Remote Sensing

Objectives

This unit will briefly explain display of remote sensing image, geometric correction, spatial enhancement, spectral enhancement and classification of remote sensing image.

At the end of the unit, the student will understand the basic steps to process the remotely sensed images and will be prepared to learn theoretical and practical digital image processing steps in the intermediated level.

1. Image Display

Each pixel is characterised by a DN (digital number) value, one for each multispectral channel. Pixels of single channel can be displayed on the screen as greyscale display. The lowest DN values are displayed as black, increasing DN values are displayed as shades of grey between black and white, and the highest DN values as white.

The following figure is grey scale display of SPOT Panchromatic without stretching.

If the DN value range is more than the full dynamic range of the output display, the apparent spatial and radiometric resolution of data in display is reduced.

If the DN value range of image is less than the dynamic range of output display, contrast stretching improves image contrast by expanding the range of DNs to utilize the full dynamic range of the display. If the data have a normal distribution, a linear stretch from the data set's minimum to its maximum DN value is sufficient.

The following figure is grey scale display of SPOT Panchromatic with stretching.
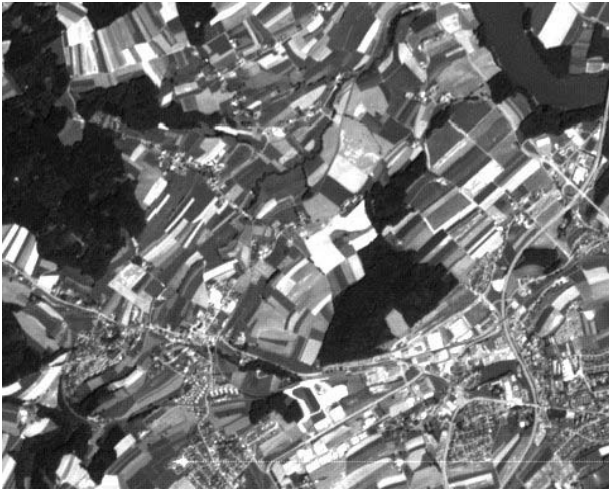
A non-linear stretch is required if the data are skewed or have a multi-modal distribution.

Three data channels from multispectral data can be simultaneously displayed as composite by displaying one channel in each of the display monitor's three-color guns (red, green, blue). The resulting RGB composite will appear as a color image in which colors are in direct proportional to the grey scale ranges of each channel.

If the visible red wavelength (channel) is assigned as red color, visible green wavelength (channel) is assigned as green color and visible blue wavelength (channel) is assigned as blue color, the composite is essentially natural color image. For example Landsat TM bands 3,2,1 as R, G, B). All other compositions are called false color composite (FCC).

The following figure illustrates the False Color Composite of a SPOT Image.
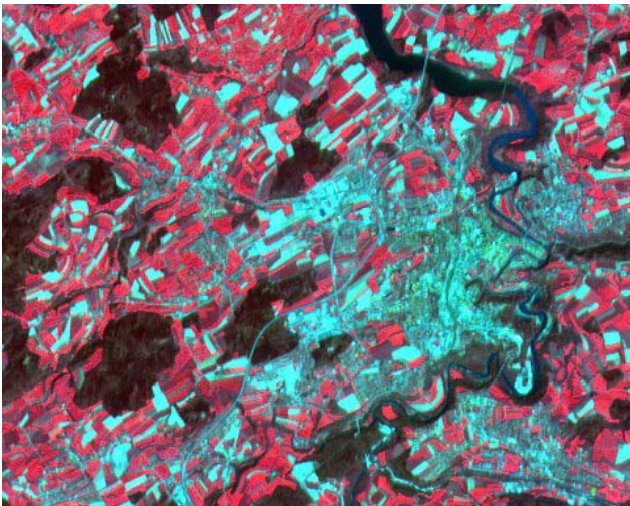
2. Registration and Rectification

Remotely sensed data contained both systematic and non-systematic geometric errors. Systematic errors are caused due to the sensor platform ephemeris and internal sensor distortion. The systematic errors can be corrected using the data from platform ephemeris and knowledge of internal sensor distortion and are corrected by the satellite-operating agency.

