Chapter 8 Image Processing Systems

8.1 Image Processing in Remote Sensing

Remotely sensed data are usually digital image data. Therefore data processing in remote sensing is dominantly treated as **digital image processing**.

Figure 8.1.1 shows the data flow in remote sensing. Figure 8.1.2 shows the major data processing techniques in remote sensing.

(1) **Input data**

There are two data sources; analog data and digital data. Digital data, for example multispectral scanner data, is converted from HDDT (high density digital tape) to CCT (computer compatible tape) for ease of computer analysis. Analog data for example, film must be digitized by an image scanner or drum scanner into digital image data.

(2) **Reconstruction / Correction**

Reconstruction, restoration and/or correction of radiometry and geometry should be undertaken in the process of preprocessing.

(3) **Transformation**

Image enhancement, spatial and geometric transformation and/or data compression is normally required to generate a thematic map or database.

(4) **Classification**

Image features are categorized, which is called labeling in image processing, using those techniques of learning, classification, segmentation and/or matching.

(5) **Output**

There are two output methods; analog output such as film or color copy, and digital output in the form of a database, which is usually used as one of the layers of geographic data in GIS (geographic information system).

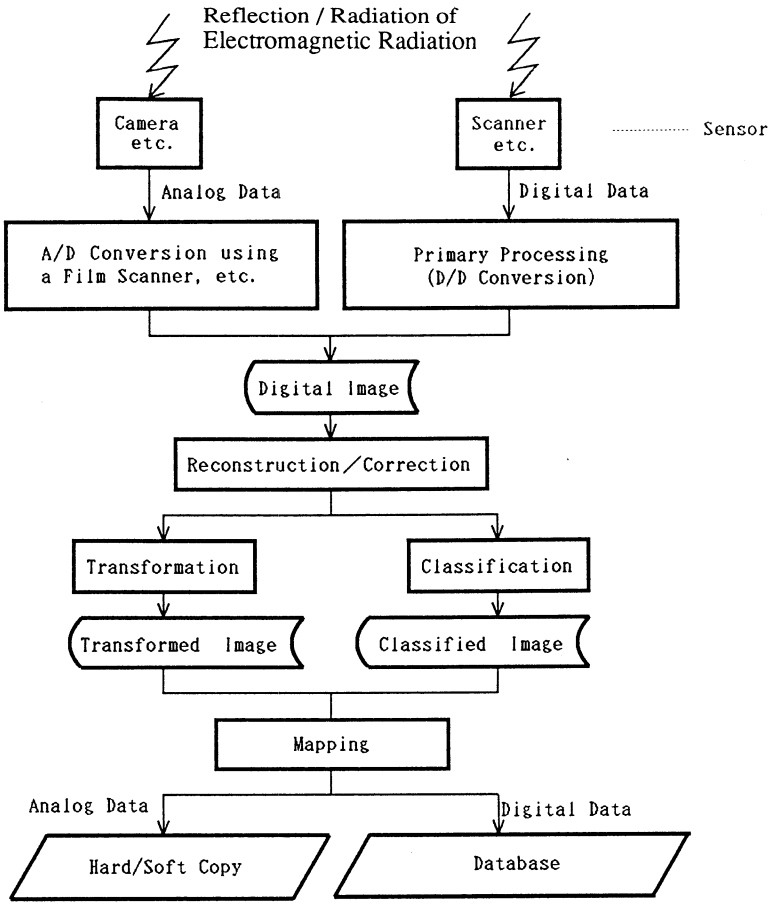


Figure 8.1.1 Data flow in remote sensing

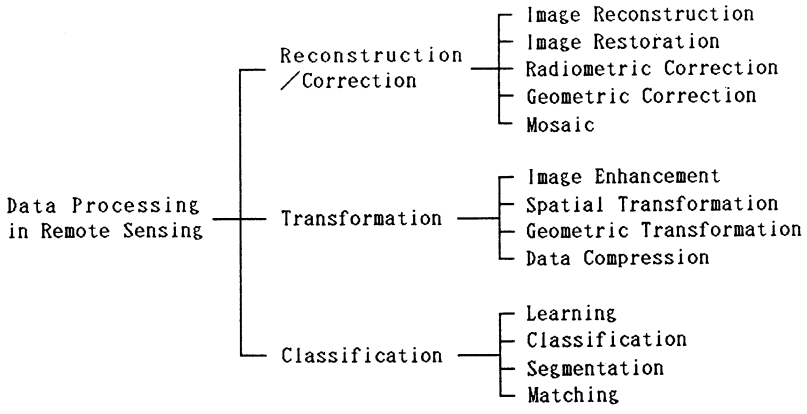


Figure 8.1.2 Data processing in remote sensing

8.2 Image Processing Systems

a. **Hardware**

There are two types of image processing hardware.

