

Chapter I

Image Processing: Introduction

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Image

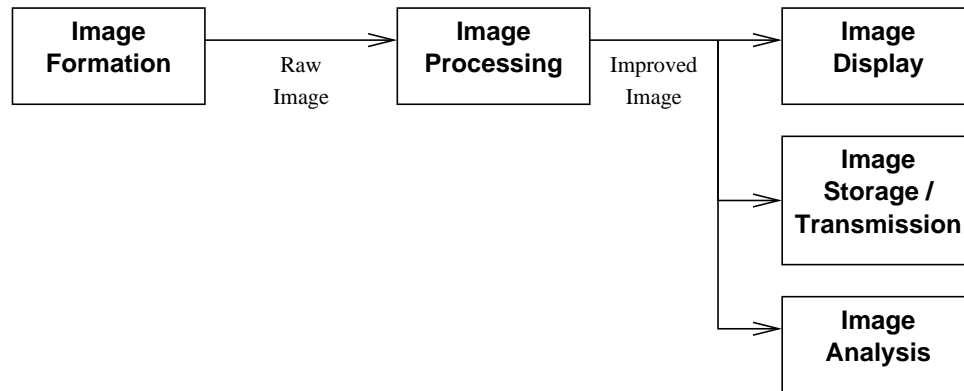
American Heritage Dictionary, 3rd edition:

- A reproduction of the form of a person or an object, especially a sculptured likeness.
- Physics. An optically formed duplicate, counterpart, or other **representative reproduction** of an object, especially an optical reproduction of an object formed by a lens or mirror.
- One that closely or exactly resembles another; a double: He is the image of his uncle.
- ...

Image Processing

Image processing is the application of 2D signal processing methods to images.

In one sense, it is anything that goes in the box labeled “image processing” in diagrams like those below.



More broadly, judging by the topics at ICIP, the IEEE International Conference on Image Processing, and the topics in the IEEE Transactions on Image Processing, the field of image processing also includes many aspects of **image formation**, **image display**, **image compression**, and **image analysis**.

Applications

- Medicine (radiological diagnoses, microscopy)
- Defense (radar, sonar, infrared, satellites, etc.)
- Robotics / machine vision (*e.g.*, “intelligent” vehicles)
- Human / computer interfaces (face / fingerprint “recognition” for security, character recognition)
- Compression for storage, transmission from space probes, etc.
- Entertainment industry
- Manufacturing (*e.g.*, part inspection)

The course emphasis will be fundamental methods and principles that apply across many applications.

History

In some sense “image processing” dates back to the earliest use of graphics by humans (see the nice discussion by Bracewell [1]).

Digital image processing, however, had to wait until the invention of the digital computer...

In the early days, topics like **median filtering** were exciting new research topics. Tools like median filtering are now available in “point and click” software like Adobe’s Photoshop, and are used by thousands of people, many with nontechnical backgrounds.

Introduction to major topics**• Image formation**

How are images created in the first place?

Includes **image reconstruction** from line-integral projections (**computed tomography**).

And reconstruction from Fourier samples (MRI, Radar, ...)

Continuous-space 2D signals and systems theory

• Image representation and modeling**• Image perception**

All digital images are approximations, how can the human visual system help choose among approximations?

• Image sampling**• Image quantization****• Image transforms****• Image enhancement**

Accentuate certain desired features for subsequent analysis or display.

• Image restoration / image filtering

Remove or minimize known degradations (*e.g.*, image blur due to faulty Hubble telescope optics)

(However, the repair of the Hubble mirror reminds us that analog solutions can sometimes prevail over digital ones. We will see why in our discussion of the limitations of image restoration.)

• Image analysis / computer vision

Extracting information from images, can be quantitative (*e.g.*, object dimensions or position) or symbolic (*e.g.*, character recognition).

• Image compression for efficient storage, transmission.

Entire courses could be devoted to each of these topics. Rather than attempting to cover as many methods for image processing as is possible, we will discuss the fundamentals in each of the above categories, hopefully in sufficient depth to facilitate subsequent independent reading of the image processing literature.

Examples

The textbook contains many graphical examples for each of the above topics.

