UNIT 1: DIGITAL IMAGE PROCESSING I

1.1 Remote Sensing Data Types

Assorted satellites with numerous sensors, each one was designed with a specific purpose. With optical sensors, the design focuses on the spectral bands to be collected. With radar imaging, the incidence angle and microwave band used plays an important role in defining which applications the sensor is best suited for. Each application itself has specific demands, for spectral resolution, spatial resolution, and temporal resolution.

The types of remote sensing data vary but each plays a significant role in the ability to analyze an area from some distance away. The first way to gather remote sensing data is through radar. Its most important uses are for air traffic control and the detection of storms or other potential disasters. In addition, Doppler radar is a common type of radar used in detecting meteorological data but is also used by law enforcement to monitor traffic and driving speeds. Other types of radar are also used to create digital models of elevation.

Another type of remote sensing data comes from lasers. These are often used in conjunction with radar altimeters on satellites to measure things like wind speeds and their direction and the direction of ocean currents. These altimeters are also useful in seafloor mapping in that they are capable of measuring bulges of water caused by gravity and the varied seafloor topography. These varied ocean heights can then be measured and analyzed to create seafloor maps.

Also common in remote sensing is LIDAR - Light Detection and Ranging. This is most famously used for weapons ranging but can also be used to measure chemicals in the atmosphere and heights of objects on the ground.

Other types of remote sensing data include stereographic pairs created from multiple air photos (often used to view features in 3-D and/or make topographic maps), radiometers and photometers which collect emitted radiation common in infra-red photos, and air photo data obtained by earth-viewing satellites such as those found in the Landsat program.

1.1.1 Multiple sources of information

Each band of information collected from a sensor contains important and unique data. We know that different wavelengths of incident energy are affected differently by each target -they are absorbed, reflected or transmitted in different proportions. The appearance of targets can easily change over time, sometimes within seconds. In many applications, using information from several different sources ensures that target identification or information extraction is as accurate as possible. The following describe ways of obtaining far more information about a target or area, than with one band from a sensor.

1.1.1.1 Multispectral

The use of multiple bands of spectral information attempts to exploit different and independent "views" of the targets so as to make their identification as confident as possible. Studies have been conducted to determine the optimum spectral bands for analyzing specific targets, such as insect damaged trees.

1.1.1.2 Multisensor

Different sensors often provide complementary information, and when integrated together, can facilitate interpretation and classification of imagery. Examples include combining high resolution panchromatic imagery with coarse resolution multispectral imagery, or merging actively and passively sensed data. A specific example is the integration of SAR imagery with multispectral imagery. SAR data adds the expression of surficial topography and relief to an otherwise flat image. The multispectral image contributes meaningful colour information about the composition or cover of the land surface. This type of image is often used in geology, where lithology or mineral composition is represented by the spectral component, and the structure is represented by the radar component.

1.1.1.3 Multitemporal

Information from multiple images taken over a period of time is referred to as multitemporal information. Multitemporal may refer to images taken days, weeks, or even years apart. Monitoring land cover change or growth in urban areas requires images from different time periods. Calibrated data, with careful controls on the quantitative aspect of the spectral or backscatter response, is required for proper monitoring activities. With uncalibrated data, a classification of the older image is compared to a classification from the recent image, and changes in the class boundaries are delineated. Another valuable multitemporal tool is the observation of vegetation phenology (how the vegetation changes throughout the growing season), which requires data at frequent intervals throughout the growing season.

"Multitemporal information" is acquired from the interpretation of images taken over the same area, but at different times. The time difference between the images is chosen so as to be able to monitor some dynamic event. Some catastrophic events (landslides, floods, fires, etc.) would need a time difference counted in days, while much slower-paced events (glacier melt, forest regrowth, etc.) would require years. This type of application also requires consistency in illumination conditions (solar angle or radar imaging geometry) to provide consistent and comparable classification results.

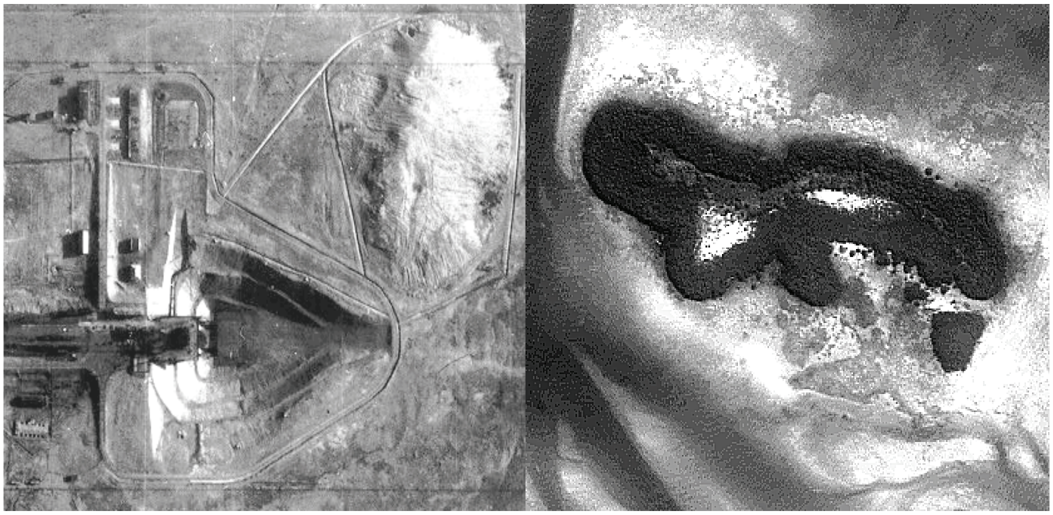
The ultimate in critical (and quantitative) multi-temporal analysis depends on calibrated data. Only by relating the brightness seen in the image to physical units, can the images be precisely compared, and thus the nature and magnitude of the observed changes be determined.

1.2 Elements of Image Interpretation

As we noted in the previous section, analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features which consist of points, lines, or areas. Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an air photo or a satellite image.

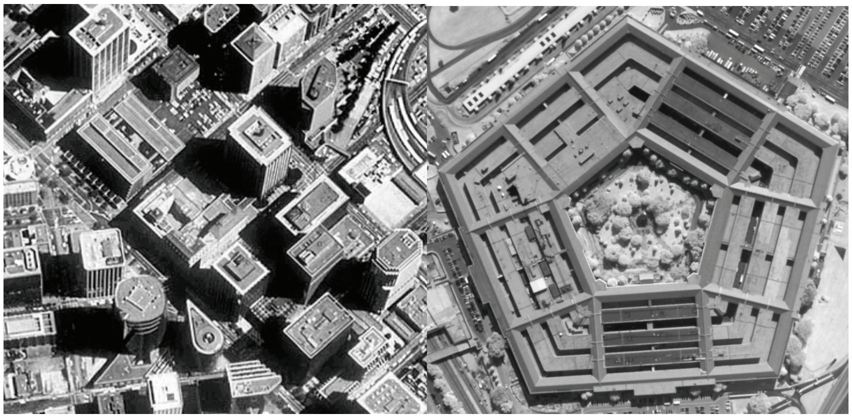
What makes interpretation of imagery more difficult than the everyday visual interpretation of our surroundings? For one, we lose our sense of depth when viewing a two-dimensional image, unless we can view it stereoscopically so as to simulate the third dimension of height. Indeed, interpretation benefits greatly in many applications when images are viewed in stereo, as visualization (and therefore, recognition) of targets is enhanced dramatically. 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.

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, and association. Visual interpretation using these elements is often a part of our daily lives, whether we are conscious of it or not. Examining satellite images on the weather report, or following high speed chases by views from a helicopter are all familiar examples of visual image interpretation. Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyze. The nature of each of these interpretation elements is described below, along with an image example of each.



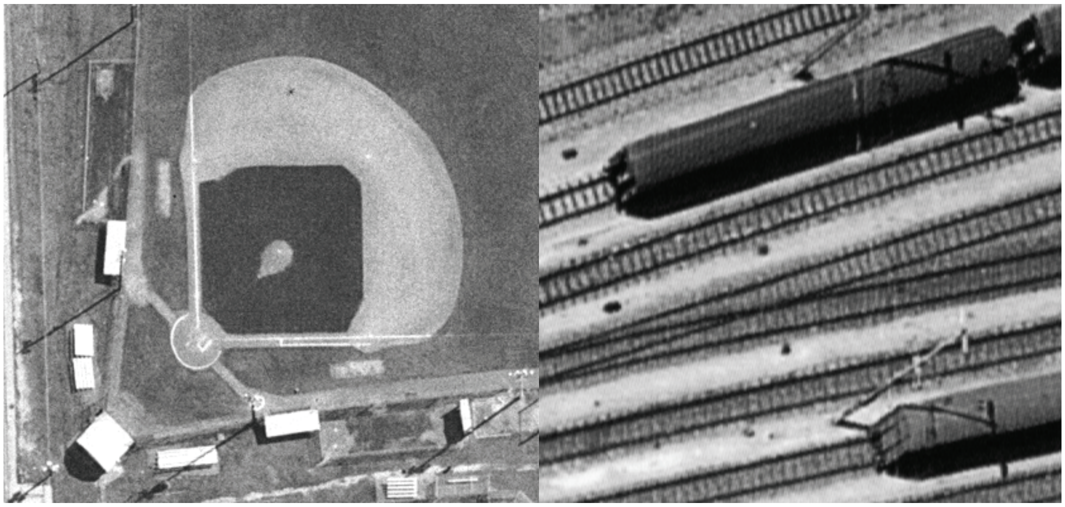
1.2.1 Tone

It refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Tone can be defined as each distinguishable variation from white to black. Color may be defined as each distinguishable variation on an image produced by a multitude of combinations of hue, value and chroma. Many factors influence the tone or color of objects or features recorded on photographic emulsions. But, if there is not sufficient contrast between an object and its background to permit at least detection, there can be no identification. While a human eye may only be able to distinguish between ten and twenty shades of grey; interpreters can distinguish many more colors. Some authors state that interpreters can distinguish at least 100 times more variations of color on color photography than shades of gray on black and white photography.



