影像處理
Digital Image Processing

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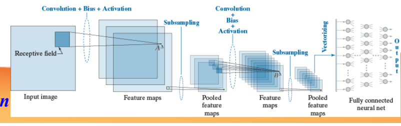
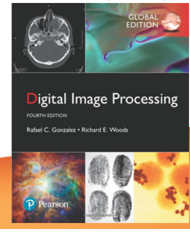
Text/ Reference Books and Lecture Notes

- Textbook:
  - "Digital Image Processing" by R. C. Gonzalez and R. E. Woods, **4th** Edition, Prentice Hall, **2017**. (開發)
  - ***DIGITAL IMAGE PROCESSING*** has been the world's leading textbook in its field for more than 40 years. As in the 1977 and 1987 editions by Gonzalez and Wintz, and the 1992, 2002, and 2008 editions by Gonzalez and Woods.
- Reference:
  - "Digital Image Processing Using MATLAB" by R. C. Gonzalez, R. E. Woods and S. L. Eddins, 2nd Edition, , 2011. (開發)
- Lecture Notes:
  - Available before the day of class.





Course Outline

- 1. Introduction to digital image processing
  - Examples of Fields that Use Digital Image Processing
  - Fundamental Steps in Digital Image Processing

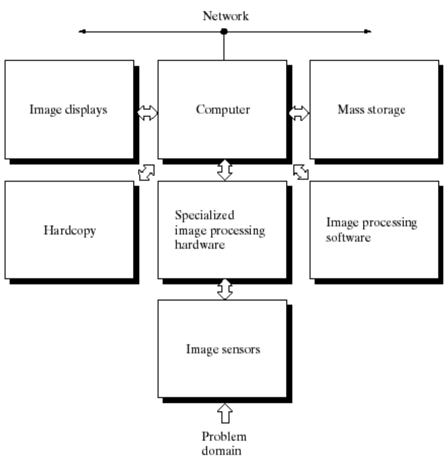


FIGURE 1.24 Components of a general-purpose image processing system.

Examples of Fields that Use DIP

- Images based on radiation from the EM spectrum are the most familiar, especially image in the X-ray and visual bands of the spectrum.

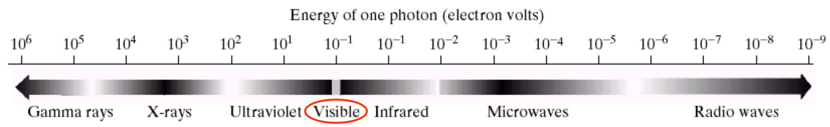
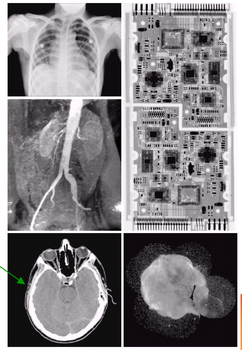


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Examples of Fields that Use DIP

- X-ray imaging
  - X-rays are among the oldest sources of EM radiation used for imaging.
  - The best known use of X-rays is medical diagnostics.
  - They are used extensively in industry and other areas, like astronomy.
  - CAT (CT) has 3-D capabilities.



a b c d e FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, (d) Mr. Joseph E. Pascente, Lixi, Inc., and (e) NASA.)

Examples of Fields that Use DIP

- Imaging in visible and infrared bands
  - Another major area of visual processing is remote sensing, which usually several bands in the visual and infrared regions of the spectrum.
  - LANDSAT:
    - The difference between visual and infrared image features are quite noticeable.

TABLE 1.1 Thematic bands in NASA's LANDSAT satellite.

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

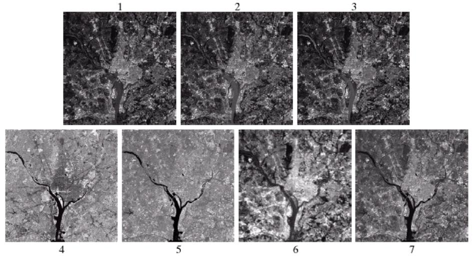
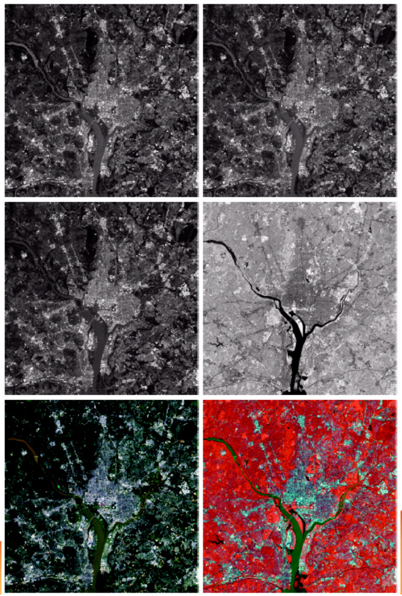


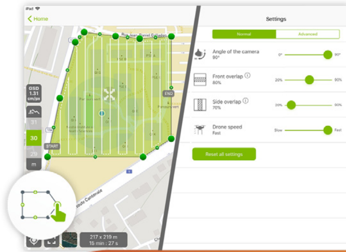
FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Multispectral Images

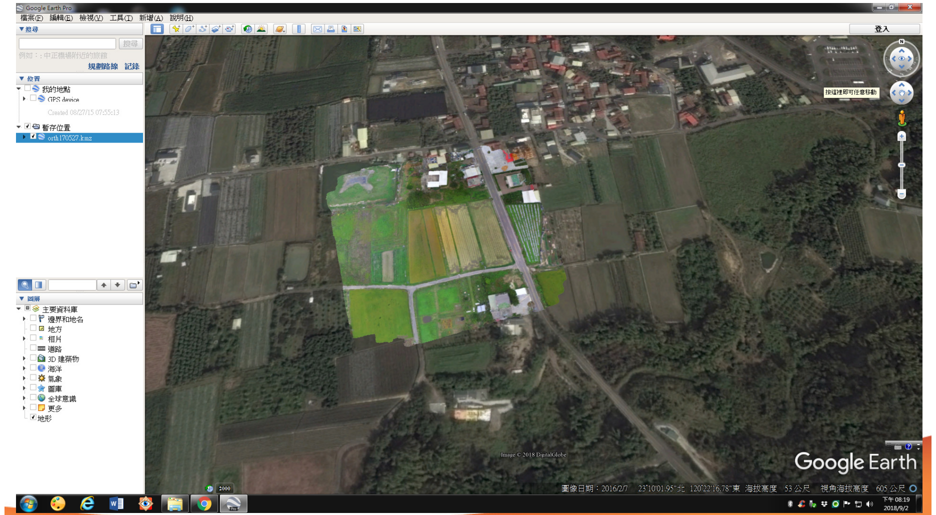


Aerial Photography

- Drone: an unmanned aircraft system; remote-controlled pilot-less aircraft; flying thingy without people inside controlling it.
- Orthomosaic