(1) **Image processing system with specific image processor**

An image processor with frame buffer is connected with a host computer as shown in Figure 8.2.1. The image processor has the function of high speed image processing and image input / output. The hardware system depends on what type of host computer (personal computer, work station, mini-computer, general purpose computer etc.) is selected and what the computer is used for.

(2) **General purpose computer**

The host computer has only a frame buffer, as shown in Figure 8.2.2. Therefore the image processing is implemented by software developed or purchased by the users. Though the transportability of the system is flexible, the size of software naturally becomes very large. Usually a personal computer or a work station is selected as the host computer.

Recently **network** systems connecting server computers and front end computers, as shown in Figure 8.2.3 have become popular.

b. **Peripherals**

Image processing systems need various peripherals, such as image input devices, to enable A/D conversion, image output devices for image display, image recorder to produce hardcopy, and image recording equipment to establish data archives (see 8.3 - 8.6).

c. **Software**

The software of image processing has the following basic subsystems.

(1) Data input/output (reading and writing CCT etc.)
(2) Image display and operation (color output, image operation, image enhancement etc.)
(3) Reconstruction and correction (geometric correction, radiometric correction etc.)
(4) Image analysis (image transformation, classification etc.)
(5) Image output (hard copy, film recording etc.)

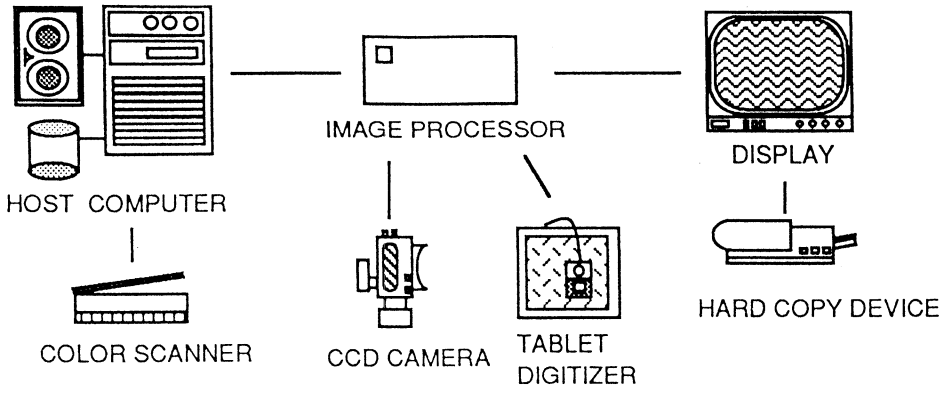


Figure 8.2.1 Image processing system with special image processor

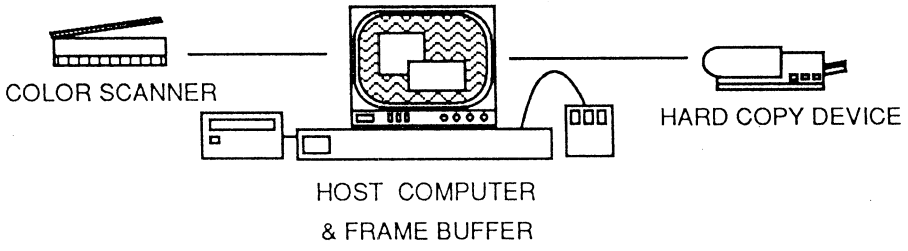


Figure 8.2.2 Image processing system with general purpose computer

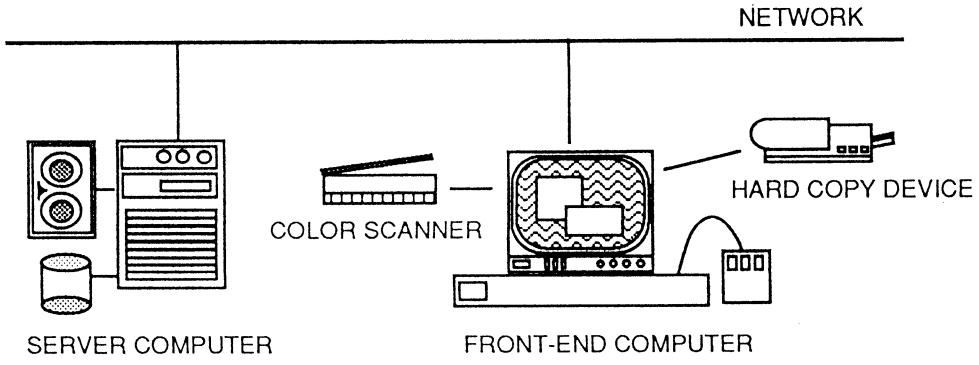


Figure 8.2.3 An example of a network system

8.3 Image Input Systems

Image input systems are defined in this section as analog to digital (A/D) converters of analog images. The image input system provides digital data which are the converted tone or color of a film or photograph. In the case of a color image, the components of the three primary colors (Red, Green and Blue) are digitized by using three color filters.

