Image Analysis and Pattern Recognition[1]

What is…

Image analysis is the extraction of meaningful information from ***images***; mainly from ***digital images*** by means of digital image processing techniques. ***Image analysis*** tasks can be as simple as reading bar coded tags or as sophisticated as identifying a person from their face characteristics.

The main idea in Image analysis is trying to 'imitate' by computer aided analysis (algorithms) the human visual cortex, which is an excellent image analysis apparatus, especially for extracting higher-level information. Though computers are indispensable for the analysis of large amounts of data, for tasks that require complex computation, or for the extraction of quantitative information, still for many applications — including medicine, security, and remote sensing — human analysts cannot be replaced by computers. For these reason, many important ***image analysis*** tools such as ***edge detectors*** and ***neural networks*** are inspired by human visual perception models.

Digital image analysis largely contains the fields of ***computer and machine vision***, and makes heavy use of **pattern recognition**, ***digital geometry***, and ***signal processing***. This field of computer science developed in the 1950s at academic institutions such as the MIT A.I. Lab, originally as a branch of ***artificial intelligence*** and ***robotics***.

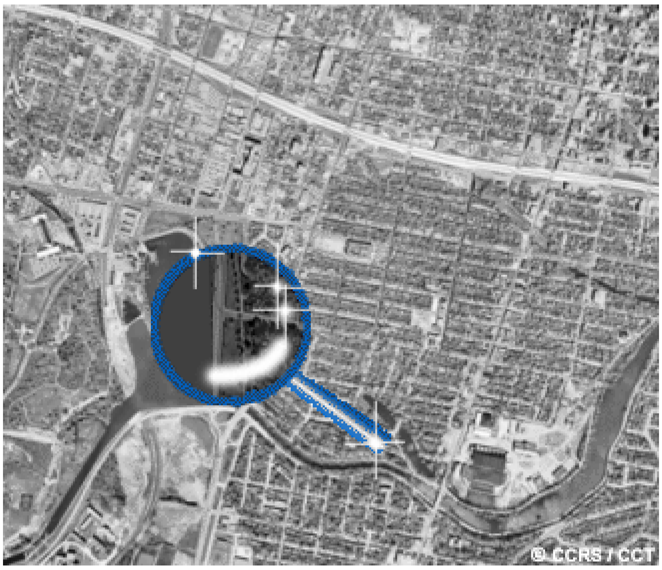
Main applications of digital image analysis in various areas of science and industry include: medicine, ***remote sensing,*** astronomy, defense, robotics, document processing and many more.

What Is It Good for?...

In order to take advantage of and make good use of ***remote sensing*** data, we must be able to extract meaningful information from the imagery. ***Interpretation*** and ***analysis*** of remote sensing imagery involves the identification and/or measurement of various targets in an image in order to extract useful information about them. Targets in remote sensing images may be any feature or object which can be observed in an image, and have the following characteristics:

- Targets may be a point, line, or area feature. This means that they can have any form, from a bus in a parking lot or plane on a runway, to a bridge or roadway, to a large expanse of water or a field.
- The target must be distinguishable; it must contrast with other features around it in the image.

[1] Excerpt from **wikipedia.org** and **Canada Centre for Remote Sensing**



Much ***interpretation*** and ***identification*** of targets in remote sensing imagery is performed manually or ***visually***, i.e. by a human interpreter. In many cases this is done using imagery displayed in a pictorial or photograph-type format, independent of what type of sensor was used to collect the data and how the data were collected. In this case we refer to the data as being in ***analog*** format. Nevertheless, ***remote sensing*** images can also be represented in a computer as arrays of pixels, with each pixel corresponding to a digital number, representing the brightness level of that pixel in the image. In this case, the data are in a ***digital*** format. So, ***visual interpretation*** may also be performed by examining digital imagery displayed on a computer screen. Both ***analogue*** and ***digital imagery*** can be displayed as black and white (also called monochrome) images, or as color images (***multispectral***) by combining different ***channels*** or ***bands*** representing different ***wavelengths***.

When remote sensing data is available in digital format, ***digital processing*** and ***analysis*** are usually performed using a computer. ***Digital processing*** may be used to enhance data as a prelude to visual interpretation. The idea is to be able to implement ***Digital processing*** and ***analysis*** procedures that will be able to ***automatically*** identify targets and extract information completely without manual intervention by a human interpreter. However, rarely is ***digital processing*** and ***analysis*** carried out as a complete replacement for manual interpretation. Often, it is done to supplement and assist the human analyst.

Some Guidelines Please…

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 (***photogrammetry*** and ***Remote Sensing***).