Non-systematic errors are caused due to the scale changes, which result from sensor platform departments from its normal altitude especially in aircraft platform. Moreover, one sensor axis is usually maintained normal to the earth's surface and the other parallel to the sensor platform's direction of travel. If the sensor surface departs from this attitude (roll, pitch and yaw), non-systematic geometric error occurred.

Non-systematic errors can only be corrected to a certain level of acceptable accuracy with a sufficient number of ground control points (GCP). GCP is a point on the earth surface where both image coordinate (row and column) and map coordinates (feet or meter or degrees in latitude and longitude) can be identified.

Most often used geometric corrections are rectification and registration. Without geometric correction, the images can't be used in GIS as they are not georeferenced.

Rectification is a process of transforming the image coordinates (measured in rows and columns) to a planimetric coordinate system or map coordinates (measured in degree of latitude and longitude, feet or meter) using an nth order polynomial. Therefore, each pixel in an image is at its correct location. Rectification process involves spatial interpolation, correlating a number of pixel coordinates on an image to corresponding ground control points (GCP) on the map. Rectification is often referred to as an image-to-map registration. Moreover, rectification process involves intensity interpolation or resampling, determining the bright value to be assigned to the new rectified pixel at the new location and at the new grid system.

Rectification involves calculation of the root mean square error (RMS) for each of the ground control points. Normally RMS error less than or equal to 0.5 pixel or 0.5 of spatial resolution is acceptable.
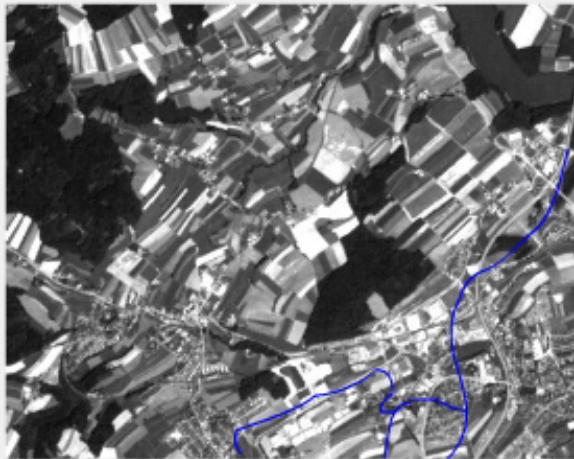
Concept : Raw image without geometric correction

The image is not geometrically corrected.

Therefore, it is not possible for georeference.

The road (blue line) line grom GIS database can not be overlaid on the image.

Display of SPOT Panchromatic data in gray scale with stretch.

The following figure illustrates the result of geometric correction.

Concept : Geometrically corrected image

After geometric correction, the image can be georeferenced.

The road in GIS can be overlaid on the groreferenced image.

Display of geometrically corrected SPOT Panchromatic in gray scale with stretch.
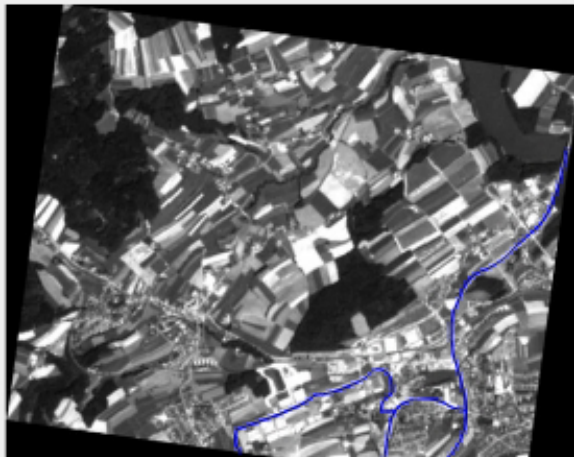
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3. Contextual Enhancement

Contextual enhancements through filtering, modify pixel values based on the values of surrounding pixels in order to reduce the noise or enhance desire characteristics of an image by emphasizing or de-emphasising data of various spatial frequency. Spatial frequency is defined by Jensen (1986) as the number of changes in brightness value per unit distance of any particular part of the image.

