Please provide the introduction / overview on this lesson

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Overview

In this chapter, you are going to learn about:

- Introduction to **convolution**
- Different types of **filter**
- How to choose **threshold**

1. Introduction > 1.2 Learning Content

Please make sure the hierarch of the content is well formed.
Please organize the lesson in 3-5 main topics and use 3-level headings.

Level 1	Level 2	Level 3
1. Convolution	1.1 Types of Filter	
2. Threshold	2.1 Choice of Threshold	

ID Will do it by looking at 1.1 Lesson overview

Image Processing	
I. General knowledge in image p rocessing and multimedia	1. Introduction to Image Processing 2. Data Structure and Color of Images 3. Ms. Visual Studio 2008 and OpenCV 4. Introduction to Multimedia Systems 5. Introduction to Video and Lossless Compression 6. Huffman Coding 7. LZ77 8. LZ78 9. LZW
II. Advance knowledge in image segmentation and luminance	10. Sampling 11. Image Segmentation-I 12. Image Segmentation-II 13. Luminance and Histogram Equalization

1. Introduction > 1.4 Learning Objectives

Please provide objective of the lesson by high light keyword and follow (Audience, Behavior, Condition, Degree) to write the objective

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Objective
Upon completion of this chapter, you will be able to: • Apply algorithm of **sobel filter** to detect edges from images. • Understand what **threshold** is.

Please provide keywords of the lesson with explanation

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Keywords	Description
Pointwise	is used to indicate that a certain property is defined by considering each value ***f(x)*** of some function ***f***. Example of pointwise addition: **(*f* + *g*)(*x*) = *f*(*x*) + *g*(*x*)**
Translation	is a **geometric transformation** that moves every point of a figure or a space by the same amount in a given direction.
Cross-correlation	is a measure of similarity of two series as a function of the lag of one relative to the other. This is als o known as a sliding **dot product** or sliding inner-product.
Hysteresis	is the time-based dependence of a system's output on present and past inputs.

2. Learn> Topic: 1. Convolution

(1) Learning Contents

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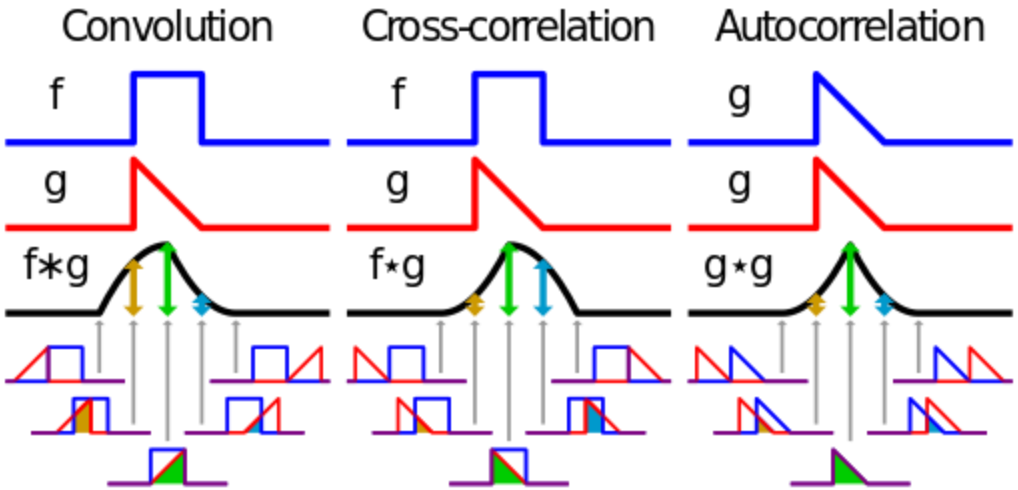
- Q: What is **convolution**?
- A: **Convolution** is a mathematical operation on two functions (***f*** and ***g***); it produces a third function giving the integral of the **pointwise** multiplication of the two functions as a function of the amount that one of the original functions is **translated**.
- Convolution is similar to **cross-correlation**.
- It has applications that include probability, statistics, computer vision, natural language processing, image and signal processing, engineering, and differential equations.



Visual comparison of convolution, cross-correlation and autocorrelation.

