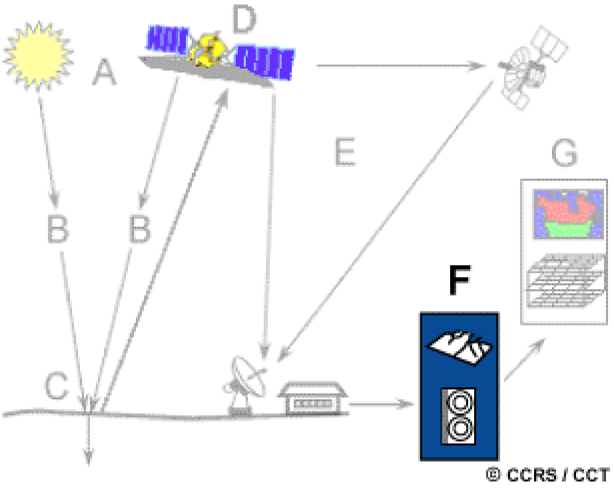
Remote Sensing

Ch. 4 Image Interpretation & Analysis
(Part 1 of 2)

4.1 Introduction
4.2 Elements of Visual Interpretation
4.3 Digital Image Processing
4.4 Pre-processing

4.1 Introduction



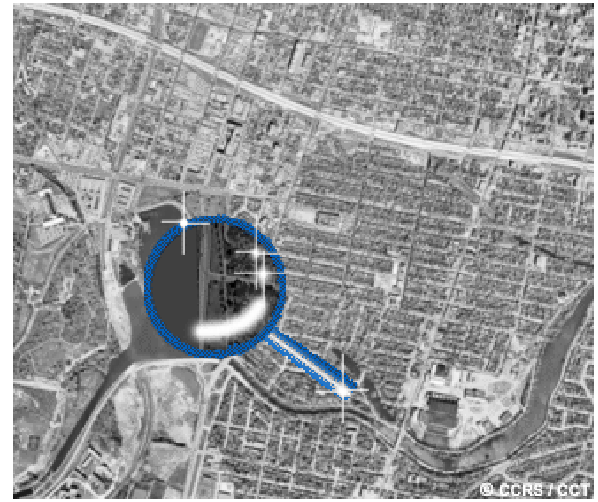
- **Interpretation and analysis** (the 6th element of the RS process) of RS imagery involves the **identification** and/or **measurement** of various targets in an image in order **to extract useful information** about them.

- **Targets** in remote sensing images may be **any feature** or **object** which can be observed in an image, and have the following characteristics:

  ✓ Targets may be a **point**, **line**, or **area** feature. This means that they can have **any form**, from a bus in a parking lot or plane on a runway, to a bridge or roadway, to a large expanse of water or a field.

  ✓ The target must be **distinguishable**; it must contrast with other features around it in the image.

4.1 Introduction



- **Analog format :** Much interpretation and identification of targets in RS imagery is performed manually or visually, i.e. **by a human interpreter**. In many cases this is done **using imagery displayed in a pictorial or photograph-type format.**

- **Digital format :** Visual interpretation may also be performed by examining **digital imagery displayed on a computer screen**.

- **Both** analogue and digital imagery **can be** displayed as **black and white** (also called monochrome) images, or as **color images** by combining different channels or bands representing different wavelengths

4.1 Introduction

- **Manual interpretation** and **analysis** dates back to the early beginnings of remote sensing for air photo interpretation.

- **Digital processing** and **analysis** is more recent with the advent of digital recording of remote sensing data and the development of computers.

  - Digital processing may be used **to enhance** data as a **prelude to visual interpretation**.

  - Digital processing and analysis may also be carried out to **automatically identify targets** and **extract information** completely **without manual intervention** by a human interpreter. However, rarely is digital processing and analysis carried out as a complete replacement for manual interpretation.

  - Often, it is done to **supplement** and **assist the human analyst**.