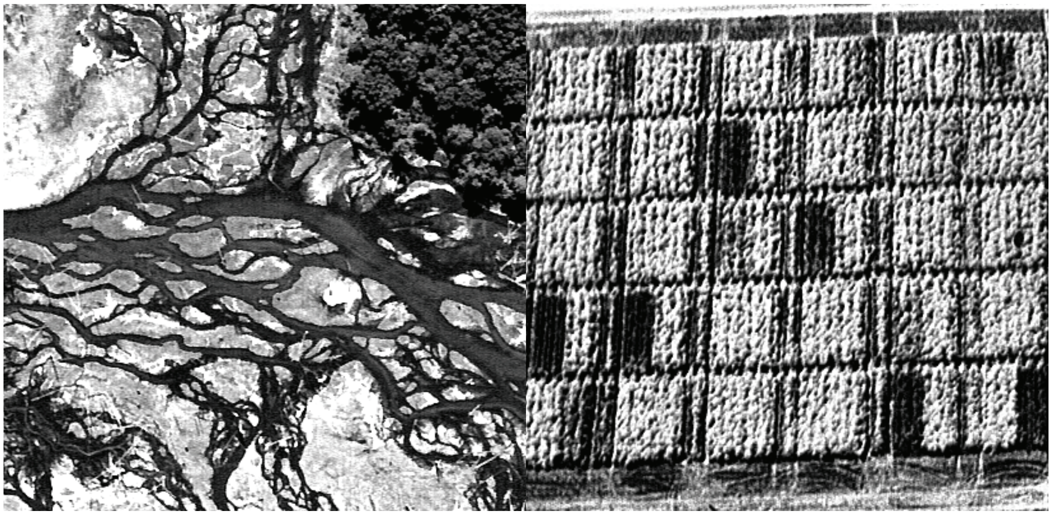
1.2.2 Shape & Height

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. Height can add significant information in many types of interpretation tasks; particularly those that deal with the analysis of man-made features. How tall a tree is can tell something about board feet. How deep an excavation is can tell something about the amount of material that was removed.



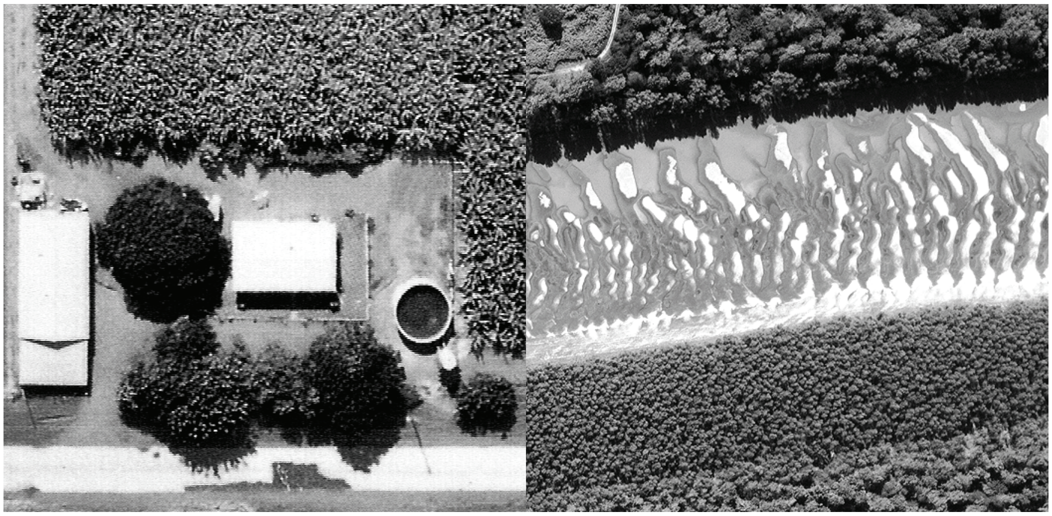
1.2.3 Size

***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.*



1.2.4 Pattern

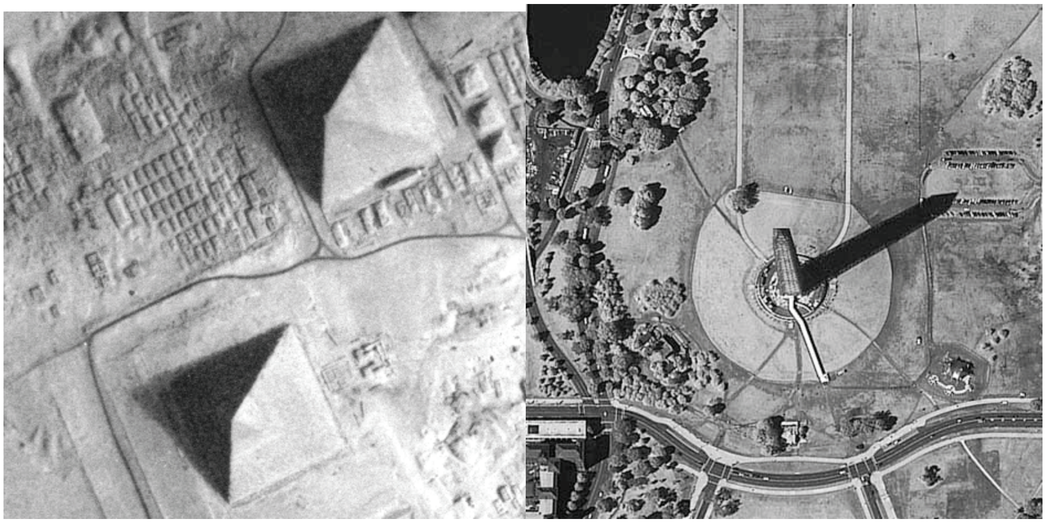
***Pattern** refers to the spatial arrangement of visibly discernible objects. Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees, and urban streets with regularly spaced houses are good examples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



1.2.5 Texture

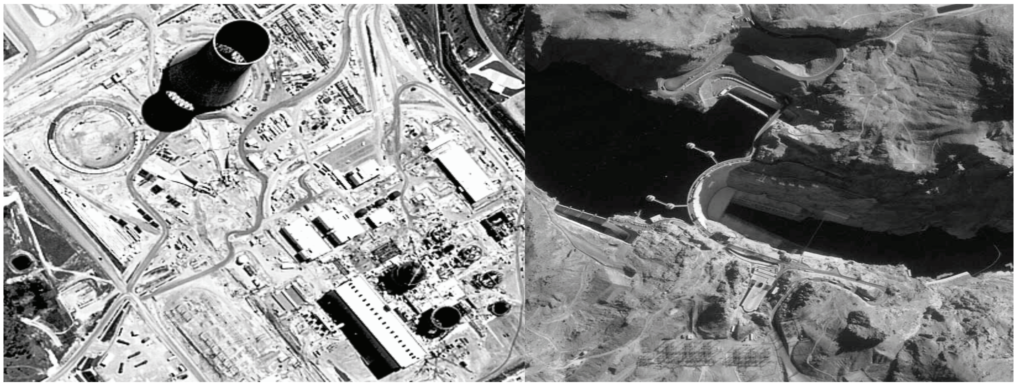
***Texture** refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation.*

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.



1.2.6 Shadow

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.*



1.2.7 Association, Resolution and Site

Associations *of some objects are so commonly associated with one another that identification of one tends to indicate or confirm the existence of another. Smoke stacks, step buildings, cooling ponds, transformer yards, coal piles, railroad tracks = coal fired power plant. Arid terrain, basin bottom location, highly reflective surface, sparse vegetation = playa. Association is one of the most helpful clues in identifying man made installations. Aluminum manufacture requires large amounts of electrical energy. Absence of a power supply may rule out this industry. Cement plants have rotary kilns. Schools at different levels typically have characteristic playing fields, parking lots, and clusters of buildings in urban areas. Large farm silos typically indicate the presence of livestock.*

Resolution *is defined as the ability of the entire photographic system, including lens, exposure, processing, and other factors, to render a sharply defined image. An object or feature must be resolved to be detected and/or identified. Resolution is one of the most difficult concepts to address in image analysis. Resolution can be described for systems in terms of modulation transfer (or point spread) functions; or it can be discussed for camera lenses in terms of being able to resolve so many line pairs per millimeter. There are resolution targets that help to determine this when testing camera lenses for metric quality. Photo interpreters often talk about resolution in terms of ground resolved distance, the smallest normal contrast object that can be detected and identified on a photo.*

Site *shows us objects are arranged with respect to one another; or with respect to various terrain features, can be an aid in interpretation. Aspect, topography, geology, soil, vegetation and cultural features on the landscape are distinctive factors that the interpreter should use when examining a site. The relative importance of each of these factors will vary with local conditions, but all are important. Just as some vegetation grows in swamps others grow on sandy ridges. Agricultural crops may like certain conditions. Man made features may also be found on rivers (e.g. power plant) or on a hill top (observatory or radar facility).*

1.3 Image rectification and corrections

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.

For discussion purposes, 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*

1.3.1 Colour Composites

While displaying the different bands of a multispectral data set, images obtained in different bands are displayed in image planes (other than their own) the color composite is regarded as False Color Composite (FCC). High spectral resolution is important when producing color components. For a true color composite an image data used in red, green and blue spectral region must be assigned bits of red, green and blue image processor frame buffer memory. A color infrared composite 'standard false color composite' is displayed by placing the infrared, red, green in the red, green and blue frame buffer memory. In this healthy vegetation shows up in shades of red because vegetation absorbs most of green and red energy but reflects approximately half of *incident Infrared energy. Urban areas reflect equal portions of NIR, R & G, and therefore they appear as steel grey.*

1.3.2 Image Rectification

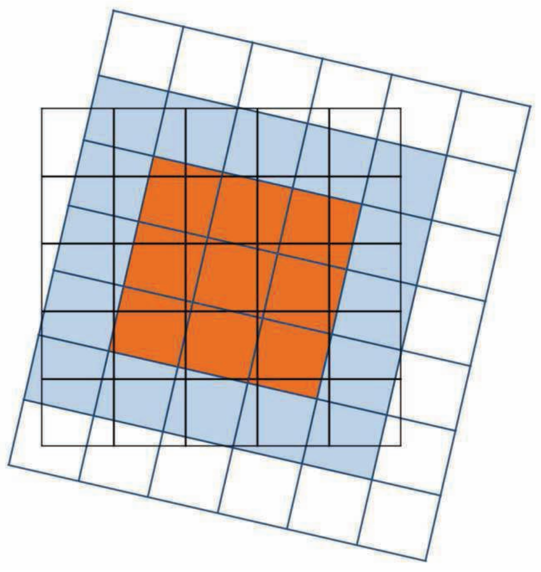
Geometric distortions manifest themselves as errors in the position of a pixel relative to other pixels in the scene and with respect to their absolute position within some defined map projection. If left uncorrected, these geometric distortions render any data extracted from the image useless. This is particularly so if the information is to be compared to other data sets, be it from another image or a GIS data set. Distortions occur for many reasons.