Google Earth



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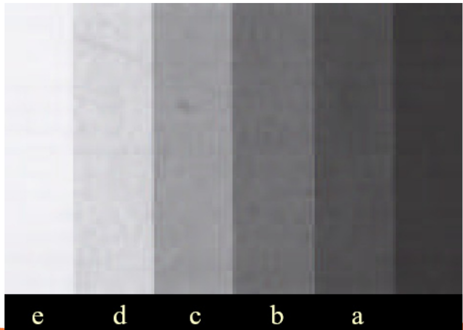
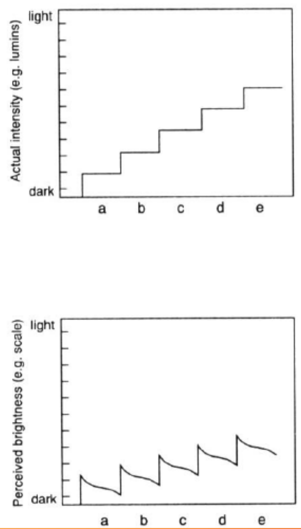
Course Outline

- 2. Digital Image Fundamentals
  - Elements of Visual Perception
  - Image Sampling and Quantization
  - Some Basic Relationships Between Pixels





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Checker-Shadow Illusion

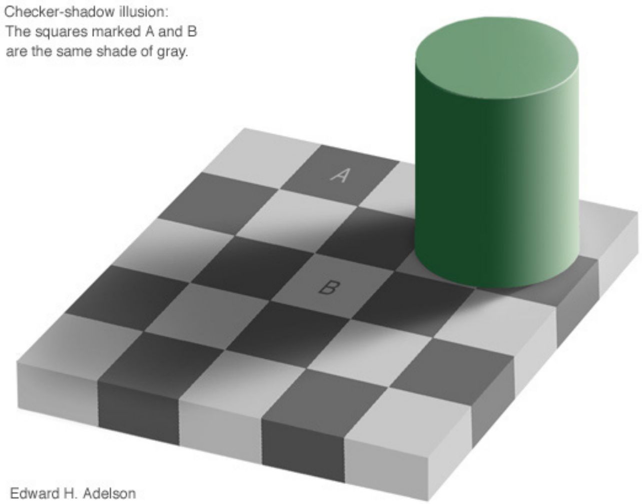

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Image Sensing and Acquisition

- Image acquisition using sensor arrays
  - This is the predominant arrangement found in digital cameras.

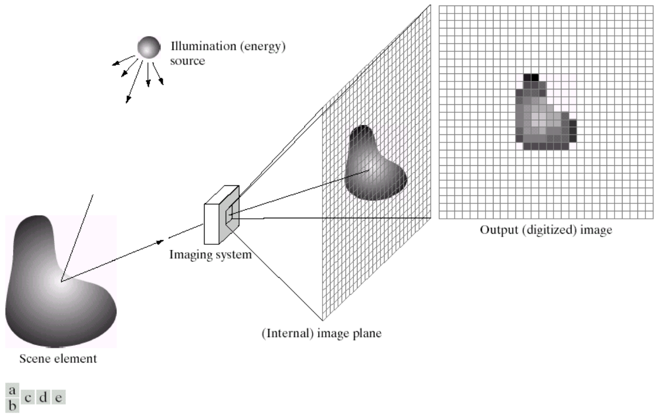

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

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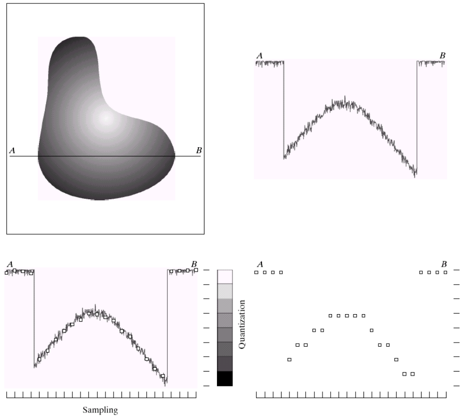
Sampling and Quantization

- Sampling: digitizing the spatial coordinates values.
- Quantization: digitizing of the amplitude values.



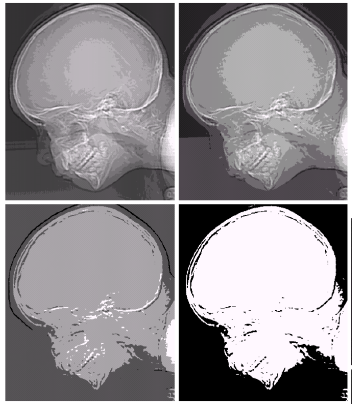
a b
c d

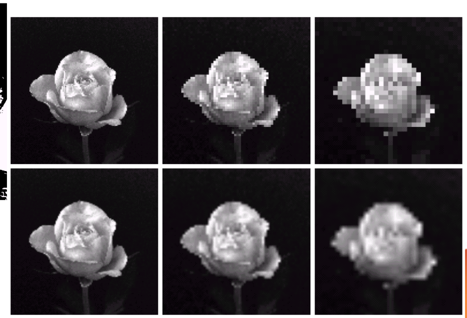
FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Course Outline

e f
g h

FIGURE 2.21 (Continued) (e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)





a b c
d e f

FIGURE 2.25 Top row: images zoomed from 128 × 128, 64 × 64, and 32 × 32 pixels to 1024 × 1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

Aliasing-Moiré Pattern

a b c

FIGURE 4.17 Illustration of aliasing on resampled images. (a) A digital image with negligible visual aliasing. (b) Result of resizing the image to 50% of its original size by pixel deletion. Aliasing is clearly visible. (c) Result of blurring the image in (a) with a 3 × 3 averaging filter prior to resizing. The image is slightly more blurred than (b), but aliasing is not longer objectionable. (Original image courtesy of the Signal Compression Laboratory, University of California, Santa Barbara.)

Panorama

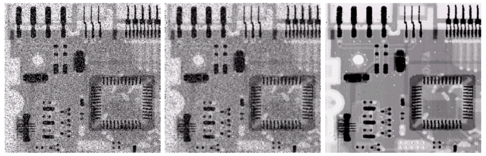
- Single-row Stitching – Manual

Course Outline

- 3. Intensity Transformations and Spatial Filtering
  - Basic Gray Level Transformations
  - Histogram Processing
  - Enhancement Using Arithmetic/Logic Operators
  - Basics of Spatial Filtering (Smoothing, Sharpening)

a b
c d

FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively. (Original image for this example courtesy of NASA.)



a b c

FIGURE 3.37 (a) X-ray image of circuit board corrupted by salt-and-pepper noise. (b) Noise reduction with a 3×3 averaging mask. (c) Noise reduction with a 3×3 median filter. (Original image courtesy of Mr. Joseph E. Pascente, Lixi, Inc.)