The function of an image input system depends on the following factors.
(1) Film size: allowable maximum size
(2) Spatial resolution: pixel size or dot per inch (DPI)
(3) Gray scale : number of bits or bytes
(4) Speed: speed of A/D conversion and data
(5) Environment : dark room or illumination
(6) Accuracy : allowable error of coordinates
(7) Type of image : transparency or reflective

Table 8.3.1 shows the comparison between five image input devices with respect to spatial resolution, density resolution, positioning accuracy etc. Figure 8.3.1 shows the typical mechanism of the five image input systems.

a. **Mechanical scanner:**
An image placed around a drum is scanned using the rotation of the drum and a shift of a light source. Though the speed of scanning is not very high, it is widely used because the spatial resolution and density resolution are very high. Recently laser beams have been used as the light source which enables a faster speed.

b. **Electronic image tube:**
Electronic image tube such as a TV camera is used for A/D conversion of an image. However, the spatial resolution, density resolution and positioning accuracy are low. The advantages are its low price and ease of use.

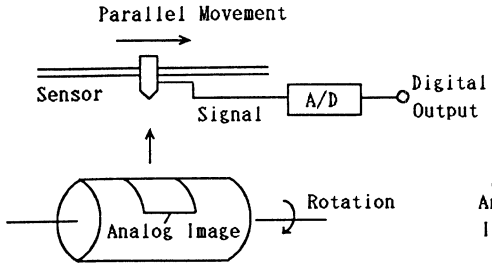
c. **CCD camera**:
The electronic image tube is now being replaced by CCD cameras with higher spatial resolution and positioning accuracy. These systems are compact and lightweight

d. **Linear array CCD camera**:
A linear array CCD with very high resolution, for example 409 pixels per line is drived mechanically to enable line, scanning on a flat table. The spatial resolution, density resolution and positioning accuracy are very high, so that desk top scanners are becoming popular.

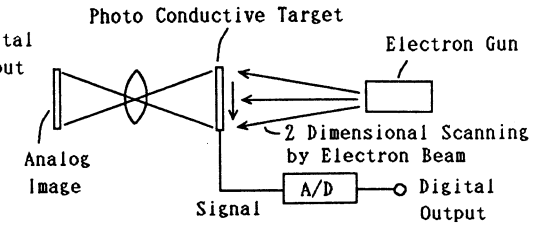
e. **Flying spot**:
An illuminated spot on a CRT is projected onto a film, at a given coordinate, with high speed. The density of the film can be digitized regularly as well as randomly depending on the input coordinates. The disadvantage is that a dark room is required.

