Topic 8

Digital Remote Sensing, Image Representation and Enhancement

Digital Image Data

Digital image data are collected by scanners, by digital capture of video, by direct digital capture, or by scanning aerial photography. In all of these procedures, the analogue data are converted to digital values usually in byte format (256 levels).

Image data are usually stored in one of three basic formats, **BIP, BIL, BSQ**. **(overhead)**

> **BIP** - band interleaved by pixel stores the Digital Number's (DN's) for each pixel together.
>
> **BIL** - band interleaved by line format stores the DN's for all pixels in each line for each channel.
>
> **BSQ** - least common, band sequential, storage of the DN's for the entire image sequentially by band.

Image Data Display for Initial Inspection **(overhead)**

> **Lineprinters** (not generally used for image display but can be used to dump small windows of values)
>
> **Color monitor** - most frequent display device in intermediate processing and exploration Most generally work with software and support a minimum of 256 color levels at 640x480 resolution or greater. It is more common to see higher resolutions, particularly on Unix workstations. We use an display in lab with 256^3 color levels (24-bit display)
>
> **Film-writer** - used to generate color negatives, positives or expose print paper in a digital to photographic process.
>
> **Color inkjet** - probably most common hard copy device.
>
> **Camera** - take a picture or use a slide maker connected to the computer.

Image Processing Equipment **(overhead)**

Provides for data **input**, **storage**, **analysis**, and **output**.

> Image data generally **input** from: **magnetic tape (9-track, 8mm), CD-ROM, or floppy disc.**

Storage is provided by: disc drives, floppy disc, magnetic tape.

The **CPU** provides for both coordination of input and output and also performs all the analysis functions as directed by the image processing software.

Output: displays, printers, plotters, magnetic tape, CD-ROM.

Other important considerations in image analysis hardware are the amount of **memory** (fast data handling), the amount of **display memory** (refresh), the **bit-depth of the processor** (number of values that can be processed at one time), the display bit depth (number of displayable colors).

Software - this should be chosen first and should be the software that will do the things you need to do including integration and compatibility with other software such as GIS.

Digitial Image Use

Digital image analysis is rapidly becoming the mainstay of mapping capabilities associated with both aerial imagery and satellite data. There are a number of positive considerations when looking at the application of digital image analysis:

(overhead)

1. It can be **faster** to do an analysis of **large amounts of data** (e.g. manual interpretation then digitizing and editing line work on a Landsat scene as opposed to automated classification).
2. Much better at **repetitive tasks** (same methods and interpretation constraints applied to multiple data sets).
3. **Less subjectivity** in results (more comparable).
4. **Direct digital results** (i.e. acreage determination)
5. **Easily integrated** with other digital technologies (GIS).

Negative considerations include:

a. **Less interpretation flexibility** (a good photo-interpreter will almost surely do a better job if hard-to-quantify information is involved (i.e. texture, context).

b. **Stupid** (the systems must be "trained")

c. **Costs** - some would content that software/hardware costs are not an issue but use of the technology always has a cost in terms of a learning curve for new users.

Examples of applications where digital is superior to manual image handling/analysis:

(overheads: GAP, Starr Mosaic, Frame Classif., ERIM)

Large-area land-cover: it is undoubtedly much more efficient to use satellite data for general land cover mapping than to use the equivalent coverage in manually interpreted satellite images or aerial photos.

Ortho-photographic products: An Orthophoto is an aerial image or satellite image that has been corrected to **remove feature displacement errors due to terrain** (relief displacement) and other image distortions. Orthophotography is the basis for almost all mapping programs (USGS, NRCS, USDAFS). Many new maps use an orthophoto product as the map base.

Change / Trend analysis: the repeatative nature of satellite imagery, combined with rapid analysis capabilities and the ease of digital overlay of rasters make digital data handling ideal in these situations.

