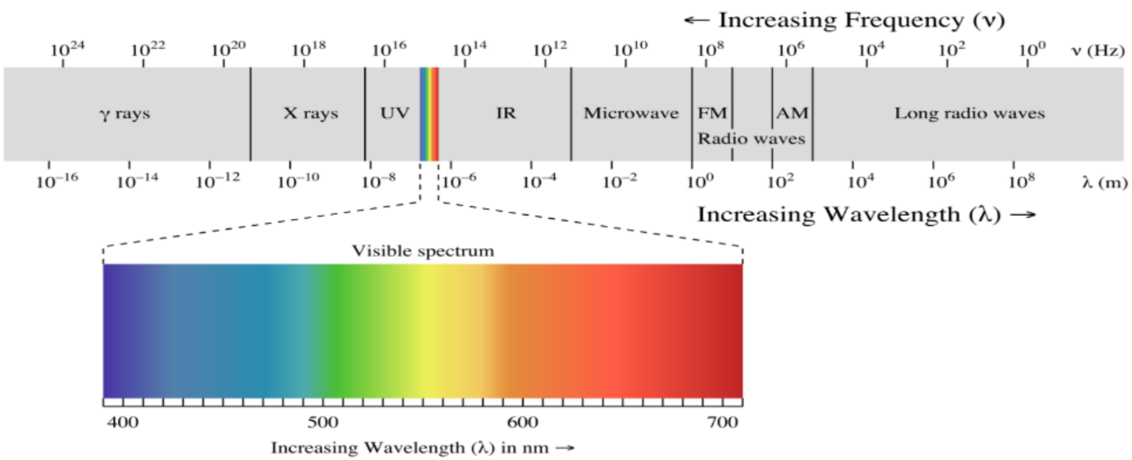
Final exam

- Online mode May 6th, 9:30 AM -11:30 AM
- 10% Multiple answers, 10% True/False, 80% calculation and understanding questions
- You are responsible for receiving the questions on Canvas, except the Multiple answers and True/False questions, please hand-write all answers on blank answer sheets, compile the answers into a single PDF file, and upload the file to canvas/assignment before the deadline of the exam.
- You have extra 15 mins to upload your results through canvas/assignment
- If you found there are some problems to upload your results, please send me your results through email asap (yxyuan.ee@cityu.edu.hk)

Lecture 1: Digital image fundamentals

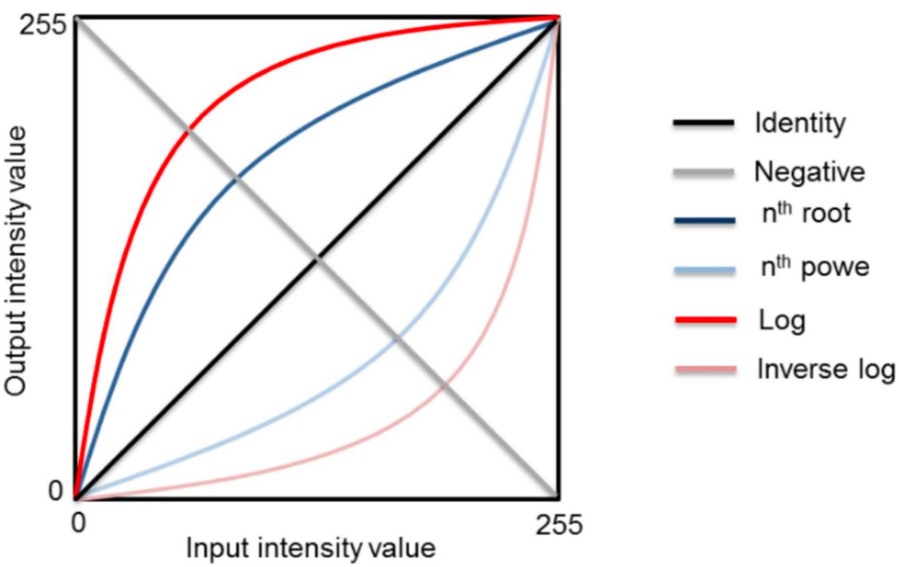
- Section
  - How to visualize light: Reflected light, Absorbed light, Emitted light
  - Different image systems: the differences, the suitable applications
  - For example, X-Rays can be utilized to identify the holes in the dental
  - Microwave Imaging can be utilized for weather forecast

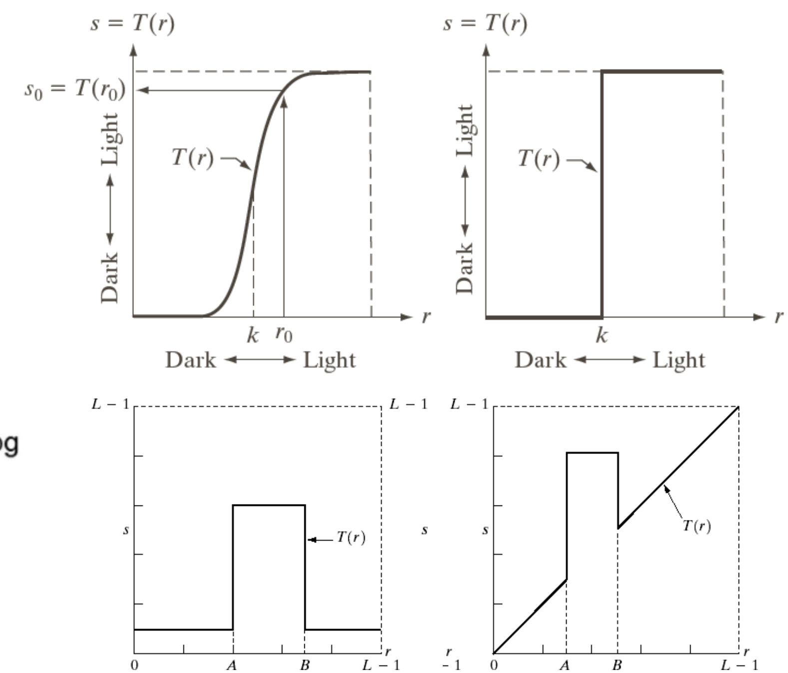




Lecture 2: Image enhancement: Spatial Domain

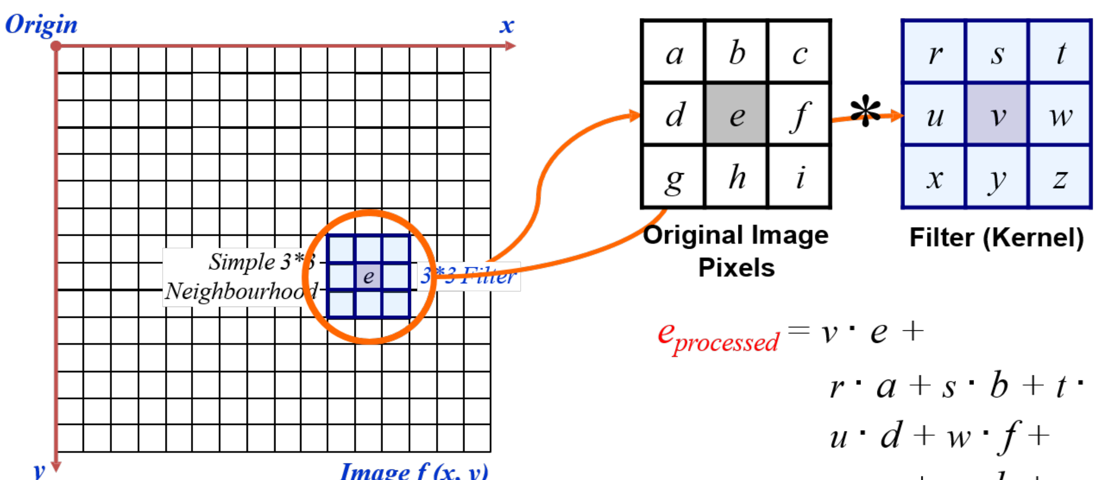
- Point processing – Gray values change without any knowledge of its surroundings (Part I)(subjective)
  - Log, power-law, linear, piecewise linear (Contrast Stretching, Intensity-level Slicing)
  - Histogram Equalization (pdf->cdf->transformation) (calculate)





