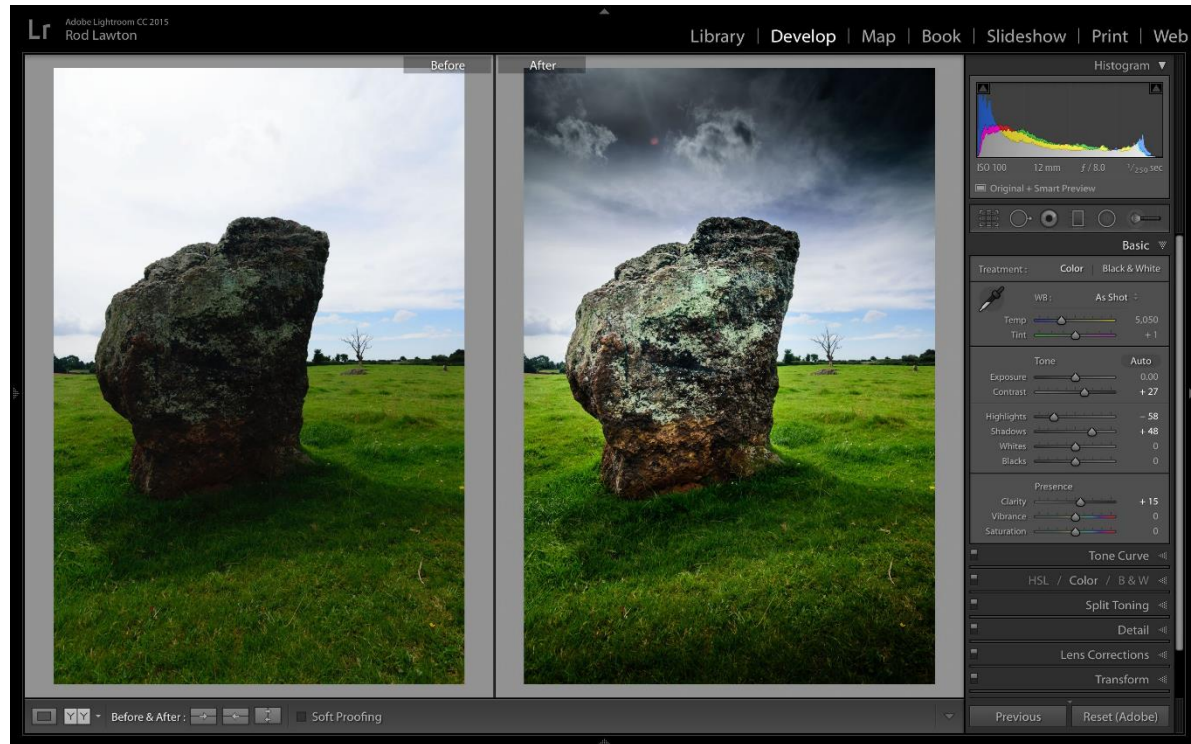# Chapter 1: "Introduction to Digital Image Processing"
## Part 1 out of 3

Digital image processing involves the manipulation & analysis of digital images with the aid of a computer.

Chapter 1: "Introduction to Digital Image Processing"

Why process image data digitally?

- To keep up with the advancement in the satellite imaging, we have to process image data digitally because we need to process images with speed & accuracy using the computer.