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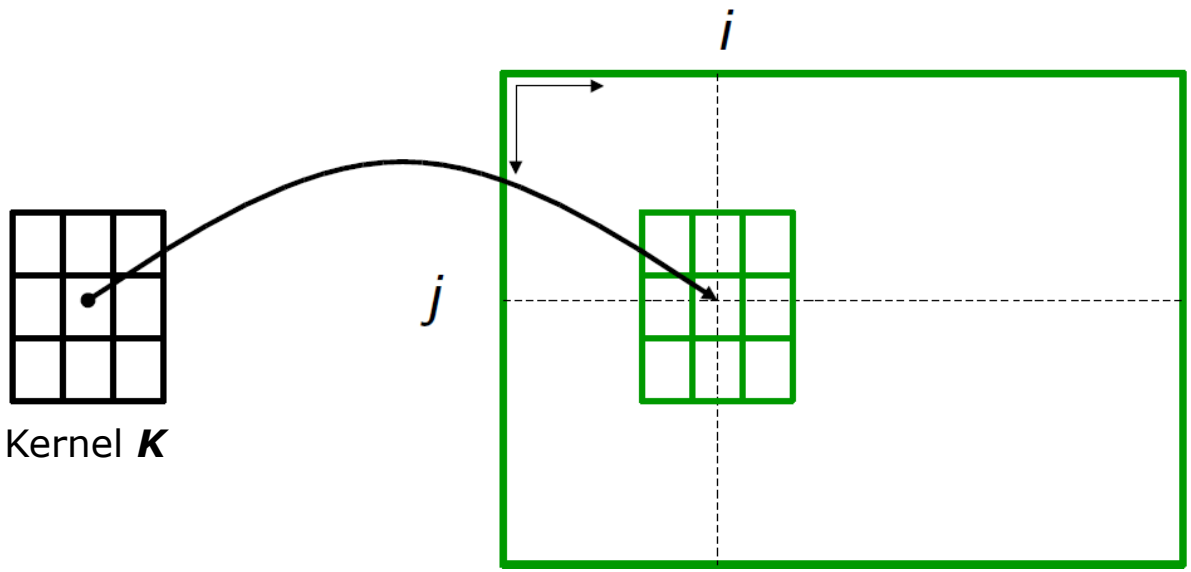
- Convolution operator with a mask or kernel ***K***:

$$I_2(i,j) = \sum_{k=0}^{2} \sum_{l=0}^{2} I_1(i+k-1, j+l-1) K(k,l)$$



2. Learn> Topic: 1.1 Types of Filter

(1) Learning Contents

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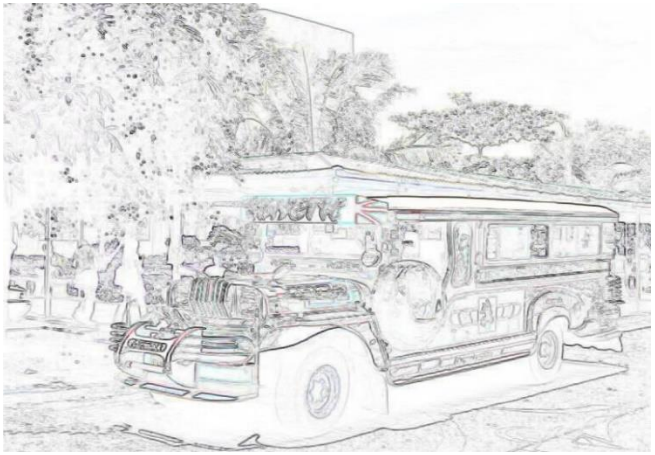
- There are several types of filter such as:
  - **Robert filter**: in 1965.
  - **Sobel filter**: in 1970.
  - **Prewitt filter**: in 1970.
  - **Kirsch filter**: in 1971.

Source image



Example of Sobel Filter

(1) Learning Contents

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▪ **Robert filter (1965)**:

$$\frac{dI}{dx} = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \qquad \frac{dI}{dy} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}$$

- Magnitude = edge strength

$$\sqrt{(\frac{dI}{dx})^2 + (\frac{dI}{dy})^2}$$

- Direction of edge normal

$$\arctan((\frac{dI}{dy})/(\frac{dI}{dx}))$$

(1) Learning Contents

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▪ Example of Robert filter.