Lecture 2: Image enhancement: Spatial Domain

- Neighborhood processing (filtering) – Gray values change depending on the gray values in a small neighborhood of pixels around the given pixel (Part I)
  - Smoothing filters: Averaging filters, Order-Statistics filters
  - Median filters
  - Sharpening: Laplacian filters, Sobel filter



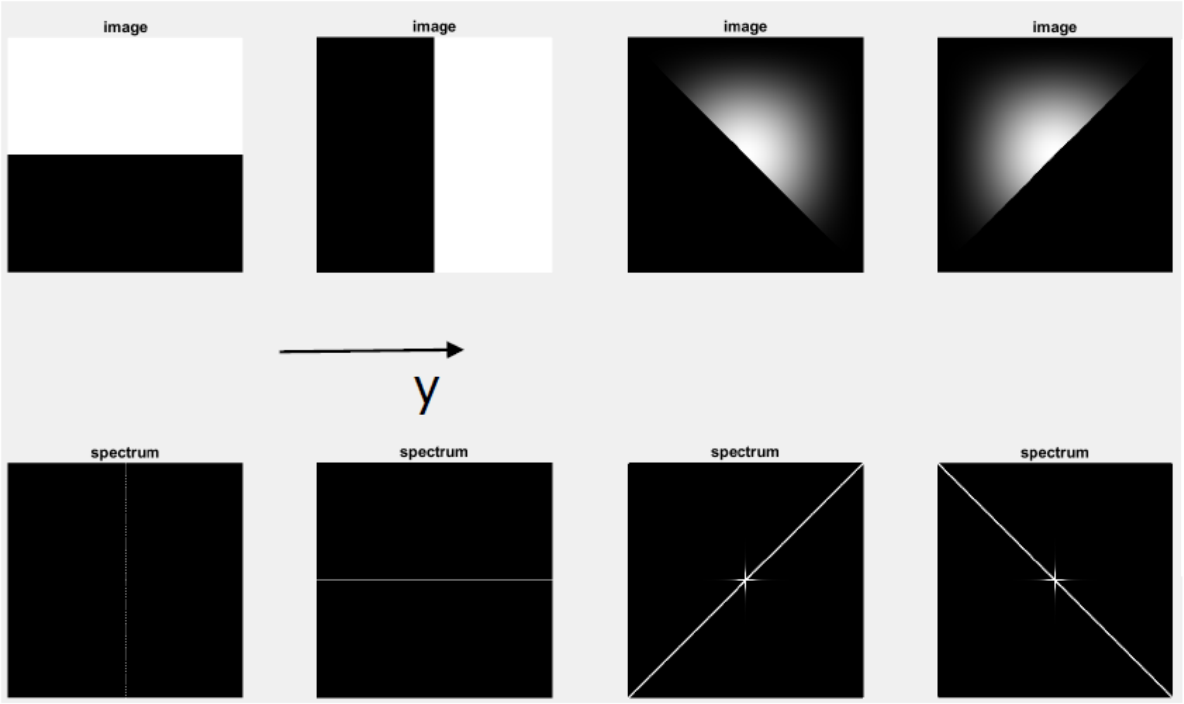
$$e_{processed} = v \cdot e + r \cdot a + s \cdot b + t \cdot c + u \cdot d + w \cdot f + x \cdot g + y \cdot h + z \cdot i$$

0	−1	0
−1	4	−1
0	−1	0

−1	−1	−1
−1	8	−1
−1	−1	−1

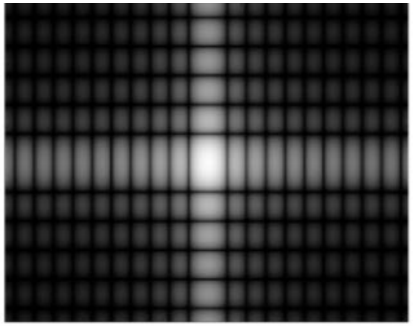
Lecture 3: Image enhancement: Frequency Domain

- Frequency transformation (matching image with spectrum)
- Need to know specific corresponding information
  - The longitudinal periodic changes in the spatial domain are reflected on the X-axis of the spectrum
  - The periodic change across horizon in the spatial domain is reflected on the Y-axis of the spectrum



Important Fourier Transform Pairs

rectangle centred at origin
with sides of length X and Y



$f(x,y)$ $|F(u,v)|$

When X is larger than Y, then the value

$$F(u,v) = \int\int f(x,y) e^{-j2\pi(ux+vy)} dx dy,$$

$$= \int_{-X/2}^{X/2} e^{-j2\pi ux} dx \int_{-Y/2}^{Y/2} e^{-j2\pi vy} dy,$$

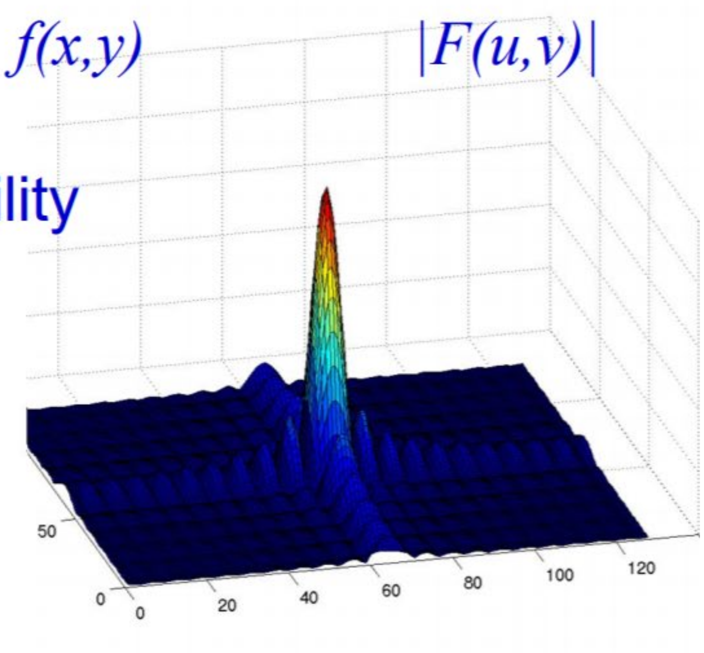
separability

$$= \left[\frac{e^{-j2\pi ux}}{-j2\pi u}\right]_{-X/2}^{X/2} \left[\frac{e^{-j2\pi vy}}{-j2\pi v}\right]_{-Y/2}^{Y/2},$$

$$= \frac{1}{-j2\pi u}\left[e^{-juX} - e^{juX}\right] \frac{1}{-j2\pi v}\left[e^{-jvY} - e^{jvY}\right],$$

$$= XY \left[\frac{sin(\pi X u)}{\pi X u}\right] \left[\frac{sin(2\pi Y v)}{\pi Y v}\right]$$