Image Processing Steps **(overhead)**

There are up to seven processes involved in digital image analysis. We will examine only four of these. The primary steps in image analysis are: **1) import (reformat), 2)preprocessing, 3) enhancement, 4) image exploration, classification, estimation, and export of results** for use in models (often driven by GIS).

1) **Reformat** - in many cases, the analyst will get the data on **computer tape** or **CD-ROM** in a form that is not directly useable by the image analysis software. In these cases, the analyst **reformats (imports)** the data and restructures the format so it can be used. This may be as simple as **providing a definition to the software** without physically changing the data, or by **rearranging the data** into a new file. In lab, we will be using data that has been converted to the file format that PCI uses.

2) **Preprocessing** - Often the image data contain unacceptable errors in calibration or "noise" that must be corrected prior to use. There are several types of errors:

   -Radiometric errors - the digital values are affected by changes in calibration of the sensors and varying atmospheric effects.

   -Spatial errors - these can be caused by changes in attitude of the platform, geometric properties of the sensor, or inconsistent operation of the sensor. These can be corrected by rectification of the data to a known coordinate system.

   -Spectral errors - fairly rare. Can be caused by deterioration of filters or lens coatings.

3) **Enhancement** - various image enhancement techniques are applied to the data to improve upon the initial interpretability. The most common way to enhance data is to change the contrast as it is displayed on a computer monitor. We'll look at several enhancement techniques in a later lecture.

4) **Image exploration** - an experienced analyst usually does a preliminary exploration of the enhanced imagery to determine any known relationships to existing field data or ancillary data sets. In other words, it is a good idea to look around before attempting a detailed classification. This step often identifies problem areas in the image that may have to be dealt with independent of the rest of the scene.

5) **Classification** - This is the process by which we generally use one or more statistical pattern recognition techniques to place each pixel (remember they each is represented by one or more DN's - one for each band) into a category. The usual product of this work is a thematic map.

6) **Estimation** - This step generally follows on the heals of classification and deals with combining a classification with other knowledge to derive more complex information about the landscape. For example, we could use a classification of forest cover to estimate leaf area (LAI) based on known differences between tree species. This same notion can be carried to biomass estimation, at least on a gross scale.

Statistical Considerations **(overhead)**

A digital image is a **3-D array** of cell values. The x,y dimensions account for the values associated with one image channel (band) that is a record of the reflectance at specific intervals. The third dimension of the array has to do with the number of channels. The location of the cells is **systematic with respect to the start point** of the image (origin) but the **image itself is a random record** that can not generally be exactly repeated, even with satellite imagery (minimal change in platform position as opposed to aerial platforms).

Given that an image is a sample of the radiance from the surface being sensed, we must use **statistical analysis techniques that are valid** for the data. For instance, if the statistical method calls for analysis of data is **normally distributed**, then we need to confirm this characteristic of the data. One way to do this is graphically is to generate a **frequency diagram** (**histogram**) that shows the frequency of each DN.

We can also look at frequency of **co-occurance of values in two channels** at one time. In this case we plot the values of each channel on the x,y axes and then use color or gray levels to indicate the frequency of co-occurance. These can also be plotted as a simple wireframe or contour diagram. These are called **scattergrams**.

Parametric methods of analysis assume that we know the underlying distribution of the data (i.e. normally distributed; data follow a bell curve). **Non-parametric** methods make no assumptions about the data distribution .

Probability density functions **(overhead)**

The first thing we can observe in data is whether it is **unimodal** or **multi-modal**. The general assumption that we make is that data we are working with is unimodal and normally distributed in each channel (**multivariate normal**). The **normal distribution** can be defined as having a mean and mode that are the same and it is symmetrical. The spread of the normal distribution is called the **standard deviation**. The area under the curve that defines the standard normal distribution defines the predicted percent of the population that falls around the mean. For example, **68.26%** of the population falls within **1 S.D.** and **95.5%** falls within **2 S.D.'s**.