- The problem is that the computers can only deal with data on digital format.
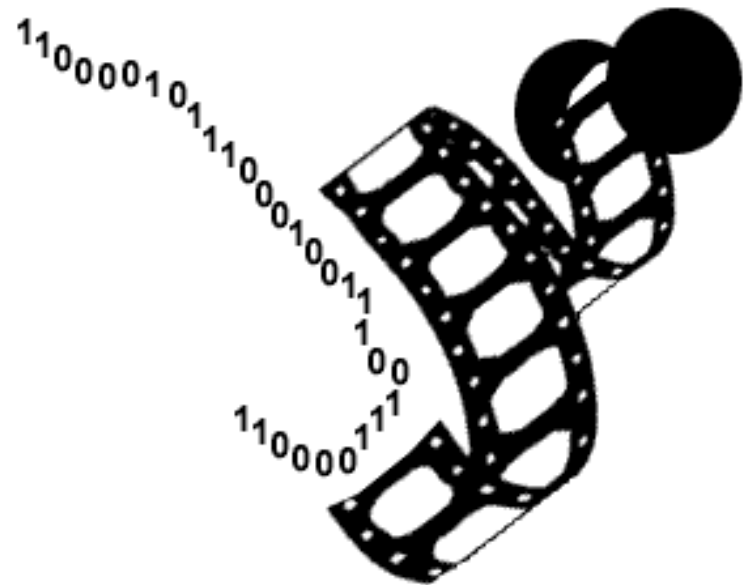
© CCRS / CCT

Chapter 1: "Introduction to Digital Image Processing"

So why do we need the computer in image processing?

Despite the fact that humans are faster in recognizing images, computers are needed because:

1. Computers are much more adept at storing & manipulating huge amount of data with speed & accuracy.

2. There are certain thresholds beyond which the human interpreter cannot detect.

3. results obtained by a computer are always repeatable, even when they are wrong!

© CCRS / CCT

Chapter 1: "Introduction to Digital Image Processing"

The question now is what is a digital image?

-A digital image is a computer compatible pictorial rendition in which the image is divided into a fine grid of pixels, when viewed, the appearance is that of continuous tone picture.

-Digital images are produced through a process referred to as discrete sampling. In which, a small image area, called pixel, is "sensed" to determine the amount of electromagnetic energy given of surface on the object.

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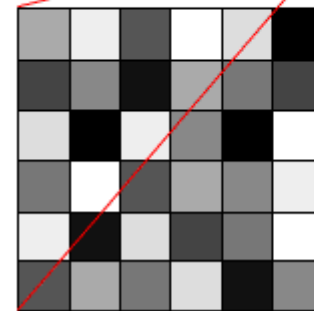
170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Chapter 1: "Introduction to Digital Image Processing"

The question now is what is a digital image? *(continue)*

- Discrete sampling of an image has two fundamental characteristics; (1) geometric resolution, & (2) radiometric resolution.

- Geometric resolution refers to the physical size of an individual pixel, with smaller pixel sizes corresponding to higher geometric resolution.

10-meter resolution.
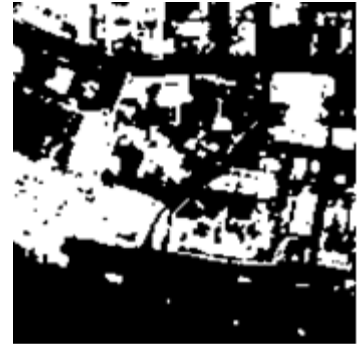
30-meter resolution.

80-meter resolution.

Chapter 1: "Introduction to Digital Image Processing"

The question now is what is a digital image? (continue)

- Radiometric resolution, on the other hand, can be broken down into level of quantization & spectral resolution.

- Quantization level refers to the conversion of the amplitude of the original electromagnetic energy. Grater levels of quantization result in more accurate digital representation of the analog signals.

1-bit quantization Level.

2-bit quantization Level.
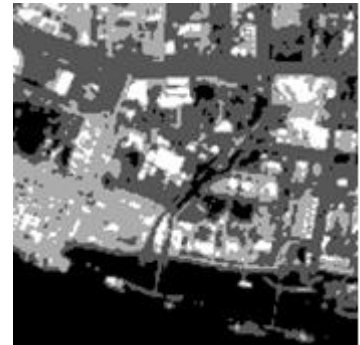
8-bit quantization Level.

Chapter 1: "Introduction to Digital Image Processing"

The question now is what is a digital image? *(continue)*

-In spectral resolution, however, samples of electromagnetic energy are normal sensed only within narrow band of the spectrum.