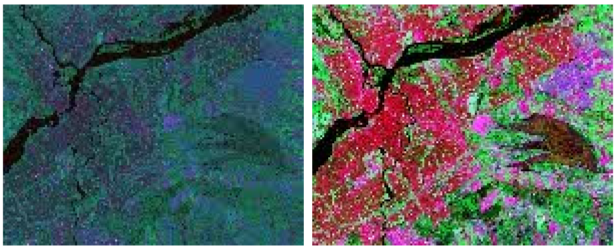
Interpretation benefits greatly in many applications when images are viewed in stereo, as visualization (and therefore, recognition) of targets is enhanced dramatically. Viewing objects from directly above also provides a very different perspective than what we are familiar with. Combining an unfamiliar 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 the human user 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***. It is normally forgotten, but the ***visual interpretation*** using these elements is often a part of our daily lives, whether we are conscious of it or not. Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyze, and therefore, many of the computer analysis methods make use of these elements.

Give Me Some Bits!!!
In today's world of advanced technology where most ***remote sensing*** data are recorded in digital format, virtually all image interpretation and analysis involves some element of digital processing. Digital image processing may involve numerous procedures including formatting and correcting of the data, digital enhancement to facilitate better visual interpretation, or even automated classification of targets and features entirely by computer. Several commercially available software systems have been developed specifically for remote sensing image processing and analysis.

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

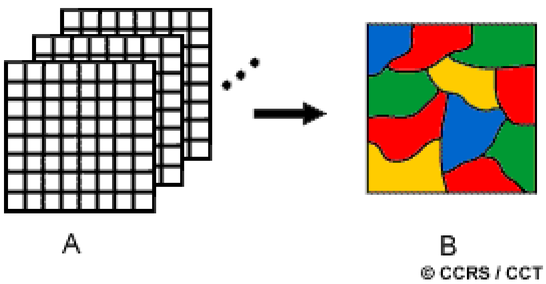
1) Preprocessing functions involve operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as ***radiometric*** or ***geometric corrections***. ***Radiometric corrections*** include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted ***radiation*** measured by the sensor. ***Geometric corrections*** include correcting for geometric distortions due to sensor-earth geometry variations, and conversion of the data to real world coordinates.



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

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

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

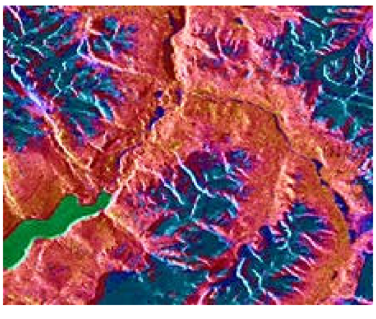


So, In Summary We Can Conclude That…

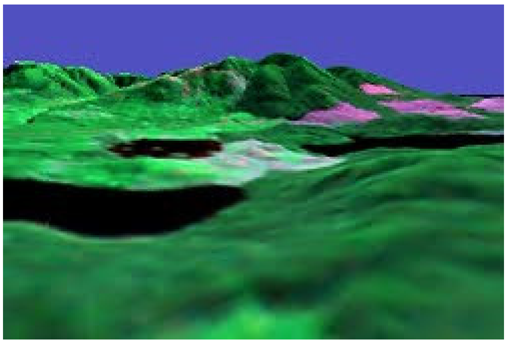
In the early days of analog ***remote sensing*** when the only remote sensing data source was aerial photography, the capability for integration of data from different sources was limited. Today, with most data available in digital format from a wide array of sensors, data integration is a common method used for interpretation and analysis. ***Data integration*** fundamentally involves the combining or merging of data from multiple sources in an effort to extract better and/or more information. This may include data that is multi-temporal, multi-resolution, multi-sensor, or multi-data type in nature.

Multi-temporal change detection can be achieved through various methods outlined above or by other more complex approaches such as multiple classification comparisons or classifications. Multi-resolution data merging is useful for a variety of applications, so that the merging of data can significantly sharpen the spatial detail in an image and enhance the discrimination of features. Multispectral data, for example, serve to retain good spectral resolution while the panchromatic data provide the improved spatial resolution.

An excellent example for multi-sensor data fusion is the combination of ***multispectral optical data*** with ***radar imagery***. These two diverse spectral representations of the surface can provide complementary information. The optical data provide detailed spectral information useful for discriminating between surface cover types, while the radar imagery highlights the structural detail in the image.