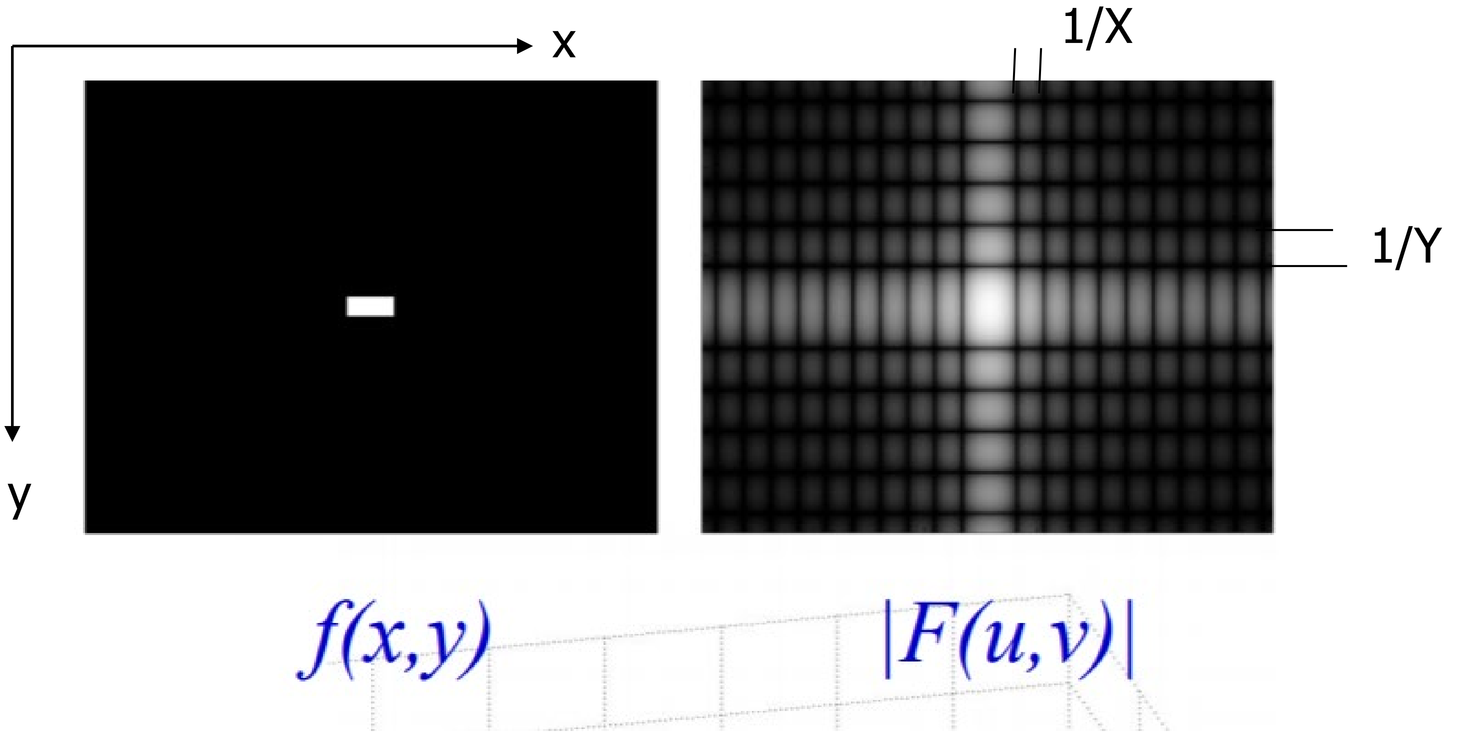
$$= XY \mathrm{sinc}(\pi \mathrm{Xu}) \mathrm{sinc}(\pi \mathrm{Yv}).$$



$|F(u,v)|$

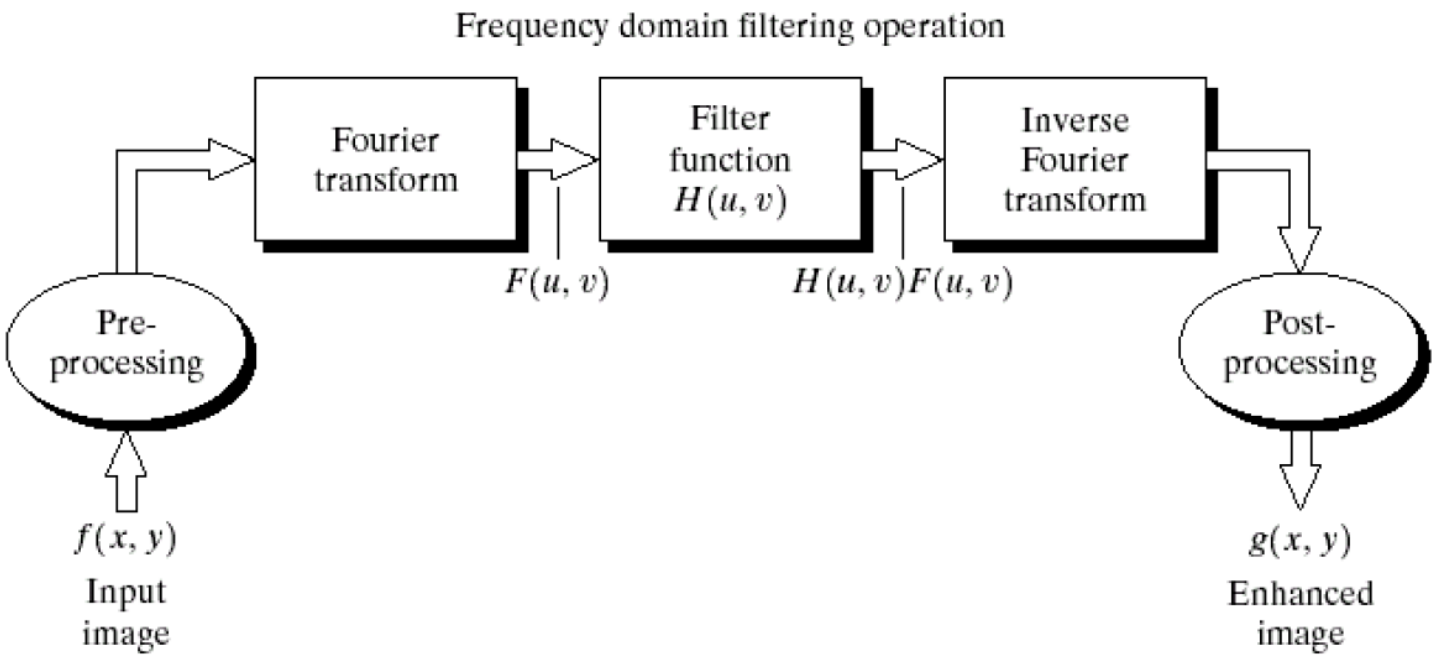
Important Fourier Transform Pairs

- The zero crossing of the spectrum is closer in the horizontal direction because the rectangle is longer in that direction



Lecture 3: Image enhancement: Frequency Domain

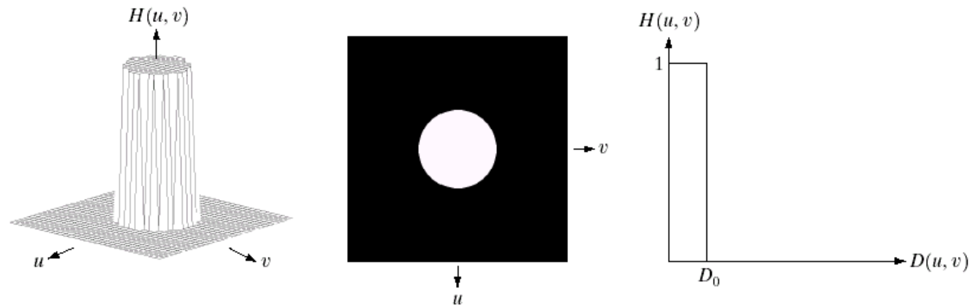
- Image Enhancement in Frequency Domain (workflow)



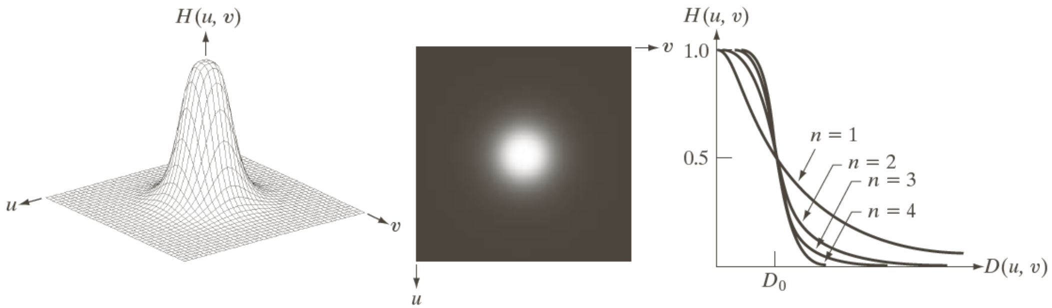
Lecture 3: Image enhancement: Frequency Domain

- Filtering in Frequency Domain
  - Low-Pass Filtering (ideal, butterworth, gaussian): passes all frequencies with magnitudes below a specific level, and attenuates all frequencies above that level.
  - High-Pass Filtering: does the opposite.
  - Laplacian Filtering: sharpen
  - Homomorphic Filtering (Principle, separating Illumination and Reflection)
    - Illumination and Reflection have different characteristics: Illumination components tend to be slow in spatial variation (low frequency components); Reflection of various objects tends to vary abruptly (high frequency components)
  - Selective Filtering – Bandpass/Bandreject, Notch Filters (A “notch” filter rejects (or passes) frequencies at a specific point)