For instance distortions occur due to changes in platform attitude (roll, pitch and yaw), altitude, earth rotation, earth curvature, panoramic distortion and detector delay. Most of these distortions can be modelled mathematically and are removed before you buy an image. Changes in attitude however can be difficult to account for mathematically and so a procedure called image rectification is performed. Satellite systems are however geometrically quite stable and geometric rectification is a simple procedure based on a mapping transformation relating real ground coordinates, say in easting and northing, to image line and pixel coordinates.

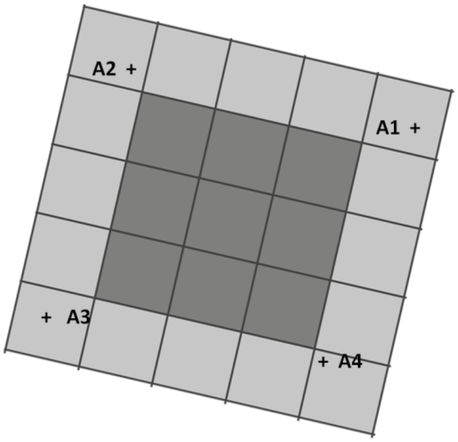
Rectification is a process of geometrically correcting an image so that it can be represented on a planar surface, conform to other images or conform to a map. That is, it is the process by which geometry of an image is made planimetric. It is necessary when accurate area, distance and direction measurements are required to be made from the imagery. It is achieved by transforming the data from one grid system into another grid system using a geometric transformation.

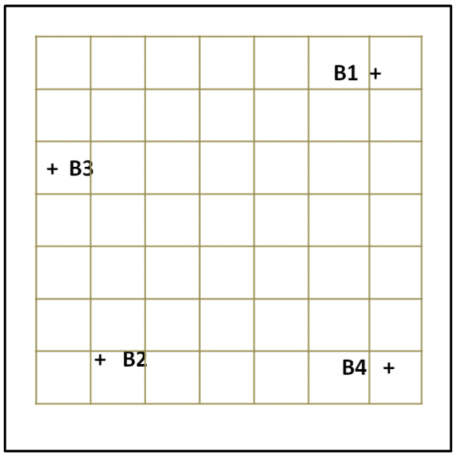
Rectification is not necessary if there is no distortion in the image. For example, if an image file is produced by scanning or digitizing a paper map that is in the desired projection system, then that image is already planar and does not require rectification unless there is some skew or rotation of the image. Scanning and digitizing produce images that are planar, but do not contain any map coordinate information. These *images need only to be geo-referenced, which is a much simpler process than rectification. In many cases, the image header can simply be updated with new map coordinate information. This involves redefining the map coordinate of the upper left corner of the image and the cell size (the area represented by each pixel).*

Ground Control Points (GCP) are the specific pixels in the input image for which the output map coordinates are known. By using more points than necessary to solve the transformation equations a least squares solution may be found that minimises the sum of the squares of the errors. Care should be exercised when selecting ground control points as their number, quality and distribution affect the result of the rectification.



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).





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 three common methods for resampling: nearest neighbour, bilinear interpolation, and cubic convolution.

Nearest Neighbor: *Each output cell value in the nearest neighbor method is the unmodified value from the closest input cell. Less computation is involved than in the other methods, leading to a speed advantage for large input rasters. Preservation of the original cell values can also be an advantage if the resampled raster will be used in later quantitative analysis, such as automatic classification. However, nearest neighbor resampling can cause feature edges to be offset by distances up to half of the input cell* *size. If the raster is resampled to a different cell size, a blocky appearance can result from the duplication (smaller output cell size) or dropping (larger cell size) of input cell values.*

Bilinear Interpolation: *An output cell value in the bilinear interpolation method is the weighted average of the four closest input cell values, with weighting factors determined by the linear distance between output and input cells. This method produces a smoother appearance than the nearest neighbor approach, but it can diminish the contrast and sharpness of feature edges. It works best when you are resampling to a smaller output cell size.*

Cubic Convolution: *The cubic convolution method calculates an output cell value from a 4 x 4 block of surrounding input cells. The output value is a distance- weighted average, but the weight values vary as a nonlinear function of distance. This method produces sharper, less blurry images than bilinear interpolation, but it is the most computationally intensive resampling method. It is the preferred method when resampling to a larger output cell size.*

Nearest neighbor resampling is the only method that is appropriate for categorical rasters, such as class rasters produced by the Automatic Classification process. Cell values in these rasters are merely arbitrary labels without numerical significance, so mathematical combinations of adjacent cell values have no meaning.

1.4 Image Classification

The overall objective of image classification is to automatically categorize all pixels in an image into land cover classes or themes. Normally, multispectral data are used to perform the classification, and the spectral pattern present within the data for each pixel is used as numerical basis for categorization. That is, different feature types manifest different combination of DNs based on their inherent spectral reflectance and emittance properties.

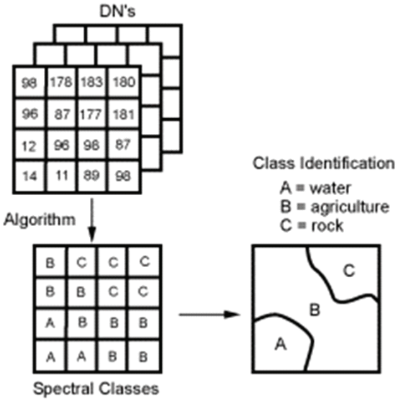
The term classifier refers loosely to a computer program that implements a specific procedure for image classification. Over the years scientists have devised many *classification strategies. From these alternatives the analyst must select the classifier that will best accomplish a specific task.*

The traditional methods of classification mainly follow two approaches: unsupervised and supervised. The unsupervised approach attempts spectral grouping that may have an unclear meaning from the user's point of view. Having established these, the analyst then tries to associate an information class with each group. The unsupervised approach is often referred to as clustering and results in statistics that are for spectral, statistical clusters. In the supervised approach to classification, the image analyst supervises the pixel categorization process by specifying to the computer algorithm; numerical descriptors of the various land cover types present in the scene. To do this, representative sample sites of known cover types, called training areas or training sites, are used to compile a numerical interpretation key that describes the spectral attributes for each feature type of interest. Each pixel in the data set is then compared numerically to each category in the interpretation key and labeled with the name of the category it looks most like. In the supervised approach the user defines useful information categories and then examines their spectral separability whereas in the unsupervised approach he first determines spectrally separable classes and then defines their informational utility.

It has been found that in areas of complex terrain, the unsupervised approach is preferable to the supervised one. In such conditions if the supervised approach is used, the user will have difficulty in selecting training sites because of the variability of spectral response within each class. Consequently, a prior ground data collection can be very time consuming. Also, the supervised approach is subjective in the sense that the analyst tries to classify information categories, which are often composed of several spectral classes whereas spectrally distinguishable classes will be revealed by the unsupervised approach, and hence ground data collection requirements may be reduced. Additionally, the unsupervised approach has the potential advantage of revealing discriminable classes unknown from previous work. However, when definition of representative training areas is possible and statistical information classes show a close correspondence, the results of supervised classification will be superior to unsupervised classification.

1.4.1 Unsupervised classification

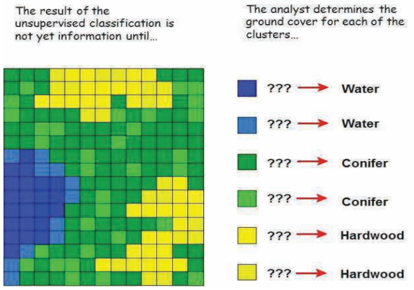
Unsupervised classifiers do not utilize training data as the basis for classification. Rather, this family of classifiers involves algorithms that examine the unknown pixels in an image and aggregate them into a number of classes based on the natural groupings or clusters present in the image values. It performs very well in cases where the values within a given cover type are close together in the measurement space, data in different classes are comparatively well separated.

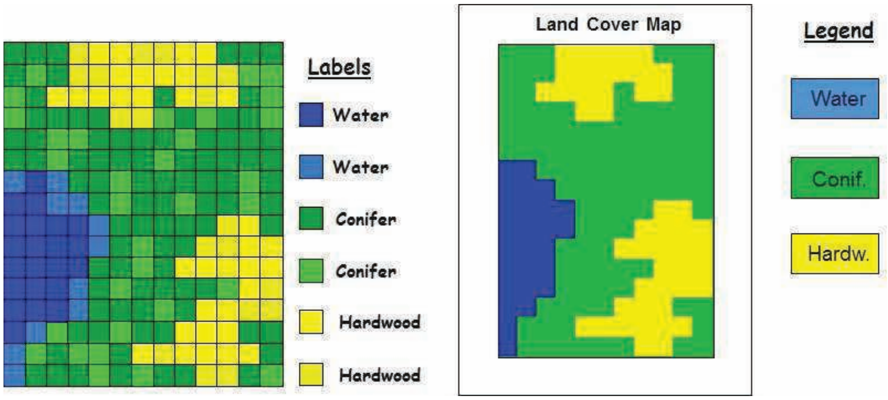


98	178	183	180
96	87	177	181
12	96	98	87
14	11	89	98

B	C	C	C
B	B	C	C
A	B	B	B
A	A	B	B

The classes that result from unsupervised classification are spectral classes because they are based solely on the natural groupings in the image values, the identity of the spectral classes will not be initially known. The analyst must compare the classified data with some form of reference data (such as larger scale imagery or maps) to determine the identity and informational value of the spectral classes. In the supervised approach we define useful information categories and then examine their spectral separability; in the unsupervised approach we determine spectrally separable classes and then define their informational utility.