Image Channel Relationships **(overhead)**

Correlation indicates the **predictability of one variable given another**. This is determined in remote sensing projects to identify the most meaningful channels of information that can be used to identify targets of interest. We do not want to analyze two channels of data that tell us the same thing about targets or separation of targets. One way to avoid this is to compute the **overall correlation for each pair of image channels** and consider elimination to the redundant channel(s). Or, we can sample from known cover of interest and use the reflectance data to determine if there is significant correlation in channels for those cover types of interest.

Common Relationships

1) responses are similar for each satellite when you look at similar channels of data (observe channels 2,3,4 in TM as compared to 1,2,3 for SPOT in the water and forest cover classes). **(overhead of TM channels)**

2) Correlations, as expected for general cover (urban/rural) tend to be similar for the visible channels (2,3 in TM and 1,2 in SPOT XS), and the mid-infrared channels for TM (5,7; see the urban vs. rural).

Image Enhancement

Image enhancement is used to generally **increase the contrast** or interpretability of all or part of an image by **re-mapping the original DN's** to new DN's for display or plotting. This is most frequently done by **modification of a look-up table** or function for changing the color computer display.

Computer display image enhancement procedures are **usually non-destructive**, that is they are a function that determines the new display output values without altering the original file.

In initial exploration of an image, we might choose to **selectively enhance** the part of the image of interest (the forest) and **reduce the contrast or entirely mask out** other parts of the image to obtain the maximum interpretive information on our target. This can be done **interactively** with the computer display or in some procedures, done to output the result in a **separate file** for future use.

A single enhancement may be sufficient to get the information or combinations of enhancements may be used to solve more complex interpretation problems. Today we'll talk about the more common procedures that are implemented with image analysis software.

Level (density) Slicing **(spot overhead)**

This technique can be used to **color code pixel DN's** either individually or by specific ranges of values in a single channel of image data. We may be **exploring** an image and reading the DN's with our display target and notice that **forest land ranges from 20-35** in the NIR channel of TM data. The image analysis software can be told to **color code this range** in a single-channel display as green. This capability helps us do a **preliminary inspection** of the imagery to determine the general cover characteristics that may be present. This technique should not be substituted for classification because there are usually overlaps in ranges of DN's for cover types that can be separated when more than one channel is used in classification.

Density slicing is accomplished by **assignment of color values for each display color gun** to the DN's of a single data channel. On most software, the possible color values for R,G,B are 0-255. Remember these are **additive color combinations**, that is, the value you use is the intensity of the color gun. 255,0,0 = red, 255,255,0 = yellow, 255,255,255 = white, 0,0,0 = black

Example: to code the DN range of 20-23 as green you would enter:

20 0,255,0
21 0,255,0
22 0,255,0
23 0,255,0

Linear Enhancement

This is the most common way to enhance data and is basically a **contrast stretch**. This can be done for each image channel (each one is mapped to a color gun on the display; RGB). Note how this is a re-mapping of the **original DN's (x axis)** to new output values for the **computer display (y axis).** For instance, if we are trying to simulate a true color image, we would select the three visible channels that correspond to red, green, and blue reflectance, then re-map these DN's to display values through a look-up table or function. The result is that the range of interest occupies the full range of color values for that channel and the ranges above and below the cut-off points are either black (0's) or bright color (255's).

(overhead)

Linear enhancements should approximate the majority part of the curve in a cumulative frequency diagram as shown. The best overall fit is obtained when you apply the linear enhancement to a unimodal data distribution.

The diagrams above indicate the data histogram (x=DN, y=freq) and cumulative frequency with the linear enhancement superimposed. Note how the slope of the enhancement line (thick line) maximizes the mapping of data values to the available range of LUT values.