Comparison with different filter banks



a b c



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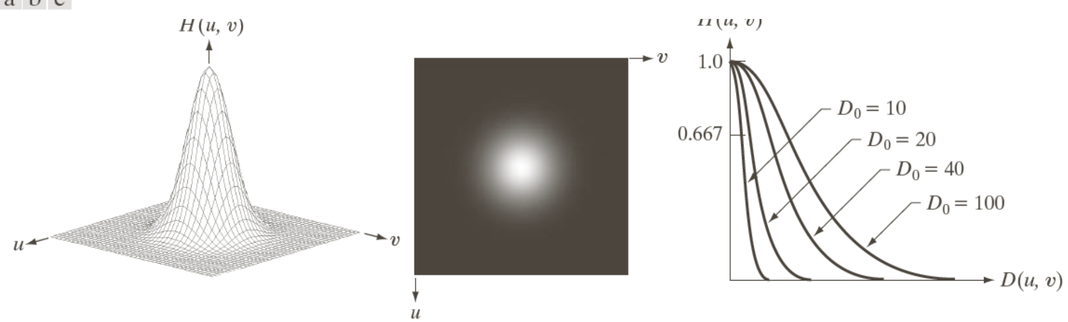


a b c

(a)Perspective plot of the transfer function
(b)Filter displayed as an image
(c)Filter radial cross sections for various values

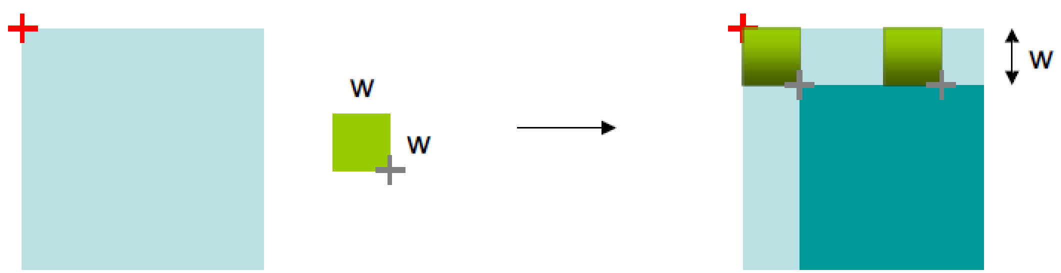
- Ideal low filter bank
  - all frequencies inside a circle of radius D_0 are passed with no attenuation
  - Presence of ripples/waves whenever there are boundaries in the image – "ringing effect"
- Butterworth lowpass filter
  - Reduces "ringing" while keeping clear cutoff
  - Tradeoff between amount of ringing and sharpness of cutoff
- Gaussian lowpass filter
  - No ringing, but allows high frequencies to pass

Lecture 4: Morphological processing

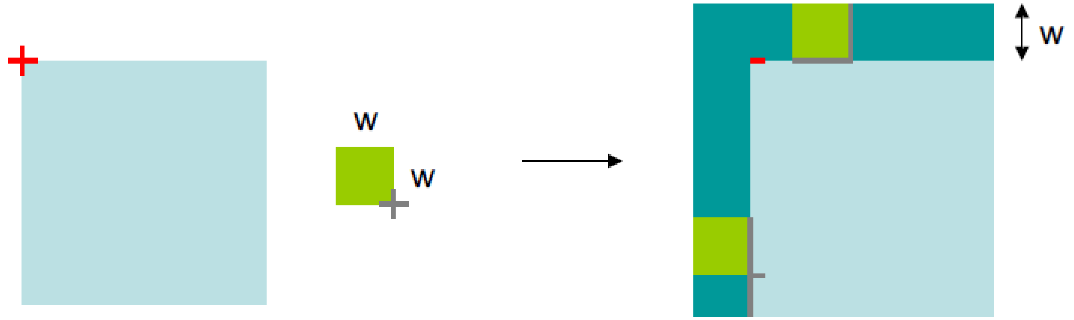
- Basic Morphological operations (calculate)
  - Hit: If any **ONE** of the ‘1’s in the SE is covered by the image, We say that the SE **hits** the image at the pixel position (the one on which the SE is centered).
  - Fit: If **ALL** of the ‘1’s in the SE are covered by the image, we say that the SE **fits** the image at the pixel position (the one on which the SE is centered).
  - Dilation
  - Erosion
  - Opening: Erosion followed by Dilation
  - Closing: Dilation followed by Erosion

Lecture 4: Morphological processing

- Applying **Fit** to an entire image is denoted Erosion
- Interpretation: shift B by z, if it is completely inside A, output a 1
- Applying **Hit** to an entire image is denoted Dilation
- Interpretation: reflect B, shift by z, if it overlaps with A, output a 1 at the center of B



$A \ominus B$



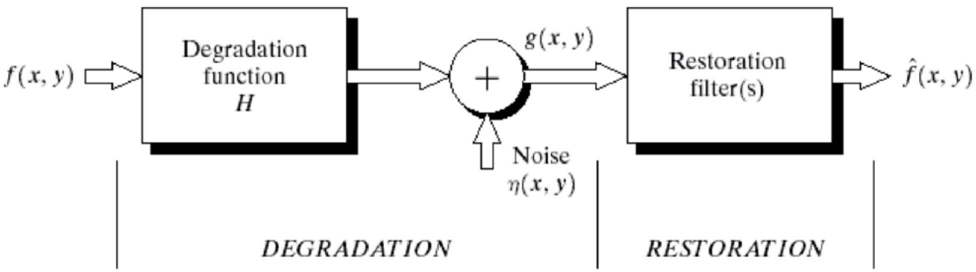
$A \oplus B$

Lecture 4: Morphological processing

- Morphological Algorithms (understand and can calculate with formula)
  - Hit or Miss Transform
  - Boundary Extraction
  - Hole Filling
  - Connected Components
  - Skeletons

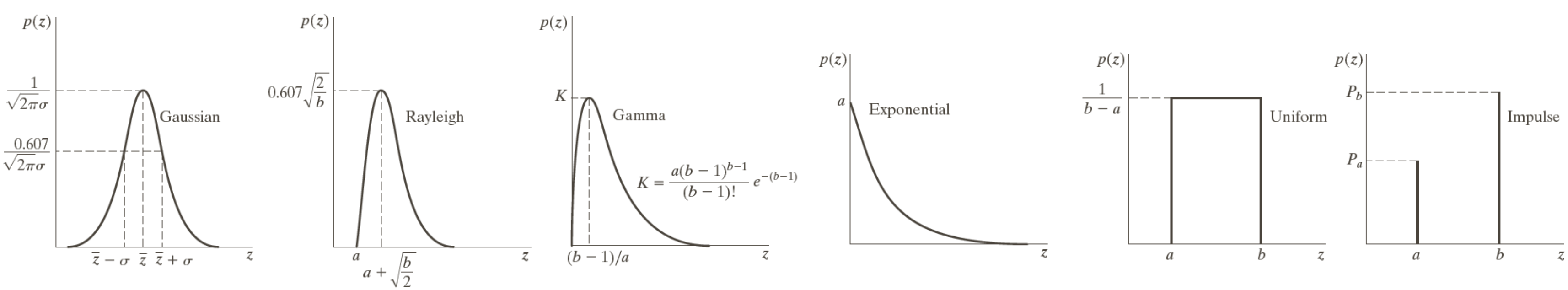
Lecture 5: Image restoration

- Degradation & Restoration Process Models (Principle)
  - Consists of 2 parts – Degradation function & Noise function



$$G(u,v) = H(u,v)F(u,v) + N(u,v)$$

- Noise Models (6 types)



Lecture 5: Image restoration

- Restoration in the presence of noise only (spatial filtering)
  - Mean filters: Arithmetic mean, Geometric Mean, Harmonic Mean Filter, Contraharmonic Mean
  - Order-statistics filters: min, max, median, midpoint, alpha-trimmed mean
  - Adaptive mean filters: preserve edge
- Estimation of the degeneration function
  - Observation
  - Experimentation
  - Modeling (motion blur, atmospheric blur)
- Inverse filtering (challenges and solutions) $G(u,v) = H(u,v)F(u,v) + N(u,v)$
- Question: If any points in H(u,v) are zero –division by zero
- Solution: Do not take zero-points of H(u,v) into account $\hat{F}(u,v) = \frac{G(u,v)}{H(u,v)} = \frac{H(u,v)F(u,v)}{H(u,v)} + \frac{N(u,v)}{H(u,v)} = F(u,v) + \frac{N(u,v)}{H(u,v)}$
- Problem: If H(u,v) becomes very small, the second term becomes very large, and it overshadows the F(u,v).
- Solution: Limit the restoration to a specific radius about the origin in the spectrum – the restoration cutoff frequency