Table 8.3.1 Characteristics of image input devices

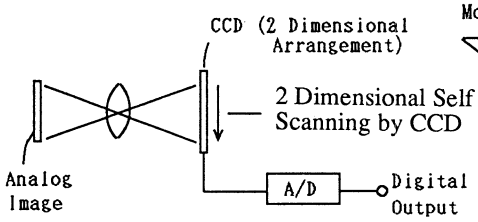
Scanning Method	Spatial Resolution	Density resolution	Positioning accuracy	Examples
Mechanical	Very High	Very High	Very High	Drum Scanner
Electronic (Image Tube)	Low	Low	Low	TV Camera
Electronic (CCD)	High	Stable but Range is Narrow	High	TV Camera CCD Camera
Electronic/ Mechanical	Very High	Stable but Range is Narrow	Very High	Desk Top Scanner
Optical Scanning	Very High	Influenced by Input Condition	Influenced by Optics	Flying Spot Scanner



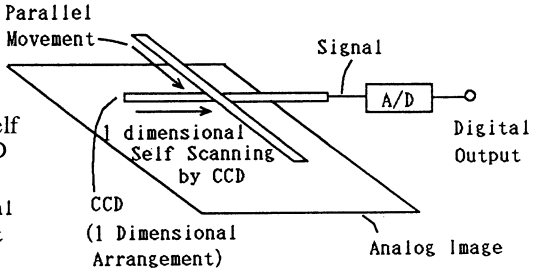
(1) Mechanical



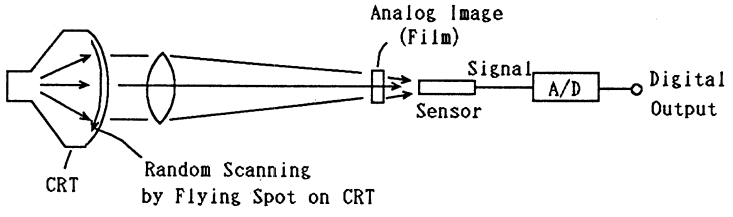
(2) Electronic(Image Tube)



(3) Electronic (CCD)



(4) Electronic/Mechanical



(5) Optical Scanning

Figure 8.3.1 Various Image Input Methods

8.4 Image Display Systems

Image display is used for displaying digital image data into a visual color image as a tool for real time "man-machine interface". An image display system consists of a frame buffer, look up table, D/A converter and a display, as shown in Figure 8.4.1.

Frame buffer is an image memory to allow high speed reading of digital image data. The size of the image memory is usually 512 x 512 to 2048 x 2048 picture elements.

Look up table is a pre-set function to enable conversion from an input signal to an output signal in real time. Linear function, contrast enhancement function, gamma function, log function etc. are mostly used, as shown in Figure 8.4.2. **D/A converter** converts digital image data in a frame buffer to an analog video signal.

Figure 8.4.3 shows **R, G, B separate type** as the D/A output system, while Figure 8.4.4 shows the **color map type**. The former system has an independent frame buffer and look up table with respect to R, G, B, which enables individual color control. Thus full color images (256 x 256 x 256 = 16,787,216 colors) can be generated. The latter system has a unified frame buffer and a R, G, B separate look up table, which only allows generation of a limited number of colors, for example 256 colors in the case of a combination of 8 bits of frame buffer and 8 bits to each of R, G, B.

There are several types of display; CRT, liquid crystal display, plasma display, for example.