-With a higher level of spectral resolution, more channels, a more accurate representation of an objects spectral response pattern can be made.
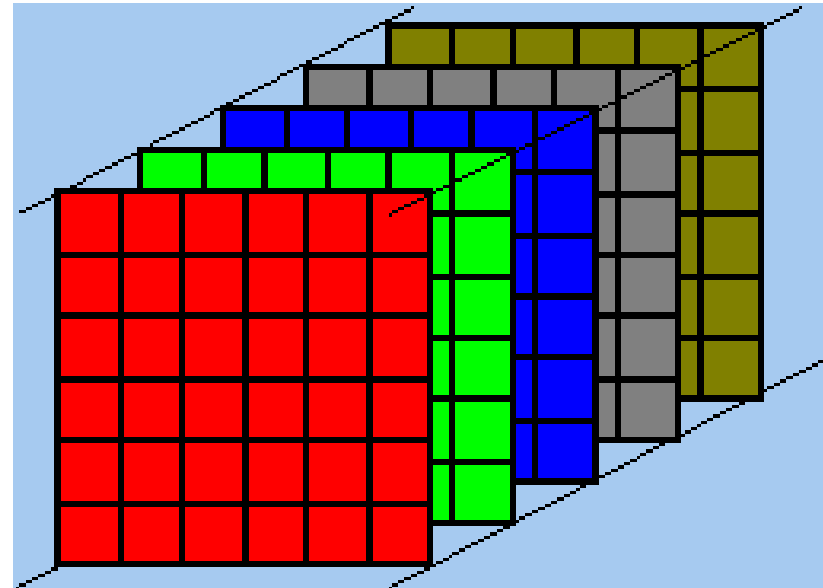
Data Acquisition in Digital Format:

Two fundamentals mechanisms to acquire images on a digital format:

1. *Acquire images on a photographic format, then digitize them, or*

2. *Acquire images on a digital format from the beginning.*
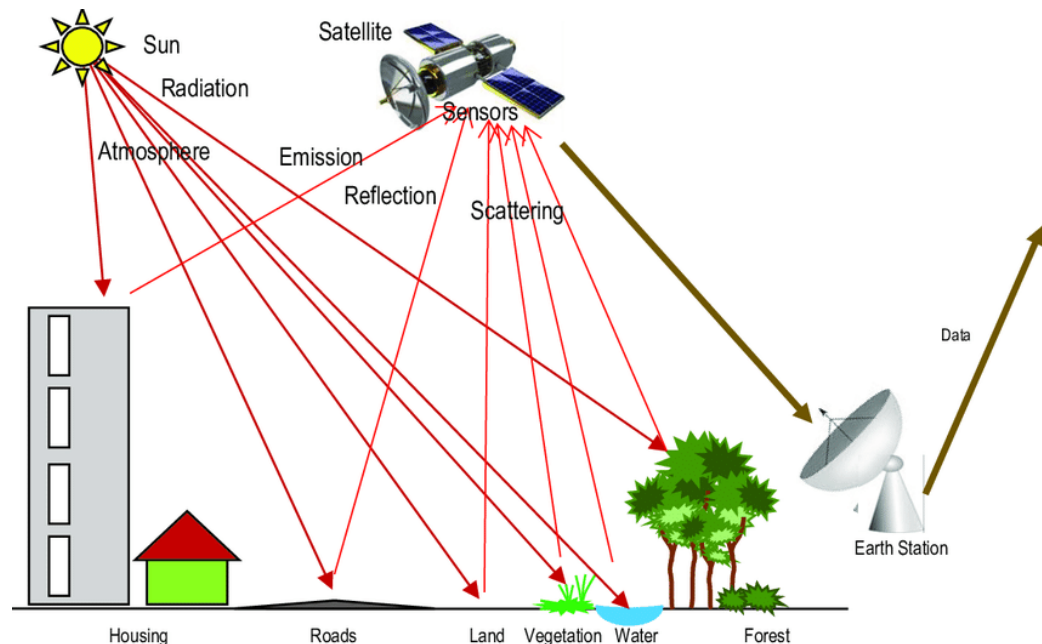
Chapter 1: "Introduction to Digital Image Processing"

Data Acquisition in Digital Format: *(continue)*

A photograph is a 2-D reflectance, or transmittance that varies as a function of x, & y position.