Reference Books

Some references I use a lot _____

bracewell:78 McGraw-Hill ny 1978 R Bracewell The Fourier transform and its applications
 bracewell:95 Prentice Hall ny 1995 Ronald N Bracewell Two dimensional imaging
 goodman:68 McGraw-Hill ny 1968 Joseph W Goodman Introduction to Fourier optics
 goodman:85 Wiley ny 1985 J W Goodman Statistical optics

Some classic image processing books _____

pratt:78 Wiley ny 1978 W Pratt Digital image processing @an 1991 edition???
 gonzoles:87 Addison-Wesley Reading, MA 1987 R C Gonzoles P A Wintz Digital image processing
 rosenfeld:82 Academic Press ny 1982 A Rosenfeld A C Kak Digital picture processing

The recommended texts _____

jain:89 Prentice-Hall New Jersey 1989 A K Jain Fundamentals of digital image processing
 lim:90 Prentice Hall ny 1990 Jae S Lim Two-dimensional signal and image processing

Some other books I have but have rarely used to date _____

castleman:96 Prentice Hall ny 1996 K R Castleman Digital image processing @an low-medium level of math
 gose:96 Prentice Hall ny 1996 E Gose R Johnsonbaugh S Jost Pattern recognition and image analysis @an introductory statistical treatments
 umbaugh:98 Prentice Hall ny 1998 S E Umbaugh Computer vision and image processing: A practical approach using CVIPtools @an lots of pictures and basic stuff

Some other interesting stuff _____

marr:82 Freeman San Francisco 1982 D Marr Vision @an classic book on human visual system from computer vision perspective
 berterio:98 IoP London 1998 M Bertero P Boccacci Introduction to inverse problems in imaging

Stuff I need to examine _____

andrews:77 Prentice-Hall NJ 1977 H C Andrews B R Hunt Digital image restoration
 dougherty:87 Prentice-Hall ny 1999 E R Dougherty Charles R Giardina Image processing: continuous to discrete
 green:89 Van Nostrand Reinhold ny 1989 William B Green Digital image processing: a systems approach @edition 2
 russ:99 CRC Press Boca Raton, FL 1999 John C Russ The image processing handbook
 sonka:99 PWS Pub. Pacific Grove, CA 1999 M Sonka Vaclav Hlavac Roger Boyle Image processing, analysis, and machine vision @edition 2

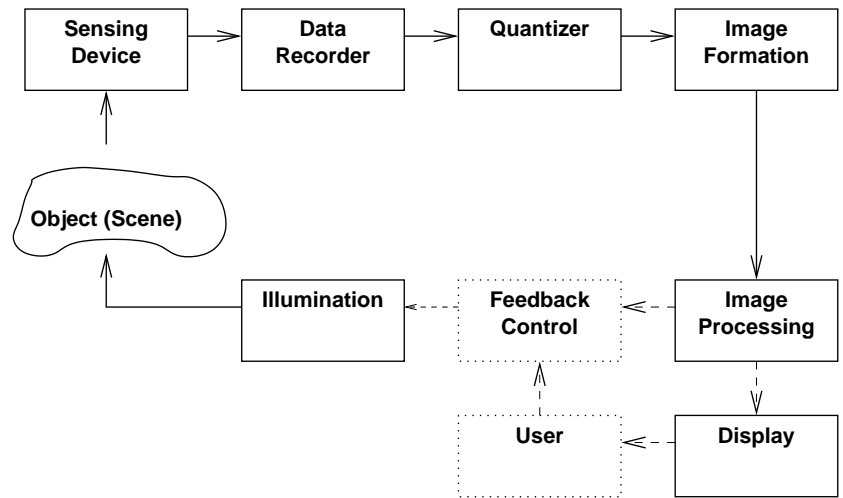
Image processing journals

There are (too) many. Here are some of my favorites.

- IEEE Trans. Image Processing
- IEEE Trans. Signal Processing
- IEEE Trans. Pattern Analysis and Machine Intelligence
- Journal of the Optical Society of America
- Optical Engineering
- IEEE Trans. Medical Imaging
- Medical Image Analysis
- ...

Sometimes image processing papers appear in SIAM journals, Inverse problems, Physics in medicine and biology, etc. And probably lots of other places I have never seen, since anyone can easily “process images” these days.

Imaging Systems and Image Formation



The **illumination** can be of many forms, each of which associated with corresponding applications.

- optical: coherent, incoherent, structured
- electromagnetic waves (radar, microwave, etc.)
- acoustic (medical ultrasound, sonar)
- ionizing radiation (x-rays, gamma rays, protons, neutrons, etc.)

(In cases like astronomical imaging, the scene itself is the illumination.)

The “Ideal” Imaging System

From [2, p. 296], “A common function of an imaging system is to provide an observer with visual information that is more detailed and/or more accurate than could be obtained with the unaided eye,” *e.g.*, telescopes, microscopes, X-ray systems, infrared imaging, Hubble restoration.

What are its characteristics?

- ??
- ??
- ??
- ??
- ??
- ??
- ??
- ??
- ??
- ??
- ??

Note: these lecture notes contain many such embedded questions that will be answered in class. If you miss an answer, you are always welcome to come ask in office hours.

But first we start with the tools...

Bibliography

- [1] R. N. Bracewell. *Two-dimensional imaging*. Prentice-Hall, New York, 1995.
- [2] J. W. Goodman. *Statistical optics*. Wiley, New York, 1985.