Example

- Given the Contraharmonic Mean Filter and the image patch, please calculate the filter results in the center

$$\hat{f}(x,y)=\frac{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q}}$$

1	200	200
200	200	200
200	200	200

(a)

1	1	1
1	1	200
1	1	1

(b)

- (1) if Q=-1 for image patch a and b
- (2) if Q=1 for image patch a and b

If Q is negative with -1

1	1	1
1	1	1
1	1	200

➡

1	1	1
1	1.124	1
1	1	200

1	200	200
200	200	200
200	200	200

If Q is positive with 1

➡

1	200	200
200	199.87	200
200	200	200

Lecture 7: Segmentation – Categories

- Edge-based Segmentation
  - Finding boundary between adjacent regions
- Threshold-based Segmentation
  - Finding regions by grouping pixels of similar gray values
- Region-based Segmentation
  - Finding regions directly using growing or splitting
- Motion-based Segmentation
  - Finding regions by comparing successive frames of a video sequence to identify regions that correspond to moving objects

Lecture 7: Edge-based Segmentation

- Finding discontinuities (sharp, local changes in intensity) as boundary of regions
- Discontinuities in digital images (Spatial filters)
  - Point (Laplacian)
  - Line (horizontal, -45 degree, vertical, 45 degree)
  - Edges (Roberts, Prewitt, Sobel, LOG, Canny)
- Techniques
  - Point detection
  - Edge (pixel) detection
  - Edge formation from edge pixels – Edge linking, Hough Transform

Lecture 7: Edge-based Segmentation

- Finding discontinuities (sharp, local changes in intensity) as boundary of regions
- Discontinuities in digital images (Spatial filters)
  - Point (Laplacian)
  - Line (horizontal, -45 degree, vertical, 45 degree)

−1	−1	−1
2	2	2
−1	−1	−1

  - Edges (Roberts, Prewitt, Sobel, LOG, Canny)

−1	0
0	1

−1	−1	−1
0	0	0
1	1	1

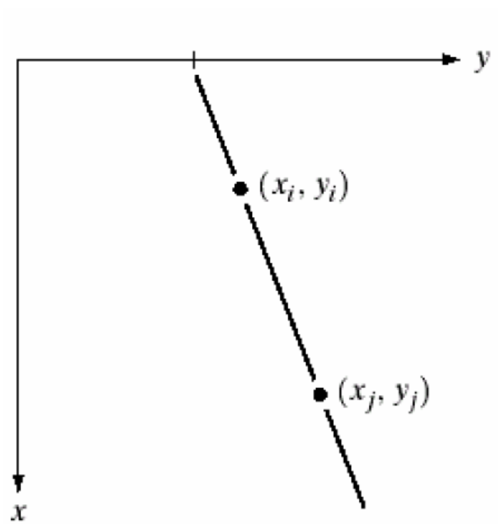
−1	−2	−1
0	0	0
1	2	1

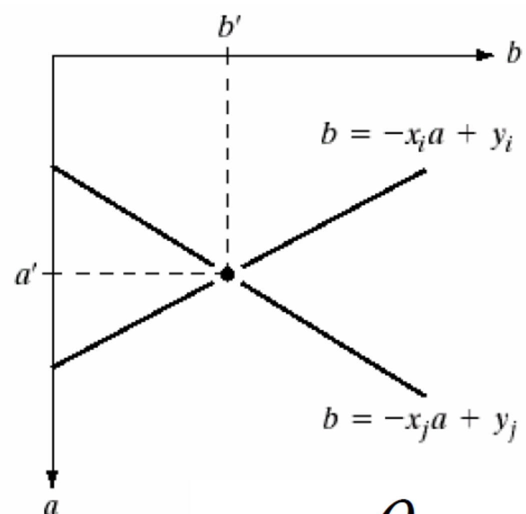
Non-maximal suppression
Double threshold

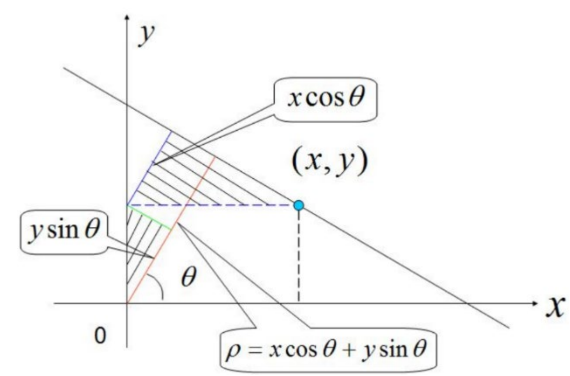
- Techniques
  - Point detection
  - Edge (pixel) detection
  - Edge formation from edge pixels – Edge linking, Hough Transform

Hough transform

- Motivation: isolated points
- Problem with this method: *a* approaches infinity as the line gets perpendicular to the *x* axis. (if a line is perpendicular to x axis, then this line is represented x=M. a->infinity) $y_i = ax_i + b$
- Solution: use the representation of the line as:



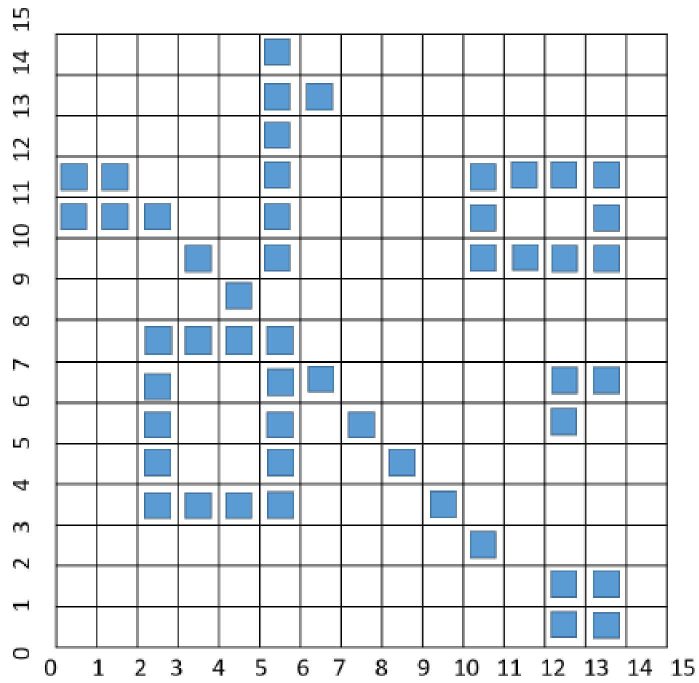




$$x\cos\theta + y\sin\theta = \rho$$

Example

- If we apply the Hough transform on the image below, what would be the maximum values for the accumulator cell in the (ρ, θ) space? What are the corresponding (ρ, θ) values.



Solution:
The maximum value is 11. There are two lines correspond to this values, with $\rho = 12/\mathrm{sqrt}(2)$, $\theta = \pi/4$ or $\rho = 5$, $\theta = 0$.

Lecture 8: Image segmenation

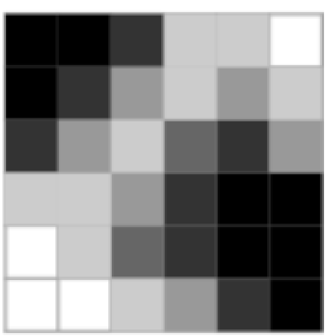
- Threshold based segmentation
  - Basic Global Thresholding
  - Optimum Global Thresholding (OSTU)
  - Multiple Thresholding
  - Variable Thresholding
- Region based segmentation
  - Region grow
  - K-means methods
- Understand principle of these segmentation methods and able to calculate the steps in the segmentation.