The density of the (x, y) position is a measure of the light-absorbing capability of the silver at that location on the image.

The gray shades, or brightness values, in such image may be converted into discrete values that are proportional to the integrated output of a small pixel.

This process is called analog-to-digital (A-to-D) conversion & creates a matrix of brightness values corresponding to the average radiance measured from individual pixels that have been scanned.

Chapter 1: "Introduction to Digital Image Processing"

Data Acquisition in Digital Format: (continue)

Three methods, to be covered hear, for converting hard-copy photography into a format suitable for digital image processing; (1) optical-mechanical scanning, (2) video digitization, & (3) linear photodiode, or charged-coupled-device (CCD) digitization.

Old photograph (analogue) → Scanner converts photo into digital data → Digital photo can be stored on a computer

Chapter 1: "Introduction to Digital Image Processing"

1. Optical-Mechanical Scanning:

- Flat-Bed & Rotating-Drum Scanners are two types of optical-mechanical scanning systems that are used to convert hard-copy photographic images into digital values.

- Both these systems measure image density with an instrument called a densitometer.

- A densitometer is a device that measures the average density of a small area of specified size on a photographic transparency or print.

Flat-Bed scanners.

SE 423, "Digital Image Processing".

Chapter 1: "Introduction to Digital Image Processing"

1. Optical-Mechanical Scanning: (continue)

- This process operates on a pixel-by-pixel basis & results in a matrix of values that are usually recorded in 8 bit quantization level ranging from 0 to 255.

- Flat-Bed & Rotating-Drum microdensitometers are relatively slow, expensive, & difficult to maintain.

- But offer repeatable spatial & radiometric accuracy.
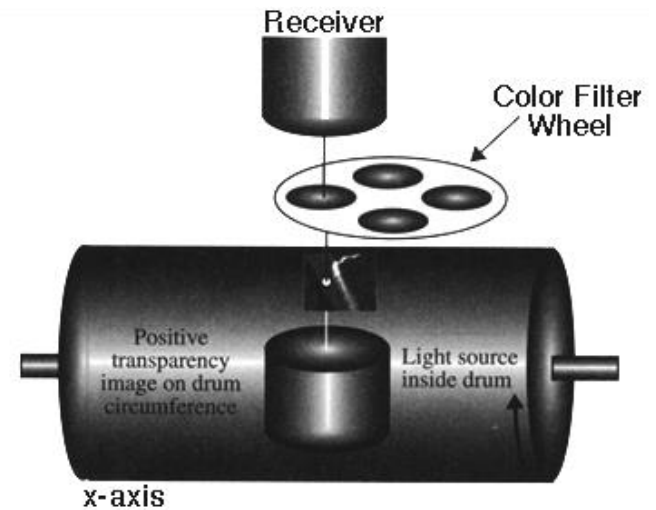
Rotating-Drum scanners.

Chapter 1: "Introduction to Digital Image Processing"

2. Video Digitization:

- Another approach to digitizing hard-copy imagery can be through the use of a video camera.

- Video digitizing involves "freezing" & then digitization of individual video frames.

- Video digitizing represents a low-cost alternative which is convenient.

- But exhibits generally poor spatial resolution & often unrepeatable radiometric or gray-scale resolution.
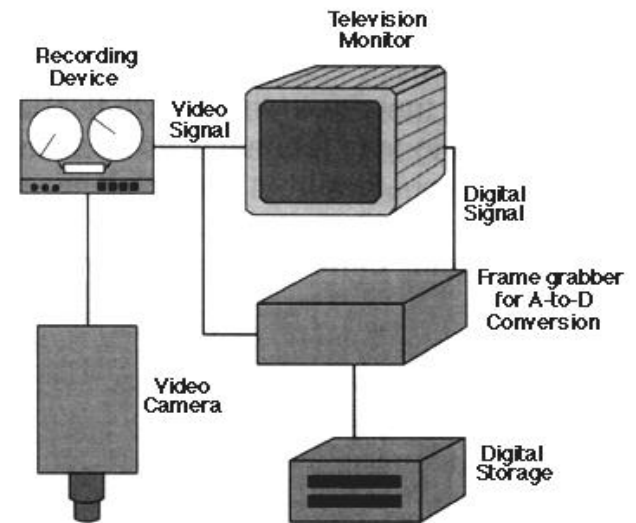
Video Digitization.