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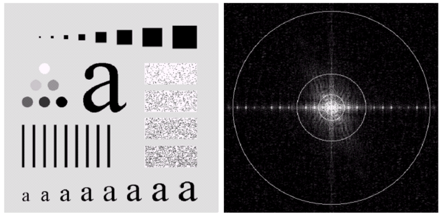
Course Outline

- 4. Filtering in the Frequency domain
  - Fourier Transform and the Frequency Domain
  - Frequency-Domain Filter (Smoothing and Sharpening)
  - Homomorphic Filtering
  - FFT based Image Registration (Optional)

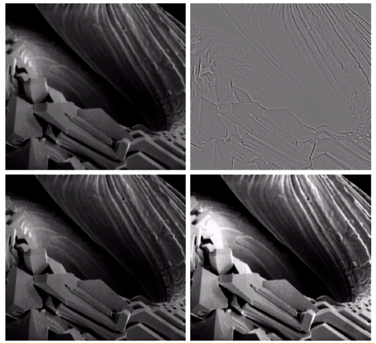


a b

FIGURE 4.11 (a) An image of size 500×500 pixels and (b) its Fourier spectrum. The superimposed circles have radii values of 5, 15, 30, 80, and 230, which enclose 92.0, 94.6, 96.4, 98.0, and 99.5% of the image power, respectively.

a b
c d

FIGURE 4.29 Same as Fig. 3.43, but using frequency domain filtering. (a) Input image. (b) Laplacian of (a). (c) Image obtained using Eq. (4.4-17) with $A = 2$. (d) Same as (c), but with $A = 2.7$. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)



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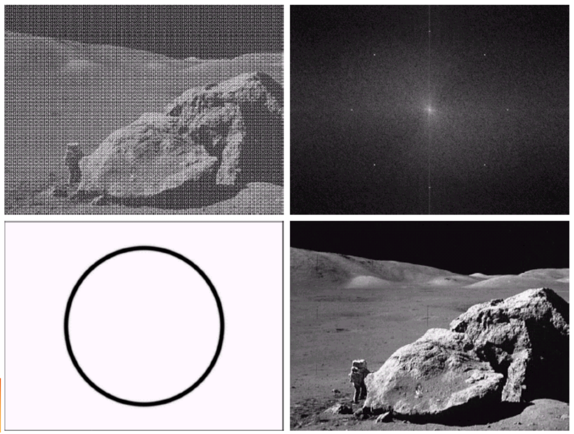
Periodic Noise Reduction by Freq. Domain Filtering

- One of the principle applications of bandreject filtering is for noise removal in applications where the general location of the noise components in the frequency domain is approximately known.



a b
c d

FIGURE 5.16 (a) Image corrupted by sinusoidal noise. (b) Spectrum of (a). (c) Butterworth bandreject filter (white represents 1). (d) Result of filtering. (Original image courtesy of NASA.)

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FFT-Based Image Registration

rotation: -0.22
scaling: 1 (disable)
tranlation: (220, -22)

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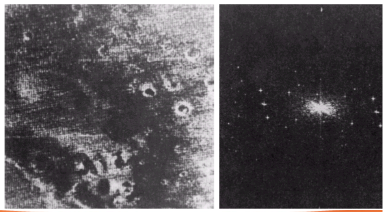
Course Outline

- 5. Image Restoration and Reconstruction
  - A model of the Image Degradation/Restoration Process
  - Periodic Noise Reduction by Frequency Domain Filtering
  - Linear, Position-Invariant Degradations
  - Inverse Filter
  - Wiener Filtering
  - Constrained Least Square Filtering
  - Geometric Transform

a b

FIGURE 5.20 (a) Image of the Martian terrain taken by *Mariner 6.* (b) Fourier spectrum showing periodic interference. (Courtesy of NASA.)



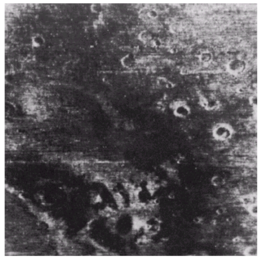


FIGURE 5.23 Processed image. (Courtesy of NASA.)

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A Model of the Image Degradation/Restoration Process

- The objective of restoration is to obtain an estimate $\hat{f}(x,y)$ of the original image.
- The more we know about *H* and η, the closer $\hat{f}(x,y)$ will be to *f(x,y).*

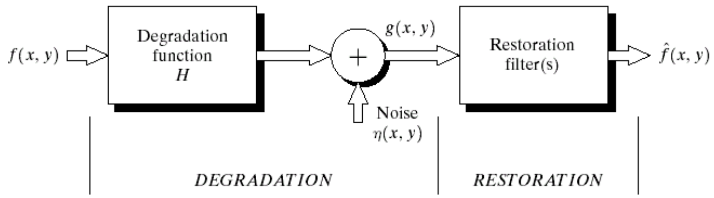

FIGURE 5.1 A model of the image degradation/restoration process.

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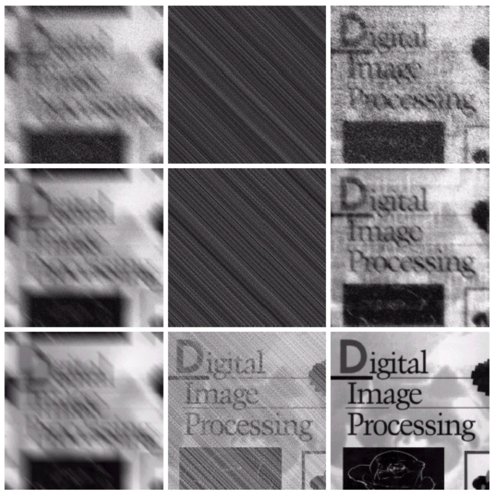
Minimum Mean Square Error (Wiener) Filtering



a b c
d e f
g h i

FIGURE 5.29 (a) Image corrupted by motion blur and additive noise. (b) Result of inverse filtering. (c) Result of Wiener filtering. (d)–(f) Same sequence, but with noise variance one order of magnitude less. (g)–(i) Same sequence, but noise variance reduced by five orders of magnitude from (a). Note in (h) how the deblurred image is quite visible through a "curtain" of noise.

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Image Restoration

- High-Resolution Image Reconstruction From Multiple Differently Exposed Images

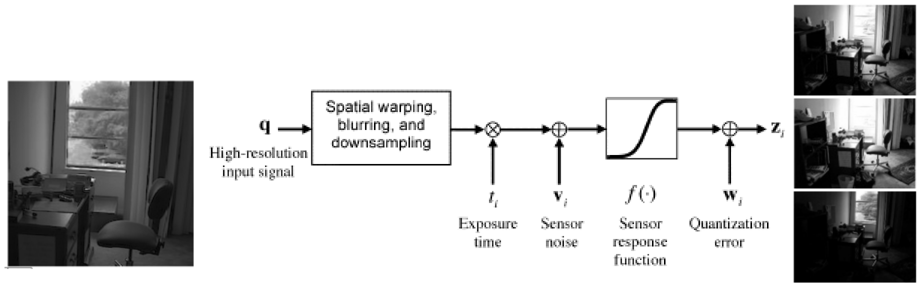

Fig. 1. Proposed super-resolution algorithm uses an imaging model that includes dynamic range and spatial domain effects.

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Image Deblurring

- Camera movement during the exposure progress lead to blurred images. We can model the blurred image as follow:

$$I = L \otimes k + n$$

- The process of recovering sharp image from blurred image is called image deblurring.

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Robust Motion Deblurring

- Two-Phase Kernel Estimation for Robust Motion Deblurring

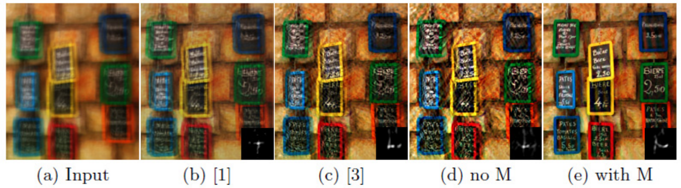

Fig. 6. Small objects such as the characters and thin frames are contained in the image. They greatly increase the difficulty of motion deblurring. (d)-(e) show our results using and not using the M map. The blur kernel is of size 51×51.