4.1 Introduction

Advantages & disadvantages of **manual** and **digital** techniques for interpretation

- ✓ Generally, **manual** interpretation requires **little specialized equipment**, while **digital** analysis requires **specialized**, and often **expensive**, **equipment**.

- ✓ **Manual** interpretation is often limited to analyzing **only a single channel** of data or **a single image at a time** due to the difficulty in performing visual interpretation with multiple images. The **computer environment** is more amenable to handling **complex images of several** or **many channels** or **from several dates**. ➔ In this sense, **digital** analysis is **useful for simultaneous analysis of many spectral bands** and can **process large data sets** much **faster** than a human interpreter.

- ✓ **Manual interpretation** is a **subjective process**, meaning that **the results will vary** with different interpreters. **Digital analysis** is **more objective,** generally resulting in more **consistent results**. However, **determining** the **validity** and **accuracy** of the results from digital processing can be difficult.

- In most cases, **a mix of both methods** is usually employed when analyzing imagery. In fact, the **ultimate decision** of the utility and relevance of the information extracted at the end of the analysis process, still must be **made by humans.**

4.2 Elements of Visual Interpretation

- **Analysis of RS imagery** involves the **identification of various targets** in an image, and those targets may be features which consist of points, lines, or areas.

- What makes **interpretation** of imagery more **difficult** than the everyday visual interpretation of our surroundings?
  - ✓ We lose our sense of depth when **viewing a two-dimensional image**, unless we can view it stereoscopically so as to simulate the third dimension of height.
  - ✓ **Viewing objects from directly above** also provides a very **different perspective** than what we are familiar with.
  - ✓ Combining an unfamiliar perspective with a very **different scale** and **lack of recognizable detail** can make even the most familiar object unrecognizable in an image.
  - ✓ Finally, we are used to seeing only the visible wavelengths, and the imaging of **wavelengths outside of this window** is more difficult for us to comprehend.

4.2 Elements of Visual Interpretation

- **Recognizing targets** is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of **the visual elements** of

tone, **shape**, **size**, **pattern**, **texture**, **shadow**, & **association**.

Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyze.

- **Tone** refers to the **relative brightness** or **color** of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allows the elements of shape, texture, and pattern of objects to be distinguished.

4.2 Elements of Visual Interpretation

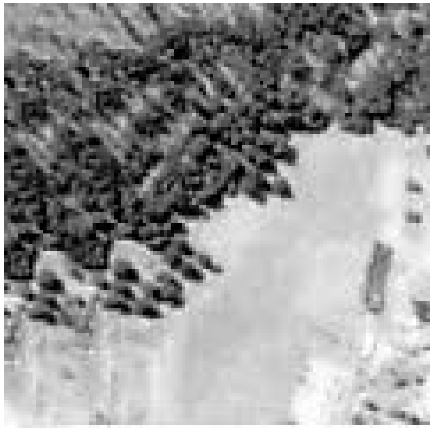
- **Shape** refers to **the general form, structure,** or **outline** of individual objects. Shape can be a very **distinctive clue** for interpretation. **Straight edge** shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more **irregular** in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by **rotating sprinkler systems** would appear as **circular shapes.**

- **Size** of objects in an image is **a function of scale**. It is important to assess the **size of a target relative to other objects in a scene**, as well as the **absolute size**, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of **land use**, and had identified an area with a number of buildings in it, **large buildings** such as factories or warehouses would suggest **commercial property**, whereas **small buildings** would indicate **residential use**.

4.2 Elements of Visual Interpretation

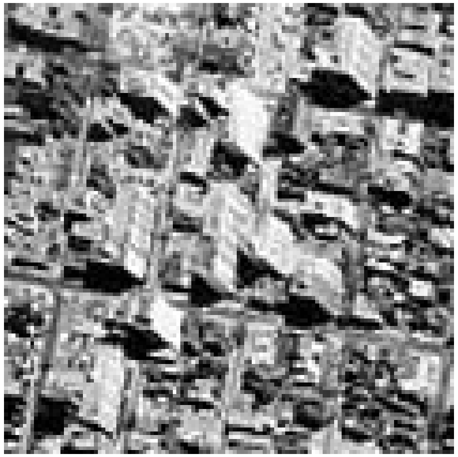
- **Pattern** refers to the **spatial arrangement of visibly discernible objects**. Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. **Orchards** with evenly spaced trees, and **urban streets** with regularly spaced houses are good examples of pattern.