Applications of multi-sensor data integration generally require that the data be geometrically registered, either to each other or to a common geographic coordinate system or map base. This also allows other ancillary (supplementary) data sources to be integrated with the remote sensing data. For example, elevation data in digital form, called ***Digital Elevation* or *Digital Terrain Models* (*DEMs/DTMs*)**, may be combined with remote sensing data for a variety of purposes. ***DEMs/DTMs*** may be useful in image classification, as effects due to ***terrain*** and ***slope*** variability can be corrected, potentially increasing the accuracy of the resultant classification. ***DEMs/DTMs*** are also useful for generating ***3-D perspective views*** by draping remote ***sensing imagery*** over the ***elevation data***, enhancing visualization of the area imaged.



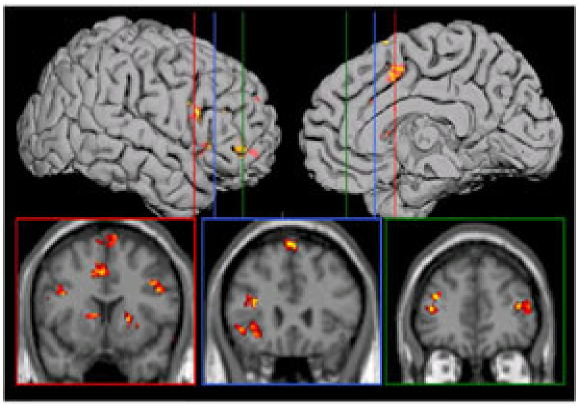
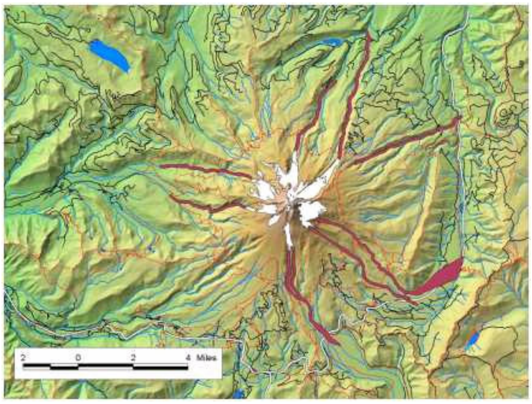
Combining data of different types and from different sources is the pinnacle of data integration and analysis. In a digital environment where all the data sources are geometrically registered to a common geographic base, the potential for information extraction is extremely wide. This is the concept for analysis within a digital ***Geographical Information System (GIS)*** database. Any data source which can be referenced ***spatially*** can be used in this type of environment. A ***DEM/DTM*** is just one example of this kind of data. Other examples could include land cover classes, forest species, road networks, and many others, depending on the application. The results from a classification of a remote sensing data set in map format, could also be used in a GIS as another data source to update existing map data. In essence, by analyzing diverse data sets together, it is possible to extract better and more accurate information in a synergistic manner than by using a single data source alone. There are a myriad of potential applications and analyses possible for many applications.

And What About Pattern Recognition In All This?

Pattern recognition is a field within the area of machine learning, and It aims to classify data (patterns) based on either *a priori* knowledge or on statistical information extracted from the patterns. Most of the pattern recognition methods exist make use of procedures and algorithms mentioned previously. The patterns to be classified are usually groups of measurements or observations, defining points in an appropriate multidimensional space.

A complete pattern recognition system make use of all the characteristics mentioned earlier: a ***sensor*** that gathers the observations to be classified or described; a ***feature extraction*** mechanism that computes numeric or symbolic information from the observations; and a ***classification*** or description scheme that does the actual job of classifying or describing observations, relying on the extracted features.

The ***classification*** or description scheme is usually based on the availability of a set of patterns that have already been classified or described (*a priori* knowledge). This set of patterns is termed the training set and the resulting learning strategy is characterized as supervised learning. Learning can also be unsupervised, in the sense that the system is not given an *a priori* labeling of patterns, instead it establishes the classes itself based on the statistical regularities of the patterns.

The ***classification*** or description scheme usually uses one of the following approaches: ***statistical*** (or decision theoretic) or ***syntactic*** (or structural). Statistical pattern recognition is based on statistical characterizations of patterns, assuming that the patterns are generated by a probabilistic system. Structural pattern recognition is based on the structural interrelationships of features. A wide range of algorithms can be applied for pattern recognition, from very simple Bayesian classifiers to much more powerful neural networks.

Typical applications, such as automatic handwrite recognition, automatic image recognition, and ***geomorphologic*** terrain features classification are examples form the subtopic ***image analysis*** of ***pattern recognition*** that deals with digital images as input to pattern recognition systems.