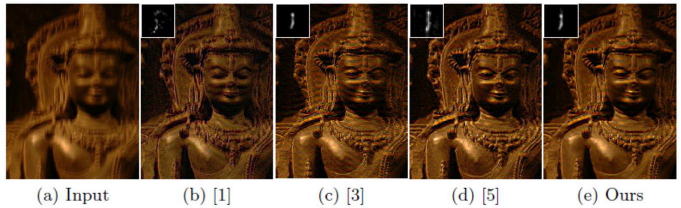

Fig. 7. Comparison of state-of-the-art deblurring methods

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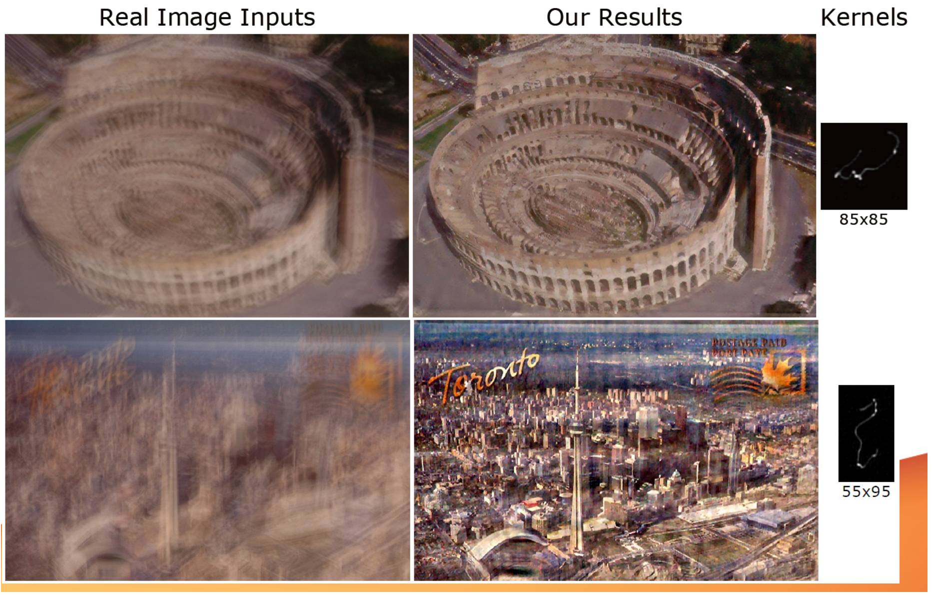
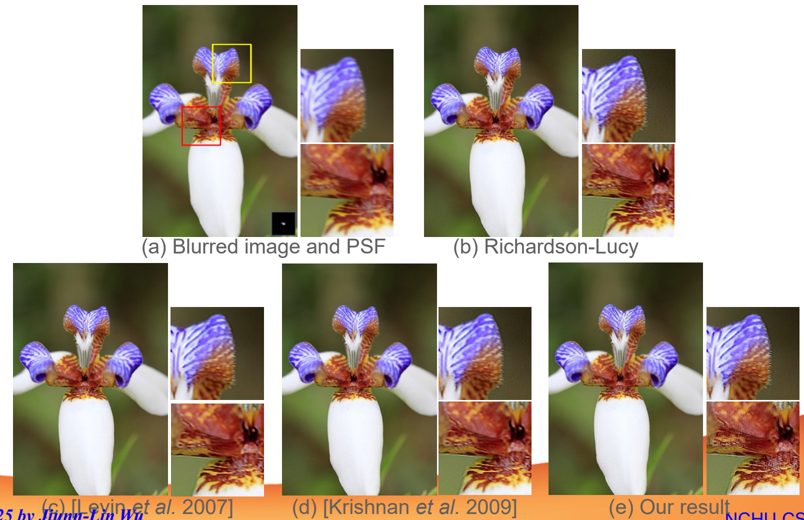
Robust Motion Deblurring



Experimental Results-Real Blurred Images

- The size of "Flower" is 533x800, and PSF size is 31x31.



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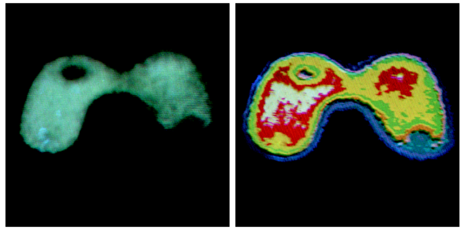
Experimental Results-Real Blurred Images

Course Outline

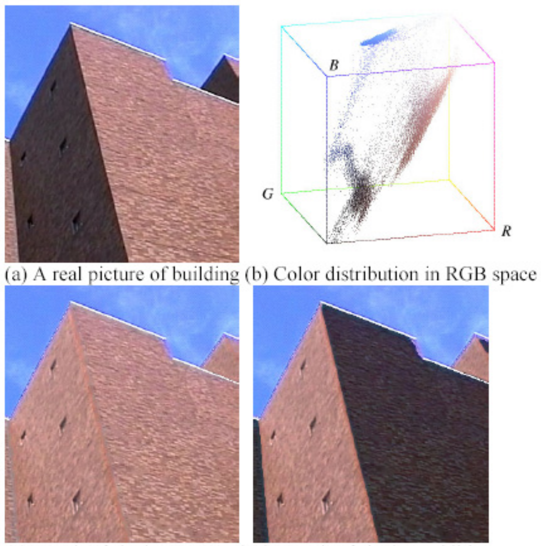
- 6.Color Image Processing
  - Color Fundamentals / Color Models
  - Pseudocolor Image Processing
  - Color Transform
  - Color Segmentation
  - Color Image Enhancement / White Balance
  - Color Image Compression



a b

FIGURE 6.20 (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)

Shadow Removal from A Real Picture

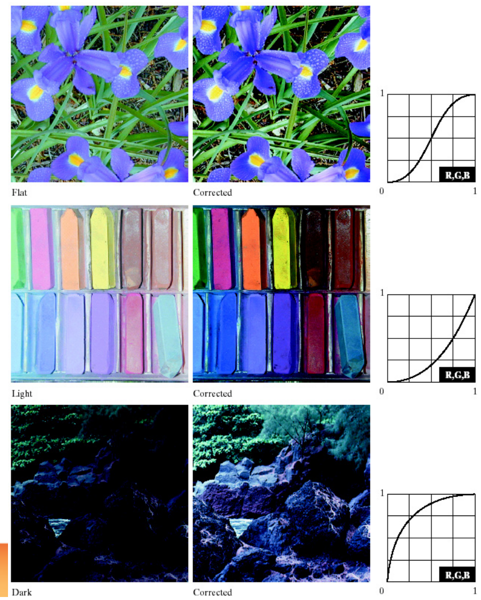


(a) A real picture of building (b) Color distribution in RGB space

(c) Result of shadow removal (d) Result of shadow addition

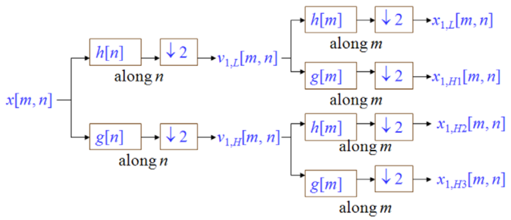
Figure 1. Shadow removal and addition.