- **Texture** refers to the **arrangement and frequency of tonal variation** in particular areas of an image. **Rough textures** would consist of a mottled tone where the grey levels change abruptly in a small area, whereas **smooth textures** would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most **important** elements for distinguishing features **in radar imagery**.



4.2 Elements of Visual Interpretation

- **Shadow** is also helpful in interpretation as it may provide an idea of **the profile** and **relative height** of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for **enhancing or identifying topography and landforms**, particularly in radar imagery.



- **Association** takes into account **the relationship between other recognizable objects** or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given for size element, **commercial properties** may be associated with proximity to major transportation routes, whereas **residential areas** would be associated with schools, playgrounds, and sports fields. In our example, a **lake** is associated with boats, a marina, and adjacent recreational land.

4.2 Elements of Visual Interpretation

Quiz Take a look at the aerial photograph right. Identify the following features in the image and explain how you were able to do so based on the elements of visual interpretation described in this section.
race track / river / roads / bridges / residential area / dam

ANS

4.2 Elements of Visual Interpretation

Quiz Take a look at the aerial photograph right. Identify the following features in the image and explain how you were able to do so based on the elements of visual interpretation described in this section.
race track / river / roads / bridges / residential area / dam

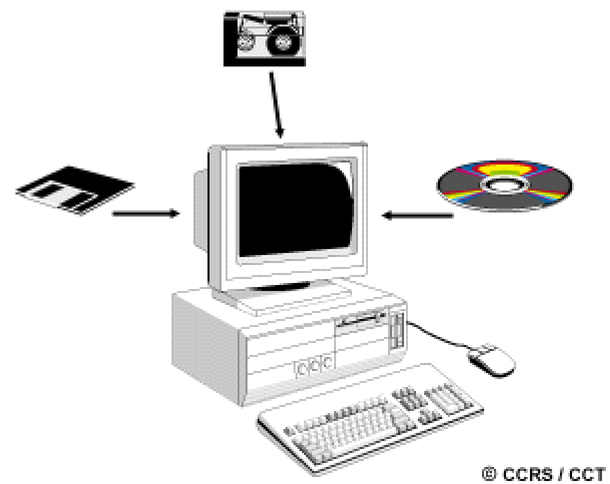
ANS

- The **race track** in the lower left of the image is quite easy to identify because of its characteristic *shape*.
- The **river** is also easy to identify due to its contrasting *tone* with the surrounding land and also due to its *shape*.
- The **roads** in the image are visible due to their *shape* (straight in many cases) and their generally bright *tone* contrasting against the other darker features.
- **Bridges** are identifiable based on their *shape*, *tone*, and *association* with the river - they cross it!
- **Residential area**s on the left hand side of the image and the upper right can be identified by the *pattern* that they make in conjunction with the roads. Individual houses and other buildings can also be identified as dark and light tones.
- The **dam** in the river at the top center of the image can be identified based on its contrasting *tone* with the dark river, its *shape*, and its *association* with the river - where else would a dam be!

4.3 Digital Image Processing

- Nowadays most remote sensing data are recorded in **digital format** and virtually all image interpretation and analysis involves some element of **digital processing**.

- Digital image processing may involve numerous procedures including **formatting** and **correcting** of the data, digital **enhancement** to facilitate better visual interpretation, or even **automated classification** of targets and features entirely by computer.



- In order to process remote sensing imagery digitally, the data must be recorded and available in **a digital form** suitable for storage on a computer tape or disk. Obviously, the other requirement for digital image processing is a computer system, sometimes referred to as an **image analysis system**, with the appropriate hardware and software to process the data. Several commercially available software systems have been developed specifically for remote sensing image processing and analysis.