2. Learn> Topic: 1.1 Types of Filter

(1) Learning Contents	☒ A : Text-based + Audio ☐ B : Text-based + Video ☐ C : Only Video
	▪ Although Robert filter can detect edges, it is still sensible to noise. ▪ Normally, all noises have high frequencies. ▪ In order to eliminate these high frequencies (noises), we need to do **smoothing**. ▪ There are several types of smoothing: ➢ **Mean smoothing or median filter**: is very widely used in digital image pro cessing because it preserves edges while removing noise (under certain c onditions). ➢ **Guassian smoothing**: is the result of blurring an image by a Gaussian fun ction. ➢ **Exponential smoothing**: is used to reduce irregularities (random irregular rising) in time series data, thus providing a clearer view of the true underlyi ng behaviour of the series. ➢ **Laplacian smoothing**: is an algorithm to smooth a polygonal mesh.

(1) Learning Contents

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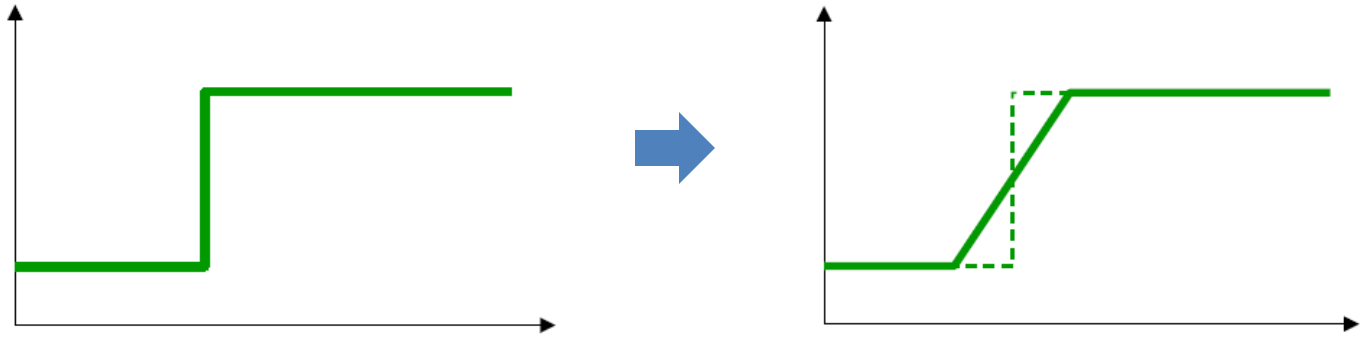
- For mean smoothing, filter 3x3:

1	1	1
1	1	1
1	1	1

/ 9



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☐ C : Only Video

- For Gaussian smoothing, it has an equation to reduce noises:

$$h(x,y) = 1/(2\pi\sigma^2)\exp(-(x^2+y^2)/(2\sigma^2))$$

- Truncated and discretized Gaussian:

0	1	0
1	4	1
0	1	0

/ 8

1	1	1
1	8	1
1	1	1

/ 16

(1) Learning Contents

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- **Sobel filter (1970)**:
  - Convolution
    - Smoothing [1 2 1]
    - Derivative [1 0 –1]

$$\frac{dI}{dx} = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix} / 4 \qquad \frac{dI}{dy} = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} / 4$$

  - Mean of derivatives at x and x – 1:

$$\frac{I[x+1] - I[x-1]}{2}$$

(1) Learning Contents

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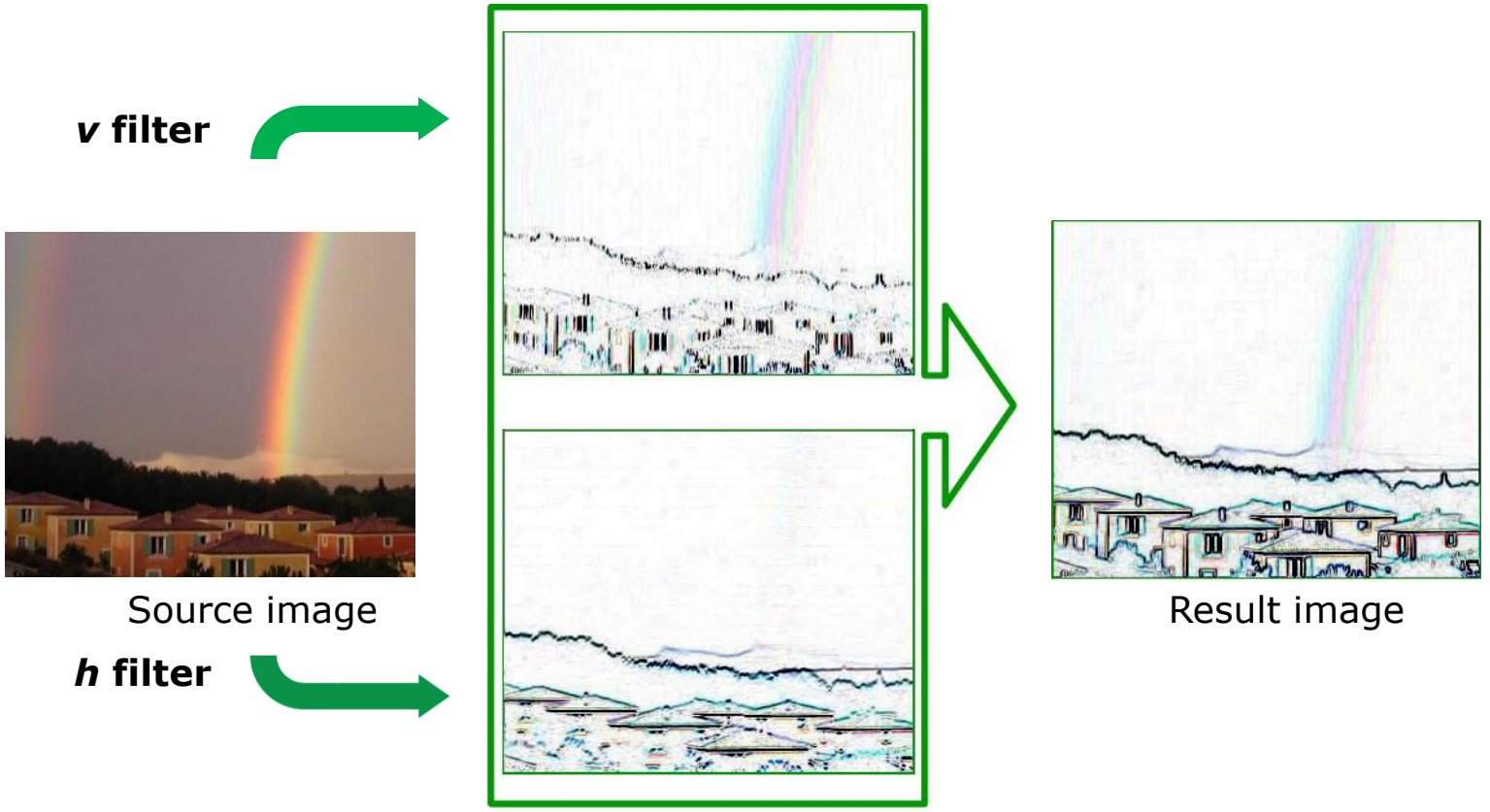
▪ Example of Sobel filter.



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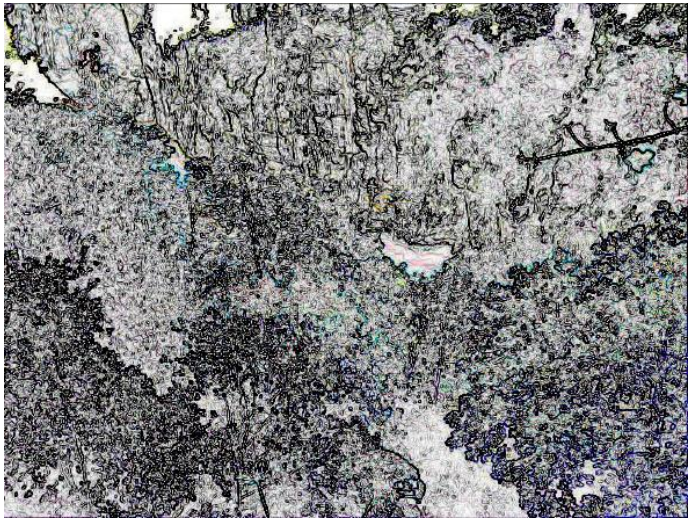
▪ Another example of Sobel filter.