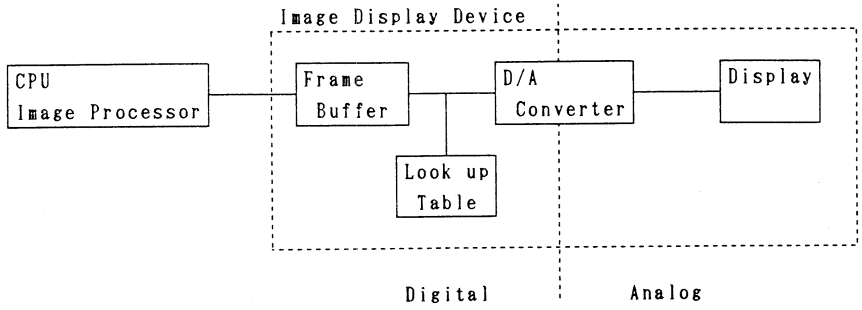


Figure 8.4.1 Organization of image display devices

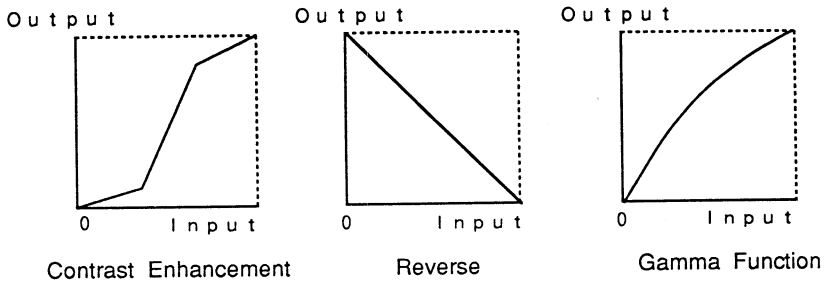


Figure 8.4.2 Examples of Lookup Table

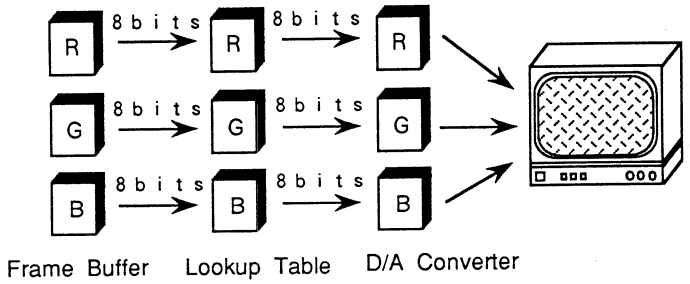


Figure 8.4.3 RGB separate type
(Example of full color display)

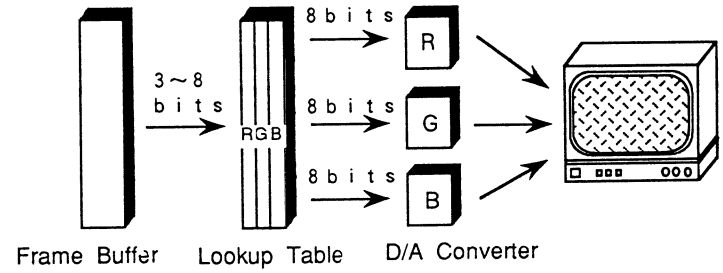


Figure 8.4.4 Color map type
(Example of 256 colors display from full color)

8.5 Hard Copy Systems

A hard copy system or image output system is used to produce an analog image on paper or a film from digital image data. Depending on the system, the recording media, resolution, gray level, output size, output rate, cost and stability, are different as compared and shown in Table 8.5.1.

a. **Silver halide photography**
This is a so-called film recorder which enables the production of film products from digital image data with a light source such as CRT and laser beam. There are two types; the drum type and the flat bed type. The resolution and gray level are excellent. Recently thermal developing systems have become operational replacing the chemical developing system.

b. **Electro photography**
The negative image is firstly generated on a photo-sensitive drum. Secondly toner is electronically placed according to the negative image. Thirdly the toner is transcribed onto plane paper. The advantage is that the running cost is low. It is widely used as an ordinary hard copy machine.

c. **Electro static recorder**
Electronically coated paper is firstly given an electric charge in a form of a negative, in accordance with the dot pattern of the image. Toner is secondly placed electro-statically dot by dot. The advantage is that a large size of output can be obtained in a short time with a moderate cost. It is sometimes called an electro static dot printer or simply a dot printer.

d. **Thermal transcripter**
There are two types; the melting type and the sublimation type. The melting type transcribes a melted ink layer using a thermal head onto plane paper with the use of a coated wax type ink ribbon. As the gray levels, are few only a limited number of color outputs, for example in the case of a classified color map, are available rather than continuous color tones. The sublimation type heats a coated ink sheet ,using a thermal head into vaporized ink, which is transcribed onto a coated paper. The gray level is so many that the image quality is similar to that of a film. The disadvantage of both types is that the paper size is limited because of the site of the ink sheet.

e. **Ink jet recorder**
A water drop of ink is ejected from a nozzle and is transcribed onto plane paper pixel by pixel. The advantage is that the ink volume can be controlled to produce a continuous gray level onto a large size of paper. The disadvantage is that nozzle maintenance is a problem, because the nozzle hole is sometimes blocked due to irregular ink particles.