4.3 Digital Image Processing

Most of the common image processing functions available in **image analysis systems** can be categorized into the following four categories:

① Preprocessing
② Image Enhancement
③ Image Transformation
④ Image Classification and Analysis

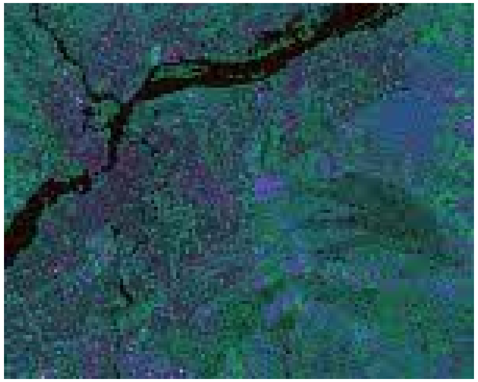
(1) Preprocessing functions involve those operations that are normally required **prior to the main data analysis** and extraction of information, and are generally grouped as **radiometric** or **geometric corrections**.

Radiometric corrections include correcting the data for *sensor irregularities* and *unwanted sensor or atmospheric noise*, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor.

Geometric corrections include correcting for *geometric distortions due to sensor-Earth geometry variations*, and conversion of the data to *real world coordinates* (e.g. latitude and longitude) on the Earth's surface.

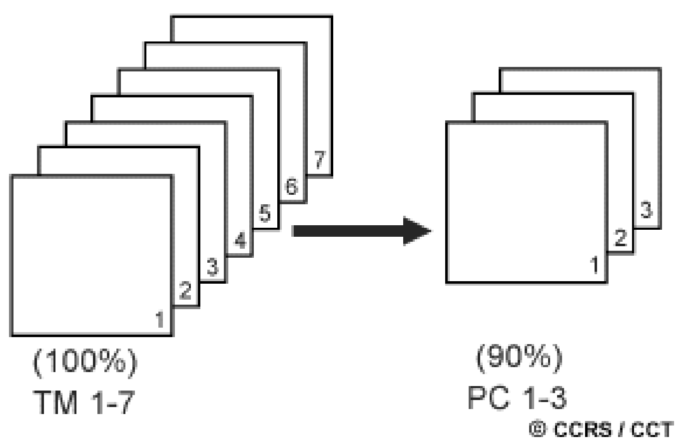
4.3 Digital Image Processing

(2) The objective of the second group of image processing functions grouped under the term of **image enhancement**, is solely to **improve the appearance of the imagery** to assist in visual interpretation and analysis. Examples of enhancement functions include **contrast stretching** to increase the tonal distinction between various features in a scene, and **spatial filtering** to enhance (or suppress) specific spatial patterns in an image.



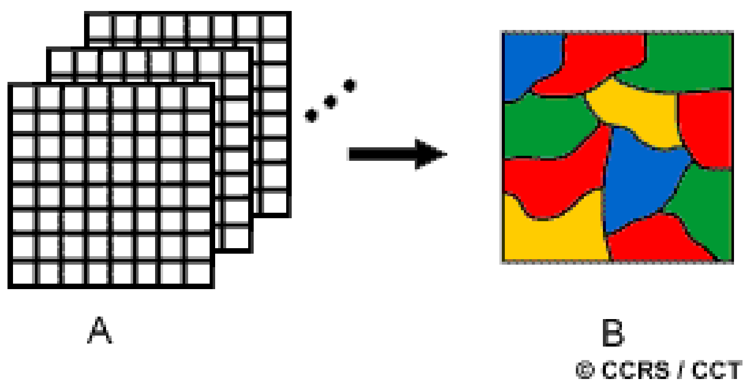
4.3 Digital Image Processing

(3) Image transformations are operations similar in concept to those for image enhancement. However, unlike image enhancement operations which are normally applied only to a single channel of data at a time, image transformations usually **involve combined processing of data from multiple spectral bands**. Arithmetic operations (i.e. subtraction, addition, multiplication, division) are performed to combine and transform the original bands into "new" images which **better display** or **highlight certain features** in the scene. We will look at some of these operations including various methods of **spectral or band ratioing**, and a procedure called **principal components analysis** which is used to more efficiently represent the information in multichannel imagery.