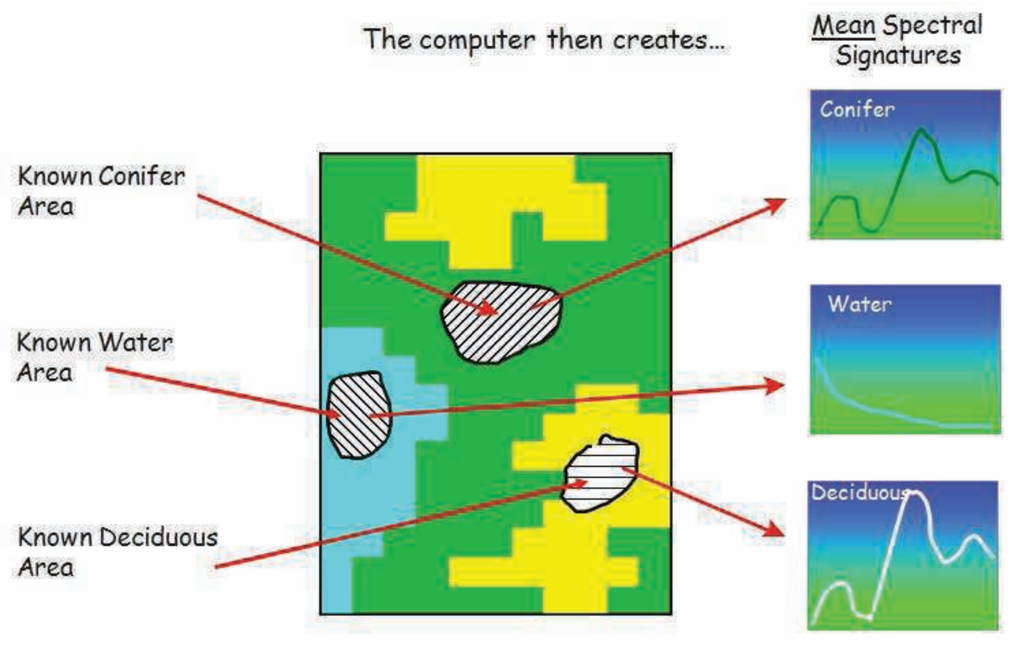
There are numerous clustering algorithms that can be used to determine the natural spectral groupings present in data set. One common form of clustering, called the "K-means" approach also called as ISODATA (Interaction Self-Organizing Data Analysis Technique) accepts from the analyst the number of clusters to be located in the data. The algorithm then arbitrarily "seeds", or locates, that number of cluster centers in the multidimensional measurement space. Each pixel in the image is then assigned to the cluster whose arbitrary mean vector is closest. After all pixels have been classified in this manner, revised mean vectors for each of the clusters are computed. The revised means are then used as the basis of reclassification of the image data. The procedure continues until there is no significant change in the location of class mean vectors between successive iterations of the algorithm. Once this point is reached, the analyst determines the land cover identity of each spectral class. Because the K-means approach is iterative, it is computationally intensive. Therefore, it is often applied only to image sub-areas rather than to full scenes.

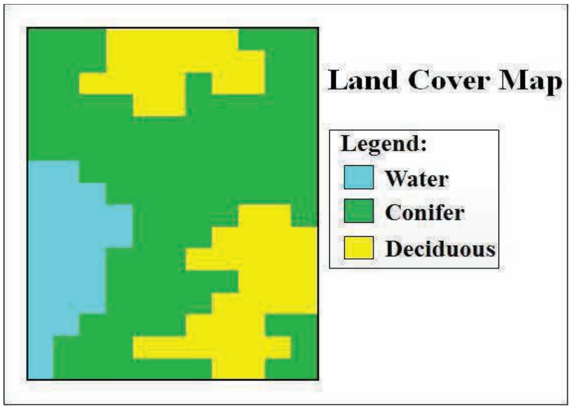
1.4.2 Supervised classification

Supervised classification can be defined normally as the process of samples of known identity to classify pixels of unknown identity. Samples of known identity are those pixels located within training areas. Pixels located within these areas term the training samples used to guide the classification algorithm to assigning specific spectral values to appropriate informational class.

1.4.2.1 Training data

Training fields are areas of known identity delineated on the digital image, usually by specifying the corner points of a rectangular or polygonal area using line and column numbers within the coordinate system of the digital image. The analyst must, of course, know the correct class for each area. Usually the analyst begins by assembling maps and aerial photographs of the area to be classified. Specific training areas are identified for each informational category following the guidelines outlined below. The objective is to identify a set of pixels that accurately represents spectral variation present within each information region.





1.4.3 Ground Truthing

Ground truthing is the process of sending technicians to gather data in the field that either complements or disputes airborne remote sensing data collected by aerial photography, satellite sidescan radar, or infrared images. The team of ground truthing scientists will be collecting detailed calibrations, measurements, observations, and samples of predetermined sites. From this data, scientists are able to identify land use or cover of the location and compare it to what is shown on the image. They then verify and update existing data and maps.

In remote sensing, ground truth is just a jargon term for at-surface or near-surface observations made to confirm their identification/classification by interpretation of aerial or satellite imagery. The term in its simplest meaning refers to "what is actually on the ground that needs to be correlated with the corresponding features in the visualized scene.

There are three main reasons to conduct ground truth activities:

To obtain relevant data and information helpful as inputs and reference in the analysis of a remotely sensed scene;

To verify that what has been identified and classified using remote sensing data is actually correct (accuracy assessment);

To provide control measurements, from targets of known identities, that are useful in calibrating sensors used on the observing platforms.

Ground truthing is a way of looking at an entire mountain range, costal plane, forest, inland sea, coral reef, dessert, grassland, river, or marsh and understand many of the realities involved. With our present technology, we canmeasure an entire watershed and understand its capacities and impact on a region and mankind's positive or negative influence.

1.4.3.1 Collecting Ground Information

The spectral signature within a pixel of an image consists of an average of reflectances of all materials within that pixel. So, for a spatial resolution of 5x5 pixels, the spectral response for a stand of vegetation will consist of a combination of spectra of all vegetation types, soil, ground litter, etc.

Take representative spectrometer readings above the canopies for as many categories or classes of vegetation as possible within time or access constraints. Features like wet and dry soils and rock outcroppings may require additional location-specific GPS data. Examples of categories of vegetation in India include grasslands, marshland, mangroves, stands of pine, and mixed vegetation, both evergreen and deciduous; Categories of soil might be wet soil and dry soil, along with soil which is contaminated and are significantly visible on satellite imagery.

Site conditions and project goals likely will dictate sampling methodology – either take many readings in a single location (narrow, deep sampling) or obtain few readings at many locations (broad, shallow sampling). If surface or subsurface contaminants are important, collect appropriate spectral data. Sampling along transects from contaminated areas to background (clean) areas across a plume may prove useful.

Collect actual leaf / soil / litter samples for later reflectance analysis in the lab. If the entire canopy consisted of leaves, presumably, its spectra would resemble the leaf spectra. In reality, the canopy is made up of different materials accounted for accordingly in its spectra.

Ground-truthing data to collect at each site include:

- *Field notes regarding site and light conditions*
- *Spectra-radiometer readings : Calibration targets (dark and light); and Vegetation*

- *Vegetation sample – leaf or leaf cluster*
- *Ground Control Points collected using a GPS*
- *Photograph of the site and write down the picture number as reference in the field note.*

1.5 Summary

This unit begins with the digital image processing techniques. Although the pre-processing is similar for all kinds of satellite imageries, the difference in the band combinations and resolutions asks for different interpretation techniques. The various keys of image visual interpretation are also described here. The rectification of a satellite data to make it compatible with other existing databases and also for accurate assessment of ground conditions is elaborated herewith. Later in the unit we also learn about the digital image processing techniques, namely supervised and unsupervised classification. Classification alone is incomplete without proper ground verification. Thus ground verification methods along with the various aspects of the ground data that has to be collected is mentioned here.

1.6 Glossary

Interpretation-*the act of interpreting; an explanation of the meaning of another's artistic or creative work; an elucidation*

Bits- *The smallest unit of information within a computer. A bit can have one of two values, 1 and 0, that can represent on and off, yes and no, or true and false.*

Calibration- *an explanation of the meaning of another's artistic or creative work; an elucidation*

Convolution- *a rolled up or coiled condition*

Interpolation- *The estimation of surface values at unsampled points based on known surface* ***Kernel-*** *the central or most important part of anything; essence; gist; core*

Model- *An abstraction of reality used to represent objects, processes, or events Values of surrounding points. Interpolation can be used to estimate elevation, rainfall, temperature, chemical dispersion, or other spatially-based phenomena. Interpolation is commonly a raster operation, but it can also be done in a vector environment using a TIN surface model. There are several well-known interpolation techniques, including spline and kriging.*

1.7 References

1. *Jensen, John R. Remote Sensing Of The Environment (2nd Ed.). Published by Dorling Kindersley India (2006) ISBN NO 10: 0131889508 ISBN 13: 9780131889507*
2. *Lillesand, Thomas M., Ralph W. Kiefer, and Jonathan W. Chipman. 2004. Remote Sensing and Image Interpretation, 5th ed., Published by John Wiley and Sons, Toronto. ISBN NO: 0471152277*
3. *http://geography.about.com/od/geographictechnology/a/remotesensing.htm*
4. *http://www.microimages.com/documentation/Tutorials/rectify.pdf*
5. *http://www.rese.ch/pdf/atcor3_manual.pdf*
6. *http://www.wamis.org/agm/pubs/agm8/Paper-5.pdf*
7. *http://educationally.narod.ru/gis3112photoalbum.html*
8. *http://www.smithsonianconference.org/climate/wpcontent/uploads/2009/09/ImageInterpretation.pdf*
9. *http://userpages.umbc.edu/~tbenja1/umbc7/santabar/vol1/lec2/2-3.html*
10. *http://gers.uprm.edu/geol6225/pdfs/04_image_interpretation.pdf*
11. *http://calspace.ucdavis.edu/GrdTruth.html*
12. *http://www.missiongroundtruth.com/groundtruth.html*