Chapter 1: "Introduction to Digital Image Processing"

3. Linear photodiode, or (CCD) digitization:

- CCDs are very small detectors designed to rapidly encode images in a numeric format for subsequent computer analysis.

- Typical output from such systems is a matrix with 1 to 12 bits per pixel & results in high spatial resolution, good radiometric accuracy, & fast digitization.

- The only drawback is that it has a relatively high initial coast.
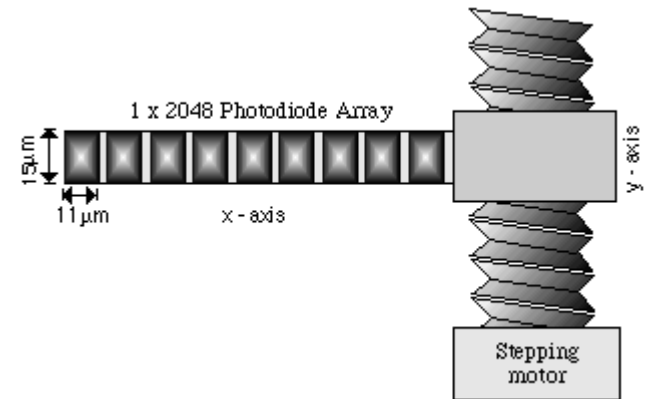
A linear photodiode.

Chapter 1: "Introduction to Digital Image Processing"

Data Already in a Digital Format:

Ideally, data are provided to the user in a digital format. This is the case with much of the remotely sensed data & digital cameras.

In order to properly process remotely sensed data, it is better to know how the data is organized & stored on digital formats, & how the data is processed by computers & software. Understanding existing digital data formats is the key for successful data processing.

Chapter 1: "Introduction to Digital Image Processing"

Data Already in a Digital Format: *(continue)*

There are many data formats used by government & commercial data suppliers, three of them is explained here; (1) Band Sequential (BSQ) Format, (2) Band Interleaved by Line (BIL) Format, (3) Band Interleaved by Pixel (BIP) Format. Each of these formats is usually proceeded on the digital type by "header" &/or "trailer" information, that consists of ancillary data such as the date of the image, altitude, sun angle, etc.
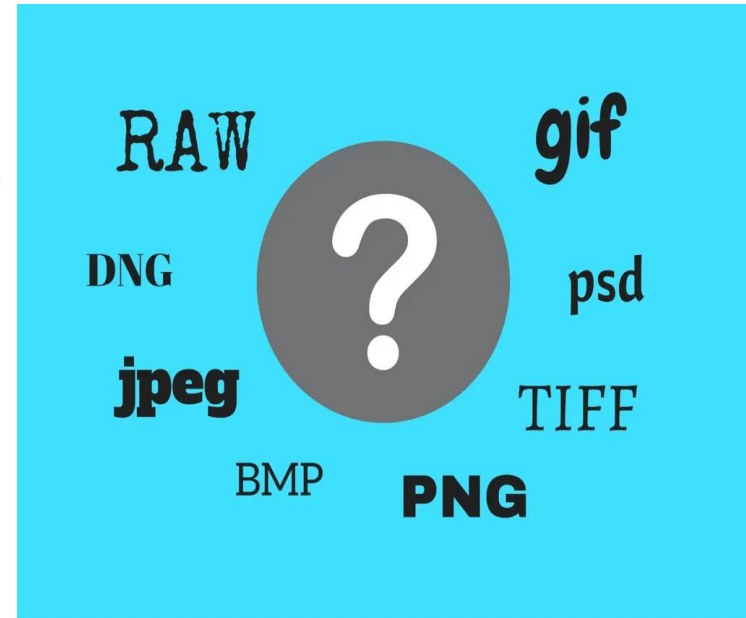
Chapter 1: "Introduction to Digital Image Processing"