The following image illustrates the edge detected SPOT Panchromatic Image.
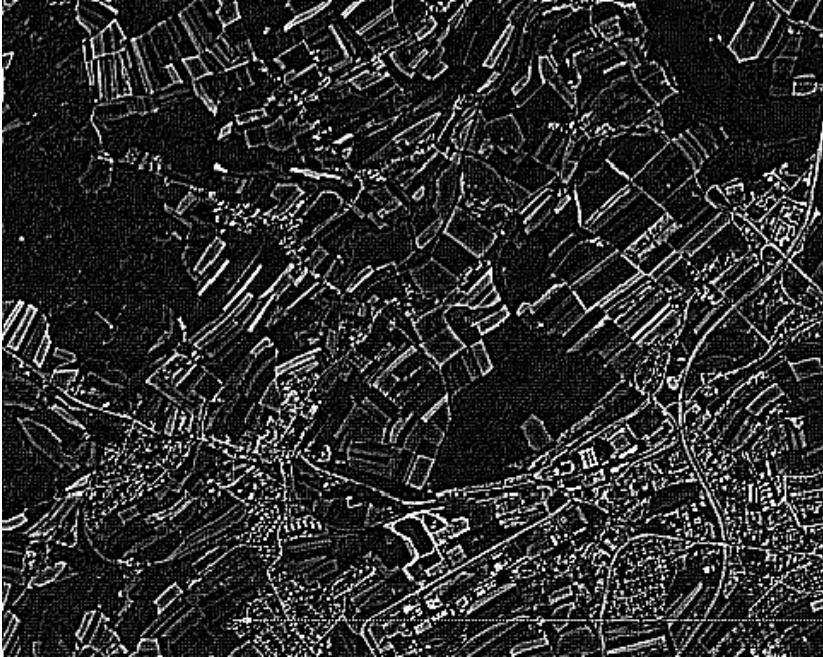
The following image illustrates the edge enhanced SPOT Panchromatic image. Compare with SPOT Image grey scale display with stretch, especially edge of land cover facets.

The following image illustrates the Average Filtered SPOT Panchromatic. The image becomes blur and smoother. The noise strip at the bottom of the image becomes less significant.
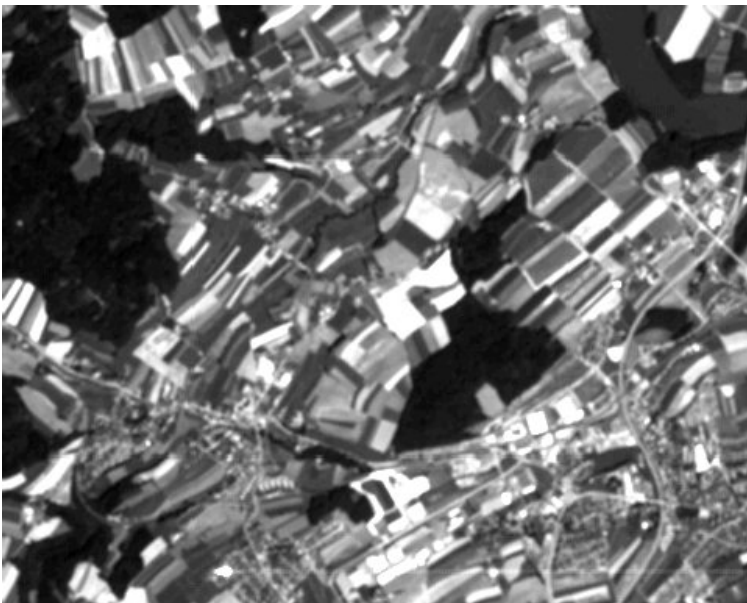
4. Multi-band transformation

Multi-band transformation techniques are used to create the new band for enhancing a feature of interest, reducing data size and redundancy. Multi-band transformation techniques require more

than one band of data and used the spectral information found in the multiple databands. Indices and principle component analyses are Multi-band transformation techniques.

<u>Indices</u>

Indices are simple algebraic operations applied to digital numbers or values of pixels in more than one band. The following indices are commonly used.