4.3 Digital Image Processing

(4) Image classification and analysis operations are used to **digitally identify** and **classify pixels** in the data. **Classification** is usually performed on multi-channel data sets (A) and this process **assigns each pixel** in an image to **a particular class or theme** (B) based on statistical characteristics of the pixel brightness values. There are a variety of approaches taken to perform digital classification. We will briefly describe the two generic approaches which are used most often, namely **supervised** and **unsupervised** classification.



4.3 Digital Image Processing

Quiz One 8-bit pixel takes up one single byte of computer disk space. One kilobyte (Kb) is 1024 bytes. One megabyte (Mb) is 1024 Kb. How many Mb of computer disk space would be required to store an 8-bit Landsat Thematic Mapper (TM) image (7 bands), which is 6000 pixels by 6000 lines in dimension?

ANS

4.3 Digital Image Processing

Quiz One 8-bit pixel takes up one single byte of computer disk space. One kilobyte (Kb) is 1024 bytes. One megabyte (Mb) is 1024 Kb. How many Mb of computer disk space would be required to store an 8-bit Landsat Thematic Mapper (TM) image (7 bands), which is 6000 pixels by 6000 lines in dimension?

ANS If we have seven bands of TM data, each 6000 pixels by 6000 lines, and each pixel takes up one byte of disk space, we have:

$$7 \times 6000 \times 6000 = 252{,}000{,}000 \text{ bytes of data}$$

To convert this to kilobytes we need to divide by 1024, and to convert that answer to megabytes we need to divide by 1024 again!

$$252{,}000{,}000 / (1024 \times 1024) = 240.33 \text{ megabytes}$$

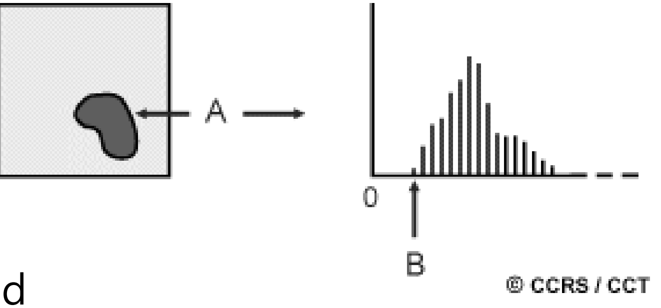
So, we would need over **240 megabytes** of disk space just to hold **one full TM image**, let alone analyze the imagery and create any new image variations! Needless to say, it takes a lot of storage space and powerful computers to analyze the data from today's remote sensing systems.

4.4 Pre-processing

- **Pre-processing operations**, sometimes referred to as image **restoration** and **rectification**, are intended to **correct for sensor-** and **platform-specific radiometric** and **geometric distortions** of data.
- **Radiometric corrections** may be necessary due to **variations in scene illumination** and **viewing geometry**, **atmospheric conditions**, and **sensor noise** and **response**. Each of these will vary depending on the specific sensor and platform used to acquire the data and the conditions during data acquisition.
- **Variations in illumination** and **viewing geometry** between images (for optical sensors) can be **corrected by modeling** the geometric relationship and distance between the area of the Earth's surface imaged, the sun, and the sensor. This is often required so as to be able to more readily **compare images** collected by different sensors at different dates or times, or to **mosaic multiple images** from a single sensor while maintaining uniform illumination conditions from scene to scene

4.4 Pre-processing

- Scattering of radiation occurs as it passes through and interacts with the atmosphere. This scattering may reduce, or attenuate, some of the energy illuminating the surface. In addition, the atmosphere will further attenuate the signal propagating from the target to the sensor. Various methods of **atmospheric correction** can be applied ranging from detailed **modeling of the atmospheric conditions** during data acquisition, to **simple calculations** based solely on the image data.