Data Already in a Digital Format: *(continue)*

Band Sequential Format

The band sequential format requires that all data for a single band covering the entire scene is written as one file. Thus, if an analyst wanted to extract the area in the center of a scene in four bands, it would be necessary to read into this location in four separate files to extract the desired information.

Band Sequential (BSQ)
Computer Compatible Tape Format
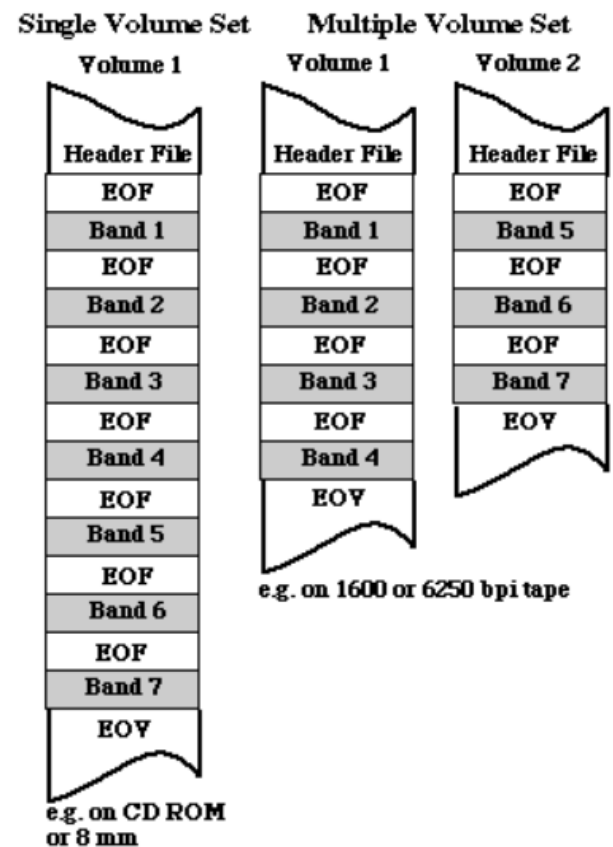
Single Volume Set

Volume 1

Header File
EOF
Band 1
EOF
Band 2
EOF
Band 3
EOF
Band 4
EOF
Band 5
EOF
Band 6
EOF
Band 7
EOV

e.g. on CD ROM or 8 mm

Multiple Volume Set

Volume 1

Header File
EOF
Band 1
EOF
Band 2
EOF
Band 3
EOF
Band 4
EOV

Volume 2

Header File
EOF
Band 5
EOF
Band 6
EOF
Band 7
EOV

e.g. on 1600 or 6250 bpi tape

Chapter 1: "Introduction to Digital Image Processing"

Data Already in a Digital Format: *(continue)*

Band Interleaved By Line Format (BIL)

The band interleaved by line (BIL) format is stored by lines. Each line is represented in all bands before the next line is recorded. This is a useful format to use if all bands of the imagery are to be used in the analysis. If some bands are not of interest, the format is inefficient if the data are on tape, since it is necessary to read serially past unwanted data.

.

Figure 2-3.2 Band Interleaved by Line Format (BIL)							
Line 1	Band 1	Line 1	Band 2	Line 1	Band 3	Line 1	Band 4
	Line 2	Band 1	Line 2	Band 2	Line 2	Band 3	Line 2 Band 4
		Line 3	Band 1	Line 3	Band 2	Line 3	Band 3	Line 3	Band 4
			Line 4	Band 1	Line 4	Band 2	Line 4	Band 3	Line 4	Band 4

Data Already in a Digital Format: *(continue)*

Band Interleaved By Pixel Format (BIP)

This format treats pixels as the separate storage unit. Brightness values for each pixel are stored one after another. It is practical to use if all bands in an image are to be used. All bands are written to the tape before values for the next pixel are represented. This format may be okay to use if only certain bands of the imagery are needed

.