Indices	Equation
Vegetation Difference Index	IR-R (infrared - red)
Vegetation Index	IR/R (infrared/red)
Normalized Difference Vegetation Index (NDVI)	(IR-R)/(IR+R)
Iron Oxide Ratio	R/B (red/blue)
Clay Mineral	Mid-infrared (1.55-1.74 micron) / Mid-infrared (2.08-2.35 micron)
Ferrous Mineral	Mid-infrared (1.55-1.74 micron) /Near Infrared
Mineral composite	Mid-infrared (1.55-1.74 micron) / Mid-infrared (2.08-2.35 micron) Mid-infrared (1.55-1.74 micron) /Near Infrared Red / Blue
Hydrothermal composite	Mid-infrared (1.55-1.74 micron) / Mid-infrared (2.08-2.35 micron) Red / Blue Near Infrared / Red

The following SPOT images illustrate the False Colour Composite and NDVI. The brighter values represent the vegetation, agriculture and forest area and the darker values represent the no vegetation area, road, harvested agriculture field, river and urban area.

Concept : Spot multispectral false color composite (FCC)

FCC display of Spot multispectral data

Spot Band 3 (NIR wavelength) as Red
Spot Band 2 (Red wavelength) as Green color
Spot Band 1 (Green wavelength) as Blur color

Red color area in the image are vegetation
because of higher reflectance of vegetation
in near infrared wavelength.

Compare red color area (vegetation) with
brighter area of the image on the next slide.
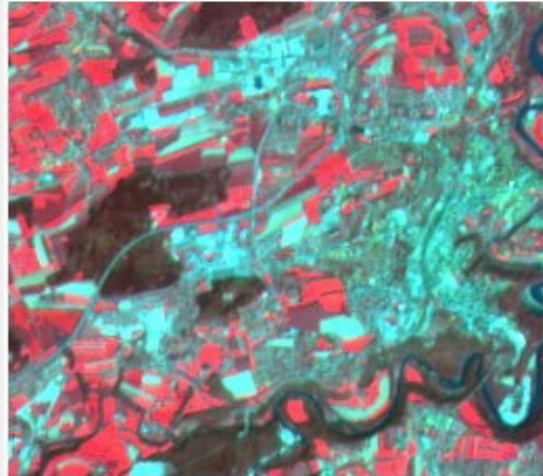
Concept : Display of Spot NDVI with stretch

According to the
NDVI formula,
NDVI Image value
ranged from -1 to
+ 1as explain below.

$(NIR - R) / (NIR + R)$

If
Minimum NIR = 0
Maximum R = 255
Then NDVI is -1.
If
Maximum NIR = 255
Minimum R = 0
Then NDVI is +1.

0   (Darkest)

-1

Then stretch -1
to 0 and +1 to
255 to display at
full dynamic
range of display.

1

255 (Brightest)

Brighter areas
represent vegetation,
which NDVI value
approach to 1 and
darker areas represent
non-vegetation which
NDVI value approch to
-1.

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Principal Component Analyses

Principal Component Analyses (PCA) is a multivariate statistical method that transforms multivariate data from different spectral channels into a series of statistically uncorrelated component. It allows redundant data to be compacted into fewer bands. Therefore the dimensionality of data is reduced. The bands of PCA are often more interpretable than the source data.

The number of input bands and the number of output PCA bands are the same. For Example, the Landsat TM has 7 Bands. Therefore, the output of PCA of TM data will be 7 PCA bands.