Piece-wise Linear Stretch **(overhead)**

A piecewise enhancement can be used to generate linear enhancements of different segments of the data distribution. This can help the analyst **better fit the cumulative frequency diagram**. Today's software packages allow you to do this or even **sketch the enhancement** by tracing the function you desire. These types of enhancements give better overall image quality for data that have **multi-modal distributions**.

Histogram Equalization

The idea behind this enhancement is to try to assign approximately **equal numbers of pixels to each output screen value**. The result does not usually accomplish this but comes close. The algorithm determines the optimum number of cells that should represent each output value, then starts at the lowest DN and accumulates pixel values from the original histogram until the optimum is exceeded. It then goes to the next output value and repeats the process where it left off. The result is a fairly close fit to the cumulative frequency histogram.

<u>Mathematical Transformations</u> **(overhead)**

Ratioing

Just as the term implies, a ratio is a mathematical combination produced by dividing the DN's for one channel by the DN's of another channel. Most software that performs this will **automatically scale** the result to a range of 0-255 unless otherwise specified. A common ratio is to divide the NIR channel by the visible red channel to produce a **vegetation index**. As we know from past discussions, vegetation reflects proportionally more light in the NIR than other targets. So high **NIR/red ratios** would provide the analyst with an extra clue to the presence of vegetation. What channels would be used for vegetation indices from **TM data? SPOT data?**

A ratio used with weather satellite data in vegetation "greeness studies" is the **NDVI** or Normalized Difference Vegetation Index produced **from AVHRR data**. The NDVI has been used for tracking green-up and senescence of vegetation over large regions. This is useful in **crop forecasting and biomass studies** at global scales.

Principal Components **(overhead)**

This is a technique of **data transformation to maximize the variance** (spread of values) in hierarchical fashion **along orthogonal axes**. If we plotted a scatter gram of the data values between two channels of data, each represented on a Cartesian axis, we would get a "cloud" of points about which we could calculate variance. The idea behind principle components is to **transform (rotate)** the axes (and therefore the data) to maximize the variance in the first axis (first component) and to maximize the remaining variance in additional **orthogonal axes**.

Calibration

Calibration procedures often include **adjustments (normalization)** of images to get more consistent data values from scene to scene. **Causes of inconsistent illumination** include:

- different sun angle
- haze or water vapor
- aspect (also sun-angle related)

Sun angle and aspect correction depend on knowing the **sun angle** and having a model of the **terrain (DEM)**. These are common corrections that are made. Correction for atmospheric effects depend on detailed knowledge of the **optical properties** of the atmosphere at the time of image acquisition (not usually known). **Field spectrometers** can be used to collect local reflectance data of targets to use in calibrating data from the sensor.

One way to approximate **haze reduction** is to use a body of deep clear water (assumed to have zero reflectance). The difference between the DN's of the water and zero may be assumed to be due to scattered light or haze. Subtracting this difference from all DN's can help reduce the scattering effect by may reduce other useful information.

When two images are to be compared, the analyst will try to obtain images that are from the same time of year, same clock time, and acquired under similar conditions. Then, he tries to find two points of consistent **minimum and maximum value** to **calculate a offset and gain for a transformation function to calibrate** one image to the other.

Spatial Filters **(overhead)**

There are a number of common spatial operators that utilize a moving window technique to calculate different information in imge data. The way these work is that the data within the **window (kernel)** are subjected to various math operations and the result is output the central pixel of the window. Thus, spatial filters can be thought of as neighborhood operators that look at all possible neighborhoods in an image. Three common filters used on image data are: **texture (variance), edge detection, and averaging**.

Texture filters - calculate the local variance (**roughness**) within the kernal and essentially measure the magnitude of difference across the kernal by determining the **sum of the difference** between each pixel value and the **mean** or the **central pixel**.

Edge detection - these filters as the name implies, mathematically define locations of sharp gradients in an image and enhance them by making these pixel values higher than their neighbors.

Averaging - or smoothing filters reduce high frequency variance by averaging all values in a local kernel of pixels.