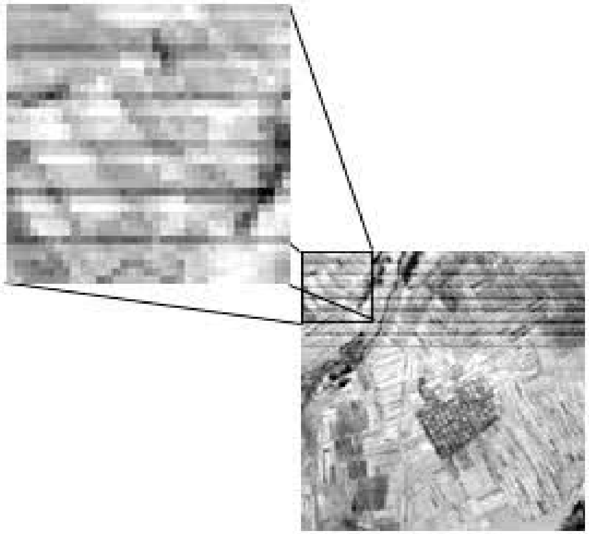


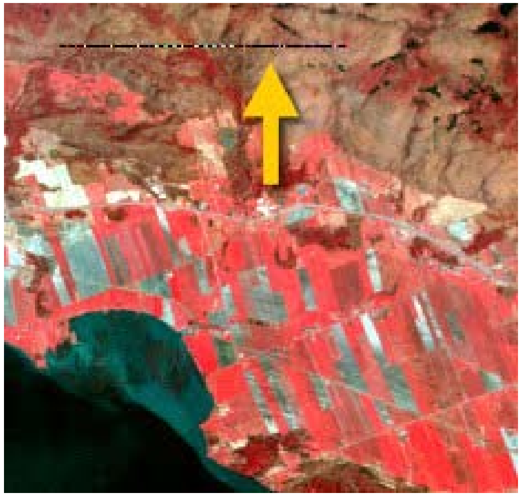
- An example of the latter method is to **examine the observed brightness values** (digital numbers), in an area of shadow or for a very dark object (such as a large clear lake - A) and **determine the minimum value** (B). The correction is applied by **subtracting the minimum observed value**, determined for each specific band, from all pixel values in each respective band. Since scattering is wavelength dependent, the minimum values will vary from band to band.
🡐 This method is based on **the assumption** that the reflectance from these features, if the atmosphere is clear, should be very small, if not zero. **If we observe values** much greater than zero, then they are considered to have **resulted from atmospheric scattering**.

4.4 Pre-processing

- Noise in an image may be due to irregularities or errors that occur in the sensor response and/or data recording and transmission. Common forms of noise include systematic **striping** or banding and **dropped lines**.

- **Striping** was common in **early Landsat MSS data** due to variations and drift in the response over time of the six MSS detectors. The "drift" was different for each of the six detectors, **causing the same brightness to be represented differently by each detector**. The overall appearance was thus a 'striped' effect. The corrective process made a relative correction among the six sensors to bring their apparent values in line with each other.
- **Dropped lines** occur when there are systems errors which result in **missing** or **defective data along a scan line.** Dropped lines are normally 'corrected' by replacing the line with the pixel values in the line above or below, or with the average of the two.





4.4 Pre-processing

• All remote sensing imagery are inherently subject to **geometric distortions**. These distortions may be due to several factors, including:

√ the perspective of the sensor optics;
√ the motion of the scanning system;
√ the motion of the platform;
√ the platform altitude, attitude, & velocity;
√ the terrain relief; and,
√ the curvature & rotation of the Earth.

• **Geometric corrections** are intended to compensate for these distortions so that the geometric representation of the imagery will be as close as possible to the real world.