Table 8.5.1 Characteristics of image output devices

System		Recording Media	Resolution	Gray Level	Output Size	Output Rate	Running Cost	Device Cost	Stability
Silverchloride Photography	CRT Type	Film	Low	Many	~4x5 inch	Fast	Low - Medium	Low	High
	FSS	Film	High	Many	~8x10 inch	Medium	Low - Medium	Medium	High
	Drum Type	Film Thermo Developing Film	High	Many	~8x10 inch	Slow	High	Low - High	High
Electro Photography		PPC	Medium	Medium	~A1	Fast	Low	High	Medium
Electrostatic Recording		CPC	Medium	Few	~A0	Slow	Medium	High	High
Thermal Transcription	Melting	PPC	Medium	Few	~A3	Medium	Low - Medium	Medium	Medium
	Sublimation	CPC	Low	Medium	~B4	Medium	Medium	Medium	High
Ink Jet		PPC	Medium	Medium	~A0	Slow	Low	Low - Medium	Low - Medium

PPC : Plane Paper Copy
CPC : Coated Paper Copy

8.6 Storage of Image Data

As the volume of image data is generally large, a storage device with a large volume is needed to record the original image data, as well as the results of image processing. The volume capacity of the recording media has increased year by year, because of industrial development. Table 8.6.1 shows the characteristics of eight different media (see 6.11).

a. **Magnetic tape**
Magnetic tape is most widely used with general purpose computers or minicomputers. The data format is well standardized so that transportability is also guaranteed. The disadvantage is that the size of the magnetic tape, as well as the magnetic tape unit, is so big that the storage space becomes bulky.

b. **Streamer Tape**
Is a small sized of cartridge tape popular in personal computers (PC) or work stations (WS). The disadvantage is its low speed of data transfer rate.

c. **Digital audio tape (DAT)**
Because its size is smaller than the streamer, and the capacity is bigger and the price is lower, the DAT is becoming popular for PC and WS. The disadvantage is its low data transfer rate.

d. **8 mm video tape**
It is cheaper in price and bigger in storage capacity than DAT. The data transfer rate is not very fast but is a little faster than streamer and DAT.

e. **Optical tape**
As the capacity is about 1 terabyte, the data transfer rate is more than ten times faster than DAT (faster than magnetic disk), rewriting is possible and the device is exchangeable. The optical tape is expected to be the new media for the next generation. While only a few manufacturers can produce the device and the price is very expensive, data capacity and the life of the tape make it economic for all large volume users since for less standard tape is used.

f. **Magneto-optical disk (MO-DISK)**
The size is compact and the capacity is also large, similar to an ordinary hard disk. Because rewriting is possible, exchange is available, the data transfer rate is much faster than tape media, and the price is lower, this media is very popular for PC and WS.

g. **Write once and read many** optical disk **(WORM)**
As rewriting is impossible, the users are decreasing. However the capacity is a little larger than a MO-DISK and the storage life is longer.

h. **Floppy disk**
Is the most popular storage for PC. The disadvantage is that the capacity is limited to a few M bytes and the data transfer rate is slow. The advantages are its low price and data exchangeability.

Table 8.6.1 Characteristics of image data storage devices

Name of Devices	Capacity (Mbyte)	Transfer Rate (Mbyte/sec)	Access Time	Random Accessibility	Device Costs	Characteristics
Magnetic Tape Drive (1/2inch)	150 (6250 bpi)	0.78	Few Minutes	Low	13,000$～	• Good Transportability • Popular for general purpose computer and mini computer
Streamer Tape Drive	150	0.23	Few Minutes	Low	1,300$～	• Popular for WS
DAT Drive (Digital Audio Tape)	1,300	0.19	Few Minutes	Medium	4,000$～	• Partitioning available • Media are small and low cost
8mm Video Tape Drive	2,500	0.25	Few Minutes	Medium	4,000$～	• Media are small and iow cost • Only one manufacture
Optical Tape Drive	1,000,000	3.0	Few Minutes	Medium	200,000$～	• Only one manufacture
Magneto Optical Disk (MO-Disk) Drive	650 (5.25 inch)	1.2	60ms	High	3,300$～	• Rewritable • Popular for PC,WS
Write Once Read Many Optical Disk(WORM-Disk) Drive	800 (5.25 inch)	1.25	120ms	High	2,700$～	• Not rewritable • Long life
Floppy Disk Drive	1 - 3	0.05	90 - 200ms	High	700$～	• Very Popular for PC • Good Transportability

(Specification and price are referred to market information as of 1991)