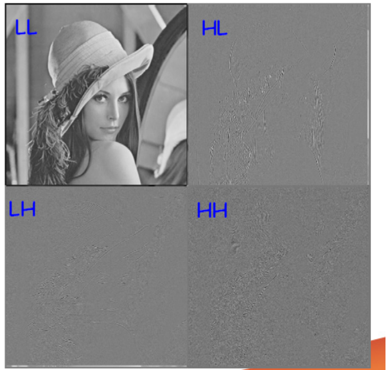
Tone and Color Corrections



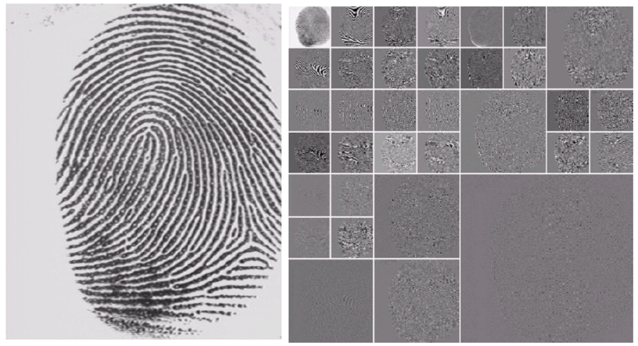
Course Outline

- 7.Wavelets and multiresolution processing
  - Multiresolution Expansions
  - Wavelet Transform





Wavelet Decomposition



a b

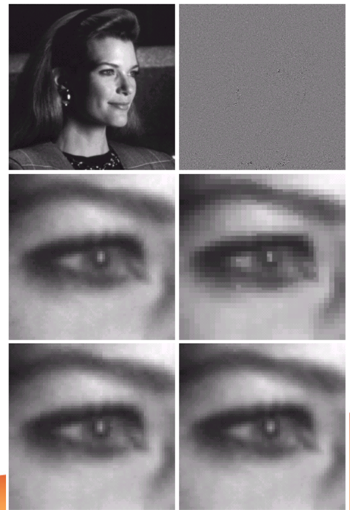
FIGURE 7.34 (a) A scanned fingerprint and (b) its three-scale, full wavelet packet decomposition. (Original image courtesy of the National Institute of Standards and Technology.)

FIGURE 7.35 An optimal wavelet packet decomposition for the fingerprint of Fig. 7.34(a).

Course Outline

- 8.Image compression and Watermarking
  - Image Compression Models
  - Elements of Information Theory
  - Error-Free Compression
  - Lossy Compression
  - Image Compression Standard
  - Fractal Image Compression

  - *More details in the class "Data Compression"*



a b
c d
e f

FIGURE 8.34 Approximations of Fig. 8.23 using 25% of the DCT coefficients: (a) and (b) 8 × 8 subimage results; (c) zoomed original; (d) 2 × 2 result; (e) 4 × 4 result; and (f) 8 × 8 result.

Multimedia Compression

- *More details in the class "Data Compression" and "Multimedia Systems"*

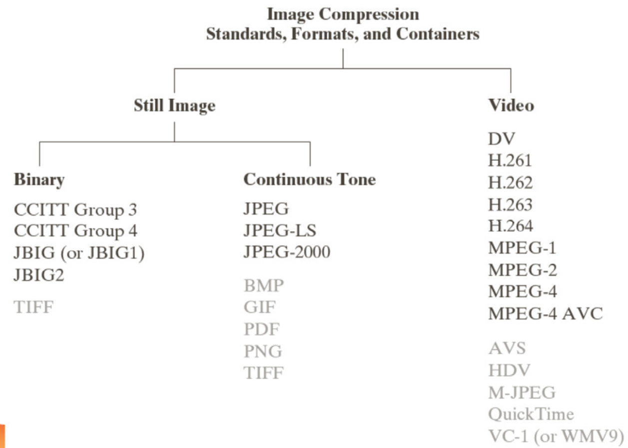
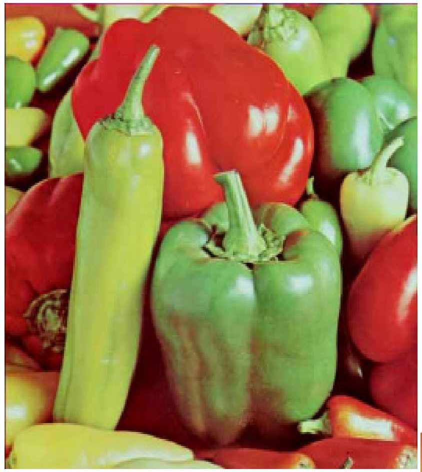


FIGURE 8.6 Some popular image compression standards, file formats, and containers. Internationally sanctioned entries are shown in black; all others are grayed.

Image Compression - JPEG

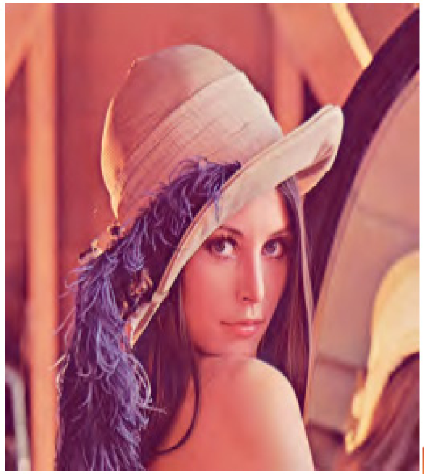
786488 bytes



26614 bytes, Cr=29.55

Image Compression – JPEG2000

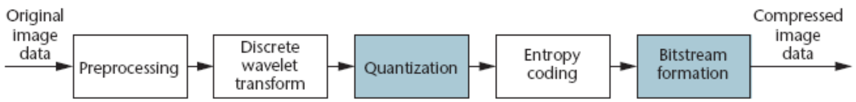
786488 bytes



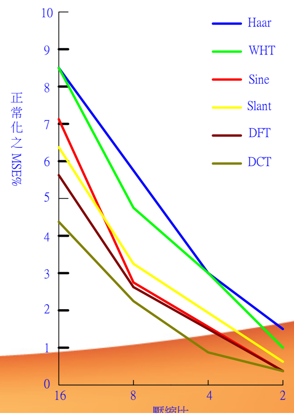
11738 bytes, Cr=67.0

Lossy Example: Transform Encoding

- Transform coding



- Rate-Distortion Curve



Course Outline

- 9.Morphological Image Processing
  - Preliminaries
  - Dilation and Erosion
  - Some Basic Morphological Algorithm

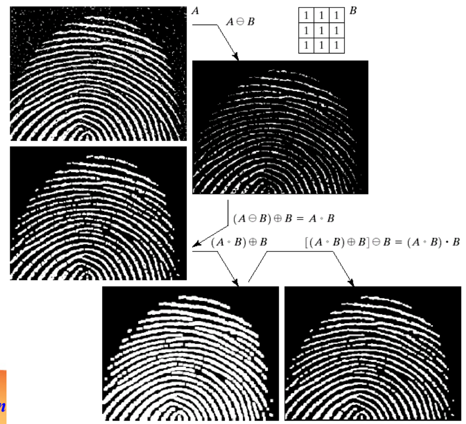
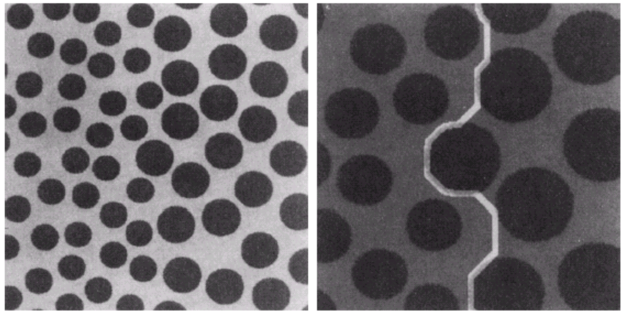


FIGURE 9.11
(a) Noisy image.
(c) Eroded image.
(d) Opening of A.
(d) Dilation of the opening.
(e) Closing of the opening. (Original image for this example courtesy of the National Institute of Standards and Technology.)