Source image



Result image

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- **Prewitt filter (1970)**:

$$\begin{pmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{pmatrix}, \begin{pmatrix} 1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -1 \end{pmatrix}, \begin{pmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{pmatrix} \ldots / 3$$

- **Kirsch filter (1971)**:

$$\begin{pmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{pmatrix}, \begin{pmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{pmatrix}, \begin{pmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{pmatrix} \ldots / 15$$

2. Learn> Topic: 2. Threshold

(1) Learning Contents

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- Q: What is **thresholding**?
- A: **Thresholding** is the simplest method of image segmentation. From a **grayscale** image, thresholding can be used to create **binary images** (Shapiro, et al. 2001 :83).
- The simplest thresholding methods replace in an image with a black pixel if the image intensity $I_{i,j}$ is less than some fixed constant T (that is, $I_{i,j}<T$), or a white pixel if the image intensity is greater than that constant.
- In the example image below, this results in the dark tree becoming completely black, and the white snow becoming completely white.

Original image

Example of a threshold effect used on an image

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☐ C : Only Video

▪ In order to enhance the result, we eliminate all the pixels that have a value below a minimum threshod (***T***).

Result image

Result image and threshold

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- Q: How to choose the threshold?
- A: We can choose the threshold by 2 different values:
  1) **Low threshold**: all **edges** are detected but we have **false positives**.
  2) **High threshold**: all the **pixels** detected are edge pixels but we are missin g some of them (**false negatives**).

Example of low threshold

Example of high threshold

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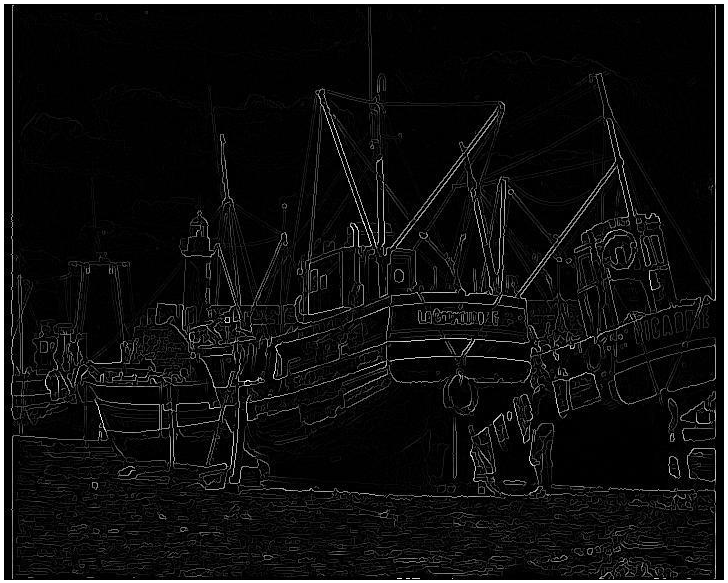
- **Hysteresis** thresholding: thresholding by **2 thresholds** for edge detection.
  - Low thresholded edges which are connected to high thresholded edges ar e **retained**.
  - Low thresholded edges which are non connected to high thresholded edge s are **removed**.



Example of Canny Deriche edge detection

Hysteresis thresholding

Please give a lesson summary.
Each topic can be summarized into a sentence, diagram, or even a word.

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Summarize

▪ **Convolution** is a mathematical operation on two functions (***f*** and ***g***). Convol ution operator with a mask or kernel ***K***:

$$I_2(i,j) = \sum_{k=0}^{2}\sum_{l=0}^{2} I_1(i+k-1, j+l-1)K(k,l)$$

▪ **Thresholding** is the simplest method of image segmentation. We can choose the threshold by 2 different values:

1) **Low threshold:** all edges are detected but we have **false positives**.
2) **High threshold:** all the pixels detected are edge pixels but we are mis sing some of them (**false negatives**).

Provide references if you think the students need.

Reference

- “Digital Image Processing” par W. K. Pratt, John Wiley & Sons, inc., Third Edition, 2001
- “Digital Image Processing” par Gonzalez et Woods, Prentice Hall, Second Edition, 2002
- http://homepages.inf.ed.ac.uk/rbf/CVonline/books.htm
- http://www.dai.ed.ac.uk/CVonline/transf.htm

4. Outro > 4.3 Assignment

Please provide the assignment such as exercise , discussion, research topic, Short essay, case studies, ...

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Assignment
1) Find a mask or kernel ***X*** and ***Y*** of Sobel filter (3x3)? 2) In your opinion, what is the range of threshold except black and white image? (from which value to which value)

4. Outro > 4.4 Next Lesson

This is the end of the lesson.
Ending message and introduction to next lesson including lesson title and topics should be given.

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Overview

- Concept of darkness and brightness
- Algorithm of histogram equalization

Next Lesson Title	**Luminance and Histogram Equalization** 1. Luminance 2. Histogram Equalization