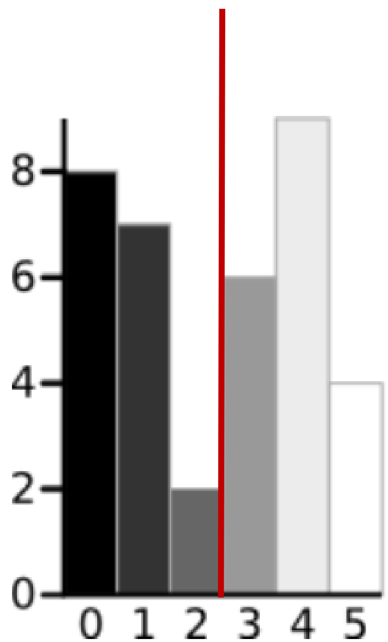
Algorithm: Basic Global Thresholding

- Select an initial estimate for the global threshold, *T*
- Threshold the image using *T*. This will produce two groups of pixels: G_1 consisting of all pixels with intensity values > *T*, and G_2 consisting of pixels with values ≤ *T*.
- Compute the average (mean) intensity values *m1* and *m2* for the pixels in G_1 and G_2, respectively.
- Compute a new threshold value: $T = \frac{1}{2}(m_1 + m_2)$
- Repeat Steps 2 through 4 until the difference between values of T in successive iterations is smaller than a predefined parameter ΔT.

Otsu's Method

- View thresholding as a statistical-decision theory problem
- Objective: Maximizes the between-class variance (minimize the within-class variance)





When the threshold is 3, the calculation of background

$$\text{Weight} \quad W_b = \frac{8+7+2}{36} = 0.4722$$

$$\text{Mean} \quad \mu_b = \frac{(0\times 8)+(1\times 7)+(2\times 2)}{17} = 0.6471$$

$$\text{Variance} \quad \sigma_b^2 = \frac{((0-0.6471)^2\times 8)+((1-0.6471)^2\times 7)+((2-0.6471)^2\times 2)}{17}$$
$$= \frac{(0.4187\times 8)+(0.1246\times 7)+(1.8304\times 2)}{17}$$
$$= 0.4637$$

When the threshold is 3, the calculation of foreground

$$\text{Weight} \quad W_f = \frac{6+9+4}{36} = 0.5278$$

$$\text{Mean} \quad \mu_f = \frac{(3\times 6)+(4\times 9)+(5\times 4)}{19} = 3.8947$$

$$\text{Variance} \quad \sigma_f^2 = \frac{((3-3.8947)^2\times 6)+((4-3.8947)^2\times 9)+((5-3.8947)^2\times 4)}{19}$$
$$= \frac{(4.8033\times 6)+(0.0997\times 9)+(4.8864\times 4)}{19}$$
$$= 0.5152$$

Within-Class Variance

$$\sigma_W^2 = W_b\,\sigma_b^2 + W_f\,\sigma_f^2 = 0.4722 * 0.4637 + 0.5278 * 0.5152 = 0.4909$$

K-means

- Partition the data points into K clusters randomly. Find the centroids of each cluster.
- For each data point:
  - Calculate the distance from the data point to each cluster.
  - Assign the data point to the closest cluster.
- Recompute the centroid of each cluster.
- Repeat steps 2 and 3 until there is no further change in the assignment of data points (or in the centroids).

$$\sum_{i \in \text{clusters}} \left\{ \sum_{j \in \text{elements of i'th cluster}} \left\| x_j - \mu_i \right\|^2 \right\}$$

K-means

- The input dataset is shown below, we first select (3,3) and (2,2) as cluster centers.
- Please calculate the process for the K-means method

No	X	Y
1	1	1
2	2	3
3	1	2
4	3	3
5	2	2
6	3	1

1. D1 $= \{(1 , 1), (2 , 2)\}$

$$= \sqrt{(2-1)^2 + (2-1)^2}$$

$$= 1.41$$

2. D1 $= \{(2 , 3), (2 , 2)\}$

$$= \sqrt{(2-2)^2 + (2-3)^2}$$

$$= 1$$

3. D1 $= \{(1 , 2), (2 , 2)\}$

$$= \sqrt{(2-1)^2 + (2-2)^2}$$

1. D2 $= \{(1 , 1), (3 , 3)\}$

$$= \sqrt{(3-1)^2 + (3-1)^2}$$

$$= 2.82$$

2. D2 $= \{(2 , 3), (3 , 3)\}$

$$= \sqrt{(3-2)^2 + (3-3)^2}$$

$$= 1$$

3. D2 $= \{(1 , 2), (3 , 3)\}$

$$= \sqrt{(3-1)^2 + (3-2)^2}$$

K-means

- The input dataset is shown below, we first select (3,3) and (2,2) as cluster centers.
- Please calculate the process for the K-means method

No	X	Y
1	1	1
2	2	3
3	1	2
4	3	3
5	2	2
6	3	1

4. D1 $= \{(3\ ,\ 3),\ (2\ ,\ 2)\}$

$$= \sqrt{(2-3)^2 + (2-3)^2}$$

$$= 1.41$$

5. D1 $= \{(2\ ,\ 2),\ (2\ ,\ 2)\}$

$$= \sqrt{(2-2)^2 + (2-2)^2}$$

$$= 0$$

6. D1 $= \{(3\ ,\ 1),\ (2\ ,\ 2)\}$

$$= \sqrt{(2-3)^2 + (2-1)^2}$$

$$= 1.41$$

4. D2 $= \{(3\ ,\ 3),\ (3\ ,\ 3)\}$

$$= \sqrt{(3-3)^2 + (3-3)^2}$$

$$= 0$$

5. D2 $= \{(2\ ,\ 2),\ (3\ ,\ 3)\}$

$$= \sqrt{(3-2)^2 + (3-2)^2}$$

$$= 1.41$$

6. D2 $= \{(3\ ,\ 1),\ (3\ ,\ 3)\}$

$$= \sqrt{(3-3)^2 + (3-1)^2}$$

$$= 2$$

K-means

No	X	Y
1	1	1
2	2	3
3	1	2
4	3	3
5	2	2
6	3	1

C1 = {(1 , 1), (1 , 2), (2 , 2), (3 , 1)}

C2 = {(2 , 3), (3 , 3)}

$$\text{Mean} = \left(\frac{x_1+x_2+\ ....x_n}{n}, \frac{y_1+y_2+\ ....y_n}{n}\right)$$

$$C1 = \left(\frac{1+1+2+3}{4}, \frac{1+2+2+1}{4}\right)$$

New C1 = (1.75 , 1.5)

$$C2 = \left(\frac{2+3}{2}, \frac{3+3}{2}\right)$$

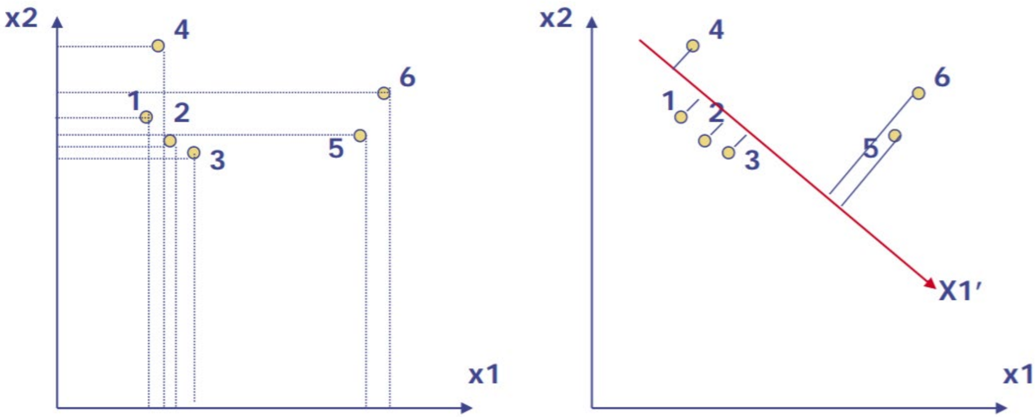
New C2 = (2.5, 3)

- Repeat until no points move

Lecture 9: PCA and LDA for face recongnition

- Introduction to face recognition
- Principal Component Analysis (PCA)
  - converts a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components
  - Purpose: Identify the orientation with largest variance

$$\alpha_1 = \arg\max_{\alpha} \left(\mathrm{var}\left(\alpha^T \mathbf{X} \right) \right), \alpha \in \mathbb{R}^{p\times 1}$$



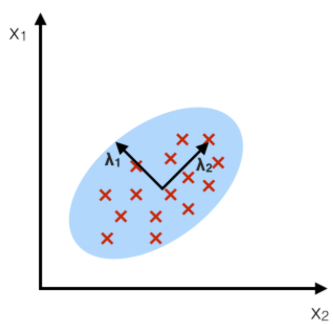
PCA projection

Linear Discriminant Analysis (LDA)