Textural Segmentation

a b

FIGURE 9.35 (a) Original image. (b) Image showing boundary between regions of different texture. (Courtesy of Mr. A. Morris, Leica Cambridge, Ltd.)



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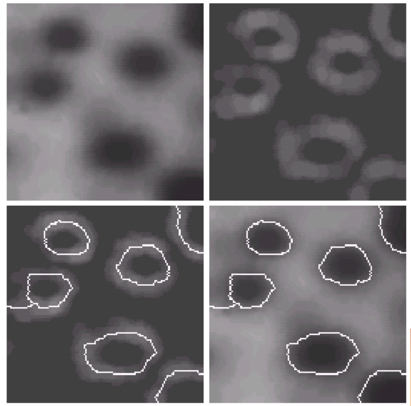
Course Outline

- 10.Image Segmentation
  - Edge Linking and Boundary Detection
  - Thresholding
  - Region-Based Segmentation

a b
c d

FIGURE 10.46 (a) Image of blobs. (b) Image gradient. (c) Watershed lines. (d) Watershed lines superimposed on original image. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)



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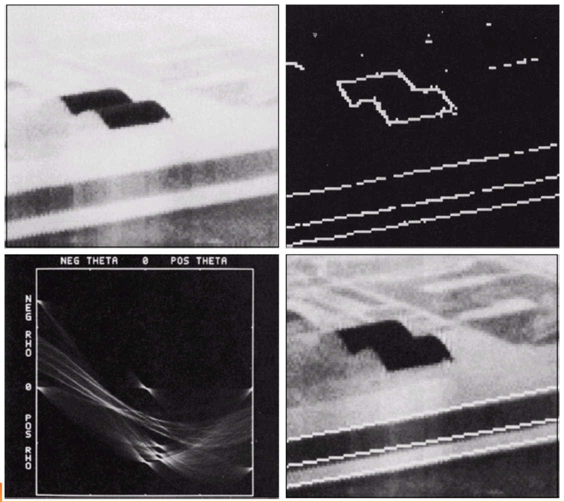
Global Processing via the Hough Transform

- Note the disappearance of the gaps as a result of linking.



a b
c d

FIGURE 10.21 (a) Infrared image. (b) Thresholded gradient image. (c) Hough transform. (d) Linked pixels. (Courtesy of Mr. D. R. Cate, Texas Instruments, Inc.)

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AOI Using Hough Transform

- Automated optical inspection using Hough Transform

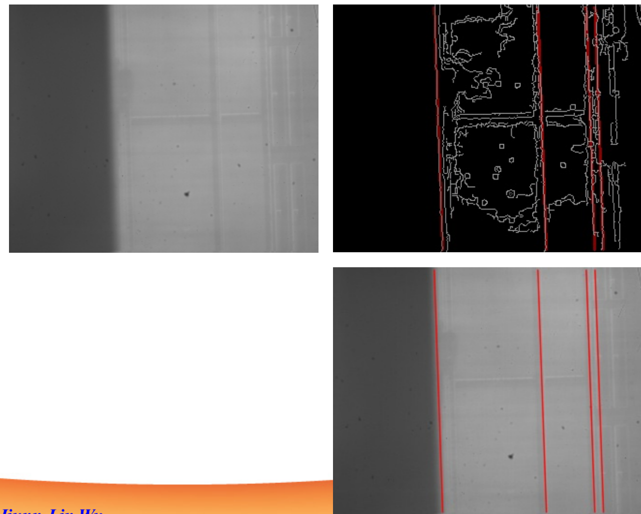

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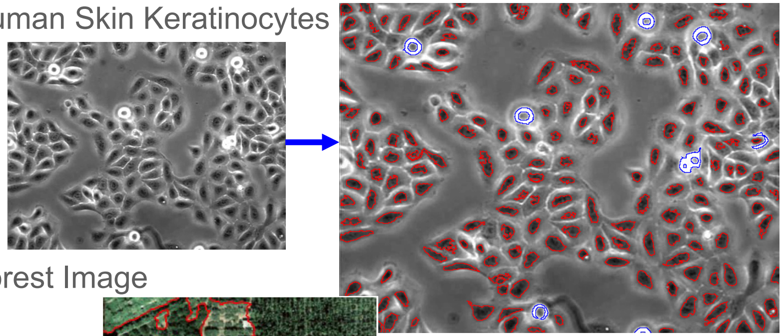
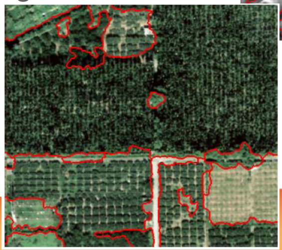
Image Segmentation

- An Automatic Counting System for Microscopic Images of Human Skin Keratinocytes



- Forest Image



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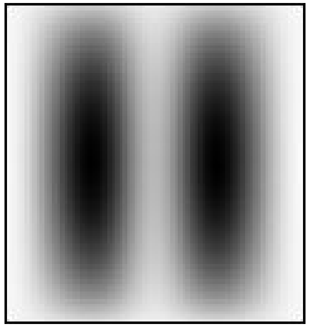
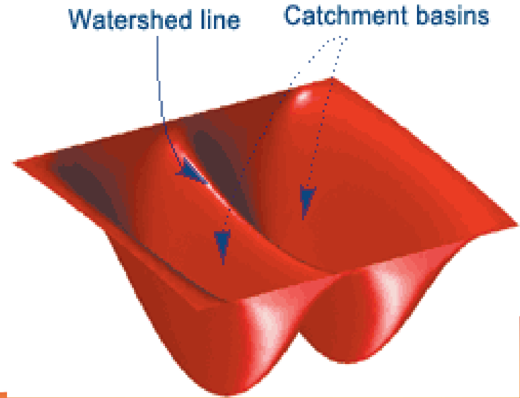
Segmentation by Morphological Watersheds

- The concept of watersheds is based on visualizing an image in three dimensions: two spatial coordinates versus gray levels. (Topographic surface)