13. *http://rst.gsfc.nasa.gov/Sect13/Sect13_1.html*

1.8 Suggested Readings

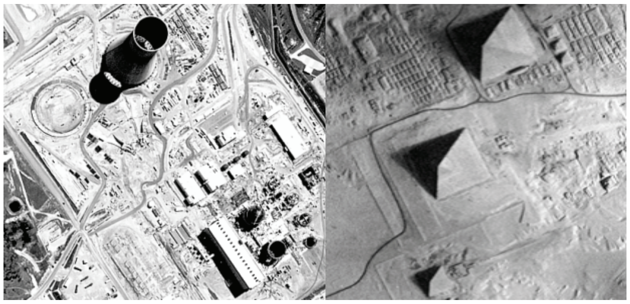
1. Jensen, John R. Remote Sensing Of The Environment (2nd Ed.). Published by Dorling Kindersley India (2006) ISBN NO 10: 0131889508 ISBN 13: 9780131889507

2. Lillesand, Thomas M., Ralph W. Kiefer, and Jonathan W. Chipman. 2004. Remote Sensing and Image Interpretation, 5th ed., Published by John Wiley and Sons, Toronto. ISBN NO: 0471152277

1.9 Terminal Questions

1. What are the 2 types of remote sensing? Explain.

2. What are the 7 image interpretation keys. Explain any 2 keys.



3. *What type of area is shown here? Which key/keys did you use interpret this?*
4. *Give 2 reasons for image rectification.*
5. *What is image to image registration and why is it done?*
6. *What are the two types of classification methods? Explain in 2 sentences each type.*
7. *What is the significance of ground truthing?*

***

UNIT 4: AESTHETICS OF MAP COMPOSITION

4.1 Introduction

"A picture is worth a thousand words" Emperor of the Xia Dynasty in China about 4,000 years ago.

A map is a graphic representation or scale model of spatial concepts. It is a means for conveying geographic information. Maps are a universal medium for communication, easily understood and appreciated by most people, regardless of language or culture. Incorporated in a map is the understanding that it is a "snapshot" of an idea, a single picture, a selection of concepts from a constantly changing database of geographic information. Maps are one means by which scientists distribute their ideas and pass them on to future generations.

A map can display only a few selected features, which are portrayed usually in highly symbolic styles according to some kind of classification scheme. In these ways, all maps are estimations, generalizations, and interpretations of true geographic conditions.

All maps are made according to certain basic assumptions, for example sea-level datum, which are not always true or verifiable. Lastly, a map is the product of human endeavor, and as such may be subject to unwitting errors, misrepresentation or bias. In spite of these limitations, maps have proven to be remarkably adaptable and useful through several millennia of human civilization.

4.1.1 Cartography

Cartography is the art and science of making maps. The purpose of the map along with the placement of all the components, like heading, scale, index, legend, labels, the colours and symbol which represent each component, contribute in making the map useful. This very subject of preserving the aesthetics of a map is cartography.

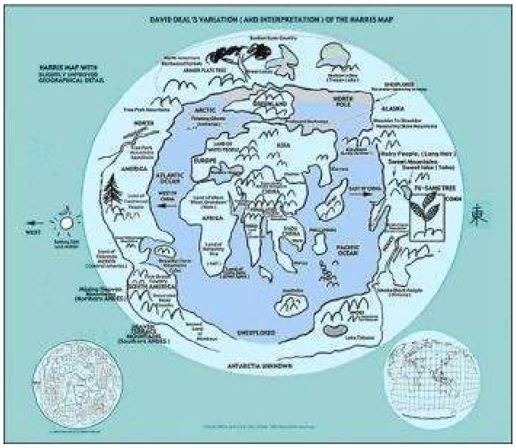
4.1.2 Brief History of Cartography

4.1.2.1 Early Maps

The oldest known maps are preserved on Babylonian clay tablets from about 2300 B.C. Cartography was considerably advanced in ancient Greece. The concept of a spherical Earth was well known among Greek philosophers by the time of Aristotle (ca. 350 B.C.) and has been accepted by all geographers since.

Greek and Roman cartography reached a culmination with Claudius Ptolemaeus (Ptolemy, about A.D. 85-165). His "world map" depicted the Old World from about 60°N to 30°S latitudes.

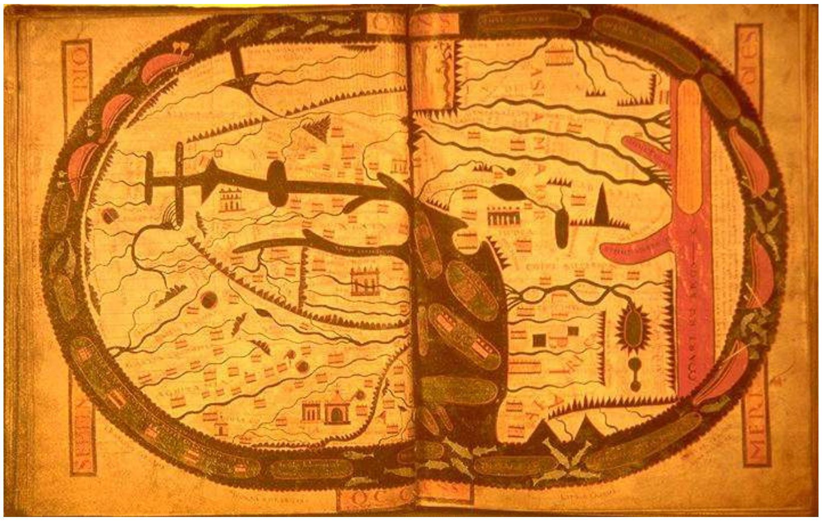
03/04/2005



The first image is one of the ancient Chinese maps from Dr. Hendon Harris Jr.'s collection, published in his book in 1973. The second drawing is the interpretation of the first map.

4.1.2.2 Medieval Maps

During the Medieval period, European maps were dominated by religious views. The T-O map was common. In this map format, Jerusalem was depicted at the center and east was oriented toward the map top.



4.1.2.3 Renaissance Maps

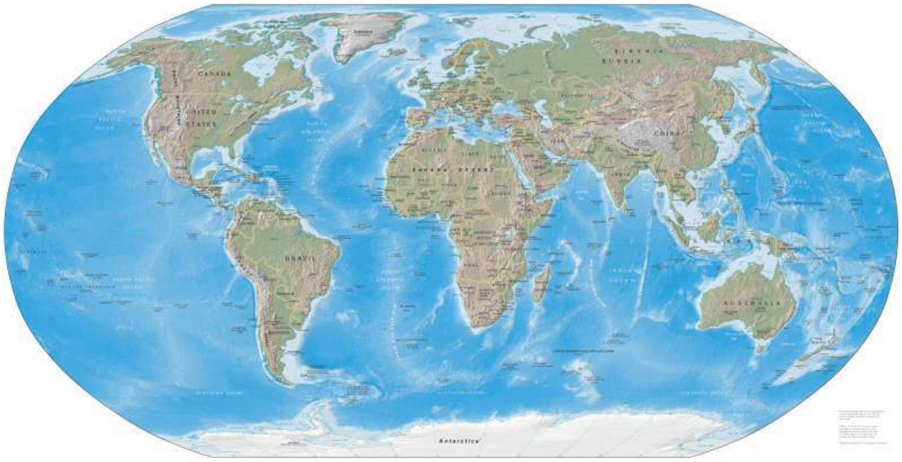
The invention of printing made maps much more widely available beginning in the 15th century. Maps were at first printed using carved wooden blocks (see above). Among the most important map makers of this period was Sebastian Münster in Basel (now Switzerland). His Geographia, published in 1540, became the new global standard for maps of the world.

Printing with engraved copper plates appeared in the 16th century and continued to be the standard until photographic techniques were developed. During the Age of Exploration in the 15th and 16th centuries map makers responded with navigation charts, which depicted coast lines, *islands, rivers, harbors, and features of sailing interest. Compass lines and other navigation aids were included, new map projections were devised, and globes were constructed. Such maps and globes were held in great value for economic, military, and diplomatic purposes, and so were often treated as national or commercial secrets--classified or proprietary maps.*

4.1.2.4 Modern Maps

The first true world map is generally credited to Martin Waldseemüller in 1507. This map utilized an expanded Ptolemaic projection and was the first map to use the name America for the New World.

Maps became increasingly accurate and factual during the 17th, 18th and 19th centuries with the application of scientific methods. Nonetheless, much of the world was poorly known until the widespread use of aerial photography following World War I. Modern cartography is based on a combination of ground observations and remote sensing. Geographic information systems (GIS) emerged in the 1970-80s period. GIS represents a major shift in the cartography paradigm. In traditional (paper) *cartography, the map was both the database and the display of geographic information. For GIS, the database, analysis, and display are physically and conceptually separate aspects of handling geographic data.*



4.2 Purpose of the Map

4.2.1 Topographic Maps

The subject of every map is a place. Topographic maps are designed especially to support a general exploration and discussion of the essential physical and cultural components of a place and it pertinent surroundings and their relationships with each other.

Data are chosen to represent these concepts; and the data are transformed into graphics portrayal in planimetric scale, and with a graphic hierarchy that makes it intuitively easy for the reader to discover the key concepts and relationships that you intend to emphasize. The art of selecting, transforming, and portraying information on a map involves the delicate balance of anticipating and answering reasonable questions related to your subject, while not overwhelming your reader's attention with needless detail, or forcing the reader to work in order to figure out what your map is intended to communicate.

4.2.1.1 Title and Labels

Include a Title that indicates the purpose for the map. This is a matter of being concise. Don't make me guess what you are trying to communicate with this map.

Put your name, your institutional context, source of primary data and date A map user expects a map to be biased, depending on the circumstances of its creation.