The following images are output of Principal Component Analyses (PCA), PCA1, PCA2 and PCA3 of Landsat TM over Fribourg. PCA1 and PCA2 are complementary. PCA3 has lesser information. RGB composite of PCA1, 2,3 is very informative.
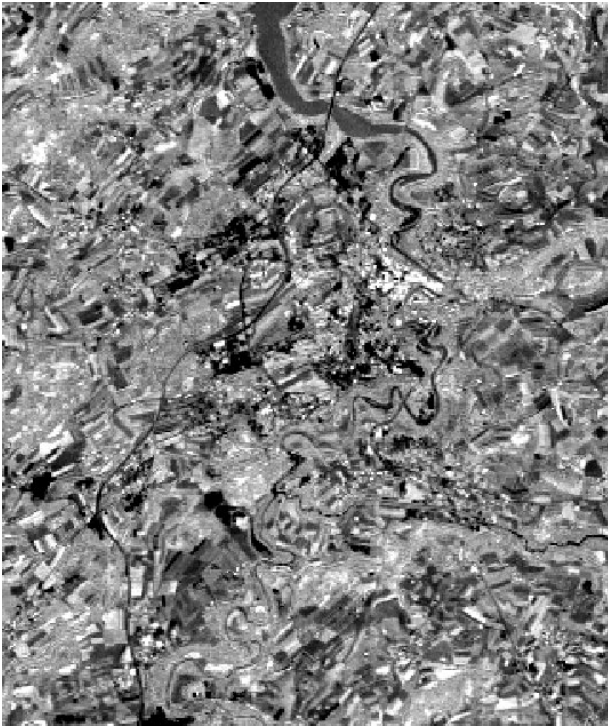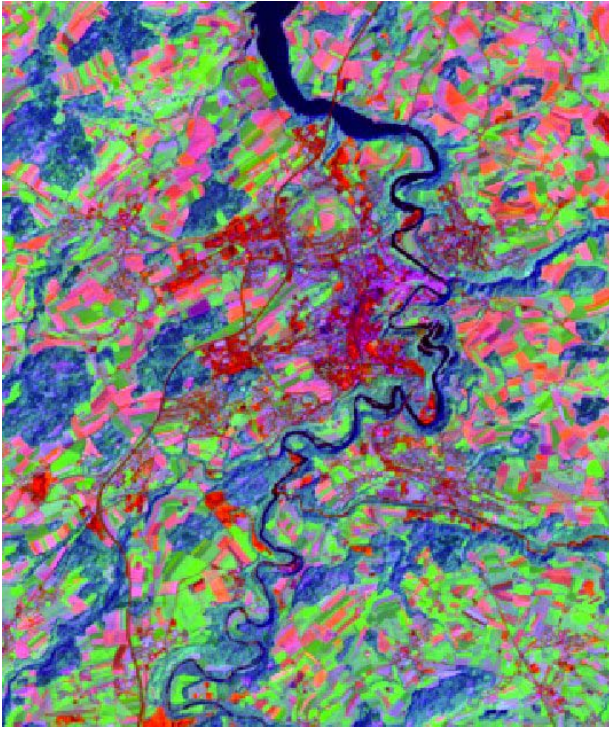
Principal Component - 1
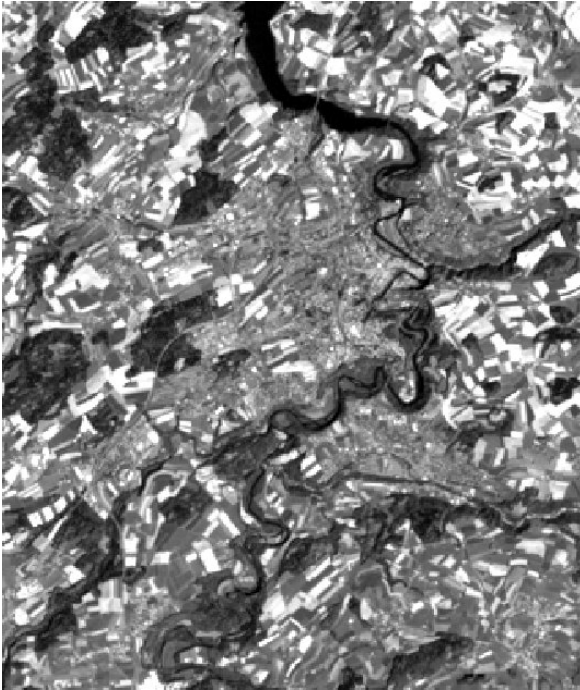
Principal Component - 2
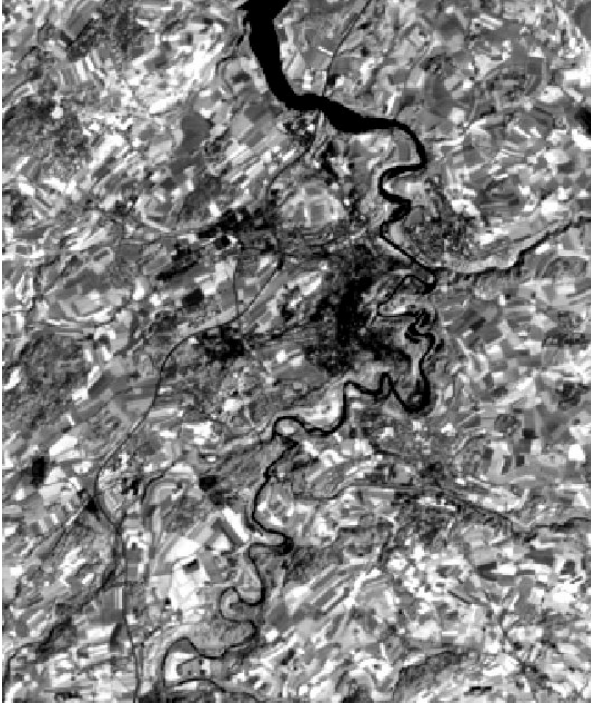
Principal Component -3