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Watershed Segmentation

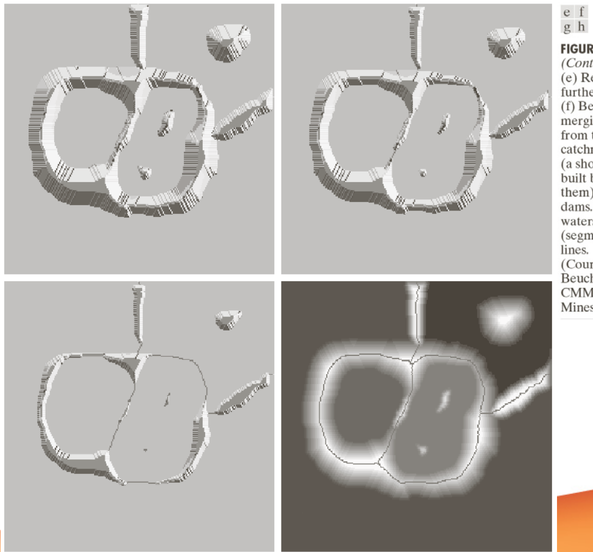

FIGURE 10.54 *(Continued)* (e) Result of further flooding. (f) Beginning of merging of water from two catchment basins (a short dam was built between them). (g) Longer dams. (h) Final watershed (segmentation) lines. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

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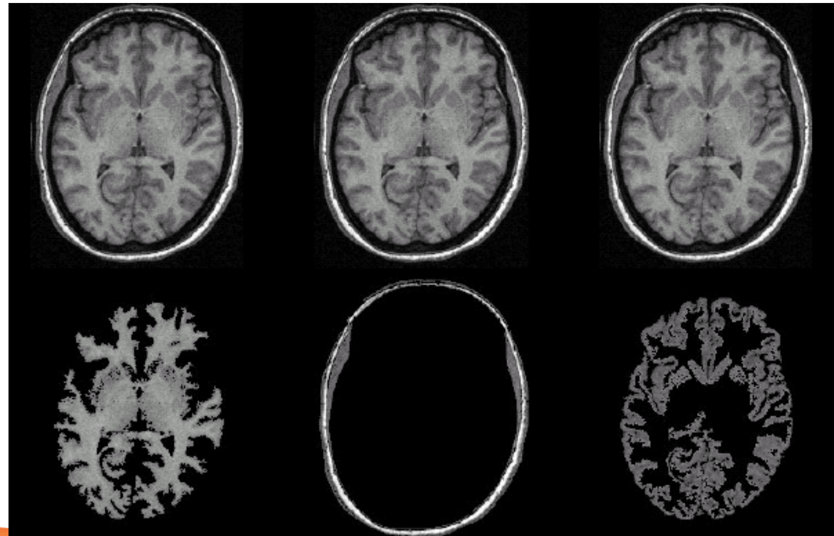
Segmentation by Region Growing



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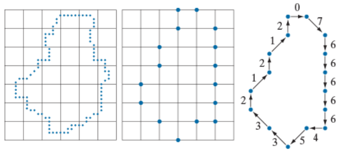
Course Outline

- 11.Feature Extraction
  - Boundary feature descriptors
  - Region feature descriptors
  - Principal components as feature descriptors (*More details in the PR class*)
  - Whole-image features
  - Scale-invariant feature transform(SIFT)



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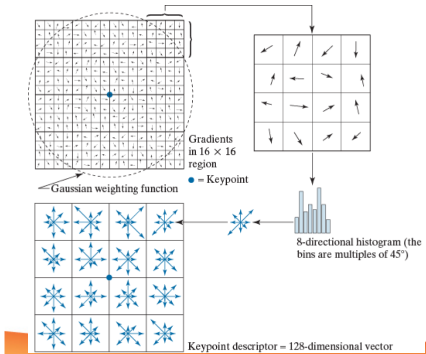
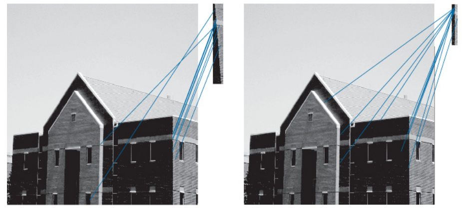
Scale-Invariant Feature Transform(SIFT)

- It is an algorithm used to detect and describe local features in digital images. It locates certain key points and then furnishes them with quantitative information (so-called descriptors) which can for example be used for object recognition. The descriptors are supposed to be invariant against various transformations which might make images look different although they represent the same object(s).





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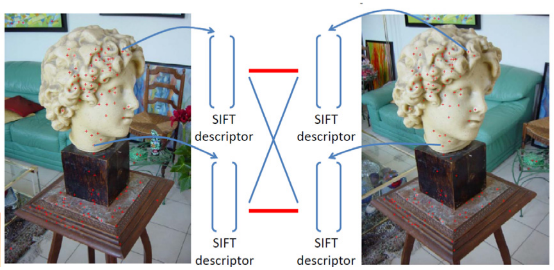
Multi-view 3D Reconstruction



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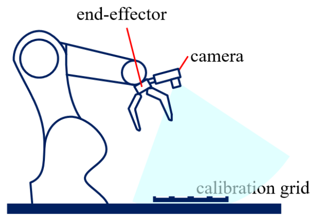
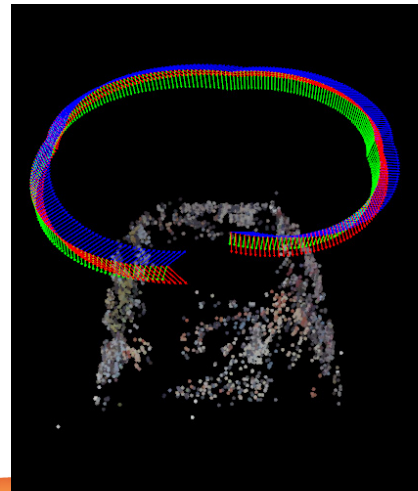
SFM

- SFM = Get the Point Cloud from Moving Cameras





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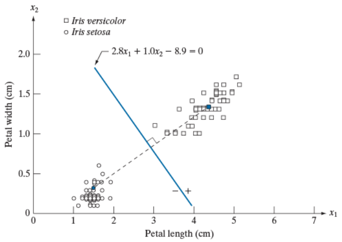
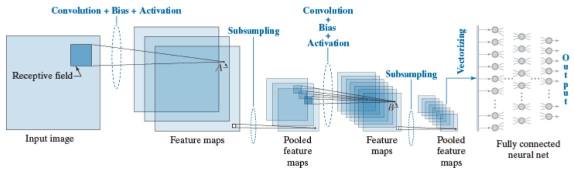
Course Outline

- 12. Image Pattern Classification
  - Expanded coverage of neural networks to include deep neural networks, backpropagation, deep learning, and, especially, deep convolutional neural networks.





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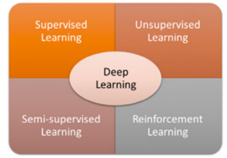
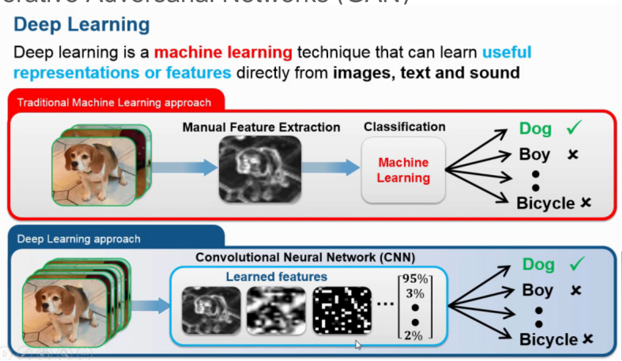
Deep Learning

- Deep Learning
  - Convolutional Neural Networks (卷積神經網路)
  - Deep Auto-Encoders
  - Residual Net
  - Recurrent Neural Networks (RNN/LSTM/GRU)
  - Generative Adversarial Networks (GAN)





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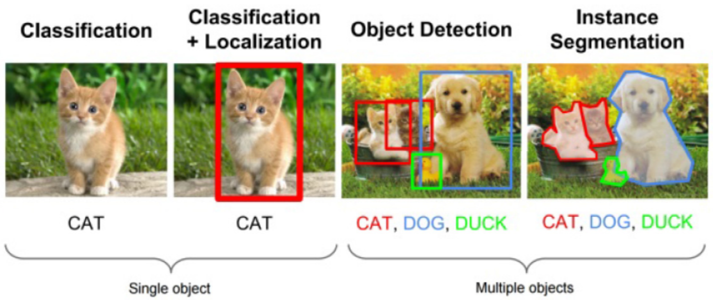
Object Localization and Detection

- We can use convolution neural networks to localize and detect objects on images.