Figure 2-3.1 Band Interleaved by Pixel Format (BIP)								
Line 1	Pixel 1	Band 1	Line 1	Pixel 2	Band 1	Line 1	Pixel 3	Band 1
Line 1	Pixel 1	Band 2	Line 1	Pixel 2	Band 2	Line 1	Pixel 3	Band 2
Line 1	Pixel 1	Band 3	Line 1	Pixel 2	Band 3	Line 1	Pixel 3	Band 3
Line 1	Pixel 1	Band 4	Line 1	Pixel 2	Band 4	Line 1	Pixel 3	Band 4
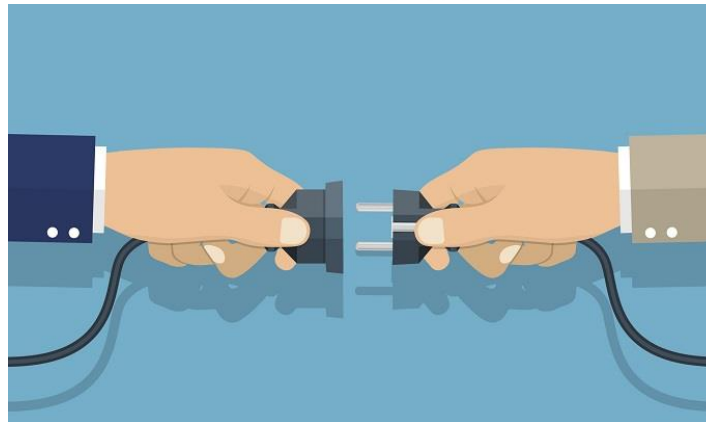
Data Exchange Standards:

The data exchange process are users import data purchased from data providers. These are usually government agencies or commercial data sources.

For data export, each internal data model must be converted to a specific file structure on disk or other media. The process is reversed for data import.

Chapter 1: "Introduction to Digital Image Processing"

Image Processing System Considerations:

Once the data are in a digital format, it is possible to analyze them using a digital image processing system to extract information from the imagery.

The analyst should know that there is a positive relationship between the accuracy of a function is performed, the speed at which the image processing is performed, & the cost.
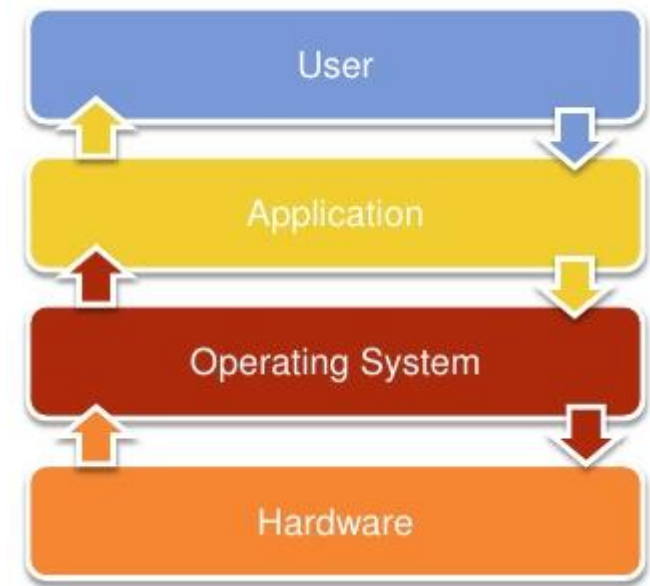
OPERATING SYSTEM OVERVIEW

Chapter 1: "Introduction to Digital Image Processing"

Image Processing System Considerations: *(continue)*

When designing a digital image processing system, the following factors should be considered in the following sequence:

- *1. The maximum number of access to the system at one time.*
- *2. Softwares necessary for the digital image processing system.*
- *3. Hardware considerations, such as the CPU, the RAM, operating systems & compilers, the amount & types of mass storage required, the spatial & color resolutions of the monitor.*

In addition to the above requirements, one should consider other necessary supporting equipments such as printers, plotters, digitizers, scanners, etc.