Include a caption that explains the critical concepts and relationships you are trying to illustrate. Without an explanation of the purpose of the map, the user may waste their time trying to figure out what the map's intention is.

The caption should convey an idea of what specific concepts are being explored by the map, and how a specific dataset has been used to portray an estimate the pattern that these concepts create on the ground. A good caption will reflect on the fitness of the data as an exact reflection of the ideal concepts. One way to make this simpler is to simply be clear that the map is a portrayal of a specific collection of observations made on a certain class of real world objects, using a particular method.

Label Key Elements on the Map. Certainly, any feature that you mention in your caption should be clearly portrayed and labeled on your map.

4.2.1.2 Scale, Projection and North

Cite Projection Method and Case All maps have a scale that should have planimetric scale properties - that is a scale that is constant in all directions and portions of the map and the north-south and east west axes should be at right angles to each other. These properties assure that *shapes and relative sizes of objects and distances will be represented correctly. Understanding this requires knowledge of the projection method used to transform the data for portrayal on the map. Therefore your choice of map projection method and case should be stated near to the north arrow and scale bar.*

Put a graphical scale bar on the map. Most maps these days are intended to be viewed on computer screens or projected against a wall. In these cases, a scale expressed as a fraction, eg. One Inch to One Mile or 1:63,000, is almost guaranteed to be wrong. In all cases a map should include a graphic scale bar. Only include fractional scales if you never to share your map in any other way than paper print.

4.2.1.3 Incorporate a Graphical Hierarchy

The key concepts as discussed in your text should be given emphasis with a bright color and bold line-weights and labels. Key relationships may be portrayed with diagramatic graphics. At a lesser level of emphasis you should provide a framework of reference for named places and circulation. There may be a hierarchy of emphasis among reference elements, such as line-weights and colors to portray different grades of roads. When color portrayal is an option, the color white should be reserved for non-map areas, such as margins, and the background of legend and text boxes. Other aspects of graphic hierarchy are discussed in the sections on topographic and thematic mapping.

4.2.1.4 Legend

A Concise Legend, if necessary the map legend should be reserved for making key distinctions that are important for understanding the points you are making in your caption. Not every symbol used on the map needs to be in the legend. When the symbology on the map is self-explanatory, or if the distinctions being symbolized objects is not an aspect of the key *concepts being described, then the map symbols should speak for themselves. When legends are included, the headings and descriptions should always be in plain english, avoiding cryptic file names and attribute codes. More tips on legends are discussed in the section on thematic maps, below.*

4.2.2 Thematic Maps

Beyond an understanding of the current context of a place, many documents will include maps that portray data that helps to support some assertion that one may want to make about a place as it relates to other places (in terms of land use or demographics or some other theme.) These are known as thematic maps. Thematic maps symbolize features according to the value of their attributes. These attributes may be qualitative, or quantitative. In the case of quantitative maps, we make a distinction between attributes that represent raw quantities versus measures of intensity.

4.2.2.1 Elements that Every Thematic Map Should Have

All of the requirements for maps, of portraying a contextual framework, listed above, apply also to thematic maps. There are additional considerations that also apply when we are trying to portray other sorts of measurements and observations on out maps.

Contextual Framework Portraying data without some frame of reference results needless difficulty for your audience to understand the relationship of the data or phenomena with the key places in and around the area of interest.

Concise, evocative legend your thematic data should be re-categorized if necessary so that your readers are not challenged to keep track of more than 5 different classes. Use plain terms in legend headings and labels. If you accept the software defaults for your legend labels and headings, *people who understand maps will also understand that you simply don't care about communicating.*

Try not to hide important information in arbitrarily broad categories The categories portrayed in the legend, whether qualitative or quantitative, should highlight distinctions that are useful.

Discuss the Aerial Precision of Mapping Units Whether the data are quantitative or qualitative, thematic data have a particular granularity. For example Census Data may be aggregated at a Block level or Tract. Land Use Data may only register distinctions for patches of ground larger than a stated Minimum Mapping Unit (like 5 acres, or a 90 meter cell.)

Graphical Hierarchy the same ideas about graphical hierarchy that apply to topographic maps may also apply with thematic maps. This is especially true with regard to the foreground layer of key topographic features and a reference layers to provide context. You may decide to drop some of the labels used in your reference layer -- particularly when your map document includes separate maps for presenting the contextual framework. Typically, the thematic layer will be the background layer of the map but you may also use transparency and an aerial photo at large scale, or shaded relief at smaller (broader) scales. When mixing background layers with transparency you should be careful that whatever background layers you use -- particularly aerial photos and or shaded relief, to not make the key distinctions in your thematic layer more difficult to read.

4.2.3 Quantitative Thematic Maps

Maps that portray quantitative measurements or summary statistics use tricks of graphics that cause the audience to visually weigh and compare aspects of places. Making effective quantitative maps and interpreting them requires an understanding the two major types of quantitative data: Intensive Statistics, *versus Raw Counts; and how the intuitive computer of the eye/mind interprets symbol color intensity versus symbol size. Intensive statistics (e.g. heat or concentration) versus extensive, count statistics (e.g. weights or counts).*

The cartographer should also understand two major classes of symbols for portraying quantitative properties: Proportional symbols change their visual weight according to a quantitative property. These are appropriate for extensive statistics. Choropleth maps portray data collection areas (such as counties, or census tracts) with color. Color is best used to represent intensive statistics such as percentages or densities. When using color this way, observe how the darkness and intensity (or value) of the color is evaluated by the eye as a measure of intensity or concentration.

Whenever you include a map portraying a proportion, such as Percent of housing units that are rental you should include a map that shows the density of the total -- e.g. total housing units per acre. It is often the case that areas that are near the ends of the scale in terms of proportion are ones that have very little actual activity in them.

Whenever your legend involves quantities of any type, your legend title or labels should explicitly state the units. When normalizing for density, please use an aerial unit that has an evocative scale. Can you create a picture in your mind of 10,000 people in a Square Kilometer? What about 100 People in a Hectare? (two soccer fields.) Convert your units if you have to.

Handy Conversion Factors		
You Have:	*Acres*	*Hectares*
Square Miles	*640*	*259*
Square Meters	*4,047*	*10,000*
0.001 Square Kilometers	*4.047*	*10*

4.3 Mapping proportions and Scales

From the very start of a cartographic project, you must keep an eye on the format of the final production--its final size and proportions and the media that will be used for production. If your final map will occupy a half page in a journal printed on 8x10 inch paper in black on white, you must design without color, with the frame of the map in the proportion of 4:5, and make allowances for lettering and symbols that may be illegible at small sizes. Strategies that work for one paper size may not work for another. Also, a map placed in a book, journal, or thesis will usually is captioned rather than titled and some of the other information needed for effective communication will move to this caption.

4.3.1 The issue of generalization, simplification, and abstraction

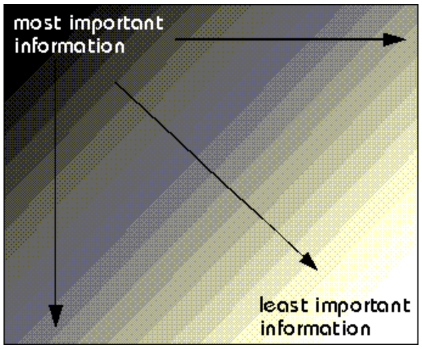
Cartography is very much a process of abstraction in which features of the real world are generalized or simplified to meet the demands of the theme and audience. Not all elements or details have a bearing on the pattern or process being studied and so some are eliminated to draw the reader's attention to those facts that are relevant. Too much detail can even hide or disguise the message of a map. The amount of detail that can be included is very much dependent on the scale at which the map will be produced, as the following examples demonstrate. A small-scale map of an area must, almost of necessity, be more generalized. Some automated systems now have the ability to provide assistance in the generalization and simplification of features.

Be aware, however, that adding just "a little" information, unless done wisely, can lead to confusion. Sometimes locator and index maps are used to help orient the reader to the location of the area of interest.

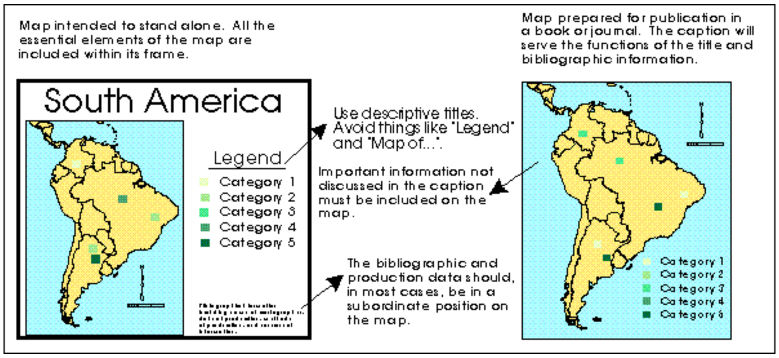
Almost all maps must include certain basic elements that provide the reader with critical information, like the title, scale, legend, body of the map, north arrow, cartographer, neatline, date of production, projection used, and information *about sources. The placement of this information and the style of its depiction will vary greatly from map to map.*

Elements are balanced within the visual hierarchy and frame of the map.

As a first approximation, the most important information should be featured near the top or to the left of the map. Less important and ancillary map elements can be positioned toward the bottom and right. In general terms, the importance of a given map element should be reflected in its position and the amount space it occupies on the map.



Once the elements are arranged to reflect their importance, attention can be given to their overall balance in the map frame. The idea here is to distribute the elements as evenly as possible within the map frame to avoid unnecessary crowding or, conversely, large blank areas. The cartographer can also align map elements within the frame to allow readers to more easily scan the page



4.3.1.1 Experiment with map layouts

Experimentation is often required to achieve an effective layout. You might begin by preparing some simple sketches of you map. Sketches such as this allow you to consider alternative layouts before you begin to compose the elements in detail.

There should be a defensible reason for each element placed on a map and for its composition

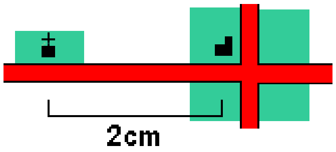
As you develop a design for a map, think carefully about every element--does it play an essential function, could it be simplified, does it require elaboration, is it of critical importance to reader comprehension, or only of background interest. Everything that appears on a map should be there for a defensible reason relating to message and audience.