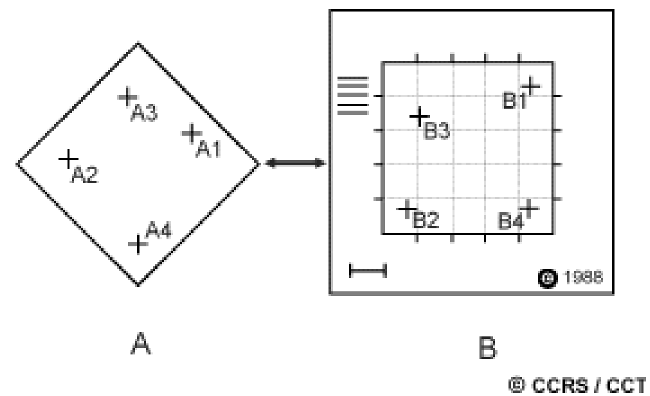
√ Many of these variations are **systematic**, or **predictable** in nature and can be accounted for by accurate modeling of the sensor and platform motion and the geometric relationship of the platform with the Earth.

√ Other **unsystematic**, or **random**, errors cannot be modeled and corrected in this way.

Therefore, **geometric registration** of the imagery **to a known ground coordinate** system must be performed.

4.4 Pre-processing

- The **geometric registration process** involves identifying the image coordinates (i.e. row, column) of several clearly discernible points, called **ground control points** (or **GCPs**), in the distorted image (A - A1 to A4), and matching them to their true positions in ground coordinates (e.g. latitude, longitude). The true ground coordinates are typically measured from a map (B - B1 to B4), either in paper or digital format. This is **image-to-map registration**.



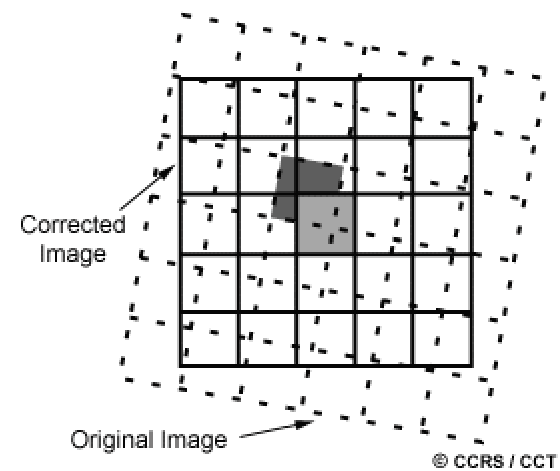
- Once several well-distributed GCP pairs have been identified, the coordinate information is processed by the computer to determine the proper transformation equations to apply to the original (row and column) image coordinates to map them into their new ground coordinates. Geometric registration may also be performed by registering one (or more) images to another image, instead of to geographic coordinates. This is called **image-to-image registration** and is often done prior to performing various image transformation procedures or for multi-temporal image comparison.

4.4 Pre-processing

• In order to actually geometrically correct the original distorted image, a procedure called **resampling** is used to determine the digital values to place in the new pixel locations of the corrected output image. The resampling process calculates the new pixel values from the original digital pixel values in the uncorrected image. There are 3 common methods for resampling:

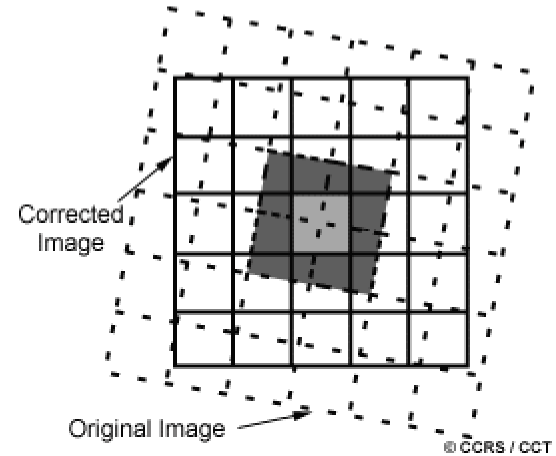
① **nearest neighbor,**
② **bilinear interpolation**, and
③ **cubic convolution**.