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Object Detectors

- Two stage object detectors: they have one part of their network dedicated to providing region proposals followed by a high quality classifier to classify these proposals.
  - R-CNN
  - Fast R-CNN
  - Faster R-CNN
  - R-FCN
  - Libra R-CNN
- One-stage object detectors: doing object detection is by combining these two tasks into one network
  - YOLO
  - SSD
  - RetinaNet

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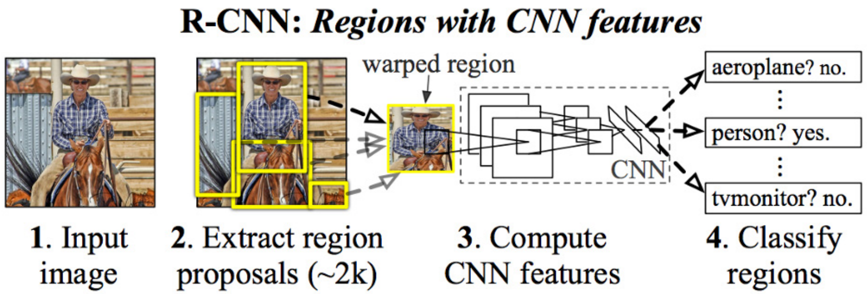
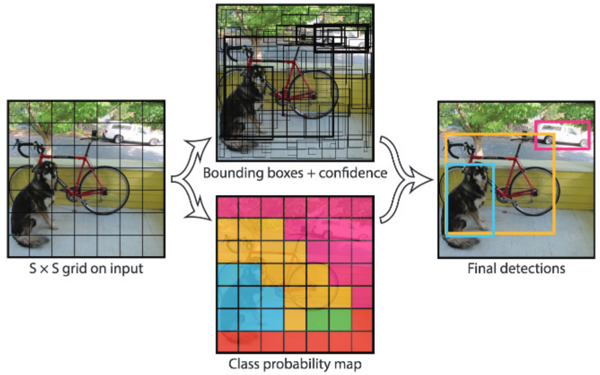
Two-Stage Object Detectors

- R-CNN, or **R**egion-based **C**onvolutional **N**eural **N**etwork, consisted of 3 simple steps:
  - Scan the input image for possible objects using an algorithm called Selective Search, generating ~2000 **region proposals**
  - Run a convolutional neural net (**CNN**) on top of each of these region proposals
  - Take the output of each **CNN** and feed it into a) an SVM to classify the region and b) a linear regressor to tighten the bounding box of the object,



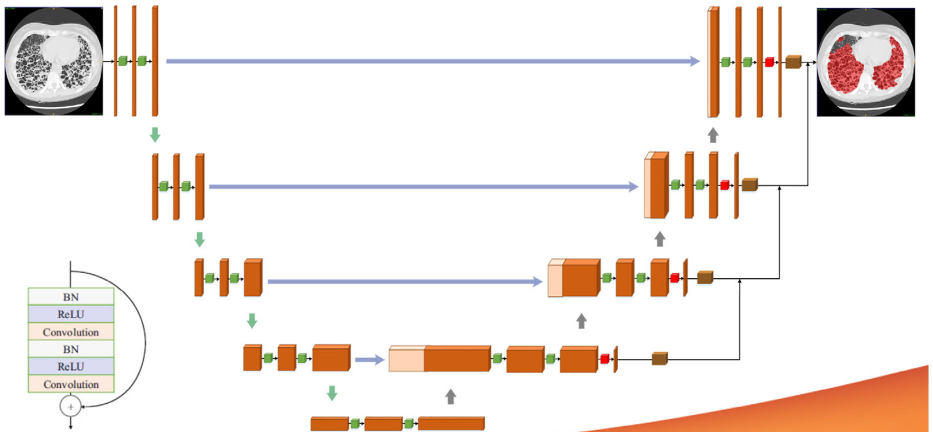
One-Stage Object Detectors

- YOLO: The input image is divided into an SxS grid, B bounding boxes are predicted (regression) and a class is predicted among C classes (classification) over the most confident ones. Source: J. Redmon and al. (2016)



Deep Learning - Unet Architecture

- We used improved 3D U-Net as the network frame for the segmentation of pulmonary fibrosis.



台中市環保局違規小廣告

桌球軌跡追蹤、落點與技戰術分析

桌球軌跡追蹤、落點與技戰術分析

台中市環保局亂丟垃圾偵測

DIP 3E - New Features

- A revision of introductory concepts that provides readers with foundation material much earlier in the book than before.
- A revised and updated discussion of intensity transformation, spatial correlation, convolution, and their application to spatial filtering.
- New discussion of fuzzy sets and their application to image processing.
- A new chapter on the discrete Fourier transform and frequency domain processing.
- New coverage of computerized tomography.
- A revision of the wavelets chapter.

DIP 3E - New Features

- A new chapter on data compression, including new compression techniques, digital video compression, standards, and watermarking.
- New coverage of morphological reconstruction, gray-scale morphology, and advanced morphological algorithms.
- New coverage of the Marr-Hildreth and Canny edge detection algorithms.
- Expanded coverage of image thresholding. (Otsu's method)
- New examples and illustrations involving over 400 new images and more than 200 new drawings and tables.
- Expanded homework sets, including over 80 new problems.
- Updated bibliography.

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DIP 4E - New Features

- New material related to histogram matching.
- Expanded coverage of the fundamentals of spatial filtering.
- A more comprehensive and cohesive coverage of image transforms.
- A more complete presentation of finite differences, with a focus on edge detection.
- A discussion of clustering, superpixels, graph cuts, and their use in region segmentation.
- New material on active contours that includes snakes and level sets, and their use in image segmentation.

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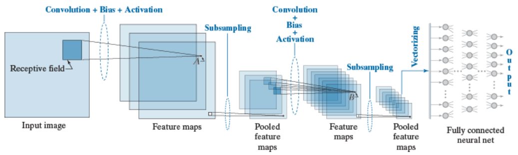
DIP 4E - New Features

- Coverage of maximally stable extremal regions.
- Expanded coverage of feature extraction to include the Scale Invariant Feature Transform (SIFT).
- Expanded coverage of neural networks to include deep neural networks, backpropagation, deep learning, and, especially, deep convolutional neural networks.



- More homework problems at the end of the chapters.
- MATLAB computer projects.

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Grading

- Homework 50%
- Final exam 30%
- Final project 20%

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