4.3.1.2 Less is more

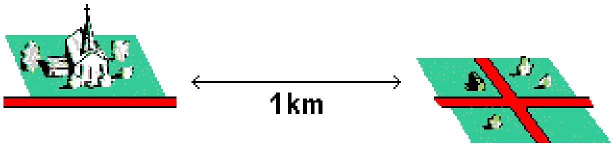
As you work, consider ways in which you can simplify your design and make it more legible. Too much detail or too complex a layout can confuse readers and work against effective communication. Do not avoid experiments, but be sure to test them carefully with your potential readers.

4.3.2 Scales

Maps are made to scale. In each case, the scale represents the ratio of a distance on the map to the actual distance on the ground. For example, if 2 cm on a map….



Represents 1 km on the ground….



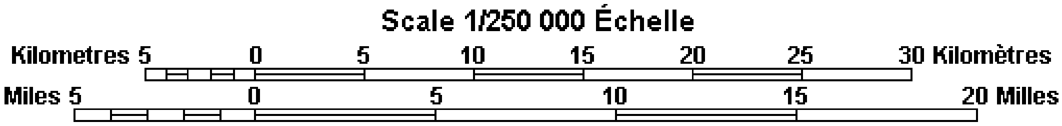
$$\frac{\text{Distance on the Map}}{\text{Distance on the Ground}} = \frac{2\text{ cm}}{1\text{ km}} = \frac{2\text{ cm}}{100\,000\text{ cm}}$$

$$= \frac{1}{50\,000}$$

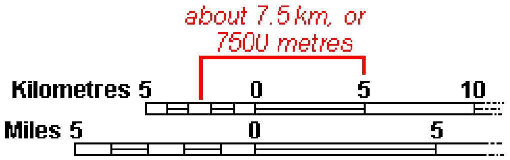
$$= \text{1/50 000 Scale}$$

The scale would be 2 cm = 1 km, or….

Use the Scale Bar found at the bottom of every National Topographic System (NTS) map to determine distances between points or along lines on the map sheet. (Note, the example below is not to scale.)



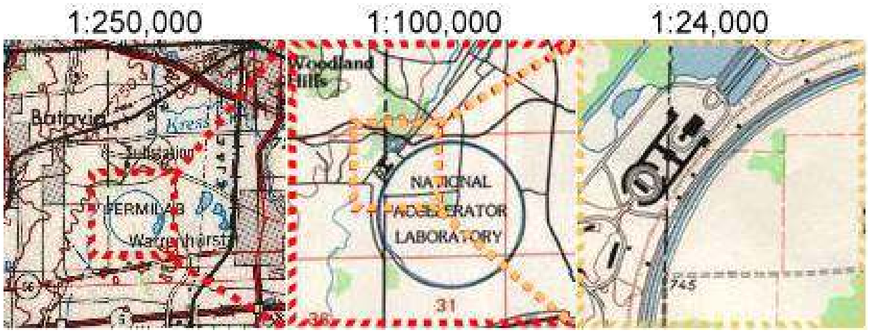
Use the secondary division on the left of the Scale Bar for measuring fractions of a kilometer. The measurement indicated is about 7.5 kilometers or 7 500 meters.



Large scale maps or Small scale maps

A large scale map shows greater detail because the scale is a larger fraction than a small scale map. Large scale maps have a scale of 1:50,000 or greater (1:24,000, 1:10,000). Maps with scales from 1:50,000 to 1:250,000 are considered intermediate. Small scale maps are those with scales smaller than 1:250,000. A map of the world that fits on two pages of letter sized paper would be very small scale with a scale of around 1:100,00,000.

Here are 3 views of the same location on maps with different scales:



4.3.2.1 Selecting the scale for the map

On a small-scale map, such as a page-size map of Switzerland, places of religious worship occur at points, but on a large scale map, such as a map of a local neighborhood, individual buildings would likely be apparent, and thus the focus might be on the area covered by the place of worship. Similarly, a river could be considered a linear phenomenon on a small-

scale map, but on a large-scale map, the emphasis could be on the area covered by the river. So, the map scale must be adapted to:

- ***The map content:*** *Some special themes cannot have various scales, but only the most logical one. For example, population density maps cannot be larger than 1:100 000 otherwise the mapped people are not representative (commuters, day laborer, etc.).*

- ***The map purpose:*** *The map scale must be adapted to the purpose of the map and not to the first design or aesthetic idea of the author. Here you should think how wide will the earth area to be mapped be?*

- ***The map precision:*** *With what measuring and counting will the map be built? Here you should think how detailed the information you display on the map will be. With large scale maps, the information is precise because they are less generalized.*

Large scale maps are on the whole not economic, not easy to handle, and sometimes misleading. And, small scales make on the whole the map difficult to read, complicate, and sometimes are meaningless. Which scale is selected for a given map design problem will finally depend on the map purpose and physical size. The amount of geographical detail necessary to satisfy the purpose of the map will also act as a constraint in scale selection.

Generally, the scale used will be a compromise between these two controlling factors. When you represent the scale graphically on the map, the measurement dimensions and the line thickness should be adapted to the map graphics.

4.4 Labeling

The general Map Labeling Problem consists of defining positions for the labels of several graphical features (cities, roads, lakes, rivers, national parks, states, countries, etc.) of a map, such that these features can be uniquely identified.

These rules are:

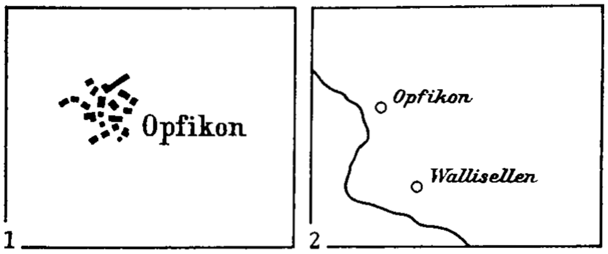
1. Readability: labels must have legible sizes;

2. Unambiguity: each label must be easily identified with exactly one graphical feature;

3. Avoidance of overlaps: labels should not overlap with other labels or other graphical features.

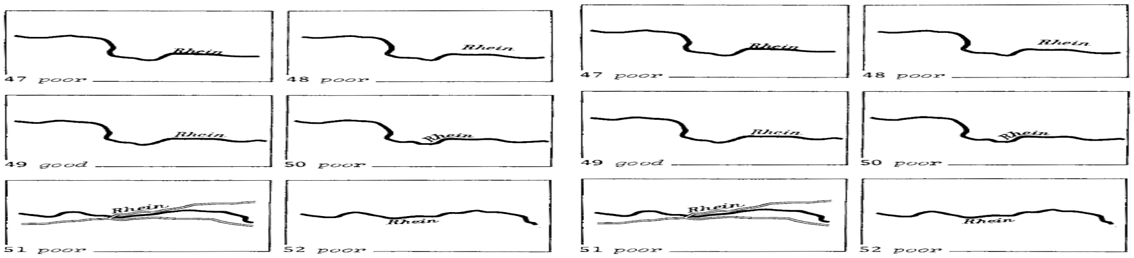
Six general requirements for a good label placement are summarized below:

- ***Readability:*** *chosen typeface, letter size and color on the one hand and positioning of the text on the other should support perception.*
- ***Definite attachment:*** *it should be clear which object belongs to a text.*
- ***Avoidance of overlaps:*** *the other map elements should not be covered by a label.*
- ***Spatial integration:*** *the label, looked on as a graphical shape without textual information, should help to clarify the spatial context of the designated object.*
- ***Site identification:*** *the chosen font should be a hint to the type of the labeled object.*
- ***Overall aesthetics:*** *the labels should not be spread over the map symetrically, but name clusters do also look disagreeable. This takes effect on generalization as well as on the placement.*

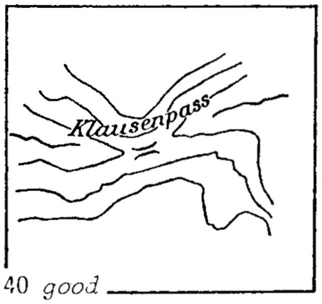


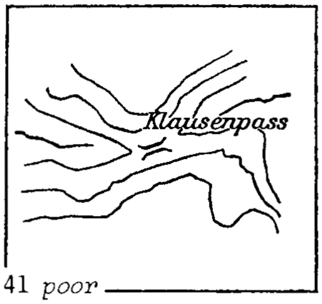
Cartographers arrange the named features in three groups, ordered by their topographical dimension: point features: cities, summits, but also area features on small scales

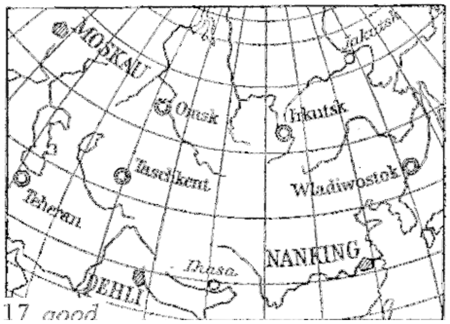
Linear features: rivers, streets, borders



Area features: mountains, islands, countries, lakes







Whereas the notations for point and linear features are arranged aside the object, they are written into the described object in case of area features (except for the case the area feature is sized too small to place the label inside its boundaries; then, it is treated like a point feature).

4.4.1 Label Placement

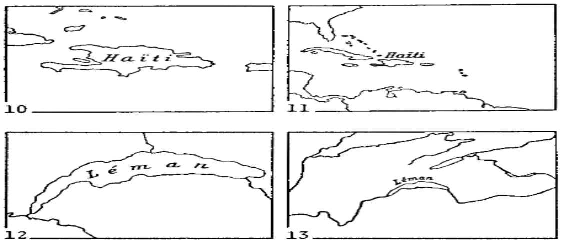
Features shown on maps and displays can be differentiated and identified in various ways: symbols, e.g. church, bridge. Labels provide the greatest flexibility to attach descriptions to point, line and area features names of administrative divisions, lakes, rivers etc. elevations of contours, spot heights, highway numbers, in cartography positioning labels is a complex and sophisticated process.