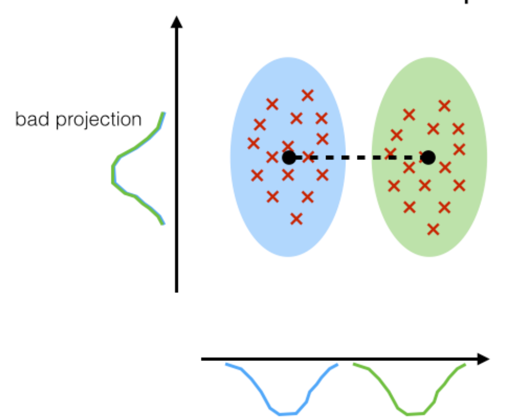
- Eigenfaces exploit the max scatter of the training images in face space
  - PCA
- Fisherfaces attempt to maximize the between class scatter, while minimizing the within class scatter.
  - Goal: find the best separation between two classes

$$J(w) = \frac{w^T S_B w}{w^T S_W w}$$

PCA:
component axes that
maximize the variance



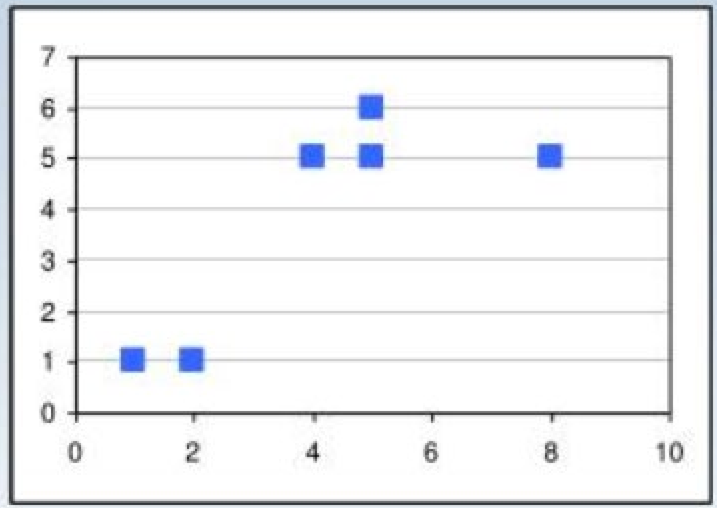
LDA:
maximizing the component
axes for class-separation



PCA Example

1) Calculate Principal Component

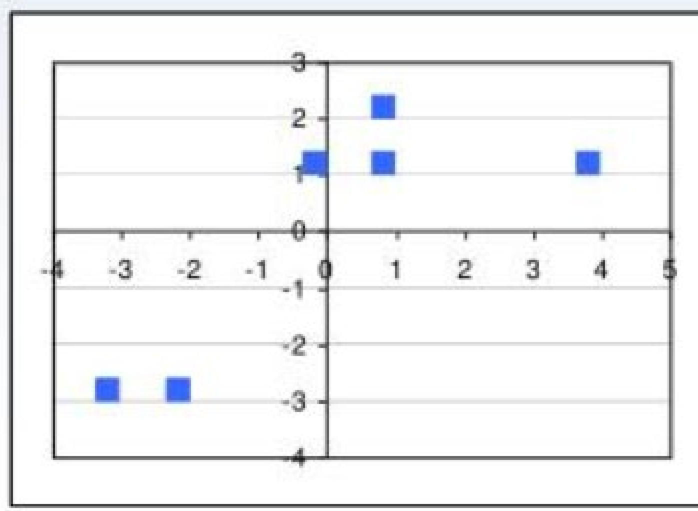
Step 1.1: Get some Data



Step 1.2: Subtract the mean

$\bar{x} = 4.17$ $\bar{y} = 3.83$

Point	X	Y	$X - \bar{X}$	$Y - \bar{Y}$
A	1	1	-3.17	-2.83
B	2	1	-2.17	-2.83
C	4	5	-0.17	1.17
D	5	5	0.83	1.17
E	5	6	0.83	2.17
F	8	5	3.83	1.17



PCA Example

Step 1.3: Covariance matrix calculation

$$C = \begin{pmatrix} 5.139 & 3.694 \\ 3.694 & 4.139 \end{pmatrix}$$

Positive cov_{ij} values

→ x and y values increase together in dataset

Step 1.4: Eigenvectors and eigenvalues calculation –Principal axis

a) Calculate eigenvalues λ of matrix C

$$C - \lambda \cdot E = \begin{pmatrix} 5.139 - \lambda & 3.694 \\ 3.694 & 4.139 - \lambda \end{pmatrix}$$

Where E is identity matrix

The characteristic polynom is the determinant. The roots of the function, that appears if you set the polynom equals zero, are the eigenvalues

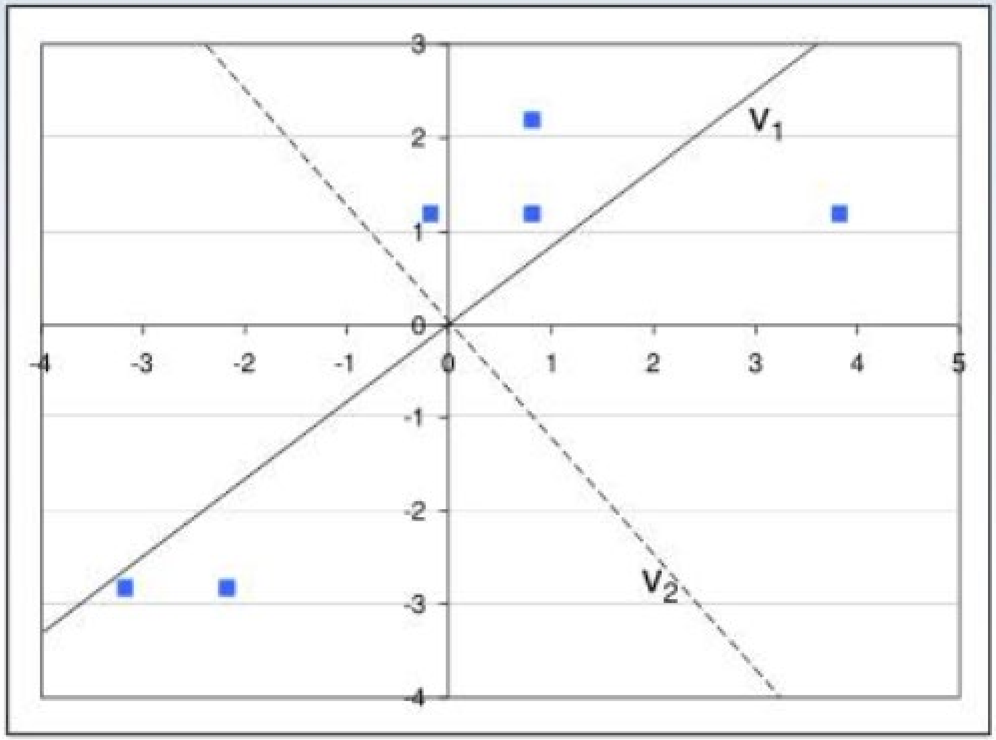
$$\det(C - \lambda \cdot E) = (5.139 - \lambda)(4.139 - \lambda) - (3.694)^2 = \lambda^2 - 9.278\lambda + 7.620 \Rightarrow \begin{matrix} \lambda_1 = 8.367 \\ \lambda_2 = 0.911 \end{matrix}$$

PCA Example

b) Calculate eigenvectors v_1 and v_2 out of eigenvalues λ_1 and λ_2 via properties of eigenvectors (see matrix algebra background(3/3))

$$\begin{pmatrix} 5.139 & 3.694 \\ 3.694 & 4.139 \end{pmatrix}\begin{pmatrix} x_1 \\ y_1 \end{pmatrix} = 8.367\begin{pmatrix} x_1 \\ y_1 \end{pmatrix} \qquad \begin{pmatrix} 5.139 & 3.694 \\ 3.694 & 4.139 \end{pmatrix}\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = 0.911\begin{pmatrix} x_2 \\ y_2 \end{pmatrix}$$