Chapter 1: "Introduction to Digital Image Processing"

Digital Image processing operations:

Digital image processing is an extremely broad subject that often involves procedures that can be mathematically complex.

The Remote Sensing Process

Statement of the Problem	→	Data Collection	→	Data-to-Information Conversion	→	Information Presentation

• Formulate Hypothesis
 (if appropriate)

• Select Appropriate Logic
 - Inductive and/or
 - Deductive
 - Technological

• Select Appropriate Model
 - Deterministic
  - Empirical
  - Knowledge-based
  - Process-based
 - Stochastic

• *In Situ* Measurements
 - Field (e.g., *x,y,z* from GPS, biomass, reflectance)
 - Laboratory (e.g., reflectance, leaf area index)

• Collateral Data
 - Digital elevation models
 - Soil maps
 - Surficial geology maps
 - Population density, etc.

• Remote Sensing
 - Passive analog
  - Frame camera
  - Videography
 - Passive digital
  - Frame camera
  - Scanners
   - Multispectral
   - Hyperspectral
  - Linear and area arrays
   - Multispectral
   - Hyperspectral
 - Active
  - Microwave (RADAR)
  - Laser (LIDAR)
  - Acoustic (SONAR)

• Analog (Visual) Image Processing
 - Using the *Elements of Image Interpretation*

• Digital Image Processing
 - Preprocessing
  - Radiometric Correction
  - Geometric Correction
 - Enhancement
 - Photogrammetric analysis
 - Parametric, such as
  - Maximum likelihood
 - Nonparametric, such as
  - Artificial neural networks
 - Nonmetric, such as
  - Expert systems
  - Decision-tree classifiers
  - Machine learning
 - Hyperspectral analysis
 - Change detection
 - Modeling
  - Spatial modeling using GIS data
  - Scene modeling
 - Scientific geovisualization
  - 1, 2, 3, and *n* dimensions

• Hypothesis Testing
 - Accept or reject hypothesis

• Image Metadata
 - Sources
 - Processing lineage

• Accuracy Assessment
 - Geometric
 - Radiometric
 - Thematic
 - Change detection

• Analog and Digital
 - Images
  - Unrectified
  - Orthoimages
 - Orthophotomaps
 - Thematic maps
 - GIS databases
 - Animations
 - Simulations

• Statistics
 - Univariate
 - Multivariate

• Graphs
 - 1, 2, and 3 dimensions

Jensen, 2007

Chapter 1: "Introduction to Digital Image Processing"

Digital Image processing operations: (continue)

All of the procedures involved in digital image processing operations may be categorized into one or more of the following five broad types of computer assisted operations:

- ◦ 1. Image Rectification & Restoration, or "pre-processing".

    The aim of these operations is to correct distorted or degraded image data to create a more faithful representation of the original scene.

- ◦ 2. Image Enhancement.

    These procedures are applied to image data in order to more effectively display the data for subsequent visual interpretation.

Chapter 1: "Introduction to Digital Image Processing"

Digital Image processing operations: *(continue)*

- ◦ *3. Image Classification.*

    The objective of these operations is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene.

- ◦ *4. Data Merging.*

    Data merging are used to combine image data for a given geographic area with other geographically referenced data sets for the same area.

Chapter 1: "Introduction to Digital Image Processing"

Digital Image processing operations: (continue)

- ◦ *5. Biophysical Modeling.*

  The objective of these procedures is to relate quantitatively the digital data recorded by a R.S. system to biophysical features & phenomena measured on the ground, such as water depth & pollution considerations.

Nonetheless, we should always remember that the bounders between these various operations are not well defined in practice.

Chapter 1: "Introduction to Digital Image Processing"

That's the end of Chapter 1

Thank You.