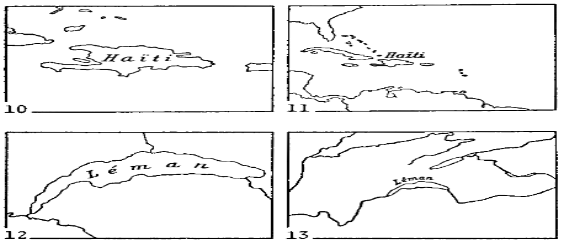
There have been few attempts to write down the rules used. It has proven difficult to emulate these rules in automated map production or GIS positioning labels on screen displays is especially difficult because of low resolution (e.g. 640 by 480 pixels), and the importance of speed.

Prof. Dr. Eduard Imhof, dean of European cartographers, has been an astute student of the esthetic-scientific characteristics of the cartographic method. In his publication of 1975. The labeling methods he described are summarized as Imhof's basic rules, mentioned below:

Names on maps should:

- *be legible*
- *be easily associated with the features they describe*
- *not overlap other map contents*
- *be placed so as to show the extent of the feature*
- *reflect the hierarchy of features by the use of different font sizes*
- *not be densely clustered nor evenly dispersed*

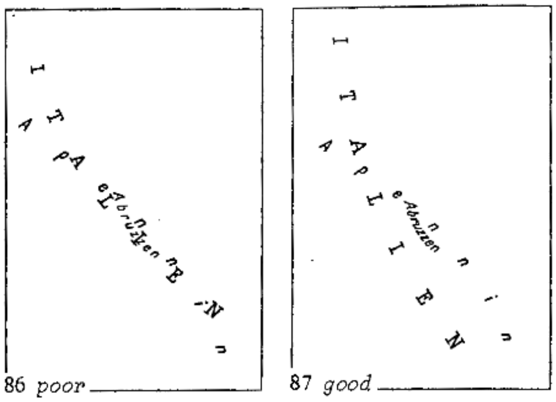




The best solution will balance conflicting objectives, e.g. need to associate name with feature vs. need to avoid overlap of contents label placement is a complex problem because of the vast number of possible positions that have to be searched and the number of conflicting objectives

two labeling problems are particularly significant in automated mapping and GIS: Over posting and polygon labeling

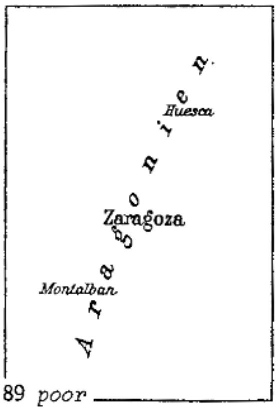
4.4.1.1 Over posting



86 poor

87 good

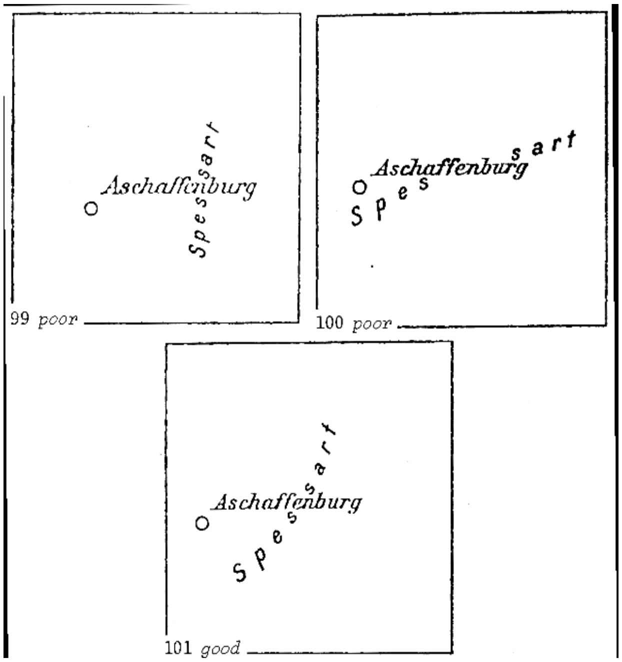
88 good



89 poor

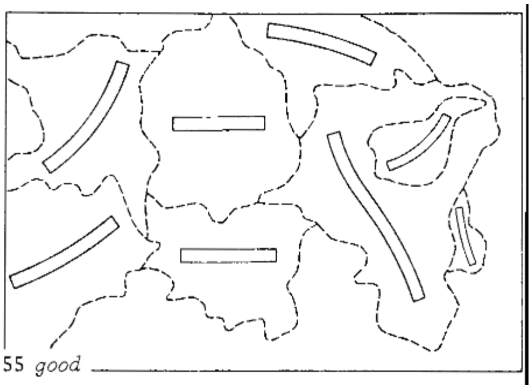
- *when features are densely packed on a map or screen, it is difficult to keep labels separated*
- *labels may overlap (over posting)*
- *labels must be positioned to avoid over posting, but without destroying the eye's ability to associate labels with appropriate features, e.g. point features*
- *optimum position for a label is above and to the right*
- *below and to the right is less acceptable*
- *least acceptable positions are to the left*
- *label can be turned (non-horizontal) if necessary, but only by a small amount*
- *over posting is a problem because the computer must search a vast number of possible positions*
- *in practice, must limit the number of positions somehow*
- *some solutions define a fixed number of possible absolute positions, like a raster*

- *other solutions define a fixed number of positions relative to the feature diagram*

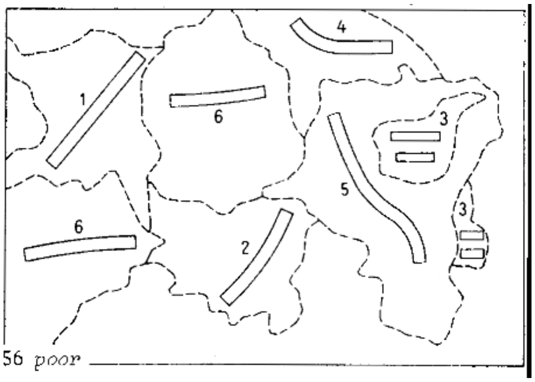


4.4.1.2 Polygon labeling

- *labeling polygons has become notorious within automated mapping as a difficult and challenging programming problem*
- *the label should be central to the feature, may be reoriented or curved to fit the feature diagram*
- *in some cases the label may be connected with the feature by an arrow diagram*



55 *good*



56 *poor*

4.4.2 Simple methods

1. Label centered on the polygon centroid problems:

- *centroid may lie outside the polygon*
- *a long label may have to be multi-line to fit inside*
- *solution fails to meet Imhof's criterion of showing the extent of the feature*

2. Variable rectangle positioned inside the polygon

- *search for feasible positions for a rectangle wholly enclosed within the polygon*
- *ratio of width to height should be as high as possible*
- *solution will not curve the label to fit the feature*

- *largest enclosed rectangle may be in an inappropriate part of the polygon diagram*

3. Skeleton

- *shrink the polygon by moving its edges inward at a uniform rate*
- *the vertices trace out a network known as the skeleton diagram*
- *position the label along the central part of the skeleton*
- *best for polygons like Florida which require curved labels*
- *practical labeling methods use combinations of rules for different shapes, sizes of polygons*
- *many developers have used the term expert system to describe label placement software*
- *an expert system works with complex sets of rules in a rule base*
- *the objective of the expert system is to emulate the complex decision process of a cartographer*

4.5 Summary

In this unit we learn about the presentation of out spatial data through maps. The basic concepts of map designing and how it has evolved through time is also outline here. The key components, like title, legend, scale along with their proper placements all contribute to the readability and usefulness of a map. The scale at which the map displays the data is also elaborated here. The labeling of features and its placement on the map together enhances the usefulness of the map.

4.6 Glossary

- ***Aesthetic***- *pertaining to a sense of the beautiful*
- ***Medieval***- *of, pertaining to, characteristic of, or in the style of the Middle Ages:*
- ***Renaissance***-*The activity, spirit, or time of the great revival of art, literature, and learning in Europe beginning in the 14thcentury and extending to the 17th century, marking the transition from the medieval to the modern world.*
- ***Attribute***- *Nongraphic descriptive information about features, characteristics or elements of a database. For a database feature like census tract, attributes might include many demographic facts including total population, average income, and age. In statistical parlance, an attribute is a variable, whereas the database feature represents an observation of the variable.*
- ***Statistics***-*The science that deals with the collection, classification, analysis and interpretation of numerical facts or data and that by use of mathematical theories of probability, imposes order and regularity on aggregates of more or less disparate elements.*
- ***Layout***- *The arrangement of elements on a map, possibly including a title, legend, north arrow, scale bar, and geographic data.*

4.7 References

1 *http://academic.emporia.edu/aberjame/map/h_map/h_map.htm*

2 *http://www.theepochtimes.com/n2/content/view/24170/*

3 *http://49987376.nhd.weebly.com/world-maps-the-need-facilitated-change.html*

4 *http://www.colorado.edu/geography/gcraft/notes/cartocom/section4.html*

5 *http://www.gsd.harvard.edu/gis/manual/style/*

6 *http://maps.nrcan.gc.ca/topo101/scale_e.php*

7 *http://www.compassdude.com/map-scales.shtml*

8 *http://gitta.info/LayoutDesign/en/html/MapSizeScale_learningObject3.html*

9 *http://www.sonic.net/~dmed/MedeCart/About_Me_files/Positioning_Names_on_Maps.pdf*

10 *http://ls11-www.cs.uni-dortmund.de/people/preuss/pages/projects/dip/dip.pdf*

4.8 Suggested Readings

1 *Misra, R.P. and A. Ramesh. 1989. Fundamentals of Cartography (Revised and Enlarged). Published by Concept Publishing Company, Mohan Garden, New Delhi, India. ISBN (Paperback): ISBN NO: 9788170222224*

4.9 Terminal Questions

1 *What, in your opinion, is the use of a map?*

2 *Name 3 criteria which should be kept in mind when labeling in a map.*

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