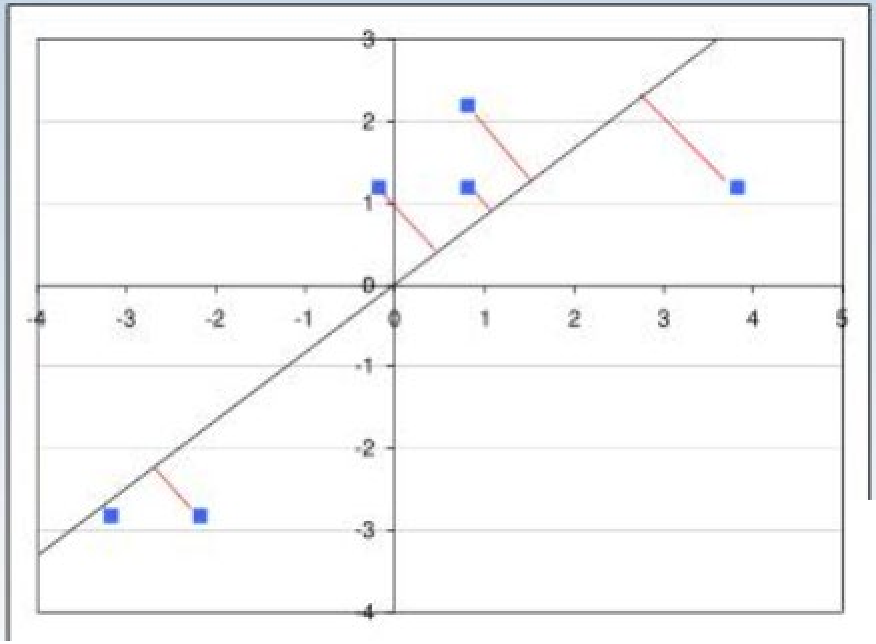
$$\Rightarrow \quad v_1 = \begin{pmatrix} x_1 \\ y_1 \end{pmatrix} = \begin{pmatrix} -0.753 \\ -0.658 \end{pmatrix} \qquad \Rightarrow \quad v_2 = \begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = \begin{pmatrix} 0.658 \\ -0.753 \end{pmatrix}$$



Eigenvector v_1 with highest eigenvalue fits the best. This is our principal component

PCA Example

2) Select the dividig point along the principal axis



Step 2.1: Calculate projections on principal axis

LDA Example

- For the given data below, please calculate the Within-class scatter matrix and Between-class scatter matrix.
- X1={(3,2),(2,3),(2,4),(5,3)}
- X2={(9,8),(8,9),(8,7),(7,8)}
- The LDA projection is then obtained as the solution of the generalized eigen value problem

$$S_W^{-1} S_B w = \lambda w$$

$$\Rightarrow \left| S_W^{-1} S_B - \lambda I \right| = 0$$

```
X1=[3,2;2,3;2,4;5,3];
X2=[9,8;8,9;8,7;7,8];
Mu1=mean(X1);
Mu2=mean(X2);
S1=cov(X1);
S2=cov(X2);
Sw=S1+S2;
Sb=(Mu1-Mu2)*(Mu1-Mu2)';
```

- Calculate eigenvalue and eigenvectors, where the eigenvector represent the project direction

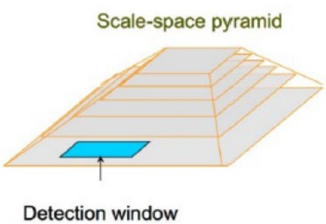
Lecture 10: face recognition

- Section A
  - Introduction of deep learning
  - DeepFace
  - FaceNet
- Section B: Deep learning in image segmentation
  - Models: Fully Convolutional Network, DeconvNet, SegNet, U-Net, PSPNet, DeepLab v1, v2, v3, v3+, transformer
  - Loss functions: **Cross entropy (CE),** Weighted cross entropy, Balanced cross entropy (BCE), Focal loss, Dice loss, Tversky loss
  - Able to choose suitable loss functions

Lecture 11: Detection

- HOG
- DPM(Deformable Part Model):capture spatial relationships

locations



scales

Scan image(s) at all scales and locations

↓

Extract features over windows

↓

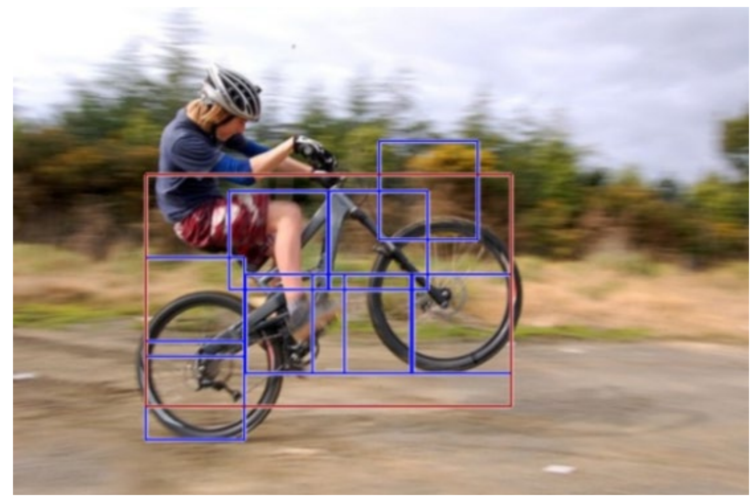
Run window classifier at all locations

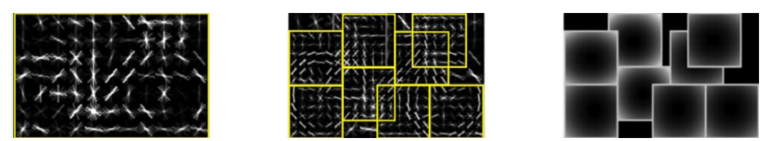
↓

Fuse multiple detections in 3-D position & scale space

↓

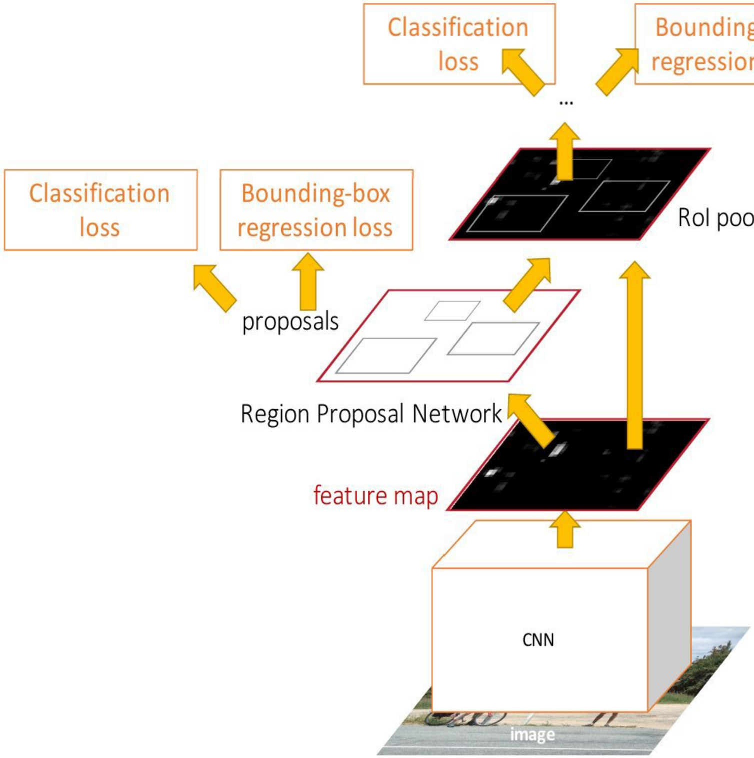
Object detections with bounding boxes





Lecture 11: Detection

- Section B
  - RCNN (Selective Search)
  - Fast-RCNN (region of interest)
  - Faster-RCNN (region proposal network)
  - Mask-RCNN (segmentation)



Report writing

- Suggestion: latex(overleaf) or word.
- Template: use online paper template.
  - https://www.overleaf.com/latex/templates/cvpr-2022-author-kit/qbmjsdxryffn
  - https://cvpr2022.thecvf.com/author-guidelines (search for ‘word’)
- Just for a case study: Squeeze-and-Attention Networks for Semantic Segmentation
  - include abstract, introduction, related work (not necessary in our report), method, results.
- 4-8 pages are good enough for your project

The Last Message For You

天高任鸟飞, 海阔凭鱼跃

The sky is unlimited for birds to fly at ease, as the ocean is boundless for fish to leap at will.

-- 阮阅《诗话总龟前集》