• **Nearest neighbor** resampling uses **the digital value from the pixel** in the original image which is **nearest to the new pixel location** in the corrected image. This is the simplest method and does not alter the original values, but may result in some pixel values being duplicated while others are lost. This method also tends to **result in a disjointed** or **blocky** image appearance.

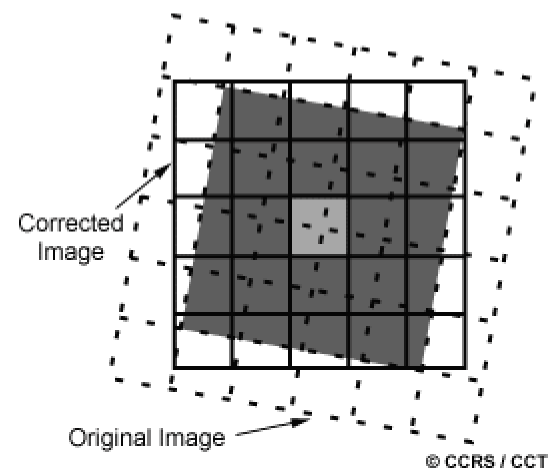


4.4 Pre-processing

- **Bilinear interpolation** resampling takes a **weighted average of four pixels** in the original image nearest to the new pixel location. The averaging process alters the original pixel values and **creates entirely new digital values** in the output image. This may be undesirable if further processing and analysis, such as classification based on spectral response, is to be done. If this is the case, resampling may best be done **after the classification process**.



- **Cubic convolution** resampling goes even further to calculate a distance **weighted average of a block of sixteen pixels** from the original image which surround the new output pixel location. As with bilinear interpolation, this method results in completely new pixel values. However, these two methods both produce images which have a much sharper appearance and **avoid the blocky appearance** of the nearest neighbor method.

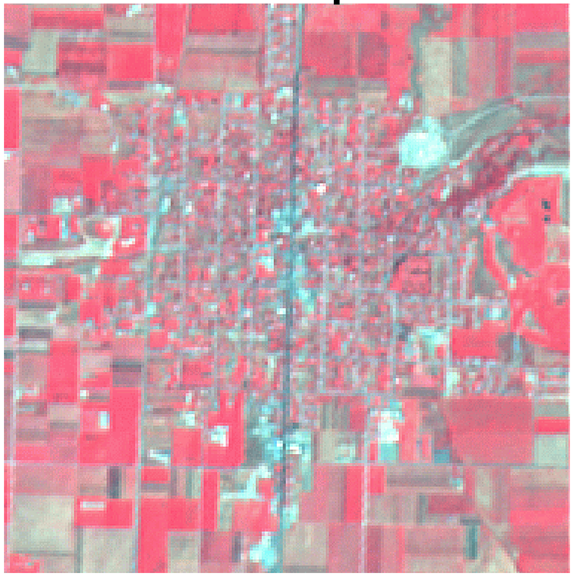


4.4 Pre-processing

Original image from SPOT

Nearest Neighbor

Bilinear Interpolation



Cubic Convolution

4.4 Pre-processing

QUIZ What would be the advantage of geometrically correcting an image to geographic coordinates prior to further analysis and interpretation?

ANS

4.4 Pre-processing

QUIZ What would be the advantage of geometrically correcting an image to geographic coordinates prior to further analysis and interpretation?

ANS It would then allow **proper measurements of distances** and **areas** to be made from features in the image. This may be particularly useful in different applications where true measurements are necessary, such as in **urban mapping** applications. Also, the geographic locations of features could be determined. Once an image is geometrically registered to a known geographic base, it **can be combined with other mapped data** in a digital environment for **further analysis**. This is the concept of **data integration** which is discussed in section 4.8.