Principal Component 123 RGB Composite

The first principal component measures the highest variation within the dataset. The second principal component describes the largest amount of variance in the data that is not already described by the first principal component.

The first 3 PCA bands account for a high proportion of the variance in the data, almost 100%. Therefore PCA is useful to compress the data into fewer bands and reduce the data redundancy.

PCA bands with least variance (6th and 7th Principal components in TM example) may show the regular noise in the data and may also show some useful information.

The RGB composite of the first, second and third principal component is very effective to interpret different land covers especially in the field, because it allows to view almost 100% of the information with a single composite image. Conveniency to the limited display capacity.

5. Classification

The classification process of an image is to group into a finite number of useful classes or categories of information based on the spectral values of pixels. If a pixel satisfies certain set of criteria or decision rule, this pixel is assigned to the information class that corresponds to that criteria. An example of classified image is land cover map, showing forest, agriculture, pasture, urban etc.

Human eyes performed pattern recognition by viewing natural color or false color composite image, grey scale image, spatially and spectrally enhanced image. Then human brain automatically sorts certain colors and textures into categories.

However, computer system or image processing system must be trained to recognize these patterns in the image. Training can be performed by unsupervised or supervised methods.
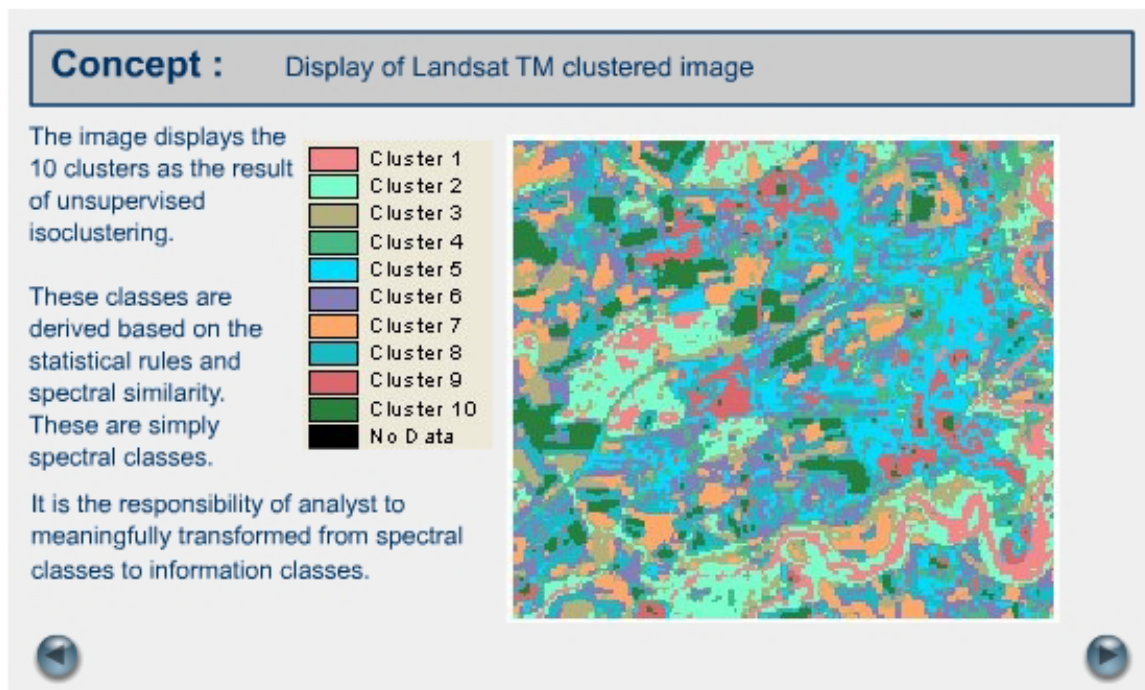
Unsupervised method or Clustering

Unsupervised clustering is an automated method to group pixels with similar spectral characteristics into clusters based on the statistical patterns that are inherent in the data. Then the analyst or interpreter assigns these clusters to a categorical name.

A standard clustering technique is iterative self-organizing data analysis (ISODATA).

Unsupervised clustering requires no prior knowledge of the area. However, interpretation of output classes or clusters may be difficult. Some clusters may be merged or split, as number of unique groups in an image is unknown.

The following figure illustrates the result of unsupervised clustering of Landsat TM (Band 1 to 5). The area is near Fribourg. There are 10 clusters in the image. Clusters are illustrated in different colors. The analyst will assign meaningful information class to these clusters. The analyst may merge or split and recode some clusters in order to assign meaningful information class. Moreover, the analyst may repeat the isodata clustering process with different number of output classes depending on his field experience and ground truth knowledge.

Concept :   Display of Landsat TM clustered image

The image displays the 10 clusters as the result of unsupervised isoclustering.

These classes are derived based on the statistical rules and spectral similarity. These are simply spectral classes.

It is the responsibility of analyst to meaningfully transformed from spectral classes to information classes.

Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
Cluster 6
Cluster 7
Cluster 8
Cluster 9
Cluster 10
No Data

Supervised Training

The analyst selects the pixels (group of pixels) that represent patterns or land cover features recognized by the analyst or identified from other sources such as maps, ground truth data and aerial photos, by drawing the polygon around these groups of pixels. These selected groups of pixels are called training samples. It is very important to select the groups of pixels as training samples that represent a particular pattern or land cover feature. Impure training samples result misclassification. However, the variability of the samples should express the hue spectral variability of each category.

Knowledge of the study area, knowledge of the data and the categories desired, is required before selecting the training samples and classification.

Signatures

The result of unsupervised and supervised training sampling is signatures. The parametric signature is based on the statistical parameters (e.g. mean, standard deviation) of the pixels of a cluster or a training sample (in the image) that corresponds to a class or a category of land cover (on the ground). The parametric signatures are used with statistically based classifiers or decision rules that assign the pixels in an image file to a class or category of land cover.

Decision Rules

After the signature are created for each pattern or land cover class, the pixels in the image are sorted into classes based on the signature by using a classification decision rule. The decision rule is mathematical and statistical algorithms to sort out the pixels into different classes or categories. The most frequently used decision rules are parallelepiped, minimum distance, Mahalanobis distance and maximum likelihood.

Concept : Display of Landsat TM classified image

The image displays the 7 land cover classes after supervised classification.

Legend:
- Water Body
- Forest
- Urban I
- Agriculture I
- Urban II
- Agriculture II
- Major road
- No Data
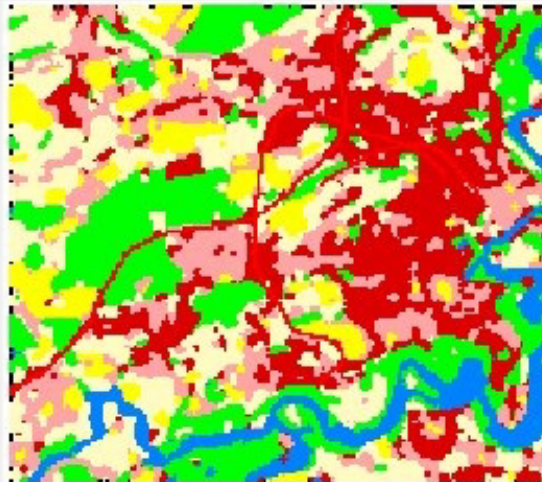
The legend represents the information classes.

The legend in this example is for the illustration purpose only.

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